SAMON
safe monitoring

Guidelines

GAS DETECTION SYSTEMS FOR THE REFRIGERATION INDUSTRY - AN OVERVIEW

Samon has a wide range of products and solutions for detection of the most common refrigerants. Our aim is to offer reliable and cost-effective solutions for applications where gas detection is essential. Samon combines high competency and specialised skills in refrigeration applications with professional service and training.

Contents

Samon’s Guidelines provide an overview of current legislation and standards relevant to gas detection for refrigeration systems. We do not claim to be comprehensive. It is everyone's responsibility to find out the actual facts in any particular case. Samon has 15 years of experience in gas detection involving refrigeration systems. Our Guidelines thus to a large extent are based on our experiences and interpretations of e.g. the most suitable alarm levels and most appropriate applications.

Parts of these Guidelines refer to Swedish national legislation. Similar legislation is most certainly in effect in other EC countries, but in slightly different flavours. We strongly recommend that national legislation be read in parallel with this document to get a full and adequate overview for each individual country.

Introduction

Samon AB develops and manufactures gas detection products for the refrigeration industry. Samon has extensive experience in providing cost-effective systems and safe gas detection for land-based as well as marine applications.

Samon has a wide range of detection options for the most common refrigerants. We aim to offer reliable and cost-effective solutions for applications in which gas detection is essential. Samon combines high competency and specialised skills in refrigeration applications with professional service and training. Early detection of gas leakage is essential for personnel safety, profitability and the environment.

Samon operates in the commercial refrigeration segment, where typical applications are refrigeration systems for hotels and offices, industrial refrigeration and marine refrigeration. Samon also offers gas detection systems for ventilation in garages.

An important operational target for all refrigeration systems can generally be said to be that they should be as tight and leak-proof as possible. There is no absolute leak-free system and the use of gas detection products aims to minimise and control this leakage. Leaking refrigeration systems generally pose a challenge to the refrigeration sector and require resolute action. Otherwise the industry may lose the initiative and be subjected to even tougher, mandatory laws and taxes to address, among other things, the associated negative environmental consequences.

The prevailing focus on climate has led to some new EU regulations and standards that clearly indicate that gas detection must be installed for greenhouse gases or carbon dioxide, and more than 50 kg of ammonia, and how these should be controlled and documented.

New rules and regulations always create uncertainty about how to interpret and apply directives and standards. The purpose of this publication is both to translate the current directives and standards into effective systems solutions and, secondly, to provide a general overview of when, how and why gas detection is required.

The booklet is aimed at everyone who is involved in various ways with planning, installing and maintaining commercial and industrial refrigeration systems.

It offers the user a comprehensive overview of what is required for different applications and how the existing standards are implemented. Ultimately, it is about personnel safety, profitability and the environment.

For the contractor, it provides advice on how various applications can be designed, what to take into account in installations, the characteristics of various gases and recommended measurement techniques.

Samon's Guidelines provide a general overview and do not claim to be fully comprehensive. Statutes and regulations change over time and it is always the reader's responsibility to find out the currently applicable regulations for any specific case.

Why gas detection?

There are several good reasons to install a gas detection system.

The main reasons are personnel safety and environmental concerns in line with current legislation. It is also financially profitable to have reliable facilities with as leak-free systems as possible.

There are four main reasons to install gas detection systems:

- For personnel health & safety
- For environmental care
- In order to comply with applicable rules and regulations
- For financial reasons

For personnel health & safety

Several of the gases in refrigeration plants are dangerous to humans.

In lesser concentrations, ammonia can cause irritation to the respiratory tract and eyes, and in higher concentrations may lead to severe injuries and eventually death.

HFC (HCFC) refrigerants and carbon dioxide displace oxygen from the air and may ultimately bring about suffocation.

HCs such as propane and isobutane are a hydrocarbon compound, containing only carbon and hydrogen. These compounds cause no damage to the environment, but are flammable. So measures to minimise risk need to be taken. HCs may also cause suffocation.

For environmental care

Most of the gases in refrigeration plants have adverse environmental effects. The so-called F gases, the fluorinated greenhouse gases, are discussed the most. Some older gases with chlorine compounds are now totally banned within the EC and may only be used in recycled form.

- **CFC/HCFC**
  - CFCs are fully halogenated hydrocarbon compounds with chlorine that have a strong impact on the ozone layer.
  - HCFCs are (incomplete) halogenated hydrocarbon compounds with chlorine that affect ozone depletion to a lesser extent than CFCs. (For example, plants in Sweden may not fill machinery with HCFCs.)
  - Uses of CFCs / HCFCs are regulated by the Montreal Protocol.
- **HFC**
  - HFCs are (incomplete) halogenated compounds that do not contain chlorine and thus do not affect the ozone layer. However, HFCs have a significant impact on global warming so emissions must be minimised.
  - The uses of HFCs are regulated by the Kyoto Protocol.

It thus is in our common interest to keep refrigerants in systems that are as free of leaks as possible.

In order to comply with applicable rules and regulations

There are a number of rules and regulations that must be followed, depending on the type of application and the refrigerants concerned. Some of the most important are given below.

F Gas Regulation (effective July 2006)
European Parliament and Council Regulation (EC) No. 842/2006. Concerns HFCs and other fluorinated greenhouse gases, but not ammonia or carbon dioxide. Affects all installations falling under the requirements, including also existing installations. Legally binding, all EC and EFTA countries have to comply with the regulation and must establish rules for penalties applicable to infringements.

EN378: 2008, Part 1-4 (effective February 2008)
Applies to all types of refrigerants and, among other things, deals with leakage detection in engine rooms, pump rooms and any other premises (known as occupied spaces) where people may congregate. Examples of such spaces are shops, production facilities, cold storage rooms, etc. The charge limit above which gas detection equipment must be installed is > 50kg for ammonia, and for all other refrigerants > 25kg. Gas detection may be required for smaller charges if practical limits are reached (see table p. 16). Applies to all new installations as well as installations where considerable renovations have been made. Effective in all EC and EFTA countries.

National refrigeration standards / legislation
In general, most countries have a specific statute for the design, installation and control of refrigeration systems. For the EC and EFTA countries, these are now harmonised in EN 378, which can be viewed as a European refrigeration standard.

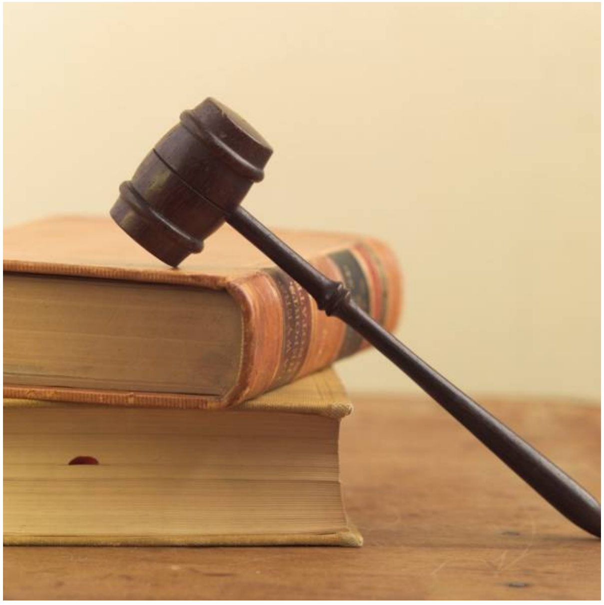
National legislation for workplace design
In general, all EC and EFTA countries have extensive legislation concerning personnel safety, stating among other things that buildings and workplaces where there is a risk of fire, dangerous leakage, oxygen deficiency or the like resulting in personal injuries must be designed so as to avoid and diminish the negative outcome of an incident. One of the precautions often recommended is that a gas detection system be installed.

National legislation on gases
All EC and EFTA countries have some legislation concerning toxic gases and the specific measures to be taken. Ammonia is typically a toxic gas. The legislation usually recommends a risk analysis in order to avoid and diminish the risks. Typically, recommendations are made to install gas detection equipment.

National legislation for occupational exposure limits
In general, all EC and EFTA countries have legislation concerning the maximum exposure of humans to hazardous gases. Usually, certain maximum exposure times for certain concentrations and gases are what is regulated.

ATEX Directive (effective May 2003)
The ATEX Directive concerns explosion-classified spaces. ATEX applies to the environment in which a refrigeration system is installed and not to the actual refrigerant in the system. When working with systems containing flammable gases, certain specific competence is required of the technicians.
The building owner/user of the premises is responsible for ATEX-classifying the space concerned. The classification is divided into zones differing between an explosive atmosphere consisting of gas, vapour or aerosol (Zone 0, Zone 1 and Zone 2) and where an explosive environment is comprised of combustible dust (Zone 20, Zone 21 and Zone 22).

Marine
Different rules apply from the respective classification organisations, with more extensive demands placed on ships classified as Clean Ship, Ship Super Clean, Green Ship, etc. Typical classification organisations are Det Norske Veritas, Lloyds Register of Shipping, Germanischer Lloyd, American Bureau of Shipping and Bureau Veritas.



For financial reasons

There is money to be saved by having an optimal system with minimal leakage.

HFCs and their mixtures have risen in price, and it is likely that additional heavy taxes and fees will be added. The filling is expensive and leakage causes loss of the expensive gas.

Poorly maintained and controlled gas detection systems may lead to unnecessary and costly false alarms, which in turn cause internal staff costs and potentially also costs for emergency & rescue services. An improperly positioned detector (e.g. a low-placed ammonia detector or a high-placed HFC detector) may lead to system failure, as the detector cannot measure the leakage and consequently cannot initiate an alarm. This may cause loss of precious gas, increased maintenance costs, increased downtimes and loss of productivity. Major overlooked leakage may cause the temperature to rise in a cold storage room, which may destroy the stored products.

Having systems that do not comply with the applicable rules and regulations may lead to fines and other penalties.

In summary, a gas detection system is cheap insurance against a number of serious risks.

Choosing the right system

A gas detection system consists of a chain - from discovery of the risk to the corrective action. It is important to think through the measures to be taken at each level of alert, and to plan for the appropriate staff to be informed, such as the plant manager and maintenance contractor.

1. What is the purpose of the alarm?
2. Which gas(es) are to be detected?
3. What detection principles are the most appropriate? How many sensors are needed, where and how should they be placed?
4. What rules and regulations apply for the refrigerant in use?
5. What is the refrigerant's density relative to air?
6. How does the ventilation affect the detected area?
7. What steps are to be taken when an alarm occurs?

The function of different alarm levels

Alarms can typically be divided into A, B or C alarms, also named pre-alarm, leakage alarm and main alarm. Each different alarm level calls for different measures:

- C = Alarm for maintenance staff.
- B = Urgent alarm for maintenance staff, flashing light activated.
- A = Emergency alarm as the B alarm, with siren activated and alarm sent to the rescue services, refrigeration plant is shut down (power supply as well)

Sources of disturbances and false alarms

False alarms in the true sense are very rare. If a detector alarms falsely, it is in most cases caused by any of the following reasons:

- Gas in low concentration in the room
- Incorrectly positioned detector
- Equipment calibrated wrongly
- Equipment not maintained and controlled accurately
- Incorrectly selected equipment
- Other gases in the room for example.
  - Solvents
  - Cleaners
  - Exhausts
  - Smoke (cigarette)
  - Some fruits
  - Defrost mist
  - Compressor oil after draining during servicing etc.

False alarms may occur in all measurement systems. IR measurement systems have the least risk of false alarms due to their better selectivity.

Purpose of the alarm

To choose the right equipment and systems, a number of parameters first must be determined. This then controls the choice of products, their placement and the alert levels.

The main objectives of a gas alarm systems are:

- Leakage alarm, monitoring unoccupied space
- Emergency alarm
- Personnel health & security
- Warning of fire and explosion hazard
- Protect stored products.

Leakage alarm, monitoring unmanned space

Monitoring of accidental leaks in order to avoid downtime, protect the environment and minimise the loss of refrigerant. There are no established alarm limits since the need has to be adapted to each refrigeration plant. Practical experience shows that the alert levels based on sanitary limits usually are too low for effective leakage alarms. The sanitary limits in turn are different depending on the type of gas. Samon's recommendation for appropriate alarm levels for leakage alarms are as per the table below:

Appropriate alarm levels	Ammonia	HFC (HCFC)	CO_2	Combustible gases (% LEL)
Pre-alarm	50-300 ppm	100-300 ppm	-	5 %
Leakage alarm	500-1000 ppm	1000 ppm	2000 ppm	10 %
Main alarm	>3000 ppm	>2000 ppm	5000 ppm	20 %

Samon's recommended levels are generally lower than those prescribed by EN378.

Emergency alarm

Emergency alarm concerns in principle only ammonia plants and explosive gases. Emergency alarms will start the evacuation of buildings, neighbourhoods, etc. and involve the monitoring of high concentrations directly dangerous to life and health. National legislation typically implies that a risk assessment / risk analysis must be made in all plants with ammonia. An action plan must be drawn up that, among other things, concerns how the staff should be alerted and act in order to be safe. In larger facilities, where there is a risk of external leakage to the surroundings, there must also be a plan for how the public should be warned.

Personnel health and safety

An Occupational Exposure Limit (OEL) is the maximum acceptable average concentration (time-weighted average) of pollutants in inhaled air, where the pollutants may be a substance or mixture of substances.

Limit values are laid down throughout the EU, but each EU member state establishes its own national OELs, often going beyond EU legislation. The average exposure time in OEL is normally eight hours per day (often referred to as TWA-8h or Time-Weighted Average - 8h). OELs are usually based on the assumption that a worker can be exposed to a substance for a working life of 40 years with 200 working days per year. May also be called PEL, Permissible Exposure Limit (e.g. USA).

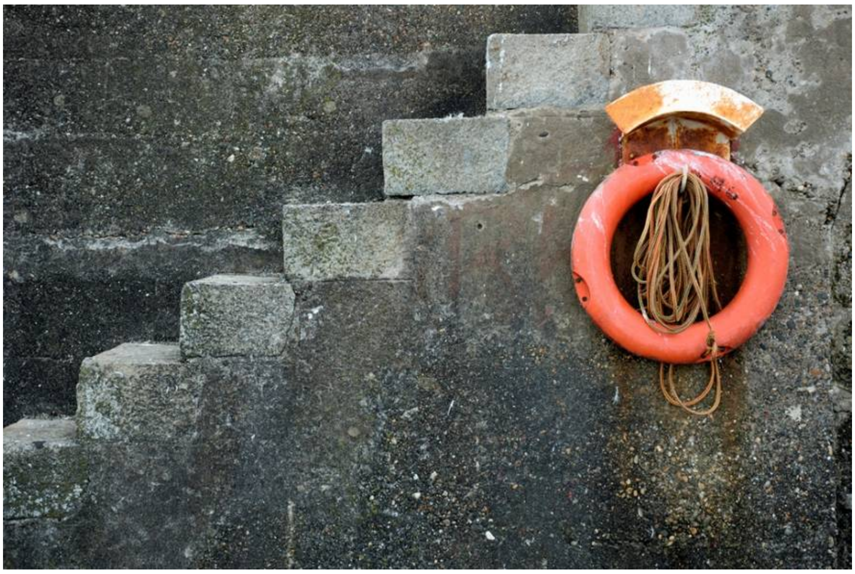
A Short Term Exposure Limit (STEL) is the maximum concentration of a chemical to which workers may be exposed continuously for up to 15 minutes without danger to health or work efficiency and safety.

A Ceiling Limit is the maximum concentration of an airborne contaminant to which an employee may be exposed at any time. A Ceiling Limit is one that may not be exceeded, and is concerns irritants and other materials that have immediate effects.

Examples of monitoring exposure limits in occupied spaces are demand-controlled ventilation in a garage (carbon monoxide and nitrogen dioxide), monitoring of work environments where toxic gases exist or may be formed, monitoring of oxygen, etc. Monitoring of exposure limits for refrigerants is unusual since most systems are in unoccupied premises such as a machinery room.

OEL - Time Weighted Average (TWA)	Exposure limit for exposure during a working day (8 hours).
Short-term Exposure Limit (STEL):	A recommended value, consisting of the time-weighted average exposure over a reference period of 15 minutes.

For more specific information, see your relevant national legislation.



European laws and regulations

Requirements for gas detection in refrigeration plants differ between countries around the world. There are some harmonising regulations and standards that are valid for Europe. Below, we present the two most important ones for the refrigeration industry. As described earlier, for personnel health & safety most countries have there own national legislation.

F Gas Regulation EC 842/2006

The F Gas Regulation is an environmental law. The objective of this regulation is to contain, prevent and thereby reduce emissions of the fluorinated greenhouse gases covered by the Kyoto Protocol.

Compliance with the F Gas Regulation is mandatory for all EC and EFTA members. EC member states should lay down rules on penalties applicable to infringements of this regulation and ensure that those rules are implemented.

The regulation came into force 4 July 2006 and a number of measures needed to be taken before 4 July 2007.

The F Gas Regulation applies to all stationary applications or equipment containing fluorinated greenhouse gases. This means that existing plants must also be adapted to comply with the regulation. The regulation applies, in other words, retroactively.

The regulation concerns all types of fluorinated greenhouse gases, for example, hydro fluorocarbons (HFCs), per fluorocarbons (PFCs) and sulphur hexafluoride (SF6) and in all types of applications, excluding mobile refrigeration applications MAC. (MAC is governed by Directive 2006/40/EC and 70/156/EC) Thus the directive does not concern ammonia or carbon dioxide.

Companies that have refrigeration, air conditioning or heat pump equipment containing fluorinated greenhouse gases must take the following steps:

1. prevent leakage of these gases; and
2. repair any detected leakage as soon as possible.

All systems filled with more than 3 kg of fluorinated greenhouse gases must be checked for leakage regularly.

Leakage checks must be performed by certified personnel. The operator of the relevant application shall ensure that the relevant personnel have obtained the necessary certification.

The filling is defined by the application or the refrigeration circuit, i.e. the uniform system through which F gas can flow.

The size of the refrigerant charge determines how often leakage checks shall be made:

a. Applications containing 3 kg or more of fluorinated greenhouse gases must be checked for leakage at least once every 12 months; this shall not apply to equipment with hermetically sealed systems that are labelled as such and contain less than 6 kg of fluorinated greenhouse gases.

b. Applications containing 30 kg or more of fluorinated greenhouse gases must be checked for leakage at least once every 6 months. This period can be extended to 12 months if a properly functioning and appropriate gas detection system is installed.

c. Applications containing 300 kg or more of fluorinated greenhouse gases must be checked for leakage at least once every 3 months. This period can be extended to 6 months when a properly functioning and appropriate gas detection system is installed.

   Operators of applications containing 300 kg or more of fluorinated greenhouse gases shall have leakage detection systems. These leakage detection systems must be checked at least once every 12 months to ensure they are functioning properly. The system must be in place latest on 4 July 2010.

The applications must be checked for leakage within one month after a leak has been repaired in order to ensure that the repair has been effective.

A leakage detection system means a calibrated mechanical, electrical or electronic device for detecting leakage of fluorinated greenhouse gases and which, upon detecting such, alerts the operator.

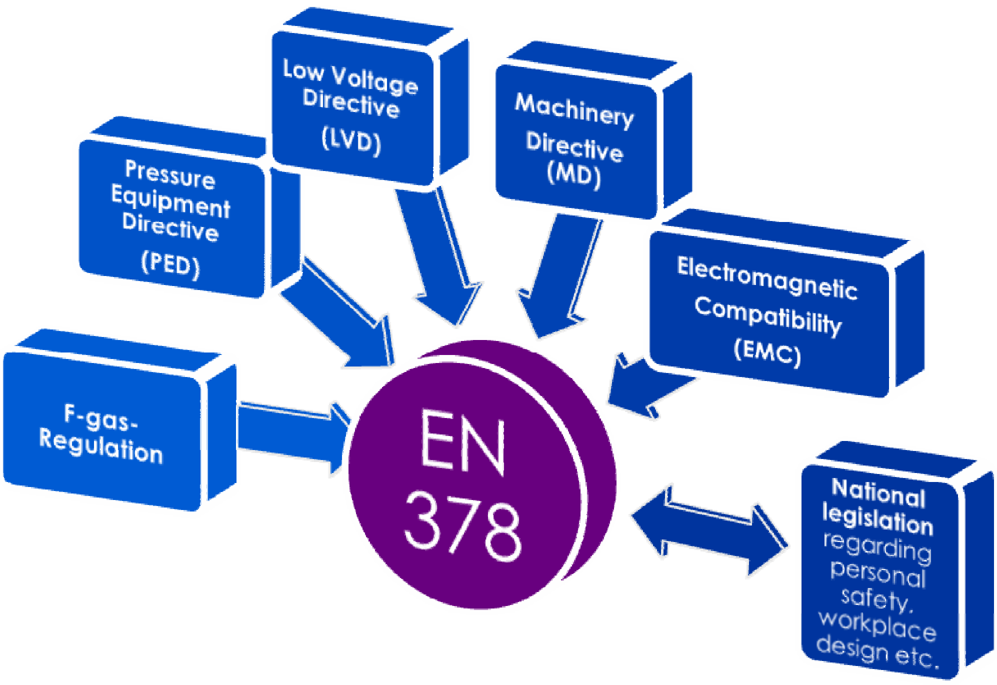
"*If a properly functioning and appropriate system for leak detection is installed, the inspection frequency required by paragraph b) and c) can be halved’*

Consequently, it may thus be a good investment to install a gas detection system, even for smaller fillings (>30 kg).

EN378:2008 part 1-4 "European Standard for Refrigeration Industry"

EN 378:2008 has been in effect since February 2008 and directly affects the design, installation and maintenance of refrigeration systems in Europe. The standard clearly states that gas detection systems must be installed for certain charges. EN 378 consists of four parts and deals primarily with personnel safety and property security, however it also concerns environmental issues.

EN378 is a quite comprehensive standard that interprets a variety of relevant directives into practical applicability for the refrigeration industry.



The standard concerns both new construction and refurbishment. Since certain fluorinated greenhouse gases are prohibited and may only be purchased now in "recycled" form, certain existing facilities must be rebuilt in compliance with EN378.

In brief:

- The standard applies to all types of refrigerants.
- Systems with filling charges of more than 25 kg of refrigerants with an ODP> 0 or GWP> 0 (meaning all refrigerants excluding ammonia, see table below) must have a fixed gas detection system installed.
- Systems with filling charges of more than 50 kg of ammonia must have a fixed gas detection system installed. (Note that national legislation concerning personnel safety often has other, more stringent requirements.)
- If there is risk of reaching critical limits (practical limits), a gas detection system is required even for smaller fillings. See table below.
- Practical limits state the prescribed maximum alert levels.
- Alarms must be triggered and ventilation must be activated at latest at the level of 25% of the LEL (Lowest Explosive Limit) or 50% of the ATEL / ODL (see table 2). However, in the case of refrigerants with a characteristic odour at concentrations below the ATEL/ODL e.g. R717, detectors are not required for toxicity. (see p 17)
- For indirect systems using ammonia with a filling of 500 kg, detection must also take place in the secondary circuit.
- Alarm systems must be inspected at least once a year by a person competent to do the job. These inspections should be documented in the facility logbook.

Requirements for alarms

- An alarm should start flashing lights and sirens both inside and outside the room with the machinery.
- The power supply for alarm systems must be independent of the power supply for ventilation.
- Independent alarm systems require ATEX-classified equipment. If it is ATEX-classified, it may still be in operation during the alarm. Otherwise, the detector must be powered down. If the ventilation and the detector are ATEX-classified, they may both remain in operation and no independent power supply is required. It is the fan and the detector that are the significant components.
- At least one detector must be installed in each room with machinery and in other areas where practical limits may be reached.

Flammable and / or toxic gases are classified according to the following table:

Table 1: Safety group classification system

		TOXICITY	
		Lower	***Higher***
FLAMMABILITY	No flame propagation	A1	B1
	Lower flammability	A2	B2
	Higher flammability	A3	B3

Practical limits

The table shows the statutory maximum levels for some commonly used refrigerants.

Table 2: Practical Limits

Refrigerant	Safety group	Practical limit (kg/m3)	Practical limit (ppm)	ATEL/ODL (kg/m3)	ODP	GWP
R134a	A1	0.25	60,000	0.25	0	1,300
R404A	A1	0.48	120,000	0.48	0	3,260
R410A	A1	0.44	148,000	0.44	0	1,830
R407A	A1	0.33	89,000	0.33	0	1,770
R407C	A1	0.31	84,000	0.31	0	1,420
R717 ammonia	B2	0.00035	500	0.00035	0	0
R290 propane	A3	0.008	4,500	0.09	0	3
R744 carbon dioxide	A1	0.1	55,500	0.036	0	1

Explanations:

ATEL = Acute Toxicity Exposure Limit
ODL = Oxygen Deprivation Limit
ODP = Ozone Depletion Potential
GWP = Global Warming Potential (CO_2 related)

Gas detection for various refrigerants

General

When it comes to monitoring hazardous gases, it is crucial for the property owner / facility user to take measures such that no risk to the staff, surroundings or environment arises. Sufficient control and supervision of the premises are thus essential.

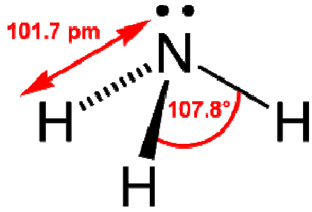
Ammonia (NH_3)

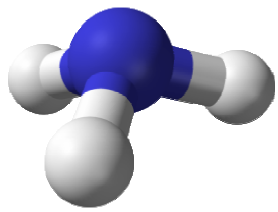
Ammonia is a commonly used refrigerant in larger plants, but since high concentrations may be directly lethal to humans, ammonia shall be treated with great respect. In most cases, the main purpose of using gas detection systems for ammonia is to trigger an emergency alarm. The alarm should lead to actions ensuring that no danger arises to people within the facility or its surroundings.

The use of ammonia in refrigeration plants is regulated by European standard (EN378: 2008), which requires that all plants with a charge of > 50 kg must have gas detection systems installed in machinery rooms and other areas where there is a risk of reaching the practical limits or to the safety of personnel.

EN378-3 states that an R717 detector is required which shall function at a concentration not exceeding:

- 350mg/m^3 (500 ppm) in machinery room (pre-alarm)
- 21 200 mg/m^3 (30 000 ppm) (main alarm)





As Ammonia has a characteristic odour at concentrations below the ATEL/ODL, no alarm level is related to the Practical Limit is required.

The level for the main alarm in EN378 is set based on 20 % of LEL.

Ammonia is lighter than air and hence tends to rise.

Gas	OEL (TWA-8h))	Short-term limits (STEL)
Ammonia	25 ppm	50 ppm

Based on Swedish standards

Appropriate alarm levels Samon's recommendation	Ammonia
Pre-alarm (C)	100-200 ppm
Leakage alarm (B)	500-700 ppm
Main alarm (A)	3000 ppm

Gas concentration ppm	Impact on unprotected humans	Time exposure
5	Minimum concentration to detect ammonia, temperature dependent, easier to detect at low temperatures and in dry environments	
20	Most people notice the smell	Unlimited exposure in most countries
50	The smell is very apparent. Persons not used to ammonia want to leave the site.	Exposure limit, 8-hour day is allowed in many countries.
100	No hazardous effects on healthy people, uncomfortable and can cause panic among people not used to ammonia.	Stay no longer than necessary.
300	Experienced persons will leave the area.	
400-700	Immediate irritation to eyes and respiratory tract.	Under normal circumstances there should be no harm even at an exposure of up to 30 minutes.
1,700	Cough, vocal cord spasm, severe irritation of the nose, eyes and respiratory tract.	½ hour of exposure leads to injury and acute care needs.
2,000-5,000	Cough, vocal cord spasm, severe irritation of the nose, eyes and respiratory tract.	½ hour or less may be lethal
7,000	Unconsciousness, respiratory distress	Lethal within minutes

Ammonia (NH3) impact on humans (source: Ammonia Partnership)

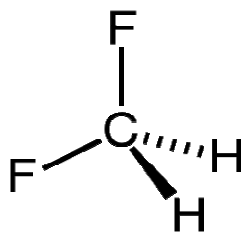
Concentrations lower than in the above table, i.e. <5 ppm, can be noticed more easily at low temperatures (below 0 degrees C). The advantage of the low perceptible level is early warning and gives people the opportunity to immediately move away from the danger zone. However, ammonia may due to its irritating and uncomfortable nature provoke panic in crowds.

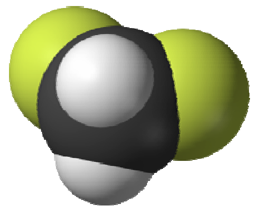
Fluorinated greenhouse gases - CFCs, HCFCs and HFCs

Fluorinated greenhouse gases are also known as Freons (Freon® is originally the chemical company DuPont's trade name for a group of CFC refrigerants). Their negative impact on the ozone layer was discovered in the 1970s and CFCs have been phased out since then.

Fluorinated greenhouse gases can be found in many varieties with different characteristics, but are all heavier than air and thus higher concentrations can displace enough oxygen to induce asphyxiation. The gases are usually not toxic (except R123a) but have a negative impact on the environment by ozone layer depletion (CFCs, HCFCs) and the impact on the greenhouse effect (HFC).

The use of HFCs in refrigeration plants is regulated by the European standard EN378:2008, which requires that all plants with a charge> 25 kg must have gas detection systems installed in machinery rooms and other areas where there is a risk of reaching the practical limits or to the safety of personnel .





Fluorinated greenhouse gases are also regulated by the F Gas Regulation (EC 842/2006) which requires that detection equipment be permanently installed for charges of > 300kg and continuous leakage control.

Given that fluorinated greenhouse gases displace oxygen in the air, the applications are typically also regulated by national laws concerned with e.g. workplace design

Gas	OEL (TWA-8h)	STEL
CFC, HCFC	500 ppm	750
HFC	500 ppm	750 ppm

Based on Swedish standards

Appropriate alarm levels Samon's recommendation	HFC (HCFC)
Pre-alarm (C)	100 ppm
Leakage alarm (B)	1000 ppm
Main alarm (A)	2000 ppm

All types of fluorinated greenhouse gases displace the oxygen from the air. Since they are odourless, they are difficult for anyone to notice. Below are examples of what happens in a non-ventilated room of approximately 50 m^3 with leakage of R134a.

R134 effect on oxygen

Leakage kg	***Concentration ppm***	***Concentration in volume %***	***Oxygen***	***Effect on humans***
21	100,645	10	About 19	The oxygen is running out. Warning level on hypoxia alarm.
42	201,290	20	About 17	Dangerous! alarm level of hypoxia alarm.
63	301,936	30	About 15	Immediate danger. Person must immediately get oxygen.
84	402,581	40	About 13	"To breathe water"

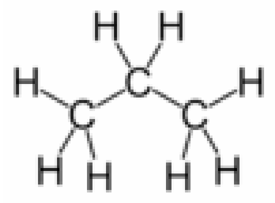
Note! HFC is a heavy and fills up the space/room from the floor. Hence concentrations may initially be much higher closer to the floor. For example, 21 kg can in the short term cause the same concentration 0.5 m above the floor as 84 kg (in above table) fully mixed in the room.

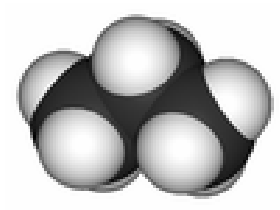
Flammable refrigerants

Hydrocarbons (HC) and propane in particular have become more appropriate as refrigerants in cooling applications.

The use of flammable refrigerants in refrigeration plants such as propane, butane etc is regulated by the ATEX Directive and European Refrigeration Standard (EN378: 2008), which requires that all plants with a charge of > 25 kg must have gas detection systems installed in machinery rooms and other areas where there is a risk of reaching the practical limits or to the safety of personnel.

Since some areas with flammable refrigerants are ATEX-classified, they in turn require ATEX-classified detection equipment.





Alarm levels will depend on where the detector is positioned and what should be protected. The following levels can be regarded as benchmarks for various applications:

Pre-alarm (C)	5 % LEL
Leakage alarm (B)	10 % LEL
Main alarm (A)	20 % LEL

Note that propane, butane and isobutane are indicated as slightly narcotic, and thus can be soporific.
Given that the flammable refrigerants displace oxygen in the air, the applications are typically also regulated by national laws concerned with e.g. workplace design and hazardous gases.

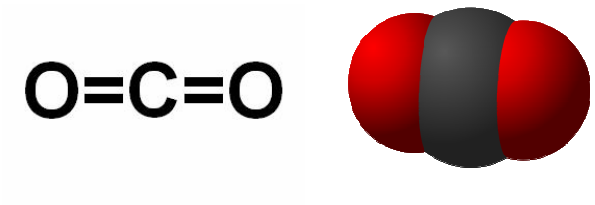
Carbon dioxide (CO_2)

Carbon dioxide as a refrigerant has become increasingly common in recent years and its use is likely to steadily increase in the future since it is a natural refrigerant. Carbon dioxide is an odourless and usually not poisonous gas, however it has two characteristics that make it dangerous to humans:

- Heavier than air - displaces oxygen
- Impacts our breathing (respiratory capacity)

The use of carbon dioxide in refrigeration plants is regulated by European Standard (EN378: 2008) which requires that all plants with a charge of > 25 kg must have gas detection systems installed in machinery rooms and other areas where there is a risk of reaching the practical limits or to the safety of personnel.

Leakage detection should be done in cold storage rooms to avoid the risk of human injury and to avoid temperature rises that destroy valuable food.



Carbon dioxide is a bit special because it occurs naturally in the air and is dangerous only in high concentrations.

As carbon dioxide displaces oxygen in the air, the applications are typically also regulated by national laws concerned with e.g. workplace design.

Gas	OEL (TWA)	Short-term limits (STEL)
CO	5,000 ppm	10,000 ppm

Based on Swedish standards

Pre-alarm (C)	-
Leakage alarm (B)	2,000 ppm
Main alarm (A)	5,000 ppm

How carbon dioxide affects humans

PPM	%	Effect
300-400	0.03-0.04	Typical outdoor air
1,000	0.1	Recommended max. concentration for good indoor air quality
5,000	0.5	Level value, no symptoms
10,000	1.0	Limit value. May cause minor physiological disturbances
20,000	2.0	Respiration increases by about 50 %
>20,000	>2.0	Palpitations, sweating, headache, dizziness, nausea
70-100,000	7-10	Unconsciousness
About 200,000	About 20	Death

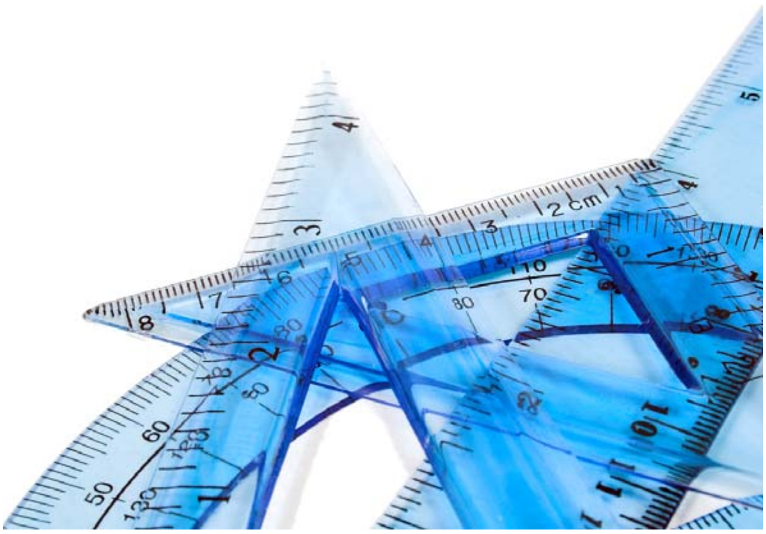
Source: Work Environment Authority (Ventilation 2009-08-17)

Measuring techniques

Measurement techniques to measure or detect gas

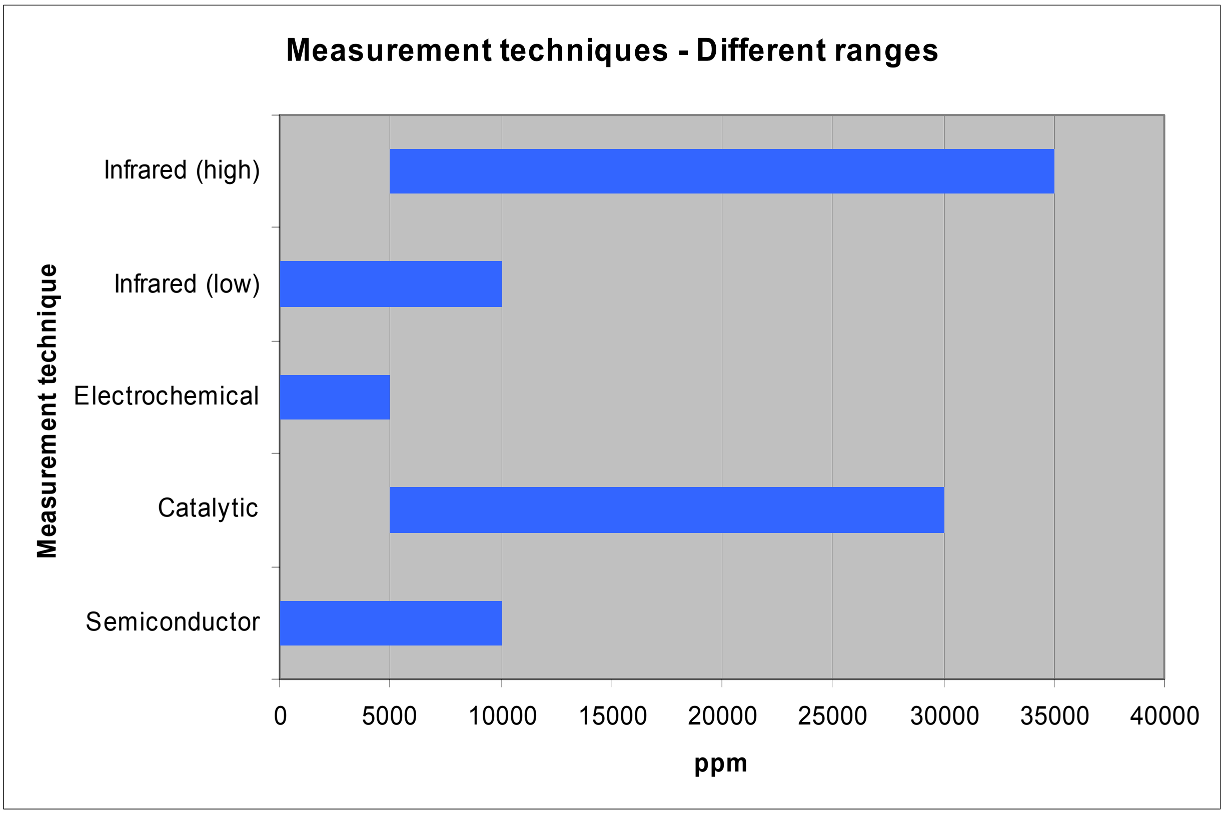
The most commonly used measurement systems for gas sensing are semiconductor sensors, electrochemical sensors, catalytic sensors and infrared measurement techniques. The systems have different advantages and disadvantages and differ substantially in cost. The table below gives a summary, based on Samon's product offerings.

Methodology	Refrigerant	Advantages	Disadvantages
Semiconductors	HFC (HCFC)	Long life (10-12 years)	Limited selectivity
	Ammonia (NH_3)	Stable zero point	Limited range
	Hydrocarbons (CH)	Low purchase price Low maintenance cost	
Electrochemical	Ammonia (NH_3)	Selectivity Medium purchase price	Short life (18-48 months) Short calibration interval Limited range High maintenance cost
Catalytic	Ammonia (NH3)	Low purchase price	Short calibration interval
	Hydrocarbons (HC)	Measures high concentrations	Life span 4-5 years High maintenance cost Not for low concentrations
Infrared technology	HFC (HCFC)	Long life	High cost of HFC and Ammonia
	Ammonia (NH3)	High selectivity	High maintenance costs
	Carbon dioxide (CO2)	Accurate Measurement	



Measurement techniques - Different ranges

The graph below gives a summary of the general suitability of various measurement techniques for different gas concentrations, regardless of the gas. It is based on Samon's product offerings.



Summary:

The choice of the sensor technique depends on different aspects. The above table and graph give some general advice, based on Samon's product offerings. Other suppliers may have other measurement ranges and recommend other sensor techniques for the different gases. As always, each case needs to be considered based on its own special circumstances.

Notes:

……

……

……

……

……

……

……

……

……

……

……

……

……

……

……

……

……

Notes:

……

……

……

……

……

……

……

……

……

……

……

……

……

……

……

……

……

SAMON

safe monitoring

SAMON AB
MODEMGATAN 2
S-235 39 VELLINGE
SWEDEN
TEL + 46 – (0)40 – 15 58 59
FAX + 46 – (0)40 – 15 60 31
WWW.SAMON.SE