Fixed Refrigerant Detection Systems for HFCs, HFC/HFO blends, HFOs and HCFCs

Introduction

This Guidance Note is designed for those involved in the specification, design and installation and operation of multi point fixed refrigerant detection systems to monitor hydro-fluorocarbon (HFC), hydrofluoroolefin (HFO), HFC/HFO blends and hydro-chloro-fluorocarbon (HCFC). Many of the principles and associated benefits of fixed leak detection systems also relate to hydrocarbon (HC) and Carbon Dioxide (CO_2) refrigerants. These will be considered in separate documents including additional and differing considerations for these refrigerant types.

What is fixed refrigerant detection?

There are two distinct activities covered loosely by the term "refrigerant detection". The first of these is commonly called "gas detection" and covers the analysis of air samples by fixed-position instruments to determine whether they contain a refrigerant gas. In refrigeration applications, these instruments are called "fixed refrigerant detectors". There are two main types of fixed refrigerant detectors; aspirated systems which use a pump to draw a sample to the system from a remote location, and point detectors which work on the diffusion of refrigerant gas to the sensor. The second activity is called leak detection and covers the systematic inspection of a refrigeration system to determine whether it is leaking. The terms gas detection and leak detection are not interchangeable, and care must be taken to ensure that the correct meaning is clearly understood. Failure to do so could result in expensive mistakes, or even in prosecution for failing to comply with regulations.

Why install a fixed refrigerant detection system?

1. **Reduction of refrigerant loss** – An early warning alarm at the first stage of the development of a leak may enable the operator to initiate a repair procedure before a significant portion of the system charge is lost and so system efficiency is maintained, energy costs are minimised and downtime is reduced. To achieve reduction of refrigerant loss, a detection system with a low Minimum Detectable Level (MDL) is required to enable early detection of small leaks. These systems typically have a MDL of 1 ppm – 25 ppm, use infrared sensor technology, and can be used for detection of all HFC, HFC/HFO blends, HFO and HCFC refrigerants. The lower the level of detection, the more effective the system will be in alerting to a leak and reducing refrigerant loss. A lower level of detection alone will not make detection of loss more effective, the number and location of the sensors will also greatly effect this.
2. **Maintaining cooling capacity and efficiency** – To maintain the system's design capacity and efficiency it is essential that the optimal quantity of refrigerant charge is contained within the circuit. An early indication of a leak and its subsequent repair may prevent the refrigerant level falling below this minimum amount and thus maintain the system cooling capacity and efficiency.
3. **Tracing the location of a leak** – A fixed refrigerant monitoring system will help to narrow down the location of a leak to a particular area or zone and a particular time, e.g. defrost cycle, if it is an intermittent leak.
4. **Pro-active maintenance** – A refrigerant detection system should be considered as an asset protection system, by utilising different alarm strategies for large and small leaks the system can alert maintenance personnel of any minor leaks and provide escalation alarms in the event of a major release.
5. **Legislation and standards** – There are several regulations and standards requiring the use of fixed leak detection systems. For compliance purposes, detectors alarming at levels typically in the range of 100 ppm – 1,000 ppm are suitable. These detectors are designed for detection of gross leaks before a safety threshold is surpassed.

a. **EU 517/2014 F-Gas Regulation**

Requires the mandatory installation of fixed leak detection systems to monitor refrigerant circuits containing charges equal to or greater than 500 tonnes equivalent of CO_2 (CO_2e) of HFC and HFC/HFO blends.

Installation of fixed leak detection reduces the required frequency of manual leak checks.

Refrigerant circuit charge size (tonnes CO_2e)	Frequency of manual leak checks with no fixed refrigerant detection installed	Frequency of manual leak checks with fixed refrigerant detection installed
≥5 – <50	12 months	24 months
≥50 – <500	6 months	12 months
≥500	n/a (fixed leak detection mandatory)	6 months

The fixed leak detection system must be checked and recalibrated annually. Responsibility for compliance is with the "operator", who is defined as the person or body with technical authority over the refrigeration system.

b. **BS EN 378:2016 Refrigeration Systems and Heat Pumps – Safety and Environmental Requirements**

Refrigerants have a "practical limit" defined in Annex E of Part 1 of the standard and expressed in kg/m^3. If the charge of a refrigeration circuit in kg divided by the room volume in m^3 exceeds the practical limit then additional safety measures such as automatic detection will be required. Requirements for refrigerant detectors and associated alarm systems are detailed in Sections 8 and 9 of Part 3 of the standard.

c. **EC2037:2000 Substances that Deplete the Ozone layer**

States that all precautionary measures practicable shall be taken to prevent and minimise leakage – applies to refrigerants which deplete the ozone layer e.g. HCFCs.

d. **BREEAM P02 – Building Research Establishment Environmental Assessment Method**

This assessment method provides credits for features which reduce the environmental impact of a building. Installation of refrigerant leak detection gains a credit in Section P02. If high risk components are located in "moderately airtight enclosures" e.g. ceiling voids, risers or mechanically ventilated plant rooms then a system measuring refrigerant concentration in air is permissible, otherwise an alternative method is required. Pipe work is considered as a high-risk area, as are compressors. Evaporator and condenser coils can be omitted.

e. **EH40/2005 Workplace Exposure Limits**

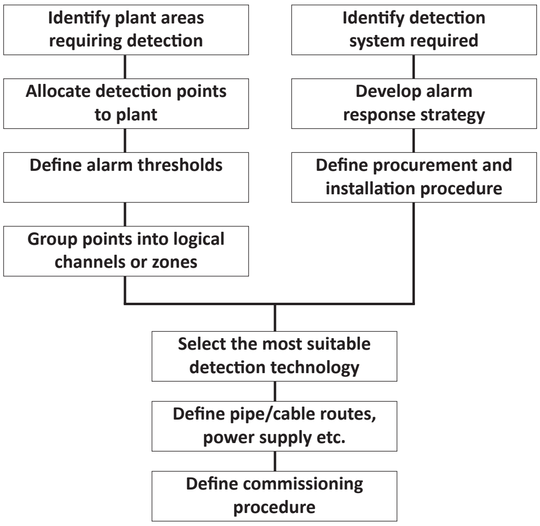
Many people are exposed to a variety of substances at work (e.g. chemicals, fumes, dusts, fibres) which can, under some circumstances, have a harmful effect on their health. These are called 'hazardous substances'. Workplace exposure limits (WELs) are British occupational exposure limits and are set in order to help protect the health of workers. WELs are concentrations of hazardous substances in the air, averaged over a specified period of time, referred to as a time-weighted average (TWA). Two time periods are used:

- long-term (8 hours); and
- short-term (15 minutes).

Charitable Incorporated Organisation 1166869
www.ior.org.uk ior@ior.org.uk +44 (0) 20 8647 7033

Effective refrigerant leak detection system

1. Design overview



A basic outline identifying sources of input is shown below:

In practice, the design process will depend on the structure of the operator's organisation. The information required for the process can be broken down into three key areas:

- Refrigeration system, from the contractor/engineer
- Operation activities and alarm procedures, from the user/operator
- Leak detection system, from the supplier

The design of the leak detection system will need to involve all parties from the start to ensure that the system installed will meet the necessary requirements.

Dependent upon the gas detection system there may be a "cycle time" for sampling which should be considered.

2. Detection system

The detection system should alert the operator to the fact that a leak is occurring and where possible indicate the location of the leak. The operator needs to know the incidence of a leak and the severity of it so that appropriate action can be taken. The detection system should, where possible, identify the area in which the leak has occurred in order to ensure that the leak is located and rectified quickly. The detection system should have a user interface where the current status of the areas being monitored is visible. This includes alarm status, faults and refrigerant gas concentration (typically displayed in parts per million (ppm)).

A risk assessment must be performed in accordance with DSEAR to determine whether the area in which a detection system is being placed is certified as a potentially explosive hazardous area. Whilst this may not always be the case, if a hazardous area is determined then the detection system should comply to the appropriate level of hazardous area protection according to the ATEX Directive 2014/34/EU. See IOR, Introduction to Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) (GN19).

3. Alarm thresholds

The detection system can have several alarm thresholds:

- Early warning alarm thresholds should correspond to the minimum leakage that a refrigeration technician is likely to identify while carrying out a thorough leak check. This will ensure that a detected leak can be found and rectified. This is typically 1 to 25 ppm.
- Intermediate level alarms may also be specified. This is typically 100 to 1000 ppm
- Higher level alarms should be set for concentrations approaching the exposure limits or BS EN378:2016 Practical Limits. For flammable refrigerants, this may be expressed as a percentage of the Lower Flammability Limit (LFL) and should be ≤25% LFL: For other refrigerants it should be ≤50% ATEL (Acute Toxicity Exposure Limit).

4. Detector/sample point placement

A detector sampling point will only detect the concentration of gas which is present at the sampling point. Detector sampling points should be located directly in the areas where a leak is most likely to occur. Positioning of the sampling point should give consideration to the density of gas in relation to air (Note: HFCs, HFOs and HCFCs are heavier than air and will initially stratify at a lower level in the event of a leak, before eventually diffusing more evenly into the atmosphere) and the air flow in the room. A greater distribution of detection sampling points will be likely to increase the speed at which a leak is detected. Consideration should also be given to the minimum detectable level of refrigerant gas concentration that the sensor can detect; as gas from a leak diffuses in a room, a lower level of detection will alert to the leak earlier in order to enable mitigating action to be taken.

The fixed leak detection system should monitor the areas of the refrigeration circuit with a high risk or history of leakage. Examples include but are not limited to: compressor shaft seals, compressor pack pipework, suction/ discharge flanges, pressure relief valves, condenser headers and coil return bends, evaporator valve stations and coils, oil separators and driers, de-superheaters, piping subject to vibration or distortion due to expansion.

Available technologies

a. Infrared absorption systems

This detection system passes an infra-red beam through a sample of air and records the spectrum of wavelengths which have been absorbed. Normally these are aspirated systems, drawing air samples into one central analyser unit. These systems are typically used for large refrigeration systems or where accuracy and reliability are important. One detector is used for multiple detection points. Every refrigerant will produce a different spectrum of absorbed light wavelengths, so accurate and reliable detection of the required refrigerant is possible with very little influence from other gases. Infrared systems normally have the ability to detect at different refrigerant concentrations so multi-level alarms are possible, providing both safety alarms and early warnings of leaks while they are developing. The lifetime costs of infrared systems can be favourable on large installations with multiple detection points as only the central analyser needs to be calibrated annually.

Consideration needs to be given to the system pumps and valves if sensing is needed in wet atmospheres. Hydrophobic filters and anti-splash covers for the sample line ends may be required. If the detection point is required in a hazardous zone it should be noted that air from the zone will be drawn into the detector for analysis.

b. Semi-conductor systems

The detector has an exposed semi-conductor which will absorb gases from the atmosphere. This affects the electrical conductivity and the change in electrical properties is measured. The semi-conductor system uses individual sensors at each detection point. These can either stand alone with integral alarm annunciation or be connected to a central control panel.

For small refrigeration systems requiring fewer detection or sampling points, the semiconductor system will have an advantage of a low initial capital cost. They are typically used where detection is required at a relatively high threshold, as a safety warning system rather than low level leak detection. Detectors may need re-calibration or replacement after detecting an emission.

In situations where accuracy is an important consideration should be given to whether other gases likely to influence the detector may be present as semi-conductor sensors are liable to cross sensitivity from other reducing gases and/or changes in temperature and humidity. Examples could be chlorine based cleaning products, aerosol propellants, chlorinated solvents and combustion products. If this is the case then an Infra-red leak detection system should be specified.

Response procedures

The response levels can be broken down into two parts, one to initiate the tracing and repair of the leak and the other to initiate any action required to prevent any harm to personnel.

As a minimum the leak detection system will provide audible and visual signals to indicate an alarm state and/or a detection system fault. Suitable and adequate training of site staff should be provided so they can take the appropriate action.

The alarm strategy must be appropriate to the staffing level of the site. If the staffing level is low or intermittent, an automated system that communicates to a manned remote location should be used.

Flashing beacons and sounders are often installed as a warning of a high level refrigerant emission, particularly in confined spaces. Care should be taken that not only do these instruct people to leave an area, but also alert personnel intending to enter affected areas, i.e. beacons will be needed both inside and outside of plant rooms and cold stores. The beacons and sounders need to be chosen to avoid confusion with fire or other alarms and should be accompanied by an appropriate warning label.

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Maintenance and calibration

Leak detection systems require an annual calibration and maintenance inspection. This is recommended for good system efficacy and is mandatory for F-Gas Regulation compliance. For the semi-conductor and infrared systems this should involve a calibration grade sample of refrigerant and synthetic air mixture at a known concentration to check the response and accuracy of the sensors. Alternatively, the sensor module can be replaced with another traceable, factory-calibrated sensor module sourced from the system manufacturer.

The refrigerant leak detector should be maintained by a trained operative and it is recommended that during maintenance the following actions are included:

- Check calibration of the sensor(s) with a calibration grade sample and recalibrate, if necessary; or replace the sensor module(s) with a new pre-calibrated sensor module.
- Carry out flow check of the pump module(s), if the system is aspirated, to ensure no blocked sampling pipes or aging pump modules.
- If local sensors are used in a network configuration, ensure they are all communicating to the central alarm panel.
- Upgrade the system firmware to the latest available version.
- Where easily accessible, visually inspect the leak detection installation and position of sensors and sample points to ensure they are in the ideal locations for detecting leaking refrigerant
- Check interfacing to local alarm system i.e. BMS, dial out, beacon/sounders
- Provide a calibration certificate to the customer for their F-Gas records

References and sources of further information

- EU 517/2014 F-Gas Regulation
- EC 2037-2000 Ozone Depleting Substances
- BS EN 378:2016 Pts 1-4 Refrigeration systems and heat pumps. Safety and environmental requirements (and amendments)
- BREEAM, Building Research Establishment Environmental Assessment Method
- EH40/2005 Workplace exposure limits
- IOR/BRA Commercial Refrigeration Good Practice Guide Part 10
- IOR Code of Practice on the Minimisation of Emissions (2009) http://www.ior.org.uk
- IOR Introduction to Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) (GN19)
- IOR REAL Zero Guidance Notes www.realzero.org.uk
- DEFRA F-Gas Support Guides https://www.gov.uk/managing-fluorinated-gases-and-ozone-depleting-substances

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