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Guidance, Tools and Training for Refrigerant Containment

Refrigerant Emissions and Leakage GN 3 - 2015

Guide to designing out leaks

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Designing out leaks: Design standards and practices

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A leak of 1 kg of refrigerant can cause the same environmental damage as the emissions from generating grid electricity to power a house for 2 years

Top ten tips for designers and specifiers

1. **Put leak reduction at the top of your list** – leakage causes increased energy use and increased carbon emissions, there are many whole life cost models to help make a convincing argument. New systems should last 20+ years, so reducing the potential for leakage from the outset will have a significant long-term impact.
2. **Design standards** – new systems should be designed to comply with EN378:2008+2012, the IOR Minimisation of Leakage Code of Practice and the PED. Even if you are making changes to an older installation, you should review the installation and recommend essential upgrades so it can conform to these standards. System components should be qualified to EN 16084.
3. **Capping valves** – consider caps that can't be completely removed from the system or valves with sealed stems that are not dependent on caps.
4. **Access to pipework** – where possible avoid routing pipework in concrete or ceiling voids where there is no access to the whole section of pipework. If you can't access it, you can't test it for leaks.
5. **Pipework joints** – use brazed or welded joints wherever possible. Do not use flared joints unless absolutely necessary. Check brazing standard, use qualified brazing personnel, and minimise the number of joints. Poor joints are often difficult to identify visually.
6. **Eliminate or reduce vibration and stress** – excessive vibration or inadequate pipework support will weaken joints and lead to leakage in the future. Also, make sure pipework is protected from impact.
7. **Fixed leak detection systems** are mandatory for large systems (dependent on charge size and GWP), and recommended in EN 378 for many smaller systems. They should be included in specifications for relevant systems.
8. **System register and labelling** – new equipment must by law be handed over to the customer suitably labelled and with a system register identifying key items such as the type and total charge of refrigerant.
9. **Specify service and maintenance** – correctly specified regimes will help to prevent leaks developing and ensure that any that do occur are fixed rapidly.
10. **Specify installer qualification standards** – use qualified installation personnel to ensure that installations are carried out competently to minimise leakage over the life of the system. Adding a trace element such as Hydrogen or Helium to oxygen-free nitrogen will improve the sensitivity of tightness testing.

1. Introduction

An example of good practice in pipework

The main objective of this guide is to provide information on aspects of design and installation standards that prevent or reduce refrigerant leakage.

In order to reduce carbon emissions, it is vital that the initial design of the refrigeration system gives priority to eliminating potential cause of leaks. Direct carbon emissions take into account the impact of refrigerants if leaked to atmosphere, and indirect carbon emissions take into account energy use associated with running refrigerating equipment. Getting the design right in the first place will reduce both aspects of these emissions and will prevent problems in the long run.

This document has been produced specifically as an aid to consultants, designers and specifiers. End users may also find it a useful addition to their design specifications. It is not intended to be a definitive guide to the design of RAC systems; rather, it offers guidance on a practical approach to leak reduction.

Under the F Gas Regulation EU517/2014 contractors "carrying out the installation, servicing, maintenance, repair or decommissioning of RACHP equipment shall be certified and shall take precautionary measures to prevent leakage of F Gases"

2. Refrigerant Selection

The F Gas Regulation imposes a "placing on the market" ban on certain systems and refrigerants, and has introduced a quota system for HFC refrigerants. This has a significant effect on the refrigerant use in new systems.

There is a gradual phase out of the use of some HFCs, dependent on GWP and application. The most applicable are shown in the table below.

Ban effective from 1st Jan …	Application	Ban effective for refrigerants with a GWP greater than …
2015	Domestic fridges, freezers	150
2020	Commercial fridges, freezers	2500
2022	Commercial fridges, freezers	150
2020	Most stationary HFC equipment	2500
2022	Central plant greater than 40 kW cooling capacity (except as the high stage of a cascade)	150 1500
2020	Moveable room air conditioning	150
2025	Single split air conditioning with less than 3kg charge	750

Note – this is for new systems sold from the dates shown, not existing systems.

A phase down of HFC started in 2015 from a baseline of the average of the annual amount placed on the market between 2009 and 2012. The table below shows the phase down schedule, which is based on CO_2 equivalent.

Year	Phase down percentage
2015	100%
2016 – 2017	93%
2018 – 2020	63%
2021 – 2023	45%
2024 – 2026	31%
2027 – 2029	24%
2030	21%

If the current rate of refrigerant use (in terms of weight) is to be maintained the effect of the phase down will be to move the industry towards the lower GWP refrigerants. The availability of high GWP refrigerants such as R404A and the R407 series will reduce rapidly. **The GWP of refrigerant must be a prime consideration when selecting refrigerant.**

3. Minimise the refrigerant charge

Refrigerant loss potential is directly linked to the amount of refrigerant in the system. The designer should always aim to maximise the specific refrigerant charge, i.e. the ratio of design cooling capacity to mass charge of refrigerant. End users should ensure that this is taken into account when comparing system options.

In practice, refrigeration systems sometimes hold an amount of refrigerant above and beyond what is required in a liquid receiver to satisfy a varying cooling load. This could lead to excessive refrigerant loss in the event of a catastrophic leak. In addition, minor leaks may go unnoticed until the “buffer” refrigerant charge has been dissipated.

The commissioning team should be informed of the exact refrigerant charge to avoid overcharging the system with refrigerant.

4. System construction

a) Minimise the number of mechanical joints and seals

A large proportion of refrigerant leaks are caused by the failure of mechanical joints and fittings. Care should be taken to avoid unnecessary joints and access points. Preference should be given to welded or brazed fittings. Brazing or welding should only be carried out by appropriately trained, certified engineers.

Where flared joints are necessary (e.g. for small filter driers), flare solder adaptors should be specified.

A Schrader badly fitted into the end of a poorly sealed copper pipe

b) Piping fittings and construction

Pipe work will depend on the type and size of the installation, refrigerant type and cost. Steel pipe has superior mechanical strength and is resistant to vibration and work hardening in comparison with copper tube.

Copper pipe is lighter and is easier to bend and join. Joints should be carefully made, particularly when brazed. It is good practice to purge an inert gas such as oxygen free nitrogen to prevent oxides (scale) forming on the inside of the pipe.

c) Pipe bracketing

Poorly laid out pipework on the ceiling void of a chill store

Refrigerant pipework represents a risk of leakage if it is damaged or inadequately supported. Designers should therefore take great care in pipe routing to ensure it cannot be walked on or damaged easily. Where this is not practicable, the pipe work should be adequately protected and warning labels should be positioned accordingly.

Incorrectly installed vibration eliminator

Consideration must be given to the minimisation of the effects of liquid hammer and vibration when designing piping layouts. The selection of appropriate pipe diameter is equally important.

d) Capping valves

Capped stop valve to the right of the photo with the control actuator to the left

Uncapped valves, especially Schraders, can lead to long-term, low level leakage. Make sure that specification includes a requirement for all valves to be capped before handing over a system to the client. Consideration should be given to supplying caps that are attached to the valve, e.g. with a chain, so that they cannot become separated.

5. Pressure relief valves

Pressure relief is a necessary design safety consideration. The pressure relief valve and its exhaust must be adequately sized. Dual-port inlet valves are preferred as these allow rapid changeover of the pressure relief valves with minimal interruption to the system.

It is feasible to install internal pressure relief valves between the compressor discharge and suction. The pressure setting of this valve must be above the manual HP cut-out pressure of the system but below the main PRV vent to atmosphere.

EN378 Part 4 Annex D Clause 6 recommends that external pressure relief devices are checked on site every five years. However, guidance should be provided by the manufacturer taking into account the operating environment.

6. Installation practice

EU 517/2014 (the F Gas regulation) specifies that engineers carrying out installation work related to refrigerant handling must hold the appropriate F-Gas handling certificate and must take precautionary measures to prevent leakage. Engineers carrying out unrelated installation activities do not need a refrigerant handling qualification. However, anyone doing work that could impact on refrigerant leakage must be qualified – e.g. an engineer setting a high pressure cut-out device should be qualified – if this was set incorrectly it could give rise to a leak. See GN1 for further information.

During construction, pipe work and fittings must be protected from dirt and moisture. Systems should be purged with nitrogen to prevent oxide build-up inside the pipe. The pipe work should be securely bracketed, especially with regards to the small bore pipe.

The system should be properly evacuated to ensure minimal moisture content after strength and tightness pressure testing with oxygen-free nitrogen (OFN).

7. Fixed leak detection systems

The F Gas Regulation dictates that systems with more than 500 tonnes CO_2 equivalent refrigerant charge have an automatic leak detection system fitted. An automatic leak detection system is defined as a "*calibrated mechanical, electrical or electronic device for detecting leakage of F-Gases which, on detection, alerts the operator or a service company of any leakage*". The detection system must be checked annually.. If fitted to systems with a smaller charge size the frequency of leak checks can be halved.

Note – the CO_2 equivalent of the charge is:

Refrigerant charge amount (kg) x GWP.

GWP values for common refrigerants is provided in the Guide to Good Leak Testing.

The requirements for refrigerant detectors are also laid down in EN 378-3:2008+2012. In essence for all A1 refrigerants (such as HFCs) this means that a refrigerant detection system is required in the machinery room where the system charge is greater than 25 kg or in any location where the maximum concentration of the refrigerant could exceed the practical limit (The practical limit of the refrigerant indicates the allowable refrigerant charge related to the smallest human occupied space as defined in EN 378:2008+2012).

8. Commissioning tests

It is important that the system is confirmed as clean and leak free as part of the commissioning process. Prior to running the refrigeration system, the system is subject to the following pressure tests:

Strength testing of the system – Usually achieved using an inert gas such as oxygen-free nitrogen. The strength test ensures the integrity of the system. EN378 part 2 clause 6.3 refers to appropriate methods and applicable test pressures.

Leak tightness testing – An initial tightness test (typically at 10-100% of the maximum allowable pressure) is usually undertaken before the strength test. This ensures that there are no major leaks on the plant prior to undertaking the strength test. The full tightness test is undertaken after the strength test. EN378 part 2 clause 6.3 refers to appropriate methods and applicable test pressures.

Leak test fluids – The standard fluid used throughout the refrigeration industry for pneumatic tightness testing is oxygen-free nitrogen, commonly referred to as OFN. Should there be a leak in the system, it will be necessary to find the exact location of the leak. The use of leak detection spray may not be appropriate in a complex piping system. In this instance, a mix of 10-30% helium (tracer) and OFN, or <5% hydrogen (tracer) and OFN is used, with specific detectors for hydrogen or helium used to pinpoint the leak. *[Note: for safety reasons do not exceed 5% hydrogen].*

Checking for leaks – During the tightness test, all joints should be checked for tightness using either a leak detecting bubble spray or an ultrasonic detector. Where a trace of helium or hydrogen has been used, an appropriate electronic leak detector that is sensitive to the trace element must be used.

Length of the test – The tightness test pressure should be held for at least one hour; a longer period of up to 24 hours may be appropriate for larger systems where a fall in pressure due to leaks may not become quickly apparent (an estimation of the leak rate should be carried out according to the pressure decay with time, taking into account temperature changes and the accuracy of the pressure gauge). Where a trace element has been added to OFN, all joints and other potential leak points should be checked using a leak detector that is sensitive to the trace element.

Rechecking – If leaks are identified during the tightness test they should be located and fixed. A further leak tightness test is performed and repeated until satisfactory results are obtained.

The European Safety Standard EN 378: 2008 Part 2 Section 6.3 details the specific requirements for these tests. It also references Standards that detail test procedures.

9. Documentation and hand over

It is a statutory requirement to provide the equipment owner with certain documentation (such as EC declaration of conformity as required by the PED, or a system log book as required by the F Gas Regulations). This is an important communication tool from the designer / installer to enable the end user to understand the system design and prevent problems such as leakage occurring in the future.

a) Commissioning data recorded should include:

- Details of pressure and tightness tests.
- The refrigerant and lubricant used and the mass or volume of the refrigerant charge.
- Safety device settings such as pressure relief valves, high and low pressure cut-outs and any temperature based protective arrangements.
- Full load running currents and supply voltages for compressor drive motor(s), where applicable, and for other drive motors on the plant.
- Design and actual operating pressures and temperatures.
- Any other relevant information.

Commissioning data should represent the best operational settings of the system achievable by the commissioning specialist. For this reason, commissioning records are important in performance monitoring of the plant, these records being used to assess how operational parameters are being sustained in use. These records should be kept for the life of the plant.

b) F Gas refrigerant records

Records must be kept throughout the life of the plant and should be completed by a certified person. They include full details of the initial refrigerant charge, leak tests and repairs, particulars of additional top-up charges and of any removal of refrigerant from the system. Details should include, for any top-up charges, notes of the cause(s) of loss of refrigerant, where found, and of remedial actions taken. A sample F Gas record is provided in the Guidance on Good Leak Testing.

c) Labelling of new equipment containing HFCs

All new equipment must be manufactured or installed with an appropriate label and instruction manuals containing information about F Gases contained in the system in English from 1st April 2008. The label must be clearly legible and remain securely in place throughout the life of the product. It must include the wording "Contains fluorinated greenhouse gases covered by the Kyoto Protocol", identify the refrigerant by abbreviated chemical name e.g. R410A, R134a, specify the quantity of HFC refrigerant in kilograms (must include the manufacturer's original charge, any fluorinated greenhouse gases added on site and the total quantity.

From January 2017 the refrigerant quantity must also be provided in CO_2 equivalent and the GWP of the refrigerant must also be stated.

The label should be placed in a way which ensures visibility to installation and servicing technicians. For any system with separate indoor and outdoor sections connected by refrigerant piping, the label information must be placed on that part of the equipment which is initially charged with the refrigerant. Suitable locations for the labels are on, or adjacent to, existing nameplates or product information labels, or adjacent to servicing access locations.

Hermetically sealed equipment containing HFC refrigerant must also be labelled with the wording "Hermetically Sealed". This is defined as: a system in which all refrigerant containing parts are made tight by welding, brazing or a similar permanent connection which may include capped valves and capped service ports that allow proper repair or disposal and which have a tested leakage rate of less than 3 grams per year under a pressure of at least a quarter of the maximum allowable pressure.

10. References and sources of further information

- F Gas Regulations – EU 517/2014 Regulation of the European Parliament and of the Council on Certain Fluorinated Greenhouse Gases
- R22 Phase Out and F-Gas Regulations available from www.ior.org.uk
- Guidance from the UK Environment Agency F Gas Support service at
- https://www.gov.uk/government/collections/eu-f-gas-regulation-guidance-for-users-producers-and-traders
- Detailed guidance notes on F Gas Regulations from http://www.gluckmanconsulting.com/f-gas-information-sheets/
- EN 378:2008+2012 Refrigerating systems and heat pumps – Safety and environmental requirements available from www.bsigroup.com (under revision)
- EN 16084 Refrigerating systems and heat pumps – Qualification of tightness of components and joints available from http://www.bsigroup.com
- EU Pressure Equipment Directive 97/23/EC,
  Pressure Equipment Regulations 1999 (SI 1999/2001) and The Pressure Equipment (Amendment) Regulations 2002 (SI 2002/1267)
- Guidance on practical issues relating to pressure systems (Guidance Note 21) available from www.ior.org.uk
- The British Refrigeration Association Joining of Copper Pipework for Refrigeration Systems – www.feta.co.uk