



With contribution of
the LIFE programme
of the European Union

Containment & Leak Detection

of Alternative Refrigerants

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Welcome to the REAL Alternatives Europe Blended Learning Programme

This learning booklet is part of a blended learning programme for technicians working in the refrigeration, air conditioning and heat pump sector designed to improve skills and knowledge in safety, efficiency, reliability and containment of alternative refrigerants. The programme is supported by a mix of interactive e-learning, printed training guides, tools, assessments for use by training providers and an e-library of additional resources signposted by users at www.realalternatives4life.eu

REAL Alternatives has been developed by a consortium of associations and training bodies from across Europe co-funded by the EU Lifelong Learning Programme, with the support of industry stakeholders. Educators, manufacturers and designers across Europe have contributed to the content. The materials will be available in Croatian, Czech, Dutch, English, French, German, Italian, Polish, Romanian, Spanish and Turkish.

Real Alternatives Europe Programme Modules	
1	Introduction to Alternative Refrigerants - safety, efficiency, reliability and good practice
2	Safety and Risk Management
3	System design using alternative refrigerants
4	Containment and leak detection of alternative refrigerants
5	Maintenance and repair of alternative refrigerant systems
6	Retrofitting with low GWP refrigerants
7	Checklist of legal obligations when working with alternative refrigerants
8	Measuring the financial and environmental impact of leakage
9	Tools and guidance for conducting site surveys

You can study each module individually or complete the whole course and assessment.

www.realalternatives4life.eu



More information is available in the online reference e-library.

Throughout the text of each module you will find references to sources of more detailed information. When you have completed the module you can go back and look up any references you want to find out more about at www.realalternatives4life.eu/e-library. You can also add extra resources such as weblinks, technical manuals or presentations to the library if you think others will find them valuable. Module 7 provides a complete list of relevant legislation and standards referred to within the programme.

Assessment options are available if you want to gain a recognised CPD Certificate.

At the end of each module are some simple self-test questions and exercises to help you evaluate your own learning. Certification and Assessment will be available from licensed REAL Alternatives training providers when you attend a course of study. The list of recognised training providers will be available on the website.

Register your interest in alternative refrigerants

at www.realalternatives4life.eu to receive updates, news and event invitations related to training, skills and refrigeration industry developments.

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Background to the programme and how it was developed.

This learning programme was developed as part of EU co-funded projects led by a consortium of partners from across Europe. It is designed to address skills shortages amongst refrigeration, air conditioning and heat pump technicians related to the safe use of alternative refrigerants. It provides independent and up to date information in an easy to use format. The project consortium included training and professional institutes as well as employer representative bodies. Stakeholders from across Europe drawn from employers, manufacturers, trade associations and professional institutes also contributed learning material, advised on content and reviewed the programme as it was developed.

The consortium partners:

- Association of European Refrigeration Air Conditioning & Heat Pump Contractors, Belgium
- Associazione Tecnici del Freddo, Italy
- IKKE training centre Duisburg, Germany
- Institute of Refrigeration, UK
- International Institute of Refrigeration
- University College Leuven-Limburg, Belgium
- London South Bank University, UK
- PROZON recycling programme, Poland.

With thanks to our stakeholders:

- CNI National Confederation of Installers, Spain
- CHKT Czech Association for cooling and air conditioning technology
- HURKT, Croatian Refrigeration Airconditioning and Heat Pumps Association
- RGAR Association General of Refrigeration, Romania
- SOSIAD Association of Refrigeration Industry and Businessmen, Turkey
- SZ CHKT Slovak Association for Cooling and Airconditioning technology

Module 4 – Containment and Leak Detection

1 Introduction

This Module provides an introduction to the topic of leakage reduction. It does not replace practical training and experience. At the end of the Module you will find links to useful additional information from a range of sources that have been peer reviewed and are recommended technical guidance if you would like to find out more about these topics. In this Module we will look at containment and leak detection of charged, operating systems. Reducing leakage is important for all refrigerants for the following reasons:

- For safety - all refrigerants are asphyxiants, many of the alternatives are flammable and R717 is toxic;
- To maintain performance – a leaking system has less capacity and consumes more power than a fully charged system;
- To minimise the cost associated with refrigerant replacement, service and the additional energy consumption;
- To improve reliability and minimize consequential losses;
- To minimise the direct effect on climate change – some of the alternatives have a significant global warming potential;
- To minimise indirect CO₂ emissions associated with additional power consumption;
- It is a legal requirement for fluorinated gases (F Gases) – this includes R32.



Figure 1, Electronic leak detector for HC refrigerant

Effective leak detection is important, but it is even more important to ensure that refrigerant containment is a high priority.

There is a lot of detail about R717 leak detection because it is significantly different from HFC detection.

2 Effective Leak testing

This section covers the different methods of leak testing and shows how they should be carried out.

The table below summarises the methods which can be used to detect each alternative refrigerant.

Table 1, Leak detection Methods

Refrigerant	Leak detection spray ¹	Electronic leak detector ¹	Fluorescent additive	Ultrasonic
R744	Good	Good, ensure the detector is sensitive to R744	OK	Good
R717		Good, ensure the detector is sensitive to R717	Not suitable	
R32		Good, ensure the detector is sensitive to the refrigerant type and is safe with a flammable refrigerant	Good	
R1234ze				
R1234yf				
HCs (R600a, R290, R1270)				

1. Ensure the system pressure is positive (i.e. above atmospheric pressure) when using either of these methods. This is especially important with R717, R1234ze, R1234yf and R600a which operate with lower pressures than other refrigerants.

For many of the methods the pressure needs to be as high as possible:

- When checking the high pressure side the system should be running, with the condensing pressure as high as possible;
- When checking the low pressure side the system should be off (but not pumped down). For example the operating pressure of an R290 system evaporating at -30°C is 0.6 bar g, but at standstill in an ambient of 20°C the pressure will be 7.4 bar g. Don't switch off R744 systems if this would result in PRVs venting;
- For a system which has saturated gas defrost, it should be on defrost when checking the low side;
- For reverse cycle heat pumps both sides of the system should be checked at the highest possible condensing pressure.



Figure 2, Leak testing

With all methods it is important that the test is carried out methodically and that all parts of the system are tested, including spurs such as pressure switch connections and pressure

relief valve vent lines. All leaks should be found – the first leak found is probably not the only leak.

Leaks should be repaired as soon as possible and the leakage point re tested.

Videos showing how bubble solution, hand held leak detectors and additive can be used effectively to identify leaks; and demonstration of a combined UV and ultrasonic device used for identifying leak points are available in the REAL Alternatives e-library.

REAL Alternatives
e-library

Leak detection spray

It is recommended that a proprietary leak detection spray is used instead of a “home-made” soap or detergent solution. Home-made solutions can be too thin, so bubbles won’t form, or too thick, so they actually mask a leak.

A proprietary leak detection spray is usually a non-corrosive substance which is of the right consistency to form bubbles easily. It can also contain an anti-freeze so it can be used on pipe work below 0°C. The spray method is a good method for pinpointing leaks, but is time consuming on a large system with many joints. It cannot be used on insulated pipe work, or on sections of the system which are running at a pressure lower than atmospheric pressure. It can take many seconds for a bubble to form if the leak rate and / or the pressure is low.

It is a good method for pinpointing the exact location of a leak which has been found by an electronic leak detector.



Figure 3, Example of bubbling caused by leakage

Videos available in the REAL Alternatives e-library demonstrate examples of leaking refrigerant causing bubbling of the detection spray and the difficulty of identifying leakage points.

REAL Alternatives
e-library

Electronic Leak Detectors

Electronic leak detectors are test instruments which need to be looked after, checked and maintained to ensure accuracy. It is recommended they are checked every time they are used. Under the F Gas regulations, which are relevant to R32 and R1234ze, they should be checked once a year. This is a minimum requirement – for optimum reliability they should be checked more frequently.

The detector should not be contaminated with oil, and the filter



(where fitted) should be replaced regularly.

The three types of leak detector most commonly used rely on different methods of detection:

- Heated diode detectors – the diode needs changing usually after 100 hours use. The photo shows a typical heated diode. This is usually the cheapest method and is the most widely used for HFC refrigerants.



- Infra red (IR) detectors – the IR sensor needs changing less frequently. The photo shows a typical IR leak detector.



- Semi conductor – the sensor general lasts several years. The photo shows a typical detector used for HCs. Similar technology is used for R717.



It is important that where electronic leak detectors are used with flammable refrigerants (R600a, R290, R1270, R32 and R1234ze for example), they are safe as well as being sufficiently sensitive to detect the refrigerant. Many electronic leak detectors which are used for HFCs are not safe for use with flammable refrigerants.

A reference leak should be used to check the detector is working correctly – just opening a cylinder or a connection on the system to check the detector is not accurate enough. The photo shows a simple calibrated reference leak device that fits onto the cylinder valve or onto a connection on the system. When the valve is



opened the flow through the device is approximately 5 g / year with the specified refrigerant. If the leak detector does not pick this up it needs servicing. This method can be used with most refrigerants, although its leak rate will vary. Its use with R744 should be checked with the supplier – the R744 pressure may exceed the maximum pressure of the device.

Reference leaks are also available for some refrigerant types. Typically these are supplied in a small container and leak at a rate of 5 g/year at 20°C.

High air flow can disperse leaking refrigerant so that it cannot be detected by an electronic leak detector. If possible condenser and evaporator fans should be stopped when checking around these components. Take care that high pressure switches do not trip and pressure relief valves do not vent as a result of switching off condenser fans. If possible, plant room ventilation and any other fans in plant rooms should be switched off to check equipment within the room. Take care that this does not result in a flammable atmosphere in the event that there is a leak.

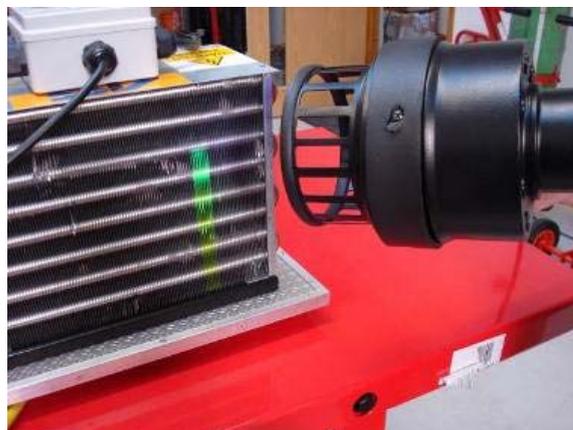
All alternative refrigerants except R717 are heavier than air, so the underside of all joints should be checked. When entering a cold room the air at floor level should be checked. Where risers are fitted in cupboards the bottom of the cupboard should be checked.

A video in the REAL Alternatives e-library demonstrates methods of testing the operation of your hand held leak detector.

REAL Alternatives
e-library

Fluorescent Additive

A fluorescent additive can be added to the oil in a system. In the event of a leak the additive and oil leak and can be detected with an ultra violet lamp. The advantage of this method is that it will show a leak even if the joint or component is not leaking during the test, a useful feature for intermittent leakage or where the entire charge has already been lost. The additive stains the pipe work and should be removed after detection.



This method does have some disadvantages:

- Some compressor manufacturers will not give warranty if the additive has been used;
- Coalescing oil separators separate out the additive so it does not enter the remainder of the system. This is particularly relevant to R744 central plant systems which usually use this type of oil separator.

Ultrasonic Leak Detectors

Ultrasonic leak detectors amplify the sound of a leak out of or into pipe work. An example is shown in the photo.

Typically these detectors have a built in receiver that detects frequencies of sound within a specific range, i.e. similar to that of leaking refrigerant. The output can be via headphones, or a visible / audible alarm.

An advantage of this method is that it can be used with any refrigerant in the system (or with nitrogen), and on parts of the system where the operating pressure is below atmospheric pressure.



Litmus

R717 can be detected by a paper which changes colour dependent on pH (acidity). Leak detection by means of phenolphthalein paper (colour change on a test strip) has poorer detection sensitivity than an electronic leak detector so is not the recommended method as a detection method on its own. However, wetted paper can be used to pinpoint the leak point, for example on a flange or pipe of an ammonia system. The litmus paper changes colour detecting a change in pH due to the absorption of ammonia into wetted paper.



Visual checks

A visual check is not included in the table of leak test methods, but its use should not be underestimated. Indicators include:

- Oil stains on pipe work;
- Oil stained insulation;
- Dust sticking to oil on pipe work;
- Corrosion, excessive wear or damaged components.

Oil stains should be cleaned after the leak has been repaired so they do not give a subsequent false indication of leakage.

The indicator (tell-tale) on a pressure relief valve should be checked because PRVs which have operated do not always seal correctly.

The main cause of a continually flashing liquid line sight glass is insufficient refrigerant, usually caused by leakage. However, a leak does not always result in flash gas in the liquid line, especially if the load and / or the ambient temperature are low, so the system should be leak tested even if the sight glass shows clear liquid.

Many receivers are fitted with low liquid level indicators and they can be used to show that the system is undercharged. They should be checked to ensure they are functioning, for example by watching the rise in liquid level on the indicator as the system is pumped down. Again, a system can still have a leak even if the receiver liquid level indicator is not showing undercharge.



Figure 4, Examples of visual indicators of leakage

Odour

Most refrigerants do not smell but R717 has a very pungent odour and R1270 has a very slight “gassy” smell.

R717 can be easily detected by smell and can be perceived by smell at low levels of at 5 ppm = 3.5 mg/m³. Leaks will need to be pinpointed using an electronic leak detector or litmus paper.

The smell of R1270 is not strong enough for it to be used as a reliable indicator of leakage.

Indirect Leak Test Methods

A leaking system’s operating conditions will usually vary from normal conditions:

- The suction pressure will be lower (unless it is controlled, for example in a central plant system);
- The useful superheat (i.e. the superheat achieved in the evaporator) will increase;
- The subcooling will reduce;
- The discharge pressure will reduce (unless it is controlled).

Excessive superheat and low or zero subcooling are both good indicators of low refrigerant charge

Measuring the liquid level in a receiver can also identify loss of refrigerant, however, liquid levels naturally vary with changing load conditions and ambient conditions.

IOR Guidance Note on
Measuring Superheat
and Subcooling

REAL Alternatives e-
library video on
superheat and
subcooling

IOR Guidance Note on
indirect leak checking

R717 Systems

Leak Testing before initial commissioning

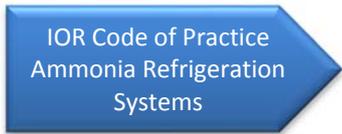
- ✓ Leak tests should be carried out on the basis of nationally approved standards.
- ✓ Of particular importance is the detection and repair of leaks on high pressure parts of the plant which will become difficult to access when the plant is put into operation.

Leak Testing in existing plants

- ✓ As soon as ammonia can be smelt, leak detection is necessary. Here again, this should be based on nationally approved standards
- ✓ Leak detectors can only estimate the leakage rate (small, medium, large) as opposed to a measured flow rate.
- ✓ Leak detection sprays have far poorer sensitivity than electronic detectors.
- ✓ If the leakage rate of an ammonia leak has to be quantified, detection instruments can be used that work according to the principle of photoacoustic infrared absorption.

Competence Requirements

Leaks testing and any faults on Ammonia systems must be monitored and rectified immediately by a qualified, competent person according to national legislation. After a fault has been rectified, the plant must be recommissioned after carrying out suitable pressure testing.



IOR Code of Practice
Ammonia Refrigeration
Systems

Leak Detection

- ✓ Ammonia is easily detected due to its strong smell (human perception limit 5 ppm = 3.5mg/m³) which will indicate the need to search for leaks.
- ✓ Leaks which under certain circumstances can remain undetected in HFC plants for a period of time are simply inconceivable in ammonia plants.
- ✓ Very small leaks in ammonia refrigeration plants (leakage rate of approx. 100g NH₃/a) cannot be detected by smell as an ammonia concentration of 5 ppm is not reached.

Principles of Avoiding Risk

- ✓ Keep the refrigerant quantity as low as possible: refrigerant that is not in the system cannot leak.
- ✓ A well planned refrigeration plant with appropriate equipment selection and use of isolation valves will reduce refrigerant emissions during maintenance and servicing.
- ✓ Components that seal well should be selected to minimise leakage. Allowance should be made for regular leak tests.
- ✓ It is important to select materials with suitable compatibility otherwise leak paths may occur. The volume of elastomers for example can increase (swell) or decrease (shrink) in combination with certain oils and ammonia.

Pipework

- ✓ Because ammonia is corrosive with copper, ammonia systems will normally be constructed using carbon or stainless steel pipework and fittings. More details on

the best practice associated with ammonia pipework is detailed in the IOR's Ammonia Refrigeration Systems Code of Practice.

- ✓ In principle welded joints should be used in preference to flanged joints to minimize the risk of leakage.
- ✓ For pipework of less than 40mm diameter socket weld fittings should be used as opposed to butt welded joints.

Monitoring water circuits for ammonia leaks

- ✓ According to EN 378 refrigeration plants with more than 500k should include measures to ascertain the presence of refrigerant in all connected water or fluid circuits.
- ✓ Ammonia must be prevented from entering the sewerage system or the cooling water of an evaporative condenser.
- ✓ The most common measuring system at present is to monitor the pH values. An ammonia leak in a water circuit causes the pH value to increase. It is advisable to install a device for differential measurement of the pH value between the inlet and outlet of the heat exchanger with automatic temperature compensation. In the case of a pH alarm, it is necessary for the heat exchanger to be shut off on the water and ammonia side by means of motor valves or by hand. Newer ion-selective measuring devices are much more precise.
- ✓ Another possibility is to use an ammonia-sensitive electrode. Differential measurement is not necessary in this case.

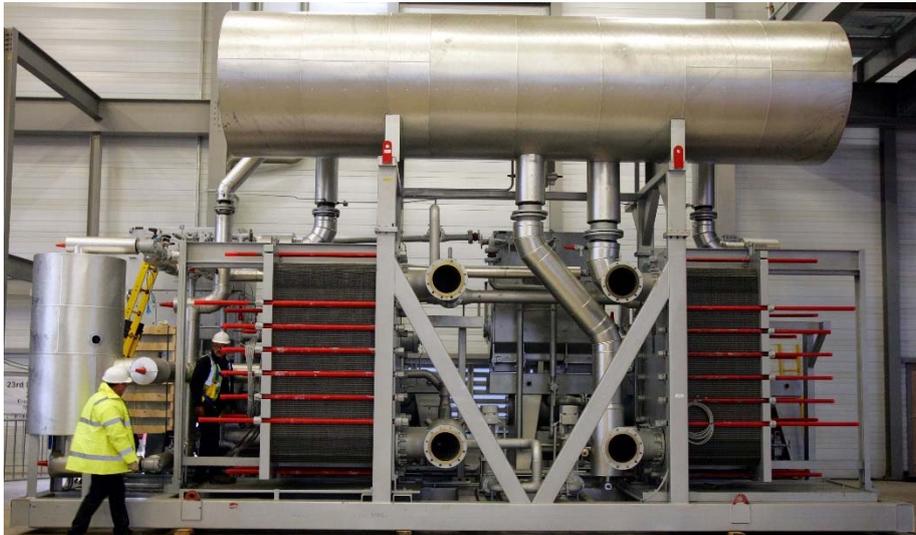


Figure 5, Example of an ammonia chiller with stainless steel pipework

3 Pressure Testing Using Nitrogen

If leaks cannot be found using the methods outlined above, or if the entire refrigerant charge has leaked, the system will need to be pressure tested using nitrogen.

The system should be slowly filled with nitrogen to the maximum allowable pressure (PS)¹ and then either:

- Each joint should be checked with leak detection spray;
Or
- The system should be held under pressure for a period of at least 12 hours and the pressure checked at the end of the test to ensure it has not reduced.

IOR SES Good Practice Guide 24 – Pressurising installed systems with nitrogen to find leaks

Effect of ambient temperature on pressure

Note that if the latter method is used the ambient temperature must also be taken into account because of the relationship between the temperature and pressure of the nitrogen gas in the system. If this is not done then an ambient temperature increase could mask a nitrogen loss. In accordance with Gay-Lussac’s Law (also called Amontons’ Law of Pressure-Temperature):



$$P2 = (P1 \times T2) / T1$$

Where:

- P1 is the pressure at the start of the test in bar absolute
- P2 is the pressure at the end of the test in bar absolute
- T1 is the ambient temperature at the start of the test in Kelvin
- T2 is the ambient temperature at the end of the test in Kelvin.

Typically, for most pressures, the pressure will change by 0.7 bar for a 5K change in temperature. For pressures associated with R744 the change will be greater.

An excel calculator can be used to do this calculation – the picture is an example of the output for a pressure test on the high side of an R744 transcritical system.

Nitrogen Pressure Change	Inputs
Starting Pressure P1 (bar g)	120.00
Starting Temperature T1 (°C)	7.00
Finishing Temperature T2 (°C)	18.00
Finishing Pressure P2 (bar g)	124.75
Pressure Change (bar)	4.75

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www.coolconcerns.co.uk

Premix trace gas

The pressure test can also be carried out using a proprietary mix of nitrogen with a trace of helium or hydrogen, typically 5% trace gas in 95% nitrogen. The advantage of using helium or hydrogen trace gas is that both have small molecules and low gas velocity and molecular mass, so they leak faster and diffuse more readily. An electronic leak

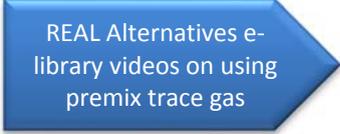


A Gas information on Trace-A-Gas

¹ EN378-2:2016 Refrigerating systems and heat pumps – Safety and environmental requirements, Design, construction, testing, marking and documentation 6.2.2

detector sensitive to the trace gas must be used, but these are readily available. The photo shows an example of one which detects both hydrogen and hydrocarbon refrigerant.

Note – pre mixed trace gas is widely available and should be used, it should not be mixed on site.

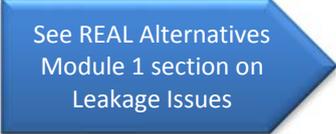


REAL Alternatives e-library videos on using premix trace gas

4 Potential Leak Points

Potential leak points on systems operating with alternative refrigerants are similar to those on conventional systems. The leak potential on HC systems tends to be low because the systems are usually close coupled with a small number of joints. The leak potential for R744 systems is generally higher as it tends to be used in central plant systems with many joints and higher operating and standstill pressures. It also has a small molecule size which diffuses more readily.

As with all refrigerants, the following are important factors in minimising leak potential:



See REAL Alternatives
Module 1 section on
Leakage Issues

- ✓ The system type – large central plant systems inherently leak more than close coupled systems – this is partly due to the on site installation and the increased number of joints in a central system;
- ✓ The operating and standstill pressures – with higher pressures even greater care is needed in the selection of components, jointing, installation and leak detection;
- ✓ The specification of components – they must be appropriate for the pressure, temperature, refrigerant and oil. This includes everything from Schrader valve cores to brazed plate heat exchangers and compressors;
- ✓ Compressors - avoid the use of open drive compressors where possible. If they must be used, ensure that they have shaft seals;
- ✓ Essential information – accurate drawings should be provided which show the location of all joints and access points;
- ✓ Design for ease of service – joints should be accessible to ensure leak detection can be easily and thoroughly carried out;
- ✓ The pipe thickness – this must be adequate for the pressure. For some parts of R744 systems steel pipe work or K65 copper tube² will need to be used to contain the high pressures;
- ✓ The method of joining pipe to pipe and pipe to component – brazed or welded joints will always have a lower leak potential than any type of mechanical joint. Technicians who braze or weld should have an appropriate qualification to demonstrate their competence. The correct jointing materials should be specified;
- ✓ Pipe work design and installation - pipe routing should be such that vibration is minimised, pipe should be adequately clamped (not just supported) in accordance with EN378³. Pipe work should be installed so that it does not chafe;
- ✓ Component installation – many components should be wet ragged during hot works to prevent damage. Schrader valve cores should be removed during hot works. Compressors should be mounted in accordance with the manufacturer's instruction to ensure they do not transmit vibration;

² K65 tube has 2.5% ferrous and is suitable for the high side of R744 trans critical systems

³ EN378-2:2016 Refrigerating systems and heat pumps – Safety and environmental requirements, Design, construction, testing, marking and documentation, 6.2.3

- ✓ Adequate pressure testing to identify leaks before putting the system into service - systems should be pressure tested for strength and leak tightness in accordance with EN378⁴. Time must be allowed for the tightness test to be thorough and for failures to be repaired and re tested;
- ✓ High pressure switch setting - in accordance with EN378⁵ the setting should be no more than 90% of PS where pressure relief valves (PRVs) are fitted. If this is not the case the PRV can vent on rapid rise of pressure because the high pressure switch does not switch the system off in time;
- ✓ Maintenance - the maintenance regime should be appropriate for the plant type. The leak test frequency specified in the F Gas regulations⁶ should be used as a minimum for all refrigerant types (see section 6), but many systems will benefit from more frequent leak testing, for example weekly or monthly. Any leaks found should be repaired immediately and the system re leak tested;
- ✓ Appropriate service - all valves should be capped, condensers kept clean to minimise pressure, controller set points should minimise head pressure and any vibration issues should be corrected.

Flared connections

The use of flared connections should be minimised, but on some connections a demountable joint is preferred (for example on liquid line filter driers on HC systems so these can be changed without the need for unbrazing). In this case a flare solder adaptor should be used. This machine made connection has a lower leak potential than a manually made flare.

The flare nut should be tightened to the correct torque using a torque wrench. Correct torque values are provided by the manufacturer of the flare solder adaptor, and also in EN378⁷ for manually made flares.

⁴ EN378-2:2016 Refrigerating systems and heat pumps – Safety and environmental requirements, Design, construction, testing, marking and documentation, 6.3

⁵ EN378-2:2016 Refrigerating systems and heat pumps – Safety and environmental requirements, Design, construction, testing, marking and documentation, 6.2.2

⁶ EC 842/2006 and EU 517/2014

⁷ EN378-2:2016 Refrigerating systems and heat pumps – Safety and environmental requirements, Design, construction, testing, marking and documentation, 6.2.3.2.3.3



Figure 6, Flare solder adaptor and tightening to the correct torque

Schrader valves

The work carried out for the UK Real Zero project in 2007 highlighted 13 common points where leaks occur and how to prevent them. A visual guide to these leakage points can be downloaded from the REAL Alternatives e-library. It is critical that all these points are leak tested. Three key areas are identified from this work and subsequent experience with alternative refrigerants. These are where there is the most potential for major improvements as outlined below.

The valve cores must be selected so they are suitable for the refrigerant and oil type and the pressure and temperature range – different systems and refrigerants can require different types of Schrader core.

The core must be removed prior to brazing the Schrader body into the system, and then re fitted when the body is cool. The core must then be tightened to the correct torque.



Figure 7, Hex cap, Schrader valve and Schrader torque tool

The valve must be capped. Note that the cap commonly used has a seal which degrades and leaks if it gets hot – a hexagonal nut or Schrader valve cap which can be carefully tightened with a specialist tool is a better option. The nut should be selected so that it does not depress the Schrader when tightened.

R744 system pressure relief valves (PRVs)

Pressure relief valves on R744 systems are a common leak point for various reasons:

- Pressures in R744 systems can rapidly rise in the event of a change in conditions or a fault;
- The standstill pressure is often higher than PS (and hence the PRV setting) for some parts of the system;
- The operating pressure is often close to PS.

PRVs don't always re seat after discharge so it is essential they are leak tested. After multiple discharges the spring weakens, reducing the PRV vent pressure and exacerbating the issues highlighted above.

To reduce PRV discharges and leakage there should be sufficient difference between the normal operating pressure and PS for each part of the system.

To the right is an example of just one type of R744 PRV; others are available from a range of manufacturers.



5 Legal Requirements

The leak test frequency must be appropriate for the system type and its age and condition. For R32 the leak test frequency is specified in the 2014 European Fluorinated Gas Regulation 517/2014. It is recommended that all non-hermetic stationary systems (even those containing low GWP alternative refrigerants) should be leak tested regularly as part of a planned maintenance regime and results recorded for internal management and reporting purposes.

F Gas Regulation
517/2014

From 1st January 2015 the required leak test frequency for systems containing fluorinated gases is shown below:

Table 2, F Gas Regulation Leak test frequency, after 01.01.2015

System Charge	Leak test frequency
5 to 50 tonnes CO ₂ equivalent i.e. 7.4 to 74 kg R32	1 / year 1 / 2 years if a fixed leak detection system is fitted
50 to 500 tonnes CO ₂ equivalent i.e. 74 to 740 kg R32	2 / year 1 / year if a fixed leak detection system is fitted
More than 500 tonnes CO ₂ equivalent Fixed leak detection must be fitted i.e. more than 740 kg R32	4 / year 2 / year if a fixed leak detection system is fitted

If a leak is found it must be fixed as soon as possible and the system re-tested at the point of repair within one month.

It is important to view this leak test frequency as a minimum. More frequent leak tests should be carried out on systems which:

- Have a high number of potential leak points (e.g. central plant systems);
- Operate at high pressure (e.g. R744 and R32 systems);
- Are old or in poor condition.

This will save money by maximizing reliability, minimizing energy use, failure and down time.

Leakage has been shown to be significantly reduced on systems which are leak tested more frequently, for example once a month.

Asda Supermarket case
study paper from
Institute of
Refrigeration

6 System Records

System records are an essential tool in reducing leakage and are a mandatory requirement for many HFC systems (and therefore R32 and R1234ze systems). System records should be interrogated to identify common patterns of leakage, to enable comparison with similar systems and to identify ways of minimizing leakage in the future. They should also be kept for non HFC systems and should include the following information:

- The type and quantity of refrigerant in the system;
- The system PS values (maximum allowable pressure)⁸;
- Leak testing carried out;
- Location of leaks found;
- Repairs carried out.

The system should also be clearly labelled with the refrigerant type and weight, for HFC systems this must be expressed in CO₂ e (Carbon Dioxide equivalent eg for R32 the CO₂e is 675 per kilo)

Below is an example template for a system log – see more in Module 9 “Tools and Guidance on Site Surveys”

F Gas Refrigerant Monitoring Tool Institute of Refrigeration (IOR) REAL Zero Project													
Site Name:													
Site Address:													
Postcode:													
Telephone No.:													
Time Period Recorded		From:		To:		Telephone No.:							
System No.	Plant Name	Plant Reference No.	REFRIGERANT		TIME PERIOD			REFRIGERANT LOSS			REFRIGERANT EMISSIONS		
			Refrigerant Type	Refrigerant GWP (relative to CO ₂)	First Record Date	Latest Record Date	Period Covered (years)	Total Refrigerant Use (kg)	12 Month Equivalent Use of Refrigerant (kg p.a.)	12 Month Equivalent Loss of Charge (% p.a.)	Carbon Equivalent of Lost Refrigerant (tonneCO ₂ e)	12 Month Carbon Equivalent of Lost Refrigerant (tonneCO ₂ e p.a.)	
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
Totals (all systems)								0.0	0.0		0.0	0.0	

Time Period Covered by This Report (years)	0.00
Carbon Equivalent of Refrigerant Emissions Over This Period (tonneCO ₂ e)	0.0
12 Month Carbon Equivalent of Refrigerant Emissions (tonneCO ₂ e p.a.)	0.0
Total Refrigerant Used Over This Period - All Systems (kg)	0.0
Total Entrained Mass of Refrigerant - All Systems (kg)	0.00
Total Refrigerant Charge Lost Over This Period - All Systems (%)	#DIV/0!

Refrigerant Use (All Systems)

The chart displays two data series for 10 systems (numbered 1 to 10). The left Y-axis represents '12 Month Equivalent Refrigerant Use (kg p.a.)' ranging from 0.0 to 1.0. The right Y-axis represents '12 Month Equivalent Loss of Charge (%)' ranging from 0% to 100%. The legend indicates that dark grey bars represent '12 Month Equivalent Use of Refrigerant (kg p.a.)' and light grey bars represent '12 Month Equivalent Loss of Charge (% p.a.)'. All bars for both series are at the 0.0 level, indicating zero usage and zero loss of charge for all systems.

Disclaimer: The IOR accepts no liability for any errors or omissions

Version 3.4 © IOR 2009

Labels

It is a legal requirement to label systems containing F Gas Refrigerants and the contents of the label are specified in the regulations. However additional reminders (such as the examples below) can be used as labels on systems, leak detectors and refrigerant cylinders to highlight to technicians the importance of leak detection. These are available to download from the REAL Alternatives e-library.

⁸ PS is defined in EN378-1:2016, Refrigerating systems and heat pumps – Safety and environmental requirements, Basic requirements, definitions, classification and selection criteria, see Module 6 – Legal Obligations, for more information.

Have you checked that I'm working before you use me?



- ✓ Have you checked your leak detector sensitivity against a calibrated leak?
- ✓ Do not assume the first leak you find is the only leak!
- ✓ Refer to the Real Zero Leak Guide at www.realzero.org.uk



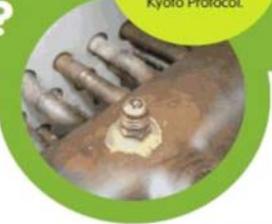

Have you found the leak before you use me?



- ✓ It is illegal to top up a system without first finding the leak!
- ✓ Refer to the Real Zero Leak Guide at www.realzero.org.uk




Have you found the leak before you charge me?



This Equipment contains fluorinated greenhouse gases covered by The Kyoto Protocol.

- ✓ It is illegal to top up a system without first finding the leak!
- ✓ Do not assume the first leak you find is the only leak!
- ✓ Refer to the Real Zero Leak Guide at www.realzero.org.uk

Contains kg of Refrigerant




7 Fixed Leak Detection Systems

Fixed leak detection is used for safety reasons and in some cases because it is a legal requirement (see previous section for HFCs). Fixed leak detection is not an alternative to manual leak checking.

Any fixed leak detection system should positively detect refrigerant in the air around the system and alarm in the event refrigerant is detected. The alarm should be treated as a priority.

Alarm level should be set at 25% of the LFL or 50% of the ATEL / ODL, whichever is the lowest⁹. Alarm levels for the alternative refrigerants are provided in the table below. Refer to EN 378 for full details about detector type and location and specific information about R717 alarms.

- IOR Guidance Note on Fixed Refrigerant Detection Systems
- Danfoss Gas Detection in Refrigeration Systems
- Eurammon Ammonia 5 Leak Monitoring at Ammonia Ref Plant
- IOR Guidance Note 10 Working with Ammonia

Refrigerant	LFL, kg/m ³	ATEL, kg/m ³	Alarm level, kg/m ³
R744	na	0.072	0.036
R717	0.116	0.00022	0.00011
R32	0.307	0.30	0.077
R1234ze	0.303	0.28	0.076
R600a	0.043	0.059	0.011
R290	0.038	0.09	0.010
R1270	0.047	0.0017	0.00085

Sensors

The sensors should be fitted at low level for all refrigerants except R717, which should be at high level. Alternatively, sensors should be fitted in the return air to the evaporator. There should be sufficient sensors to provide protection for the entire area. Sensors should be fitted in areas which pipe work passes through such as riser cupboards and ceiling voids.

The picture to the right is an example of one type of fixed leak detection device.



Calibration/Service

The fixed leak detection system should be accessible for calibration / service and protected from damage. There should be a facility to test the alarm. Alarms should be bump tested once a year as a minimum. Ideally the alarm system should warn both visibly and audibly with a buzzer (sounder) at least 15 dBA above the background noise level, both inside and outside the space.

⁹ EN 378-3:2016 9.3.1

R717 Detection Systems

Ammonia refrigeration machine rooms are monitored with fixed detectors as specified in EN 378 as a compulsory feature for plants filled with a quantity of more than 50kg. Smaller leaks are not detected because of the higher trigger threshold of approx. 500ppm.

Sensor Types

Toxic gases are normally detected in industrial environments by electro-chemical cells. Semi-conductor and pellistor (or catalytic) sensors are used for flammable gas detection. Sensors and systems for use in ammonia plantrooms must be intrinsically safe and suitable for Zone 2 hazardous areas.

a) Electro-chemical cells

- ✓ Electro-chemical sensors are designed to detect low levels of ammonia (50ppm and 500ppm) The sensors are essentially small batteries which start to discharge as soon as they are manufactured.
- ✓ The discharge rate is increased when in the presence of the target gas (and in some instances, but to a lesser extent, by other gases). They have a lifetime of perhaps eighteen months to four years (dependant on background gas levels and operational conditions of temperature and humidity).
- ✓ When using electrochemical cells, it must be accepted that they are consumable items which need replacement at regular intervals and that this may be expensive.

b) Semi-conductor Sensors

- ✓ The 10,000 ppm ammonia gas detection level can be covered with rugged semi-conductor sensors.
- ✓ The main advantages of semi-conductor sensors are long life, their ability to operate in harsh environments, fast response time and lower power consumption.
- ✓ The major disadvantage is their response to other gases, leading in some cases to spurious alarms.

c) Pellistor (or Catalytic) Sensors

- ✓ These sensors can also be used to detect the 10,000 ppm ammonia concentrations. The fundamental principle of the pellistor sensor is that the flammable gas is burnt on the surface of a heated platinum wire coated with a catalyst. Rises in temperature and resistance are detected electrically.
- ✓ However the sensor head can be “poisoned” by other compounds and the sensitivity can be markedly reduced if the sensor is immersed in large concentrations of the gas it is supposed to be detecting.
- ✓ Note, a pellistor may not detect if switched on in the presence of a gas with a concentration above the Lower Explosive Limit (LEL)

Infra Red Detection Systems

With this system, a small vacuum pump is used to draw filtered samples from several points and deliver them in sequence to an infrared analyser. The analyser searches the sample for the presence of the specific gas and can identify the zone from which it was taken. The analyser can detect ammonia levels in the range 0 ppm to 10,000 ppm.

Alarm Thresholds and switching function

- ✓ BS EN378 calls for low concentration level action at not greater than 500 ppm and for high concentration level action at not greater than 30,000 ppm.

- ✓ The low concentration level alarms are associated with toxic levels. At the low concentration level the mechanical ventilation shall be activated. In addition, an alert can be sent if the plant is remotely monitored.
- ✓ At the high concentration level all electrical circuits within the plant room except the vent fans must be isolated. Emergency lighting etc should be switched on.

Spread of gas and positioning the sensors

- ✓ The number and placement of gas detectors on a job will relate to its size and the amount of machinery specified. A detector can normally cover an area of about 36m².
- ✓ Priority should be given to positions close to compressor shafts seals and liquid pumps. In general for ammonia the sensors should be placed above the machinery, however on pumped ammonia installations one sensor should be placed at low level near the pumps to detect liquid spillage.
- ✓ It may be appropriate to fit several sensors around the machinery room, however at least one sensor shall be suitable to detect the low alarm level.
- ✓ A sensor in the safety valve discharge pipework can monitor for leaks or triggering. A rupture disks with pressure monitoring is also suitable.

8 Self Test Module 3

Try the sample multiple choice assessments below to check your learning

Question 1 -

According to the latest F Gas regulation (EU517/2014) how frequently must an R1234ze system with a charge of 300kg and no fixed leak detection system.

- I. It does not need to be leak tested
- II. Once per year
- III. Twice per year
- IV. Four times per year

Question 2-

Which refrigerant can be detected by the use of litmus paper?

- I. R32
- II. R744
- III. R290
- IV. R717

Question 3-

Which of these refrigerants is lighter than air?

- I. R744
- II. R32
- III. R717
- IV. R290

Question 4-

According to F Gas Regulation 517/2014 a system needs a fixed leak detection system when it contains tonnes CO₂ equivalent more than:

- I. 50
- II. 150
- III. 300
- IV. 500

The answers are on the bottom of the next page

What next?

The information in this guide is an introduction to the most common alternative refrigerants. There is much more information in the documents highlighted in the links. Go to the on line reference e-library at www.realalternatives4life.eu/e-library to explore any additional information you may find useful.

If you would like to gain a REAL Alternatives 4 LIFE Certificate you need to take a full end of course assessment at a licensed REAL Alternatives 4 LIFE training centre. Information about assessments is available at <http://www.realalternatives4life.eu>

You can now continue your self-study with one of the following **Real Alternatives 4 LIFE** programme Modules:

1. Introduction to Alternative Refrigerants - safety, efficiency, reliability and good practice
2. Safety and risk management
3. System design using alternative refrigerants
4. Containment and leak detection of alternative refrigerants
5. Maintenance and repair of alternative refrigerant systems
6. Retrofitting with low GWP refrigerants
7. Checklist of legal obligations when working with alternative refrigerants
8. Measuring the financial and environmental impact of leakage
9. Tools and guidance for conducting site surveys

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