With contribution of the LIFE programme of the European Union

Maintenance & Repair

of Alternative Refrigerant Systems

Contents

1-Hazards of Refrigerant
2-Flammable refrigerants
3-R744 (Carbon Dioxide)
4-R717 (Ammonia)
5-Self Test questions & Next Steps

Refrig.	Inhalation	Flammability	Pressure	Other
R744	Low toxicity	Non flammable	Much higher	Pressure rise of trapped liquid high and risk of trapping cold liquid high. Possibility of solid R744 formation.
R717	Highly toxic	Mildly flammable	Lower	
R32	Asphyxiant	Mildly flammable	Higher	Products of decomposition highly toxic
R1234ze	Asphyxiant	Mildly flammable	Lower	Products of decomposition highly toxic
R600a	Asphyxiant	Highly flammable	Much lower	
R290	Asphyxiant	Highly flammable	Similar	
R1270	Asphyxiant	Highly flammable	Similar	

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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 4 LIFE has been developed by a consortium of associations and training bodies from across Europe co-funded by the EU, 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 on line 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 5 -

Guidance on the Maintenance and Repair of Alternative Refrigerant Systems

This Module focusses on the differences when servicing and maintaining systems which use an alternative refrigerant. It provides an introduction to this topic. 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.

The following pages focus on the differences when servicing and maintaining systems which use an alternative refrigerant. It is based on good refrigeration practice, with additional information relevant to working with flammable refrigerants, toxic refrigerant and very high pressure refrigerant.

Information about the safe working environment is included as well as the following procedures where relevant:

- Leak testing
- Recovery / disposal
- Evacuation
- Un brazing and brazing
- Charging
- Component replacement.

Full procedures are not provided – the information outlines the critical points which differ from those for conventional refrigerants. The information is intended for experienced service and maintenance technicians. It is recommended that technicians have an individual F Gas certificate to demonstrate competence in handling traditional refrigerants, and undergo additional training on the specific alternative refrigerant.

Technicians should attend in depth training before working with alternative refrigerants.

1 Hazards of Refrigerants

REAL Alternatives Module 2

The table below is a reminder of the hazards of the alternative refrigerants; full details are in Module 2 Safety and Risk Management. The traffic light system indicates the severity of the hazard compared to R404A as an example. You will need to carry out or refer to a risk assessment prior to carrying out any work. The risks are assessed according to the type of work, environment and other people in the area.

Table 1, hazards of alternative refrigerants

Refrig.	Inhalation	Flammability	Pressure	Other
R744	Low toxicity	Non flammable	Much higher	Pressure rise of trapped liquid high and risk of trapping cold liquid high. Possibility of solid R744 formation.
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Green – similar to R404A or not as severe;
Amber – slightly more severe than R404A;
Red – significantly more severe than R404A.

Service Procedure Differences

The properties of the alternative refrigerants, and in particular their hazards, affect how systems are serviced and maintained. The impact on the main procedures (where different from traditional HFCs) is summarised in the table below, and covered in more detail in the remainder of this guide.

Remember
If you are unsure of anything - Do Not Proceed.
Stop work and ask the question!

Table 2, service procedure differences

<table>
<tr><th>Refrig.</th><th>Work area</th><th>Equipment</th><th>Leak testing</th><th>Charging</th><th>Recovery / disposal</th></tr>
<tr><td>R744</td><td>Very well ventilated</td><td>Suitable for the very high pressure</td><td>Method must be sensitive to R744</td><td>Initial charge should be gas to prevent dry ice formation</td><td>Venting is the usual practice</td></tr>
<tr><td>R717</td><td rowspan="6">Very well ventilated and free from sources of ignition</td><td>Suitable for use with R717 and free from sources of ignition</td><td>Method must be safe and sensitive to R717</td><td></td><td>Recovered</td></tr>
<tr><td>R32</td><td>Suitable for the high pressure and free from sources of ignition</td><td>Method must be safe and sensitive to R32</td><td></td><td>Recovered</td></tr>
<tr><td>R1234ze</td><td rowspan="3">Free from sources of ignition</td><td>Method must be safe and sensitive to R1234ze</td><td></td><td>Recovered</td></tr>
<tr><td>R600a</td><td rowspan="3">Method must be safe and sensitive to HCs</td><td rowspan="3">Charge weight is less so accuracy important</td><td rowspan="3">Small amounts* can be vented, otherwise HC is recovered</td></tr>
<tr><td>R290</td></tr>
<tr><td>R1270</td></tr>
</table>

*Small amounts are usually considered to be less than 150g.

Suitable gloves and safety glasses should be worn when working with any refrigerant, and when carrying out hot works (brazing / welding).

2 Working Safely with Flammable Refrigerants

This section covers the safe handling of:

- Hydrocarbons (R600a, R290, R1270);
- R32;
- R1234ze;
- R717 (which is also covered in a separate section).

The safe working environment and Personal Protective Equipment (PPE)

When you work with flammable refrigerants the area must:

- Be well ventilated
- Have no source of ignition within 3 m (a typical safe area when working on flammable refrigerant systems).

If necessary introduce forced ventilation using a suitable fan assembly. This has an Ex rated fan motor and a 5m cable which enables it to be switched on outside the safe work area.

Figure 1, suitable ventilation fan

When carrying out invasive work, or if a leak is suspected, check and monitor the work area using an HC detector. It is important that the detector cannot be zeroed out to background flammable refrigerant levels and alarms at 20% of the lower flammability level. The photo shows suitable detectors for HCs.

Figure 2, flammable gas detectors

Figure 3, dry powder fire extinguisher

Figure 4, CO2 fire extinguisher

You should also have a fire extinguisher to hand. This should either be a dry power type with a capacity of at least 2 kg, or an equivalent sized CO_2 type.

Equipment

Some standard tools and equipment can be used safely with flammable refrigerants, including gauge manifold sets. Note – this is not the case for R717.

Most standard vacuum pumps can be safely used because usually the only potential source of ignition is the on / off switch. In addition, the flammable refrigerant discharged by the pump is usually safely dispersed and does not result in a flammable zone, providing the pump is located in a well-ventilated area. The section on evacuation below shows how you can avoid the hazard associated with the switch.

Figure 5, Example of equipment used for servicing HC systems

Standard recovery machines cannot be safely used to recover flammable refrigerants and therefore must not be used. Unlike vacuum pumps there are several sources of ignition (e.g. on / off switches, relays, pressure switches). In addition, a leak would result in a flammable zone around the machine. These hazards cannot be avoided; therefore the correct recovery machine must be used as specified in the section on recovery.

Most electronic leak detectors used for HFC and HCFC leak detection are not safe and sensitive for use with flammable refrigerants, so electronic detectors specifically for flammable gases (or leak detection spray) must be used, as described in the section on leak testing.

BRA Guide to servicing hydrocarbon refrigerants in a commercial environment

Leak testing

Flammable refrigerant systems must be leak tested using a method that is safe and sensitive:

See REAL Alternatives Guide 4 Guide on leak testing

- Leak detection spray
- A suitable electronic flammable gas detector (examples are shown in the photos below).

If you cannot find leaks using these methods you should recover the remaining charge and leak tightness test the system, using nitrogen or nitrogen with a trace of helium or hydrogen.

Figure 6, electronic leak detectors suitable for HCs

Refrigerant recovery

Flammable refrigerant must be recovered using a suitable recovery machine such as the Care Saver recovery machine (a standard recovery machine for halocarbon type refrigerants must not be used). Note – this is not suitable for use with R717.

- Evacuate the recovery cylinder to remove air before filling it with flammable refrigerant.
- Do not mix flammable refrigerants with other types of refrigerant in a recovery cylinder.
- When recovering hydrocarbon refrigerants, do not fill the recovery cylinders with more than 45% of the HFC safe fill weight.
- Label the recovery cylinder to show it contains a flammable substance.

Figure 7, Recovery machine for use with HCs, R32 and R1234ze

Evacuation

The vacuum pump must be checked to ensure the on / off switch is the only source of ignition. If this is the case the vacuum pump can be safely used with flammable refrigerant if the on / off switch is not used:

- Move the switch to the on position and plug the pump into a socket outside the 3 m zone and control it from this socket.
- Locate the vacuum pump in a well-ventilated area or outside.

Un-brazing (disconnecting a brazed joint by applying heat)

To safely un-braze joints:

- Continuously monitor the area with a flammable refrigerant detector.
- Ensure there is good natural or forced ventilation.
- Recover the flammable refrigerant from the system (see recovery procedure), making sure you are recovering all the refrigerant from the entire system.
- Run the recovery machine for long enough so the system is under vacuum and as much of the refrigerant is removed from the system as possible.
- Fill the system with oxygen free dry nitrogen to a pressure of 0.1 bar g.
- Connect a vent line to the system, open to atmosphere.
- Un-braze the connections.

Ensure all the refrigerant has been removed prior to unbrazing by connecting to both the high and low sides of the system.

Brazing

To safely braze joints:

- Continuously monitor the area with a flammable refrigerant detector.
- Ensure there is good natural or forced ventilation.

- When re-brazing connections, ensure at least one access point on the system open to atmosphere and purge with dry nitrogen.

Charging

- Ensure there is good natural or forced ventilation.
- For HCs – use refrigerant grade HC, do not use lpg / fuel gas.
- If charging lines are not evacuated purge them carefully (by opening then closing the cylinder valve before purging).
- Do not over charge the system (for example, the HC charge weight is approximately 45% the charge weight for an equivalent HFC system).
- Accurately weigh in the charge when charging critically charged systems. The tolerance is typically ±5%. Do not adjust refrigerant charges, always use the manufacturer's indicated charge.

Component replacement

- Replace electrical devices and compressors with **like for like** components.
- Ensure sealed electrical boxes are correctly re sealed before putting the system back into operation.
- Do not modify components or relocate components.

3 Working Safely with R744 (Carbon Dioxide)

The main differences when working with R744 are associated with high pressures, the increased risk and likelihood of trapping liquid and issues associated with dry ice formation.

The safe working environment and PPE

Figure 8, personal CO2 alarm

The work area should be very well ventilated and monitored with a CO_2 detector (either the fixed detection in the area or with a personal detector). Typical alarm levels are:

- Pre alarm at 1%, 10,000 ppm
- Main alarm at 2%, 20,000 ppm.

R744 is an asphyxiant and can cause hyperventilation and disorientation. Ear defenders will also be necessary when venting R744 systems.

Most R744 systems are more complex than traditional system so before working on an R744 system ensure you know how the system works and what all the components do, especially isolation valves.

Equipment

On trans critical systems the pressure will be up to 120 bar g, and on cascade sub critical systems it will typically be up to 45 bar g. The cylinder pressure will be high, e.g. 99 bar g when the cylinder temperature is 40^{O}C.

Tools and equipment must be rated for the pressure:

- Hoses (braided steel, copper tube or pneumatic hose);
- Gauges / gauge manifold set;
- Connections to cylinders / cylinder adaptors;
- Nitrogen regulator and manifold for pressure testing - a strength test pressure of up to 132 bar g may be necessary (the photo shows an appropriate regulator).

Figure 9, appropriate regulator for pressure testing R744 systems

When connecting to systems:

- Ensure R744 is not trapped in lines, fittings etc;
- If a pressure relief valve is fitted to access equipment ensure it vents in a safe direction.

The photos show examples of appropriate charging equipment.

Figure 10, cylinder connected to charging equipment

Figure 11, connection to system

Figure 12, connection to cylinder

Leak detection

CO_2 has a smaller molecule size compared to HFC refrigerants and diffuses more easily. This, coupled with the higher pressure, means that R744 systems have a greater leak potential. Leak detection methods include:

See REAL Alternatives Guide 4 on Leak Testing

- A visual check - for example look for oil stains;
- Leak detection spray;
- Suitable electronic leak detectors such as those shown in the photo (there is CO_2 in the atmosphere so these will detect a leak above this level).

Figure 13, leak detectors suitable for R744

Disposal

R744 is usually vented rather than recovered:

- Vent into a very well ventilated area or outside;
- Beware of the asphyxiation hazard;
- Beware of the very high noise level (wear ear defenders);
- Beware of dry ice formation in the system (e.g. at orifice plates) and in the vent line when approaching the triple point. Dry ice can block the vent line so it appears that all the refrigerant has been vented;
- Wear appropriate gloves - the pipe temperature will drop;
- Beware of the very high pressures - secure the vent line so it cannot whip;
- Do not leave the system unattended while venting.

Dry Ice

If dry ice forms the pressure will drop to 0 bar g. When the dry ice sublimes the pressure will rapidly increase due to the change of state coupled with the temperature increase. Check the pressure in the system before accessing it. If dry ice does form:

- Do not heat it;
- Isolate the vent line and monitor the system pressure;
- You will see when the dry ice has sublimed – it can take a long time;
- Continue venting.

Evacuation

Systems must be evacuated if they have been open to air or after pressure testing. Moistures produces acids which are harmful to the system:

CO_2 + moisture = carbonic acid

Air in trans critical systems causes major problems because it is a non-condensable gas and increases the system pressures (as it will with all refrigerant systems, but the additional pressure is more critical in an R744 system).

Charging

Many R744 systems have a fixed permanent charging point to reduce cylinder handling (see the example in the photo). These lines should either have a valve at only one end so they cannot trap refrigerant or be fitted with a PRV and always primed with gas (not liquid).

Figure 14, example of a remote charging point

When charging with R744:

- Ensure the area is very well ventilated;
- Ensure refrigerant grade CO_2 (i.e. R744) is used;
- Ensure cylinders are upright and secure, for example in a suitable trolley;
- Open cylinders slowly, remember the high pressure can de stabilise a cylinder;
- Purge the lines carefully to eliminate air, moisture and other contaminants.

It is important to prevent dry ice formation:

- Charge gas (from cylinders) until the system pressure is above the triple point of 4.2 bar g (e.g. charge to 10 bar g);
- Then charge liquid (from cylinders or bulk).

The charging sequence for cascade systems is important - charge and run the high side first.

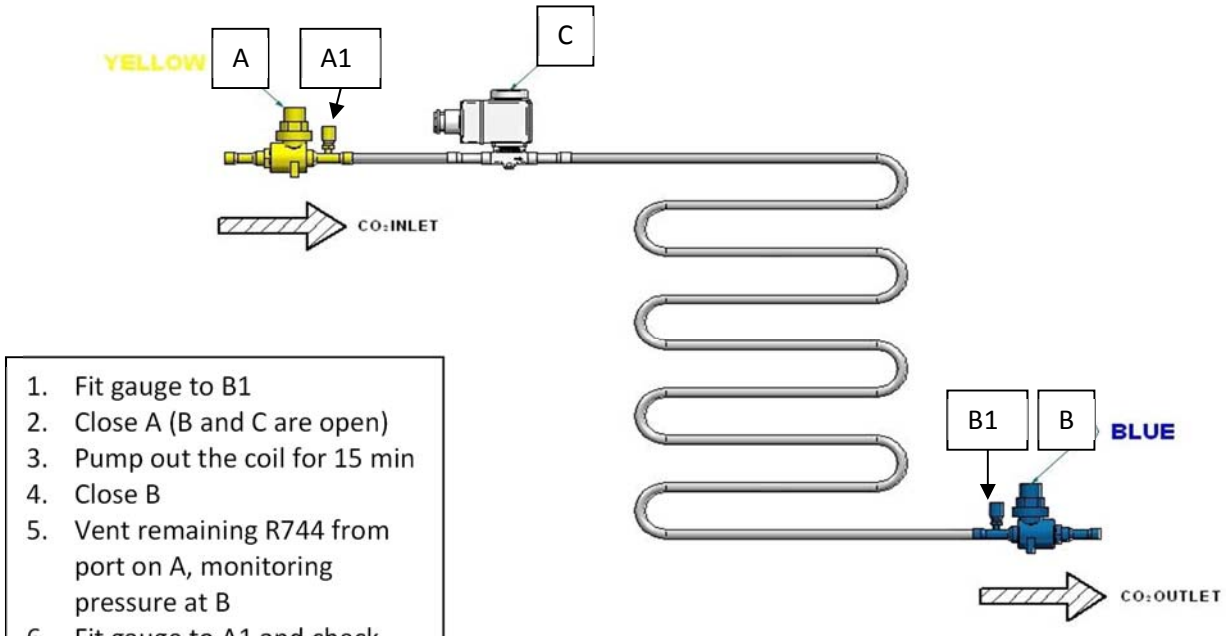
After charging you must ensure R744 is not trapped in charging equipment or hoses so open all valves on the charging equipment. Do not close valves until you are sure there is only R744 gas in the lines at a low pressure, e.g. 10 bar g.

In many systems the setting of the pressure relief valve (PRV) protecting the section of the system you are charging will be below the pressure of the R744 in the cylinder. You must charge slowly and carefully to prevent the PRV venting.

Isolating / replacing components

The R744 must be removed either by:

- Venting as described above;
  or
- Transferring liquid to another part of the system;
  or
- Evaporating liquid as described below.



1. Fit gauge to B1
2. Close A (B and C are open)
3. Pump out the coil for 15 min
4. Close B
5. Vent remaining R744 from port on A, monitoring pressure at B
6. Fit gauge to A1 and check pressure

Figure 15, removing R744 from an evaporator

Ensure that you …

- Do not trap R744 liquid;
- Do not use control valves as isolation valves;
- Do not braze or weld pipe work / components containing R744.

Note - a magnet might not open a solenoid valve because of the very high pressure - listen to ensure it opens.

Dry Ice

Dry ice can be formed in the system when venting R744.

It is very cold, so when you open the system the surfaces are very cold and moisture will condense more readily on these surfaces. This must be dried as thoroughly as possible and the system evacuated before being put back into service.

The photos below show an example of this during a drier core replacement.

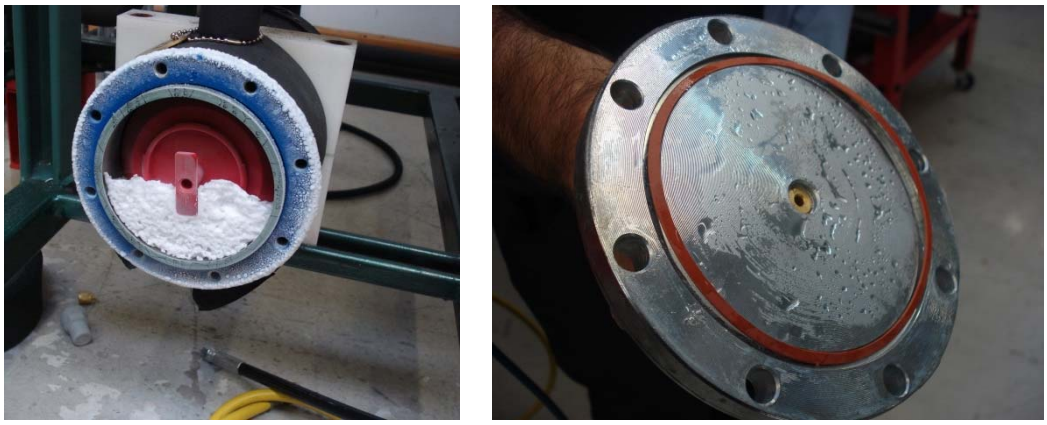


Figure 16, example of dry ice and moisture within a drier core housing

4 Working Safely with R717 (Ammonia)

The safe working environment and PPE

In addition to the precautions taken with other flammable refrigerants, positive pressure breathing apparatus may also be necessary. You must be trained in the use of this safety equipment before using it.

Figure 17, example of breathing apparatus

Personal protection equipment shall be worn when working with R717 and when purging oil and this should include at least chemical resistant gauntlet gloves, well-fitting goggles and a canister type respirator.

Access to eye wash solution should be available and for ammonia charges in excess of 1000 kg, an emergency temperature controlled water drench shower.

All procedures that involve opening the system up must be subject to detailed risk assessments and method statements with appropriate actions taken to minimise the risk to personnel. Ventilation is vital.

IOR Guidance Note on Ammonia Servicing

REAL Alternatives Guide 4 on Leak Testing

The Guidance Note from the Institute of Refrigeration includes more detailed information and covers, for example, the recommendation not to work alone, and to provide information about the work to a third party.

Equipment

All equipment used must be suitable for use with R717. Copper and brass components and fittings must not be used. On the whole, equipment used for HFC refrigerants is **not** suitable for use with R717.

The photo shows a belt driven vacuum pump suitable for use with R717.

Figure 18, vacuum pump suitable for use with R717

Leak detection

R717 leaks can be detected by the following means:

- A visual check - for example look for oil stains;
- Leak detection spray;
- A suitable electronic leak detector;
- Phenolphthalein paper.

Removal of refrigerant for service

Systems would usually be pumped down – either to another part of the system or into storage vessels – to carry out service work. A small amount of gas can be vented. Large systems may have dedicated pump out devices:

- For vapour - typically a compressor and condenser set capable of operation to low back pressure;
- For liquid - a pump unit.

Figure 19, Example of an ammonia pump

Oil recovery

Because ammonia and mineral oil are almost totally immiscible, any lubricant that enters the low side of a system tends to stay there as a layer of oil below the ammonia unless lubricant recovery devices are installed or oil is purged from the system. So for some systems the oil must be periodically manually recovered and new oil charged into the system.

Oil should be drained into a suitable open metal container and then disposed of in accordance with the relevant waste handling regulations. Never remove oil from the system without first pumping down and properly isolating the component or section of the system from which you are draining the oil.

IOR Guidance Note of Oil draining from Ammonia Systems

For safety reasons it is essential that the correct procedure is followed and is carried out by a suitably trained and certified person.

5 Self Test Module 5

Try the sample multiple choice assessments below to check your learning:

Question 1 –
When working with R1270 what is the recommended radius around the work area that should be free from sources of ignition?

I. 0.3 m
II. 1 m
III. 3 m
IV. 10 m

Question 2-
What is the usual method for removing R744 from a system?

I. It is vented in an area that is well ventilated
II. It is recovered using a high pressure recovery machine
III. It is pumped into high pressure cylinders
IV. The system is pumped down

Question 3 –
For which refrigerant is the charge weight particularly important?

I. R32
II. R1234ze
III. R744
IV. R600a

Question 4 –
When you have to do invasive work on a system containing flammable refrigerant, the working area has to be monitored by a leak detector that alarms at which percentage of the lower flammability limit for that refrigerant?

I. 100%
II. 20%
III. 50%
IV. 150%

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

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This project has been funded with support from the European Commission. This publication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Correct answers@ Q1 =iii, Q2 = 1, Q3 = iv, Q4 = ii