



With contribution of
the LIFE programme
of the European Union

Safety and Risk Management

with Alternative Refrigerants

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Welcome to the REAL Alternatives 4 LIFE 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.

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 4 LIFE 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 2 -

Introduction to Safety and risk management with Alternative Refrigerants

Aim of this Module

This Module brings together information about the hazards of alternative refrigerants and summarises how to safely apply and work with them. More detailed information about using these refrigerants is included in modules 1 (Introduction), 3 (Design), 4 (Leak Detection) and 5 (Service). This module:

- Identifies the hazards of the alternative refrigerants
- Shows how they are minimised during design, installation, service and at the end of life
- Shows how risk is assessed and managed

This module does not replace practical training which is essential when working with these refrigerants. Throughout this guide you will find references to useful additional information from a range of sources that have been peer reviewed and are recommended technical guidance if you need further information.

1 Outline of Safety Hazards

All alternative refrigerants covered in this guide have additional hazards compared to the traditional HFC refrigerants. These include:

- Flammability
- Toxicity
- High pressures

The table below summarises the hazards of the alternative refrigerants.

Table 1, hazards of alternative refrigerants

Refrigerant	Inhalation	Flammability	Pressure ¹	Other
R744	Lower toxicity	Non flammable	Much higher	Pressure rise of trapped liquid high and risk of trapping cold liquid high. Possibility of solid R744 formation.
R717	Higher toxic	Lower flammability	Lower	
R32	Asphyxiant	Lower flammability	Higher	Products of decomposition highly toxic
R1234ze	Asphyxiant	Lower flammability	Lower	Products of decomposition highly toxic
R600a	Asphyxiant	Higher flammability	Much lower	
R290	Asphyxiant	Higher flammability	Similar	
R1270	Asphyxiant	Higher flammability	Similar	

For all refrigerants – risk is reduced by minimising leak potential.

¹ Compared to R404A

2 Safety Classification

The safety classifications below are defined in ISO817:2014 ² and are also used in EN378-1:2016³. The classification has two parts: A or B followed by 1, 2L, 2 or 3.

- A or B represents the degree of toxicity
 - A is lower toxicity (most refrigerants are class A)
 - B is higher toxicity (R717 is class B)
- 1, 2L, 2 or 3 represents the degree of flammability
 - 1, non flammable
 - 2L, lower flammability
 - 2, flammable
 - 3, higher flammability

The table below lists the safety classification of the common alternative refrigerants.

Table 2, safety information

Refrigerant	Safety classification ^a	LFL, kg/m ³ ^b	Auto ignition temp, °C	PL, kg/m ³ ^c	ATEL / ODL ^d kg/m ³
CO ₂ R744	A1	Not applicable	Not applicable	0.1	0.072
NH ₃ R717	B2L	0.116	630	0.00035	0.00022
HFC R32	A2L	0.307	648	0.061	0.30
HFO R1234ze	A2L	0.303	368	0.061	0.28
HFO R1234yf	A2L	0.289	405	0.058	0.47
HC R600a	A3	0.043	460	0.011	0.059
HC R290	A3	0.038	470	0.008	0.09
HC R1270	A3	0.047	455	0.008	0.0017

- a. The safety classification is as listed in EN378-1.
- b. LFL (kg/m³) is the Lower Flammability Limit as listed in EN378-1.
- c. PL is the Practical Limit as listed in EN378-1. For A1 refrigerants it is the highest concentration in an occupied space that will not result in escape impairing effects. For flammable refrigerants it is approximately 20% LFL.
- d. ATEL / ODL is the Acute Toxicity Exposure Limit / Oxygen Deprivation Limit as listed in EN378-1. This is the level above which there is an adverse effect that results either from a single or multiple exposures in a short space of time (usually less than 24 hours).

² ISO817:2014 Refrigerants – Definitions and safety classification.

³ EN378-1:2016, Refrigerating systems and heat pumps – Safety and environmental requirements, Part 1 – Basic requirements, definitions, classification and selection criteria

3 Flammability

The flammability classification is explained in table 3 below.

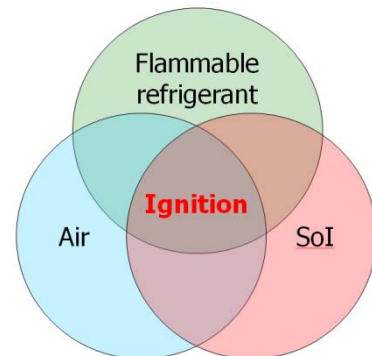


Table 3, flammability classification

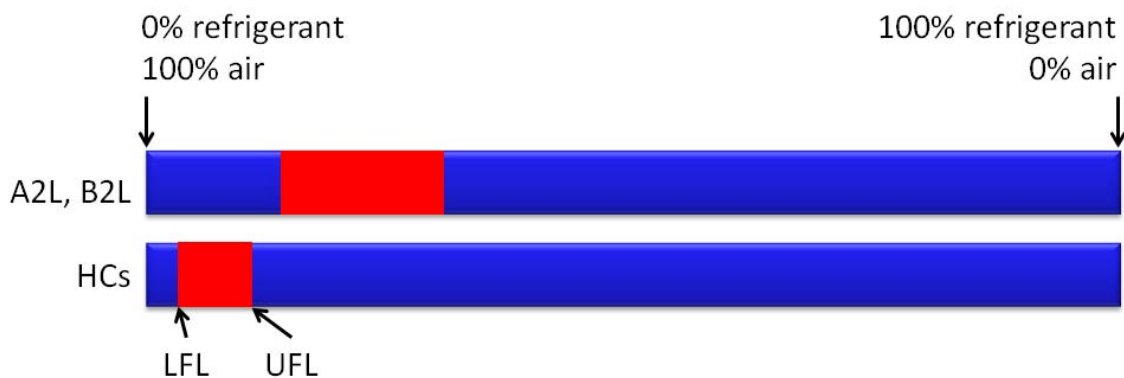
Safety classification	Lower Flammability level, % in air by volume ⁴	Heat of combustion, J/kg	Flame propagation
1	No flame propagation when tested at 60°C and 101.3 kPa		
2L, lower flammability	> 3.5	< 19,000	Exhibit flame propagation when tested at 60°C and 101.3 kPa and have a maximum burning velocity of ≤ 10 cm/s when tested at 23°C and 101.3 kPa
2, flammable	> 3.5	< 19,000	Exhibit flame propagation when tested at 60°C and 101.3 kPa
3, higher flammability	≤ 3.5	≥ 19,000	Exhibit flame propagation when tested at 60°C and 101.3 kPa

Note – the **2L** safety classification is a new class and is now included in EN 378.

Three conditions are required for combustion – fuel, oxygen and a source of ignition. For all flammable refrigerants combustion will occur if the refrigerant concentration in air is between the lower and upper flammability levels and if there is a source of ignition.



The flammable range for HCs, A2L refrigerants and R717 is shown in the chart below (the lower flammability level is also listed in table 2):



⁴ For example, R290 has an LFL of 0.038 which is approximately 2% in air by volume

An open flame will ignite all flammable refrigerants, e.g. a brazing flame, match, cigarette lighter.

Sparking electrical devices will ignite A3 (HC) refrigerants and possibly 2L refrigerants. Sparking electrical devices can include:

- On / off switches, e.g. on electrical sockets, vacuum pumps, recovery machines
- Contactors
- Light switches
- Standard thermostats
- Standard compressor relays and overload protectors (klixons)
- Standard pressure switches (high pressure, low pressure, oil differential pressure)
- Standard light starters (ballasts)
- Standard timers (e.g. for defrost) and controllers
- Electronic leak testers

Electrical devices which comply with EN60079 part 7⁵ or 15⁶ are not sources of ignition when applied to a zone 2 classification. The type of electrical protection is related to zone. Typically zone 2 applies but if the zone is different other component classifications might apply.



⁵ EN 60079-7:2015 Explosive atmospheres. Equipment protection by increased safety "e"

⁶ EN 60079-15:2010 Explosive atmosphere. Equipment protection by type protection "n"

4 Asphyxiation and Toxicity



All refrigerants are asphyxiants because they displace air. Inhalation of any refrigerant vapour in sufficient quantities can cause asphyxiation and cardiac sensitisation and have an effect on the central nervous system. These can lead to dizziness, lethargy or irregular heartbeat. Asphyxiation is a hazard if a large amount is released, particularly into an enclosed area such as a cold room or plant room.

R717 is toxic and has a very low practical limit (0.00035kg/m³). R717 is irritating and corrosive.

- Inhalation: exposure to high concentrations causes immediate burning of the nose, throat and respiratory tract. This can result in respiratory distress or failure. Inhalation of lower concentrations can cause coughing, and nose and throat irritation. R717's pungent odor provides early warning of its presence, but exposure also causes odor fatigue, reducing awareness of one's prolonged exposure at low concentrations.
- Skin contact: exposure to low concentrations of R717 may produce rapid skin or eye irritation. Higher concentrations of ammonia may cause severe injury and burns. Contact with liquid R717 can also cause frostbite, as with all refrigerants.

Products of decomposition

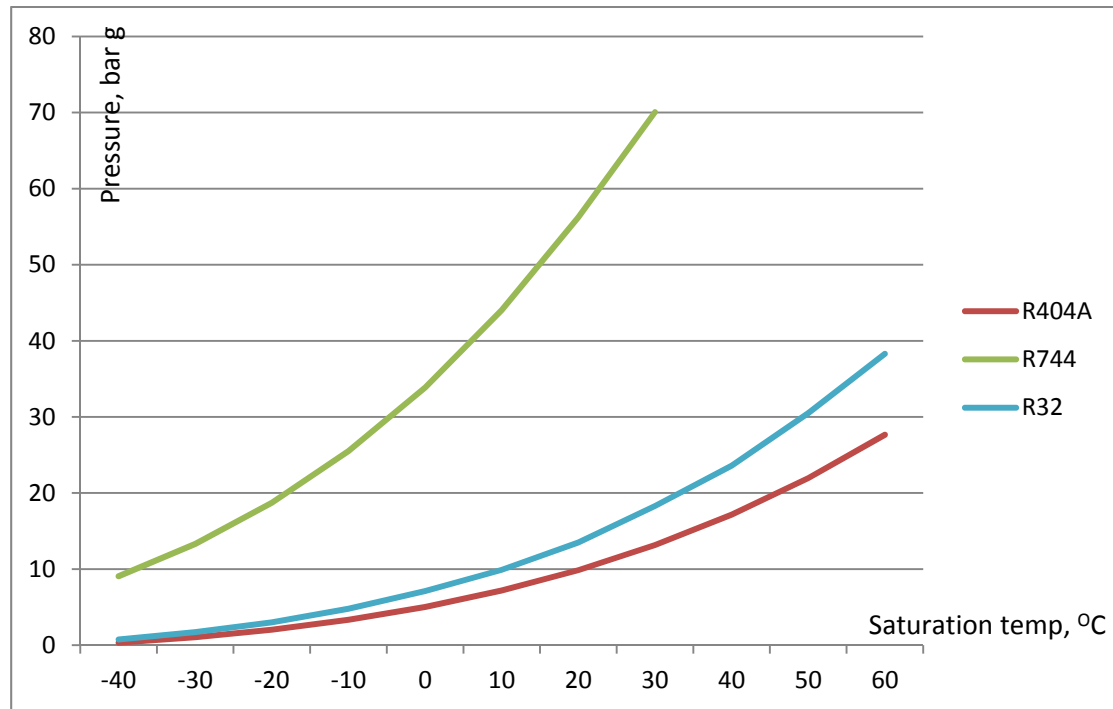
HFC and HFO form toxic products of decomposition when burnt e.g. when an A2L refrigerant such as R32 is ignited by an open flame. Hydrogen fluoride is produced which forms hydrofluoric acid when in contact with moisture (e.g. in the air or in your mouth). The effects of inhalation or contact are very severe and usually require hospital treatment. This is a hazard with all HFC refrigerants, but A2L HFCs and HFOs pose a greater risk because they are ignited by an open flame such as a brazing torch.

5 Higher Pressures

Most of the alternative refrigerants operate at pressures less than or similar to R404A. But R32 and R744 operate at higher pressure, as shown in the graph below.



Figure 1, pressure temperature, high pressure refrigerants



The operating and standstill pressures of R32 are similar to R410A (currently commonly used in air conditioning systems).

The table below shows typical pressures for R744:



Table 2, Typical R744 pressures

	Typical pressure Bar g (MPa)
Setting of PRV in high side of transcritical system (i.e. PS)	120 (12)
High side of transcritical system, operating above the critical point	90 (9)
Intermediate pressure in a transcritical system	35 to 65 (3.5 to 6.5)
Setting of PRV in high side of the low stage of a cascade system (i.e. PS)	40 (4)
High side pressure in the low stage of a cascade system	30 (3)
Low temperature (LT) evaporator	15 (1.5)
High temperature (HT) evaporator	30 (3)
Cylinder standing outside in an ambient of 5°C	40 (4)
Plant at stand still in an ambient of 20°C	55 (5.5)

6 Using R744 safely

Summary of key hazards which are more severe than for traditional refrigerants:

Asphyxiation. The practical limit is lower than for other low toxicity (safety class A) refrigerants. Hyperventilation followed by hypoventilation will occur at concentrations as low as 30,000 ppm. The concentration of R744 resulting from a leak will rise rapidly due to the higher pressure and consequent rate of escape from the system.

High pressure. The operating pressure is up to 90 bar g on transcritical systems. The pressure in a new cylinder of R744 will be approximately 99 bar g in a 40°C ambient.

Pressure rise of trapped liquid. The pressure of trapped liquid will rise by approximately 10 bar for every 1K temperature increase. This is greater than for other refrigerants and in addition the potential for trapping cold liquid refrigerant is greater on R744 system because of the low liquid line temperatures (they are usually below ambient temperature).

Dry ice. Dry ice will be formed when the pressure of R744 vapour is reduced to below 4.2 barg (the triple point). This can, for example, block vent lines.

Design to reduce risk

All components, including pipe work and fittings, must be suitable for the PS values.

See REAL Alternatives
Guide 3

Fixed leak detection should be fitted wherever a leak could result in a concentration greater than the ATEL. For R744 the ATEL / ODL is 0.072 kg/m³, so the alarm should be set at 0.036m³ (approximately 20,000 ppm). Typically there will also be a pre alarm at 5,000 ppm because of the rapid rise in concentration in the event of a leak due to the high pressures of R744.

See REAL Alternatives
Guide 4

Working safely

Appropriate personal protective equipment (PPE) should be worn by anyone working invasively on R744 systems. This includes gloves and safety goggles, and ear defenders when venting refrigerant.

See REAL Alternatives
Guide 5

Enclosed areas should not be entered if the fixed gas detection is alarming or if there is any other indication of a leak. A personal R744 detector should be used if there is no fixed leak detection.

Work should be carried out in a well ventilated area.

Charging and connection equipment should be suitable for the pressure. This depends on the ambient (and hence cylinder pressure) and the pressure of the system / section of system being charged or vented.

All charging and vent lines should be secured so they cannot whip.

Clear procedures should be prepared for all service activities which eliminate the potential for trapping cold liquid either in the system or the charging / access equipment.

R744 should be vented as liquid so that the majority of the refrigerant is vented from the system prior to reaching the triple point. Care should be taken to avoid dry ice formation in the vent line during this process. Using a short vent line with a large diameter (greater than 12 mm diameter) will minimise the risk of this.

7 Using R717 safely

Summary of key hazards which are more severe than for traditional refrigerants:

Toxicity. R717 is toxic and corrosive. Inhalation damages the nose, throat and lungs. Skin contact causes irritation and burns.

Low flammability. R717 in air can potentially be ignited by a naked flame and unsealed electrical devices.

Design to reduce risk

The charge size should be restricted in accordance with EN 378 part 1 Annex C table C.1.

See REAL Alternatives
Guide 1

R717 has a very low practical limit (0.00035 kg/m³). Fixed leak detection should be used if a leak can result in a concentration exceeding this. The low level should be set at 500 ppm and should activate mechanical ventilation and a supervised audible alarm. The high level should be set at 30,000 ppm and should stop the plant and isolate electrics.

See REAL Alternatives
Guide 4

The system should be designed to prevent ignition in the event of a leak (see next section on flammable refrigerants for further information).

See REAL Alternatives
Guide 3

Working safely

Appropriate personal protective equipment (PPE) should be worn by anyone working invasively on R717 systems. This includes gloves and safety goggles. Breathing apparatus may also be necessary.

See REAL Alternatives
Guide 5

Enclosed areas should not be entered if the gas detector is alarming or if there is any other indication of a leak.

The work area must be well ventilated with no source of ignition within 3 m of the system and associated equipment.

All equipment used should be suitable for use with R717.

8 Using flammable refrigerants safely

Summary of key hazards which are more severe than for traditional refrigerants:

Flammability. A2L, B2L and A3 refrigerants are potentially flammable in air. They will be ignited by an open flame and by sparks from unsealed electrical devices.

Design to reduce risk

The charge size should be restricted in accordance with EN 378 part 1 Annex C table C.2 (except for R717 where toxicity is the dominant hazard and table C.1 applies).

See REAL Alternatives
Guide 1

Leak simulation testing should be carried out to identify if sources of ignition (e.g. sparking electrical devices) are in a flammable zone in the event of a leak. If the testing identifies that sources of ignition are in a potentially flammable zone one of the following options should be adopted:

See REAL Alternatives
Guide 3

- The use of suitable safe (e.g. Ex rated) electrical devices;
- Re positioning electrical devices outside the flammable zone;
- Sufficient permanent ventilation.

Gas detection may be required for some systems / refrigerants (EN 378 Part 1 specifies when they should be used).

See REAL Alternatives
Guide 4

Working safely

Appropriate personal protective equipment (PPE) should be worn by anyone working invasively on flammable refrigerant systems. This includes gloves and safety goggles. In addition a flammable refrigerant monitor should be used to continuously monitor the work area for the presence of flammable gas.

See REAL Alternatives
Guide 5

The work area must be well ventilated with no source of ignition within 3 m of the system and associated equipment.

The recovery machine and leak detector must be suitable for use with the flammable refrigerant.

Prior to unbrazing (or debrazing) connections any remaining refrigerant charge should be removed from the system, the system evacuated and then purged at low pressure with oxygen free dry nitrogen.

If electrical devices are to be replaced like for like replacements should be used.

The European ATEX⁷ Workplace Directive applies to workplaces where flammable substances are used, including areas where technicians are

See IoR Guidance Note
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⁷ ATEX is the name commonly given to the European Directive on Minimum Requirements for Improving the Safety and Health Protection of Workers Potentially at Risk from Explosive Atmospheres

working invasively on flammable refrigerant systems. The points above are based on this directive, but you should refer to ATEX 137 for full information. The UK Institute of Refrigeration has a guidance note which summarises this.

9 Risk assessment

A risk assessment is the method by which you decide how likely it is that harm will occur from a particular activity (i.e. the level of risk) and what measures to take to control the risk. Risk is part of everyday life – you are not expected to eliminate risks, but you should know what the main risks are and how to manage them responsibly. This guide deals only with the risks associated with the use of alternative refrigerants - they have additional hazards compared to traditional refrigerants.

A **hazard** is something that could cause harm. A **risk** is the likelihood that a hazard could cause harm.

There are four stages to risk assessment:

1. Identify the hazards, use sections 1, 6, 7 and 8 for this;
2. Identify who could be harmed, typically this is the technician and in some cases other workers and the general public;
3. Evaluate the risks, taking into account the likelihood of occurrence and the consequent severity. Take into account control measures, see sections 6, 7 and 8 for this;
4. Record the findings.

UK HSE documents
Risk Assessment
How to control risks at
work

If the risk assessed is high you will need to consider other control measures. For example, when working on a flammable refrigerant appliance moving the appliance to outside to work on it could reduce risk to a low level.

The risk assessment below is an example covering the recovery of R1270 from a display cabinet with a charge of 850 g, fitted with Schrader valves on the high and low side. Recovery is to take place on the shop floor.

Activity	R1270 recovery
Location	XX supermarket
Assessed by	XX
Assessment date	XX

Likelihood (L)

1	Unlikely
2	Likely
3	Almost certain

Severity (S)

1	Minor injury
2	Serious injury
3	Catastrophic injury or fatality

Evaluation matrix

Severity	3	Medium	High	High
	2	Low	Medium	High
	1	Low	Low	Medium
		1	2	3
Likelihood				

Risk level (R)

Low	
Medium	
High	

Persons at risk	Hazards identified	Control measures	Risks after controls		
			L	S	R
Refrigeration technician Shop staff	Combustion	Work is carried out outside trading hours. Barriers are erected around the work area to keep shop staff away. The work area is well ventilated. There are no sources of ignition within 3 m of the HC cabinet and service equipment. A recovery machine suitable for use with HC refrigerant is used, and is switched outside the 3 m work area. A fire extinguisher is located within the work area. An HC detector is used to warn of an HC leak into the work area. The technician has received training and been assessed in safe handling of HC refrigerants.	1	2	2
Refrigeration technician Shop staff	Overfilled recovery cylinder	Cylinders are clearly marked with the HC safe fill weight. Scales are used to weigh the cylinder during recovery to ensure the safe fill weight is not exceeded.	1	2	2
Refrigeration technician	Freeze burns	Technician wears gloves and safety goggles while working.	2	1	2
Refrigeration technician Shop staff	Asphyxiation	Work area is well ventilated. An HC detector is used to want of an HC leak into the work area.	1	1	1

10 Self Test Module 2

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

Question 1 -

The hazards of R32 include which of the following:

- i. High flammability
- ii. Low flammability
- iii. High toxicity
- iv. Dry ice formation

Question 2 –

R290 is classified in EN378 as a refrigerant Class:

- I. A2
- II. A3
- III. B2
- IV. A2L

Question 3 –

Which of the following will not ignite an A3 refrigerant:

- I. An HFC leak detector
- II. An open flame
- III. Ex rated fan motor
- IV. A standard compressor relay

Question 4 –

A fixed leak detector for use with R717 should alarm at:

- I. 500 ppm
- II. 5,000 ppm
- III. 50,000 ppm
- IV. Leak detection is not required with R717.

(answers are shown on the bottom of the following page)

What next?

The information in this provides an introduction to the safety hazards and how they should be managed for 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 Certificate you need to take a full end of course assessment at a licensed REAL Alternatives training centre. Information about assessments is available at <http://www.realalternatives4life.eu>

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