Guide to

Flammable Refrigerants

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Supported by the HEVAC Air Conditioning Group and the Heat Pump Association

Guide to Flammable Refrigerants

This Guide has been prepared by Cool Concerns Ltd at the request of the Council of the British Refrigeration Association (BRA) because of the increase in the application of flammable refrigerants such as hydrocarbons, HFOs and flammable HFCs. It provides impartial information about the flammability issues associated with these refrigerants to end users, specifiers, building owners, manufacturers and contractors. It is an introduction to flammable refrigerants and signposts where more detailed information can be obtained if necessary.

Scope of this Guide:

- Hydrocarbons (HCs);
- Hydrofluoroolefins (HFOs);
- Flammable hydrofluorocarbons (HFCs).

Ammonia (R717) is not included in this Guide. Section 10 shows where there is detailed information about R717.

This guide applies to the use of flammable refrigerants in new, specially designed systems. Existing systems using non-flammable refrigerants must not be retrofitted to flammable refrigerants.

At the time of publication many of the standards referred to in this document are in revision. This includes EN378, ISO 5149 and ISO 817. The text indicates which versions are referenced in this document. Refer to the British Standards Institute for details of revisions.

For full information …

This Guide is an introduction to flammable refrigerants. In many instances more detailed information is essential.

It is recommended that the application and installation of systems using flammable refrigerants are checked, for example by an independent expert. This should include confirmation that:

- The system has been produced to specification and to the relevant regulations and standards;
- The system charge does not exceed the limits appropriate for its location;
- Sources of ignition are not located in a potentially flammable zone around a system charged with a flammable refrigerant;
- Appropriately trained and qualified engineers work on the equipment.

End users should be made aware that systems are charged with a flammable refrigerant. Where applicable, information about the minimum room size the equipment can be located in and the potentially flammable zone extent around the equipment should be provided.

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1. Introduction

The trend towards the use of flammable refrigerants has increased over the last decade. Hydrocarbons are now used widely in small integral systems as well as in some larger systems. HFOs such as R1234ze have lower flammability and are being introduced in trial applications. Flammable HFCs such as R32 are also starting to be used.

Helpful definitions

HC = hydrocarbon – naturally occurring substances containing only hydrogen and carbon;
HFC = hydrofluorocarbon – halocarbon containing only hydrogen, fluorine and carbon;
HFO = hydrofluoroolefin – halocarbon containing only hydrogen, fluorine and unsaturated carbon;

Refrigerants are classified according to their flammability and toxicity. "A" classification indicates low toxicity ("B" is high toxicity). The numbers 1, 2 or 3 following the A or B indicate the degree of flammability.

The safety classifications below are defined in ISO817:2009 [1] and are also used in EN378-1:2008 A2:2012[2].

Safety classification	Lower Flammability level, % in air by volume	Heat of combustion, J/kg	Flame propagation
A1	No flame propagation when tested at 60^{O}C and 101.3 kPa		
A2, lower flammability	> 3.5	< 19,000	Exhibit flame propagation when tested at 60^{O}C and 101.3 kPa
A2L, lower flammability, proposed sub classification	> 3.5	< 19,000	Exhibit flame propagation when tested at 60^{O}C and 101.3 kPa and have a maximum burning velocity of ≤ 10 cm/s when tested at 23^{O}C and 101.3 kPa
A3, higher flammability	≤ 3.5	≥ 19,000	Exhibit flame propagation when tested at 60^{O}C and 101.3 kPa

Note – it is proposed to include the **A2L** safety classification in revisions of EN 378 and ISO 817. It is already used in ASHRAE standards (American Society of Heating, Refrigeration and Air Conditioning Engineers) and is in de facto use, so it is included in this document. To highlight that it is not yet in the standards referenced here it will be shown as "A2L (proposed)" in the text of this document.

[1] ISO817:2009 Refrigerants – Definitions and safety classification. Note that the A2L classification is not yet adopted – it is in the current proposed revision of ISO817.
[2] EN378-1:2008+A2:2012, Refrigerating systems and heat pumps – Safety and environmental requirements, Part 1 – Basic requirements, definitions, classification and selection criteria

The table below lists the most common flammable refrigerants. There are many other flammable HFCs listed in various standards, but they are not used in the UK so have not been listed below.

Refrig.	BP [1]	Safety group [2]	LFL, kg/m^3 [3]	LFL, % [4]	Auto ignition temp, ^{O}C	PL, kg/m^3 [5]	GWP [6]
HC R600a	-12	A3	0.038	1.8	460	0.011	3
HC R290	-42	A3	0.038	2.1	470	0.008	3
HC R1270	-48	A3	0.047	2.7	455	0.008	3
HC Care 30 [7]	-23 / -32	A3	0.041	2.0	460		3
HC Care 50 [7]	-43 / -49	A3	0.038	2.0	460		3
HFO R1234yf	-29.4	A2 A2L (proposed)	0.299	6.5	405	0.06	4
HFO R1234ze [7]	-19	A2L (proposed)		5.8 [8]	288 to 293		6
HFC R32	-51.7	A2 A2L (proposed)	0.307	14.4	648	0.061	550
HFC R143a	-47	A2	0.282	8.2	750	0.056	4300
HFC R152a	-25	A2	0.13	4.8	455	0.027	120

1. BP is the boiling point at atmospheric pressure. For zeotropic blends it is the saturated liquid (bubble) / saturated gas (dew) temperatures.

2. The safety group is as listed in EN378-1.

3. LFL (kg/m^3) is the Lower Flammability Limit as listed in EN378-1.

4. LFL (%) is the Lower Flammability Limit as listed in ISO817:2009.

5. PL is the Practical Limit as listed in EN378-1.

6. GWP is the Global Warming Potential as listed in EN378-1.

7. These refrigerants are not listed in the current versions of EN378 or ISO817. The information is from the refrigerant suppliers.

8. HFO1234ze does not exhibit flame limits under standard test conditions, but it does at temperatures above 30^{O}C. The LFL stated is at 60^{O}C.

2. Regulations, Standards and Codes of Practice

There are regulations and standards which cover the use of flammable refrigerants. These, for example, cover the design of systems and components, specify maximum refrigerant charge sizes, specify how cylinders and charged systems should be transported and outline the required competence of engineers.

ATEX is the name commonly given to the legal requirements for controlling explosive atmospheres and the suitability of equipment and protective systems used in them.

- ATEX 95 (94/9/EC) covers the design of equipment and protective systems intended for use in potentially explosive atmospheres.

- ATEX 137 (99/92/EC) covers the minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres. It applies, for example, to service engineers working on HC systems. DSEAR (Dangerous Substances and Explosive Atmosphere Regulations) is the UK implementation of ATEX 137. It also covers oxy acetylene brazing in the work place.

EN378 (see below) is not harmonised with the ATEX directive and it does not specify that ATEX applies, but it does reference ATEX harmonised standards such as EN60079.

System designers and manufacturers should follow the principles of ATEX to assess whether the risk of an explosive atmosphere can occur. In the case of HC refrigerant more detailed information is provided in the BRA Code of Practice - Design and Manufacture of Refrigerated Cabinets Running on Hydrocarbon Refrigerants. Although this Code covers small systems, much of the information is applicable to a wider range of systems.

The following documents include guidance on systems using flammable refrigerants.

Document	Title	Guidance (relevant to flammable refrigerants)
ISO817:2005	Refrigerants -- Designation system	An unambiguous system for numbering refrigerants. It includes safety classifications (A1, A2, A3).
EN378-1:2008 A2:2012	Refrigerating systems and heat pumps – Safety and environmental requirements, Basic requirements, definitions, classification and selection criteria	Practical limit Maximum charge sizes
EN378-2:2008 A2:2012	Refrigerating systems and heat pumps – Safety and environmental requirements, Design, construction, testing, marking and documentation	High pressure protection Ventilated enclosures
EN378-3:2008	Refrigerating systems and heat pumps – Safety and environmental requirements, Installation site and personal protection	Machinery rooms Refrigerant detectors

EN378-4:2008 A2:2012	Refrigerating systems and heat pumps – Safety and environmental requirements, Operation, maintenance, repair and recovery	Repairs to flammable refrigerant systems Competence of personnel working on flammable refrigerant systems
EN60079-0:2009	Explosive atmospheres – Equipment – general requirements	Categorisation of flammable gases Classification of equipment Zones
EN60079-10-1:2009	Explosive atmospheres – Classification of areas – explosive gas atmospheres	Zones and classification of equipment Leak simulation testing Air flow requirements
EN60079-14:2008	Explosive atmospheres – Electrical installations design, selection and erection	Location of sources of ignition Wiring
EN60079-15:2010	Explosive atmospheres – Equipment protection by type of protection "n"	Electrical equipment and enclosures for use in potentially flammable areas Labelling of electrical equipment
EN60335-2-24:2010	Household & similar electrical appliances – Safety Part 2-24: Particular requirements for refrigerating appliances, ice-cream appliances & ice-makers	Systems with less than 150 g flammable refrigerant charge.
EN60335-2-40:2003	Household & similar electrical appliances – Particular requirements for electrical heat pumps, air conditioners and dehumidifiers	Design, application and servicing of AC systems using flammable refrigerants.
EN60335-2-89:2010	Household & similar electrical appliances – Safety Part 2-89: Particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant condensing unit or compressor	Systems with less than 150 g flammable refrigerant charge, leak simulation testing for area classification.
ADR	European Agreement concerning the International Carriage of Dangerous Goods by Road	Transport of flammable gases in systems or equipment by road
RID	Regulations concerning the international carriage of dangerous goods by rail	Transport of flammable gases in systems or equipment by rail
IoR A2 and A3 Code	Institute of Refrigeration Safety Code of Practice for Refrigerating Systems utilising A2 and A3 refrigerants	General guidance
BRA HC Cabinet Code	British Refrigeration Association Design and Manufacture of Refrigerated Cabinets Running on Hydrocarbon Refrigerants	Information for designers on the safe application of HC refrigerants in refrigerated cabinets such as display cases.

3. Transport of Flammable Gases in Cylinders and Equipment

This section covers both the transport of flammable gases in cylinders, for example by the service contractor, and the transport of refrigeration and air conditioning systems which are charged with flammable refrigerant, for example by the equipment manufacturer. The most common requirements of service companies and manufacturers are covered below.

Transport of cylinders by road

The ADR Regulation 2007[3] is a European agreement which standardises transport regulations across Europe. ADR applies to everyone carrying gases in the course of his or her work in a vehicle. Cylinders are assigned a number of transport units dependent on capacity or the maximum weight of product. If the total load is below the ADR threshold basic legal safety regulations apply, above the threshold the full ADR legislation applies.

The threshold depends on the products being transported, but most service companies will not exceed the threshold. The basic legal safety requirements for a load below the ADR threshold (small load exemptions) carried in a closed vehicle are as follows:

- Drivers should be aware of the hazards of the products, how to safely handle them, emergency procedures and the use of fire fighting equipment;
- Vehicles should be well ventilated;
- One 2kg fire extinguisher should be carried;
- Cylinder valves should be closed and adaptors disconnected;
- Cylinders should be secure and clearly labelled.

It is recommended that vehicles are marked with the appropriate warning diamond (the red flammable gas diamond for flammable refrigerants) and that information about the load is carried, for example in the form of a TREMCard (Transport Emergency Card – available from the refrigerant supplier).

Transport of charged systems

Much of this information has been provided by Business Link[4].

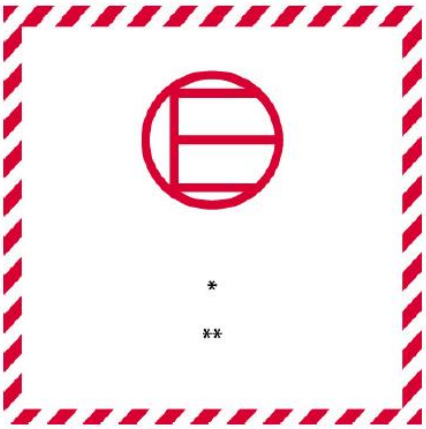
Transport of charged systems by road

Part 3 (Dangerous goods list, special provisions and exemptions related to limited and excepted quantities) of the ADR Regulation applies to the transport of systems charged with flammable refrigerant.

Flammable liquefied gases shall be contained within refrigerating machine components. These components shall be designed and tested to at least three times the working pressure of the machinery. The refrigerating machines shall be designed and constructed to contain the liquefied gas and preclude the risk of bursting or cracking of the pressure containing components during normal conditions of carriage. Refrigerating machines and refrigerating machine components are not subject to the requirements of ADR if they contain less than

[3] European Agreement concerning the International Carriage of Dangerous Goods by Road
[4] Business Link is an online government resource for businesses, see section 10

12 kg of gas. The maximum number of packages in any vehicle or container should not exceed 1000.



Excepted packages should be marked with the label, left (minimum size 100mm x 100mm)

* The label number

** The name of the consignor or of the consignee shall be shown in this location if not shown elsewhere on the package.

Specialist advice should be sought regarding the detail of ADR and requirements for documentation.

Transport of charged systems by sea

The International Maritime Dangerous Goods (IMDG) code provides guidance on transporting dangerous goods by sea. Information about the IMDG code is provided on the International Maritime Organization (IMO) website (see section 10).

The IMDG code is used by operators transporting dangerous goods on journeys involving a sea crossing. This includes ferry services. In the UK the Merchant Shipping (Dangerous Goods and Marine Pollutant) Regulations 1997 and the Dangerous Substances in Harbour Areas Regulations 1987 also apply.

Transport of charged systems by rail

The carriage of dangerous goods by rail is governed by Appendix C of the Convention Covering International Carriage by Rail - International Carriage of Dangerous Goods by Rail. The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009 (as amended) apply in Great Britain.

Transport of charged systems by air

The International Civil Aviation Organization's (ICAO) Technical Instructions are an internationally agreed set of provisions governing the requirements for transporting dangerous goods by air. The International Air Transport Association (IATA, see section 10) publishes the Dangerous Goods Regulations in accordance with the ICAO technical instructions. Publications and more information on the carriage of dangerous goods by air is available on the Civil Aviation Authority website (see section 10).

Some airlines and countries have their own derogations, known as State and Operator Variations. The IATA Dangerous Goods Regulations provides more information.

Acceptance of airfreight depends on individual carriers and specific advice should be taken before considering airfreight of appliances **containing** flammable refrigerants. Guidance can be found on the IATA web site, see section 10.

4. Maximum Flammable Gas Charge Size

The amount of flammable refrigerant which can be used in systems is restricted and depends on a number of factors:

- Location of equipment, e.g. below or above ground level;
- Occupancy of area being cooled, e.g. unrestricted access by the public or authorised access only;
- Type of system, e.g. direct expansion or secondary / refrigeration or air conditioning.

The limits are different for comfort cooling / heating and non comfort cooling / heating applications.

Systems with less than 150 g flammable refrigerant charge can be located anywhere, though it should be noted that ATEX applies to all commercial premises regardless of charge size, so the potentially flammable zone should still be assessed (see section 6 for more information).

Comfort cooling / heating applications

For comfort cooling / heating applications the maximum charge is based on the LFL of the refrigerant, the floor area and the height of the indoor unit:

$$M = 2.5 \times LFL^{1.25} \times h \times \sqrt{A}$$

M = max charge, kg
LFL = lower flammability limit, kg/m^3
h = height of unit, m, (0.6 for floor mounted, 1.0 for window, 1.8 for wall, 2.2 for ceiling)
A = floor area, m^2

Examples

A split AC system with a ceiling mounted indoor unit in a room 9 m long by 5.5 m wide using R290:

$$M = 2.5 \times 0.038^{1.25} \times 2.2 \times \sqrt{(9 \times 5.5)} = 0.65 \text{ kg}$$

As above but using R32:

$$M = 2.5 \times 0.307^{1.25} \times 2.2 \times \sqrt{(9 \times 5.5)} = 8.84 \text{ kg}$$

Non comfort cooling / heating applications

Two limits are specified:

- The "**practical limit**" based on room size;
- The "**overall maximum charge"** based on system location and occupancy.

Whichever is the lowest applies.

Practical limits

EN378-1 specifies practical limits for all the refrigerants it covers. Note – some refrigerants such as the proprietary hydrocarbon blends are not currently included in this standard.

To determine the maximum charge imposed by the practical limit (PL), the room volume is multiplied by PL.

Examples of maximum charge determined by PL

Cold room size 4 m by 5 m by 2.5 m high, cooled by a direct expansion system using R290.

> Cold room volume = 8 m x 5 m x 2.5 m = 100 m^3.
> R290 PL = 0.008 kg/m^3.
> Max charge = 100 x 0.008 kg = 0.8 kg.

As above but using R1234yf.

> Cold room volume = 8 m x 5 m x 2.5 m = 100 m^3.
> R1234yf PL = 0.06 kg/m^3.
> Max charge = 100 x 0.06 kg = 6 kg.

Preparation room 3 m by 4.5 m by 2.8 m high, in which a direct expansion ice maker using R1270 is located.

> Preparation room volume = 3 m x 4.5 m x 2.8 m = 37.8 m^3.
> R1270 PL = 0.008 kg/m^3.
> Max charge = 37.8 x 0.008 kg = 0.302 kg.

The practical limit can be exceeded in machine rooms, but if this is the case the design of the machine room must comply with EN378 and it will be designated a special machine room (see sub section at the end of this section).

In addition to the limits above, EN378 also specifies overall maximum charges – whichever is lowest applies. The section below shows these.

Overall maximum charge sizes

The tables below summarise the most common scenarios for A2 and A3 refrigerants. Refer to EN378-1 for other scenarios and full information.

Direct expansion systems

Area being cooled [1]	System location	Max change, A2 refrigerants	Max charge, A3 refrigerants
All areas	Part or all of system below ground	As below	1 kg
General occupancy - class A	Whole of system at ground level or above	38 x LFL	1.5 kg
General occupancy - class A	Whole of system at ground level or above and in an unoccupied machine room or open air	132 x LFL	5 kg
Supervised occupancy – class B	Whole of system at ground level or above and in human occupied area	10 kg	2.5 kg
Supervised occupancy – class B	Whole of system at ground level or above; compressor and receiver in open air or machine room	25 kg	2.5 kg
Authorised access – class C	Whole of system at ground level or above and in human occupied area	10 kg, or 25 kg if < 1 person per 10 m^2, and there are sufficient emergency exits	10 kg
Authorised access – class C	Whole of system at ground level or above; compressor and receiver in open air or machine room	25 kg, or No restriction if < 1 person per 10 m^2	25 kg

Indirect systems

Area being cooled [1]	System location	Max change, A2 refrigerants	Max charge, A3 refrigerants
All areas	Part or all of system below ground	As below	1 kg
General occupancy - class A	Whole of system at ground level or above, compressor and receiver in open air or machine room	Apply comfort cooling / heating practical limit	1.5 kg
General occupancy - class A	Whole of system at ground level or above and in an unoccupied machine room or open air	No restriction if exit to open air and no direct communication with A and B areas	5 kg
Supervised occupancy – class B	Whole of system at ground level or above, compressor and receiver in open air or machine room	No restriction if machine room has no direct communication to occupied space	2.5 kg
Supervised occupancy – class B	Whole of system at ground level or above and in an unoccupied machine room or open air	No restriction if machine room has no direct communication to occupied space	10 kg
Authorised access – class C	Whole of system at ground level or above, compressor and receiver in open air or machine room	No restriction	25 kg
Authorised access – class C	Whole of system at ground level or above and in an unoccupied machine room or open air	No restriction	No restriction

1. Area being cooled, see table below for full explanation and examples. If there is more than one category of occupancy the more stringent applies. If occupancies are isolated from each other the requirements of the individual category applies.

Class	Location where …	Examples
A	People may sleep; The number of people present is not controlled; Any person has access without being personally acquainted with the personal safety precautions	Hospitals and nursing homes Prisons Theatres, lecture halls Supermarkets, restaurants, hotels Transport termini Ice rinks
B	Only a limited number of people may be assembled, some of them being necessarily acquainted with the general safety precautions. May be a room or part of a building.	Laboratories Places for general manufacturing Office buildings
C	Not open to the general public where only authorised persons are granted access. Authorised persons are acquainted with general safety precautions.	Cold stores and abattoirs Refineries Non public areas in supermarkets Manufacturing facilities (e.g. chemicals, food)

Special machine rooms

A special machinery room is a machinery room intended only for the installation of the complete refrigerating system or components of the refrigerating system. It is accessible only to competent personnel for the purposes of maintenance and repair. EN378-3:2008 specifies general requirements for machine rooms plus additional requirements for A3 refrigerants. These include specifications for:

- Sealing of piping and ducting through walls;
- Doors and exits;
- Ventilation
- Emergency mechanical ventilation;
- Explosion relief;
- Equipment inside the room;
- Alarms and leak detection systems.

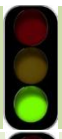
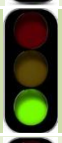
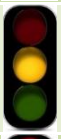
5. Systems / Applications

Some system types are ideal for use with flammable refrigerants whereas for others flammable refrigerants should never be used. The table overleaf is a very simple summary showing which systems are suitable and which are not. It uses a traffic light system:

Green – these systems are suitable for the refrigerant type indicated, and the charge size is **usually** within the limits specified in EN378. Some design changes are required to electrical devices and / or ventilation (see section 6 for more information on this).

Amber – these systems can and are used with the refrigerant type indicated, but there are restrictions because of the maximum charge or practical limit specified in EN378. Some design changes are required to electrical devices and / or ventilation (see section 6).

Red – these systems should not be used with the refrigerant type indicated, usually because the charge size exceeds the maximum specified in EN378-1.

System	HCs	HFOs and flammable HFCs
Integral systems, < 150 g charge		
Integral systems, 150 g to 1.5 kg charge, e.g. ice makers		
Integral supermarket display cabinets and serve overs, 150 g to 1.5 kg charge, to be located on a supermarket shop floor		
Cold room or beer cellar cooled by a mono block system		
Cold room or beer cellar cooled by a remote condensing unit		
DX process cooling		
Split AC systems		
Portable AC systems		
VRV / VRF systems		
Water (and other fluid) chillers		
Central plant systems		
Existing CFC, HCFC and HFC systems		

Note – this table should be used as an **indication** of the suitability of different systems.

6. Overview of Design

A leak of flammable refrigerant can result in a potentially flammable zone around the system. Sources of ignition within the potentially flammable zone will present a hazard in the event of a leak. An essential part of the design process is to identify the extent of the potentially flammable zone and ensure there are no sources of ignition inside it.

As an example, the process for ensuring HC systems are safe is summarised below for any system which contains sources of ignition, regardless of the charge size.

Step 1	Minimise the refrigerant charge size. Reduce leakage potential.
Step 2	Carry out simulated leak testing (area classification) to determine the extent of the potentially flammable zone in the event of a leak. *Note – this must be carried out by a suitably qualified competent person in a controlled (safe) area. A risk assessment must be carried out prior to releasing flammable refrigerant. This procedure was developed for HCs that can be vented and are not controlled by legislation such as the Fluorinated Gas (F Gas) Regulation*[5].
Step 3	Identify sources of ignition within the potentially flammable zone.
Step 4	Option 1 - move the source of ignition outside the potentially flammable zone. Option 2 - replace the source of ignition with a suitable device. Option 3 - increase the air flow and / or maintain a permanent air flow to reduce the potentially flammable zone. Option 4 - locate the source of ignition in a suitable enclosure (this is usually cost prohibitive for small systems and difficult to achieve).
Step 5	Label the system with the ISO flammable gas label, information about the safe working procedures and minimum room sizes if appropriate. An example label is given in Appendix 1.

[5] EC Regulation No 842/2006 on certain fluorinated greenhouse gases

More detailed information about the design of HC systems is provided in the BRA Code of Practice for the Design and Manufacture of Refrigerated Cabinets Running on Hydrocarbon Refrigerants. Much of this information is also relevant to larger systems and for A2 refrigerants.

The approach for area classification for A2 and A2L (proposed) refrigerants has not yet been determined. It requires some consideration in view of the potential release of refrigerants controlled by the Fluorinated Gas Regulation.

7. Overview of Manufacture

Systems should be assembled and processed in accordance with EN378 and following good refrigeration practice. There are issues related specifically to the use of flammable refrigerants which must be addressed:

Accuracy of charge for critically charged systems. Because of the lower charge weight of HCs and flammable HFCs compared to non-flammable HFCs, the tolerance can be less than ±5g in small systems.

Location. The charging area must not be below ground level. There must be no below ground areas adjacent to the charging areas where leaking refrigerant could collect.

Ventilation. Usually two levels of ventilation are used which extract air at low level from the charging area and discharge it to an area outside. Fan motors should be rated for use in a potentially flammable atmosphere.

Sources of ignition. An area around the charging equipment should be free from sources of ignition.

Flammable gas detection. The type used should accurately sense the refrigerant being used, and not be affected by other airborne substances. Sufficient sensors should be used to ensure a leak of flammable refrigerant is detected. In this event the control system should switch on the high level ventilation and activate an alarm.

Storage of flammable refrigerant. The minimum quantity of flammable refrigerant should be inside the charging area. All other cylinders should be stored outside in a safe area.

Operator training. Operators charging flammable refrigerant and their supervisors should be trained in the safe handling of these refrigerants. See section 9 for more information.

Access. Access to the charging area should be restricted to personnel who have received safe handling training.

Flammable refrigerant supply. Any pipe work associated with flammable refrigerant charging should be protected from accidental damage.

Fire extinguishers. Fire extinguishers should be located in the charging area (dry powder or CO_2 types).

8. Overview of Service

Systems should be serviced and maintained following good refrigeration practice, with some changes to tools, equipment and procedures. Engineers working on flammable gas system should be appropriately trained, see Section 9.

Tools and equipment

Tools should be rated for use in a Zone 2 area or have been suitably tested for use with flammable refrigerants. Type 'n' protection according to EN60079-15 is deemed as suitable for this application. Note – this is not intrinsic safety.

- A **flammable gas detector** should be used to monitor the air in the work area. The photo shows a detector suitable for HC refrigerants.
- If an **electronic leak detector** is used it must be safe and sensitive to the flammable refrigerant. Most HFC leak detectors do not need this requirement. Leak detection fluid can be used.
- HFC **recovery machines** have not been assessed for use with flammable refrigerants. Approval must be sought from the manufacturer before using a standard HFC recovery machine with any flammable refrigerant – they may be safe to use with flammable HFCs but not HCs. A recovery machine suitable for use with HCs is available and could be used with other flammable refrigerants.
- More accurate **scales** are necessary when charging small, critical charged systems with some flammable refrigerants such as HCs. An accuracy of ±5 g is often necessary – most scales used for service are not this accurate.
- A dry powder or CO_2 **fire extinguisher** must be available at the location.
- A suitable **ventilation fan** should be used when working inside if there is insufficient natural ventilation.

Procedures

The work area must be well ventilated with no source of ignition within 3 m of the system and the service equipment such as a vacuum pump and recovery machine. Note – 3 m is the typical zone required for HC refrigerants. For A2 and A2L (proposed) refrigerants, and where there is good ventilation, the zone may be less.

The vacuum pump should be controlled by a switch outside the 3m zone (the vacuum pump's switch should not be used as it is a source of ignition) and the pump should be located in a well-ventilated area.

Prior to un brazing joints the flammable refrigerant must be removed from the system, and the system filled with nitrogen.

Faulty electrical devices and compressors must be replaced with like for like components.

Procedures for working with A2 and A2L (proposed) refrigerants have not yet been formulated, so the procedures for A3 refrigerants (HCs) should be followed until these are available.

9. Training

EN378-4 specifies that anyone working on flammable refrigerants systems should receive training which includes the following:

- Knowledge of legislation, regulation and standards relating to flammable refrigerants;

- Detailed knowledge of and skill in handling flammable refrigerants, personal protective equipment, refrigerant leakage prevention, handling of cylinders, charging, leak detection, recovery and disposal.

Training on the design of flammable refrigerant systems and training for technicians who will be handling these refrigerants in manufacture and service has been available in the UK since the mid 1990s.

In early 2012 City and Guilds launched an HC pathway unit as part of the new City & Guilds 6187[6] - C & G 6187-21 Understand and apply hydrocarbon RAC system installation, testing, servicing and maintenance techniques. The Unit includes both a theory and a practical assessment. The photo shows the equipment used in the practical assessment. Candidates do not need to do the other parts of the C & G 6187 qualification as this unit is a stand-alone qualification (successful candidates will receive a City & Guilds certificate).

Anyone handling the HFOs and flammable HFCs must have an F Gas qualification such as City and Guilds 2079 or the Construction Skills J11.

[6] Certificate and Diploma in Refrigeration Air-conditioning and Heat Pump Systems

10. Sources of Further Information

This table below provides details of organisations and publications for more information about various aspects of HC refrigerants.

Item	Website
Companies who provide products and services related to HC refrigerants	www.hydrocarbons21.com
British Refrigeration Association	www.feta.co.uk
Institute of Refrigeration Safety Code of Practice for systems utilising A2 and A3 refrigerants	www.ior.org.uk
Ammonia Refrigeration Systems Code of Practice	www.ior.org.uk
Standards referenced in this Code	www.bsigroup.co.uk
City and Guilds	www.cityandguilds.com
HFO1234yf in the automotive industry	www.sae.org
American Society of Heating, Refrigeration and Air Conditioning Engineers	www.ashrae.org
Business Link – various information relating to transportation of systems charged with flammable refrigerant	www.businesslink.gov.uk
International Air Transport Association (IATA) for the transport of systems charged with flammable refrigerant by air	www.iata.org
Civil Aviation Authority for information on the carriage of systems charged with flammable refrigerant by air	www.caa.co.uk
International Maritime Organisation for information about the carriage of systems charged with flammable refrigerant by rail	www.imo.org

Appendix 1, Example Label for a Flammable Refrigerant System

Refrigerant R290 (Propane)

This unit must not be located in a room or area with a volume less than XXX m^3.

Note: Only engineers who have been trained in the safe handling and use of hydrocarbon (HC) refrigerants should work on this system.

- Work on this system in a well-ventilated area or outside.
- Use a local leak detector to indicate if there is hydrocarbon in the air around the system before and during work on the system (place it at low level - HCs are heavier than air).
- Ensure there are no sources of ignition (flames or sparking electrical components) within 3 m (10 feet) of your work area.
- If replacing components, use like for like replacements.

- Take great care when brazing to ensure all HC has been removed from the system.

Use refrigerant grade propane (R290).