Guidelines
for the use of
Hydrocarbon Refrigerants
in
Static Refrigeration and
Air Conditioning Systems

from

ACRIB

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Foreword

With the introduction of the revised EU Ozone Depleting Substances Regulation in October 2000 and the introduction of a Climate Change Policy by the UK Government in November 2000, it is considered likely that more refrigeration system designers and users will be turning to alternative refrigerants such as hydrocarbons. The increased application of this technology will bring with it many technical and safety issues. People working in this industry have relatively little practical or theoretical knowledge about hydrocarbon refrigerants. It is therefore in the interests of the industry to make available as much technical and safety information as possible. Much of the knowledge and expertise already exists, and ACRIB has brought this together into a comprehensive guide by reference to the range of detailed documentation available, as well as some of the basic information necessary for engineers working with refrigeration systems using hydrocarbons.

This document is intended to highlight the differences between hydrocarbon refrigerants and other refrigerants and to direct readers to the authoritative documents that should be consulted.

There are suitable alternative refrigerants on the market today to replace many of the traditional refrigerants which are in common use and, in some cases, are the only alternatives. However, the new generation of environmentally acceptable hydrocarbon products is gaining widespread acceptance for many applications, both commercial and domestic. They do not pose any threat to the ozone layer and have a very low impact on global warming. The UK Government's Climate Change policy has focused many people's minds on global warming and its causes and, while the refrigeration and air conditioning industry is not a major contributor, hydrocarbons offer us the opportunity to reduce this contribution.

These environmental benefits do not however come without some costs. Hydrocarbons are flammable and, if due diligence is not observed, safety could easily be compromised. Only engineers who are competent to use these gases should be allowed access to them to ensure that the good name of the refrigeration and air conditioning industry is maintained.

ACRIB supports and encourages change. The benefits of change will help to create a better climate for our future and improve the quality of life for all.

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1. REFRIGERATION ISSUES

Whilst the most notable aspects associated with hydrocarbon refrigeration system design are safety matters, general refrigeration issues should also be considered. These include thermodynamic properties, material compatibility and component selection.

1.1 Refrigerant selection

Refrigerant selection is generally based on matching refrigerant vapour pressures to operating conditions, although this is not always the case. Refrigerants should also be selected so that they contribute to good system efficiency. With respect to blended refrigerants, these should only be selected when the effect of temperature glide and composition shift is not an issue. As general guidance on refrigerant selection, Table 1.1 provides an indication to the application ranges and equivalent fluorinated refrigerants where HCs could be employed. Please refer to your refrigerant supplier for more information on correct refrigerant selection.

Table 1.1: Application ranges for Hydrocarbon Refrigerants.

Refrigerant	Application Range	Replacement
R600a (isobutane)	high/medium temperature; domestic appliances.	(R12, R134a)*
CARE 30 (R600a/R290 blend)	high/medium temperature; commercial, automotive, domestic.	R12, R134a
R290 (propane)	high/medium/low temperature; commercial, industrial; freezers, air-conditioning, heat pumps.	R22, R404A, R407C, R507A
R1270 (propylene or propene)	high/medium/low temperature; commercial, industrial; industrial and process refrigeration , air-conditioning, heat pumps, chillers.	R22, R404A, R407C, R507A
CARE 50 (R290/R170 blend)	high/medium/low temperature; commercial, industrial; industrial and process refrigeration , air-conditioning, heat pumps, chillers.	R22, R404A, R407C, R507A
R170 (ethane)	Low temperature cascade systems	R13, R23, R503

*R600a possesses a volumetric refrigerating capacity that is approximately half that of R12 and R134a. Therefore R600a is not a “thermodynamic” replacement for these refrigerants.

When using hydrocarbon refrigerants it is essential to use refrigerant grade products only. Commercial grade hydrocarbons contain significant quantities of sulphur, water, and other impurities and could contribute to oil degradation, shorten the compressor life and invalidate any warranties. Also, unlike commercial LPG Hydrocarbon refrigerants are not odourised. Another problem with commercial LPG is that the composition of any specific hydrocarbon can be variable thus drastically changing the properties of the refrigerant from cylinder to cylinder.

1.2 Refrigerant properties

Refrigerant properties are necessary to describe the operating characteristics of the refrigerant within a system. In particular, physical properties of refrigerants are useful for determining the applicability of a refrigerant under design operating conditions. Thermodynamic and transport properties of refrigerants are necessary for predicting system behaviour and performance of components. Basic properties are provided in Table 1.2. For more comprehensive data the refrigerant supplier or reference texts should be consulted.

Table 1.2: Physical Properties of Refrigerants

Refrigerant	Mol. Mass (kg/kmol)	Normal boiling pt. at 1 Atm.	Critical temp. (°C)	Critical pressure (bar, abs.)	Temp. glide at 25ºC (K)	Latent heat at 25ºC (kJ/kg)	Saturation press at 25ºC (bar, abs.)
R600a	58.1	-11.7	135.0	36.45	0	332	3.5
CARE 30	51.0	-31.7	105.5	34.01	7.8	353	5.2
R290	44.1	-42.1	96.7	42.48	0	342	9.6
R1270	42.1	-47.7	91.8	46.18	0	338	11.5
CARE 50	46.8	-49.1	79.3	33.86	3.9	348	10.1
R170	30.1	-88.8	32.2	48.91	0	299	24.0

1.3 Lubricants

Hydrocarbon refrigerants possess full chemical compatibility with nearly all lubricants commonly used within refrigeration systems. Good miscibility is maintained with most lubricants under all operating conditions. Due to the particularly good solubility with mineral oils, it may be necessary to use a lubricant with lower solubility or increased viscosity to compensate for possible thinning under situations where high solubility could occur. Suppliers should be consulted for properties of oil/refrigerant combinations.

Lubricants containing silicone or silicate (often used as anti-foaming additives) are not compatible with hydrocarbon refrigerants and should not be used. If changing or selecting a lubricant for a hydrocarbon refrigerant application, always consult the compressor manufacturer as to their recommendations. Table 1.3 details the various lubricants and their compatibility characteristics.

Table 1.3: Compatibility of various lubricants with HC refrigerants

Lubricant Type*	Compatibility
Mineral (M)	Fully soluble with hydrocarbons. Excessive solubility at high temperature conditions. Compensate by selection of a high viscosity grade oil.
Alkyl benzene (AB)	Fully soluble and typical viscosity grades applicable to all applications.
Semi-synthetic (AB/M)	A blend of AB and M oils achieving desirable properties for use with hydrocarbons.
Polyolester (POE)	Generally exhibit excessive solubility with hydrocarbons. May necessitate higher viscosity grade.
Polyalkylene Glycol (PAG)	Soluble and partially soluble with hydrocarbons depending upon the conditions. Normal grades are generally satisfactory.
Poly-alpha-olefins (PAO)	Soluble with hydrocarbons but typically used for low temperature applications.

*It is recommended that the compressor manufacturer be consulted to determine the selection of the correct lubricant.

1.4 Materials

Virtually all common elastomer and plastic refrigeration materials used as 'O' rings, valve seats, seals and gaskets are compatible with hydrocarbon refrigerants. These include Neoprenes, Vitons, Nitrile rubbers, HNBR, PTFE and Nylon. Materials that are not compatible and should not be used in hydrocarbon refrigeration systems are EPDM, natural rubbers and silicone rubbers.

Whilst testing has been conducted on a number of selected materials with hydrocarbons it should be noted that there are numerous different grades available in the market and for this reason compatibility should be checked with the manufacturer or supplier of the component.

1.5 General system components

Typically system components used for fluorocarbon refrigerants do not differ significantly when using hydrocarbons. Component suppliers should be consulted regarding other in-line components such as pressure regulators, solenoid valves etc.

Evaporators and condensers

Evaporators and condensers using hydrocarbons tend to be virtually the same design and size as those used for conventional fluorocarbon refrigerants that operate at similar pressures. Heat transfer coefficients tend to be higher for most hydrocarbons but this does not significantly effect heat exchanger dimensions. All common types of heat exchanger are suitable for use with hydrocarbon based refrigerants including:

- Air cooled
- Shell and tube (flooded and direct expansion)
- Plate heat exchangers

Suction-liquid heat exchangers should also be considered since they contribute to improved system efficiency especially when using hydrocarbons

Compressors
Most compressor types are suitable for use with hydrocarbon refrigerants and compressor suppliers should be consulted for application and selection. Using a compressor with hydrocarbons without the supplier's approval may invalidate the warranty.

In order to secure satisfactory performance, long life, and to protect the compressor against overload, certain design criteria should be observed. Compressor application notes and data should always be consulted when designing a system. Ensure compressors are clearly labelled to indicate that hydrocarbon refrigerants are being used in the system. The use of crankcase heaters should be considered to avoid excessive oil solubility.

Refrigerant Control Devices
All expansion device types are suitable for use with hydrocarbon-based refrigerants and component suppliers should be consulted for application and selection.

Design and selection criteria are the same as those for conventional fluorinated refrigerants. Capillary tube length is specific to each refrigerant. Computer programmes and tables are available for determining capillary tube size and length, although trial and error is generally the preferred route. Thermostatic Expansion Valves (TEVs) for hydrocarbons are available from control suppliers. Alternatively TEVs for other refrigerants that operate with similar pressure-temperature relationships can be used. Electronic Expansion Valves (EEV) may also be used. EEV's used in hydrocarbon systems must conform to the requirements of electrical components as detailed in Section 2.6.6.

Desiccants
Desiccants are used within filter dryers. Most commonly used desiccants are compatible with hydrocarbon refrigerants. Acceptable types are XH-5, XH-6 or equivalent.

Pipe size selection
When selecting refrigerant line sizes, specific hydrocarbon refrigerant pipe sizing literature should be used. Despite most hydrocarbon refrigerants having similar operating pressures to the "equivalent" fluorocarbon refrigerants, thermodynamic and transport properties can differ significantly, thus data for other refrigerants will not be directly applicable. Refrigerant suppliers should provide the appropriate pipe size selection data.

2. SAFE SYSTEM DESIGN AND CONSTRUCTION

2.1 General Safety Issues

All hydrocarbon refrigerants are highly flammable but non-toxic. This gives them an "A3" classification according to BS EN378 Part 1. Reference should be made to this Standard which details the requirements for the safe use of flammable refrigerants in commercial and industrial applications. For more detailed information on these safety requirements refer to the Institute of Refrigeration Safety Code for A3 refrigerants.

There are many other safety requirements that should be considered in the design and construction of all refrigerating and air conditioning installations, regardless of the flammability of the refrigerant used. General safety standards and codes of practice, referenced in this document, should be consulted for this additional information.

2.2 Allowable Refrigerant Charge

The limiting factor associated with the use of hydrocarbon refrigerants is the refrigerant charge size, the occupancy category and the room size. The charge size requirements according to Annex C of BS EN378 Part 1 are detailed in Table 2.1[4,7].

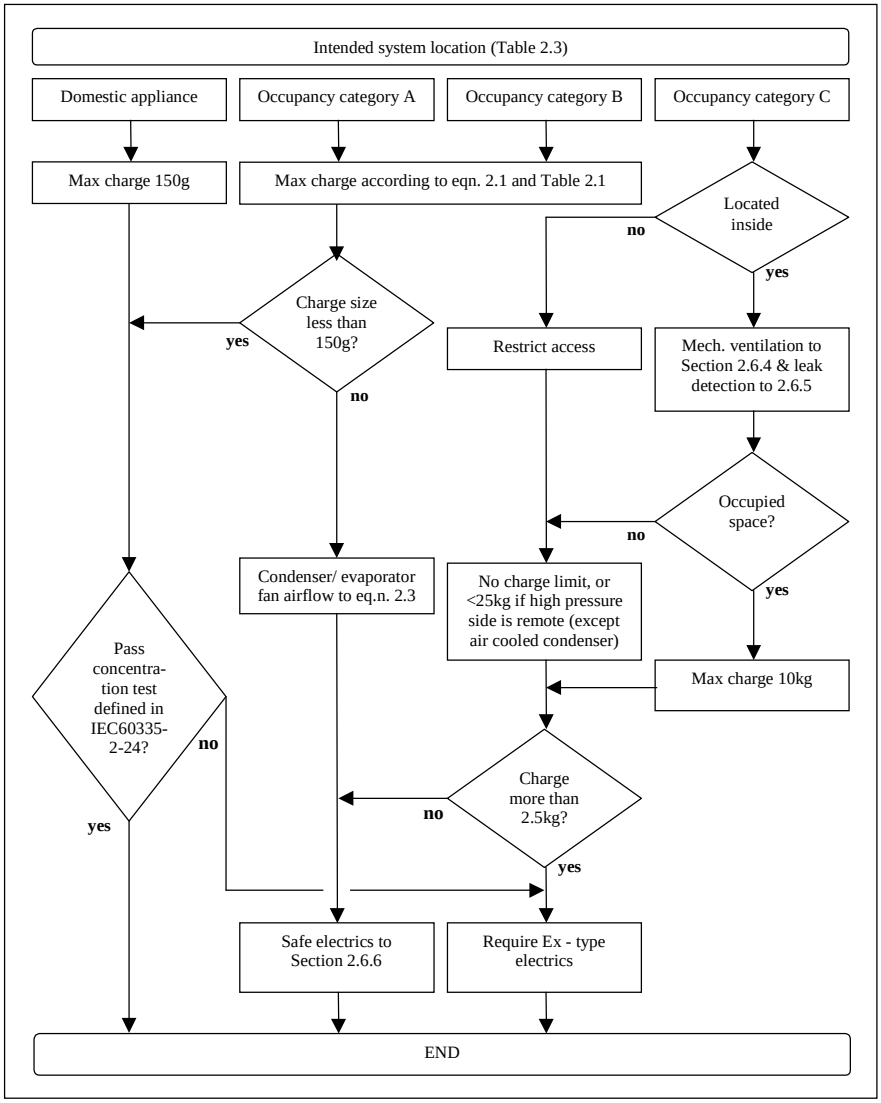
Table 2.1: Charge size requirements for various location categories

Category	Examples	Requirements
A (domestic/ public)	Hospitals, prisons, theatres, schools, supermarkets, hotels, dwellings.	• <1.5kg per sealed system • <5kg in special machinery rooms or in the open air for indirect systems
B (commercial/ private)	Offices, small shops, restaurants, places for general manufacturing and where people work.	• <2.5kg per sealed system • <10kg in special machinery rooms or open air for indirect systems.
C (industrial/ restricted)	Cold stores, dairies, abattoirs, non-public areas of supermarkets, plant rooms.	• <10kg in human occupied spaces • <25kg if high pressure side (except air cooled condenser) is located in a special machinery room or in the open air • No limit if all refrigerant is contained in a special machinery room or in the open air.

Systems with charge sizes of 0.15kg or less can be installed in any size of room. Systems with charge size of more than 0.15kg room size should be such that a sudden loss of refrigerant shall not raise the mean concentration in the room above the practical limit (approximately 0.008kg/m^3). The general approach to safe design of systems containing hydrocarbon refrigerants is detailed in Figure 2.1. This flow chart provides general

guidance to the appropriate measures associated with a specific refrigerant charge size and the locations that they are permitted.

Figure 2.1 Flow chart indicating design routes according to safety standards.



2.3 Flammable Properties of Hydrocarbons

Table 2.2 provides property data relevant to hydrocarbon refrigerants. These values are necessary in the design stage when determining maximum refrigerant charge, ventilation flow rates and maximum allowable temperatures of components.

Table 2.2: Flammability properties of selected hydrocarbon refrigerants[4,7]

Refrigerant*	Number	Lower Flammability Limit (LFL)		Auto-ignition temperature (°C)
		By volume (%)	By mass (kg/m^3)	
Ethane	R170	3.0	0.037	515
Propane	R290	2.1	0.038	470
Iso-butane	R600a	1.8	0.043	460
Propylene	R1270	2.5	0.043	455
CARE 30	-	2.0	0.041	460
CARE 50	-	2.2	0.038	460

* Properties for other hydrocarbons can be found in the literature.

The practical limit as used in EN378 is defined as 20% of the LFL.

2.4 Safety standards and codes of practice

There are a number of codes and safety standards that are appropriate to the use of flammable refrigerants and related equipment. The selection of appropriate documents is not always obvious and therefore the objective of this section is to provide a degree of clarity in this area. These standards and codes of practice are current at the time of publishing. Checks should be made to ensure these are still current.

Generally, refrigeration systems should be designed and constructed in accordance with general machinery requirements. These are detailed in various regional codes and standards as set out in Section 4. The following documents deal with subjects that are mainly relevant to pressure issues in commercial and industrial systems:

- BS 4434 (withdrawn)
- BS EN 378
- Institute of Refrigeration Code of Practice for A3 Refrigerants

Domestic and small hermetic type refrigeration systems often have other safety issues such as electrics related to them since they are considered as appliances. Requirements for these types of systems are detailed in the following:

- BS EN 60335-2-24
- BS EN 60335-2-40
- BS EN 60335-2-89 (draft at time of publication)

BS EN 60335-2-24 applies to systems that use up to 150g of flammable refrigerants. At the time of publishing BS EN 60335-2-40 does not include requirements for flammable refrigerants but is currently under revision. A new draft incorporating requirements for flammable refrigerants in air conditioners is available from British Standards Institution.

Regardless of the type of system, standards also exist for the refrigeration compressors:

- pr EN 12693 (draft at time of publication)
- BS EN 60335-2-34

Where very large quantities of flammable refrigerant are being employed, it is appropriate to consider standards that deal with hazardous areas. These standards are aimed directly at very large commercial and industrial type applications where flammable materials are used and provide a general approach to risk assessment and design of such environments:

- BS EN 1127-1

In particular, the most fundamental difference between systems using flammable refrigerants and non-flammable refrigerants is the use of suitable electrical equipment that will not pose a risk in the event of a release. Whilst there are a range of different methodologies to deal with such electrical apparatus, the following standards provide information on the general approach for using electrical equipment in any potentially flammable areas:

- IEC 60079-0
- BS EN 60079-10
- BS EN 60079-11
- BS EN 60079-14
- BS EN 60079-15

Finally, it is expected that engineers involved in the design, construction and maintenance of refrigerating systems be competent. Competency in this context is defined in a draft standard:

- pr EN 13313 (draft at time of publication)

Standards are not exhaustive in their requirements and if a safe system of work can demonstrate an equal level of safety as that implied by the standard and satisfy UK legislation, then this approach is equally acceptable. Indeed Notified Bodies often set their own construction and test criteria where standards are not yet available or existing standards are not considered appropriate for use.

2.5 Design

Specific design requirements are generally applied to a system based on the refrigerant charge size and location. If manufacturer's data is not available, charge sizes can be approximated from internal system volumes and refrigerant densities based on design operating temperatures. Below is an explanation of the rules governing equipment design.

2.5.1 Refrigerant Charge

The equivalent hydrocarbon charge of a CFC or HCFC system will be approximately 40% to 50% of the mass. Under no circumstances should the system be overcharged. Consult refrigerant suppliers for conversion data.

2.5.2 Categories

The various requirements will be denoted with the following categories, depending upon whether or not they apply to the corresponding categories.

Table 2.3 Installation/Charge Size categories

	Refrigerant Charge Size							
Occupancy Category	<0.15 kg	0.15-1 kg	1-1.5 kg	1.5-2.5 kg	2.5-5 kg	5-10 kg	10-25 kg	>25 kg
A	A1	A2	A3	A4	A5	A6	n/a	n/a
B	B1	B2	B3	B4	B5	B6	n/a	n/a
C	C1	C2	C2	C4	C5	C6	C7	C8

Occupancy types as defined in Table 2.3 are as follows:

Occupancy Category A - Rooms, parts of buildings or buildings where people may sleep, people are restricted in their movements or an uncontrolled number of people are present or to which any person has access without being personally acquainted with the general safety precautions (e.g. hospitals, courts, prisons, theatres, supermarkets, schools, lecture halls, public transport termini, hotels, dwellings, restaurants).

Occupancy Category B - Rooms, parts of buildings or buildings where only a limited number of people may be assembled, some being necessarily acquainted with the general safety precautions of the establishment (e.g. business or professional offices, small shops, small restaurants, laboratories, places for general manufacturing and where people work).

Occupancy Category C - Rooms, parts of buildings or buildings where only authorised persons have access, who are acquainted with general and special safety precautions of the establishment and where manufacturing, processing or storage of materials or products takes place.

2.5.3 Construction

Allowable Charge Size (All)

If the charge is more than 0.15 kg, then a sudden loss of refrigerant should not raise the mean concentration in the room above the practical limit (0.008 kg/m^3).
The total charge size is governed by the room volume. This can be determined by equation 2.1[4,7].

$$M_r = 0.2 \cdot (LFL) \cdot V_{room} \quad \text{(Equation 2.1)}$$

Where:

M_r = maximum allowable refrigerant charge per separate refrigerant circuit (kg)

V_{room} = room volume (m^3)

LFL = Lower Flammability Limit of refrigerant (kg/m^3) from Table 2.2

Similarly, the minimum room volume for a specific refrigerant charge is determined by equation 2.2[1,4].

$$V_{room} = \frac{M_r}{0.2 \cdot (LFL)} \quad \text{(Equation 2.2).}$$

In practical terms, for a $100m^3$ of room volume, the maximum allowable charge would be 800g of R290 per refrigerant circuit. Charges in systems below ground (i.e. cellars and basements) are restricted to a maximum of 1.0kg even with larger room sizes. Sealed systems containing a charge of less than 150g can be situated in any location, regardless of room volume[13,24].

Note that all charge limits apply per single refrigerant circuit, on the basis of probability that two circuits will not have catastrophic failures simultaneously.

Avoidance of Stratification (All)

In the event of a "catastrophic" leak it is possible that stratification of refrigerant can occur, resulting in the formation of flammable concentrations at low level. In order to prevent this from occurring the fan associated with the refrigerating system should be able to provide a minimum air flow, as detailed in equation 2.3[7]. This only applies to equipment that contain refrigerant charges above 150g. The fan operates only during the compressor on-cycle since the probability of a catastrophic leak during off-cycle is negligible.

$$\dot{V}_{air} = C \cdot \frac{M_r}{(LFL)} \quad \text{(Equation 2.3)}$$

Where:

$\dot{V}_{air}$ = minimum air flow rate from the fan (m^3/h)

The constant, C, depends upon the origin of the air flow:

$C = 17$, when the evaporator fan on an air conditioning unit is providing the air flow into the room, or,

$C = 20$ when the condenser fan on a refrigerating unit is providing the air flow into the room.

The different constants result from the effectiveness of fan mixing, primarily due to the velocity of the discharged air.

Maximum Refrigerant Charge (All)

The maximum allowable refrigerant charge for specific installation types, subject to other requirements are as follows:-

- Direct expansion systems in a human occupied space is limited to A1-A3, B1-B4 and C1-C6.
- Indirect systems in a human occupied space will be limited to A1-A5, B1-B6 and C1-C6.
- Systems with high pressure side (but not air cooled condenser) in a machinery room will be limited to A1-A5, B1-B6 and C1-C7.
- Systems with all refrigerants containing parts in a machinery room or in open air shall be limited to A1-A5, B1-B6 and C1-C8.

Type of System (A4, A5, B6, C6)

The size of refrigerant charge can only be used within an indirect type refrigerating system.

Combustible Materials (All)

Materials used to construct the refrigerating system should not be combustible.

2.5.4 Use of Components

Pressure Relief (A3-5, B3-B6, C3-C8)

These systems must use some type of pressure relief device but not only a fusible plug.

The discharge capacity of a pressure relief device shall be established in accordance with pr EN 12284.

It is preferable to use an automatic pressure relief valve on the high side, vented to the low side before other pressure relief/bursting disc devices discharge refrigerant to the atmosphere.

Pressure Switches (A3-A5, B3-B6, C3-C8)

These systems must use low and high pressure switches located on the suction and discharge sections of the system.

Vibration Elimination (All)

If the equipment is solidly mounted then vibration eliminators to the suction and discharge lines should not under normal circumstances be required. If the compressor is mounted on rubber or spring mounts it may be advisable to install vibration eliminators to the suction and discharge line.

Pipe Connections (All)

Eliminate flared connections or compression fittings wherever possible. Use brazed joints only.

Charging (A4, A5, B4-B6, C4-C8)

Where reasonably practicable, charging points for systems shall be in the open air. Where this is not practicable they shall not be sited near exit passageways.

Other System Components (All)

Other system mechanical components such as pressure vessels, compressors, heat exchangers, piping and fittings should conform to the requirements of the relevant standards.

2.6 Installation

2.6.1 General

Minimum Room Volume (All)

Systems, or part of a system should not be located within a space or room where its volume is such that an entire refrigerant leak would cause a refrigerant/air mixture of a concentration higher than one-fifth of the Lower Flammability Limit (LFL) of the refrigerant (equation 2.2). If this is not possible and the installation is in a machinery room then the use of a refrigerant leak detector and mechanical ventilation should be employed. (See section 2.6.3, 2.6.4 and 2.6.5).

Floor Voids (All)

If equipment that could release its charge is installed in a room with a floor void, certain precautions should be taken. Where sources of ignition exist within the floor void, then it should either be sealed or the space ventilated. In particular, precautions should be made against refrigerant collecting in drains.

Maximum Charge Below Ground Level (A3-A5, B3-B6, C3-C8)

Refrigeration systems containing more than 1.0 kg should not be located in spaces below ground level. The allowable charge size method of calculation (equation 2.1) is particularly applicable below ground level.

Location of Large Systems (A5, B6, C8)

These systems must be located out in the open air, or within a special machinery room.

Location of Systems in Hallways (A2-A5, B2-B6, C2-C8)

These systems should not be installed in hallways and lobbies.

Systems on Roofs (All)

In the case of installations on the roof of a building, precautions shall be taken to ensure that in the event of a leak, refrigerant cannot enter the building.

2.6.2 Refrigeration Piping

Refrigerant Piping (A4, A5, B4-B6, C4-C8)

Systems with these charge sizes cannot have piping passing through rooms which do not contain machinery as a part of the same refrigeration system. Where impractical this requirement can be overcome by using a sheath around the pipework, with each end vented to the rooms containing the refrigerating machinery or to the outside.

Piping Duct Services (All)

Piping ducts must not contain any other pipework or electrical wires or cables unless protection is provided to prevent damage due to interaction between services. Piping through ducts shall not contain any mechanical connections or other line components. Any ducts through which refrigerant piping passes must be vented to the atmosphere.

Piping Through Walls, Floors, Ceiling and Roof Spaces (All)

Piping passing through fire resisting walls and ceilings shall be so sealed as not to allow spreading of fire to neighbouring rooms. Pipe ducts and shafts shall be shut off from other rooms in such a way as to resist the spread of fire.

Piping through false ceilings is permitted provided that a false ceiling is not completely sealed.

Pipework Routing Arrangements

The route of the pipework between the evaporator and the condensing unit or compressor, and remote condenser, should be as direct and as short a distance as possible.

Water Circuits (All)

For systems using an indirect cooling circuit, there is a possibility of accidental release of refrigerant into the secondary circuit from a rupture of the evaporator or condenser wall. This should be dealt with by one of the following options:

- Incorporate an air vent/air separator within the secondary circuit, on the outlet pipe from the evaporator or condenser. Ensure that it is adequately sized such that it will release any refrigerant back into the housing, machinery room, special area or to the outside. Thus the release can then be dealt with as any normal refrigerant release from the primary circuit.

- Use a 'double-walled' heat exchanger, of the type which is laser-welded, designed such that it can only vent to atmosphere rather than the secondary circuit in the event of damage.

2.6.3 Machinery Rooms

Machinery rooms for systems using flammable refrigerants shall be designed to prevent the ignition of an explosive refrigerant/air mixture. There should be warning notices stating that smoking, naked lights or flames are prohibited. Fire extinguishers should be used in accordance with local fire authorities.

Machinery rooms must not be constructed out of combustible materials. If it is possible for the concentration of refrigerant to reach the Lower Flammability Limit then some explosion relief should be provided in the construction of the machinery room. This may be in the form of movable panels or louvres.

Locate all refrigerant containing machinery so that damage from external sources would be difficult.

NOTE: Although a machinery room does not necessarily serve exclusively for refrigeration equipment, boilers and other open flame devices should not share the space. Air intakes for equipment should not be taken from within the machinery room, or close to such machinery room ventilation outlet.

2.6.4 Ventilation

Refrigeration machinery rooms should be vented to the outside air by means of natural or mechanical ventilation.

Free Air Movement (All)

Ensure that free air movement can be achieved around all refrigerant containing parts of the system. Openings for outside air should be positioned such that short circuiting does not occur.

Mechanical Ventilation (All)

Where the refrigerant charge of a single refrigerating circuit exceeds the mass in equation 2.1 a machinery room using hydrocarbons must employ mechanical ventilation capable of providing the minimum ventilation rate. The minimum ventilation rate depends upon the type of electrical protection within the machinery room. Where the electrical

installation is protected according to Section 2.6.6 the mechanical ventilation rate should be equivalent to at least 10 room volume changes per hour[4].

Where the electrical installation does not conform to Section 2.6.6 the minimum ventilation rate is defined by equation 2.4 [5].

$$\dot{V}_{\min} = \frac{M_r}{t_r \cdot (SF) \cdot (LFL)} \qquad \text{(Equation 2.4)}$$

Where:

$V_{\min}$ = minimum volume flow rate of extract fan (m^3/hr)

M_r = largest mass of refrigerant within any single circuit of any refrigerating system (kg)

t_r = minimum release time of refrigerant following a catastrophic leak (typically 0.17 hr)

SF = safety factor (0.5)

LFL = Lower Flammability Limit of refrigerant (kg/m^3) from Table 2.2 of this Code.

In all cases a refrigerant detector should be linked into the initiation of mechanical ventilation. The location of the sampling point should be at low level (where heavier than air refrigerants are used). The ventilation must either be running continuously or use a refrigerant detector starting device set at 20% of the LEL. Lower ventilation rates can be initiated upon detection of lower refrigerant concentrations.

The inlet of the extract ventilation should be located at floor level, and ducted to a safe location. Discharge points for vented air or openings for fresh air shall be positioned so as to avoid discharged air being drawn back into the building such as ventilation system inlets, opening windows and doors and sources of ignition. The rejection of flammable material shall not present a hazard externally, such as entering a building or being in contact with sources of ignition. The mechanical ventilation system should be designed to maintain the room at a lower pressure than surrounding areas so that there will be no escape of leaked refrigerants to other areas. Fans for mechanical ventilation should use motors of the non-sparking type and the fan blades and cowling should be designed so as to avoid sparking as a result of metal-to-metal contact. Mechanical ventilation equipment should be installed with independent emergency control located outside, of, and near to the machinery room.

NOTE: To obtain a reduced air flow under non-emergency conditions, multi-speed fans may be used.

Machinery rooms can also use natural ventilation provided that it is designed adequately.

2.6.5 Refrigerant Detection

Refrigerant vapour detectors shall be provided in machinery rooms to activate an alarm and to automatically switch on ventilation fans if the concentration of refrigerant release exceeds the Practical Limit. Detectors should be used to isolate electrical equipment that does not conform to the electrical requirements detailed in Section 2.6.6, and to warn persons that a fault has occurred. Sampling points should be installed at strategic points

within machinery rooms. Points should be located so that they provide rapid signals in the event of a leak, and that the effect of air movement does not inhibit their effectiveness. Refrigerant leak detectors shall be calibrated for the specific refrigerant they are intended to detect. Where the refrigerant is heavier than air, sampling points shall be located at floor level. A detector can normally cover an area of about $36m^2$ provided it is mounted at floor level[4].

Refrigerant Leak Detection (A4, A5, B4-B6, C4-C8)

If the concentration within the machine room can rise above the practical limit then a refrigerant leak detection device should be installed.

Refrigerant Detection Alarm (A4, A5, B4-B6, C4-C8)

When a leak of refrigerant is detected, the device shall initiate an alarm in the machinery room and also elsewhere so that emergency action may be initiated. The alarm shall be in the form of an audible signal, a flashing light or both.

Detectors should be used to isolate electrical equipment that does not conform to the requirements for electrical equipment in section 2.6.6, and to initiate mechanical ventilation and to warn persons that a fault has occurred.

2.6.6 Sources of Ignition

There should be no sources of ignition as part of the refrigerating system or equipment.

Electrical Components (All)

Precautions should be taken to avoid the possibility of direct sources of ignition from exposed electrical contacts. Electrical items that have the potential to produce electrical sparks during normal operation should receive particular attention to eliminate them as potential sources of ignition. The following methods can be applied:

- Insulate terminals
- Locate within IP65 enclosure
- Replace with solid state type component
- Replace with Ex type component
- Locate externally

Providing such items only comprise of solid state parts or have casings which are solid encapsulated or otherwise sealed to at least IP54 or are located externally to the casing of the refrigerant containing parts then adequate precautions as required above are normally achieved.

NOTE: For manufactured appliances rather than installed equipment, an alternative option exists. For systems containing less than 150g of refrigerant a leakage test from the refrigeration circuit can be conducted to determine whether sufficient refrigerant

reaches the components to present a hazardous situation [13,24]. This test should be conducted under controlled conditions.

Care should be taken to ensure that electrical terminations, including capacitor terminations are adequately tightened and secured against loosening and that adequate insulation is provided to avoid live parts shorting together.

Motors, including fans, pumps and compressors should be of brushless design.

Components to consider as possible sources of ignition are:

On/off manual switches	Liquid level switch	Condensate pump switch
Thermostats	Flow switches	Fan speed controllers
Pressure switches	Start relays	Humidity controllers
Oil differential switches	Thermal overload relays	Programmable controllers
Fan delay switches	Potential relays	Defrost timers/switches
Contactors	Universal relays	Time switches/relays
Isolator switches		

NOTE: This list is not exhaustive.

Ex-rated components (A5, A6, B5, B6, C5-C8)

If the refrigerant charge exceeds 2.5kg in any one refrigerant circuit then the selection of electrical apparatus and its installation should be in accordance with BS EN 60079. For example, Ex rated components can be used.

NOTE: In machinery rooms it is sufficient to fit leak detection equipment which isolates all plant room electrics via a contactor, upon detection of refrigerant. The detection device should also initiate ventilation with an appropriate extract system from a separate dedicated power supply.

Hot Surfaces (All)

Parts of refrigerating machines whose surfaces could become excessively hot shall be avoided. All components that could come into contact with released refrigerant shall have a maximum surface temperature not higher than 100K below the auto-ignition temperature of the refrigerant used. Auto-ignition temperature for various refrigerants are provided in Table 2.2.

2.6.7 Pipework Installation

The following should be installed in accordance with the BRA Guide to Good Refrigeration Practice, and BRA jointing of Copper Pipework for Refrigeration Systems:

- Copper Tubing
- Copper to Copper Pipework Fittings
- Swaged Joint

- Installation of Line Components
- Pipework Support Methods for Copper Pipework
- Methods for Cutting Tube
- Tube Bending
- Brazing of Pipework

2.7 Marking and Instructions

Marking of Systems Installed on Site (All)

Safety instructions relating to the refrigerant in use shall be predominately displayed in machinery rooms. Refrigerating systems installed on site shall be provided with a clearly visible plate giving at least the following information:-

- The installers name and address.
- The year of installation.
- The refrigerant type and number.
- The allowable pressures for the systems.
- The approximate refrigerant charge.

Marking of Compressors and Unit Systems (All)

Each unit system and compressor shall be provided with a permanently connected plate giving at least the following:-

- Manufacturer or vendors name.
- Model or type reference.
- Serial number.
- Refrigerant for which it is designed (for unit systems only).
- System charge weight of refrigerant.
- Test pressure and allowable pressure (not for domestic refrigeration).

Marking of Pipes (All)

Pipes shall be marked, preferably according to a suitable code, e.g. a colour code, to indicate the substance flowing through them.

'Flammable Gas' Stickers (All)

All systems should have at least two hydrocarbon 'flammable refrigerant' stickers placed on them before commissioning. The stickers should be located on the compressor, receiver and any other part of the system to which an engineer would have access to the refrigerant.

Instructions (All)

The supplier or manufacturer shall provide at least one copy of a leaflet or instruction manual containing at least the following information:

- Name, address and telephone number of the manufacturer.
- Name, address and telephone number for customer service, if different from item above.
- Full instructions for the operation, maintenance and servicing of the system and its components, including:
  (a) A description of the system and its components, its functioning and its purpose, including a refrigerating system schematic diagram and electrical circuit diagram.
  (b) Procedure for normal starting and stopping of the system.
  (c) Procedure for stopping the system in an emergency.
  (d) Causes of possible faults and appropriate methods of repair.
  (e) Proposals for planned maintenance including leak testing.
  (f) Reference to the requirements of charging the refrigerant.
  (g) A warning against the charging with the incorrect refrigerant.
  (h) Precautions relating to the storage of supplementary refrigerant in a machinery room.
  (i) The refrigerant to be used and a warning that substitution of another refrigerant should not be made without the approval of a competent person.
  (j) Precautions to be made to prevent freezing in heat exchangers.
  (k) The functions, routine testing and maintenance of all safety and alarms.
  (l) Procedures to be followed in the event of emergencies and/or injuries to persons.
  (m) Details of any necessary protective equipment.

- Warning notes:-
  (a) Warning - keep ventilation openings in the appliance enclosure or in the structure clear of obstruction.
  (b) Warning - do not use mechanical devices or other means to accelerate the defrosting process, other than those recommended by the manufacturer.

2.8 General considerations for workshop/manufacturing

Production areas within factories and workshops require additional precautions in addition to those detailed in other sections. Whilst the scope of this publication does not allow for detailed coverage of these requirements, the following lists items that should be considered.

- Storage and handling of hydrocarbon refrigerant cylinders
  (a) General requirements
  (b) Open air storage
  (c) Storage within specially designed buildings and outhouses
  (d) Storage within parts of a building

- Bulk storage installations
  (a) Location, separation and security requirements
  (b) Underground and mounded vessels
  (c) Fittings and piping

(d) Fire precautions

- Appliance charging areas
  (a) General requirements
  (b) Factory - bay area
  (c) Factory – production line

- Electrical requirements

- Safety Management

A comprehensive risk assessment should be conducted prior to installation. Documents relating to the areas detailed above can be obtained from the Liquified Petroleum Gas Association (LPGA) and from standards dealing with hazardous areas. Additional further information and appropriate codes can be obtained from the refrigerant supplier.

3. SERVICE, MAINTENANCE AND REFRIGERANT HANDLING

This Section deals with practical aspects relating to the handling of both the hydrocarbon refrigeration machine and the hydrocarbon refrigerant itself. It is recommended that companies who use hydrocarbon refrigerants either in equipment they manufacture or equipment for which they are responsible, put into place a general strategy to ensure that correct work practices are employed.

Note that the requirements detailed under Section 3 are not exhaustive, but are intended as a comprehensive guide only. Additional precautions may be appropriate dependent upon the particular equipment and conditions.

3.1 Practical Competence

Any person who is involved with working on or breaking into a refrigerant circuit should hold a current valid certificate from an industry accredited assessment authority, which authorises their competence to handle refrigerants (including hydrocarbons) safely in accordance with an industry recognised assessment specification.

Servicing shall only be performed as recommended by the equipment manufacturer. Maintenance and repair requiring the assistance of other skilled personnel shall be carried out under the supervision of the person competent in the use of flammable refrigerants.

Refer to the draft European Standard prEN 13313.

3.2 General Approach to Hydrocarbon Refrigerant Handling

All flammable refrigerant gases when mixed with air form a flammable mixture. The effect of ignition of such a mixture can be severe. It is therefore important that the appropriate safety requirements are observed at all times when working with flammable refrigerants.

Any equipment used in the process of repair must be suitable for use with flammable refrigerants. All tools and equipment (including measuring equipment) are to be checked for suitability for working on the equipment, particular attention is to be paid to the selection of:

- Refrigerant recovery units.
- Refrigerant leak testing units
- Electrical test meters
- Refrigerant recovery cylinders
- Portable lighting

If the installation permits, it is recommended that the equipment be removed from its existing position to a controlled workshop environment suitable for the type of repair where work can be conducted safely.

3.3 Safety checks

3.3.1 Checks to the area

Prior to beginning work on systems containing hydrocarbon refrigerants, safety checks are necessary to ensure that the risk of ignition is minimised. For repair to the refrigerating system prior to conducting work on the system, the following precautions shall be complied with:

Work procedure
Work shall be undertaken under a controlled procedure so as to minimise the risk of a flammable gas or vapour being present while the work is being performed.

General work area
All maintenance staff and others working in the local area should be instructed as to the nature of work being carried out. Work in confined spaces must be avoided. The area around the workspace is to be sectioned off. Ensure that the conditions within the area have been made safe by control of flammable material

Checking for presence of refrigerant
The area shall be checked with an appropriate refrigerant detector prior to and during work to ensure the technician is aware of potentially flammable atmospheres. Ensure that the leak detection equipment being used is suitable for use with flammable refrigerants, i.e. non-sparking, adequately sealed or intrinsically safe (see section 3.4).

Presence of fire extinguisher
If any hot work is to be conducted on the refrigeration equipment or any associated parts, appropriate fire extinguishing equipment shall be available to hand. Have a dry powder or CO_2 fire extinguisher adjacent to the charging area.

No ignition sources
No person carrying out work in relation to a refrigeration system which involves exposing any pipe work which contains or has contained flammable refrigerant shall use any sources of ignition in such a manner that it may lead to the risk of fire or explosion. All possible ignition sources, including cigarette smoking, should be sufficiently far away from the site of installation, repairing, removing and disposal during which flammable refrigerant can possibly be released to surrounding space. Should there be a need for brazing or welding to be undertaken refer to section 3.5.1. Prior to work taking place, the area around the equipment is to be surveyed to establish any flammable hazards or ignition risks. Display 'No Smoking' signs.

Ventilated area
Ensure that the area is in the open or that it is adequately ventilated before breaking into the system or conducting any hot work. A degree of ventilation should continue during the period that the work is carried out. The ventilation should safely disperse any released refrigerant and preferably expel it externally to the atmosphere.

3.3.2 Checks to the refrigeration equipment

Where electrical components are being changed, they are to be “fit for purpose”, and to the correct specification. At all times the manufacturers maintenance and service guidelines are to be followed. If in doubt consult the manufacturers Technical Department for assistance.

The following checks should be applied to installations using flammable refrigerants:

- That the charge size is in accordance with the room size within which the refrigerant containing parts are installed, according to section 2.5.3. (Note that hydrocarbon charge sizes are typically 40% to 50% of CFC, HCFC and HFC charge sizes)
- That ventilation machinery and outlets are operating adequately and not obstructed, according to section 2.6.4.
- Confirm operation of equipment such as refrigerant leak detectors and mechanical ventilation systems.
- If an indirect refrigerating circuit is being used, the secondary circuit should be checked for the presence of refrigerant.
- Ensure that marking to the equipment continues to be visible and legible. Marking and signs that are worn should be corrected (see section 2.7).
- Refrigeration pipe or components are not installed in a position where it is likely to be exposed to any substance which may corrode refrigerant containing components, unless the components are constructed of materials which are inherently resistant to being corroded or are suitably protected against being so corroded.

The engineer is referred to the requirements for the installation of equipment in Section 2 of this guide.

3.3.3 Checks to electrical devices

Repair and maintenance to electrical components shall include initial safety checks and component inspection procedures. If a fault exists that could compromise safety, then no electrical supply should be connected to the circuit until it is satisfactorily dealt with. If the fault cannot be corrected immediately but it is necessary to continue operation, an adequate temporary solution shall be used, but this must be reported to the owner of the equipment so all parties are aware.

Initial safety checks should be as follows:

- Capacitors are discharged. This should be done in a safe manner to avoid possibility of sparking.
- Do not work on “live” electrical components and wiring whilst charging, recovering or purging the system.
- Continuity of earth bonding.

During repairs to sealed components, all electrical supplies must be disconnected from the equipment being worked upon prior to any removal of sealed covers, etc. If it is absolutely necessary to have an electrical supply to equipment during servicing, then a

permanently operating form of leak detection shall be located at the most critical point to forewarn the individual of a potentially hazardous situation.

For repairs to sealed components, particular attention should be paid to the following:

- Ensure that by working on electrical components, the casing is not altered in such a way that the level of protection is affected. This should include damage to cables, too many connections, terminals not made to original specification, damage to seals, incorrect fitting of glands, etc. This includes secure mounting of apparatus.
- Ensure that seals or sealing materials have not degraded such that it is no longer serving the purpose of preventing the ingress of flammable atmospheres. Replacement parts shall be in accordance with the manufacturer.

NOTE. The use of silicon sealant may inhibit the effectiveness of some types of leak detection equipment. Intrinsically safe components do not have to be isolated prior to working on them.

Information for repair to intrinsically safe components shall be observed:

- Do not apply any permanent inductive or capacitance loads to the circuit without ensuring that this will not exceed the permissible voltage and current permitted for the equipment in use
- Intrinsically safe components are the only types that can be worked on while live in the presence of a flammable atmosphere. However, test apparatus should also be of an appropriate rating
- Replace only with parts specified by the manufacturer. Other parts may result in the ignition of refrigerant in the atmosphere from a leak

Check that cabling will not be subject to wear corrosion, excessive pressure, sharp edges or any other adverse environmental effects. This should also take into account the effects of aging or continual vibration from sources such as the compressor or fans.

3.4 Detection of Hydrocarbon Refrigerants

Under no circumstances should potential sources of ignition be used in the searching or detection of refrigerant leaks. A halide torch (or any other detector using a naked flame) must not be used.

The following leak detection methods can be used on systems containing hydrocarbons:

- Electronic leak detectors may be used to detect hydrocarbons, but the sensitivity may not be adequate, or may need re-calibration. (Detection equipment should be calibrated in a refrigerant-free area.) Ensure that the detector is not a potential source of ignition and is suitable for hydrocarbon refrigerants. Leak detection equipment should be set at a percentage of the LFL of the refrigerant and should be calibrated to the refrigerant employed and the appropriate percentage of gas (25% maximum) is confirmed.

- Leak detection fluids are suitable for use with hydrocarbon refrigerants but the use of detergents containing chlorine should be avoided as the chlorine may react with the refrigerant and corrode the copper pipework.
- Oil additives such as those used in fluorescent leak detection systems will operate with hydrocarbons.
- If a leak is suspected from a hydrocarbon refrigerant system all naked flames should be removed/extinguished.

If a leakage of refrigerant is found which requires brazing, all of the refrigerant shall be recovered from the system, or isolated (by means of shut off valves) in a part of the system remote from the leak. Oxygen Free Nitrogen (OFN) should then be purged through the system both before and during the brazing process.

3.5 Breaking into a System and Charging

3.5.1 Removal and evacuation

When breaking into the refrigerant circuit to make repairs - or for any other purpose - conventional procedures are used. However, it is important that best practice is followed since flammability is now a consideration. The following procedure shall be adhered to:

- remove refrigerant
- purge the circuit with inert gas
- evacuate
- purge again with inert gas
- open the circuit by cutting or brazing,

The refrigerant charge should be recovered into the correct recovery cylinders, the system is then to be “flushed” with OFN to render the unit safe, this process may need to be repeated several times. On no account use compressed air or oxygen for this task.

Flushing is achieved by breaking the vacuum in the system with OFN and continuing to fill until the working pressure is achieved, then venting to atmosphere, and finally pulling down to a vacuum. This process is repeated until satisfied that no hydrocarbons are within the system. When the final OFN charge is used, the system can be vented down to atmospheric pressure to enable work to take place. This operation is absolutely vital if brazing operations on the pipework are to take place.

Ensure that the outlet for the vacuum pump is not close to any ignition sources and there is ventilation available.

3.5.2 Charging

The charging of refrigeration systems with hydrocarbon refrigerants is similar to those using halocarbon refrigerants. As with all blend refrigerants, hydrocarbon refrigerant blends should also be charged in the liquid phase in order to maintain the correct composition of the blend.

The following additional requirements should be adhered to:-

- Ensure that contamination of different refrigerants does not occur when using charging equipment. Hoses or lines are to be as short as possible to minimise the amount of refrigerant contained in them.
- It is recommended that cylinders be kept upright and refrigerant is charged in the liquid phase.
- Ensure that the refrigeration system is earthed prior to charging the system with refrigerant.
- Label the system when charging is complete. The label should state that hydrocarbon refrigerants have been charged into the system and that it is flammable. Position the label in a prominent position on the equipment. (see Section 2.7)
- Extreme care shall be taken not to overfill the refrigeration system. (Note that hydrocarbon charge sizes are typically 40% to 50% of CFC, HCFC and HFC charge sizes)

Prior to recharging the system it should be pressure tested with OFN to a minimum in accordance with BS EN 378.

The system must be leak tested on completion of charging but prior to commissioning. A follow up leak test should always be carried out prior to leaving site.

3.5.3 Commissioning

A refrigeration system containing hydrocarbon is commissioned in exactly the same manner as systems containing CFC/HFC/HCFC refrigerants.

Ensure that correct marking is applied to the system (see section 2.7).

3.5.4 Decommissioning

Before carrying out this procedure, it is essential that an engineer is completely familiar with the plant and all its detail. It is recommended good practice that all refrigerants are recovered safely. Prior to the task being carried out, an oil and refrigerant sample should be taken in case analysis is required prior to re-use of reclaimed refrigerant. It is essential that electrical power is available before the task is commenced.

1. Become familiar with the equipment and its operation.
2. Isolate system electrically.
3. Before attempting the procedure ensure that:
   - Mechanical handling equipment is available if required for handling refrigerant cylinders.
   - All personal protective equipment is available and being used correctly.
   - A competent person should supervise the recovery at all times.
   - Recovery equipment and cylinders conform to the requirements in section 3.5.5.
4. Pump down refrigerant system if possible.

5. If a vacuum is not possible, make a manifold so that refrigerant can be removed from various parts of the system.
6. Make sure that cylinder is situated on the scales before recovery takes place.
7. Start the recovery machine and operate in accordance with manufacturer's instructions.
8. Do not overfill cylinders. (No more than 80% volume liquid charge).
9. Do not exceed the maximum working pressure of the cylinder, even temporarily.
10. When the cylinders have been filled correctly and the process completed, make sure that the cylinders and the equipment are removed from site promptly and all isolation valves on the equipment are closed off.
11. Recovered refrigerant should not be charged into another refrigeration system unless it has been cleaned and checked.

NOTE. Label equipment stating that it has been de-commissioned and emptied of refrigerant. The label should be dated and signed. Ensure that there are labels on the equipment stating the equipment contains hydrocarbon refrigerant.

3.5.5 Recovery

When removing refrigerant from a system, either for servicing or decommissioning it is recommended good practice that all refrigerants are removed safely.

When transferring refrigerant into cylinders, ensure that only appropriate refrigerant recovery cylinders are employed. Ensure that the correct number of cylinders for holding the total system charge are available. All cylinders to be used are designated for the recovered refrigerant and labelled for that refrigerant (i.e. special cylinders for the recovery of hydrocarbon refrigerants). Cylinders should be complete with pressure relief valve and the cylinder and associated shut-off valves in good working order. Empty recovery cylinders are evacuated and if possible cooled before recovery occurs.

The recovery equipment shall be in good working order with a set of instructions concerning the equipment is at hand and be suitable for the recovery of hydrocarbon refrigerants. In addition, a set of calibrated weighing scales should be available and in good working order. Hoses are complete with leak-free disconnect couplings and are all in good condition. Check that refrigerant recovery machines can be used with hydrocarbon refrigerants. The main points to observe are:-

- Check before using the recovery machine that it is in satisfactory working order, has been properly maintained and that any associated electrical components are sealed to prevent ignition in the event of a refrigerant release. Consult manufacturer if in doubt.
- Follow the advice given in this Code of Practice on general safety and the handling of cylinders.

The recovered refrigerant must be returned to the refrigerant supplier in the correct recovery cylinder, and the relevant Waste Transfer Note arranged. Do not mix hydrocarbon refrigerants with other refrigerants in recovery units and especially not in cylinders.

If compressors or compressor oils are to be removed, ensure that it has been evacuated to an acceptable level to make certain that flammable refrigerant does not remain within the lubricant. The evacuation process shall be carried out prior to returning the compressor to the suppliers. Only electric heating to the compressor body shall be employed to accelerate this process. When oil is drained from a system, it shall be carried out safely.

3.6 Handling Of Cylinders

Hydrocarbon refrigerant is available in 300g, 3.5 kg, 12 kg and 46 kg cylinders, and 420g non refillable cylinders. A pressure relief valve is fitted to the cylinder to prevent excess pressure build up. The cylinders are fitted with liquid off-take valves incorporating a non-return valve and a 1¼" ACME connection. A fitting is available to convert to refrigeration industry standard threaded fittings and can be obtained from the refrigerant supplier. The fitting is to be removed from the cylinder when not in use.

There is an automatic excess flow valve within the liquid valve. It will operate and close the valve if the refrigerant flow out of the cylinder is too fast, i.e. hoses not connected or split and refrigerant is escaping from the cylinder. Closing it and then opening it again slowly resets this valve.

Safe cylinder handling differs little from other refrigerant cylinders which are as follows:

- Do not remove or obscure official labelling on a cylinder
- Always refit the valve cap when the cylinder is not in use
- Use and store cylinders in an upright position.
- Check the condition of the thread and ensure it is clean and not damaged.
- Store and use cylinders in dry, well-ventilated areas remote from fire risk
- Do not expose cylinders to direct sources of heat such as steam or electric radiators
- Do not repair or modify cylinders or cylinder valves
- Always use a proper trolley for moving cylinders even for a short distance – never roll cylinders long the ground
- Take precautions to avoid oil, water and foreign matter entering the cylinder
- If it is necessary to warm the cylinder, use only warm water or air, not naked flames or radiant heaters, the temperature of the water or air must not exceed 40°C
- Always weigh the cylinder to check if it is empty – it's pressure is not an accurate indication of the amount of refrigerant that remains in the cylinder
- Use only dedicated recovery cylinders for the recovery of hydrocarbon refrigerants

3.7 Transport Of Cylinders

The Road Traffic (Carriage of Dangerous Substances by Road) Regulations apply to the transportation of cylinders containing hydrocarbons. These regulations also apply to the carriage of other compressed gasses such as oxygen, acetylene and halocarbon refrigerants. Failure to comply with the regulations will result in prosecution. To comply with these regulations you must:

- Carry written information giving the details of the substances carried (such as COSHH safety data sheets or TREMCARD transport emergency card). This information must be available in an emergency, so it should be located in a position where it is visible and accessible.
- Know and understand the hazards and emergency procedures for handling these substances.
- Carry a dry powder fire extinguisher of at least 2 kg capacity. (It is recommended that the driver of the vehicle is trained in the practical use of fire extinguishers).
- Cylinders must be located in an upright position with their valve uppermost and be properly secured.
- Carry no more than 4 x 46 kg cylinders or 12 x12 kg cylinders. (If you have 1 x 46 kg cylinder you cannot carry more than 3 x 12 kg cylinders at the same time)
- Ensure adequate ventilation in the vehicle (this may require modifications to a closed van)
- Display flammable gas hazard warning signs on the rear of the vehicle
- No naked flames or smoking allowed
- Never leave cylinders in a closed vehicle unsupervised for longer than necessary

For further information on transport of cylinders please contact your refrigerant supplier.

3.8 Storage Of Cylinders

Cylinders should be preferably stored outside and never stored in residential premises. Cylinders may be stored in commercial and industrial premesis according to the following guidelines for storage. -

- Quantities stored are to be restricted to no more than 70 kg and stored in specific dedicated areas or cages.
- Access to storage areas restricted to 'authorised persons only', and such places shall be marked with notices prohibiting smoking and the use of naked flames.
- Cylinders containing hydrocarbon refrigerants should be stored at ground level, never in cellars or basements. Cylinders should be readily accessible, and stored upright.
- Static electricity build-up should be avoided

3.9 Carriage of Systems

Adherence to National and International Regulations is necessary if refrigeration equipment containing a charge of hydrocarbon refrigerant is to be transported. Particular requirements are generally determined by the equipment charge size. In general, the applicable Regulations require adequate packaging and marking. Transport companies should also be consulted when transporting equipment containing hydrocarbon refrigerants. Hydrocarbon refrigerants have United Nations number designation UN 1965, and refrigerating systems containing flammable refrigerants have United Nations number designation UN 3358. The following summarises various transportation Regulations for equipment containing flammable gas:

Transport by road:

Within the UK, the Carriage of Dangerous Goods by Road Regulations (CDGR, 1996) exempts equipment containing less that 1kg of flammable refrigerants. It does not permit transport of equipment containing more than 10kg.

Transport by road and rail within Europe (but not including the UK) is covered by the Articles Dangereuses par Routier (ADR, 1999). Equipment containing less than 12 kg of flammable refrigerant is exempt from regulations for carriage provided it is protected by design (i.e. conforms to the appropriate safety standards). Where the charge is above 12 kg, the equipment is subject to the provisions for any receptacle containing flammable gases.

The United Nations Model Regulations for Transport of Dangerous Goods (1999) generally applies to transport by road and rail outside Europe. Equipment containing less than 12kg are exempt from the regulations provided it is protected by design. For equipment containing over 12kg, it must be subject to a pressure type-test of at least three times the maximum working pressure and comply with the packaging requirements detailed in these regulations.

Transport by sea:

The International Maritime Dangerous Goods Code (IMDG, 2001) prescribes requirements for transport of equipment by sea. Refrigerating machines containing less that 100g of flammable refrigerant are not subject to the regulations. Otherwise packaging requires special marking. Refrigerating machines may be carried unpacked in crates or other appropriate over-packs, provided that the equipment has been pressure tested and designed so as to prevent the release of refrigerant during transport conditions. However, if the charge is less that 12 kg then these requirements do not apply.

Transport by air:

The International Civil Aviation Organisation/International Air Transport Association (IATA, 2000) prescribes the Regulations for transport by air. This forbids transport of equipment containing more than 0.1kg in either passenger or cargo planes. If transport by air is necessary, the regulations do permit up to 150kg of flammable refrigerant to be carried by cylinder, so systems can be charged on-site.

NOTE: In line with other requirements, the refrigerant charge is applicable per refrigerant circuit.

4. REFERENCES

These standards and codes of practice are current at the time of publishing. Checks should be made to ensure these are still current.

1. **BRA Guide to Good Commercial Refrigeration Practice**, Issue 1 (ISBN 1 870623 15 0) British Refrigeration Association (April 2000)

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3. **BRA Task Procedures and Risk Assessments**: Model Method Statements, issue 3 (ISBN 1 870623 13 4) British Refrigeration Association (April 2000)

4. **BS 4434: 1995** Specification for safety and environmental aspects in the design, construction and installation of refrigerating appliances and systems., BSI, London 1997.

5. **BS 5345: 1976** Code of practice for the selection, installation and maintenance of electrical apparatus for use in potentially explosive atmospheres (other than mining applications or explosive processing and manufacture)

6. **BS EN 1127-1: 1998** Explosive atmospheres – explosion prevention and protection. Basic concepts and methodology.

7. **BS EN 378: 2000** Refrigerating systems and heat pumps – safety and environmental requirements.

8. **BS EN 60079-10: 1998**. Electrical Apparatus for Explosive Gas Atmospheres. Classification of hazardous areas.

9. **BS EN 60079-11: 1997** Electrical Apparatus for Explosive Gas Atmospheres. Electrical apparatus with type of protection “i”.

10. **BS EN 60079-14: 1997** Electrical Apparatus for Explosive Gas Atmospheres. Electrical installations in hazardous areas (other than mines).

11. **BS EN 60079-15: 1994** Electrical Apparatus for Explosive Gas Atmospheres. Electrical apparatus with type of protection “n”.

12. **BS EN 60079-18: 1994** Electrical Apparatus for Explosive Gas Atmospheres. Electrical apparatus with type of protection “m”.

13. **BS EN 60335-2-24: 1994** Specification of household and similar electrical appliances. Particular requirements. Refrigerators, food-freezers and ice-makers.

14. **BS EN 60335-2-34: 2000** Specification of household and similar electrical appliances. Particular requirements. Motor-compressors.

15. **BS EN 60335-2-40: 1993** Specification of household and similar electrical appliances. Particular requirements. Electric heat pumps, air conditioners and dehumidifiers.

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18. **prEN12284** Pressure Relief Valves

19. **pr EN 13313**. Refrigerating Systems and Heat Pumps - Competence of Personnel (Draft at time of publication, 1999)

20. **EN 50054** Electrical apparatus for the detection and measurement of combustible gases – General requirements and test methods.

21. **EN 50057** Electrical apparatus for the detection and measurement of combustible gases – Performance requirements for Group II apparatus indicating up to 100% lower explosive limit.

22. **EN 60529: 1991** Degrees of protection provided by enclosure (IP code)

23. **IATA, 2000**, International Air Transport Association, Dangerous Goods Regulations, 40th Edition, Geneva.

24. **IEC 60079-0: 1998** Electrical Apparatus for Explosive Gas Atmospheres. General requirements.

25. **IEC 60335-2-89** (Draft at time of publication). Specification of household and similar electrical appliances. Particular requirements. Commercial refrigerating appliances with an incorporated or remote refrigerant condensing unit.

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