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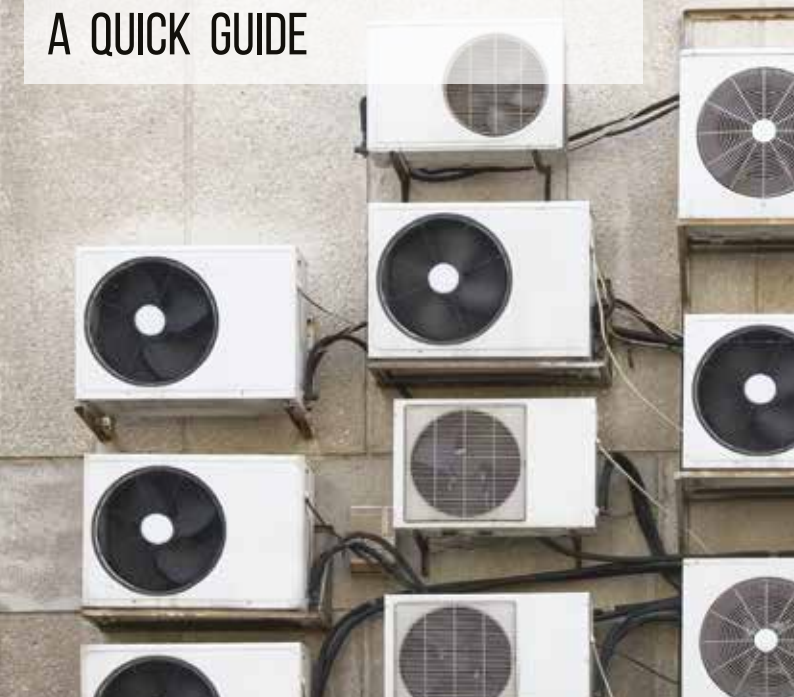
GOOD SERVICING PRACTICES FOR FLAMMABLE REFRIGERANTS: A QUICK GUIDE



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CONTENTS

! This guide book is not a replacement of proper training for refrigeration technicians. Inclusion of images of equipment and tools in this guide book does not constitute an endorsement of the companies or products.

1 CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

Refrigeration and air-conditioning (RAC) equipment operating on ultra-low to medium global warming potential (GWP) refrigerants, e.g. HC-290 (propane), HC-600a (iso-butane) and HFC-32 (methylene fluoride), is now widely available. This market change is globally driven and in response to ozone layer depletion, climate change and the demand for higher energy efficiency. RAC servicing technicians need to have the necessary skills for the safe management of all refrigerants and equipment whose function depends on them.

FIGURE 1: PROPANE CYLINDER

These alternatives can have different properties compared to HCFC-based refrigerants, such as higher flammability, higher toxicity or higher working pressures. Compliance with safety standards is

extremely important for RAC servicing technicians. RAC servicing technicians must have updated knowledge about good practices for handling these alternative refrigerants. Good servicing practices have also been recognised as the best approach towards supporting national obligations for the protection of the ozone layer.

1.2 OBJECTIVES OF THIS GUIDE BOOK

The aim of this guide book is to provide RAC servicing technicians with a quick reference to the key safety classifications and technical properties of commercially-available flammable refrigerants. Additionally, it provides important safety guidance for the installation and servicing of room air-conditioners with a cooling capacity up to 14 kilowatts, 48,000 BTU/hour or about 4 Refrigeration Tonnes (RT) and designed to use flammable refrigerants.

FIGURE 2: RESIDENTIAL AIR-CONDITIONER

Please note that the instruction described in this guide book are **not** to be applied for the management of ammonia and carbon dioxide refrigerants and related systems.

All flammable refrigerants must be handled with precautions and in accordance with national regulations, operation manuals and/or safety standards. Manufacturers' refrigerant charge limits must always be complied with when servicing.

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CHAPTER 2
COMMON TYPES OF FLAMMABLE REFRIGERANTS

2.1 USE OF REFRIGERANTS IN RAC EQUIPMENT

Table below shows the most commonly used refrigerants in domestic refrigerators, stand-alone commercial refrigerators and room air-conditioners.

TABLE 1 REFRIGERANTS MOST COMMONLY USED IN RAC EQUIPMENT

RAC EQUIPMENT	MEDIUM/ LOW GWP[1] NON-ODS[2]	HCFC	HIGH GWP NON-ODS
DOMESTIC REFRIGERATOR	HC-600a (R-600a)	-	HFC-134a (R-134a)
STAND-ALONE COMMERCIAL REFRIGERATOR	HC-290 (R-290), R-744(CO_2)	HCFC-22 (R-22)[3]	HFC-134a R-404A
ROOM AIR-CONDITIONER	HFC-32(R-32) HC-290(R-290)	HCFC-22	R-410A

[1] Global warming potential [2] Ozone depleting substance [3] R-22 is being phased out under national regulation

2.2 FLAMMABILITY PROPERTIES OF REFRIGERANTS

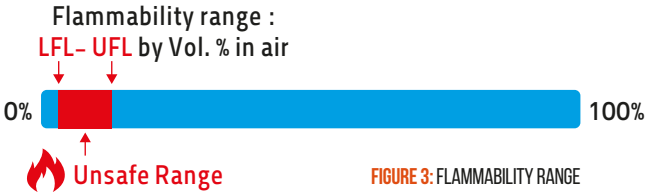

FIGURE 3: FLAMMABILITY RANGE

LOWER FLAMMABILITY LIMIT (LFL)

- The minimum concentration of the refrigerant that is capable of propagating a flame.

UPPER FLAMMABILITY LIMIT (UFL)

- The maximum concentration of the refrigerant that is capable of propagating a flame.

AUTO-IGNITION TEMPERATURE

- The lowest temperature at which a refrigerant will spontaneously ignite in a normal atmosphere without an external source of ignition (flame or spark).

! Since a flame can be propagated in the range between LFL–UFL, one should avoid the concentration of refrigerant in the working area reaching the LFL and the temperature of refrigerant from reaching the auto–ignition temperature.

TABLE 2 KEY PROPERTIES OF THE MORE COMMON AND COMMERCIALLY-AVAILABLE REFRIGERANTS

REFRIGERANT	HFC-134a (R-134a)	HCFC-22 (R-22)	R-404A	R-407C
LOWER FLAMMABILITY LIMIT (LFL)	Not Flammable	Not Flammable	Not Flammable	Not Flammable
UPPER FLAMMABILITY LIMIT (UFL)	Not Flammable	Not Flammable	Not Flammable	Not Flammable
AUTO-IGNITION TEMPERATURE (°C)	743°C	635°C	728°C	704°C

REFRIGERANT	R-410A	HFC-32 (R-32)	HC-290 (R-290)	HC-600a (R-600a)
LOWER FLAMMABILITY LIMIT (LFL)	Not Flammable	14.4% By Volume	2.1% By Volume	1.7% By Volume
UPPER FLAMMABILITY LIMIT (UFL)	Not Flammable	33.4% By Volume	9.6% By Volume	9.7% By Volume
AUTO-IGNITION TEMPERATURE (°C)	N/A	648°C	450°C	530°C

2.3 UNDERSTANDING REFRIGERANT SAFETY CLASSIFICATION

The International Organization for Standardization (ISO) standard **ISO–817 : Refrigerants–designation and safety classification** categorizes refrigerants on the basis of

- Toxicity : which is assigned by the character A or B.
- Flammability : which is assigned a classification 1, 2, 2L or 3.

TABLE 3 REFRIGERANT SAFETY CLASSIFICATION

CLASS	SAFETY GROUP	
	A LOWER TOXICITY	B HIGHER TOXICITY
3 HIGHER FLAMMABILITY	A3 e.g. R–290, R–600a	B3
2 FLAMMABILITY	A2 e.g. R–152a	B2
2L LOWER FLAMMABILITY	A2L e.g. R–32, R–1234yf	B2L e.g. R–717 (ammonia)
1 NO FLAME PROPAGATION	A1 e.g. R–22, R–134a R–410A, R–404A, R–407C, R–744	B1 e.g. R–123

! Full safety checks and procedures must be followed at all times and for all refrigerants, even when they are classified as lower toxicity or non–flammable.

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CHAPTER 3
SAFE HANDLING OF FLAMMABLE REFRIGERANTS

3.1 UNDERSTANDING THE FIRE TRIANGLE

The fire triangle is composed of the three components that produce a physicochemical reaction to ignite a fire: heat, fuel, and oxygen. A fire can occur naturally when these three elements are simultaneously present in the appropriate proportions.

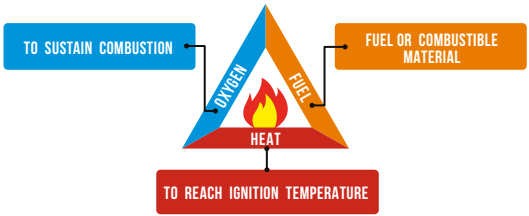

FIGURE 4: FIRE TRIANGLE

The RAC servicing technician must organise and prepare work areas to avoid all potential fire hazard situations.

3.2 CHARGE LIMITATION OF FLAMMABLE REFRIGERANT IN ROOM AIR-CONDITIONERS USED FOR "HUMAN COMFORT"

To prevent fire hazards from the use of flammable refrigerant, relevant standards have been adopted to limit the charge size of flammable refrigerant in RAC equipment. In principle, the following factors must be considered to determine charge limits of flammable refrigerants in a RAC system:

FLAMMABILITY GROUP OF THE REFRIGERANT

For example, R-32 (Group 2L) and R-290 (Group 3) have different flammability properties which affect the charge limits in the RAC system.

OCCUPANCY CLASSIFICATION

This factor indicates the level of restriction that people can access in the rooms and parts of buildings in which a RAC system is installed. These are classified into general occupancy, supervised occupancy and authorized occupancy.

LOCATION CLASSIFICATION OF RAC EQUIPMENT

Charge limitation also depends on the location of the refrigerant-containing parts, e.g. whether it is located in an occupied space, a machinery room (enclosed room or space with mechanical ventilation), in the open air or in a ventilated enclosure.

FORMULA FOR CALCULATION

To determine the maximum allowable charge size, a RAC servicing technician should be properly trained to comply with the manufacturer's operational manual for the specific RAC equipment being installed / serviced, as well as the relevant national standards.

In cases where national standards do not exist, the formula in Table 4 can be useful for RAC servicing technicians to determine the charge limits of R-32 (Group 2L) and R-290 (Group 3) in unitary and split-type air-conditioners installed for 'human comfort' in rooms/parts of buildings classified as "General Occupancy."[4] The maximum allowable charge size calculated in this guide book is based on the formula specified in the ISO 5149-1:2014 standard.

[4]General occupancy is rooms, parts of a building where people can sleep, people are restricted in their movement or the uncontrolled number of people is present without being personally acquainted with the necessary safety precautions.

To calculate charge limit requirements of RAC systems which are:

- Not unitary and split-type air-conditioners,
- Not installed for 'human comfort' in the general occupancy category,

>> please refer to relevant requirements indicated in the ISO 5149 - 1:2014 standard.

Charge limitation is the standard maximum allowable charge size of refrigerant in the respective occupancy type and location in which the RAC equipment can be safely used. It is not the actual charge size of refrigerant in the system.

TABLE 4 FORMULA FOR CALCULATION OF CHARGE LIMITS

REFRIGERANT GROUP	FORMULATION
FLAMMABILITY CLASS 2L E.G. R-32	$M_{MAX} = 2.5 \times LFL^{1.25} \times h_0 \times A^{0.5}$ BUT NOT MORE THAN 39 x LFL
FLAMMABILITY CLASS 2 AND CLASS 3 E.G. R-290	$M_{MAX} = 2.5 \times LFL^{1.25} \times h_0 \times A^{0.5}$ BUT NOT MORE THAN 26 x LFL

WHERE

- M_{MAX} — Maximum allowable charge in a room in kg
- A — Room area in m^2
- LFL — Lower Flammability Limit in kg/m^3
- h_0 — Height factor in m, based upon the method of mounting the appliance
  - 0.6 metres for floor location
  - 1.0 metres for window mounted
  - 1.8 metres for wall mounted
  - 2.2 metres for ceiling mounted

LFL OF R-32 IS 0.307 KG/M^3

LFL OF R-290 IS 0.038 KG/M^3

EXAMPLE OF CALCULATION

A RAC servicing technician would like to install an **R-32** wall mounted air-conditioner in a 30 m^2 room.

$$M_{max} = 2.5 \times LFL^{1.25} \times h_0 \times A^{0.5}$$
$$= 2.5 \times 0.307^{1.25} \times 1.8 \times 30^{0.5}$$
$$= 5.63 \text{ kg.}$$

Check whether the calculated amount is more than $39 \times LFL = 39 \times 0.307 = 11.97$ kg. In this case, the M_{max} is less than 11.97 kg. **Therefore, 5.63 kg. is the maximum allowable charge size.**

A RAC servicing technician would like to install an **R-290** wall mounted air-conditioner in a 30 m^2 room.

$$M_{max} = 2.5 \times LFL^{1.25} \times h_0 \times A^{0.5}$$
$$= 2.5 \times 0.038^{1.25} \times 1.8 \times 30^{0.5}$$
$$= 0.41 \text{ kg.}$$

Check whether the calculated amount is more than $26 \times LFL = 26 \times 0.038 = 0.99$ kg. In this case, the M_{max} is less than 0.99 kg. **Therefore, 0.41 kg. is the maximum allowable charge size.**

TABLE 5 MAXIMUM ALLOWABLE CHARGE SIZE OF R-32 IN AIR-CONDITIONING EQUIPMENT

AREA (M^2)	M_{MAX} FLOOR LOCATION (KG)	M_{MAX} WINDOW MOUNTED (KG)	M_{MAX} WALL MOUNTED (KG)	M_{MAX} CEILING MOUNTED (KG)
9	1.03	1.71	3.09	3.77
12	1.19	1.98	3.56	4.35
15	1.33	2.21	3.98	4.87
18	1.45	2.42	4.36	5.33
21	1.57	2.62	4.71	5.76
24	1.68	2.80	5.04	6.16
27	1.78	2.97	5.34	6.53
30	1.88	3.13	5.63	6.88
33	1.97	3.28	5.91	7.22
36	2.06	3.43	6.17	7.54
39	2.14	3.57	6.42	7.85
42	2.22	3.70	6.66	8.15
45	2.30	3.83	6.90	8.43
48	2.37	3.96	7.12	8.71
51	2.45	4.08	7.34	8.98
54	2.52	4.20	7.56	9.24
57	2.59	4.31	7.76	9.49
60	2.66	4.43	7.97	9.74

The RAC servicing technician must ensure that the actual charge size of refrigerant in the AC system being installed/serviced does not exceed the maximum charge size.

TABLE 6 MAXIMUM ALLOWABLE CHARGE SIZE OF R-290 IN AIR-CONDITIONING EQUIPMENT

AREA (M^2)	M_{MAX} FLOOR LOCATION (KG)	M_{MAX} WINDOW MOUNTED (KG)	M_{MAX} WALL MOUNTED (KG)	M_{MAX} CEILING MOUNTED (KG)
9	0.08	0.13	0.23	0.28
12	0.09	0.15	0.26	0.32
15	0.10	0.16	0.29	0.36
18	0.11	0.18	0.32	0.39
21	0.12	0.19	0.35	0.42
24	0.12	0.21	0.37	0.45
27	0.13	0.22	0.39	0.48
30	0.14	0.23	0.41	0.51
33	0.14	0.24	0.43	0.53
36	0.15	0.25	0.45	0.55
39	0.16	0.26	0.47	0.58
42	0.16	0.27	0.49	0.60
45	0.17	0.28	0.51	0.62
48	0.17	0.29	0.52	0.64
51	0.18	0.30	0.54	0.66
54	0.18	0.31	0.55	0.68
57	0.19	0.32	0.57	0.70
60	0.19	0.32	0.58	0.71

The RAC servicing technician must ensure that the actual charge size of refrigerant in the AC system being installed/serviced does not exceed the maximum charge size.

3.3 REQUIRED MINIMUM FLOOR AREA

When a RAC servicing technician installs a system with a flammable refrigerant charged with a particular quantity of refrigerant 'm', in kg, the required minimum floor area ('A_{min}') should be calculated using the following formula :

$$A_{min} = \left(\frac{M}{2.5 \times LFL^{1.25} \times h_0} \right)^2$$

This formula can be applied when the range of the charge size is between:

- (6 x LFL) to (39 x LFL) for flammability class 2L
- (4 x LFL) to (26 x LFL) for flammability class 2&3

There are no room volume restrictions when the refrigerant charge is:

- below or equal to (6 x LFL) for flammability class 2L
- below or equal to (4 x LFL) for flammability class 2&3

TABLE 7 MINIMUM FLOOR AREA REQUIREMENTS

	NO VOLUME RESTRICTION	A_{min} FORMULA SHOULD BE APPLIED
R-32	CHARGE SIZE ≤ 1.8 KG	BETWEEN 1.8 AND 12.0 KG
R-290	CHARGE SIZE ≤ 0.15 KG	BETWEEN 0.15 AND 1.0 KG

TABLE 8 MINIMUM FLOOR AREA REQUIREMENT OF R-32 IN AIR-CONDITIONING EQUIPMENT

ACTUAL CHARGE SIZE (KG)	A_{min} FLOOR LOCATION (M^2)	A_{min} WINDOW MOUNTED (M^2)	A_{min} WALL MOUNTED (M^2)	A_{min} CEILING MOUNTED (M^2)
LESS THAN 1.8 KG	NO VOLUME RESTRICTION			
1.8	27.6	9.9	3.1	2.1
2.0	34.0	12.3	3.8	2.5
2.2	41.2	14.8	4.6	3.1
2.4	49.0	17.6	5.4	3.6
2.6	57.5	20.7	6.4	4.3
2.8	66.7	24.0	7.4	5.0
3.0	76.6	27.6	8.5	5.7
3.2	87.2	31.4	9.7	6.5
3.4	98.4	35.4	10.9	7.3
3.6	110.3	39.7	12.3	8.2
3.8	122.9	44.2	13.7	9.1
4.0	136.2	49.0	15.1	10.1
4.2	150.1	54.0	16.7	11.2
4.4	164.8	59.3	18.3	12.3
4.6	180.1	64.8	20.0	13.4
4.8	196.1	70.6	21.8	14.6
5.0	212.8	76.6	23.6	15.8

TABLE 9 MINIMUM FLOOR AREA REQUIREMENT OF R-290 IN AIR-CONDITIONING EQUIPMENT

ACTUAL CHARGE SIZE (KG)	A_{min} FLOOR LOCATION (M^2)	A_{min} WINDOW MOUNTED (M^2)	A_{min} WALL MOUNTED (M^2)	A_{min} CEILING MOUNTED (M^2)
LESS THAN 0.15 KG	NO VOLUME RESTRICTION			
0.15	35.5	12.8	3.9	2.6
0.20	63.2	22.7	7.0	4.7
0.25	98.7	35.5	11.0	7.3
0.30	142.1	51.2	15.8	10.6
0.35	193.4	69.6	21.5	14.4
0.40	252.6	90.9	28.1	18.8
0.45	319.7	115.1	35.5	23.8
0.50	394.7	142.1	43.9	29.4
0.55	477.6	171.9	53.1	35.5
0.60	568.4	204.6	63.2	42.3
0.65	667.1	240.2	74.1	49.6
0.70	773.7	278.5	86.0	57.5
0.75	888.1	319.7	98.7	66.1
0.80	1,010.5	363.8	112.3	75.2
0.85	1,140.8	410.7	126.8	84.9
0.90	1,278.9	460.4	142.1	95.1
0.95	1,425.0	513.0	158.3	106.0

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CHAPTER 4
GOOD SERVICING PRACTICES FOR FLAMMABLE REFRIGERANTS

WARNING: During servicing and repair activities, there is a very high possibility that refrigerant may be released. There can be potential sources of ignition especially in areas surrounding refrigerant charging and recovery. This leakage can also occur in the process of connecting and disconnecting of hoses.

WARNING: RAC equipment designed for non-flammable refrigerants e.g. R-22 or R-410A are **not** designed to be used with flammable refrigerants and vice versa.

- Technicians must **not** retrofit any RAC system to use flammable refrigerants;
- Technicians must **not** drop-in/top-up flammable refrigerants in any RAC system not originally designed and/or manufactured to use flammable refrigerant.

4.1 TEMPORARY FLAMMABLE ZONE

Technicians should always consider working areas as "temporary flammable zones" during installation and maintenance. **This zone must be free from all ignition sources.**

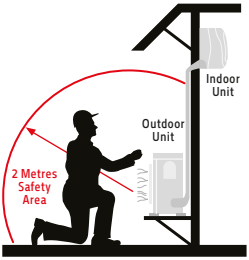

FIGURE 5: TEMPORARY FLAMMABLE ZONE

A "Temporary flammable zone" is a minimum of 2 metres from the point in all directions for small appliances. For larger systems, a greater distance should be allowed.

4.2 HANDLING AND STORAGE OF FLAMMABLE REFRIGERANTS

Handling and storage requirements for flammable refrigerant cylinders are similar to those used for Liquefied Petroleum (LPG) cooking gas. As a normal rule, the maximum quantity of gas cylinders stored in residential premises must not exceed 50 liters (water capacity of cylinder).

FIGURE 6: PROHIBITED ACTIVITIES IN CYLINDER STORAGE AREA

The minimum fire protection for a storage facility of flammable refrigerants where the aggregate capacity is less than 1,000 liters (water capacity) is a water hose connected and ready for use.

THE FOLLOWING PRECAUTIONS SHOULD BE OBSERVED:

- The storage area must be well ventilated and free of combustible materials.
- Store the cylinders on the ground floor and above, but not in basements and other enclosed rooms.
- Keep the cylinders away from sources of heat and direct sun.
- Don't store the cylinders near sources of ignition (electrical sockets, power outlets, lights and switches, electric motors and similar equipment).
- Any potential ignition sources must be at least 3 metres away from the cylinder.
- Protect the cylinders from falling or being knocked over.
- Never place cylinders lying on their side.
- Have access to emergency services e.g. fire, police etc.

4.3 SERVICING TOOLS AND EQUIPMENT FOR FLAMMABLE REFRIGERANT

GENERAL REQUIREMENTS

- Electrical and electronic tools used on systems containing flammable refrigerants should be rated for use in a hazardous area.
- The working area should be monitored with a leak detector designed for the refrigerant being installed/serviced to ensure that the concentration of refrigerant around working area does not exceed the limit.
- A dry-powder or CO_2 fire extinguisher must be available at the location.
- When working in a confined space or an area with insufficient natural ventilation, an explosion-proof or suitable ventilation fan should be used at all times. The electricity power switch for this fan must be outside of working area.

FIGURE 7: EXPLOSION-PROOF VENTILATION FAN

Battery-powered hand drills and screwdrivers, heat guns, as well as domestic equipment such as hair dryers and the like should never be used in a confined area where flammable RAC equipment is being repaired since these tools can act as ignition sources.

VACUUM PUMP

Only specifically-designed vacuum pumps suitable for flammable gases must be used. **A two stage vacuum pump** is recommended for evacuating moisture from a system being serviced, ideally pulling a vacuum in the system to 200-500 microns.

- Reciprocating compressors are unable to generate vacuums to the desired level.
- Using the refrigeration system's compressor for vacuuming may lead to compressor failure.

The vacuum pump should be positioned so that when it is switched on/off, it is located in a place where any leaked flammable refrigerants cannot reach it.

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FIGURE 8: COMPRESSORS MUST NOT BE USED FOR VACUUMING

VACUUM GAUGE

A vacuum gauge capable of reading pressure in the 5 – 5,000 micron range should be used when evacuating a system.

For electronic gauges, ensure that they are designed for use in the presence of flammable refrigerants by checking the user manual.

REFRIGERANT CHARGING EQUIPMENT

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FIGURE 9: REFRIGERANT CHARGING EQUIPMENT

Careful control and monitoring of refrigerant charging during servicing for flammable refrigerants is very important. Very accurate weighing scales for RAC servicing are required for all flammable refrigerants. Due to the small charges, the volumes of refrigerant can only be known with accurate weighing scales.

Electronic scales should be suitable for use in an area where flammable refrigerants may be present and as confirmed by the manufacturer.

REFRIGERANT RECOVERY MACHINE

There are recovery machines specifically designed for flammable refrigerants. Recovery machine for HCFC/HFC refrigerants should **not be used** for hydrocarbon (HC) refrigerants.

Always check with the user manual to confirm whether the recovery machine is suitable for the specific flammable refrigerant being recovered.

FIGURE 10:
RECOVERY MACHINE FOR HYDROCARBON REFRIGERANTS

MANIFOLD/GAUGE/HOSE SET

Materials should be compatible with the relevant refrigerant (e.g. able to withstand the maximum pressure). In case of electronic gauges/manifolds, these must be suitable for use in the presence of flammable refrigerants.

PERSONAL PROTECTIVE EQUIPMENT (PPE)

FIGURE 11: SAFETY GOGGLES AND HAND GLOVES

Ensure that all necessary tools and personal protective equipment (PPE) are available. Ensure that technicians are properly trained on the use of these PPE.

RECOVERY CYLINDER

Never use disposable cylinders to recover refrigerant. Separate recovery cylinders must be used to recover different refrigerants. Technicians must always ensure that there is no mixing of refrigerants when using recovery cylinders. Each recovery cylinder must be properly labelled to indicate the recovered refrigerant type, owner and other data deemed useful.

FIGURE 12: RECOVERY CYLINDER (LEFT) AND DISPOSABLE CYLINDER (MIDDLE AND RIGHT)

Recovery cylinders must be hydrostatically tested and date stamped every 5 years and in accordance with international standards.

Safe refrigerant capacity: A recovery cylinder must not be refilled with refrigerant to more than 80% of the water capacity (WC) in weight.

Never expose a cylinder to direct sunlight or other sources of heat, this can lead to an explosion.

LEAK DETECTOR

When servicing RAC equipment that use hydrocarbon refrigerants, a special leak detector designed for combustible gases is mandatory. The device should have both audio and visual detections.

FIGURE 13: LEAK DETECTOR FOR HYDROCARBONS

HFC leak detectors cannot detect hydrocarbons, and they **are not safe** for use with flammable refrigerants.

> **!** Never use an open flame to perform leak testing of flammable refrigerants – it will cause ignition and which may lead to fire or explosion. For R-32, it can also form hydrogen fluoride, a toxic and corrosive substance.

4.4 PRE-SERVICE SAFETY

Prior to any service, maintenance, or repair of the system the following assessment must be completed:

- Check the history of servicing repairs.
- Identify the safety classification of the refrigerant in the system being serviced.
- Confirm that no ignition sources are present and no flammable materials are stored in the work area.
- Ensure that suitable fire extinguishing equipment (CO_2 or dry-powder type) is available and functioning.
- Section off the space around the work area and place appropriate and visible safety "Work in Progress" signage.
- Ensure that the work area is adequately ventilated.
- Confirm that the ventilation near the work area can safely disperse any released refrigerants to the outside.
- Ensure that suitable flammable refrigerant detectors are present, operating and able to warn of a leak.
- Wear required personal protective equipment (PPE) or safety gear.

4.5 GOOD SERVICING PRACTICE PROCEDURES

Always comply with the equipment manufacturer's user manual for the specific system. Ensure that all good practice tools are readily available. Good RAC equipment servicing practices using flammable refrigerants should follow the following procedures.

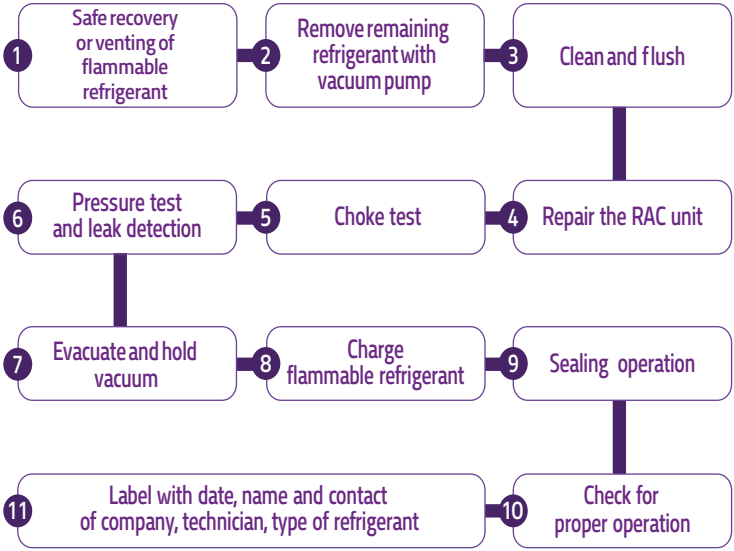


FIGURE 14: GOOD PRACTICE PROCEDURES

1 SAFE RECOVERY OR VENTING OF FLAMMABLE REFRIGERANT

R-32	HYDROCARBON (R-290 AND R-600A)
With recovery machine – As R-32 has a moderate GWP, it should not be vented to the atmosphere. Use a suitable recovery machine to recover R-32 from the system.	**With recovery machine** – Use a suitable recovery machine to recover hydrocarbon refrigerants from the system.
	Without recovery machine – Safely vent using piercing pliers or piercing valve and a long hose to reach a safe area outside. Use suitable extractor fan or open window or door for ventilation.

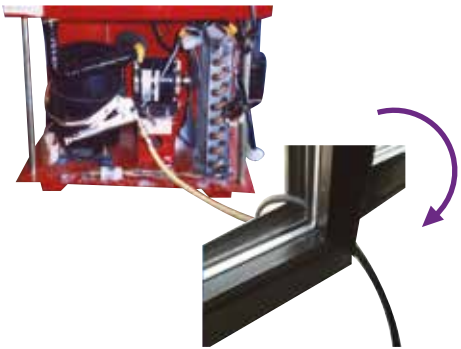


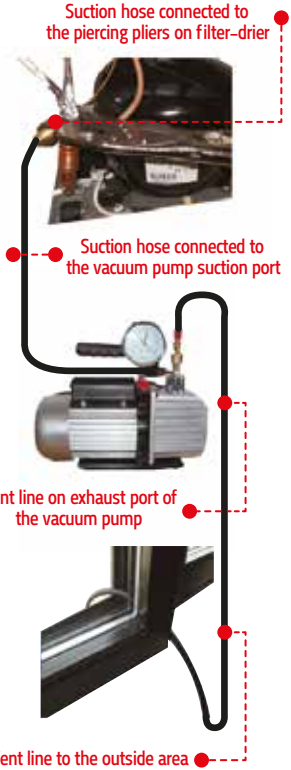
FIGURE 15: OPEN WINDOW OR DOOR FOR VENTILATION

2 REMOVE REMAINING REFRIGERANT WITH VACUUM PUMP

Ensure that most of the refrigerant has been removed before opening the system

Remove the refrigerant using a vacuum pump

Pressure in the system should not be reduced to below 2 pounds per square inch gauge (psig) or 0.14 bar



3 CLEAN AND FLUSH

After debrazing the old filter from the repaired RAC equipment.

Use dry nitrogen with a two stage regulator, at a pressure of about 5 bar

Use hexane / methylene dichloride (MDC) or other environmentally approved flushing solution where chemical cleaning is needed

Do not use carbon tetrachloride (CTC), R-141b, oxygen, air or petrol for flushing

Nitrogen flush

4 REPAIR THE RAC UNIT

Follow the precautions summarized in the **"Handling of flammable refrigerant" section above. Always follow the servicing procedures described in the manufacturer's user manual.**

Use correct components specially designed for flammable refrigerants

R-290 and R-600a are highly flammable refrigerants, servicing technician is strongly advised not to braze the tube, but use 'Lokring' through mechanical extrusion of pipe connection and sealing, which is safe and reliable.

For HFC-32, servicing technician can braze the tube; always ensure that there is no refrigerant in the system.

FIGURE 16: BRAZING

5 CHOKE TEST

Ensure that there are no chokes during brazing. Introduce dry nitrogen through the process tube checking for a free passage

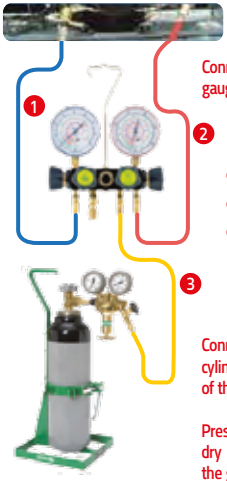
Use dry nitrogen with a two – stage nitrogen regulator

FIGURE 17: TWO STAGE REGULATOR

6 PRESSURE TEST AND LEAK DETECTION

After the system is reassembled and sealed, use dry nitrogen for leak testing.
Do not use compressed air nor any refrigerant.

Test pressure to be regulated at 20 bar and close the cylinder valve when reading 20 bar



Connect a 4–valve manifold gauge set to the system.

1. Low pressure side
2. High pressure side
3. Nitrogen supply

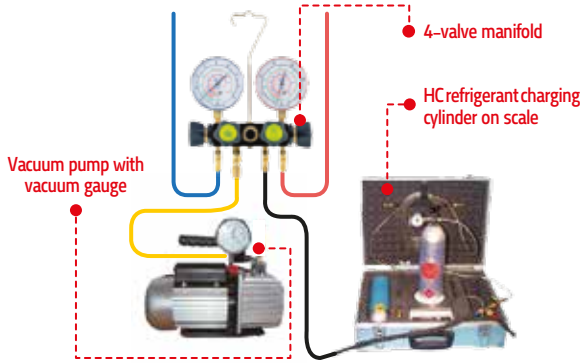
Connect the Nitrogen cylinder to the centre port of the manifold gauge set.

Pressurize the system with dry nitrogen while transferring the gas from both, the high and low pressure side

Use a soap solution → Brush/spray each joint–look for bubbles

FIGURE 18: SOAP SOLUTION

7 EVACUATION AND HOLD VACUUM



1. Connect to tube adapter or schraeder valve (not piercing pliers).
2. Switch on pump, then open the valves.
3. Evacuate to at least 500 microns or lower.
4. Close the valves to isolate the pump.
5. In the absence of a micron vacuum gauge, the vacuum pump should be run for at least half an hour after the Bourdon–type vacuum gauge reading shows –30"/–760 mm/0 millibar (at sea level).
6. Do the vacuum holding for 5 minutes. There should not be sharp rise in the micron gauge.
7. Vacuum pressure should be as low as possible. It must not be higher than 1,500 microns in the holding period of 5–10 minutes.

8 CHARGE FLAMMABLE REFRIGERANT

Only charge an evacuated system

Charging should be done slowly/ gradually

Use weighing scales for accurate charge quantity

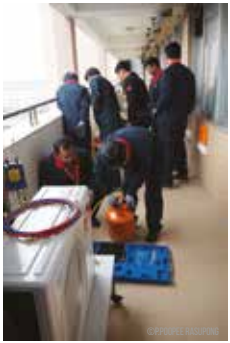


FIGURE 19: REFRIGERANT CHARGING TRAINING

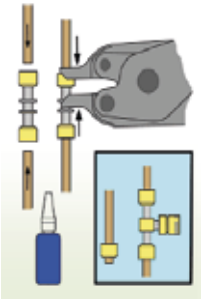
Greater control and accuracy are required for hydrocarbons because of the smaller quantity of charge. The actual charge size depends on the original manufacturer charge, however it is limited to maximum charge as shown in the Table 6, page 21

9 SEALING OPERATION

For sealing the process tube of hydrocarbon, servicing technician is strongly advised not to braze the tube, but use 'Lokring' through mechanical extrusion of pipe connection and sealing, which is safe and reliable.

For split air-conditioners based on R-32 or R-290,

- Close the valve properly
- Cap the valve
- Check for leaks



@ XU CHEN

@ P. POOPEERASUPONG

FIGURE 20: LOKRING

10 CHECK FOR PROPER OPERATION

Check and document the following:

- Records of last service
- Check temperature
- Check pull down time
- Check compressor current
- Check vibration

11 LABEL WITH TYPE OF REFRIGERANT, DATE, NAME AND CONTACT OF COMPANY AND RAC SERVICING TECHNICIAN

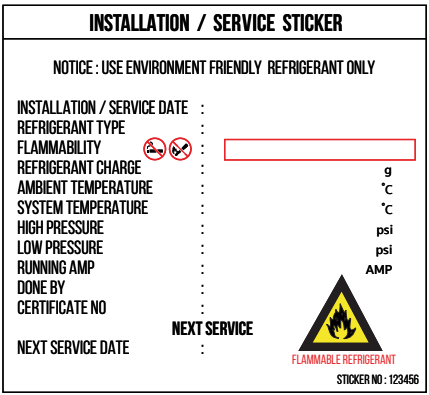
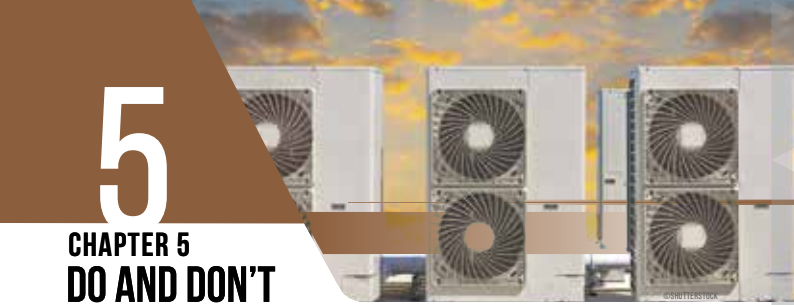


FIGURE 21: EXAMPLE OF SERVICING LABEL



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CHAPTER 5
DO AND DON'T CHECKLIST

DO	Work in a naturally well-ventilated area, outdoors or use forced/induced ventilation system.
	Wear proper safety gloves, goggles, and clothing that covers exposed skin while handling refrigerants.
	Keep the cylinders away from sources of heat and direct sun.
	Store only a minimum number of hydrocarbon cylinders indoors.
	Work with skilled partners.
	Have a list of emergency contacts readily available.

DON'T
Do not smoke, drink or eat while in the work area.
Do not store cylinder in basements and other enclosed rooms.
Do not keep flammable refrigerant in an area that has naked flames, gas cookers, gas water heaters, gas/wood–fire room or space heaters.
Do not allow any ignition source within 3 metres of the cylinder.
Do not let flammable refrigerants accumulate.
Do not place cylinders lying on their side.
Do not work alone. At least two persons per site.

6

CHAPTER 6

PRESSURE-TEMPERATURE CHART OF R-134A, R-22 AND R-410A

(Red figures under kPa are negative kilopascals and red figures under pounds per square inch gauge (psig) are inches of mercury)

Temperature		R-134a		R-22		R-410A	
C	F	kPa	psig	kPa	psig	kPa	psig
-40	-40	-50	15	4	1	74	11
-38	-36	-45	13	14	2	88	13
-36	-33	-38	11	25	4	108	16
-34	-29	-32	9	36	5	130	19
-32	-26	-25	7	49	7	147	21
-30	-22	-17	5	62	9	172	25
-28	-18	-9	3	76	11	194	28
-26	-15	0	0	92	13	219	32
-24	-11	10	2	108	16	244	35
-22	-8	20	3	125	18	272	40
-20	-4	31	5	143	21	301	44
-18	0	43	6	163	24	332	48
-16	3	56	8	184	27	364	53
-14	7	69	10	205	30	398	58
-12	10	84	12	229	33	435	63
-10	14	99	14	253	37	473	69
-8	18	115	17	279	41	513	74
-6	21	133	19	306	44	556	81
-4	25	151	22	334	48	601	87
-2	28	171	25	365	53	648	94
0	32	191	28	396	57	697	101

Temperature		R-134a		R-22		R-410A	
C	F	kPa	psig	kPa	psig	kPa	psig
2	36	213	31	429	62	749	109
4	39	236	34	464	67	803	117
6	43	260	38	501	73	860	125
8	46	286	42	539	78	919	133
10	50	313	45	579	84	982	142
12	54	341	50	621	90	1,047	152
14	57	371	54	665	97	1,115	162
16	61	402	58	711	103	1,186	172
18	64	435	63	759	110	1,260	183
20	68	470	68	808	117	1,338	194
22	72	506	73	860	125	1,418	206
24	75	544	79	915	133	1,502	218
26	79	583	85	971	141	1,590	231
28	82	625	91	1,029	149	1,681	244
30	86	668	97	1,090	158	1,776	258
32	90	713	103	1,154	167	1,874	272
34	93	761	110	1,219	177	1,976	287
36	97	810	118	1,288	187	2,082	302
38	100	861	125	1,359	197	2,193	318
40	104	915	133	1,432	208	2,307	335
42	108	970	141	1,508	219	2,426	352
44	111	1,028	149	1,587	230	2,549	370
46	115	1,089	158	1,669	242	2,676	388
48	118	1,151	167	1,753	254	2,808	407
50	122	1,216	176	1,841	267	2,945	427
52	126	1,284	186	1,931	280	3,086	448
54	129	1,354	196	2,025	294	3,233	469
56	133	1,427	207	2,122	308	3,384	491
58	136	1,502	218	2,222	322	3,541	514
60	140	1,581	229	2,325	337	3,703	537

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CHAPTER 7

PRESSURE-TEMPERATURE CHART OF R-32, R-290 AND R-600A

Temperature		R–32		R290 (propane)		R600a (isobutane)	
C	F	kPa	psig	kPa	psig	kPa	psig
–40	–40	76	11	111	16	28	4
–38	–36	93	13	121	18	32	5
–36	–33	111	16	132	19	35	5
–34	–29	130	19	143	21	38	6
–32	–26	150	22	155	22	42	6
–30	–22	172	25	168	24	46	7
–28	–18	195	28	181	26	51	7
–26	–15	220	32	196	28	56	8
–24	–11	247	36	211	31	61	9
–22	–8	275	40	227	33	66	10
–20	–4	304	44	244	35	72	10
–18	0	336	49	263	38	78	11
–16	3	369	54	282	41	85	12
–14	7	405	59	302	44	92	13
–12	10	442	64	323	47	100	15
–10	14	481	70	345	50	108	16
–8	18	523	76	369	54	117	17
–6	21	567	82	393	57	126	18
–4	25	613	89	419	61	136	20
–2	28	661	96	446	65	146	21
0	32	712	103	475	69	157	23

Temperature		R-32		R290 (propane)		R600a (isobutane)	
C	F	kPa	psig	kPa	psig	kPa	psig
2	36	765	111	504	73	168	24
4	39	821	119	535	78	180	26
6	43	880	128	568	82	193	28
8	46	941	137	602	87	206	30
10	50	1,006	146	637	92	220	32
12	54	1,073	156	674	98	235	34
14	57	1,143	166	712	103	251	36
16	61	1,217	176	752	109	267	39
18	64	1,293	188	794	115	284	41
20	68	1,373	199	837	121	302	44
22	72	1,457	211	882	128	321	47
24	75	1,544	224	928	135	340	49
26	79	1,634	237	977	142	361	52
28	82	1,728	251	1,027	149	382	55
30	86	1,826	265	1,079	156	405	59
32	90	1,928	280	1,133	164	428	62
34	93	2,034	295	1,189	172	452	66
36	97	2,144	311	1,247	181	477	69
38	100	2,258	328	1,307	190	504	73
40	104	2,377	345	1,370	199	531	77
42	108	2,500	363	1,434	208	559	81
44	111	2,628	381	1,500	218	589	85
46	115	2,760	400	1,569	228	620	90
48	118	2,898	420	1,640	238	652	95
50	122	3,040	441	1,713	248	685	99
52	126	3,187	462	1,789	259	719	104
54	129	3,340	484	1,867	271	754	109
56	133	3,498	507	1,948	283	791	115
58	136	3,662	531	2,031	295	829	120
60	140	3,832	556	2,117	307	869	126

REFERENCES

1. The Australian Institute of Refrigeration, Air-Conditioning and Heating (AIRAH), Flammable Refrigerants-Safety Guide, ISBN: 978-0-949436-05-4, 2013 (av ailable online at https://www.airah.org.au/imis15_prod/Content_Files/TechnicalPublications/Flammable-Refrigerant-Safety-Guide-2013.pdf)

2. International Organization for Standardization (ISO), ISO 5149-1:2014(E), Refrigerating systems and heat pumps – Safety and environmental requirements –Part 1 Def initions, classification and selection criteria, First Edition, 2014

3. United Nations Environment Programme, Good Servicing Practices: Phasing out HCFCs in the Refrigeration and Air-Conditioning Sector , 2015 (available online at http://www.unep.org/ozonaction/Portals/105/Files/7723-e-Good%20Servicing%20Practices%20Phasing%20out%20HCFCs%20in%20the%20Refrigeration%20and%20 Air-Conditioning%20Servicing%20Sector_Training%20guide.pdf)

4. United Nations Environment Programme, Safe Use of HCFC Alternatives in Refrigeration and Air-conditioning, 2015 (available online at http://www.unep.fr/ozonaction/information/mmcfiles/7740-e-SafeUseofHCFCAlternativesinRefrigerationandAir-conditioning.pdf)

5. GIZ Proklima publication "Good Practices in Refrigeration 2010" (available online at https://www.giz.de/.../giz2010-engood-practic-esin-refrigeration.pdf)

6. Department of Environment Malaysia, Training Manual For Refrigeration & Air-conditioning Servicing Sectors (RACS) First Edition, 2014.

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