



GOOD SERVICING PRACTICES FOR FLAMMABLE REFRIGERANTS: A QUICK GUIDE

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The project was supervised by
Dr. Shamila Nair-Bedouelle, Head, UN Environment OzonAction

This project was managed by
Artie Dubrie, Regional Network Coordinator, Pacific Islands Countries, UN Environment OzonAction
Pipat Poopeerasupong, HPMP Officer, UN Environment OzonAction
Chaad Somma, Communication Assistant, UN Environment OzonAction

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Bertoldo Esteban Jr, Federated States of Micronesia

Shaofeng Hu, Regional Network Coordinator, South-East Asia, UN Environment OzonAction

Anshu Kumar, India

Tingxun Li, China

Siow Wei Lim, Malaysia

Michael Moller, Australia

Fiji Refrigeration and Air-conditioning Association

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CONTENTS

- | | | |
|----------|--|-------------|
| 1 | INTRODUCTION | P.7 |
| 2 | COMMON TYPES OF
FLAMMABLE REFRIGERANTS | P.10 |
| 3 | SAFE HANDLING OF
FLAMMABLE REFRIGERANTS | P.14 |
| 4 | GOOD SERVICING PRACTICES
FOR FLAMMABLE REFRIGERANTS | P.25 |
| 5 | DO AND DON'T CHECKLIST | P.47 |
| 6 | PRESSURE-TEMPERATURE CHART OF
R-134A, R-22 AND R-410A | P.49 |
| 7 | PRESSURE-TEMPERATURE CHART OF
R-32, R-290 AND R-600A | P.51 |



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.

2

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

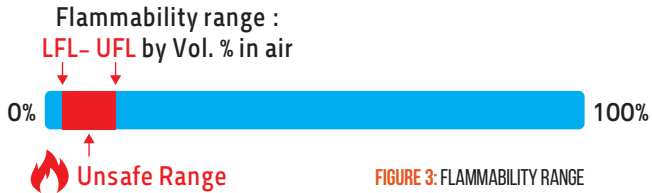
¹ Global warming potential

² Ozone depleting substance

³ R-22 is being phased out under national regulation

2.2

FLAMMABILITY PROPERTIES OF REFRIGERANTS



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
COMMERCIALY-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.

3

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.

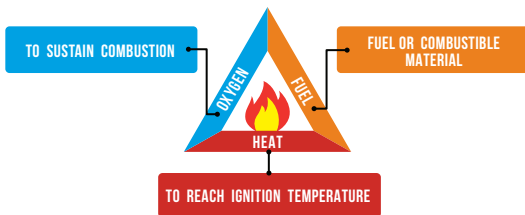


FIGURE 4: FIRE TRIANGLE

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.

⁴General 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
 $0.307 \text{ KG}/\text{M}^3$

LFL OF R-290 IS
 $0.038 \text{ KG}/\text{M}^3$

EXAMPLE OF CALCULATION

A RAC servicing technician would like to install an R-32 wall mounted air-conditioner in a 30 m² room.

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

Check whether the calculated amount is more than $39 \times \text{LFL} = 39 \times 0.307 = 11.97 \text{ kg}$. 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 m² room.

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

Check whether the calculated amount is more than $26 \times \text{LFL} = 26 \times 0.038 = 0.99 \text{ kg}$. 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 :

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

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

4

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.**

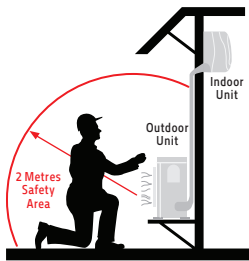


FIGURE 5: TEMPORARY FLAMMABLE ZONE



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).



**NO DIRECT
HEATING**



**NO
PUNCTURING**



**NO ROLLING
NO DROPPING**



**TANK UNDER
PRESSURE**

BOTH MAY CAUSE EXPLOSION



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 CO₂ 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
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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

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.



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FIGURE 9: REFRIGERANT CHARGING EQUIPMENT

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.



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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.



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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 (CO₂ 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.

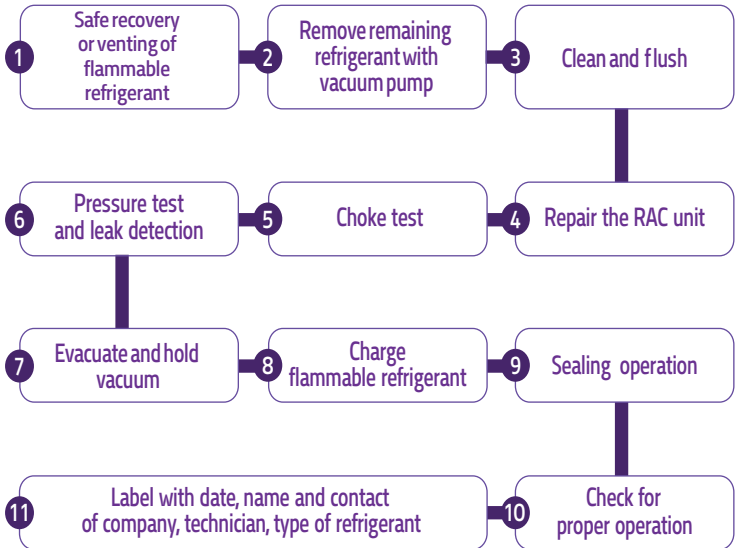


FIGURE 14: GOOD PRACTICE PROCEDURES

1

SAFE RECOVERY OR VENTING OF
FLAMMABLE REFRIGERANT

R-32	HYDROCARBON (R-290 AND R-600A)
<p>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.</p>	<p>With recovery machine – Use a suitable recovery machine to recover hydrocarbon refrigerants from the system.</p>
	<p>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.</p>

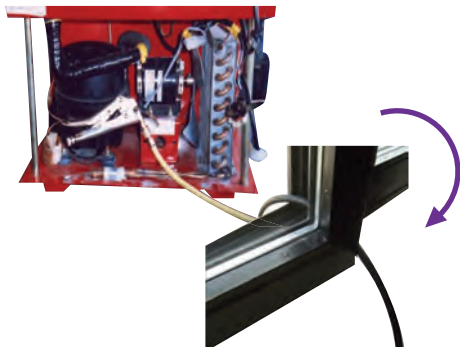


FIGURE 15: OPEN WINDOW OR DOOR FOR VENTILATION

2

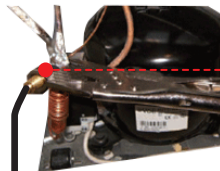
REMOVE REMAINING REFRIGERANT WITH VACUUM PUMP

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

Suction hose connected to the piercing pliers on filter-drier



Suction hose connected to the vacuum pump suction port



Vent line on exhaust port of the vacuum pump



Vent line to the outside area

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



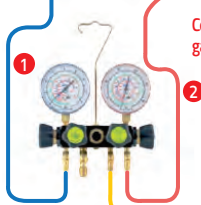
FIGURE 17: TWO STAGE REGULATOR

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

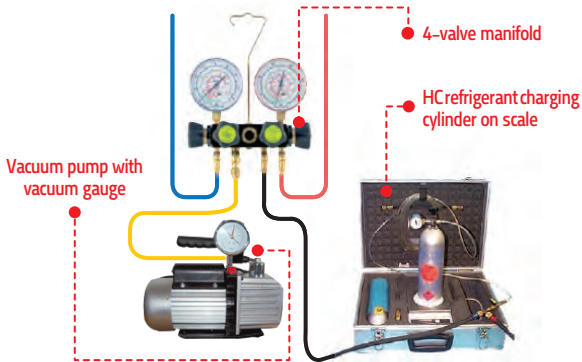
Brush/spray each joint—look for bubbles



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

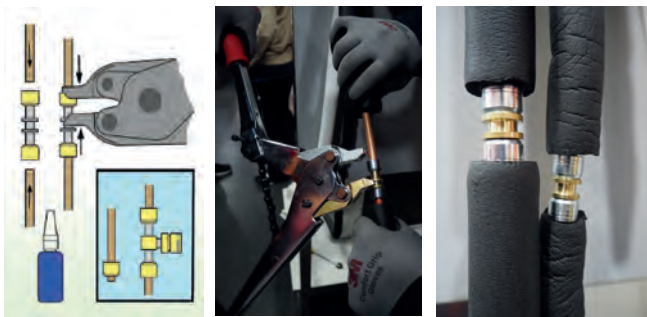
9

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**




INSTALLATION / SERVICE STICKER	
NOTICE : USE ENVIRONMENT FRIENDLY REFRIGERANT ONLY	
INSTALLATION / SERVICE DATE :	:
REFRIGERANT TYPE :	:
FLAMMABILITY   :	<input style="border: 1px solid red;" type="text"/>
REFRIGERANT CHARGE :	g
AMBIENT TEMPERATURE :	°C
SYSTEM TEMPERATURE :	°C
HIGH PRESSURE :	psi
LOW PRESSURE :	psi
RUNNING AMP :	AMP
DONE BY :	:
CERTIFICATE NO :	:
NEXT SERVICE	
NEXT SERVICE DATE :	:
	 FLAMMABLE REFRIGERANT
	STICKER NO : 123456

FIGURE 21: EXAMPLE OF SERVICING LABEL

5

CHAPTER 5 DO AND DON'T CHECKLIST

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.

DO

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

(All figures are in gauge pressure)

Temperature		R-134a		R-22		R-410A	
C	F	kPag	Psig	kPag	Psig	kPag	Psig
-40	-40	-48	-7.0	5	0.8	75	10.9
-38	-36	-43	-6.2	15	2.3	91	13.2
-36	-33	-37	-5.3	26	3.8	109	15.8
-34	-29	-30	-4.4	38	5.5	128	18.5
-32	-26	-23	-3.3	51	7.3	148	21.4
-30	-22	-15	-2.2	64	9.3	169	24.5
-28	-18	-7	-1.0	78	11.4	192	27.9
-26	-15	2	0.3	94	13.6	216	31.4
-24	-11	12	1.7	110	15.9	242	35.2
-22	-8	22	3.2	127	18.4	270	39.2
-20	-4	33	4.8	145	21.1	299	43.4
-18	0	45	6.5	165	23.9	330	47.9
-16	3	57	8.3	186	26.9	363	52.7
-14	7	71	10.3	207	30.1	398	57.8
-12	10	85	12.4	231	33.4	435	63.1
-10	14	101	14.7	255	37.0	474	68.7
-8	18	117	17.0	281	40.7	515	74.7
-6	21	134	19.5	308	44.7	558	81.0
-4	25	153	22.2	336	48.8	604	87.6
-2	28	172	25.0	366	53.2	652	94.5
0	32	193	28.0	398	57.7	702	101.8

Temperature		R-134a		R-22		R-410A	
C	F	kPag	Psig	kPag	Psig	kPag	Psig
2	36	215	31.1	431	62.5	755	109.5
4	39	238	34.5	466	67.6	810	117.5
6	43	262	38.0	502	72.9	868	125.9
8	46	288	41.7	541	78.4	929	134.7
10	50	315	45.6	580	84.2	992	143.9
12	54	343	49.8	622	90.2	1,059	153.6
14	57	373	54.1	666	96.6	1,128	163.7
16	61	404	58.6	711	103.1	1,201	174.2
18	64	437	63.4	759	110.0	1,277	185.2
20	68	472	68.4	808	117.2	1,356	196.6
22	72	508	73.7	859	124.6	1,438	208.5
24	75	546	79.2	913	132.4	1,523	220.9
26	79	585	84.9	968	140.5	1,612	233.8
28	82	627	90.9	1,026	148.8	1,705	247.3
30	86	670	97.2	1,086	157.5	1,801	261.2
32	90	715	103.7	1,148	166.6	1,901	275.7
34	93	762	110.5	1,213	175.9	2,004	290.7
36	97	811	117.6	1,280	185.6	2,112	306.3
38	100	862	125.0	1,349	195.7	2,223	322.4
40	104	915	132.8	1,421	206.1	2,338	339.1
42	108	971	140.8	1,495	216.9	2,457	356.4
44	111	1,028	149.1	1,572	228.0	2,581	374.3
46	115	1,088	157.7	1,651	239.5	2,709	392.8
48	118	1,149	166.7	1,733	251.4	2,840	412.0
50	122	1,214	176.0	1,817	263.6	2,977	431.8
52	126	1,280	185.7	1,905	276.3	3,118	452.2
54	129	1,349	195.7	1,995	289.3	3,263	473.2
56	133	1,421	206.1	2,087	302.7	3,413	495.0
58	136	1,495	216.8	2,183	316.6	3,567	517.4
60	140	1,571	227.9	2,281	330.8	3,726	540.4

7

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

(All figures are in gauge pressure)

CHAPTER 7

Temperature		R-32		R-290 (propane)		R-600a (isobutane)	
C	F	kPag	psig	kPag	psig	kPag	psig
-40	-40	80	11.6	12	1.7	-71	-10.3
-38	-36	96	13.9	21	3.1	-68	-9.9
-36	-33	114	16.5	32	4.6	-65	-9.4
-34	-29	133	19.2	43	6.3	-61	-8.8
-32	-26	153	22.2	55	8.0	-56	-8.2
-30	-22	174	25.3	68	9.9	-52	-7.6
-28	-18	197	28.6	81	11.8	-48	-6.9
-26	-15	222	32.2	96	13.9	-43	-6.2
-24	-11	248	36.0	111	16.1	-38	-5.5
-22	-8	276	40.0	127	18.5	-32	-4.7
-20	-4	305	44.2	144	20.9	-26	-3.8
-18	0	336	48.8	162	23.6	-20	-2.9
-16	3	369	53.6	182	26.3	-13	-1.9
-14	7	404	58.6	202	29.3	-6	-0.9
-12	10	441	64.0	223	32.3	2	0.2
-10	14	480	69.7	245	35.6	10	1.4
-8	18	522	75.7	269	39.0	18	2.7
-6	21	565	82.0	293	42.5	28	4.0
-4	25	611	88.6	319	46.3	37	5.4
-2	28	659	95.6	346	50.2	48	6.9
0	32	710	103.0	375	54.3	58	8.5

Temperature		R-32		R-290 (propane)		R-600a (isobutane)	
C	F	kPag	psig	kPag	psig	kPag	psig
2	36	763	110.7	404	58.7	70	10.1
4	39	819	118.8	436	63.2	82	11.9
6	43	878	127.3	468	67.9	95	13.7
8	46	940	136.3	502	72.8	108	15.7
10	50	1,004	145.6	538	78.0	122	17.7
12	54	1,072	155.4	575	83.3	137	19.9
14	57	1,142	165.7	613	88.9	153	22.2
16	61	1,216	176.3	653	94.8	169	24.5
18	64	1,293	187.5	695	100.8	186	27.0
20	68	1,373	199.2	739	107.1	204	29.6
22	72	1,457	211.3	784	113.7	223	32.4
24	75	1,544	224.0	831	120.5	243	35.2
26	79	1,635	237.2	879	127.5	264	38.2
28	82	1,730	250.9	930	134.9	285	41.3
30	86	1,829	265.2	982	142.5	308	44.6
32	90	1,931	280.1	1,036	150.3	331	48.0
34	93	2,038	295.5	1,093	158.5	355	51.6
36	97	2,148	311.6	1,151	166.9	381	55.3
38	100	2,263	328.2	1,211	175.6	407	59.1
40	104	2,382	345.4	1,273	184.7	435	63.1
42	108	2,505	363.3	1,337	194.0	464	67.3
44	111	2,633	381.9	1,404	203.6	494	71.6
46	115	2,765	401.0	1,472	213.5	524	76.1
48	118	2,902	420.9	1,543	223.8	557	80.7
50	122	3,044	441.4	1,616	234.3	590	85.6
52	126	3,190	462.7	1,691	245.2	624	90.6
54	129	3,341	484.6	1,768	256.4	660	95.8
56	133	3,498	507.3	1,848	268.0	697	101.1
58	136	3,659	530.7	1,930	279.9	736	106.7
60	140	3,826	554.9	2,014	292.1	775	112.5

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UN ENVIRONMENT

P.O. Box 30552 Nairobi, Kenya

Tel: ++254-(0)20-762 1234

Fax: ++ 254-(0)20-762 3927

E-mail: uneppub@unep.org

For more information, contact:
UN Environment, Economy Division
OzonAction

1 rue Miollis, Building VII,
75015, Paris, France

Tel: +331 4437 1450

Fax: +331 4437 1474

ozonaction@unep.org

www.unep.org/ozonaction

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