GOOD SERVICING PRACTICES FOR FLAMMABLE REFRIGERANTS

A QUICK GUIDE

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Acknowledgement

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The technical comments provided by GIZ-Proklima are also acknowledged.

Contents

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

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 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

Most of these alternatives have different properties compared to HCFC-based refrigerants, such as flammability, toxicity or higher working pressures. Compliance with safety standards is extremely important for RAC servicing technicians. RAC servicing technicians need to update knowledge about good service practices (GSPs) for handling these alternative refrigerants. GSPs have been recognised as the best approach towards reducing consumption of refrigerants and efficient operation of the serviced RAC equipment and 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 a quick reference to the safety classifications and 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 tonne of Refrigeration (TR) and designed to use flammable refrigerants like R-290, HFC-32, etc.

Please note that the instructions 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.

Figure 2: Residential Air-conditioner

2. COMMONLY USED REFRIGERANTS AND THEIR CHARACTERISTICS

2.1 Use of Refrigerants in RAC Equipment

Table below shows the most commonly used refrigerants in domestic refrigerators, stand-alone commercial refrigeration appliances/ equipment 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 Refrigeration appliances	HC-600a (R-600a) 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-22)	R-410A

2.2 Flammability Properties of Refrigerants

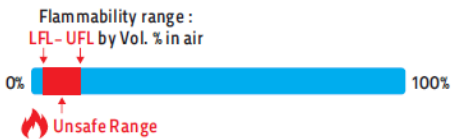


Figure 3: Flammability Range

1 GWP = Global warming potential
2 ODS = Ozone depleting substance
3 R-22 is being phased out under national regulation.

Lower Flammability Limit (LFL)

The minimum concentration of the refrigerant can ingite that if air and ingnition source is available in that area is capable of propagating a flame.

Upper Flammability Limit (UFL)

The minimum concentration of the refrigerant can ingite that if air and ingnition source is available in that area 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 refrigerant can be ignited or can catch fire in the range between LFL-UFL, one should avoid the concentration of flammable refrigerant in the working area or part of the area reaching the LFL and the temperature of refrigerant from reaching the auto-ignition temperature. The lower flammability limit is the minimum concentration of solvent vapor in oxidizing gas (air) that is capable of propagating a flame through a homogeneous mixture of the oxidizer and below the lower flammability limit, the mixture is too lean to burn or explode. The upper flammability limit is the maximum concentration of solvent vapor in an oxidizing gas (air) above which propagation of flame does not occur. Mixtures with solvent vapor concentrations above the upper flammability limit are too rich in a solvent or too lean in oxidizer to burn or explode the solvent vapor. Below the lower flammability limit, the mixture is too lean to burn or explode.

Table 2: Key flammable 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**	**635**	**728**	**704**

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**	**450**	**530**

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 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.

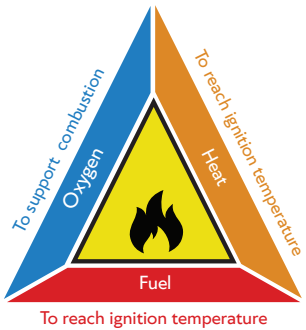


Figure 4: Fire triangle

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 classification category of the refrigerant:** For example, R-32 (category 2L) and R-290 (category 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."** The maximum allowable charge size calculated in this guide book is based on the formula specified in the ISO 5149-1:2014 standard.

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 quantity of refrigerant in the respective occupancy type and location in which the RAC equipment can be safely used. It is not the actual charge quantity of refrigerant in the system.

Table 4: Formula for calculation of charge limits

Refrigerant Category	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** $39 \times LFL$
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** $26 \times LFL$

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-290 is 0.038 kg/m³

LFL of R-32 is 0.307 kg/m³

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

$m_{max} = 2.5 \times LFL^{1.25} \times h_0 \times A^{0.5}$

$= 2.5 \times 0.307^{1.25} \times 1.8 \times 30^{0.5}$

$= 5.63$ kg

Check whether the calculated amount is more than 39 x LFL = 39 x 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.

$m_{max} = 2.5 \times LFL^{1.25} \times h_0 \times A^{0.5}$

$= 2.5 \times 0.038^{1.25} \times 1.8 \times 30^{0.5}$

$= 0.41$ kg

Check whether the calculated maximum allowable refrigerant quantity is less than the maximum limit 26 x LFL = 26 x 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 quantity.**

Table 5: Maximum allowable charge quantity 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 quantity of refrigerant charge in the AC system being installed/ serviced does not exceed the maximum allowable charge quantity.

Table 6: Maximum allowable charge quantity 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 quantity of refrigerant in the AC system being installed/ serviced should not exceed the maximum allowable charge quantity.

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 (m2)	A_{min} Window Mounted (m2)	A_{min} Wall Mounted (m2)	A_{min} Ceiling Mounted (m2)
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 GOOD SERVICING PRACTICES FOR FLAMMABLE REFRIGERANTS

WARNING
During servicing and repairing 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. The 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.**

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

Figure 5: Temporary flammable zone

4.2 Handling and Storage of Flammable Refrigerants

Handling and storage requirements for flammable refrigerant cylinders are similar to those used for other flammable gases. 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 required 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;
- ✓ Do not remove or destroy original stickers of the cylinder;
- ✓ Protect the cylinders from falling or being knocked over;
- ✓ Close the cylinder with a cap any time the cylinder is not used;
- ✓ Do not repair or modify the cylinder/cylinder valve or the cylinders' connections;
- ✓ The cylinders should be kept vertical. Never place cylinders lying on their side;
- ✓ Never roll the cylinder across the ground;
- ✓ Always carry a dry powder fire extinguisher during transportation of cylinder;
- ✓ Have access to emergency services e.g. fire, police etc;
- ✓ Alarm to be fitted in the room for flammable gas.

4.3 Servicing Tools and Equipment for Flammable Refrigerant

General Requirements

- ✓ Electrical and electronic tools used on systems containing flammable refrigerants especially hydrocarbon 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 create vacuums to the desired level.**
- **Using the refrigeration system's compressor for vacuuming may lead to compressor failure.**

The vacuum pump should be placed in a position so that any leaked flammable refrigerant, especially the hydrocarbons should not reach to the any likely ignition source when it is switched on/off. Before operating vacuum pump check for wear and tear or damage of electrical wires and plugs.

Figure 8: Compressors must not be used for vacuuming

Vacuum Gauge

A vacuum gauge capable of reading pressure in the range of 5-5,000 micron 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

Charging of flammable refrigerants into the system should be done very carefully and accurately. Very accurate weighing scales for RAC servicing are required for charging flammable refrigerants especially hydrocarbon refrigerants as the required charge quantity of these refrigerants are low.

Electronic scales should be used only in an area where flammable refrigerants can be handled and as confirmed by the manufacturer.

Figure 9: Refrigerant Charging Equipment

Refrigerant Recovery Machine

There are recovery machines available in the market 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.

@ cm-green

Figure 10: Recovery machine for hydrocarbon refrigerants

Manifold/Gauge/Hose Set

The tools 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 flammable hydrocarbon refrigerants.

Personal Protective Equipment (PPE)

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

Figure 11: Safety goggles and hand gloves

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, weight, owner and other data deemed useful.

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

Figure 12: Recovery cylinder (left) and disposable cylinders (right)

Safe cylinder refrigerant capacity

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

- Maximum allowable gross cylinder weight= (0.8xWCxSG) + TW
  Where : WC - water capacity; SG-specific gravity of the specific refrigerant recovered at 250C; TW – tare weight of the recovery cylinder
- Never expose a cylinder to direct sunlight or other sources of heat, this can lead to an explosion.

Leak Detector

When servicing RAC equipment charged with hydrocarbon refrigerants, the service technician should have a special leak detector designed for combustible gases . 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 there are no ignition sources 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;
- ✓ Do not release any flammable refrigerant inside / in the work area it must be released only in safe outside space;
- ✓ 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;
- ✓ Place a warning signboard in front of work area and at the end of the refrigerant vent-line;
- ✓ Switch off cell phones during servicing. Don't smoke during servicing work.

4.5 Good Servicing Practice Procedures

Always comply with the equipment manufacturer's user manual for the specific system and EN 378-4-2016. The following procedure should be followed before working on the refrigerant circuit:

- ✓ remove refrigerant using vacuum pump (up to the system 2 psig or 0.14 bar pressure) purge the sysyem circuit with inert gas (e.g. nitrogen);
- ✓ evacuate to a pressure of 30 kPa absolute (or 0.03 MPa);
- ✓ purge again with inert gas (e.g. nitrogen);
- ✓ open the refrigerant circuit;
- ✓ Do not keep the system open for a long time, plug the open end of system tube (s) with a cap.

Ensure that all good service practice tools are readily available. Good RAC equipment servicing practices using flammable refrigerants should follow the following procedures.

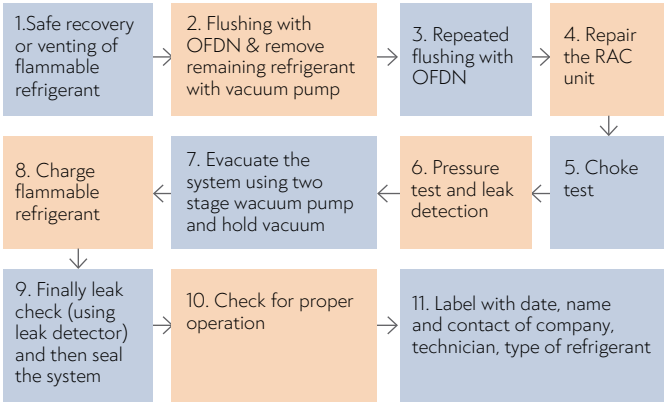


Figure 14: Good Service practice

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.

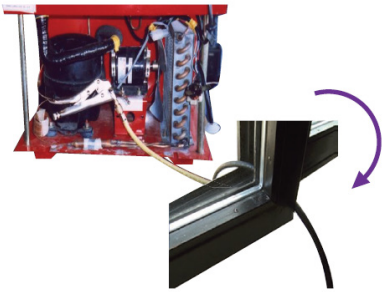
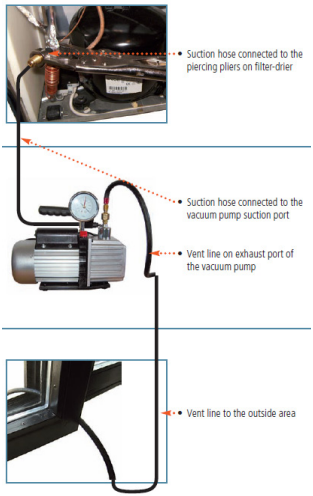


Figure 15: Open window or door for ventilation

2. Remove remaining refrigerant with vacuum pump

Ensure that most of the refrigerant has been removed before opening the system
Remove the remaining 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
Flush the system with OFDN to inertize



3. Clean and flush

Debraze the old filter from RAC system only after flushing the system with OFDN.

Use dry nitrogen with a two stage regulator, at a pressure of about 5 bars
Use hexane / methylene dichloride (MDC) or other environmentally approved flushing solution where chemical cleaning is needed
Do not use refrigerant/ 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/Replace with 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 and system is flushed with OFDN while brazing.

Figure 16: Brazing

5. Choke test

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

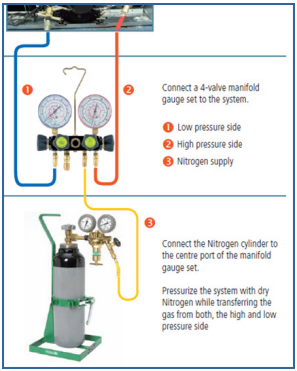
Use OFDN cylinder with a two-stage regulator

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.

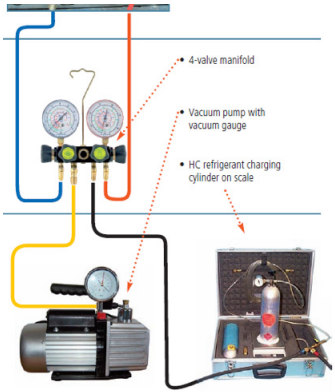
Test pressure to be regulated at system working pressure (10 bar to 20 bar) or as specified by the manufacturer and close the cylinder after test pressure is reached



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 (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 at least 5 minutes to maximum 20 minutes. There should not be sharp rise in the micron gauge reading.
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
- Always use electronic weighing scales with an adequate weighing resolution of the scale for accurate charge quantity.
- In case of hydrocarbons use electronic weighing scale with a resolution 1.0 g for R-600a and 2.0 g for propane.

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 table 6, page 21.

9. Sealing operation

For sealing the refrigerant line (tube) of hydrocarbon, servicing technician is strongly advised not to braze the tube, but use 'Lock ring' 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

Figure 20: Lokring

10. Check for proper operation

Check and document the following:

- Records of last service
- Check temperature of supply and return air in case of air conditioner
- Check pull down time
- Check compressor current

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 AND SERVICE AIR-CONDITIONER ONCE PER YEAR.

INSTALLATION / SERVICE DATE	:	
REFRIGERANT TYPE	:	
FLAMMABILITY	:	
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

5. DOES AND DONT'S CHECKLIST

Does	Work in a naturally well-ventilated area, outdoors or use a 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.
	Always have a dry powder fire extinguisher.
Dont's	Do not smoke, drink or eat while in the work area.
	Do not store cylinders 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 or direct sun.
	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. 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

Temperature		R-134a		R-22		R-410A	
-2	28	172	25.0	366	53.2	652	94.5
0	32	193	28.0	398	57.7	702	101.8
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

Temperature		R-134a		R-22		R-410A	
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)

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

Temperature		R-32		R-290 (propane)		R-600a (isobutane)	
-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
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

Temperature		R-32		R-290 (propane)		R-600a (isobutane)	
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

References

1. The Australian Institute of Refrigeration, Air-Conditioning and Heating (AIRAH), Flammable Refrigerants-Safety Guide, ISBN: 978-0-949436-05-4, 2013 (available 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 Definitions, 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%20Air-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-en-good-practices-in-refrigeration.pdf)
6. Department of Environment Malaysia, Training Manual For Refrigeration & Air-conditioning Servicing Sectors (RACS), First Edition, 2014.

For more information, contact:
UN Environment, OzonAction
1 rue Miollis, Building VII, 75015,
Paris, France

Ozone Cell
Ministry of Environment, Forest
and Climate Change
Government of India
Core 4B, 2nd Floor,
India Habitat Centre
Lodhi Road, New Delhi – 110 003
Tel. : +91-11-2464 2176
Fax: +91-11-24642175
Email: ozone-mef@nic.in ,
pmucfc-mef@nic.in
Website: http://ozonecell.in