Techniques and Regulations for the Safe Handling of Flammable Hydrocarbon and Hydrofluoroolefin Refrigerants

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These standards and codes of practice are current at the time of publishing. You should check to ensure they are still current.

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Preface

The information in this course is intended for educational purposes only. Procedures described in this manual are for use only by qualified air conditioning and refrigeration service technicians who already hold EPA Section 608 Type II, Type III, or Universal Certification. **This training course is not a substitute for the operator manual of any equipment manufacturer.**

Safety Precautions

Take safety precautions when using all HVAC equipment. Improper use of HVAC equipment can cause explosion and serious personal injury.

Always read the entire manufacturer's operator manual before turning on any equipment for the first time. **Never turn on any equipment if you do not understand its operation. Where procedures described in this manual differ from those of a specific equipment manufacturer, you should follow the equipment manufacturer's instructions.**

Use caution when working with hydrocarbon refrigerants; hoses could contain liquid flammable refrigerant under pressure. Use only approved refillable storage cylinders. Do not overfill any storage cylinder beyond its rated capacity.

Always wear safety glasses. Protect the skin from flash freezing.

Do not leave any refrigerant recovery or recovery–recycling machine on and unsupervised. For flammable refrigerants, never use any equipment that is not rated to handle flammable refrigerants. All refrigerant recovery and recycling devices are to be used by trained refrigeration technicians only. Misuse of refrigerant recovery and recycling devices can cause explosion and personal injury.

EPA Regulations

Technical and legislative information presented in this book is current as of the date of the manual's latest publication. Because of rapidly advancing technology and changing regulations in the hydrocarbon refrigerant area, no representation can be made for the future accuracy of the information. Visit the EPA's Internet home page at http://www.epa.gov for the latest details.

Liability

Mainstream Engineering Corporation assumes no liability for the use of information presented in this publication. This information is presented for educational purposes only.

Manufacturer’s operator manuals must be consulted for the proper operation of any piece of equipment.

The content of this course is limited to information and service practices needed to contain, conserve, and re-use flammable refrigerants, and to prevent their escape into the atmosphere.

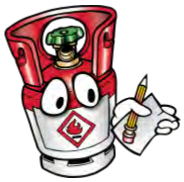
This manual is not intended to teach air conditioning–refrigeration system installation, safety, troubleshooting, or repair. Refrigeration technicians should already be well versed in these areas before taking this course.

Document Conventions

The following helpful information appears throughout this document:

Caution

Cautions indicate the possibility of bodily harm or damage to your equipment.



Note

Notes contain related information.

Tip

Tips are designed to provide hints or shortcuts.

Example

Examples provide practical applications of a concept.

Chapter 1. What Are Hydrocarbon Refrigerants?

A hydrocarbon is an organic compound consisting only of carbon and hydrogen atoms. A halocarbon is any compound derived from a hydrocarbon by replacing at least one hydrogen atom with a halogen. For halocarbon hydrofluorocarbon (HFC) refrigerants, some of the hydrogen atoms are replaced with fluorine atoms.

Although the fluorine atoms reduce the flammability of the refrigerants, the fluorine is harmful to the environment. The hydrocarbon refrigerants are therefore flammable (because the hydrogen atom has not been replaced with a halogen such as fluorine).

Hydrocarbon (HC) refrigerants are classified as American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) safety group A3, meaning they have low toxicity and are highly flammable.

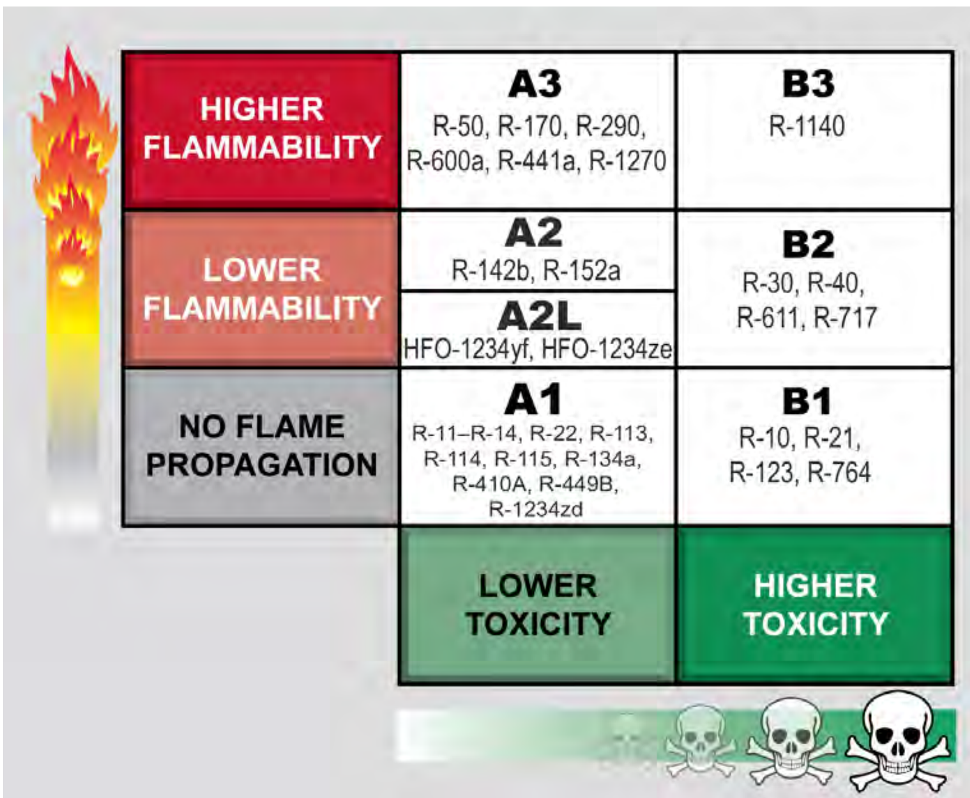


Figure 1. Refrigerant safety group classification

Physical Properties of Hydrocarbons

Hydrocarbon refrigerants are components of oil and natural gas that are found in nature. Although hydrocarbon refrigerants have excellent environmental, thermodynamic, and thermo-physical properties, these refrigerants are highly flammable. Table 1 summarizes the physical properties of hydrocarbons [ACRIB, 2001].

Table 1. Physical Properties of HC Refrigerants

ASHRAE Number	Chemical Name	Molecular Formula	Normal Boiling Point or Bubble/Dew Points (°F) at 1atm	Critical Temperature (°F)	Critical Pressure (psig)
R-600a	Isobutane	C_4H_{10}	10.9	274.4	513.2
R-601a	Isopentane	C_5H_{12}	81.9	370.0	475.5
R-290	Propane	C_3H_8	–43.7	206.1	601.7
CARE 30	Propane/ Isobutane blend		–25.1/ –11.0	221.9	478.4
R-50	Methane	CH_4	–263.2	–116.1	658.3
R-170	Ethane	C_2H_6	–127.8	90.0	684.5
R-441a	Ethane/ Propane/ Isobutane blend	3.1 ± 0.3% C_2H_6 54.8 ± 2% C_3H_8 42.1 ± 2.6% C_4H_{10}	–43.4/ –4.7	243.1	
R-1150	Ethylene	C_2H_4	–154.8	48.56	716.6
R-1270	Propylene	C_3H_6	–53.7	196.0	646.0

HC Refrigerant Types

R-600a (Isobutane)

Isobutane, also called 2-methylpropane, has four carbon atoms, the chemical formula C_4H_{10}, and a branched structure. Isobutane is often written as $CH(CH_3)_2$-CH_3 to distinguish it from butane, which is a straight-chain hydrocarbon with the same chemical formula.

The Chemical Abstracts Service (CAS) registry number for isobutane is 75-28-5. As a refrigerant, isobutane is designated as R-600a by the ASHRAE Standard 34-2010 “Designation and Safety Classification of Refrigerants” [ASHRAE, 2010]. Isobutane is also referred to as HC-600a and iso-C_4H_{10}.

Refrigerant R-600a, which was used in residential refrigerators up to the 1940s, has again found acceptance in domestic refrigerators and freezers in Europe where most of today's refrigerators using R-600a refrigerant are manufactured. Isobutane R-600a is a well-suited refrigerant for household applications with good energy efficiency, but this refrigerant has very different characteristics when compared to R-134a, which means it is not a drop-in replacement for R-134a, especially because R-600a is flammable.

One significant difference between R-600a and R-134a is the normal operating pressure, which is much lower for R-600a. For example, as shown in Table 2, R-600a at 20 °F is barely above atmospheric pressure. In addition, R-600a has roughly half the volumetric capacity of R-134a, which means the swept volume of the compressor must be about twice as large to move the same mass of refrigerant. However, the volumetric cooling capacity, which is a value calculated from suction gas density and latent heat of evaporation at the suction gas pressure, is only slightly lower, so less refrigerant mass flow is required.

Table 2. Saturated Pressure–Temperature Relationship for Common HC Refrigerants

Temperature	Pressure (psig)					
(°F)	HC-600a	HC-601a	HC-290	HC-441a	HC-1150	HC-1270
0.0	6.4*	25.5*	23.7	204.5	373.42	33.194
5.0	3.6	24.8	27.6	221.7	401.45	37.951
10.0	0.5	24.1	31.8	239.7	430.94	43.055
15.0	1.4	23.2	36.3	258.8	461.96	48.52
20.0	3.2	22.3	41.1	278.9	494.56	54.362
25.0	5.1	21.3	46.3	300.0	528.84	60.597
30.0	7.2	20.2	51.8	322.3	564.88	67.241
35.0	9.4	18.9	57.7	345.6	602.79	74.309
40.0	11.9	17.6	63.9	370.2	642.72	81.819
45.0	14.5	16.1	70.6	395.9	684.89	89.787
50.0	17.3	14.5	77.6	422.9		98.229
55.0	20.3	12.7	85.1	451.2		107.16
60.0	23.5	10.7	93.0	480.9		116.61
65.0	27.0	8.6	101.4	512.1		126.57
70.0	30.6	6.3	110.2	544.7		137.09
75.0	34.5	3.9	119.5	578.9		148.16
80.0	38.7	1.2	129.3	614.8		159.81
85.0	43.1	0.8	139.7	652.7		172.06
90.0	47.8	2.4	150.5			184.93
95.0	52.7	4.0	161.9			198.43
100.0	57.9	5.8	173.9			212.59
105.0	63.5	7.7	186.5			227.42
110.0	69.3	9.7	199.6			242.95
115.0	75.5	11.8	213.4			259.19
120.0	82.0	14.1	227.9			276.18
125.0	88.8	16.6	242.9			293.92
130.0	95.9	19.2	258.7			312.46

* Red indicates inches of Mercury

R-290 (Propane)

Propane has three carbon atoms, the chemical formula C_3H_8, and the CAS Number 74-98-6. As a refrigerant, propane has ASHRAE designation R-290. Propane is also referred to as HC-290 and $CH_3CH_2CH_3$.

Refrigerant R-290 was used in refrigeration plants in the past and is still used in industrial plants in Europe. For residential heat pumps and air conditioners, R-290 has been used in Germany and Sweden for some time.

The pressure difference between R-290 and R-22 or R-404A is very little. Evaporator and condenser designs are similar to R-22 or R-404A, but special care has to be taken because of the flammability of these HC refrigerants.

Using pure R-290 as a substitute for R-22 results in approximately a 7–10% lower cooling capacity. The larger 10% capacity decrease is associated with higher operating conditions. However, the coefficient of performance for cooling (COPc) is approximately 2–8% higher when using R-290 to replace R-22. In this case, the higher 8% COPc occurs at the lower operating temperatures.

In addition, the compressor discharge pressure when using R-290 is about 14–18% lower than the R-22 discharge pressure. Using R-290 instead of R-22 also results in approximately 12–14% lower power consumption and lower pressure drops in the heat exchanger coils.

If R-290 were charged into an unchanged refrigeration system that was designed for R-22, the charge in terms of mass (weight) would be much lower, but the charge in terms of volume would be about the same. Because liquid volume in the evaporator and condenser determine optimum charge (not the mass of refrigerant), the R-290 charge would be about 40% of the charge by mass of an R-22 system. The charge size limitation for flammable refrigerants is 57 g (0.13 lb) for household refrigerators and 150 g (0.35 lb) for retail food refrigeration, which equates to a R-22 charge of about 0.31 pounds for household refrigerators and 0.83 pounds for retail food refrigerators.

R-441a

R-441a, also known as HCR188C, was the first hydrocarbon refrigerant to be approved for sale in the United States by the Environmental Protection Agency (EPA). This refrigerant is a blend of four hydrocarbons and has ASHRAE certification as being non-toxic. R441a was designed to replace R-134.

The blend is composed of ethane (3.1% by mass), propane (54.8% by mass), isobutane (6.0% by mass), and butane (36.1% by mass). R441a is a very high pressure refrigerant; for example, at 80 °F, the saturation pressure is 614.8 psig (Table 2), which is 2.6 times the 235.8 psig saturation pressure of R-410A.

R-1270

R-1270 is also referred to as refrigerant-grade propylene or propene and is being used as a replacement for R-22 and R-502 in new systems. R-1270 should not be used to retrofit any existing system. The capacity of R-1270 is similar to that of R-22 under all operating temperature conditions.

Other HC Blends

Another alternative refrigerant to R-22 is an HC blend of 20% by weight R-290 and 80% by weight of R-1270 instead of pure R-290.

An HC blend of 50% (by weight) of R-290 and 50% of R-600a has been used to replace R-134a in refrigeration applications. For this replacement, energy consumption drops by approximately 5% and the refrigerant charge is reduced by 35–40%.

Materials Compatibility

Lubricants

Hydrocarbon refrigerants are chemically compatible with most of the common lubricants used in refrigeration systems. Good miscibility is maintained with most lubricants under all operating conditions. HC refrigerants have good solubility with mineral oils, so you might have to use a non-mineral oil lubricant with lower solubility. If you use a mineral oil lubricant, increase the viscosity to compensate for the oil thinning because the high-solubility HC refrigerant lowers the viscosity of mineral oil. If unsure, consult your lubricant supplier for the properties of the specific oil–refrigerant combination.

Caution

Never use lubricants containing silicone or silicate, which are often used as anti-foaming additives, because these lubricants are not compatible with HC refrigerants.

Never use any leak-sealing or moisture-drying compounds with HC refrigerants because these compounds all contain silicates.

Table 3 describes the compatibility of HC refrigerants and lubricants [Air Conditioning and Refrigeration Industry Board, 2001].

Caution

If you are changing or selecting a lubricant for a hydrocarbon refrigerant application, always consult the compressor manufacturer for recommendations.

Table 3. HC Refrigerant Compatibility with Lubricants

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

Desiccants

Desiccants are used in filter dryers. Most of the commonly used desiccants are compatible with HC refrigerants. Acceptable types are XH-5, XH-6, or the equivalent. You can use molecular sieve desiccant types such as XH5, XH6, XH7, and XH9, and the universal filter drier MS 594.

Materials

Almost all common elastomer and plastic refrigeration materials that are used as O rings, valve seats, seals, and gaskets are compatible with HC refrigerants. These include neoprene, Viton™, nitrile rubber, hydrogenated nitrile butadiene rubber (HNBR), polytetrafluoroethylene (PTFE aka Teflon™), and nylon. Ethylene propylene diene terpolymer (EPDM), natural rubbers, or silicone rubbers are not compatible.

Caution

Do not use EPDM, natural rubbers, and silicone rubbers in HC refrigerant systems. These materials are not compatible.

Tip

Although a number of materials have been tested with hydrocarbons, many different grades are available in the market. Always check compatibility with the manufacturer or supplier of the component.

An EPA SNAP (Significant New Alternatives Policy) rule allows the use of isobutane and propane with charge limit restrictions (up to 57 g for household refrigerators and up to 150 g for commercial refrigerators). Underwriters Laboratory (UL) has approved the use of propane in window air-conditioning applications with charge limits.

The EPA SNAP ruling published in December 2016 allows the following:

- Use of R-600a (isobutane) and R-441A in retail food refrigeration
- Use of R-170 (ethane) in very low temperature refrigeration and non-mechanical heat transfer
- Use of R-290 (propane) in household refrigerators
- Use of R-290, R-600a, and R-441A in vending machine
- Use of HFC-32, R-290, and R-441A in self-contained room air conditioners, packaged terminal air conditioners, packaged terminal heat pumps, windows AC units, and portable AC units designed for use in a single room

Chapter 2. What Are Hydrofluoroolefin Refrigerants?

Hydrofluoroolefins (HFO) refrigerants are unsaturated hydrofluorocarbons (HFCs) that are heavily promoted as the next generation of refrigerants because of their environmental friendliness, although they are not as green as the HC refrigerants. They are less flammable, but they are still flammable.

Refrigerant manufacturers have developed numerous HFO blends tailored to specific applications. HFO-1234yf, HFO-1234ze, and HFO-1234zd are furthest along in development. They are all classified as A2L, meaning they are "slightly" flammable (L for low) as opposed to HC refrigerants, which are flammable. (See Figure 1 on page 1 for a diagram of the refrigerant safety classifications.)

The performance of HFO-1234yf closely matches that of HFC-134a. HFO-1234yf is being adopted for motor vehicle air conditioning (MVAC) systems. HFO-1234yf has potential for chillers and commercial refrigeration applications that currently use HFC-134a.

HFO-1234ze has a lower volumetric capacity than HFO-1234yf and could potentially be used for centrifugal compressors. HFO-1234ze is easier to manufacture than HFO-1234yf and less costly, which makes it attractive for large chillers that require high quantities of refrigerant. HFO-1234ze has been approved for use with centrifugal, reciprocating, and screw chillers. R-1234yf is a replacement for R-134a, and R-1234ze is a replacement for air conditioning applications.

Major refrigerant manufacturers are developing HFO blends suitable for applications that would traditionally use HCFC-22, HFC-404A, and HFC-410A. However, HFO-1234yf is not a viable alternative for these refrigerants because of its significantly lower volumetric capacity.

The HFO blends under development are designed to offer higher capacities with tradeoffs in either GWP or flammability. The GWP values of these blends range from less than 150 to around 600, which are still significantly lower than the GWP values of the HFCs they would replace but are significantly higher than the HC refrigerants. Therefore, these HFO blends are being proposed for use to replace HFC refrigerants, but they are flammable, and this could impede acceptance. HFOs have no chlorine, and they have zero ozone depletion potential (ODP).

HFC refrigerants, such as R-134a, R-125, R-1434a, and R-152a, and HFC blends, such as R-407A, R-407B, R-410A, and R-5078, are all composed of hydrogen, fluorine, and carbon connected by *single bonds*. Although HFOs are also composed of hydrogen, fluorine, and carbon, they contain at least one *double bond* between the carbon atoms.

Because HFO refrigerants like the HFC refrigerants contain fluorine atoms, these fluorine atoms reduce the flammability, which is the reason the HFO refrigerants are classified as slightly flammable and HC refrigerants (which by definition never contain fluorine) are flammable. Table 4 summarizes the physical properties of HFOs.

Table 4. Physical Properties of HFO Refrigerants

ASHRAE Number	ASHRAE Classification	Molecular Formula	Normal Boiling Point or Bubble/Dew Points (°F) at 1atm	Critical Temp (°F)	Critical Pressure (psig)
R-1234yf	A2L	$CF_3CF = CH_2$	–14.8	215.6	602.7
R-1234zd	A1		65.0	330.1	518.2
R-1234ze(E)	A2L	$CF_3CH = CHF$	–2.1	229.0	534.5
R-1336mzz(Z)	A1	$CF_3CH=CHCF_3$(Z)	59.2	309.2	531.2

Refrigerant manufacturers are also developing several additional HFO-based A2L refrigerant options to substitute for HFC-134a, HCFC-22, and HFC-404A. These developmental refrigerants have GWP values ranging from 150 to 500.

Cost is a major concern with HFOs and HFO blends. Although actual costs under the conditions of full-scale production are unknown, current HFO-based refrigerants will almost certainly have a higher cost than the refrigerants they would replace. Additionally, with HFO systems, the efficiency tends to decrease as the GWP of the refrigerant decreases. Therefore, implementing HFOs as a replacement for HFCs requires a tradeoff between GWP and system efficiency. As a rule of thumb, the efficiency of HC refrigerants typically outperforms the efficiency of HFO refrigerants.

HFO Refrigerant Types

R-1234yf

R-1234yf, which is also referred to as HFO-1234yf, has a chemical name of 2,3,3,3-tetrafluoropropene and is an HFO with the formula $CF_3CF=CH_2$. EPA has listed R-1234yf for automobile air conditioners, and R-1234yf is being used as a replacement for R-134a as a refrigerant [EPA, 2015]. R1234yf should not be used to retrofit any existing system, including existing R-134a systems.

The new refrigerant is patented and manufactured in a joint venture between Honeywell and DuPont. Other manufacturers have also been licensed to produce the refrigerant. Honeywell markets the new refrigerant under the trademark Solstice® YF [Honeywell, 2017]. DuPont and European manufacturer Chemours are selling R1234yf under the trademark Opteon™ YF [Chemours, 2017]. Figure 2 shows a photo of an R-1234yf refrigerant cylinder.

Figure 2. R-1234yf refrigerant cylinder

R-1234zd

R-1234zd, also referred to as HFO-1234zd, is another a fluorinated gas from the HFO family with a low GWP and low pressure. This refrigerant is suitable for new industrial air conditioning applications and the cooling of buildings where cooling water or intermediate fluids are used in large systems with centrifugal compressors (one or more stages) and where R-123 might have been used in the past. Linde and Honeywell market this refrigerant as Solstice® ZD and as a replacement for R-123 in new chiller applications [Honeywell, 2017].

However, compressors using this new refrigerant would require larger impeller diameters for the same cooling capacity because of the substantially lower volumetric cooling capacity and the higher required compression ratio.

R-1234ze

R-1234ze, also referred to as HFO-1234ze, has a chemical name of trans-1,3,3,3-tetrafluoroprop-1-ene and is an HFO with the formula $CF_3CH{=}CHF$.

R-1234ze has two isomers, R-1234ze(Z) and R-1234ze(E) with different properties. R-1234ze(Z) has a higher boiling point (50.0 °F) associated with a higher critical temperature (308.7 °F) and a volumetric capacity roughly 50% lower than R-1234ze(E).

R-1234ze(E) is the isomer that is typically sold for use and is marketed as Solstice ZE. Because there is currently no HVAC/R application for R-1234ze(Z), the R-1234ze that is typically sold is the (E) isomer. Currently, R-1234ze(E) is being used as a replacement for R-22.

Caution

Do not use R-1234ze to retrofit any existing system including existing R-22 systems.

Like R-1234yf, R-1234ze(E) is patented and manufactured in a joint venture between Honeywell and DuPont. Other manufacturers have also been licensed to produce the refrigerant. Linde and Honeywell market this refrigerant as Solstice ZE. R-1234ze(E) is also proposed as a replacement for R-410A.

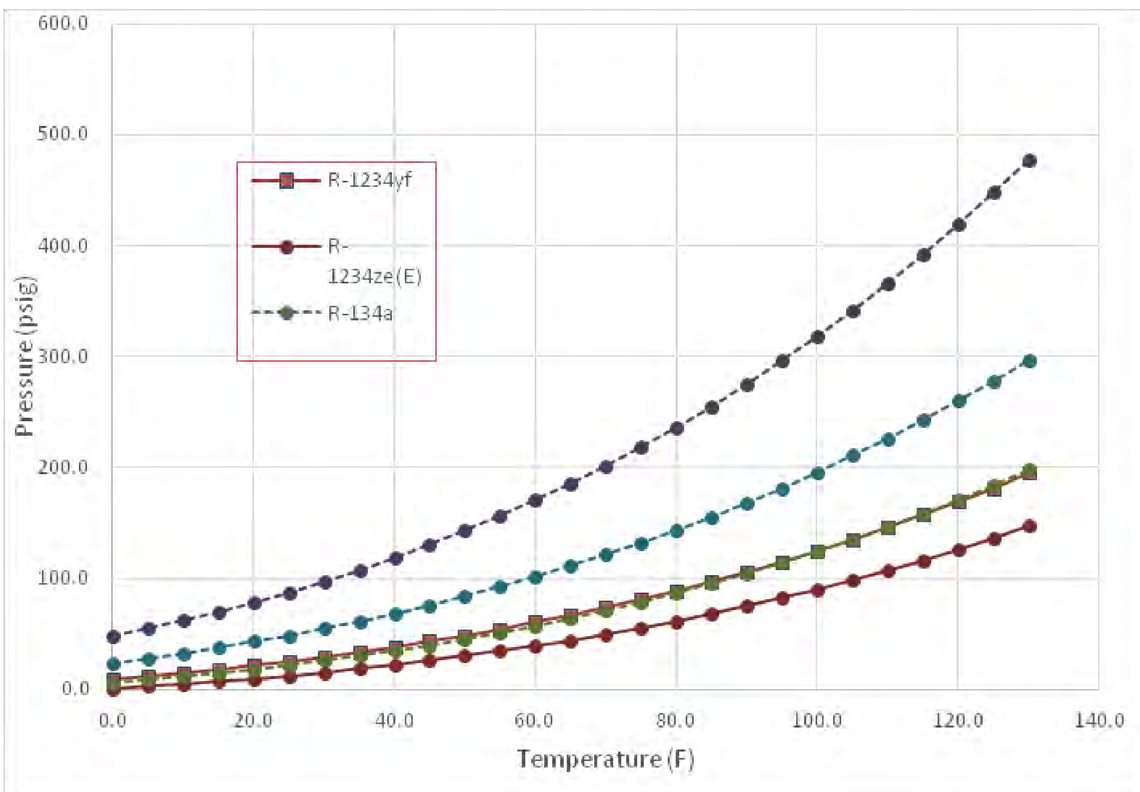


Figure 3. Saturation pressure–temperature plots for R-1234yf and R-1234ze(E) compared to common HFC refrigerants

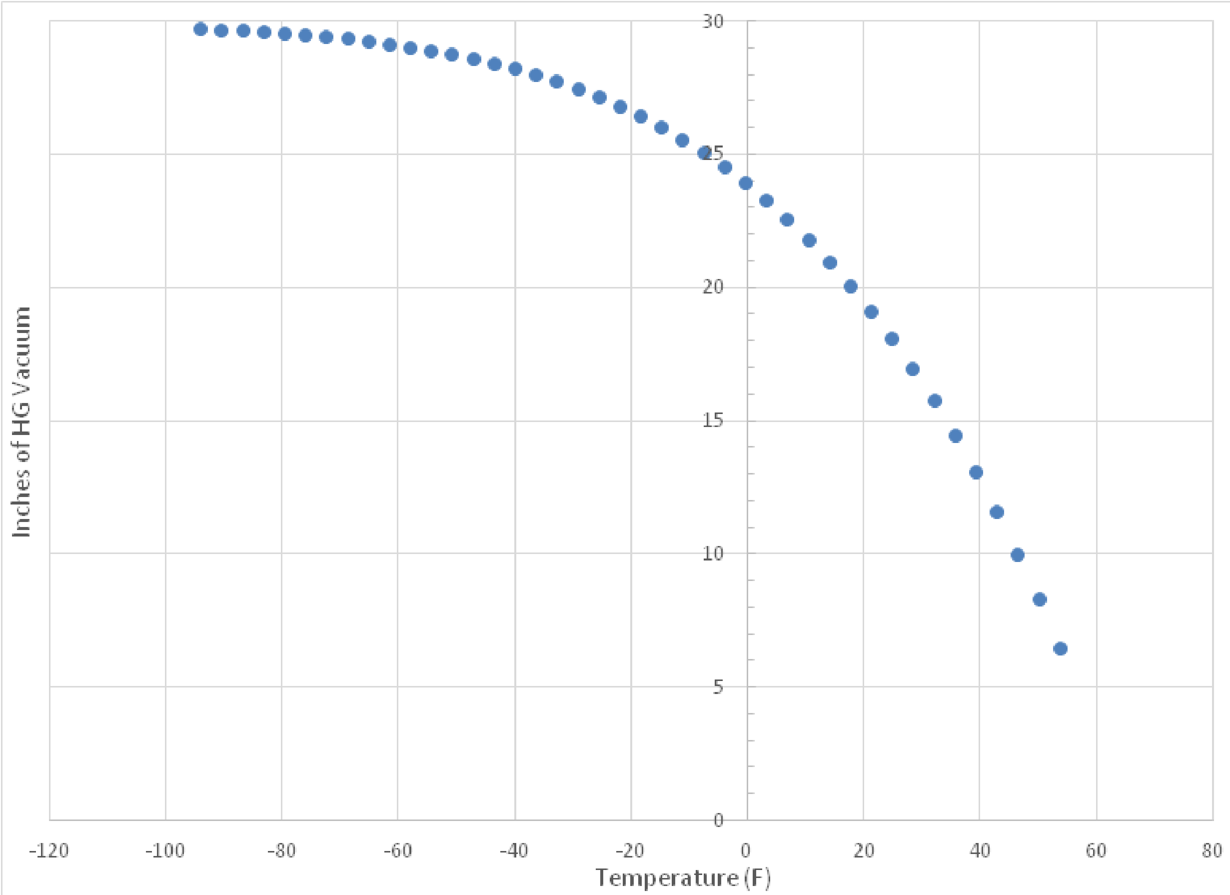


Figure 4. Saturation pressure–temperature plot for R-1234zd

Table 5. Saturation Pressure–Temperature Relationship of R-1234yf and R-1234ze Refrigerants

Temperature	Pressure (psig)	
(°F)	R-1234yf	R-1234ze(E)
0.0	9.2	0.9
5.0	12.0	2.8
10.0	14.9	4.9
15.0	18.2	7.2
20.0	21.6	9.8
25.0	25.5	12.5
30.0	29.4	15.5
35.0	33.8	18.8
40.0	38.4	22.3

Temperature (°F)	Pressure (psig)	
	R-1234yf	R-1234ze(E)
45.0	43.5	26.2
50.0	48.8	30.1
55.0	54.5	34.7
60.0	60.6	39.3
65.0	67.1	44.4
70.0	74.0	49.8
75.0	81.3	55.6
80.0	89.0	61.8
85.0	97.3	68.1
90.0	106.0	75.2
95.0	115.2	82.5
100.0	124.9	90.5
105.0	135.1	98.7
110.0	146.0	107.5
115.0	157.3	116.7
120.0	169.2	126.5
125.0	181.8	136.9
130.0	195.0	147.7

Table 6. Saturation Pressure-Temperature Relationship of R-1234zd Refrigerant

Temperature (°F)	Vacuum in-Hg
–94.0	29.7
–90.4	29.7
–86.8	29.7
–83.2	29.6
–79.6	29.6
–76.0	29.5
–72.4	29.4
–68.8	29.4
–65.2	29.3
–61.6	29.2
–58.0	29.0
–54.4	28.9
–50.8	28.8
–47.2	28.6

Temperature (°F)	Vacuum in-Hg
–43.6	28.4
–40.0	28.2
–36.4	28.0
–32.8	27.8
–29.2	27.5
–25.6	27.2
–22.0	26.8
–18.4	26.5
–14.8	26.0
–11.2	25.6
–7.6	25.1
–4.0	24.5
–0.4	23.9
3.2	23.3
6.8	22.6
10.4	21.8
14.0	21.0
17.6	20.1
21.2	19.1
24.8	18.1
28.4	17.0
32.0	15.8
35.6	14.5
39.2	13.1
42.8	11.6
46.4	10.0
50.0	8.3
53.6	6.5

R-449B

R-449B is an HFO/HFC blend classified by ASHRAE as a non-flammable, non-ozone-depleting class A1 refrigerant with a global warming potential (GWP) of 1296. Arkema, Inc. manufactures this new refrigerant as Forane® 449B [Arkema, 2016]. EPA’s approval allows R-449B refrigerant to be installed in new and retrofit R-22 and R-404A commercial refrigeration supermarket systems, remote condensing units, low-temperature standalone equipment, refrigerated food processing and dispensing equipment, commercial ice machines, and refrigerated transport.

Materials Compatibility

Lubricants

HFOs are miscible (soluble) in POE (polyolester) oils but are not miscible (not soluble) in mineral or AB (alkyl benzene) oils. Therefore, mineral and AB oils cannot be used with HFO refrigerants.

POE oil is recommended for using R-1234yf, R-1234ze, and R-1234zd. However, because of the higher miscibility of the R-1234 refrigerants with oils, a higher viscosity lubricant is probably required. Use the lubricants recommended by compressor manufacturers to avoid potential problems with lowered viscosity of the refrigerant–lubricant mixture.

Desiccants

Desiccants are used in filter dryers. Most of the commonly used desiccants are compatible with HFO refrigerants. Acceptable types are XH-5, XH-6, or the equivalent.

Materials

In general, fluorocarbon and silicone elastomers exhibit significant swelling in the presence of HFO refrigerants. EPDM and neoprene show signs of one or more components of the elastomer being separated from the material formulation as a result of interaction with the HFO refrigerants as well as a reduction in the volume of these elastomers, which is the consequence of this separation. Clearly, you should only use materials specifically approved for use with HFO refrigerants.

However, interactions between refrigerants containing R-1234ze(E) and ester-based materials are worse than interactions between R-1234yf and ester-based materials.

Caution

Do not use EPDM, neoprene, fluorocarbon, or silicone rubbers in HFO refrigerant systems. These materials are not compatible.

Example

Material compatibility with R-1234yf does not assure compatibility with R-1234ze or R-1234ze(E).

Tip

Always check compatibility with the manufacturer or supplier of the component.

Chapter 3. Environmental Comparison of HC, HFO, and HFC Refrigerants

Both hydrocarbon (HC) and hydrofluoroolefin (HFO) refrigerants have zero ozone depletion potential (ODP) and lower global warming potential (GWP) compared to hydrofluorocarbon (HFC) refrigerants. The HC refrigerants have GWPs that are lower than the HFOs and are less expensive, but they are more flammable.

According to EPA studies, the overall environmental risk posed by HC refrigerants is lower than or comparable to the environmental risk posed by other substitutes. Although the HC refrigerants are volatile organic compounds (VOCs), when used properly according to EPA guidelines, the emissions would not significantly affect local air quality. The environmental risks associated with ODP, GWP, and VOC effects for the three hydrocarbons isobutane, propane, and R-441A, and the three HFOs R-1234yf, R-1234ze, and R-1234zd are lower than or comparable to other acceptable substitutes.

The overall climate impacts from the use of these refrigerants also depend on the energy use by the appliances in which they are used because the indirect climate impacts associated with electricity consumption usually exceed the impact from the refrigerants themselves over the full life cycle of refrigerant-containing products [ORNL, 1997]. When a hydrocarbon or HFO appliance is more energy efficient than the appliance it replaces, greenhouse gas emissions are reduced beyond those attributable to the substitute refrigerant alone. Conversely, the greenhouse gas benefits of a substitute refrigerant in a replacement hydrocarbon appliance would be offset if that appliance had lower energy efficiency than the appliance it replaced.

EPA did not find any detailed life-cycle analysis addressing greenhouse gas emissions associated with substituting traditional ozone-depleting refrigerants with hydrocarbons. Energy efficiency of these refrigerants is likely to be comparable to or higher than that of ozone-depleting refrigerants and of HFC refrigerants that are sometimes used (e.g., HFC-134a) [Ben & Jerry's, 2008; A.S. Trust & Holdings, 2007, 2009; GE, 2008].

Hydrocarbons are regulated as VOCs under sections of the Clean Air Act that address plans to attain and maintain air quality standards for ground-level ozone, which is a respiratory irritant. EPA's 1994 risk screen document (EPA, 1994) describes the potential emissions of VOCs from all substitutes for all end-uses in the refrigeration and air-conditioning sector as likely to be insignificant relative to VOCs from all other sources (i.e., other industries, mobile sources, and biogenic sources).

In fact, according to EPA calculations, if all appliances manufactured in the household refrigeration and retail food refrigeration end-uses leaked their entire charge over the course of a year, the resulting increase in annual VOC emissions from isobutane, propane, and R-441A as a percent of all annual VOC emissions in the U.S. would be negligible. Therefore, the use of these hydrocarbons for household and retail food refrigeration is sufficiently small that a switch from an ozone-depleting substance (ODS) or from an HFC refrigerant would not have a noticeable impact on local air quality.

International experts came to a similar conclusion in Safeguarding the Ozone Layer and the Global Climate System: Special Report of the Intergovernmental Panel on Climate Change [IPCC/TEAP, 2005].

Similarly, EPA expects that additional releases of hydrocarbons into the environment from use as a refrigerant will have an insignificant impact on ecosystem risks. Because hydrocarbons are volatile and break down quickly in the atmosphere into naturally occurring compounds such as carbon dioxide, EPA does not expect any significant amount of deposition that might adversely affect aquatic or terrestrial ecosystems [EPA, 2011].

Global Warming Potential

The global warming potential (GWP) of a greenhouse gas quantifies its potential to lead to global warming relative to the potential of carbon dioxide (CO_2) over a specified time. EPA reports the 100-year integrated GWPs of isobutane, propane, and R-441A are significantly lower than the 100-year integrated GWPs of the substances they would be replacing and are significantly lower than those of other acceptable refrigerants in these end-uses (e.g., HFC-134a, R-404A, and R-410A). Although the GWPs of HFOs are lower than the HFC refrigerants they are replacing, they are not as low as the GWP of HC refrigerants.

Ozone-Depleting Potential

The ozone-depleting potential (ODP) of a chemical is the ratio of its impact on stratospheric ozone compared to the impact of an identical mass of CFC-11. The ODP of CFC-11 is defined as 1.0. Other CFCs and hydrochlorofluorocarbons (HCFCs) have ODPs ranging from 0.01 to 1.0 [WMO, 2011]. The ODP of HCFC-22 is 0.055, and the ODP of R-502 is 0.334. Like HFC refrigerants that replaced CFCs and HCFCs, the HC and HFO refrigerants have an ODP of zero.

Temperature Glide

The 400 series refrigerant blends are known as non-azeotropic blends, which means they experience a temperature glide during evaporation and condensation. In contract, a pure refrigerant or an azeotropic (500 series) refrigerant blend has a single boiling point temperature (no glide) at a given pressure. As shown in Table 7, R-410A is a near azeotropic refrigerant that can be treated as an azeotropic-like refrigerant.

Why is this important? If the refrigerant has a significant glide and there is a leak in the system, more of the more volatile refrigerant leaks out (compared to the other refrigerants in the blend). This change in the ratio of the components changes the properties of the blend. The performance properties could change and/or other properties such as flammability could change. Refrigerant blends must be charged as a liquid to assure that the ratio of the individual refrigerants in the blend remain at the proper ratios.

The hottest temperature of the temperature glide is known as the dew point. Any mixed refrigerant temperature above the dew point is superheated. The lowest temperature of the temperature glide is known as the bubble point. Any mixed refrigerant temperature below the bubble point is subcooled.

Table 7 shows a few examples of HC and HFC refrigerants with a temperature glide. Many of the HFC refrigerant mixes have been specifically engineered for a small temperature glide.

Table 7. Temperature Glide of HC and HFC Refrigerants

Refrigerant Type	Refrigerant Name	Temperature Glide (°F)
HC	CARE 30	14.0
HC	R-436a	14.6
HC	R-441a	38.7
HFC	R-404a	1.4
HFC	R-410a	0.2
HFC	R-437a	6.7

Saturation Pressure–Temperature Behavior of HC and HFO Refrigerants

Figure 5 shows a plot of the HC and HFO refrigerant pressure–temperature behavior against common refrigerants. In some cases, the saturation pressure–temperature behavior is similar; however, the latent heat of evaporation, which is the evaporative cooling effect per unit volume, is typically not the same regardless of the similarity of the pressure–temperature curve. Differences in the latent heat per volume result in differences in the required volumetric displacement of the compressor and the size of the heat exchangers, such as the evaporator and condenser.

Example

A refrigerant with a smaller latent heat of vaporization per unit volume requires a greater compressor displacement to provide equivalent cooling. Likewise, a refrigerant with a smaller latent heat per volume could require a larger evaporator. There is no drop-in replacement for existing systems.

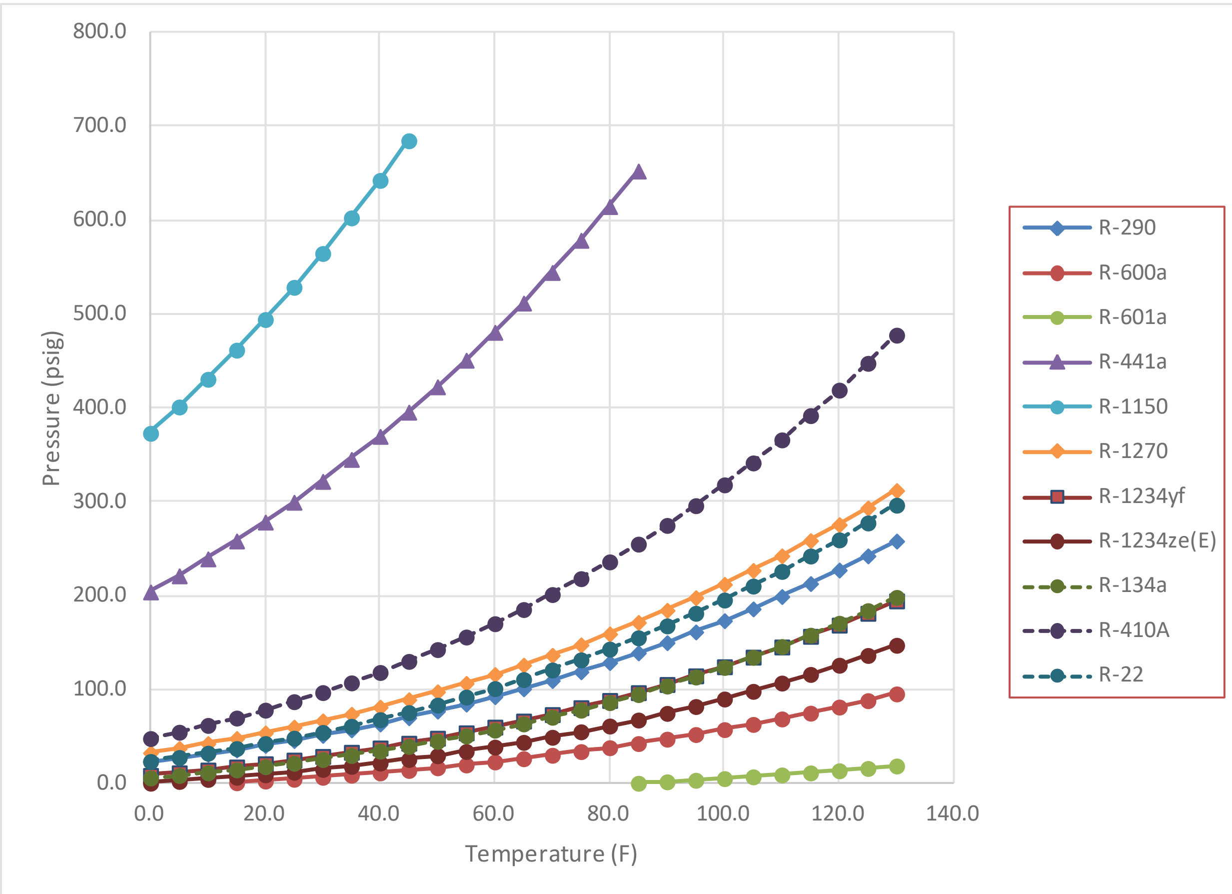


Figure 5. Saturation pressure–temperature comparison of new and traditional refrigerants

Chapter 4. What is the EPA SNAP Program?

The Significant New Alternatives Policy (SNAP) program is EPA's program to evaluate and regulate substitutes for the ozone-depleting chemicals that are being phased out under the stratospheric ozone protection provisions of the Clean Air Act (CAA). The list of SNAP-approved refrigerants evolves as the EPA makes decisions based on its overall understanding of the environmental and human health impacts of various new refrigerants as well as its current knowledge about available substitutes. Section 612 allows the EPA to prohibit the use of a substitute refrigerant when the EPA has determined that there are other available substitutes that pose less overall risk to human health or the environment.

The SNAP program is designed to accomplish the following:

- Identify and evaluate substitutes in end-uses that have historically used ozone-depleting substances (ODSs)
- Evaluate the overall risk to human health and the environment of both existing and new substitutes
- Publish lists of acceptable and unacceptable substitutes by end-use
- Promote the use of acceptable substitutes
- Provide the public with information about the potential environmental and human health impacts of substitutes

To evaluate the acceptability of substitutes, the EPA analyzes risks to human health and the environment from the use of various substitutes in different industrial and consumer uses. EPA reviews the following characteristics when evaluating each proposed substitute:

- Ozone depletion potential
- Global warming potential
- Toxicity
- Flammability
- Occupational and consumer health and safety
- Local air quality
- Ecosystem effects

Background and History of the SNAP Program

Hydrocarbon refrigerants have been in use for over 15 years in countries such as Germany, the United Kingdom, Australia, and Japan in the end-uses addressed by

EPA's rule. In Europe and Asia, equipment manufacturers have designed and tested household and commercial refrigerators and freezers to account for flammability and safety concerns associated with hydrocarbon refrigerants.

The 2010 Report of the United Nations Environment Programme (UNEP) Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee (RTOC) estimates that approximately 100 million household refrigerators and freezers are manufactured annually worldwide. One-third of these now use either isobutane or an isobutane/propane blend, and this proportion is expected to increase to 75% by 2020. In the retail sector, RTOC observes that hydrocarbon refrigerants continue to gain market share in Europe and Japan [RTOC, 2010, pp. 50, 51, 64].

Because hydrocarbon refrigerants have zero ODP and very low GWP compared to other refrigerants, many companies are interested in using them in the United States as well.

The SNAP program listed isobutane (R-600a) and R-441A as acceptable substitutes for chlorofluorocarbon (CFC)-12 and hydrochlorofluorocarbon (HCFC)-22 in household refrigerators, freezers, and combination refrigerators and freezers, subject to use conditions including limitations on the allowable refrigerant charge.

This action also lists propane (R-290) as an acceptable substitute for CFC-12, HCFC-22, and R-502 in retail food refrigerators and freezers (standalone units only) [EPA, 2011].

An EPA SNAP rule effective May 2012 allows the use of HFO-1234yf in motor vehicle air conditioning systems. An EPA SNAP rule effective August 2012 allows the use of HFO-1234ze in centrifugal, reciprocating, and screw compressor chillers and the use of HFO-1233zd in centrifugal chillers.

In the EPA's ruling effective January 2017, additional climate-friendly flammable substitutes were listed as acceptable, subject to use conditions, in new equipment in the following end-uses:

- Ethane in low-temperature refrigeration and in non-mechanical heat transfer
- Isobutane in retail food refrigeration (standalone commercial refrigerators and freezers) and in vending machines
- Propane in household refrigerators, freezers, or combination refrigerators and freezers, in vending machines, and in room AC units
- Hydrocarbon blend R-441A in retail food refrigeration (standalone commercial refrigerators and freezers), in vending machines, and in room AC units
- HFC-32 (difluoromethane) in room AC units

The EPA SNAP rule effective January 2017 also finalized the proposed restriction that non-exempt substitute refrigerants can only be sold to technicians certified under sections 608 or 609 of the CAA. In the case of MVAC refrigerants, EPA exempted the sale of small cans of non-ODS substitutes to allow the do-it-yourself (DIY) community to continue servicing their personal vehicles. As of January 1, 2018, small cans of non-exempt substitute refrigerant must be outfitted with self-sealing valves. Sales are permitted if the cans without self-sealing valves were manufactured or imported before 2018.

Appliances containing 50 or more pounds of ODS or substitute refrigerant that leak more than 75% of the appliance full charge in each of two consecutive 12-month periods have to be retired or mothballed. Owners or operators of appliances that leak 125% of their full charge in a calendar year must submit a report to EPA detailing their repair efforts. The report must be submitted no later than March 1 following the calendar year of the ≥ 125% leak (see Record Keeping Procedures on page 61).

EPA Rule on Refrigerants

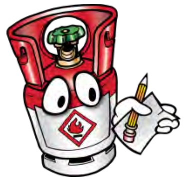
EPA found that using isobutane (R-600a) and R-441A (HCR-188C1) in household refrigeration is acceptable. Use of propane (R-290) is acceptable in retail food refrigeration. Use of ethane is acceptable in very low temperature refrigeration and in non-mechanical heat transfer. Use of HFC-32 (difluoromethane) is acceptable in room air conditioning units. Use of R-502, which is one of the refrigerants for which propane is listed, is acceptable as a substitute in the retail food refrigeration end-use.

EPA established the following use conditions for these refrigerants:

- These refrigerants may be used only in new equipment designed specifically and clearly identified for the refrigerant. None of these substitutes may be used as a conversion or retrofit refrigerant for existing equipment designed for other refrigerants.
- These refrigerants may be used only in refrigerators or freezers that meet the EPA requirements for household refrigeration or retail food refrigeration end-uses.
- The charge size limitations for household refrigeration is 57 g (0.0126 lb or 2.0 ounces weight) and 150 g for retail food refrigeration end-uses. The charge size limitations apply to each refrigerant circuit in a refrigerator or freezer, not necessarily the entire appliance.
- Refrigeration units using HC refrigerants must be clearly labeled.
- All pipes, hoses, or other devices through which the refrigerant passes and where service puncturing or otherwise creating an opening from the refrigerant circuit to the atmosphere might be expected must have red

markings to denote the system charge is a flammable refrigerant. The color must be present at all locations through which the refrigerant is serviced (e.g., process tubes). In addition, the red coloring must be in place at all times and be replaced if removed.

- EPA recommends unique fittings at service apertures.



Note

EPA does not prohibit the sale of hydrocarbon refrigerants in containers designed to contain less than 5 pounds (2.3 kg) of refrigerant.

Covered End Uses

As stated previously, the two end-uses specified by EPA are retail food refrigerators and freezers (standalone units only), and household refrigerators, freezers, and combination refrigerators and freezers. The HC refrigerants can only be used in new equipment that was specifically designed and clearly identified for the HC refrigerant.

Caution

You may not retrofit existing equipment for HC refrigerant use.

EPA did not review the substitutes isobutane or R-441A in the retail food refrigeration end-use. Because the use profiles and handling practices for these chemicals in these end-uses are similar to the combinations of substitutes and end-uses that were accepted, isobutane and R-441A can be used for retail food refrigeration and propane in household refrigeration.

Household Refrigeration

Household refrigeration consists of appliances that are intended primarily for residential use, although they may be used outside the home. Household freezers offer storage space only at freezing temperatures. Products with both a refrigerator and freezer in a single unit are most common. EPA's rule includes a use condition that limits the refrigerant charge in this end-use to 57 g (2.0 ounces by weight) or less of charge in each sealed system.

Retail Food Refrigerators and Freezers

Retail food refrigeration includes refrigeration systems such as cold storage cases that are designed to chill food or keep it at a cold temperature for commercial sale. This rule addresses the use of hydrocarbons in standalone units only. A standalone appliance is one using a hermetically sealed compressor and for which all refrigerant-containing components, including but not limited to at least one compressor, condenser, and evaporator, are assembled into a single piece of equipment before delivery to the ultimate consumer or user. Such equipment does not require addition or removal of refrigerant when placed into initial operation. Standalone equipment is used to store chilled beverages or frozen products. Examples include reach-in beverage coolers and standalone ice cream cabinets.

Retail food refrigeration does not apply to large refrigeration systems such as walk-in coolers or the direct expansion refrigeration systems typically found in retail food stores. It also does not apply to vending machines. The refrigerant charge in this end-use is limited to 150 g (5.3 ounces by weight) or less.

Other Use Conditions

The U. S. Occupational Safety and Health Administration (OSHA) addresses the use of flammable substances in the workplace through its regulations at 29 CFR 1910.106. EPA decided that the manufacturer is in the best position to determine how to address the risks of installing a hydrocarbon refrigerant considering the specific characteristics of its production facilities and personnel. In addition to OSHA requirements, other forces such as concerns for liability, costs of fire and casualty insurance, and reputational interests could also dictate a firm's behavior with respect to worker health and safety protections.

Original equipment manufacturers (OEMs) must institute safety precautions as needed in their facilities to address potential hazards in the production of appliances using hydrocarbon refrigerants. OSHA regulations are in place to address such hazards.

Odorization is one way to alert manufacturing or servicing personnel of the presence of a hydrocarbon refrigerant. EPA's final rule does not prohibit the introduction of an odorant into isobutane, propane, or R-441A refrigerant as long as the refrigerant remains within purity specifications; however, according to EPA, the use conditions, such as red exterior markings and adherence to UL standards, provide ample safeguards to alert manufacturers, service personnel, and customers of the presence of a flammable refrigerant.

Charge Size Limitations

Charge size is limited to 57 g for household refrigeration and 150 g charge size limitations for retail food refrigeration end-uses. The charge size limitations apply to each refrigerant circuit in a refrigerator or freezer, not necessarily the entire appliance. Unlike the charge limit for the household refrigeration end-use, the charge limit for the retail food refrigeration end-use *does not* reflect an additional amount of refrigerant assumed to be solubilized in the oil.

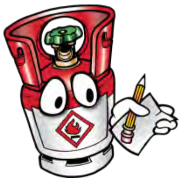
Color-Coded Hoses and Piping

Appliances containing hydrocarbon refrigerants must have red Pantone Matching System (PMS) #185-marked pipes, hoses, and other devices through which the refrigerant passes to indicate the use of a flammable refrigerant. The color is required at all service ports and where service puncturing or otherwise creating an opening from the refrigerant circuit to the atmosphere would be expected to occur. The color must extend a minimum of 1 inch in both directions from such locations.

This color is the same color specified in AHRI Guideline N-2008, Assignment of Refrigerant Container Colors, to identify containers of flammable refrigerant, such as propane, isobutane, and R-441A [AHRI, 2008]. The purpose of the colored hoses and tubing in this case is to enable service technicians to identify the use of a flammable refrigerant and to take additional precautions (e.g., reducing the use of sparking equipment) as appropriate to avert accidents, and particularly if labels are no longer legible. Adding red coloring on tubing inside the appliance provides additional assurance that technicians will be aware that a flammable refrigerant is present.

This does not mean that the entire hose or process tube must be colored. For process tubes, the tube must be colored for at least one inch with the red mark to extend from the compressor. This way, if the process tube is cut for service, the red marking still remains after the tube is welded back together.

If further servicing would leave the colored portion of the process tube less than 1 inch long, the red marking must be extended to at least 1 inch. If there is not enough room to extend the marking at least 1 inch, you need to install a new process tube with at least 1 inch of red marking. For other locations—for example, if a service port or refrigerant access valve is added to the system—the red mark must extend at least 1 inch in both directions from the port or valve.



Note

UL Standards referenced in this rule do not allow the inclusion of service ports in finished products using flammable refrigerants; however, service ports can be added during servicing and the red line marking requirement would still apply.

The red coloring must always be present (not just applied initially at installation) even when a hose or piping is replaced or removed.

A colored sleeve or cap can be used as long as the requirements of the use condition (red color, location, and dimension) are met. However, to remain in compliance with the use condition, a technician who removes a sleeve during servicing is required to replace that sleeve on the serviced tube with another sleeve.

Labeling

Notification is necessary to alert technicians and personnel who dispose of or recycle appliances that a refrigerant has the potential to ignite if a sparking source is nearby. This is particularly true during the years these products are first introduced into the market because most technicians in the United States, as well as those involved in the disposal chain, might not yet be familiar with flammable refrigerants.

Labeling provides a warning of the presence of a flammable refrigerant. Danger and Caution labels must be permanently attached at specified locations on household and retail appliances that are using hydrocarbon refrigerants. The lettering must be 1⁄4 inch (6.4 mm) to make it easier for technicians, consumers, retail store owners, and emergency first responders to see the warning labels (see Chapter 7 for more information).

Refrigerant Containers

EPA *has not* limited the sale of the hydrocarbon refrigerants in containers designed to hold less than five pounds (2.3 kg).

Refrigerant Container Colors

The Air-Conditioning, Heating, and Refrigeration Institute (AHRI) published a guideline that defines the colors to use for refrigerant containers. They divided refrigerants into four classes:

- CLASS I Liquid Refrigerants—Normal boiling point greater than 20°C
- CLASS II Low Pressure Refrigerants—Compressed gas refrigerants with a minimum cylinder service pressure not exceeding 3447 kPa gage
- CLASS III High Pressure Refrigerants—Compressed gas refrigerant with a minimum cylinder service pressure exceeding 3447 kPa gage
- CLASS IV Flammable Refrigerants

All refrigerant containers must be painted light green gray. If the refrigerant has flammable compounds or mixtures that could become flammable if there is a leak, the container must also have a red band on the shoulder or top of the container. To see the exact colors required for the container of each type of refrigerant, see AHRI's 2016 Guideline for Assignment of Refrigerant Container Colors [AHRI, 2016].

Unique Fittings

Although EPA does not require unique fittings, unique fittings are recommended.

Service ports are not allowed in new household refrigerators or standalone retail food refrigerators that use flammable refrigerants, but Clean Air Act regulations require a process tube when a service fitting is not being used. This process tube must have at least a one-inch-long red marking on the tube to indicate flammable refrigerant, and if this marking is removed or shortened, it must be replaced with a new red mark that is at least one inch long. If a service port or access valve is installed after manufacture, it must have the red flammable marking applied at least one inch in both directions from the valve. Such fittings, if installed, should be designed specifically for flammable refrigerants.

Only technicians specifically trained in handling flammable refrigerants should service refrigerators and freezers containing these refrigerants. Technicians should also gain an understanding of techniques and service practices that should be used to minimizing the risk of fire and how to use flammable refrigerants safely. Of course, as stated previously, flammable refrigerants are used only in appliances specifically designed for flammable refrigerants.

Caution

Non-refrigerant-grade hydrocarbons should never be used as refrigerants because the impurities in the lower grade can cause serious problems. The contaminants are typically not removed by the filter-drier and can cause the lubricant to thicken, resulting in increased wear or passage clogging.

Training Requirements

In the ruling effective January 2017, EPA requires that technicians be certified to handle HFCs and other non-exempt substitutes. EPA also finalized the requirement for certifying organizations to publish lists or create online databases of technicians that they certify [EPA, 2016b].

Training is an important way for technicians to learn about the safe handling of flammable refrigerants and become certified. Other countries where hydrocarbon refrigerants are currently in wide use have long-standing training programs on flammable refrigerants. The use of hydrocarbon refrigerants, and training on such use, is in its infancy in the United States and is generally tied directly to specific products or applications, rather than generally to multiple types of products.

Since the inception of the SNAP program and the Section 608 refrigerant management program, EPA has continued to list a variety of new refrigerants as acceptable. EPA has not previously required that certified technicians be recertified as a result of the listing of the additional refrigerants.

Moreover, the goals of the Section 608 technician certification program reflect the need to reduce emissions during servicing, maintenance, repair, and disposal. They do not substitute for the proper training that is normally provided through trade schools, apprenticeships, or other industry mechanisms. Given the extent of technical knowledge available within the industry, the industry is better equipped than EPA to define the specific contents of such training.

Although EPA does not require training as a use condition for these substitutes, to ensure that they can be used as safely as other available refrigerants, technicians must be certified and should receive training on the safe handling of hydrocarbon refrigerants through courses such as this one.

Recovery and Recycling Equipment

Only use recovery or recycling equipment that has been tested and certified for use with the specific HFO or HC refrigerant being recovered. These recovery units have been specifically designed to provide additional safeguards to avoid explosion and fire hazards.

Chapter 5. What are the Safety Classifications of HC and HFO Refrigerants?

ASHRAE Safety Classifications

ASHRAE 34-1992, "Number Designation and Safety Classification of Refrigerants," classifies refrigerants according to their toxicity and flammability (the entire standard can be obtained directly from ASHRAE at http://www.ashrae.org/technology/page/1933). Generally, the higher the toxicity and flammability, the higher the potential for risk and liability. ASHRAE assigns a letter to indicate toxicity of the refrigerant.

Toxicity

ASHRAE 34 divides refrigerant compounds into either low-toxicity or high-toxicity groups. The toxicity group is assigned depending on the acceptable exposure level (AEL) of the compound (see Figure 1 on page 1).

Refrigerants with lower toxicity have AELs of more than 400 parts per million (ppm) and are classified as type A.

Refrigerants with higher toxicity have AELs of less than 400 ppm and are classified as type B.

Older refrigerants, such as CFC-11 and HCFC-22, had very high safe exposure limits, as does the alternative refrigerant HFC-134a. One popular alternative refrigerant, HCFC-123 has a very low allowable exposure limit (30 ppm) and is classed along with ammonia and sulfur dioxide as higher in toxicity.

EPA evaluated the toxicity impacts of HC refrigerants isobutene, propane, and R-441A to workers and consumers for the household refrigeration and retail food refrigeration end-uses. EPA calculated the maximum time-weighted average (TWA) exposures for these hydrocarbons under different exposure scenarios and compared them to relevant industry and government exposure limits.

To assess occupational exposure for the household refrigeration and retail food refrigeration end-uses, EPA estimated the number of refrigerant releases during appliance manufacture and disposal, and the refrigerant amounts released per event. For each refrigerant, EPA used those estimates to calculate the maximum 8-hour TWA exposure, which was then compared to the corresponding workplace guidance level (WGL). EPA found that occupational exposures to these hydrocarbons should not pose a toxicity threat in either end-use because the TWAs were well below the industry and government exposure limits.

To assess consumer and end-user exposure for the household refrigeration end-use, EPA modeled 15- and 30-minute TWAs for catastrophic refrigerant release in a consumer kitchen under a reasonable worst-case scenario. Even under the very conservative modeling assumptions that were used, EPA found that exposures to any of the three hydrocarbons would not pose a toxicity threat to end-users in the household refrigeration end-use because the TWAs were significantly lower than the no-observed adverse effect level (NOAEL) and/or acute exposure guideline level (AEGL).

Likewise, to assess consumer and end-user exposure for the retail food refrigeration end-use, EPA estimated 15- and 30-minute TWAs as acute/short-term consumer exposures resulting from catastrophic leakage of refrigerant from retail food refrigerators and compared the TWAs to standard toxicity limits. Again, the EPA concluded that none of the three hydrocarbons posed a toxicity threat in the retail end-use because the TWAs were significantly lower than the NOAEL and/or AEGL.

Finally, EPA assessed the exposure risk to the general population for the three hydrocarbons in their respective end-uses. To do so, EPA estimated factory and on-site releases of each hydrocarbon and compared them to the reference concentration (RfC) each hydrocarbon. In all cases, the modeled exposure concentrations were significantly lower than the RfC, leading EPA to conclude that isobutane, propane, and R-441A are unlikely to pose a toxicity risk to the general population. These toxicity risks are lower than or comparable to those posed by the other acceptable substitutes in these end-uses. The HC refrigerants discussed to date are all listed as non-toxic, which is toxicity level A (see Table 4 on page 9).

In terms of the toxicity of HFO refrigerants, there is some disagreement. Although they are officially listed as non-toxic (toxicity level A), some scientists are urging a reevaluation after studies showed the recommended replacement releases toxic chemicals upon combustion.

Example

R-1234yf is listed as slightly flammable and non-toxic; however, in a fire, the refrigerant would form highly poisonous carbonyl fluoride *as well as hydrogen fluoride. “It has been known for some time now that combustion of R-1234yf results in the production of the toxic hydrogen fluoride,” said Andreas Kornath, Professor of Inorganic Chemistry at Munich University. “Our analysis has now shown that 20% of the gases produced by combustion of the compound consist of the even more poisonous chemical carbonyl fluoride” (Green Car Congress, 2014).*

However, a risk assessment conducted by SAE (Society of Automotive Engineers) stated that R-1234yf is safe for use in automotive air conditioning. According to their analysis, although they agree that the combustion of R-1234yf does create carbonyl fluoride, they claim it only lasts for a fraction of a second before reacting to form another safer compound and therefore is not around in the air long enough to put bystanders, passengers, or first responders in any danger. In addition, because they claim carbonyl fluoride is also formed during the burning of R-134a, R-1234yf is no worse than existing refrigerants.

Flammability

The ASHRAE 34 standard also classifies refrigerants according to their flammability. To indicate flammability, a number from 1 to 3 is assigned:

- Number 1 (or Class 1) is given to refrigerants with no flame propagation.
- Number 2 (or Class 2) is given to refrigerants with low flammability. (HFO refrigerants are typically classified as 2L to mean limited flammability; they are not classified as Class 1.)
- Number 3 (or Class 3) is given to refrigerants with high flammability.

Figure 1 (page 1) illustrates these safety group classifications.

Class 3 refrigerants exhibit flame propagation at 60 °C and 101.3 kPa, and have either a lower flammability limit (LFL) of less than or equal to 0.10 kg/m3 or a heat of combustion greater than or equal to 19,000 kJ/kg.

ASHRAE Standard 34-2010 categorizes isobutane, propane, and R-441A in the flammable (Class 3) group, making the overall classification A3.

ASHRAE Standard 34-2010 categorizes R-1234yf and R-1234ze(E) as classification 2 or 2L where the L is used to denote limited flammability. R-1234zd is nonflammable classification 1. Therefore, R-1234yf and R-1234ze(E) are classified A2L, and R-1234zd is classified A1.

Flammability Limits of Hydrocarbon Refrigerants

Because they are flammable, isobutane, propane, and R-441A could pose a significant safety hazard for workers and consumers if handled incorrectly. Isobutane, propane, and R-441a have lower flammability limits (LFLs) of 18,000 ppm, 21,000 ppm, and 16,000 ppm, respectively. The ODS (ozone-depleting substance) for which these refrigerants are substitutes—CFC-12, HCFC-22, and R-502—and other substitutes available in this end-use are not flammable. When the concentration of a flammable refrigerant reaches or exceeds its LFL in the presence of an ignition source (e.g., a static electricity spark resulting from closing a door, use of a torch during servicing, or a short circuit in wiring that controls the motor of a compressor), an explosion or fire could occur.

Flammability risks are of particular concern because household refrigeration appliances and retail food refrigeration appliances in the United States traditionally have used refrigerants that are not flammable. Without mitigation, the risks posed by flammable refrigerants would be higher than those posed by non-flammable refrigerants because individuals might not be aware that their actions could cause a fire. Mitigation is designed specifically to minimize flammability risks.

Tip

To use these substitutes safely, minimize the presence of potential ignition sources. Also reduce the likelihood that the levels of these refrigerants will reach their LFLs.

Production facilities and other facilities where large quantities of the refrigerant are stored should have proper safety precautions in place to minimize the risk of explosion. EPA recommends that these facilities be equipped with proper ventilation systems to minimize the risks of explosion and be designed to reduce risks from possible ignition sources.

To determine whether the three hydrocarbon refrigerants would present flammability concerns for service and manufacture personnel or for consumers, EPA reviewed the detailed assessments of the probability of events that might create a fire, as well as engineering approaches to avoid sparking from the refrigeration equipment. EPA also conducted risk screens to evaluate reasonable worst-case scenarios to model the effects of the sudden release of the refrigerants.

The worst-case scenario analysis for each of the three hydrocarbons revealed that even if the full charge of the unit were emitted within one minute, the concentration would not reach the LFL for that hydrocarbon. However, because hydrocarbon refrigerants are flammable and manufacture personnel, service personnel, and consumers in the United States might not be widely familiar with refrigeration appliances containing flammable refrigerants, training, certification, and restricted use are being used to safeguard personnel, create awareness, and ensure safe handling.

Use Conditions

Restricted use conditions ensure that the flammable substitutes present risks that are lower than or comparable to those of other substitutes that are currently or potentially available. EPA made recommendations, such as proper ventilation and storage practices, and use of appropriate tools and recovery equipment to mitigate safety risks for manufacture and servicing personnel.

EPA's interpretation of the risk of ignition-related failures in residential refrigerators for internal leak events is based on information presented in Risk Assessment of Flammable Refrigerants for Use in Home Appliances [A. D. Little, 1991].

This A. D. Little report used historical leak rate data provided by three refrigerator manufacturers to estimate possible leakage rate failures. Failure scenarios were based on independent, random events. For a leak to pose a potential risk for ignition, the refrigerant had to be present in amounts that meet or exceed the LFL.

However, the ability of a refrigerant to accumulate and reach its LFL is a function of both the rate at which the leak occurs and the size of the enclosed spaces that can trap the refrigerant and allow it to build up. A.D. Little distinguished catastrophic leaks (the loss of a significant portion of refrigerant charge over a few minutes) from slow leaks, observing that only catastrophic or fast leaks would allow refrigerant to accumulate to a level of concern. The report goes on to calculate the average risk that a leak is a fast leak as 0.1% and the worst-case risk that a leak is a fast leak as 1%.

The use conditions require any household refrigerator using isobutane to be designed specifically for use with flammable refrigerant in a manner that complies with the UL 250 Standard. Equipment that is in compliance with UL 250 must have passed appropriate ignition or leakage tests that ensure that if there is a leak, refrigerant concentrations would not reach or exceed 75% of the LFL inside any internal or external compartment for electrical components.

Even if a refrigerant is present in sufficient quantity (i.e., at LFL), the refrigerant will not ignite if there is no ignition source. Because the risks are sufficiently small, HC refrigerants are acceptable for use in the United States, subject to the specific charge limitations that have been put in place to mitigate potential risks.

Asphyxiation

In evaluating potential human health impacts of isobutane, propane, and R-441A, EPA considered the risk of asphyxiation to workers (store employees and technicians) and consumers. Of course, asphyxiation is a concern with current refrigerants as well.

The EPA calculated the maximum charge of each refrigerant that would result in a reduction of oxygen levels to 12% in air, which is the no-observable adverse effect level (NOAEL) for hypoxia [ICF, 1997]. Specifically, under these worst case conditions, EPA calculated that the charge sizes necessary to reduce the oxygen level in air to the 12% NOAEL in the household refrigeration end-use would be 625 grams and 535 grams (for isobutane and R-441A, respectively), which is much larger than the 57 gram charge size limitation required in the use conditions in their rule [ICF, 2011a and 2011c].

Likewise, the charge size necessary to achieve the NOAEL in the retail food refrigeration end-use would be 904 g for propane, which is six times greater than the 150 g charge size limitations in their rule [ICF, 2011b]. This risk is lower than or comparable to that of other available substitutes in these end-uses.

Chapter 6. What are the HC and HFO Safe Handling Practices?

In this chapter, you'll learn about best practices for handling HC (hydrocarbon) and HFO (hydrofluoroolefin) refrigerants safely.

Charge Limitations

Household Refrigeration

EPA stipulated that the charge size not exceed 57 g for household refrigeration. The EPA also assumed that 7 g of refrigerant be solubilized in the oil (and assumed not to immediately vaporize with the refrigerant in the event of a leak), and therefore the EPA modeled a maximum refrigerant release of 50 g [ICF, 2009a and ICF, 2011a].

A typical U.S. household refrigerator using HFC-134a has a charge of roughly 140 g and a charge of isobutane providing comparable cooling would be 40–50% of the charge of HFC-134a, or a charge of about 56–70 g.

UL has tested household refrigerators, freezers, and combination refrigerators and freezers for safety, especially for flammability concerns. UL developed the 50-gram allowable leak limit as the result of testing during development of the UL 250 standard for household refrigerators and freezers.

The 50 g allowable leak limit for household refrigerators in UL 250 differs from the 150 g allowable leak limit for commercial refrigerators and freezers in UL 471 because of factors such as the difference in the room sizes modeled for household versus retail appliances. Therefore, building on the UL allowance of a 50 g allowable leak limit, EPA concluded that the maximum charge size should be 57 g for the household refrigeration end-use.

The 57 g charge size limit applies to each sealed system. A household refrigeration appliance can incorporate multiple sealed systems. Having multiple sealed systems is less of a concern than having a single system with the same combined charge because the probability of two sealed systems leaking simultaneously is very low. In addition, hermetically sealed systems are less likely to leak, presenting a lower probability of fire or explosion. Hermetically sealed systems provide an increased level of safety in normal use.

Retail Food Refrigeration

EPA finalized the 150 g charge size limit for the retail food refrigeration end-use. This definition applies to any appliances produced or imported into the United States as well as U.S. manufactured appliances that will be exported. Again, the charge size limitation applies to each sealed system in an appliance.

HC and HFO Refrigerant Recovery

After evaluating the HC refrigerants, EPA concluded that they present overall environmental and human health risks that are lower than or comparable to other acceptable substitutes in the household refrigeration and retail food refrigeration end-uses. Risks can be mitigated to ensure the substitutes can be used as safely as other available substitutes.

Flammability could pose a concern for the servicing and disposal of appliances containing HC and HFO refrigerants. The requirements for labeling and coloring the tubing red at access locations serve as notification to servicing or disposal personnel that the appliance contains a flammable refrigerant.

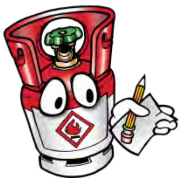
Caution

If the refrigerant is flammable, you must use recovery equipment designed specifically for flammable refrigerants.

Recovery Techniques

EPA regulations prohibit venting of any refrigerant including HC or HFO refrigerants during service, maintenance, repair, and disposal. Under the Clean Air Act, EPA established regulations that require technicians to maximize the recovery and recycling of refrigerants when they are servicing or repairing air conditioning and refrigeration equipment. If you are going to dispose of the equipment, you must also follow EPA's safe disposal requirements to ensure the refrigerants are removed and the equipment does not enter the waste stream with the charge intact.

Identifying the Refrigerant



Note

Before beginning a refrigerant recovery procedure, you must ALWAYS know the type of refrigerant that is in the system.

Each type of refrigerant has its own recovery evacuation requirements that you must understand before you start the recovery procedure. You should check the nameplate on the system to identify the refrigerant used, or you can use an ARI 700 purity test to determine the type of refrigerant. You may also be able to use the saturation pressure/temperature characteristics of the refrigerant to verify the refrigerant type. However, the only completely reliable method of accurately determining the refrigerant type is to take a sample of the refrigerant and send it to a certified testing laboratory for analysis.

Sometimes the refrigerant used in a system can be determined by the type and age of the equipment. You need to ensure only one type of refrigerant is in the appliance. Mixing refrigerants is not only unsafe, it will most likely make reclamation impossible.

Note

If you are using a replacement refrigerant, the recovery machine must be specifically certified for the replacement refrigerant. Just because the recovery machine is certified for the original refrigerant does not mean you can use the machine with any replacement refrigerant. In fact, the machine is most likely not suitable for the replacement HC or HFO refrigerant.

Use Pressure and Temperature to Identify Refrigerant

If the label identifying the refrigerant is missing, or if you suspect the unit has a different refrigerant than the one on the label, you might be able to use the pressure–temperature method for determining the type of refrigerant.

Saturated refrigerants have a specific pressure rating at a specific temperature. If you know the temperature of the air surrounding the refrigerated appliance (the unit must have been powered off for sufficient time for the unit to reach this ambient air temperature) and you can measure the pressure of the refrigerant, you might be able to identify the refrigerant by looking at the pressure–temperature chart. However, the pressure–temperature method has several flaws.

- The saturation pressure–temperature relationship of some refrigerants is similar and difficult to distinguish. Figure 5 (page 20) shows that many refrigerants have almost identical pressure–temperature saturation curves.

Examples

R-134a and R-1234yf have nearly identical saturation pressure–temperature behavior and would be impossible to tell apart. Likewise, R-22 and R-1270 have similar behavior. Only *refrigerants like R-410A, R-441a, R-1150, and R-601a are easy to distinguish in terms of their pressure–temperature behavior.*

- Non-condensable gases in the system will raise the system pressure, making it difficult to determine the refrigerant, unless you are trying to select the refrigerant type from two very different choices such as R-601a and R-134a.
- Non-azeotropic blends, such as R-441a, which are the 400-series refrigerants, have pressure–temperature characteristics that can change as they fractionate at a leakage site. Therefore, if the system has a leak or has been improperly charged (charged as a vapor instead of as a liquid), the saturation pressure–temperature curve would be very different, potentially making refrigerant identification impossible.

If you are unsure of the refrigerant but know the correct refrigerant with which to recharge the system, the best practice would be to recover the refrigerant into a dedicated recovery tank and return the refrigerant to a recycling facility. Then, recharge the system with new or reclaimed refrigerant. Never use a refrigerant recovery device that has not been specifically designed to recover the specific HC or HFO refrigerant being recovered.

Alternatively, if you are simply trying to determine the refrigerant that should be charged into a system that carries no name plate for reference, contact the equipment manufacturer, or get the compressor model number from the unit and contact the compressor manufacturer to determine the refrigerant. Major compressor manufacturers have this information available online.

Evacuation Requirements

The recovery requirements for appliances are different depending on the classification of the equipment. The size of the appliance, how the appliance is used, and even the date of manufacture of the recovery unit affect the required recovery level.

Currently, any non-leaking unitary system that uses a flammable HC refrigerant is limited to normal charges below 5 pounds. Therefore, certified recovery machines fabricated for recovery of these HC refrigerants have to remove at least 90% of the refrigerant’s normal charge when the compressor is operational or 80% if the compressor of the system is non-functional.

If the HC refrigerant system has leaks, you must isolate leaking components from non-leaking components wherever possible and evacuate non-leaking components to the specified levels (80% or 90% depending on the status of the compressor).

The isolated leaking components or the entire system, if the leaking components could not be isolated, must be evacuated to at least 0 psig to be in compliance with EPA regulations.

Proper Recovery/Recycling Equipment

Only use recovery equipment and recovery cylinders that have been specifically designed (and marked) to accommodate flammable refrigerants. This hardware must be certified for the recovery and containment of the exact refrigerant you are planning to recover. When comparing the saturation pressure–temperature characteristics for R-1234yf in Figure 3 (page 11) with the saturation pressure–temperature characteristics for R-1234zd in Figure 4 (page 12), although these refrigerants have similar names, their pressures at a given temperature are different. Therefore, a recovery machine or other hardware rated for one refrigerant is not suitable for recovery of another refrigerant unless explicitly stated.

Before you use any recovery equipment, inspect the equipment for signs of damage, leaks, loose or faulty electrical connections, rust, corrosion, or deterioration. Do not use any equipment that has questionable integrity or that could be faulty. You must check your recovery device for refrigerant leaks on a regular basis.

If your recovery cylinders and equipment use Schrader valves, you must inspect the Schrader valve core for bends and breakage, replace the damaged Schrader valve core to prevent leakage, and cap the Schrader ports to prevent accidental depression of the valve core.

If your recovery cylinders have pressure relief valves, you must also regularly inspect the pressure relief valves. When you find corrosion build up within the body of a relief valve, replace the valve.

To recover any HC or HFO refrigerant, you need the proper equipment:

- EPA-approved recovery unit certified for use with the refrigerant being recovered
- Manifold gauge set rated for the pressure of the refrigerant to be recovered
- Charging hoses rated for the pressure of the refrigerant to be recovered
- Approved Department of Transportation (DOT) refrigerant recovery tank (storage cylinder) rated for the pressure of the refrigerant to be recovered and properly marked for use with flammable refrigerants.

All recovery equipment now manufactured is required to have an EPA-approved certification label, and all recovery cylinders must have a current hydrostatic-test date stamped on them.

Caution

When operating refrigerant recovery or recycling equipment, follow these precautions:

- ***Maximize the ventilation to the area.***
- ***Wear safety glasses with side shields.***
- ***Wear protective gloves.***
- ***Wear protective shoes.***

Follow all safety precautions and user instructions for the equipment.

Tip

Have two recovery tanks for each refrigerant. You can use one tank to store dirty refrigerant that will not be returned to a system. You can then hold the refrigerant until you can sell it to a refrigerant recycler. Use the second recovery tank for the temporary storage of recovered refrigerant while servicing a unit.

Recovery Unit

Because the flammable refrigerant charge is limited by regulation, any flammable recovery unit has very little charge to be removed, and therefore, vapor recovery is a practical method of removing the refrigerant. The benefit of vapor recovery is that essentially only refrigerant is transferred to the recovery tank, leaving the lubricant in the system.

When the refrigerant is recovered as a vapor, the recovery takes longer, but you can make the recovery quicker by ensuring the hoses and valve ports are not restricted. Always use the shortest hoses possible, and remove any restrictions in the hoses such as valve core depressors.

Heating the system or cooling the recovery tank speeds up recovery. When the pressure in the system is increased by heating the system, the recovery is faster.

Caution

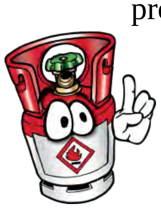
Never use a flame to heat the system!

In the inverse situation, when the pressure in the system is reduced, which is possibly caused by the evaporation of the refrigerant as it is removed from the system, the vapor becomes less dense and the recovery is slower.

During vapor recovery, the vapor is drawn from the appliance into the recovery system. The vapor passes through the compressor of the recovery system and into the condenser of the recovery unit (which cools and condenses the recovered vapor). This is why the recovery machine must be certified for the refrigerant being recovered and for use with flammable refrigerants.

Cooling the recovery tank lowers the pressure in the recovery tank, thus lowering the head pressure on the recovery machine and increasing the recovery rate.

Recovery during low ambient temperatures, on the other hand, slows the recovery process. Although the recovery tank is cooler, the system is also cooler.



Tip

The fastest recovery is with a warm system and a cool recovery tank.

The warmer the system, the warmer and more dense the vapor is. Therefore, the compressor in the recovery unit is able to transfer more refrigerant per minute. Hence, any method to warm the system (via heat lamps or defrost heaters, or by raising the temperature in the equipment room, etc.) and cool the recovery tank speeds recovery. Again, never use an open flame to warm the system!

Cautions

When recovering flammable refrigerants, always ensure that the refrigeration system, recovery unit, and recovery tank are all properly grounded.

Never apply an open flame to a charged system or a refrigerant cylinder.

When using a dual-valve recovery tank, you might be able to configure a recovery machine to clean and filter the refrigerant. Combining the recovery unit, a dual-valve recovery tank, three hoses, and a filter drier (with ¼" flare fittings) as shown schematically in Figure 6 allows the cleaning of refrigerant, but it does not make your recovery machine a certified recycling machine. The setup is shown with actual hardware in Figure 7.

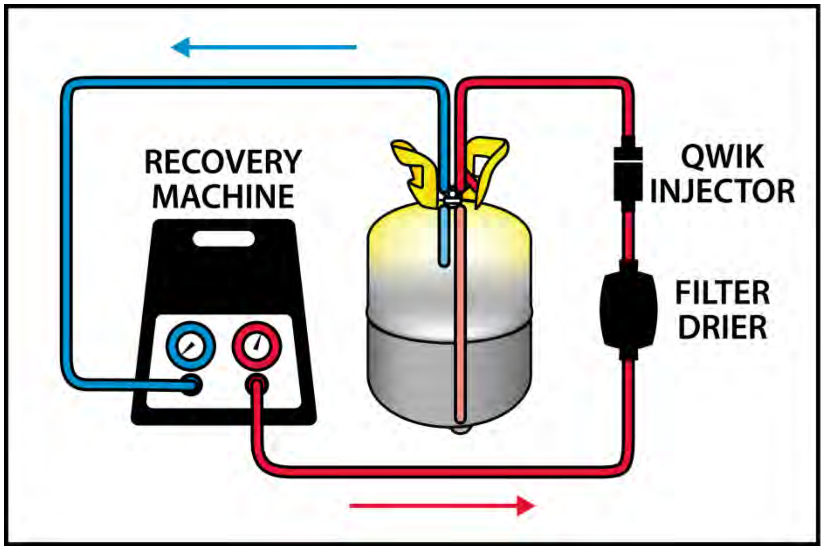


Figure 6. Cleaning and filtering refrigerant while servicing the unit

Figure 7. Photo of refrigerant being cleaned and filtered

In this configuration, a Mainstream half-ounce QwikInjector® has also been plumbed into the line to allow QwikShot® to be introduced into the refrigerant. This helps remove acid and water from the system.

Although this configuration cleans the refrigerant by using multiple passes through a new filter drier (assisted by the QwikShot®), the refrigerant cannot be called recycled because an approved recovery machine was not used. The recovered refrigerant is simply cleaner.

Pressure Decay Leak Test

For small systems, one of the best leak-checking procedures is a pressure decay leak test, also referred to as a static pressure decay leak test or standing pressure test. This procedure is ideal for small systems because even a slight loss in refrigerant results in an easily detectable pressure drop since the overall system volume is so small.

Before you evacuate a system, you need to use a pressure decay leak test to verify no leaks exist. Whenever you evacuate a system with a leak, you draw air, moisture, and other contaminants into the system, making subsequent deep evacuation much more difficult.

A simple method to determine the existence of a leak in the system is to pressurize using a pressure source that will not change an appreciable amount with temperature changes. Dry nitrogen is a good gas to use. If you are going to use an electronic leak detector, add a small amount of HFC refrigerant into the system before pressurizing with nitrogen.

Mixtures of nitrogen and the HFC refrigerant used as holding charges or as leak-test gases are not subject to the EPA venting prohibition because in these cases the ozone-depleting compound is not used as a refrigerant. However, you may not avoid recovering refrigerant by adding nitrogen to a charged system!

Tip

Before nitrogen is added, you MUST evacuate the system to the required level. Otherwise, the refrigerant–nitrogen mixture is considered a refrigerant, and its release is a violation of the EPA regulation and subject to a fine.

Never use mixtures of refrigerant, air, or oxygen to leak-check a system. If you mix one refrigerant with a different refrigerant, the mixture could become combustible under pressure. The same thing could happen if you mix a refrigerant with air or oxygen.

The safest way to check a system for a leak is to use dry nitrogen gas or other inert gases that you know are dry and clean. Never use compressed air because of the risk of explosion with flammable refrigerants and the risk of system contamination. Compressed shop air is quite wet and contains trace amounts of oil, which can be incompatible with the system oil.

Pressurize the system to the pressure indicated on the system nameplate, record the pressure, and watch for pressure degradation over a sufficient time period. If no nameplate exists, use the normal operating condenser temperature and saturation pressure–temperature table for the refrigerant to determine the normal operating condenser pressure and use that pressure.

Example

How long is sufficiently long? On a small appliance with a normal charge of 150 g (0.33 lb) or less, a sufficiently long time is 15 minutes.

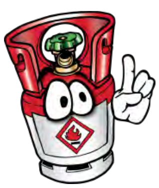
Some natural changes in pressure occur due to temperature, which must be adjusted for unless the temperature remains relatively constant. To adjust for the effect of a temperature change on pressure, use the following formula, where the pressures are in psia (not psig) and the temperatures are in degrees Rankine (not Fahrenheit). The system has a leak if the pressure drops and the drop is more than the accuracy of the gauges or the variation due to temperature change.

$$P_{new} = P_{original} \times T_{new} / T_{original}$$

where

P_{new} is the new pressure in psia at the new temperature T_{new} in degrees Rankine

$P_{original}$ is the original pressure in psia at the original temperature $T_{original}$ in degrees Rankine



Tip

To convert a temperature from degrees Fahrenheit to degrees Rankine, add 460 to the degrees Fahrenheit to get the temperature in degrees Rankine.

To convert a pressure from psig to psia, add 14.7 to the pressure in psig to get the pressure in psia.

Pressure Decay Leak Test Procedure

1. If you are *not* going to use an electronic leak detector with this test, skip to Step 2. If you are going to use a refrigerant leak detector, put a small amount of HFC refrigerant in the system and bring the system pressure up to about 10 psig. *Do not use mixtures of nitrogen and any other refrigerant except HFC refrigerants as a leak test mixture*. Venting CFC or HCFC refrigerant from any appliance, hardware, or device is illegal. The release is presumed to be a refrigerant and is a violation of the EPA regulations and subject to a fine.
2. Use the nitrogen to increase the pressure to the maximum pressure of the system as indicated on the manufacturer's nameplate.
3. Isolate the system from the nitrogen source. Tap the gauge slightly to make sure the needle is free, and record the pressure. Any drop in pressure

after compensating for temperature changes indicates a leak. If you see a pressure drop, remember the manifold gauge and connections could be leaking, not the system.

4. Check for leaks while the system is pressurized because the leaks are easier to detect. If refrigerant was added in Step 1 before the system was pressurized, you can use an electronic halide leak detector. Otherwise, use soap bubbles or an ultrasonic detector.
5. When you are convinced that the system is leak free, dehydrate the system using the Triple Evacuation Method to ensure that no trapped air, refrigerant, and/or water is in the system.

Caution

Always use a pressure regulator on the nitrogen cylinder. Do not pressurize any system above the working pressure of the system written on the equipment nameplate.

Triple Evacuation

Using the Triple Evacuation Method, the eventual goal is to reach a final deep vacuum, at least 500 microns, 0.5 mmHg absolute. The process is essentially to accomplish the following:

- Draw a deep vacuum
- See if the vacuum can hold
- Refill the system with dry nitrogen and repeat until a deep vacuum is achieved and held

During each vacuum decay test, isolate the system from the vacuum pump and wait to see if the pressure rises (water is boiling off). Because the quantity of gas trapped in the system is essentially zero, you don't need to make any compensation for temperature changes.

If you see an increase in pressure, the system could have a leak, but this is unlikely for a high-pressure system because you already passed the pressure decay leak test with the system at a much higher pressure. If the pressure increases to a point and then stops at some point either above or below 0 psig, water (if below 0 psig) or refrigerant (if above 0 psig) is still evaporating. Only if the system had a leak would the pressure increase stop at 0 psig (atmospheric pressure).

If the pressure increases above 0 psig, refrigerant is still trapped in the system. The refrigerant could be trapped in or under any oil in the system. The trapped refrigerant is continuing to evaporate, which causes the vapor pressure to rise above ambient pressure.

If the pressure rises from the initial deep vacuum but stops at some vacuum level below ambient pressure, water is probably trapped in the system. Table 8 provides the saturation pressure/temperature chart for water at different evacuation levels.

Example

Refer to the following table for this example. If the pressure increase stopped at 22,000 microns, (22 mmHg absolute), the trapped water is evaporating at 75 °F. This evaporation further cools the remaining water, dropping the pressure at which additional water evaporates.

Table 8. Saturation Temperature/Pressure Behavior for Water

Temperature °F	Pressure	
	(mmHg)	Microns
35	5.	5,000
40	6.	6,000
45	8.	8,000
50	9.	9,000
55	11.	11,000
60	13.	13,000
65	16.	16,000
70	19.	19,000
75	22.	22,000
80	26.	26,000
85	31.	31,000
90	36.	36,000
95	42.	42,000
100	49.	49,000
105	57.	57,000
110	66.	66,000
115	76.	76,000
120	88	88,000

Triple Evacuation Procedure

The triple evacuation procedure is an evacuation method where the system is initially evacuated (pulled-down) to a vacuum of at least 500 microns to 2,000 microns. Then, a small amount of dry nitrogen is introduced into the system to raise the pressure to above ambient pressure (typically to about 10–15 psig).

The nitrogen is then purged (vented), typically through the vacuum pump. Recovery of the nitrogen is not required. This process of evacuation followed by nitrogen pressurization is repeated (three total evacuations), and the third evacuation should achieve a vacuum of 500 microns or less.

Triple evacuation is an effective method for dehydration because it uses the dry nitrogen to sweep through the refrigerant lines to push out moisture. Air is 78% nitrogen, so this process does not harm the environment. Whenever you use dry nitrogen from a portable cylinder, you must use a pressure regulator, and for safety reasons, you should always use a pressure relief valve (or bust disk) inserted in the downstream line from the pressure regulator to avoid over pressurization of the system.

Required Tools

The tools you need to perform a triple evacuation are a two-stage vacuum pump, a gaseous nitrogen supply (nitrogen tank and regulator), and a micron vacuum gauge.

Vacuum Pump

A vacuum pump removes fluids such as air, other non-condensable gases, and water from a system, drawing the system pressure to below atmospheric pressure, or 0 psig. A vacuum pump can consist of a single- or two-stage design. The two-stage vacuum pump is necessary for HVAC/R appliances.

The size of the pump is rated according to the volumetric pumping capacity, normally measured in cubic feet per minute (cfm). Three- to six-cfm pumps are typically used in residential applications.

The vacuum pump may also have a gas ballast valve, which helps to prevent moisture that is being evacuated in the system from condensing into the vacuum pump oil and reducing the vacuum level the vacuum pump can achieve.

Figure 8 shows a typical two-stage vacuum pump and the location of the gas ballast valve (brass knob).

The gas ballast valve is used to help keep impurities (such as refrigerants and moisture) from condensing and mixing with the vacuum pump oil. If refrigerants or moisture condense in the vacuum pump oil, the vacuum pump won’t be able to obtain a deep vacuum. During the first stages of evacuation, refrigerant or moisture vapors are more highly concentrated. The gas ballast valve allows some ambient air into the vacuum pump to dilute the impurities and reduce the condensation of refrigerant and/or moisture into the vacuum pump oil.

Follow these steps when using a gas ballast valve:

1. Keep the gas ballast valve closed when the vacuum pump is not being used.
2. After connecting the vacuum pump and starting evacuation, open the gas ballast valve (1/4 turn to fully opened) during the initial evacuation.
3. When the vacuum pressure has dropped into a vacuum of at least 20 to 25 inches of mercury, close the gas ballast valve and continue the evacuation procedure to reach the ultimate vacuum. If you forget to close the gas ballast valve, a deep vacuum will not be achieved.

Figure 8. Two-stage vacuum pump with gas ballast valve shown

Vacuum pumps are also rated for the degree of vacuum they can achieve in microns. A two-stage vacuum pump is necessary to pull the deep vacuums (below 500 microns), which is necessary for proper deep evacuation and removal of water in systems.

The extraction of the air and non-condensables lowers the pressure inside the system below atmospheric pressure, which causes any trapped liquid water to evaporate and be exhausted by the vacuum pump.

Electronic Vacuum Gauge (Micron Gauge)

An electronic vacuum gauge or micron gauge displays the vacuum level directly in microns and is the only accurate field method to determine the evacuation level of a deep vacuum. Figure 9 shows a typical electronic micron gauge. The micron gauge is much more accurate at measuring very deep vacuums (very low pressures) when compared to a manifold gauge.

Figure 9. Electronic micron vacuum gauge

The compound (blue) low-side pressure gauge on a manifold set measures evacuation levels using an inaccurate scale based on inches of mercury. This scale ranges from 0 inches of mercury (no vacuum) to 30 inches of mercury (full vacuum). By comparison, the micron gauge expands this scale tremendously at the deeper vacuum levels, providing greater measurement resolution.

Example

There are 25,000 microns between 29 inches of mercury and 30 inches of mercury. Most manufacturers recommend the system pressure be reduced to a vacuum level of between 300 and 500 microns. A manifold gauge does not provide sufficient accuracy for this type of measurement.

Evacuation Process

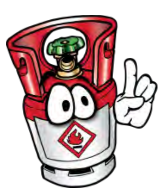
When you evacuate a system, you need accurate readings from the micron gauge. For the most accurate readings, connect your vacuum gauge close to the system to be evacuated (ideally directly on a service port) and as far as possible from the vacuum pump. Never connect the gauge in-line between the vacuum pump and the system. Always measure the vacuum with the vacuum pump shut off and isolated.

When shutting off a vacuum pump, follow this procedure:

1. Shut off or isolate the service hose that is being used to evacuate the system, isolating the pump from the system.
2. Break the vacuum in the line between the vacuum pump and the system.
3. Shut off the vacuum pump. If you simply shut off the vacuum pump without isolating the vacuum pump or without breaking the vacuum in the connecting hose, the vacuum in the system or the hose draws vacuum pump oil into the system or hose, resulting in the contamination of the system or hose.
4. Measure the final system vacuum with the system isolated and the vacuum pump turned off.
5. After you isolate the vacuum pump from the system, wait 10 to 15 minutes to verify the vacuum gauge does not reach a level that exceeds 500 microns. If the gauge reading does not exceed 500 microns during the waiting period, you know the system has been evacuated adequately.

Caution

On very large systems where the vacuum pump can operate for long periods unattended, such as all night, you need to take precautions in case the power fails during the procedure. Arrange solenoid valves in the vacuum pump line that will isolate the system (normally closed) automatically and break the vacuum (normally open) in the connecting hose. Otherwise, a large system left unattended during a power failure could be contaminated with vacuum pump oil.



Tips

A system is said to be dehydrated when the vacuum indicator shows you have reached and held the required final vacuum.

Use vacuum lines (hoses) that are equal to or larger than the pump intake connection. The piping connection to the vacuum pump should be as large in diameter and as short in length as possible.

Remove any restrictions in the hose such as unnecessary Schrader valve core depressors.

A micron gauge reading between 1,000 and 5,000 microns indicates some moisture remains in the system and requires further evacuation.

A micron gauge reading that increases to more than 5,000 microns during the waiting period suggests the likelihood of a leak in the system. When a leak exists, you need to disconnect the evacuation equipment to identify and repair the system leak.

Evacuation can be a slow, tedious process. Rushing the process only leads to improper evacuation levels that cause equipment to operate below peak efficiency and experience premature component failure. You can't over-evacuate a system.

Expediting the Evacuation Process

Certain techniques can expedite evacuation. Factors affecting the speed of evacuation include the size of the equipment being evacuated, the ambient temperature, and the amount of moisture in the system. The capacity of a vacuum pump and its suction line size determine the length of dehydration time. During dehydration of a refrigeration system, you can heat the system to decrease dehydration time.

Leak Repairs

Never use any leak sealing or moisture drying compounds with any HFO or HC refrigerants because these compounds all contain silicates. Always follow proper brazing techniques for flammable refrigerants.

Brazing

Pipe Connections

When you braze joints in an HC or HFO system, you must perform the brazing of the joints in an area detached from the system. If this is not possible, you need to fully evacuate the system prior to brazing.

Perform the following before you start working on the system:

- Inspect the area around the equipment to ensure there are no flammable hazards or ignition risks.
- Display No Smoking signs.
- Ensure that the refrigeration system is grounded.

Charging

After a system has been installed or repaired, the system is ready to be charged with refrigerant only after you complete all of the following:

- Ensure that the refrigeration system, the refrigerant tank, and any other metallic component in the refrigerant flow circuit is electrically grounded before charging the system with refrigerant.
- Install a fresh filter drier before performing any leak tests.
- Successfully complete a standing-pressure leak check at the maximum system pressure.
- Evacuate to at least 500 microns (ideally 300 microns) by using a triple evacuation procedure if necessary (see Triple Evacuation on page 46).

Tip

The charge being added to flammable systems is very low. Ensure the charging scale has sufficient accuracy to meter the proper amount of charge into the system.

Liquid Charge

Like any other blend, HFO and HC refrigerant blends should be charged as a liquid to maintain the correct composition.

Tip

Be careful to meter the refrigerant into the system slowly to avoid compressor knocking.

Recharging the System with Recovered Refrigerant

You can probably charge the refrigerant back into the system if the refrigerant has been recovered from the system and held in a refillable cylinder where contamination of the refrigerant was not likely. However, the charge is small, so this might not be the best choice because the cost of the refrigerant is minimal.

If you have any question about the refrigerant quality, the only fail-safe method is to replace the refrigerant.

Caution

Ensure that the refrigeration system is grounded before charging the system with refrigerant.

Venting

Like any other refrigerant, whenever possible you should not vent any HC or HFO refrigerant. Legally, you cannot vent HFO refrigerants, such as R-1234yf, R-1234zd, and R-1234ze, during service, maintenance, repair, and disposal.

However, the following substitutes in the following end-uses can be vented [EPA, 2016b]:

- Carbon dioxide, nitrogen, and water in any application
- Ammonia in commercial or industrial process refrigeration or in absorption units
- Chlorine in industrial process refrigeration (processing of chlorine and chlorine compounds)
- Hydrocarbons in industrial process refrigeration (processing of hydrocarbons)
- Ethane (R-170) in very low temperature refrigeration equipment and equipment for non-mechanical heat transfer
- Propane (R-290) in retail food refrigerators and freezers (standalone units only); household refrigerators, freezers, and combination refrigerators and freezers, self-contained room air conditioners for residential and light commercial air-conditioning; heat pumps; and vending machines
- Isobutane (R-600a) in retail food refrigerators and freezers (standalone units only); household refrigerators, freezers, and combination refrigerators and freezers; and vending machines
- R-441A in retail food refrigerators and freezers (standalone units only); household refrigerators, freezers, and combination refrigerators and freezers; self-contained room air conditioners for residential and light commercial air-conditioning; heat pumps; and vending machines.

De minimis releases associated with good faith attempts to recycle or recover refrigerants are also not subject to the venting prohibition. Refrigerant releases are de minimis only if applicable recovery and service practices are observed and all reasonable efforts to contain refrigerant and prevent releases are followed.

Note

The knowing release of a Class I or Class II refrigerant or a non-exempt substitute refrigerant after its recovery from an appliance is a violation of the venting prohibition and subject to fines.

Static Electricity Concerns

When the concentration of a flammable refrigerant reaches or exceeds the lower flammability limit (LFL), an explosion or fire can occur if an ignition source such as a spark, open-flame, or other very hot surface exists. A static electricity spark can serve as such an ignition source.

As shown in Figure 10, to support an explosion or fire, the concentration of the flammable refrigerant in air must be between the lower and upper flammable levels.

Example

For flammable refrigerant shown in Figure 10, if the concentration is below the lower flammability level of approximately 2%, the concentration isn't high enough for combustion. If the concentration is above the upper flammability level of approximately 10%, insufficient oxygen prohibits combustion.

Figure 10. Example of a possible hydrocarbon refrigerant flammability limits

Handling

HC refrigerant is available in 300 g (0.66 lb), 3.5 kg (7.7 lb), 12 kg (26.4 lb), and 46 kg (101.4 lb) cylinders, and 420 g (0.93 lb) non-refillable cylinders. HFO refrigerants are commonly available in 4.5 kg (10 lb) non-refillable cylinders.

A pressure relief valve is fitted to the refrigerant cylinders to prevent excess pressure build up. The cylinders are also fitted with a liquid off-take valve that incorporates a non-return (check) valve (to prevent field refilling) and a 1¼" ACME connection. A fitting is available to convert to refrigeration industry standard threaded fittings and can be obtained from the refrigerant supplier.

Tip

To avoid any static electrical spark, ensure that the refrigeration cylinder is grounded when not in use and before connecting to the system.

There is an automatic excess flow valve within the liquid valve. This valve activates to stop the supply of refrigerant if the refrigerant flow out of the cylinder is excessive. Excessive flow might be caused by a major leak in the system or a service hose that was disconnected. To reset the automatic excess valve, close the supply valve and then slowly reopen the valve.

Cautions

Always follow these safety precautions:

- ***Never apply an open flame or live steam to a refrigerant cylinder.***
- ***Do not cut or weld any refrigerant line when refrigerant is in the unit.***
- ***Always refit the valve cap when the cylinder is not in use.***
- ***To avoid any static electrical spark, ensure that the refrigeration cylinder is grounded when not in use and before connecting to the system.***
- ***Ensure the threads are clean and undamaged.***
- ***Store and use cylinders in dry well-ventilated areas away from any fire risk.***
- ***To prevent overheating, keep cylinders away from sources of heat.***
- ***Do not modify cylinders or cylinder valves.***
- ***Never roll cylinders along the ground.***
- ***Weigh the cylinder to ensure the cylinder is empty.***
- ***Only use dedicated recovery cylinders specifically designed for the flammable refrigerant for the recovery of flammable HFO and HC refrigerants.***

Sales Restrictions

According to the EPA [EPA, 2016b], no one may sell or distribute any Class I or Class II substance or, starting on January 1, 2018, any non-exempt substitute for use as a refrigerant unless the one of the following conditions are met:

- The buyer has been certified as a Type I, Type II, Type III, or Universal technician.

- The buyer employs at least one technician who is certified as a Type I, Type II, Type III, or Universal technician and provides proof to the seller.
- The buyer has been Section 609 MVAC certified and the refrigerant is acceptable for use in MVACs.
- The buyer employs at least one person who is Section 609 MVAC certified, provides proof of certification to the seller, and the refrigerant is acceptable for use in MVACs.
- The refrigerant is sold only for eventual resale to certified technicians or to appliance manufacturers (e.g., sold by a manufacturer to a wholesaler, sold by a technician to a reclaimer).
- The refrigerant is sold to an appliance manufacturer.
- The refrigerant is contained in an appliance (as part of the appliance) with a fully assembled refrigerant circuit.
- The refrigerant is charged into an appliance by a certified technician or a supervised apprentice during maintenance, service, or repair of the appliance.
- The non-exempt substitute refrigerant is intended for use in an MVAC and is sold in a container designed to hold two pounds or less of refrigerant, has a unique fitting, and has a self-sealing valve.

Persons who sell or distribute any Class I or Class II refrigerant, or starting on January 1, 2018, any non-exempt substitute refrigerant, must keep invoices that indicate the name of the purchaser, the date of sale, and the quantity of refrigerant purchased unless they are selling exempt substitutes or small cans of MVAC refrigerant.

All records must be kept for three years. Electronic or paper copies of all records must be maintained by manufacturers of containers holding two pounds or less of non-exempt substitute refrigerant for use in an MVAC to verify self-sealing valves meet the requirements. All records must be kept for three years after each purchase. (See Record Keeping Procedures on page 61 for more information.)

If the refrigerant is used, no person may sell or distribute any Class I or Class II substance or non-exempt substitute consisting wholly or in part of used refrigerant unless the refrigerant meets one of the following requirements:

- The refrigerant was reclaimed by a certified technician.
- The refrigerant has been recycled and was used only in an MVAC or MVAC-like appliance and is to be used only in an MVAC or MVAC-like appliance.
- The refrigerant is contained in an appliance that is sold or offered for sale together with a fully assembled refrigerant circuit.

- The refrigerant is being transferred between or among a parent company and one or more of its subsidiaries, or between or among subsidiaries having the same parent company.
- The refrigerant is being transferred between or among a Federal agency or department and a facility or facilities owned by the same Federal agency or department.

MVAC Self-sealing Valve Specifications

Effective January 1, 2018, all containers holding two pounds or less of non-exempt substitute refrigerant for use in an MVAC that are manufactured or imported on or after that date must meet the following requirements for self-sealing valves:

- Each container holding two pounds or less of non-exempt substitute refrigerant for use in an MVAC must be equipped with a single self-sealing valve that automatically closes and seals when not dispensing refrigerant.
- The leakage rate from each container must not exceed 3 g per year when the self-sealing valve is closed. This leakage rate applies to new, full containers as well as containers that could be partially full.
- The container must be tested for leakage by an independent test laboratory in the United States that is not owned, operated, or affiliated with the applicant certifying equipment and/or products.

Sales are permitted if the cans without self-sealing valves were manufactured or imported before 2018 [EPA, 2016b].

Shipping

Department of Transportation Regulations

Portable refillable recovery tanks or containers used to store or ship flammable refrigerants must meet DOT standards.

Shipping Labels

When transporting cylinders containing used refrigerant, DOT requires that you attach DOT classification tags. Before shipping any used refrigerant in a cylinder, you must properly label the refrigerant container.

The shipping paperwork provides the following:

- Vital information to first responders after an accident. This paper identifies the materials involved so protective actions can be taken for your own safety and the safety of the public.
- Proper shipping name of the refrigerant
- Hazard class
- 4-digit United Nations Identification number preceded by the letters UN.
- 24-hour emergency response telephone number

Cylinder Loading

When you load the cylinders into the vehicle for shipping, you MUST place the refrigerant cylinders in an upright position and secure the cylinders so they cannot move during transport.

Storage

When storing flammable refrigerants, you must take extra precautions because of their potential flammability. Local fire codes often restrict the storage of flammable materials. In addition, other federal, state, and local regulatory agencies might have regulations related to flammable refrigerants. Check with these authorities for more information.

Risk Assessment

Before storing any canisters with flammable HC and HFO refrigerants, you need to assess the following risks:

- Thermal radiation from a warehouse fire
- Explosion hazards
- Quantities of flammable material being stored
- Nature and location of materials stored
- Areas set aside for segregated storage of flammable substances
- Drainage systems
- Presence of neighbors with hazard potential
- The maximum number of persons on site and their likely locations
- Total quantity of hazardous substances and the maximum individual quantities
- Type and characteristics of the packaging

Major Accident Prevention Policy

If you decide to store flammable HC or HFO refrigerants, you need to ensure an accident prevention policy is written and followed. This plan should cover all the possible major hazards and be developed to include the following strategies:

- Inspect the storage containers for signs of damage, rust, corrosion, or deterioration. Replace any equipment or containers with questionable integrity or that could be faulty.
- Check the containers for refrigerant leaks on a regular basis.
- Install and maintain break-glass fire alarms in strategic locations.
- Install and maintain an alarm system that can be heard and seen (strobe light) by all employees.
- Display No Smoking signs.
- Establish at least two emergency evacuation assembly areas.
- Rehearse the evacuation procedures.
- Instruct employees to set off the alarm if a fire has broken out and then evacuate the building.
- Set up a well-equipped first aid room.
- Instruct employees to know the location of information for fire fighters, including the layout of building, type and quantity of hazardous materials, location and type of firefighting equipment, and the person to contact in the case of an emergency.

Procedures for Damaged Equipment

If any equipment or containers that contained flammable refrigerant are damaged, as a minimum implement the following procedures:

- Read the data on the hazards of the refrigerant.
- Wear appropriate personal protective equipment, such as safety goggles and protective clothing.
- Keep a fire extinguisher within reach.

Move the damaged or leaking equipment to a designated area that is far away from the main storage area, is well ventilated, is equipped with appropriate security features, and has segregated areas to ensure compliance with the rules for hazardous substances.

Record Keeping Procedures

Effective January 2018, you need to keep comprehensive records that track the flammable refrigerants being handled [EPA, 2016b]. This information should include the following:

- Chemical names and brand names of refrigerants
- Hazard category
- Storage location or all flammable substances, not just the refrigerants
- List of other relevant equipment used to handle the flammable refrigerants
- Details of electrical installations in the region where flammable refrigerants could be present
- All potential hazards to firefighters

All records must be kept for at least three years in electronic or paper format. Technicians must also record the amounts of ozone depleting substances (ODSs) and non-exempt substitute refrigerant transferred for reclamation by refrigerant type.

EPA requires you to maintain records of all refrigerant recovered during the disposal of any refrigerant containing appliance. You must record the total amount of refrigerant, by type, recovered from any appliance you dispose. This recordkeeping requirement has been developed to discourage the illegal venting of refrigerants during disposal. The EPA requires you to keep records when disposing of any appliance with a normal charge that is more than 5 and less than 50 pounds. These records include the following:

- Company name
- Location of the appliance
- Date of recovery
- Type of refrigerant recovered for each appliance

Chapter 7. Summary

This chapter lists two HC end-use case and summarizes allowable substitute refrigerants and use conditions. Additional information is also included that you might find helpful for each end use.

End Use 1

The first approved HC refrigerant end use is household refrigerators, freezers, and combination refrigerators and freezers (new equipment only).

Substitute Refrigerants

Isobutane (R-600a) and R-441A can be used as substitutes for CFC-12, HCFC-22, and R-134a.

Use Conditions

These refrigerants may be used only in new equipment designed specifically and clearly identified for the refrigerant (i.e., none of these substitutes can be used as a conversion or ‘‘retrofit’’ refrigerant for existing equipment designed for a different refrigerant).

These refrigerants may be used only in a refrigerator or freezer, or combination refrigerator and freezer, that meets all requirements listed in Supplement SA to the 10th edition of the Underwriters Laboratories (UL) Standard for Household Refrigerators and Freezers, UL 250, dated 1993, and updated August 2000. In cases where the EPA final rule includes requirements more stringent than those of the 10th edition of UL 250, the appliance must meet the requirements of the final rule in place of the requirements in the UL Standard.

The quantity of the substitute refrigerant (i.e., normal charge size) shall not exceed 57 g (2.0 ounces) in any refrigerator, freezer, or combination refrigerator and freezer for each circuit.

Safety Information

Applicable OSHA requirements at 29 CFR part 1910 must be followed, including those at 29 CFR 1910.106 (flammable and combustible liquids), 1910.110 (storage and handling of liquefied petroleum gases), 1910.157 (portable fire extinguishers), and 1910.1000 (toxic and hazardous substances).

Maintain proper ventilation at all times during the manufacture and storage of equipment containing hydrocarbon refrigerants through adherence to good manufacturing practices as per 29 CFR 1910.106. If refrigerant levels in the air surrounding the equipment rise above one-fourth of the lower flammability limit, evacuate the space. Only allow reentry after the space has been properly ventilated.

Wear appropriate personal protective equipment, including chemical goggles and protective gloves, when handling all refrigerants.

Tip

Take special care to avoid contact with your skin because the rapid evaporation of refrigerants can cause freeze burns on the skin.

Keep a class B dry-powder-type fire extinguisher nearby.

Only use spark-proof tools when working on refrigerators and freezers with HC refrigerants.

Use recovery equipment designed for flammable refrigerants. All equipment should be grounded, including refrigerant tanks both during use and storage.

Only technicians specifically trained and certified in handling flammable refrigerants should service refrigerators and freezers containing flammable HFO and HC refrigerants. You should gain an understanding of minimizing the risk of fire and the steps to use flammable refrigerants safely.

Permanent Markings

As provided in clauses SA6.1.1 and SA6.1.2 of UL Standard 250, the following permanent markings must be attached to the units.

On or Near Evaporators Contacted by Consumer

DANGER
Risk of Fire or Explosion.
Flammable Refrigerant Used.
Do Not Use Mechanical Devices To Defrost Refrigerator.
Do Not Puncture Refrigerant Tubing.

Near Machine Compartment

DANGER
Risk of Fire or Explosion.
Flammable Refrigerant Used.
To Be Repaired Only By Trained Service Personnel.
Do Not Puncture Refrigerant Tubing.

Near Machine Compartment

CAUTION
Risk of Fire or Explosion.
Flammable Refrigerant Used.
Consult Repair Manual/Owner's Guide Before Attempting To Service This Product.
All Safety Precautions Must be Followed.

Exterior of Refrigerator

CAUTION
Risk of Fire or Explosion.
Dispose of Properly In Accordance With Federal or Local Regulations.
Flammable Refrigerant Used.

Near Exposed Refrigerant Tubing

CAUTION
Risk of Fire or Explosion Due To Puncture Of Refrigerant Tubing;
Follow Handling Instructions Carefully.
Flammable Refrigerant Used.

The letters for these markings must be at least ¼ inch high. The refrigerator, freezer, or combination refrigerator and freezer must have red (PMS #185) marked pipes, hoses, or other devices through which the refrigerant is serviced (typically known as the service port) to indicate the use of a flammable refrigerant.

This red color must be present at all service ports and where service puncturing or otherwise creating an opening from the refrigerant circuit to the atmosphere might be expected (e.g., process tubes). The color mark must extend at least 1 inch from any possible refrigerant service port or process tube and must be replaced if removed.

End Use 2

The second approved HC refrigerant end use is commercial (retail) food refrigerators and freezers (standalone units and new equipment only).

Substitute

Propane (R-290) can be used as a substitute for CFC-12, HCFC-22, and R-502.

Use Conditions

As with End Use 1, these refrigerants may be used only in new equipment specifically designed and clearly identified for the refrigerants (i.e., none of these substitutes may be used as a conversion or "retrofit" refrigerant for existing equipment designed for other refrigerants).

These substitutes may only be used in equipment that meets all requirements in Supplement SB to the 10th edition of the Underwriters Laboratories (UL) Standard for Commercial Refrigerators and Freezers, UL 471, dated November 2010. In cases where the final rule includes requirements more stringent than those of the 10th edition of UL 471, the appliance must meet the requirements of the final rule in place of the requirements in the UL Standard.

The charge size for the retail food refrigerator or freezer shall not exceed 150 g (5.3 ounces) in each circuit.

Permanent Markings

The permanent markings for this use case are the same as Use Case 1.

UL References

These use conditions contain references to certain standards from Underwriters Laboratories Inc. (UL). The standards are incorporated by reference, and the referenced sections are made part of the regulations in part 82:

- UL 250: Household Refrigerators and Freezers. 10th edition. Supplement SA: Requirements for Refrigerators and Freezers Employing a Flammable Refrigerant in the Refrigerating System. Underwriters Laboratories, Inc. August 25, 2000.
- UL 471. Commercial Refrigerators and Freezers. 10th edition. Supplement SB: Requirements for Refrigerators and Freezers Employing a Flammable Refrigerant in the Refrigerating System. Underwriters Laboratories, Inc. November 24, 2010.

For information on the availability of this material at NARA, call (202) 741-6030, or go to http://www.archives.gov/federal_register/code_of_federal_regulations/ibr_locations.html.

End Use 3

Although HFO-1234yf is not yet being used in stationary HVAC/R systems, Cadillac XTS, Chrysler (200C, 200S, 300, 300C), Dodge (Challenger, Charger, Dart, Ram 1500), Fiat 500, and Jeep (Cherokee, Renegade) have all switched to the use of R-1234yf refrigerant in their vehicle A/C systems.

Substitute Refrigerants

Although not a drop in replacement, R-1234yf is being used as a substitute for CFC-12, HCFC-22, and R-134a. The performance of HFO-1234yf closely matches that of HFC-134a.

Along with being adopted for motor vehicle air conditioning (MVAC) systems, HFO-1234yf also has potential for chillers and commercial refrigeration applications that currently use HFC-134a.

End Use 4

R-1234zd is suitable for new industrial air conditioning applications and the cooling of buildings where cooling water or intermediate fluids are used in large systems with centrifugal compressors (one or more stages) and where R-123 might have been used in the past. Linde and Honeywell market this refrigerant as Solstice® ZD and as a replacement for R-123 in new chiller applications [Honeywell, 2017].

However, compressors using this new refrigerant require larger impeller diameters for the same cooling capacity because of the substantially lower volumetric cooling capacity and the higher required compression ratio.

End Use 5

R-1234ze has two isomers, R-1234ze(Z) and R-1234ze(E) with different properties. R-1234ze(Z) has a higher boiling point (50.0 °F) associated with a higher critical temperature (308.7 °F) and a volumetric capacity roughly 50% lower than R-1234ze(E). R-1234ze(E) is the isomer that is typically sold for use and is marketed as Solstice ZE. Because there is currently no HVAC/R application for R-1234ze(Z), the R-1234ze that is typically sold is the (E) isomer. Currently, R-1234ze(E) is being used as a replacement for R-22.

End Use 6

HFO-1336mzz is another refrigerant being considered as a replacement for the R-123 in centrifugal chillers and as a working fluid in high-temperature heat pumps.

Chapter 8. Acronyms

AEGL—acute exposure guideline level

AEL—acceptable exposure level

AHRI—Air-Conditioning, Heating, and Refrigeration Institute

ASHRAE—American Society of Heating, Refrigerating and Air-Conditioning Engineers

CAA—Clean Air Act

CAS—Chemical Abstracts Service

CFC—chlorofluorocarbon

CFR—Code of Federal Regulations

CO_2—carbon dioxide

DIY—do it yourself

DOT—Department of Transportation

EPA—United States Environmental Protection Agency

EPDM—ethylene propylene diene terpolymer

FR—Federal Register

g—gram

GWP—global warming potential

HC—hydrocarbon

HCFC—hydrochlorofluorocarbon

HFC—hydrofluorocarbon

HFO—hydrofluoroolefin

HNBR— hydrogenated nitrile butadiene rubber

ICF—ICF International, Inc.

IPR—industrial process refrigeration

kg—kilogram

kJ—kilojoule

kPa—kilopascal

LFL—lower flammability limit

NARA—National Archives and Records Administration

NOAEL—no observable adverse effect level

OEM—original equipment manufacturer

ODP—ozone depletion potential

ODS—ozone-depleting substance

OSHA—United States Occupational Safety and Health Administration

PAG—polyalkylene glycol lubricant

PAO—poly-alpha-olefin lubricant

PMS—Pantone® Matching System

ppm—parts per million

psia—pounds per square inch absolute

psig—pounds per square inch gauge

PTFE—polytetrafluoroethylene

RfC—reference concentration

RTOC—Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee

SAE—Society of Automotive Engineers

SNAP—Significant New Alternatives Policy

TEAP—Technology and Economic Assessment Panel

TLV—Threshold Limit Value

TWA—time-weighted average

UL—Underwriters Laboratories Inc.

UNEP—United Nations Environment Programme

VOC—volatile organic compound

WGL—workplace guidance level

WMO—World Meteorological Organization

Chapter 9. Definitions

Adequate ventilation. According to OSHA regulations at 29 CFR 1910.110, ventilation is adequate when the concentration of the gas in a gas–air mixture does not exceed 25% of the lower flammable limit or subject to alternative safety provisions.

Appliance. Any device that contains and uses a refrigerant and is used for household or commercial purposes, including any air conditioner, refrigerator, chiller, or freezer. Thus a refrigerator, freezer, or combination refrigerator and freezer, for example, could consist of two appliances provided that the refrigerant in the first appliance (i.e., the first compressor, condenser, evaporator, and metering device) does not mix with the refrigerant in the second appliance (e.g., the second compressor, condenser, evaporator, and metering device).

Asphyxia. The displacement of the oxygen in a room by the denser refrigerant.

Azeotrope. A blend of two or more components whose equilibrium vapor-phase and liquid-phase compositions are the same at a given pressure. This means there is no temperature glide. These refrigerants are given a 500-series ASHRAE designation and behave like a single refrigerant with the bubble point and dew point being the same temperature. Azeotropes can be charged as a liquid or vapor.

Bubble point. The temperature at which a refrigerant first begins to evaporate (boil). The temperature difference between the dew point and the bubble point is the temperature glide of a non-azeotropic blend. Azeotrope blends or pure refrigerants have no temperature glide—the dew point temperature and bubble point temperature are the same.

Capillary tube. A passive throttling device comprised of a small-diameter long tube located upstream of the evaporator that drops the pressure in the system, causing refrigerant to flash into a two-phase mixture. It does not actively control the pressure drop to maintain a prescribed superheat at the exit of the evaporator.

Class I refrigerant. Refrigerants that have an ozone depletion potential (ODP) greater than 0.2. All chlorofluorocarbons (CFCs) are Class I refrigerants. The use of Class I refrigerants has been completely phased out.

Class II refrigerant. Refrigerants that have an ozone depletion potential (ODP) less than 0.2 and compounds containing hydrogen, fluorine, chlorine, and carbon atoms. Although ozone depleting substances, they are less potent at destroying stratospheric ozone than chlorofluorocarbons (CFCs).

Commercial refrigeration. Refrigeration appliances used in retail food and cold storage warehouse sectors. Retail food includes the refrigeration equipment found in supermarkets, convenience stores, restaurants, and other food service establishments. Cold storage includes the equipment used to store meat, produce, dairy products, and other perishable goods.

Compound. Substance formed by a union of two or more elements in a definite proportion by weight.

Critical component. Component without which the equipment or appliance will not function, will be unsafe in its intended environment, and/or will be subject to failures that would cause the equipment or appliance to be unsafe.

Dehydrate. To remove water from the system.

Deep vacuum. Evacuation of a system down to a low vacuum, typically below 500 microns, with the goal of removing non-condensable gases as well as evaporating and removing water from the system. All systems should be evacuated to at least 500 microns, ideally 300 microns.

Degrees Celsius. Temperature scale, abbreviated as °C, where water boils at 100 °C and freezes at 0 °C. To convert from degrees Celsius to degrees Fahrenheit, multiply the temperature in degrees Celsius by 1.8 and add 32.

Degrees Fahrenheit. Temperature scale, abbreviated as °F, where water boils at 212 °F and freezes at 32 °F. To convert degrees Fahrenheit to degrees Celsius subtract 32 from the temperature in degrees Fahrenheit then divide by 1.8. To convert from degrees Fahrenheit to degrees Rankine add 460.

Degrees Kelvin. Absolute temperature scale, abbreviated as K, where water boils at 373 K and freezes at 273 K. To convert from degrees Rankine to Celsius subtract 273.

Degrees Rankine. Absolute temperature scale, abbreviated as °R, where water boils at 672 °R and freezes at 492 °R. To convert from degrees Rankine to Fahrenheit subtract 460.

Dew point. Temperature at which a liquid first begins to condense. The temperature difference between the dew point and the bubble point is the temperature glide of a non-azeotropic blend. Azeotrope blends or pure refrigerants have no temperature glide—the dew point temperature and bubble point temperature are the same.

Disposal. Process leading to and including any of the following:

- The discharging, depositing, dumping, or placing of any discarded appliance into or on any land or water.
- The disassembly of any appliance for discharging, depositing, dumping, or placing of its discarded component parts into or on any land or water.
- The disassembly of any appliance for reuse of its component parts.

Electronic vacuum gauge or micron gauge. Electronic vacuum gauge that displays the vacuum level directly in microns and is the only accurate field method to determine the evacuation level of a deep vacuum.

Evacuation. The process of extracting any air, non-condensable gases, or water from the system and thereby reducing the pressure to some value below 0 psig.

EXV. The abbreviation for an electronic expansion valve, a throttling device located upstream of the evaporator, that actively controls the pressure drop (via electrical feedback from a temperature sensor) to maintain a prescribed superheat at the exit of the evaporator.

Fractionation. The separation of a liquid mixture into separate parts by the preferential evaporation of the more volatile component.

Follow-up verification test. Test that involves checking the repairs within 30 days of when the appliance returns to normal operating characteristics and conditions. Follow-up verification tests for appliances from which the refrigerant charge has been evacuated means a test conducted after the appliance or portion of the appliance has resumed operation at normal operating characteristics and conditions of temperature and pressure, except in cases where sound professional judgment dictates that these tests would be more meaningful if performed before the return to normal operating characteristics and conditions. A follow-up verification test with respect to repairs conducted without evacuation of the refrigerant charge means a reverification test conducted after the initial verification test and usually within 30 days of normal operating conditions. Where an appliance is not evacuated, you only need to conclude any required changes in pressure, temperature, or other conditions to return the appliance to normal operating characteristics and conditions.

Full charge or Normal charge. Amount of refrigerant required for normal operating characteristics and conditions of the appliance as determined by using one or a combination of the following four methods:

- Use of the equipment manufacturer’s determination of the normal charge
- Use of appropriate calculations based on component sizes, density of refrigerant, volume of piping, and other relevant considerations
- Use of actual measurements of the amount of refrigerant added to or evacuated from the appliance, including for seasonal variances
- Use of an established range based on the best available data regarding the normal operating characteristics and conditions for the appliance, where the midpoint of the range serves as the normal or full charge

Halocarbon. Halogenated hydrocarbon containing one or more of the three halogens: fluorine, chlorine, and bromine. Hydrogen may or may not be present.

High-pressure appliance. An appliance that uses a refrigerant with a liquid phase saturation pressure between 170 psia and 355 psia at 104°F. This definition includes but is not limited to appliances using R-401A, R-409A, R-401B, R-411A, R-22, R-411B, R-502, R-402B, R-408A, R-410A, and R-402A.

Hydrocarbon. Compound containing only the elements hydrogen and carbon.

Initial verification test. Leak tests that are conducted after the repair is finished to verify that a leak or leaks have been repaired before refrigerant is added back to the appliance.

Isomer. One of a group of substances having the same combination of elements but arranged spatially in different ways.

King valve. Combination shut-off and service valve typically used on the inlet and outlet of a compressor, and on the inlet and outlet of packaged condensing units.

Leak inspection. Examination of an appliance to *determine the location of refrigerant leaks*. Potential methods include, but are not limited to, ultrasonic tests, gas-imaging cameras, bubble tests, or the use of a leak-detection device operated and maintained according to manufacturer guidelines. Methods that determine whether the appliance is leaking refrigerant but not the location of a leak, such as standing pressure decay tests, sight glass checks, viewing receiver levels, pressure checks, and charging charts, must be used in conjunction with methods that can determine the location of a leak.

Leak rate. The rate at which an appliance is losing refrigerant, measured between refrigerant charges and projected over the next 12 months. The leak rate is expressed in terms of the percentage of the full charge of the appliance that would be lost in the next 12 months if the current rate of loss were to continue over that period. Use the following three steps to determine the leak rate:

Step 1. Determine the *Refrigerant Added*, which is the amount of leaking refrigerant as the sum of the pounds of refrigerant added to the appliance over the period in days (*D*) that has passed since the last time the unit was properly charged. If *D* is greater than 365, use 365 instead.

Step 2. Determine the normal or *Total Charge*.

Step 3. Use the following formula to determine the leak rate as a percentage.

$$\frac{\frac{\text{Refrigerant Added}}{\text{Total Charge}} \times 365 \text{ days per year}}{D} \times 100$$

D = ***the shorter*** *of the number of days since refrigerant was last added* ***or*** *365 days*

LFL. Lower flame limit. The minimum concentration in air at which flame propagation occurs.

Low-loss fitting. Any device that is intended to establish a connection between hoses, appliances, or recovery/recycling machines, and that is designed to close automatically or to be closed manually when disconnected to minimize the release of refrigerant from hoses, appliances, and recovery or recycling machines.

Low-pressure appliance. An appliance that uses a refrigerant with a liquid phase saturation pressure below 45 psia at 104 °F. This definition includes but is not limited to appliances using R-11, R-123, R-113, and R-245fa.

Major maintenance, service, or repair. A service or repair that involves removal of the compressor, condenser, evaporator, or auxiliary heat exchanger coil.

Medium-pressure appliance. An appliance that uses a refrigerant with a liquid phase saturation pressure between 45 psia and 170 psia at 104 °F. This definition includes but is not limited to appliances using R-114, R-124, R-12, R-134a, and R-500.

Micron. One thousandth (1/1,000) of a millimeter of mercury vacuum. Atmospheric pressure is 760 mm of mercury or 760,000 microns.

Mixture. Blend of two or more components that do not have a fixed proportion to one another and that no matter how well blended, they still retain a separate existence (oil and water, for example).

Mothball. To evacuate refrigerant from an appliance, or the affected isolated section or component of an appliance, to at least atmospheric pressure, and to temporarily shut down that appliance.

Motor vehicle air conditioner (MVAC). Mechanical vapor compression refrigeration equipment used to cool the driver or passenger compartment of any motor vehicle. Technicians who repair or service MVAC systems for consideration (e.g., payment or bartering) must be trained and certified under Section 609 by an EPA-approved technician training and certification program such as Mainstream's (www.epatest.com). Section 609 certification is required to service any MVAC system for consideration (e.g., payment or bartering), regardless of what refrigerant is used in the system.

Non-azeotropic refrigerant. Synonym for zeotropic, which is the preferred term though less commonly used as a descriptor. Non-azeotropic or zeotropic refers to blends comprising multiple components of different volatilities that, when used in refrigeration cycles, change volumetric composition and saturation temperatures (exhibit temperature glide) as they evaporate (boil) or condense at constant pressure. These refrigerants are given a 400-series ASHRAE designation.

Non-condensables. Gases that do not condense anywhere in the vapor compression system and typically accumulate in the condenser.

Normal charge or Full charge. Quantity of refrigerant within the appliance or appliance component when the appliance is operating with a full charge of refrigerant.

Normal operating characteristics and conditions. Appliance operating temperatures, pressures, fluid flows, speeds, and other characteristics, including full charge of the appliance, that would be expected for a given process load and ambient condition during normal operation. Normal operating characteristics and conditions are marked by the absence of atypical conditions affecting the operation of the appliance.

Opening an appliance. Any maintenance, service, repair, or disposal of an appliance that would release any refrigerant in the appliance to the atmosphere. Connecting and disconnecting hoses and gauges to measure pressures, add refrigerant, or recover refrigerant from the appliance are not considered opening an appliance.

Process stub or Process tube. Length of tubing that provides access to the refrigerant inside a small appliance or room air conditioner that can be resealed at the conclusion of repair or service. After refrigerant is added or removed, the process tube is usually pinched to stop refrigerant flow and then could be brazed to provide a long-lasting seal. The tube is used solely as a refrigerant access point for service technicians and must contain a red stripe at least 1 inch long when the system contains flammable refrigerant.

psia. Absolute pressure in pounds per square inch, where 0 psia corresponds to 29.9 inches of mercury vacuum, and 14.7 psia corresponds to atmospheric pressure 0 psig (pounds per square inch gauge).

psig. Gauge pressure in pounds per square inch, where 0 psig corresponds to atmospheric pressure (14.7 psia). A positive psig value indicates the pressure in pounds per square inch above the ambient pressure.

Reclamation. To reprocess recovered refrigerant to all of the specifications in AHRI Standard 700-2016, Specifications for Refrigerants that are applicable to that refrigerant and to verify that the refrigerant meets these specifications using the analytical methodology described in the standard.

Recovery. To remove refrigerant in any condition from an appliance and to store it in an external container without necessarily testing, cleaning, filtering, or processing it in any way.

Recovery efficiency. The percentage of refrigerant in an appliance that is recovered (relative to the total charge).

Recovery vacuum. Used to recover refrigerant in the system and prevent its escape into the atmosphere. This evacuation, which uses an EPA-approved recovery or recycling machine, is performed on a charged refrigeration system before the system is opened for repair. Like any other vacuum, it is never used to determine if the system has any leaks. Before a Recovery Evacuation is to be performed, the required evacuation level must be determined based on the quantity and type of charge, and the manufacture date of the recovery equipment. If the system has a leak, you only need to recover to atmospheric pressure to avoid ingesting air into the recovered refrigerant.

Recycling. To extract refrigerant from an appliance and to clean refrigerant for reuse without meeting all of the requirements for reclamation. In general, recycled refrigerant is refrigerant that is cleaned using oil separation and single or multiple passes through devices such as replaceable core filter driers, which reduce moisture, acidity, and particulate matter. However, no test is required to be performed to verify that the refrigerant was actually cleaned in any way.

Refrigerant. The fluid used for heat transfer in a refrigeration system, which absorbs heat during evaporation at low temperature and pressure, and releases heat during condensation at a higher temperature and pressure. A refrigerant is any Class I or Class II substance or its substitute that is used for cooling or refrigeration.

Refrigerant circuit. Parts of an appliance that are normally connected to each other (or are separated only by internal valves) and are designed to contain refrigerant.

Refrigerant equipment. Equipment used for providing refrigeration, freezing, or cooling.

Refrigerant migration. Movement of refrigerant to the coldest part of the system when an operating system is shut down.

Retire. When referring to an appliance, the removal of the refrigerant and the disassembly or impairment of the refrigerant circuit such that the appliance as a whole is rendered unusable by any person in the future.

Retrofit. To convert an appliance from one refrigerant to another refrigerant. Retrofitting includes the conversion of the appliance to achieve system compatibility with the new refrigerant and could include, but is not limited to, changes in lubricants, gaskets, filters, driers, valves, o-rings, or appliance components.

RfC. Refrigerant concentration level. The safe RfC is the concentration of refrigerant that is considered a safe level to protect the general population against adverse systemic (i.e., non-cancer) health effects.

Sealed system. Independently operated refrigeration system, including a compressor, evaporator, condenser, metering device, and refrigerant. For example, a refrigerator-freezer might employ one sealed system to chill food in the refrigerator section and a second sealed system to keep food frozen in the freezer compartment.

Self-contained recovery equipment. Recovery or recycling equipment that is capable of removing refrigerant from an appliance without the assistance of components contained in the appliance.

Small appliance. Any appliance that is fully manufactured, charged, and hermetically sealed in a factory with five pounds or less of refrigerant, including, but not limited to, refrigerators and freezers (designed for home, commercial, or consumer use), medical or industrial research refrigeration equipment, room air conditioners (including window air conditioners, portable air conditioners, and packaged terminal air heat pumps), dehumidifiers, under-the-counter ice makers, vending machines, and drinking water coolers.

Substitute. Any chemical or product substitute, whether existing or new, used as a refrigerant to replace a Class I or II ozone-depleting substance. Examples include, but are not limited to, hydrofluorocarbons, perfluorocarbons, hydrofluoroolefins, hydrofluoroethers, hydrocarbons, ammonia, carbon dioxide, and blends thereof.

System-dependent recovery equipment. Refrigerant recovery equipment that requires the assistance of components contained in an appliance to remove the refrigerant from the appliance.

System mothballing. Intentional shut down of a refrigeration appliance undertaken for an extended period of time by the owners or operators of that facility, where the refrigerant has been evacuated from the appliance or the affected isolated section of the appliance, at least to atmospheric pressure.

Technician. Any person who in the course of maintenance, service, or repair of an appliance (except MVACs) could be reasonably expected to violate the integrity of the refrigerant circuit and therefore release refrigerants into the environment. Technician also means any person who in the course of disposal of an appliance (except small appliances, MVACs, and MVAC-like appliances) could be reasonably expected to violate the integrity of the refrigerant circuit and therefore release refrigerants from the appliances into the environment. Activities reasonably expected to violate the integrity of the refrigerant circuit include but are not limited to the following: attaching or detaching hoses and gauges to and from the appliance; adding or removing refrigerant; adding or removing components; and cutting the refrigerant line. Activities such as painting the appliance, rewiring an external electrical circuit, replacing insulation on a length of pipe, or tightening nuts and bolts are not reasonably expected to violate the integrity of the refrigerant circuit. Activities conducted on appliances that have been properly evacuated are not reasonably expected to release refrigerants unless the activity includes adding refrigerant to the appliance. Technicians could include but are not limited to installers, contractor employees, in-house service personnel, and owners and/or operators of appliances.

Temperature glide. Difference between the dew point and the bubble point.

Triple evacuation. Evacuation method where the system is evacuated (pulled-down) initially to a vacuum of at least 500 to 2,000 microns. Then, a small amount of dry nitrogen is introduced into the system to raise the pressure to above ambient pressure (typically to about 15 psig). The purpose of the nitrogen is to absorb moisture from the system. The nitrogen is then purged (vented). Recovery of the nitrogen is not required. This process is repeated two additional times (or more if necessary) until a final evacuation of at least 500 microns is achieved.

TXV. Thermal expansion valve, which is a throttling device located upstream of the evaporator that actively controls the pressure drop (via the effect of the pressure developed in a sensing bulb acting on a metering valve) to maintain a prescribed superheat at the exit of the evaporator.

Vacuum pump. Device used to pump the air, moisture, and other non-condensables out of a system and, hence, evacuate the system. The extraction of the air and non-condensables lowers the pressure inside of the system (below atmospheric pressure), which causes any trapped liquid water to evaporate and be exhausted by the vacuum pump. Single-stage and two-stage vacuum pumps are commonly used in the HVAC/R industry. A two-stage vacuum pump is necessary to pull the deep vacuums (below 500 microns), which are necessary for the proper evacuation and removal of water in systems. Both the single-stage and two-stage vacuum pumps are rated by their volumetric capacity, typically expressed in cubic feet per minute (cfm). Three to six cfm pumps are typically used in residential applications.

References

ACRIB (Air Conditioning and Refrigeration Industry Board). 2001. *Guidelines for the use of Hydrocarbon Refrigerants in Static Refrigeration and Air Conditioning Systems*, Carshalton, Surrey SM5 2JR, acrib@acrib.org.uk.

Air-Conditioning, Heating, and Refrigeration Institute. 2016. *Guideline for Assignment of Refrigerant Container Colors, Guideline N with Addendum 1*. http://www.ahrinet.org/App_Content/ahri/files/Guidelines/AHRI_Guideline_N_2016.pdf. Accessed 24 February 2017.

Arkema. 2016. U.S. EPA approves Arkema's Forane® 449B refrigerant for applications under SNAP program. http://www.arkema-americas.com/en/media/news-overview/news/U.S.-EPA-approves-Arkemas-Forane-449B-refrigerant-for-applications-under-SNAP-program/. Accessed 29 January 2017.

A.S. Trust & Holdings, Inc. 2007. Significant New Alternatives Policy Program Submission to the United States Environmental Protection Agency. June 2007.

A.S. Trust & Holdings, Inc. 2009. HCR-188C New Composition. Follow-up to the HCR-188C Significant New Alternatives Policy Program Submission to the United States Environmental Protection Agency. August 2009.

Ben and Jerry's. 2008. Ben and Jerry's/Unilever, Significant New Alternatives Policy Program Submission to the United States Environmental Protection Agency, October 2008.

Bolaji, B. O., and Z. Huan. 2012. Comparative analysis of the performance of hydrocarbon refrigerants with R22 in a sub-cooling heat exchanger refrigeration system. *Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy*, 226 (7), 882–891.

Chemours. Opteon™ YF cools like HFC-134a in automotive air conditioning systems. https://www.chemours.com/businesses-and-products/fluoroproducts/opteon-yf/. Accessed 21 Jan 2017.

EPA. 2016a. Protection of Stratospheric Ozone: New Listings of Substitutes; Changes of Listing Status; and Reinterpretation of Unacceptability for Closed Cell Foam Products Under the Significant New Alternatives Policy Program; and Revision of Clean Air Act Section 608 Venting Prohibition for Propane. Federal Register, Vol. 81, No. 231, December 1, 2016.

EPA. 2016b. Protection of Stratospheric Ozone: Update to the Refrigerant Management Requirements under the Clean Air Act. 40 CFR Part 82 [EPA-HQ-OAR-2015-0453; FRL-9950-20-OAR] RIN: 2060-AS51.

EPA, 2015. Protection of Stratospheric Ozone: Change of Listing Status for Certain Substitutes Under the Significant New Alternatives Policy Program; Final Rule. Federal Register, Vol. 80, No. 138. July 20, 2015.

EPA, 2015. Protection of Stratospheric Ozone: Listing of Substitutes for Refrigeration and Air Conditioning and Revision of the Venting Prohibition for Certain Refrigerant Substitutes. Final Rule. Federal Register, Vol. 80, No. 69, April 10, 2015.

EPA, 2011. Protection of Stratospheric Ozone: Listing of Substitutes for Ozone-Depleting Substances—Hydrocarbon Refrigerants. Final Rule. Federal Register, Vol. 76, No. 244, December 20, 2011, Rules and Regulations.

EPA, 1994. Significant New Alternatives Policy Technical Background Document: Risk Screen on the Use of Substitutes for Class I Ozone-Depleting Substances: Refrigeration and Air Conditioning. Stratospheric Protection Division. March, 1994.

GE, 2008. General Electric. Significant New Alternatives Policy Program Submission to the United States Environmental Protection Agency, October 2008.

Green Car Congress. 2014. LMU study finds 20% of gases from combustion of R1234yf MAC refrigerant consist of highly toxic carbonyl fluoride. http://www.greencarcongress.com/2014/04/20140411-lmu.html. Accessed 27 Jan 2017.

Honeywell. Solstice® yf Refrigerant. https://www.honeywell-refrigerants.com/americas/product/solstice-yf-refrigerant/. Accessed 25 Jan 2017.

ICF, 2009a. ICF Consulting. "Significant New Alternatives Policy Program—Refrigeration and Air Conditioning Sector—Risk Screen on Substitutes for CFC-12 in Household Refrigerators and Household Freezers—Substitute: Isobutane." May 22, 2009.

ICF, 2011a. ICF Consulting. ''Significant New Alternatives Policy Program Refrigeration and Air Conditioning Sector—Risk Screen on Substitutes for CFC-12 and HCFC-22 in Household Refrigerators and Household Freezers—Substitute: Isobutane.'' June 2011.

IPCC/TEAP, 2005. Safeguarding the Ozone Layer and the Global Climate System: Special Report of the Intergovernmental Panel on Climate Change. Edited by Bert Metz, Lambert Kuijpers, Susan Solomon, Stephen O.

Andersen, Ogunlade Davidson, Jose Pons, David de Jager, Tahl Kestin, Martin Manning and Leo Meyer. Cambridge University Press. 2005. Available online at: *http://www.ipcc.ch/pdf/special-reports/sroc/sroc_full.pdf.*

Little, A.D., 1991. Risk Assessment of Flammable Refrigerants for Use in Home Appliances (draft report). Arthur D. Little, Inc., for EPA, Division of Global Change. September 10, 1991. Docket item EPA-HQ-OAR-2009-0286-0023.

ORNL, 1997. J. Sand, S. Fischer, and V. Baxter, ''Energy and Global Warming Impacts of HFC Refrigerants and Emerging Technologies,'' 1997, Oak Ridge National Lab.

RTOC, 2010. The 2010 Report of the United Nations Environment Programme (UNEP)'s Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee (RTOC). Available online at *http://ozone.unep.org/Assessment_Panels/TEAP/Reports/RTOC/RTOC-Assessment-report-2010.pdf*.

Sciance, Fred. 2013. The Transition from HFC-134a to a Low-GWP Refrigerant in Mobile Air Conditioners HFO-1234yf. General Motors Public Policy Center, October 29. Downloaded from https://www.epa.gov/sites/production/files/2014-09/documents/sciance.pdf.

Wikipedia. https://en.wikipedia.org/wiki/List_of_refrigerants. Accessed 21 Jan 2017.

World Meteorological Organization (WMO), 2011. WMO Scientific Assessment of Ozone Depletion: 2010. Available online at *http://ozone.unep.org/Assessment_Panels/SAP/Scientific_Assessment_2010/index.shtml.*

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