Environmentally Safe Refrigerant Service
Tips & Techniques for Type I HVAC/R Technicians

Interactive Reference and Training Guide
for EPA Section 608 Type I Open Book Online
Certification in the Proper Use of Refrigerants,
Including Recovery, Recycling, and Reclamation

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Preface

The information in this course is intended for educational purposes only. Described procedures are for use only by qualified air conditioning and refrigeration service technicians. **This training course isn't a substitute for any equipment manufacturer's operator manual.**

Take safety precautions when using all heating, ventilation, and air conditioning (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. Use extreme caution when working with refrigerants; hoses can contain liquid refrigerant under pressure. Use only approved refillable storage cylinders. Don't overfill any storage cylinder beyond its rated capacity. Always wear safety glasses. Protect the skin from flash freezing. **Never turn on any equipment if you don't understand its operation. Where procedures described in this manual differ from those of a specific equipment manufacturer, follow the equipment manufacturer's instructions.**

Don't leave any refrigerant recovery or recovery–recycling machine ON and unsupervised. All refrigerant recovery and recycling devices are to be used by trained refrigeration technicians only. Again, misuse of refrigerant recovery and recycling devices can cause explosion and personal injury.

Technical and legislative information presented in this online course is current as of the date of the manual's latest publication. Because of rapidly advancing technology and changing regulations in the refrigerant recovery and recovery–recycling field, 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.

Mainstream Engineering Corporation assumes no liability for the use of information presented in this publication. This information is presented for educational purposes only. Consult your manufacturer's operator manuals 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 reuse refrigerants, and to prevent their escape into the atmosphere when servicing small appliance vapor compression systems. **This manual isn't intended to teach air conditioning–refrigeration system installation, troubleshooting, or repair.** Refrigeration technicians should already be well versed in these areas before taking this course.

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Introduction

This introduction will explain the following:

- Document conventions used in this training course
- Basic information about the Small Appliance service technicians who can be helped by using this book
- Certification information and summary of the online and proctored testing requirements

Document Conventions

All tips, notes, examples, cautions, and warnings appear with the following icons:

Certification Information

Technicians must pass an EPA-certified exam before performing maintenance, service, or repair that could be reasonably expected to release refrigerants from appliances into the atmosphere.

Activities that could violate the integrity of the refrigerant circuit include:

- Attaching and detaching hoses and gauges to and from the appliance to add or remove refrigerant or to measure pressure
- Adding refrigerant to and removing refrigerant from the appliance
- Replacing components of the refrigeration circuit including but not limited to the compressor, condenser, evaporator, expansion (throttling) device, or filter drier

Activities that aren't expected to violate the integrity of the refrigerant circuit include:

- Painting the appliance
- Cleaning the exterior of the evaporator or condenser coils
- Replacing fans or blowers
- Straightening heat exchanger fins
- Rewiring an electrical circuit
- Replacing insulation on a length of pipe
- Replacing a faulty capacitor, contactor, or potential relay
- Tightening nuts and bolts on the appliance

Performing maintenance, service, repair, or disposal of appliances that have been evacuated also wouldn't be expected to release refrigerants unless the maintenance, service, or repair consists of adding or removing refrigerant to the appliance.

The term technician includes, but isn't limited to, installers, contractor employees, in-house service personnel, and in some cases, owners and/or operators. All technicians must be certified by an approved technician certification program, such as the one offered by Mainstream Engineering Corporation (www.epatest.com).

When certified, your EPA Section 608 certification has no expiration date; however, EPA regulations can change after you become certified. Therefore, you are responsible for understanding and complying with any future changes in the law.

If you lose your certification card, you can demonstrate your certification to others by visiting Mainstream's certification website at www.epatest.com, or you can request a replacement card at this website. Certified by someone else, you can request a replacement card from your certifying organization.

Types of Technicians

Technician certification has three levels depending on the appliance you need to work on. The types of EPA certification are described in the following sections.

Type I Technicians

Technicians who maintain, service, or repair small appliances that reasonably could be expected to release refrigerants from the appliances into the atmosphere must be properly certified as Type I or Universal technicians. A small appliance is defined by the EPA as a unitary system that contains less than five pounds of refrigerant charge, such as small refrigerators, water coolers, window air conditioners, and dehumidifiers.

The Type I Small Appliance certification is available as either an open-book online exam (with a higher score requirement for passing) or a closed-book proctored format. Only Type I certification is available in the open-book online format.

Note

If you take the Core exam in the open-book format and later want to receive a Type II, Type III, or Universal certification, you must retake the Core exam in a proctored environment. You won't need to repeat the 25 Type I questions.

Type II Technicians

Type II technicians maintain, service, or repair medium-, high-, or very high-pressure appliances that don't qualify as small appliances. Individuals who dispose of medium-, high-, or very high-pressure appliances must also be properly certified as Type II technicians. Essentially, if you work on any system that doesn't qualify as a small appliance or a low-pressure system (or motor vehicle air conditioners [MVAC] or MVAC-like system), you need Type II or Universal certification.

Technicians receiving a passing grade on the Type II exam and the Core exam are certified to recover refrigerant during the maintenance, service, or repair of medium- and high-pressure equipment and very high-pressure refrigerants, including CFC-13 and CFC-503.

Type III Technicians

Technicians who maintain, service, or repair low-pressure appliances or dispose of low-pressure appliances that could be expected to release refrigerants from appliances into the atmosphere must be properly certified as Type III or Universal technicians.

Universal Technicians

If you hold Type I, Type II, and Type III certifications, you are issued a Universal certification card and are eligible to maintain, service, or repair all appliances covered by each of those certifications.

Universal certification doesn't include motor vehicle air conditioning (MVAC) certification. If you also work on MVAC systems, you need a Section 609 MVAC certification as well.

MVAC Technicians

Technicians who maintain, service, or repair motor vehicle air conditioners (MVACs) must be properly certified as Section 609 MVAC technicians. Mainstream also offers the MVAC Section 609 certification exam and training materials at www.epatest.com. The MVAC certification is a 25-question, open-book format.

MVAC systems provide passenger comfort cooling for cars, trucks, buses, and rail vehicles. If you are working on an MVAC system and payment of any kind is involved (including non-monetary), you must be certified under Section 609 of the Clean Air Act, and you must use approved refrigerant-handling equipment. Mainstream also offers online training and testing for EPA Section 609 MVAC certification.

Technicians who service or repair MVAC-like appliances (e.g., farm equipment and other non-road vehicles) can choose to be certified under either the Section 609 MVAC program or the Section 608 Type II program.

However, any car, bus, train, or off-road equipment that uses an air conditioner operating on R-22 or any other high-pressure non-exempt refrigerant (such as R-407C or R-410A) isn't considered an MVAC or MVAC-like AC unit. Because these air conditioners use a high-pressure refrigerant, the service technician must have a Section 608 Type II (or Universal) certification. Therefore, if you are servicing such equipment, you should obtain Section 608 Type II certification.

The EPA definition for MVAC-like appliances is a mechanical vapor-compression appliance used to cool the driver or passenger compartment of an off-road motor vehicle using a low- or medium-pressure refrigerant and a refrigerant charge of less than 20 pounds.

Note

Emerging electric vehicles use hermetically sealed compressors that are electric powered. These compressors can be serviced by MVAC Section 609 certified technicians as long as the compressors don't use a high-pressure refrigerant such as R-22, R-407C, R-410A, or R-1234yf.

If the air conditioner uses a high-pressure refrigerant (except carbon dioxide), Section 608 certification is required. Although carbon dioxide is a high-pressure refrigerant, it is an exempt refrigerant, making it exempt from any certification requirements.

Examination Details

Mainstream Engineering is approved by the EPA as a certifying agency for Section 608 Type I, II, III, and Universal exams, as well as Section 609 MVAC certification.

Mainstream also offers other training and certification exams, including Techniques and Regulations for the Safe Handling of Flammable Hydrocarbon (HC) and Hydrofluoroolefin (HFO) Refrigerants, R-410A Service Techniques, Green Certification, Preventive Maintenance Certification, and Indoor Air Quality Certification. Information on these training and certification programs is available at www.epatest.com.

Type I, II, and III certification exams consist of 25 Core questions and 25 specific Type I, II, or III questions for a total of 50 multiple choice questions.

The Universal certification exam consists of 25 Core questions, 25 Type I questions, 25 Type II questions, and 25 Type III questions for a total of 100 multiple choice questions.

Technicians can take any of the certification exams as many times as necessary. The passing grade for the Type I open-book online exam is 84 percent (21 of 25 correct).

When retaking the exam, you only need to repeat the sections you haven't already passed. For example, if you took the Core exam and the Type I exam, passed the Core exam, but failed the Type I exam, you would only need to retake the 25 questions of the Type I exam.

Note

As stated earlier, if you take the Core exam in the open-book format and later want to receive a Type II, Type III, or Universal certification, you must retake the 25 Core exam questions in a proctored environment, but you don't need to retake the 25 Type I exam questions.

Core Section

Ozone Depletion

Earth's Atmosphere

The earth's atmosphere is composed of the troposphere and the stratosphere. The troposphere, the lowest part of the atmosphere, extends from the earth's surface to approximately 9 miles into space at the equator but less at the polar regions.

The stratosphere, which is the layer above the troposphere, extends approximately 30 miles into space. The stratospheric layer contains 90 percent ozone, which is a gas that helps form the earth's protective shield against the sun's harmful ultraviolet (UV-B) rays.

Ozone

Ozone in the stratosphere is a fairly simple, yet unstable, molecule made up of three oxygen atoms. The instability of the molecule allows free oxygen atoms to react easily with nitrogen, hydrogen, chlorine, and bromine. Because chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) contain a chlorine atom, when they enter the stratosphere, they can destroy ozone. CFCs and HCFCs don't dissolve in water or easily break down in the atmosphere, so they are more likely to reach the stratosphere when compared with most other compounds containing chlorine.

In fact, according the Rowland–Molina theory, each chlorine atom in the stratosphere can destroy 100,000 ozone molecules. This decrease in the amount of ozone in the stratosphere allows more ultraviolet radiation to reach the earth's surface.

Legislative Action

Because ozone depletion in the stratosphere is a global problem, national and international consensus holds that halocarbons, including CFCs, halons, carbon tetrachloride, and methyl chloroform, must be restricted because of the risk of depletion of the stratospheric ozone layer through the release of chlorine or bromine. Bromine is even more damaging to the stratospheric ozone layer than chlorine.

The EPA evaluated the risks of ozone depletion in *Assessing the Risks of Trace Gases That Can Modify the Stratosphere* (1987) and concluded that an international approach was necessary to safeguard the ozone layer effectively.

In 1987, the United States and 22 other countries signed the Montreal Protocol on Substances That Deplete the Ozone Layer. The Montreal Protocol is an international treaty that addresses ozone-depleting substances and their alternatives. This agreement called for a phase out of certain CFCs, HCFCs, and halons. The countries responsible for approximately 95 percent of the world's production capacity for CFCs and halons have signed the Montreal Protocol.

Monitoring of the Ozone Layer

The strongest evidence that HCFCs are in the stratosphere is based on measurements of HCFCs in air samples taken from the stratosphere. NASA continues to release data acquired by Arctic Airborne Stratospheric Experiments to demonstrate the existence of HCFCs in the stratosphere.

According to the Rowland–Molina theory, chlorine monoxide is the key agent responsible for stratospheric ozone depletion. Finding chlorine monoxide in the upper stratosphere indicates that the ozone layer is being destroyed. The chlorine monoxide levels over the United States and Canada and as far south as the Caribbean were many times greater than gas phase models had predicted. Scientists believe that these levels are only partially explainable by emissions from volcanic eruptions.

Scientists also found that levels of hydrogen chloride in the stratosphere, a chemical compound that stores atmospheric chlorine in a less reactive state, were low. This finding provides further evidence for the existence of chemical processes that convert stable forms of chlorine into ozone-destroying forms.

Observations of hydrogen chloride and nitrogen oxide imply that chlorine and bromine were more effective in destroying ozone than previously believed. In fact, refrigerants containing bromine are the most harmful to stratospheric ozone.

Primary Sources of Chlorine in the Atmosphere

CFCs and HCFCs are the compounds at the heart of the ozone depletion issue. Although some people believed that naturally occurring events, such as volcanic eruptions, contributed heavily to problems with the ozone, data shows that chlorine in the stratosphere comes mainly from manufactured chemicals rather than from natural sources such as volcanoes. This is supported by the following evidence:

- The rise in the amount of chlorine in the stratosphere matches the rise in the amount of fluorine, which has different natural sources than chlorine.
- The rise in the amount of chlorine in the stratosphere matches the rise in ozone-depleting emissions.

- Air samples taken from the stratosphere over erupting volcanoes show that volcanoes contribute only a small quantity of chlorine to the stratosphere when compared to CFCs and HCFCs.

In addition, the violence of a volcanic eruption isn't strong enough to send hydrogen chloride (HCl) directly into the stratosphere. For HCl to get into the stratosphere, it would have to remain airborne for two to five years. This is unlikely because the moisture in the troposphere and steam from the volcano would clean particles containing the chlorine.

Tests have shown that natural sources only contribute 15 percent of methyl chloride to stratospheric chlorine levels, and natural sources of HCl contribute only 3 percent. That means 82 percent of stratospheric chlorine comes from ozone-depleting substances.

To stop damage to the stratospheric ozone layer, technicians in the United States are required to recover all refrigerants that have an ozone depletion potential (ODP) above zero and a global warming potential (GWP) higher than carbon dioxide (value above 1). Although HFCs have no ODP, their GWP is thousands of times greater than the GWP of hydrofluoroolefin (HFO) and hydrocarbon (HC) refrigerants. The use of alternative non-ozone depleting refrigerants and low GWP refrigerants will ultimately eliminate the use of CFCs, HCFCs, and HFCs.

CFCs

Chlorofluorocarbons (CFCs) have the highest ozone depletion potential and therefore are the most harmful to stratospheric ozone. The ODP is a relative measure of the ability of CFCs and HCFCs to destroy ozone. The potential of any substance to destroy the ozone is ranked relative to CFC-11, which is given the ODP value of 1. Table C–1 contains a list of the ODP of common refrigerants and shows that the ODP of CFCs is higher than HCFCs. Hydrofluorocarbons (HFCs) have a zero ODP but do contribute to global warming, another issue that is discussed later.

Table C–1. Abbreviated Table of Common Refrigerants

Refrigerant	Chemical Composition	ODP	GWP
R-11	CFC	1.0	4600
R-12	CFC	0.820	10600
R-13	CFC	1.0	14000
R-22	HCFC	0.034	1700
R-23	HCFC	0.0	12000
R-113	CFC	0.9	6000
R-114	CFC	0.850	9800
R-115	CFC	0.4	7200

Refrigerant	Chemical Composition	ODP	GWP
R-116	CFC	0.0	11900
R-123	HCFC	0.012	120
R-124	HCFC	0.026	620
R-125	HFC	0.0	3400
R-134a	HFC	0.0	1300
R-141b	HCFC	0.11	630
R-142b	HCFC	0.065	2270
R-225ca	HCFC	0.025	120
R-225cb	HCFC	0.033	586
R-290	HC	0	20
R-401A	HCFC	0.027	1100
R-401B	HCFC	0.028	1200
R-402A	HCFC	0.013	2700
R-402B	HCFC	0.02	2300
R-404A	HFC	0.0	3922
R-407C	HFC	0.0	1700
R-410A	HFC	0.0	3000
R-444A	HFC & HFO Blend	0	92
R-445A	HFO & HFC Blend	0	130
R-449	HFO	0	1282
R-452A	HFO	0	2141
R-500	CFC	0.605	7900
R-502	CFC	0.221	4500
R-503	CFC	0.599	13000
R-507A	HFC		3985
R-513A	HFO & HFC Blend	0	573
R-600	HC	0	20
R-600a	HC	0	20
R-1233zd	HFO	0	1
R-1234yf	HFO	0	<1
R-1234ze(E)	HFO	0	<1
R-1270	HC	0	2

The most common CFC refrigerants are R-12 and R-500. See Table C–1 for a complete list of CFCs and other common refrigerants.

HCFCs

Hydrochlorofluorocarbons (HCFCs) are a family of refrigerants containing hydrogen, chlorine, fluorine, and carbon. Because the hydrogen reduces the stability of the compound, these refrigerants have an increased deterioration potential before reaching the stratosphere, which means HCFCs have a low ODP, but their ODP isn't zero. HCFCs were used to replace CFCs because they cause less depletion of the ozone, making HCFCs less harmful to stratospheric ozone than CFCs, but worse than HCFs.

In 2010, a ban was placed on the production, sale, or importation of new systems that use HCFC-22 or HCFC-142b refrigerants or blends containing these refrigerants with the implementation of two rules: the Pre-Charged Appliance Rule, and the Allocation Rule. Currently, these refrigerants can only be used in the service and repair of existing equipment.

The Pre-Charged Appliances rule bans the sale or distribution of pre-charged air conditioning and refrigeration products and components containing HCFC-22 or HCFC-142b, or blends containing one or both of these substances. The ban applies to appliances and components manufactured on or after 2010.

The Allocation Rule, along with existing EPA requirements, prohibits charging newly manufactured appliances with virgin HCFC-22 or HCFC-142b or blends containing these refrigerants. It is illegal to purchase a dry-charged system and then charge the system with HCFC-22 or HCFC-142b.

These sales and production restrictions on HCFC-22 and HCFC-142b also affect any refrigerant blend that contains these refrigerants. HCFC-22 is used as a component in other common refrigerant blends including R-401A, R-402A, R-409A, and R-502 (see Table C–2). These refrigerants have applications in retail food refrigeration, cold storage warehouses, industrial process refrigeration, and transport refrigeration.

Additional less common refrigerants that contain either HCFC-22 or HCFC-142b are listed in Table C–2 along with other new blends that don't contain any HCFCs.

Table C–2. ASHRAE Number Assignments for Common Refrigerants

ASHRAE 34 Number	TYPE	Composition/ Concentration %	Safety Group
22	HCFC	100% R-22	A1
123	HCFC	100% R-123	B1

ASHRAE 34 Number	TYPE	Composition/ Concentration %	Safety Group
125	HFE	100% R-125	
236fa	HFC	100% R-236fa	A1
245ca	HFC	100% R-245ca	A2L
401A	HCFC	R-22: 53% R-152a: 13% R-124: 34%	A1
401B	HCFC	R-22: 61% R-152a: 11% R-124: 28%	A1
401C	HCFC	R-22: 33% R-152a: 15% R-124: 52%	A1
402A	HCFC	R-125: 60% R-290: 2% R-22: 38%	A1
402B	HCFC	R-125: 38% R-290: 2% R-22: 60%	A1
404A	HFC	R-125: 44% R-143a: 52% R-134a: 4%	A1
407C	HFC	R-32: 23% R-125: 25% R-134a: 52%	A1
408A	HCFC	R-125: 7% R-143a: 46% R-22: 47%	A1
409A	HCFC	R-22: 60% R-124: 25% R-142b: 15%	A1
409B	HCFC	R-22: 65% R-124: 25% R-142b: 10%	A1
410A	HFC	R-32: 50% R-125: 50%	A1
411A	HCFC	R-1270: 1.5% R-22: 87.5% R-152a: 11%	A2
412A	HCFC	R-22: 70% R-218: 5% R-142b: 25%	A2
414A	HCFC	R-22: 51%	A1

ASHRAE 34 Number	TYPE	Composition/ Concentration %	Safety Group
		R-124: 28.5% R-600a: 4.0% R-142b: 16.5%	
414B	HCFC	R-22: 50% R-124: 39% R-600a: 1.5% R-142b: 9.5%	A1
416A	HCFC	R-124: 39.5% R-134a: 59% R-600: 1.5%	A1
421	HFC	R-125: 58% R-134a: 42%	A1
441A	HC	R-600: 36% R-600a: 6% R-290: 55% R-170: 3%	A3
452A	HFO/HFC Blend	R-32: 11% R-125: 59% R-1234yf: 30%	A1
452B	HFO/HFC Blend	R-32: 67% R-125: 7% R-1234yf: 26%	A2L
507A	HFC	R-125: 50% R-143a: 50%	A1
508A	HCFC	R-23: 39% R-116: 61%	A1
508B	HCFC	R-123: 46% R-116: 54%	A1
509A	HCFC	R-22: 44% R-218: 56%	A1
600a	HC	n-butane	A3
1234yf	HFO	100% R-1234yf	A2L
1234ze	HFO	100% R-1234ze	A2L

The use of any HCFC in new systems is banned, and HCFCs can only be used for the service and repair of existing equipment. This means it is illegal to retrofit a system to R-22 or take a system designed for R-407C or a new system that has not been charged with any refrigerant (dry charge) and charge it with R-22.

Beginning January 1, 2020, the ban on the production or import of any HCFC refrigerant will take effect. After that date, only reclaimed or recovered HCFCs can be used in existing equipment.

Most small commercial AC systems manufactured before 2015 used HCFC-22; however, because of the ban on HCFC-22 in new equipment, HFC-410A is now the refrigerant commonly used in new residential and small commercial heat pump and air conditioning systems.

Because HCFCs still contain chlorine, they have an ODP greater than zero. Some common HCFCs are R-22, R-123, and R-124.

HFCs

Hydrofluorocarbons (HFCs) are a family of refrigerants containing hydrogen, fluorine, and carbon, but no chlorine. HFC refrigerants won't damage stratospheric ozone; they all have an ODP of zero.

The most common HFC refrigerants are R-134a, R-404A, R-407C and R-410A. See Table C–1 for a complete list of HFCs and other common refrigerants.

Although HFCs have zero ODP, they do have a high global warming potential (GWP). According to the EPA, CFCs, HCFCs, and HFCs all contribute to global warming. Many European nations are now considering banning refrigerants with a GWP above 150 or even 100.

HFOs

Hydrofluoroolefin (HFO) refrigerants are also a family of refrigerants containing hydrogen, fluorine, and carbon, but they are more reactive than HFCs because of the reactivity of the carbon–carbon bond. This increased reactivity means they have GWPs that are lower and have shorter atmospheric lifetimes when compared to any CFC, HCFC, or HFC refrigerant.

HFOs like HCs can be flammable, but HFOs are less flammable than HCs because HFOs contain fluorine. Although the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) classification of a non-toxic (A) lower flammability (2) refrigerant would be A2, some HFO refrigerants are non-flammable and some are classified as A2L, meaning that they are of even lower flammability with a maximum burning velocity of less than 4 inches per second. (See Figure C–16 on page 79 for ASHRAE safety classifications.)

However, the presence of the fluorine, which reduces the flammability, also means that HFO refrigerants can form reactive acids. HFO refrigerants aren't miscible in mineral oil, but they are miscible in synthetic lubricants such as POE. Therefore, synthetic lubricants such as POE should be used with HFO refrigerants. .

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 AC applications.

Major refrigerant manufacturers are also developing HFO blends suitable for applications that would traditionally use HCFC-22, HFC-404A, and HFC-410A. 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.

HCs

Hydrocarbon (HC) refrigerants are natural, nontoxic refrigerants that have no ODP and absolutely minimal GWP. Because HC refrigerants are organic compounds consisting only of carbon and hydrogen atoms, they are all highly flammable. They are listed by ASHRAE as safety group A3, meaning they have low toxicity (A) and are highly flammable (3). (See Figure C–16 on page 79 for ASHRAE safety classifications.)

HCs such as HC-290 propane, HC-600 n-butane, HC-600a isobutane, and HC-1270 propylene have very low GWPs, all below 4 (making their GWP lower than any CFC, HCFC, or HFC); however, they are all highly flammable.

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. 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 isn't a drop-in replacement for R-134a, especially because R-600a is flammable. Another significant difference between R-600a and R-134a is the normal operating pressure, which is much lower for R-600a.

R-290 propane has three carbon atoms, the chemical formula C_3H_8. Refrigerant-grade propane R-290 is cleaner and dryer than the propane used for cooking. Propane cylinders for grilling contain impurities that can damage refrigeration equipment.

R-441a, also known as HCR188C, was the first hydrocarbon refrigerant to be approved for sale in the United States by the EPA. This refrigerant is a blend of four hydrocarbons and has ASHRAE certification as being non-toxic. R-441a was designed to replace R-134. R-441a is a very high-pressure refrigerant; for example, at 80 °F, the saturation pressure is 614.8 psig, which is 2.6 times the 235.8 psig saturation pressure of R-410A.

Because all HC refrigerants are flammable, their use is currently limited to systems with a very small refrigerant charge, and the systems must have special labeling requirements to warn service technicians that the refrigerant is flammable. For additional training on the use of flammable refrigerants including both HFO and HC refrigerants, see our training in the Safe Handling of Flammable Hydrocarbon (HC) and Hydrofluoroolefin (HFO) Refrigerants, which is available at www.epatest.com.

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.

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). 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 machines
- 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

HFEs

Hydrofluoroethers (HFEs) are a family of refrigerants containing hydrogen, fluorine, carbon, and oxygen. Like HFCs, HFE refrigerants won't damage stratospheric ozone because they all have an ODP of zero.

The following refrigerants are HFEs. See Table C–1 for a complete list of HFEs and other common refrigerants.

- HFE-125 GWP 12,400
- HFE-236ca GWP 5,350

- HFE-245fa GWP 812

HFEs can have lower GWP than other refrigerants such as HFCs. However, many still have GWPs far above 100 and could be unsuitable as long-term replacement refrigerants for HFCs and HCFCs.

Note

Because HFO and HC refrigerants have no ODP and very low GWP, they are beginning to be used in limited new equipment applications or as components of new refrigerant blends. However, HC refrigerants are flammable and some of the HFO refrigerants are also flammable. HFO-1234yf is being used by some manufacturers to replace R-134a in automotive air conditioning applications.

Effects on Human Health

When ozone depletion occurs, the penetration of UV-B radiation increases, resulting in potential health and environmental harm including the following:

- Increased incidence of certain skin cancers and cataracts
- Suppression of the immune system
- Decreased crop yields and damage to marine organisms
- Increased formation of ground-level ozone
- Increased weathering of outdoor plastics

ODP and GWP of Common Refrigerants

The ODP is based on a value of 1.0 for R-11 and indicates the ability of chemicals to destroy ozone molecules in the stratosphere. The GWP represents how much a given mass of a chemical contributes to global warming over a given time period compared to the same mass of carbon dioxide. The GWP of carbon dioxide, which is defined as 1.0, is used as the baseline for comparing the GWP of refrigerants. All GWP values represent GWP over a 100-year time period.

HCs such as HC-290 propane, HC-600 n-butane, HC-600a isobutane, and HC-1270 propylene have very low GWPs, all below 4 (making their GWP lower than any CFC, HCFC, HFC, or HFO); however, HCs are highly flammable.

HFOs are more reactive than HFCs because of the reactivity of the carbon–carbon bond. This reduces their global warming potential, so like HCs, HFOs have GWPs that are lower than any CFC, HCFC, or HFC refrigerant. However, like HCs, HFOs can be flammable, but HFOs are less flammable than HCs because they contain fluorine. The presence of the fluorine also means that HFO refrigerants can form reactive acids that lead to compressor burnouts. For example, HFO-1234yf and HFO-1234ze(E) are flammable, while HFO-1336mzz(Z) and HFO-1233zd(E) aren't flammable.

Flammable refrigerants require different labeling, handling, and safety requirements, and have restrictions on where they can be used. For further training on this subject, see our HC/HFO training manual available at www.epatest.com.

Both HC and HFO refrigerants have zero ODP and very low GWPs that are about the same as carbon dioxide. CFCs, HCFCs, and HFCs have GWPs that are hundreds and even thousands of times greater.

The use of HFOs or blends containing HFOs continues to increase. HFOs are being used or proposed for a number of applications. HFO-1234yf has been chosen to replace R134a in MVAC systems. HFO-1234ze(E) and HFO 1233zd(E) are used in chillers, and HFO-1336mzz(Z) has been suggested for high-temperature heat pumps.

Another application is to use these new HFOs as a component of lower GWP refrigerant blends. For example, HFO-1234yf and/or HFO-1234ze(E) are components of refrigerant mixtures R-444A, R-448A, R-449A, R-450A, R-513A; however, although they are proposed as replacements of the more traditional refrigerants, in many cases, they operate at comparatively higher compressor discharge temperatures.

The following HFO-based refrigerant blend replacement refrigerants are non-ozone depleting and have very low GWP:

- HFO-449A is a replacement for R-404A, R-507, R-407A, and HCFC-22 for new equipment and retrofit of existing systems.
- HFO-452A is a replacement for R-404A/R-507 in new equipment and retrofit of existing systems.
- HFO-452B is a replacement for R-410A in new equipment.
- HFO-513A is a replacement for HFC-134a in new equipment.
- HFO-514A is a replacement for HCFC-123 in low-pressure centrifugal chillers in new equipment.

Table C–1 provides a list of common refrigerants and their chemical composition, ODP, and GWP. As shown in the table, HFCs like R-410 with a GWP of 3,000 means that the GWP of R-410A is thousands of times greater than the GWP of carbon dioxide which is 1. The GWP of R-404A is 3,922, making it the highest of all the commonly used refrigerants.

Clean Air Act

The original Clean Air Act of 1963 established funding for the study and cleanup of air pollution. But there was no comprehensive federal response to address air pollution until Congress passed a much stronger Clean Air Act in 1970 that covered the entire country.

That same year, Congress created the EPA and gave it the primary role in carrying out the law. Since then, the EPA has been responsible for a variety of Clean Air Act programs to reduce air pollution nationwide.

In 1990, Congress dramatically revised and expanded the Clean Air Act, providing the EPA even broader authority to implement and enforce regulations reducing air pollutant emissions. The 1990 amendments also placed an increased emphasis on more cost-effective approaches to reduce air pollution. The program calls for phasing out production and use of ozone-destroying chemicals and capturing and ultimately eliminating CFCs. The program did not authorize the EPA to mandate the elimination of high GWP refrigerants, rather the mandate was only to eliminate ozone-depleting refrigerants.

In 1992 the Fourth Meeting of the Montreal Protocol was convened. In this meeting, the parties took a number of actions, including accelerating the phase-out schedule of CFCs, halons, carbon tetrachloride, and methyl chloroform, and added HCFCs and methyl bromide to the list of chemicals to be controlled under the Montreal Protocol. Halons were completely phased out by 1994. The production and sale of virgin CFCs, halogenated CFC, carbon tetrachloride, and methyl chloroform ended in 1995. The production and sale of virgin HCFCs ended in 2010.

In addition to setting the schedule for the phasing-out of environmentally damaging refrigerants, the Clean Air Act has been responsible for prohibiting the venting of refrigerants and authorizing the EPA to set standards for the recovery of refrigerants.

EPA

Under the Clean Air Act, the EPA set limits on certain air pollutants, including how much pollution can be in the air anywhere in the United States. This limit helps to ensure basic health and environmental protection from air pollution for all Americans. The Clean Air Act also gives EPA the authority to limit emissions of air pollutants coming from sources like chemical plants, utilities, and steel mills. Although states, tribes, and local governments can make laws that follow the Clean Air Act/EPA regulations, they also may set and enforce stronger air pollution laws than those set by EPA. They can't make laws that weaken the federal requirements.

EPA sets regulations under Section 608 of the Clean Air Act that establish a recycling program for ozone-depleting refrigerants recovered during the servicing and disposal of air conditioning or refrigeration equipment. Although venting refrigerant from any air conditioning or refrigeration system is illegal, it is also illegal to vent refrigerant from any recycling, recovery, or reclamation machine; from a charging cylinder; or from any refrigerant storage or recovery cylinder. Together with the prohibition on venting during servicing, repair, and disposal of refrigerants, the EPA regulations are substantially reducing emissions of ozone-depleting refrigerants.

The regulations require persons servicing air conditioning and refrigeration equipment to observe certain service practices that reduce refrigerant emissions, establish equipment and off-site reclaimer certification programs, and establish a technician certification program.

A sales restriction on refrigerant is included so that only certified technicians are legally authorized to purchase or handle controlled refrigerants. However, technicians aren't required to be EPA Section 608 certified if they aren't opening up the refrigerant circuit—if they aren't servicing any component that would result in the release of refrigerant. For example, technicians don't require certification to change a capacitor, install a new blower or fan, or rewire an external electric circuit.

Under Section 608 of the Clean Air Act, EPA established regulations that require persons servicing or disposing of air conditioning and refrigeration equipment to acquire refrigerant recovery and/or recycling equipment and to comply with the recovery requirements.The recovery requirements for Type I Small Appliances are detailed in the Type I certification section of this training guide.

MVAC service technicians are governed under Section 609 of the Clean Air Act. If you are an MVAC technician, you must obtain a Section 609 MVAC certification.

Standards for recovering refrigerants are necessary to maintain adequate supplies for service calls after the production bans, prevent the venting of refrigerants to the atmosphere, and prevent stratospheric ozone depletion.

Recordkeeping Requirements

Those involved in the refrigerant industry face considerable recordkeeping requirements under Section 608 of the Clean Air Act. This includes owners and operators of systems using the refrigerants; technicians who service, repair, or dispose of such systems; wholesalers of refrigerants; refrigerant disposal facilities; and refrigerant reclaimers.

When you work with refrigerants, you must keep proper records including the following:

- Date
- Type of service
- Equipment location
- Equipment owner
- Normal charge
- Amount of refrigerant added or removed

However, you don't need to record the serial number or model number of a unit from which refrigerant is being recovered.

A violation of the Clean Air Act, including improper recordkeeping, is subject to a penalty of up to $44,539 per day per violation.

Technicians servicing small appliances are not required to find and repair leaking systems. However, finding and repairing leaks always conserves refrigerant when servicing an appliance.

Revocation of Your Certification

Section 608 technician certification doesn't expire, but you are responsible for complying with any future changes in the law. The EPA can require technicians to demonstrate their ability to perform proper procedures for recovering and/or recycling refrigerant. If you fail to successfully demonstrate or properly use the equipment, EPA can revoke your technician certification.

Refrigeration technicians who violate the Clean Air Act could lose their EPA certification, be fined, or be required to appear in federal court. Some of these violations include falsifying or failing to keep required records, failing to reach required evacuation levels before opening or disposing appliance, and knowingly releasing refrigerants while repairing appliances.

Tip

Remember, all non-exempt refrigerants must be recovered, not just CFCs and HCFCs.

Recovery and Recycling

EPA defines "appliance" as any device that contains and uses a working fluid that is a refrigerant (or its substitute) and is used for household, commercial, or industrial cooling, or refrigeration or other vapor-compression heat pump purposes, including any air conditioner, refrigerator, chiller, or freezer. Any device that doesn't use a working fluid, such as a thermo-electric cooler or desiccant dehumidifier, isn't subject to EPA Section 608 regulations because no refrigerant could escape into the atmosphere if the unit were disassembled.

To implement the safe disposal requirements of Section 608, EPA requires that you remove all refrigerants in appliances, machines, and other goods before you open them for service, repair, or disposal.

EPA also requires all air conditioning and refrigeration equipment, except EPA-defined small appliances, be provided with a servicing aperture that would facilitate recovery of the refrigerant. Small appliances can be fitted instead with a process stub for use with a piercing access valve. The purpose of this requirement is to make it easier for technicians to recover refrigerant from these systems.

Equipment Types

Recovery equipment can be divided into two main types, self-contained and system-dependent equipment:

- Self-contained equipment has its own means of drawing refrigerant out of the system and is capable of removing the refrigerant (liquid and/or vapor) from an appliance without the assistance of components contained in the appliance. All recycling machines are self-contained.
- System-dependent recovery equipment relies solely on the compressor in the appliance and/or the pressure of the refrigerant in the appliance to recover the refrigerant. System-dependent recovery equipment can only be used on appliances with 15 pounds or less of refrigerant.

All devices used for refrigerant recovery and recycling must meet EPA standards and have a label stating EPA compliance. To demonstrate EPA compliance, manufacturers of recovery and recycling units must have their equipment tested to demonstrate compliance with AHRI 740 test protocol, which is the test procedure for recovery and recycling equipment.

Recovery

Any global-warming or ozone-depleting refrigerant must be recovered before opening or disposing of any appliance. This means every refrigerant, with the exception of carbon dioxide, n-butane (R-600), isobutane (R-600a), propane (R-290), and other exempt refrigerants, must be recovered when the system or appliance is opened for service or repair or before disposal.

If the equipment is to be repaired and placed back in service, after recovering refrigerant to the appropriate vacuum level, you should "break the vacuum" with nitrogen before opening an evacuated system to the air because this prevents the vacuum from drawing air and contaminants into the system when the system is opened.

Recycling

The EPA has always emphasized the importance of recycling as the only source of phased-out refrigerants, which are necessary to re-charge equipment that uses a phased-out refrigerant. Recycling eliminates or at least defers the cost of early retirement or the retrofitting of equipment due to the unavailability of a suitable refrigerant.

Production of all CFCs has now been phased out, and the phase-out of HCFCs is underway. Reclaimed supplies of CFCs are still available, but the cost is substantial.

When a particular refrigerant is phased out, technicians can still service these systems; however, if additional refrigeration is needed to charge the system, it can only come from recovered, recycled, or reclaimed refrigerants.

Venting

It is illegal for individuals to intentionally vent ozone-depleting or global-warming substances used as refrigerants into the atmosphere while maintaining, servicing, repairing, or disposing of air conditioning or refrigeration equipment. Although you aren't required to recover exempt refrigerants, such as carbon dioxide, R-600a isobutane, or R-290 propane, you may recover these refrigerants for recycling.

Only four types of refrigerant releases are permitted and don't violate the EPA venting regulations:

1. "De minimis" (small unavoidable) quantities of refrigerant released in the course of making good-faith attempts to recapture and recycle or safely dispose of refrigerant. De minimis releases of refrigerant that result from purging hoses or from connecting or disconnecting hoses to charge or service appliances aren't considered violations of the prohibition on venting. However, service hoses and recovery and recycling equipment must be equipped with low-loss fittings to reduce these connection losses.
2. Refrigerants emitted in the course of normal operation of air conditioning and refrigeration equipment (as opposed to during the maintenance, servicing, repair, or disposal of this equipment) such as from mechanical purging and leaks. However, EPA requires the repair of substantial leaks in systems with more than 50 pounds of charge.
3. A leak test trace gas mixture of nitrogen to pressurize the system and a small quantity of the system refrigerant to activate a refrigerant leak detector when searching for a leak. This mixture isn't considered a

refrigerant and may be released. However, the release of mixtures of nitrogen and refrigerant that result from adding nitrogen to a charged appliance to leak check the appliance is a violation of EPA standards. In other words, you can't add nitrogen to a system simply to call it a leak test gas and avoid refrigerant recovery. To use a leak test gas, the refrigerant in the system must be recovered (to the required evacuation levels). *After repairs are made*, you may add a small quantity of the system refrigerant to the system before the system is pressurized with nitrogen. The small quantity of refrigerant that is mixed with the nitrogen is added so that you can use an electronic leak detector to search for leaks. The leak check mixture doesn't need to be recovered and can be vented. If you're not planning to use an electronic refrigerant leak detector, don't use a leak check gas, but instead use pure nitrogen.

It is illegal to intentionally vent any refrigerant including refrigerants with zero ODP, such as HFCs, because even though the refrigerant might have zero ODP, the refrigerant still contributes to global warming and must not be vented. When the EPA determines that a refrigerant in a system doesn't pose a threat to the environment if released, (such as carbon dioxide, R-600a isobutane, R-290 propane), the EPA declares that refrigerant to be *exempt* from the recovery requirement and you don't need to recover it.

Sale of Used Refrigerant

Selling used refrigerant that isn't reclaimed is prohibited. As a result, under EPA regulations you may only sell recovered refrigerant to reclamation facilities to be purified to the required AHRI 700 level. (This industry-set purity standard is also used for new virgin refrigerant.) Only then can the recovered refrigerant be resold for use in refrigeration equipment. You can find a list of EPA-certified refrigerant reclaimers on the EPA website.

The AHRI 700 standard is a purity standard set by the Air Conditioning Heating and Refrigeration Institute (AHRI) to ensure that refrigerant is free of contaminants that can damage air conditioning and refrigeration equipment. Virgin refrigerant must meet this standard, and reclaimers are required to return refrigerant to this purity level and to verify this purity using the laboratory protocol set forth in the same standard. Table C–3 lists some of the key purity requirements specified in the standard.

Table C–3. Brief Summary of Key Requirements of the AHRI Purity Standard

Contaminants	Requirement
Acidity	Less than 0.01%
Moisture (by weight)	Less than 10 ppm
Non-condensable gas (by volume)	Less than 1.5%

Nonvolatile residue	Less than 100 ppm
Chloride content	None

The key to reclamation is testing to verify the refrigerant is pure. The method used to clean the refrigerant doesn't matter—in fact, no cleaning is required if not necessary. The only requirement is that the used refrigerant be tested to show it meets the purity requirements of new refrigerant, namely, it meets AHRI 700 purity requirements.

Who Can Buy Refrigerants

The only people who can legally buy new or reclaimed non-exempt refrigerants for non-motor-vehicle applications are technicians who have been certified by the EPA for refrigerant recovery. The technician must hold EPA Section 608 Type I, Type II, Type III, or Universal certification.

Every supplier who sells any HVAC/R refrigerant must verify that either the purchaser is a Section 608-certified technician or the company the purchaser works for has at least one Section 608-certified technician.

Tip

If you are a Mainstream-certified technician and you lose your certification card, you can verify your certification by visiting the Mainstream EPA website at www.epatest.com. Records of all your Mainstream HVAC/R certifications are available at this location.

This refrigerant sales restriction excludes refrigerant already contained inside refrigerators or air conditioners with fully assembled refrigerant circuits (such as household refrigerators, window air conditioners, and packaged air conditioners). In other words, you don't need EPA certification to purchase a refrigerator, even though by purchasing a refrigerator, you are also purchasing the refrigerant inside the refrigerator.

Only Section 608-certified technicians can purchase refrigerants intended for use with stationary refrigeration and air conditioning equipment. Section 609-certified technicians can't purchase refrigerants that are intended for use with stationary equipment.

Disposal

Equipment that might enter the waste stream as a complete system with the charge intact (e.g., household refrigerators and freezers, and room air conditioners) must have the refrigerant recovered before disposal. Therefore, before you dispose of any system containing a refrigerant, you must first recover the refrigerant.

When you are recovering refrigerant, you can’t reuse (refill) a disposable refrigerant cylinder. You can recycle the metal of a disposable cylinder when you’re finished if are sure that all refrigerant has been recovered and the cylinder is rendered useless.

Tip

To render the cylinder useless before disposal, break off the valve or puncture the cylinder. This keeps anyone from using the cylinder for any pressurized gas storage purpose.

Caution

In spite of the warnings, some people use old disposable refrigeration cylinders to store compressed air. This is a dangerous, unsafe practice. Disposable cylinders are fabricated with a lightweight steel shell that is unpainted on the inside. Even very little internal corrosion (rust) can severely weaken the structure although the painted exterior looks fine. The corrosion can allow the cylinder to explode.

Any cylinder of refrigerant that contains both liquid and vapor will be at the saturation pressure for that refrigerant. For example, a disposable R-410 cylinder with only one pound of refrigerant left in the steel disposable tank will still be at 277 psig if it is stored in a 90 °F environment. Therefore, don’t leave almost empty disposable cylinders lying around where they can be forgotten until they explode. Instead, to discard a cylinder, recover any remaining refrigerant, render the disposable cylinder useless (puncture or break off the valve), and discard or recycle the metal.

Anyone in the disposal chain can remove the refrigerant, but the last person in the chain, namely the scrap metal or landfill operator, is the individual who must ensure all of the refrigerant has been removed and must maintain records (keep the signed statements) to verify it has been done.

CFC Refrigerant Tax

The Internal Revenue Service (IRS) imposes environmental taxes on certain ozone-depleting substances (ODSs). This tax is imposed on an ODS when first sold by its manufacturer or importer, and the manufacturer or importer is liable for the tax.

If you have more than 400 pounds of CFC refrigerants in inventory, there is a floor tax on these CFCs. For more information, refer to the instructions for IRS Form 6627. For questions regarding tax filing requirements, contact the IRS Customer Account Services staff toll-free at 1-800-829-4933.

Enforcement

The EPA Office of Enforcement and Compliance Assurance website accepts anonymous reports of suspected or witnessed unlawful releases of refrigerant or other violation of the clean air regulations. EPA enforces the regulations by investigating reported leaks, conducting surprise inspections, and offering rewards of up to $10,000 for information about unreported violations. However, EPA doesn't automatically offer a $10,000 reward or any other bounty for persons who inform the agency of possible refrigerant violations.

Substitute Refrigerants and Oils

Refrigerant Blends

ASHRAE has a specific numbering system (based on the chemical structure) to designate refrigerants. This organization also maintains a list of approved refrigerants and details on their composition and safety on the ashrae.org website.

Refrigerant blends are also numbered according to the ASHRAE system. Blends are comprised of two or more refrigerants that have different physical characteristics. Refrigerant blends that are composed of two different refrigerants are called binary blends. Refrigerant blends that are composed of three different refrigerants are called ternary blends.

Blends of refrigerants are formulated to alter the saturation pressure–temperature behavior, typically in an attempt to produce a new refrigerant blend with saturation pressure–temperature behavior that is similar to an earlier CFC or HCFC refrigerant.

Temperature Glide

Pure refrigerants have a single boiling (and condensation) point temperature at a given pressure. However, a blend can exhibit a "temperature glide," which means the temperature varies as the refrigerant evaporates or condenses.

The temperature where the refrigerant starts to evaporate (called the bubble point temperature) is different (lower) from the temperature where the last bit of refrigerant evaporates (called the dew point). Similarly, the temperature where the first bit of refrigerant vapor starts to condense to a liquid (the dew point) is different (higher) from the point where the last bit of refrigerant condenses (bubble point).

Temperature glide is the difference between the dew point temperature and the bubble point temperature of a blend.

Example

R-22 at 200 psig boils (evaporates) at 101 °F. Condensation of R-22 at 200 psig also occurs at the same temperature, namely 101 °F. This refrigerant has no temperature glide. Examples of refrigerants that do have a temperature glide are given in later examples.

Types of Refrigerant Blends

Blends are divided into two classifications, azeotropic or non-azeotropic (also called zeotropic), depending on the temperature glide characteristics of the blend.

Azeotropic Blends

Azeotropic blends are refrigerant blends that behave like a single component refrigerant over its entire range, that is, they have only a single boiling point temperature at a given pressure. Their temperature glide is zero. These blends can be treated like a pure refrigerant during servicing. You can charge them as a liquid or vapor, and you can top them off (because any leak hasn't altered the composition of the blend).

Refrigerant blends that have this singular boiling point temperature at a given pressure and behave as a single "new" refrigerant (azeotropic blend) are given a 500-series ASHRAE refrigeration designation. Therefore, R-500, R-501, and R-502 are all azeotropic refrigerant blends, behave as a pure refrigerant, and have no temperature glide during boiling or condensation.

An azeotropic refrigerant mixture acts like a single-component refrigerant over its entire range. Under normal conditions, azeotropic blends don't separate.

Non-Azeotropic or Zeotropic Blends

Like azeotropic blends, non-azeotropic (zeotropic blends) also consist of multiple refrigerants blended together. However, a non-azeotropic refrigerant mixture still acts like a mixture of refrigerants after blending and doesn't behave like a single refrigerant.

The volumetric composition and saturation temperatures of non-azeotropic blends change as they evaporate or condense at constant pressure. As a result, the blend separates in the evaporator or combines in the condenser at a slightly different temperature (for a constant pressure). Therefore, non-azeotropic blends have a temperature glide (refer to earlier temperature glide section).

These non-azeotropic blends can't be treated like a pure refrigerant during servicing. You can only charge them as a liquid, and when the system has a leak, you can't top off the refrigerant because these non-azeotropic blends fractionate during a leak or during vapor charging. Therefore, the characteristics of the blend change because the more volatile refrigerant boils off in a greater ratio during a leak or during vapor charging. This dramatically alters the composition and the properties of the refrigerant.

Because the non-azeotropic refrigerant blends leak from a system in uneven amounts due to different vapor pressures, you can't top off these systems. Instead, you need to recover all of the refrigerant and send the refrigerant to a reprocessing (reclamation) facility. After repairs, you must recharge the system using only liquid (not vapor) charging.

These non-azeotropic refrigerants are given a 400-series ASHRAE refrigeration designation.

Example

R-407C at 200 psig begins evaporation at 91.9 °F and finishes evaporation at 101.2 °F. Similarly, during condensation, the first refrigerant to condense at 200 psig condenses at 101.2 °F and the last bit of refrigerant condenses at 91.9 °F. The temperature glide of R-407C is 9.3 °F (101.2 °F – 91.9 °F = 9.3 °F).

Near-Azeotropic Blends

Another informal classification of refrigerant blends is called near-azeotropic. Near-azeotropic blends are non-azeotropic blends that have a very small temperature glide. That is, they change volumetric composition and saturation temperatures in nearly the same way as azeotropic blends. The temperature glide is so small you wouldn't be able to detect it in the field. The following example shows that the temperature glide of the non-azeotropic R-410A is only 0.2 °F, making R-410A a near-azeotropic refrigerant blend.

Example

At 200 psig, R-410A begins evaporation at 69.5 °F and finishes evaporation at 69.7 °F, which is too small a temperature difference to be measured with conventional HVAC/R field measuring devices. During condensation, the first refrigerant to condense at 200 psig condenses at 69.7 °F, and the last bit of refrigerant condenses at 69.5 °F. The temperature glide of R-410A is only 0.2 °F, just two-tenths of a degree.

Although you can treat R-410A and other near-azeotropic refrigerants as an azeotropic refrigerant, most manufacturers recommend that you still charge them as a liquid. They can be topped off, however, and this is a significant benefit.

Tip

The ASHRAE numbering system does simplify things somewhat because you know you can service any 500-series refrigerant like a pure refrigerant without any concern about fractionation. You can charge 500-series azeotropic refrigerants as a liquid or a vapor, and after a leak, you can top off systems containing this type of blended refrigerant.

Charging a Refrigerant Blend

In general, you should charge 400-series non-azeotropic blended refrigerants as a liquid. Because these non-azeotropic refrigerant blends are a mixture of different refrigerants with different volatilities, if you charge them as a vapor, the refrigerant with the highest vapor pressure (most volatile) is charged into the system at a higher proportion than the other refrigerant components. This is referred to as fractionation.

The only way you can be sure the non-azeotropic blend is charged properly and doesn’t fractionate during charging is to charge it as a liquid.

Changing to a Different Refrigerant

According to EPA, there are no “drop-in” service replacements for any refrigerants. The term drop-in replacement means that the refrigerant provides *exactly the same* cooling, efficiency, pressure ratio, and other performance factors as the original refrigerant *with no changes* to existing equipment. Despite what some sales materials claim, every replacement refrigerant requires some change to the system. However, some changes are only minor, and the performance differences can be minimal.

SNAP Approval

The Significant New Alternatives Policy (SNAP) Program is EPA's program to evaluate and regulate the *safety* of substitutes for the ozone-depleting chemicals that are being phased out under the stratospheric ozone protection provisions of the Clean Air Act. EPA reviews substitutes on the basis of ozone depletion potential, global warming potential, toxicity, flammability, and exposure potential as described in the final SNAP rule.

SNAP approval *does not* mean the particular new SNAP-approved refrigerant is well suited for any particular retrofit application. SNAP approval only means the refrigerant reduces the overall risk to human health and the environment.

For more information, visit www.epa.gov/ozone/snap/refrigerants/.

Retrofit Refrigerants

The term "retrofit" describes special procedures required to convert a vapor-compression refrigeration or cooling system to use an alternative refrigerant. The retrofit designation identifies substitutes that may be used in systems retaining at least some of the original equipment. Retrofitting an existing system is generally less expensive than installing a new system.

Example

R-407C can be used as a retrofit refrigerant in existing R-22 systems, or new AC systems could be fabricated using R-407C as the refrigerant. R-410A can't be used as a retrofit refrigerant because of the much higher service pressures, but new systems can be designed and fabricated to accommodate the higher system pressures. In fact, most new residential AC systems are using R-410A.

Alternative refrigerant technologies such as a new high-pressure refrigerant or a flammable refrigerant can only be used in new equipment.

Tip

Although some manufacturers of alternative refrigerants are marketing their products as drop-ins, remember that according to the EPA, because every system must have some changes to accommodate the replacement refrigerant (even if the change is minor), there is no such thing as a refrigerant that can literally be dropped into the existing refrigerant system.

Using Synthetic Oils

Back when CFC-12 and HCFC-22 were the most commonly used refrigerants and HFCs weren't in use, the refrigerant oils were all mineral oils (oil that was obtained from crude oil wells). Because most of the new refrigerants aren't compatible with mineral oil, the type of oil had to change to synthetic oils.

The two general classes of oils used today are mineral oil and synthetic oils. The most common synthetic oils are polyolester (POE), also referred to as ester oil, and alkylbenzene oil (AKB). Another emerging synthetic oil is polyvinyl ether (PVE) oil.

Tip

When changing the type of oil used in a system, always check the manufacturer's recommendations. POE oil isn't compatible with mineral oil. You must remove the mineral oil and flush the system using an approved non-aqueous flushing solution like Qwik ***System Flush***® *before you can retrofit the system with any replacement refrigerant that uses an ester oil.*

Ester Oil

The type of oil that is most commonly used in stationary refrigeration applications with HFC refrigerants, such as HFC-134a and HFC-410A, is an ester oil. The most common ester oil is POE oil. Although HFC refrigerants are typically compatible with most existing refrigeration and air conditioning equipment parts, they aren't compatible with the mineral oils that were used in a system because the mineral oil isn't miscible with the HFC refrigerants. However, POE oil is miscible with both HFC and HFO refrigerants as are other synthetic oils. Instead of mineral oil, you can use any appropriate synthetic oil.

Caution

Don't mix ester-based oils with any other oils. In general, you should never mix different types of oils in a system.

All synthetic oils (including POE, PVE, and polyalkylene glycol [PAG] oils) are extremely hygroscopic, which means they readily absorb moisture. When working on a system with any synthetic oil, be especially careful not to let excess moisture get into the system.

For example, although mineral oil has a water saturation limit of only 25 parts per million (ppm), the new synthetic oils absorb much greater concentrations of water. POE oil has a saturation limit of 2,500 ppm, which is 100 times the limit of mineral oil. PVE has a saturation limit of 6,500 ppm, which is 260 times that of mineral oil, and PAG has a saturation limit of 10,000 ppm, which is 400 times that of mineral oil. With the potential for so much more water in the system, you have to be careful to avoid moisture entry into the system, and you have to rigorously pursue deep evacuation and follow triple evacuation methods.

Alkylbenzene and Mineral Oil

For HCFC refrigerant installations and conversions, you can use mineral oil, alkylbenzene refrigeration oil, or a combination of the two. Alkylbenzene is a synthetic refrigeration oil and is more expensive, but it can be used with all halocarbon refrigerants.

The synthetic lubricant commonly used with ternary blends containing HCFCs is alkylbenzene.

PAG Oil

PAG oils have been used in automotive R-134a MVAC systems but aren't commonly used in stationary HVAC systems. PAG oils can't tolerate even very small amounts of chlorides, and chlorides can come from coatings in tubing, outdated flushing methods, or residual amounts of CFC refrigerant that might have been in the system.

POE Oil

The synthetic lubricant commonly used with HFC refrigerants and HFC blends is POE oils.

Refrigeration Principles

Cooling (refrigeration or air conditioning) is the process of removing or extracting heat from a lower temperature place where you don't want the heat and rejecting this heat to a higher temperature location.

Heat normally flows from hot to cold, just like water normally flows downhill. To get water to go uphill, you would have to use a water pump; to get heat to flow in the opposite direction (to flow uphill) from cold to hot, you need a heat pump. Technically, then, all refrigeration and air conditioning systems are heat pumps.

However, the HVAC/R industry uses a slightly different nomenclature. Even though all machines that pump heat in the opposite direction are heat pumps, in the HVAC/R industry, a heat pump is a vapor-compression cooling system with a reversing valve so that the system can provide interior cooling during hot ambient temperature and interior heating during cold ambient temperatures.

System Components

Most common refrigeration systems have four major parts (see Figure C–1):

- **compressor**—changes a low-pressure vapor to a high-pressure vapor. The common types of small hermetic compressors are reciprocating, rotary, and scroll compressors. Larger types of compressors include centrifugal and screw compressors.
- **condenser**—changes a high-pressure vapor to a high-pressure liquid by rejecting heat from the refrigerant causing the refrigerant to condense.
- **expansion valve or throttling device**—drops the pressure to lower the saturation temperature and allow the refrigerant to evaporate or boil in the evaporator, drawing heat into the refrigerant.
- **evaporator—**changes (boils or evaporates) the low-pressure two-phase mixture of liquid and vapor refrigerant into an all-vapor stream of refrigerant, drawing heat into the refrigerant (thus providing cooling) during evaporation.

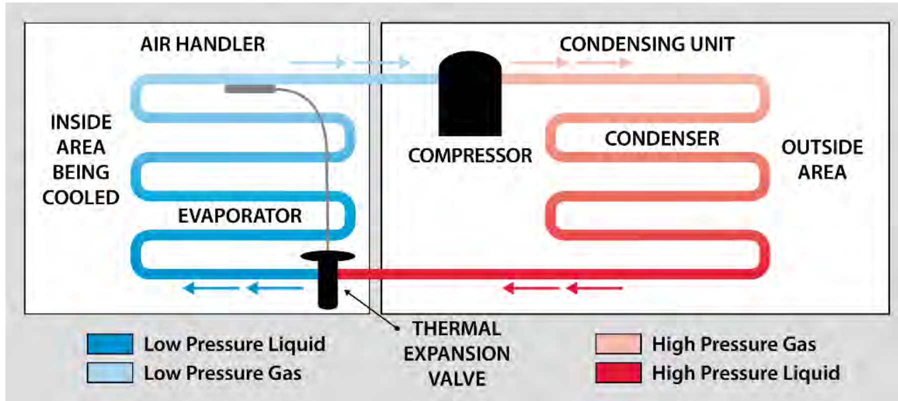


Figure C–1. Components of a cooling system

The next section explains how these components work together to provide cooling.

How a Vapor Compression System Operates

An electric motor drives the compressor, which compresses the refrigerant from a low-pressure, slightly superheated vapor to a high-pressure, highly superheated vapor. This work done on the refrigerant by the compressor causes the refrigerant to heat as it is compressed. Other factors that cause the refrigerant to heat are inefficiencies in the compression process and inefficiencies in the electric motor if the motor is cooled by the refrigerant. Hermetic and semi-hermetic compressors are cooled by the refrigerant.

Refrigerant exits the compressor as a superheated vapor. When the superheated, high-pressure vapor exits the compressor, it passes through condenser coils, which are designed to reject this heat into the ambient air.

The rejection of this heat causes the refrigerant to condense into a liquid. This liquid is typically cooled a few degrees below the saturation temperature for the pressure of the refrigerant (subcooled). The number of degrees the refrigerant is cooled below the saturation temperature is referred to as the subcooling. Refrigerant enters the condenser as a high-pressure vapor and leaves the condenser of an operating system as a high-pressure liquid, typically slightly subcooled by 5 to 15 °F.

The refrigerant then goes from the condenser to the filter drier, which cleans and dries the refrigerant. This cleaning and drying is important for two reasons:

- The liquid refrigerant will soon flow through the throttling device (aka expansion valve), but because the throttling device has the smallest refrigerant passage in the system, all impurities must be removed before the refrigerant enters the throttling device.
- The sudden drop in pressure associated with the throttling device also results in a sudden drop in saturation temperature. Therefore, if any

water is in the refrigerant, the most likely place for this water to freeze is during this sudden drop in temperature that occurs in the expansion device. Frozen droplets of water can clog the expansion device. Therefore, the best place to remove water from the refrigerant is also just upstream of the throttling device.

As stated previously, upon exiting the filter drier, the liquid refrigerant enters the throttling device, which is essentially a small opening or narrow passage that drops the pressure of the refrigerant. This metering device can be passive, such as an orifice plate or capillary tube, or can be actively controlled, such as a thermostatic expansion valve (TXV) or electronic expansion valve (EXV), to maintain the superheat of the refrigerant at the exit of the evaporator.

Refrigerant enters this metering or expansion valve as a liquid and exits the expansion valve (throttling device) as a mixture of liquid and vapor, referred to as a saturated two-phase mixture (both liquid and vapor phases exist).

This saturated two-phase refrigerant (now at the low-pressure side of the system) then evaporates or boils at the saturation temperature corresponding to this lower pressure. As the refrigerant evaporates or boils, it changes from a two-phase mixture of liquid and vapor to all vapor and absorbs heat from the surrounding area to provide cooling.

Refrigerant exits the evaporator as either a saturated vapor or superheat vapor. Typically, the refrigerant is heated slightly above the saturated temperature, and the number of degrees the vapor is heated above the saturation temperature is referred to as the superheat. This refrigerant is superheated to ensure that no liquid refrigerant is present in the refrigerant stream entering the compressor because a compressor can't compress liquid refrigerant and attempting to do so can damage the compressor.

Refrigerant entering the compressor of a refrigeration system is a superheated, low-pressure vapor.

The compressor then compresses the refrigerant from a low-pressure refrigerant vapor coming from the evaporator and discharges this refrigerant as an even more superheated vapor at a higher pressure, which then flows to the condenser.

The whole process operates continuously by transferring heat from the evaporator section inside the cool area to the condenser section outside the cool area by pumping the refrigerant continuously through the system. When the desired cold temperature is reached, the compressor stops and so does the heat pumping.

When the system is shut down, refrigerant migrates to the coldest part of the system. This movement is called refrigerant migration.

After the compressor shuts down, the compressor crankcase (oil sump) often becomes the coolest part of the system because of the difference in vapor pressure between the oil and the refrigerant. When the refrigerant migrates into the crankcase, the refrigerant can dilute the oil, reducing its lubrication capability. This diluted lubricant can fail to adequately lubricate the wear surfaces of the compressor and can result in premature compressor failure. In addition, when the compressor starts up, any refrigerant dissolved in the compressor oil quickly evaporates out (boils out) because of the sudden drop in pressure associated with compressor start up. This causes the oil to foam, which reduces the lubrication quality of the oil.

To avoid the accumulation of refrigerant in the compressor and also prevent oil foaming, a crankcase heater is typically located on the exterior surface of the compressor and is activated any time the compressor isn't operating.

Note

When refrigerant is compressed as described, it is called a vapor-compression cycle. Cooling occurs in this type of direct-expansion vapor-compression refrigeration system when refrigerant draws in heat and the liquid turns to a vapor in the evaporator. Whenever the refrigerant evaporates or boils in the evaporative heat exchanger, cooling is the result.

Types of Compressors

Compressors are grouped into one of three basic categories: fully hermetic, semi-hermetic, and open-drive compressors.

A fully hermetic compressor has the electric drive motor completely sealed within the same welded casing without gasketed sealing surfaces of any kind.

If the hermetic enclosure completely seals the drive motor and compressor within the same casing but relies on stationary gasketed sealing surfaces between non-moving surfaces, the compressor is called semi-hermetic.

If the compressor doesn't have a hermetic enclosure but has a rotating shaft seal to prevent refrigerant inside the compressor from leaking to the outside, it is referred to as a non-hermetic, shaft-driven, or open-drive compressor

Caution

Never operate a hermetic compressor when there is a vacuum in the system because the hermetic compressor uses the flow of refrigerant to cool the motor that is enclosed in the hermetic housing. Operating in a vacuum means there is no appreciable refrigerant flow to cool the electric motor, which results in a

rapid rise in the motor winding temperature and rapid compressor motor burnout. For this reason, recovery machines should not use hermetic compressors.

Also, if you are doing a system-dependent recovery, which uses the system compressor, watch the system carefully if it has a hermetic compressor to ensure that an excessive vacuum isn't developed. Such a deep vacuum can quickly result in a system burnout, which ruins the system compressor and any remaining refrigerant.

Required Tools

Fittings

Low-loss fittings are used to connect the refrigerant recovery device to an appliance in a way that prevents loss of refrigerant from the hoses. These fittings can be manually closed or close automatically when you connect and disconnect the recovery and recycling machine. Figure C–2 shows a photograph of two common low-loss service hose terminations.

Figure C–2. Two common styles of low-loss service hose terminations

The EPA requires that the service hoses on recovery and recycling machines be equipped with low-loss fittings.

Gauges

Pressure gauges used in HVAC systems need to be able to measure both high and low pressures. High-pressure gauges used in the United States typically measure in pounds per square inch gauge, abbreviated as psig. The low-pressure gauge typically has a dual scale, referred to as a compound gauge, which measures in psig for pressures above the ambient pressure and measures vacuum in inches of mercury.

Typically, the compound gauge measures the vacuum in units of inches of mercury ("Hg) below atmospheric with a complete vacuum at 29.9 "Hg and essentially no vacuum at 0 "Hg (0 psig). When the pointer indicates zero, the pressure is the same as the atmospheric pressure. The pointer moves counterclockwise for vacuum indications and clockwise for pressure indications.

To complicate matters, gauges that measure a deep vacuum typically use an ***absolute*** scale where 0 represents a perfect vacuum and 760 mmHg absolute represents an atmospheric pressure of 0 psig, which is no vacuum at all. However, to provide better measurement accuracy, a micron gauge is typically used for deep vacuums. With a micron gauge, a perfect vacuum equals 0 microns, and 1 micron equals 0.001 millimeter of mercury (mmHg) pressure absolute. This means 760 mmHg absolute would equate to 760,000 microns, and a deep vacuum of 500 microns is a vacuum of 0.5 mmHg absolute, or 0.0097 psia.

A single absolute pressure scale (in pounds per square inch absolute or psia) can be used where 0 psia represents a perfect vacuum (just like 29.9 "Hg, 0 mmHg, or 0 microns), and 14.7 psia represents atmospheric pressure, equivalent to 0 psig. This type of pressure gauge is rarely used in HVAC/R applications.

Two-Valve Manifold Gauge Sets

Manifold gauge sets use both a high-pressure gauge (typically colored red) and a dual-scale, low-pressure compound gauge (typically blue). The manifold gauge set allows the simultaneous measuring of both high- and low-side system pressures during system operation or during servicing. Figure C–3 shows a schematic of a two-valve (three hose) manifold and Figure C–4 shows a photo of a manifold.

The two-valve type of manifold is constructed so that the high-pressure gauge displays the pressure in the high-pressure hose even if the high-pressure valve is closed. Opening the high-pressure valve opens the path between the high-pressure hose and the center hose.

Likewise, the low-pressure gauge displays the pressure in the low-pressure hose even if the low-pressure valve is closed. Opening the low-pressure valve opens the path between the low-pressure hose and the center hose.

Opening both the low-pressure and high-pressure valves allows refrigerant to flow between the high-pressure, low-pressure, and center hoses. Typically, the high-pressure hose is connected to the high-pressure side of the system, the low-pressure hose is connected to the low-pressure side of the system, and the center hose is connected to a refrigerant recovery device, vacuum pump, or refrigerant source.

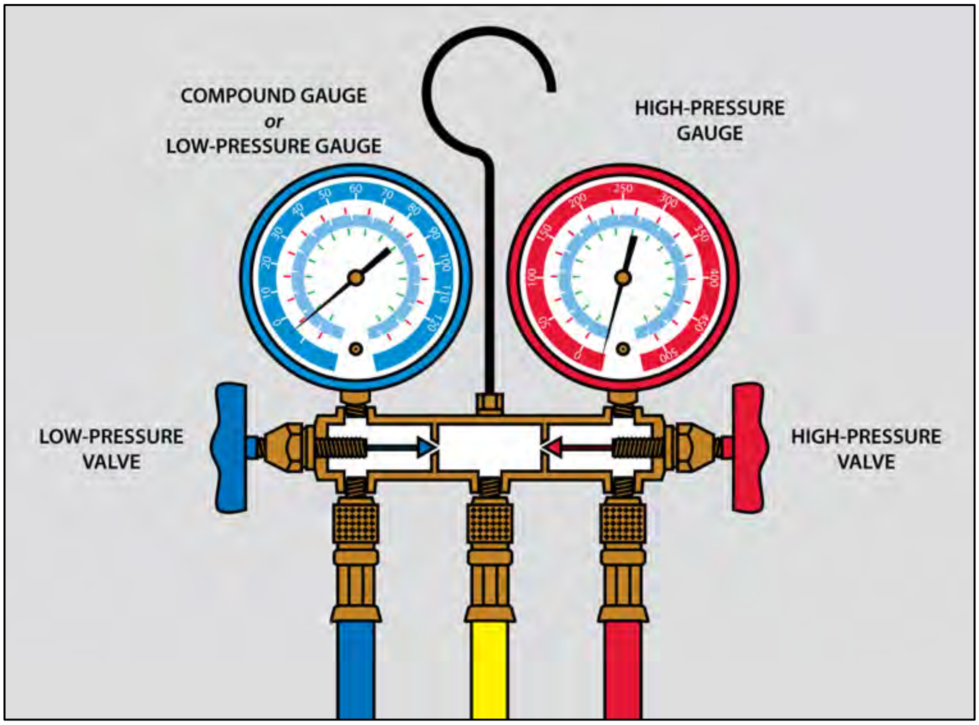


Figure C–3. Schematic of two-valve, three-hose manifold

Figure C–4. Photo of two-valve, three-hose manifold

Tip

Because the high-pressure (typically red) hose is connected to the high-pressure side of the system and the low-pressure hose (typically blue) is connected to the low-pressure side of the system, the center hose of a three-port manifold (typically yellow) is connected to everything else. That is, the center port on a three-port manifold is used for recovery, evacuation, and charging.

Caution

Be careful not to trap any liquid refrigerant in sealed hoses or the manifold gauge because increased ambient temperatures could cause the all-liquid refrigerant in these sealed components (which don't contain a pressure relief device like a recovery tank does) to expand, creating very high pressures and bursting the device. Sealed devices that contain at least 20 percent vapor have room for expansion, which is the reason recovery tanks are never filled with liquid to more than 80 percent of their volume.

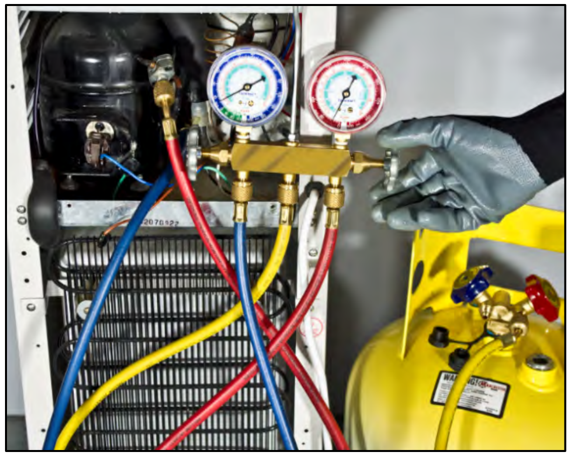
When you use self-sealing hoses on a manifold set, the most likely time a hose will be damaged is when liquid refrigerant is trapped in the service hose connected to the liquid charging line. Why does this happen? When charging liquid refrigerant into a system, if you disconnect the low-loss fitting from the Schrader valve on the system first and then close the manifold valve isolating that line, liquid refrigerant from the refrigerant supply is most likely trapped in the line. Then, as the line warms and the solid liquid volume of refrigerant expands with no place to go, the pressure in the hose can get quite high and damage or burst the hose.

To solve this problem, perform the following steps:

1. Close the manifold valve isolating the line so some or all of the liquid in the line can be drawn into the system being charged.

2. Disconnect the low-loss fitting.

These two steps are shown in Figure C–5.



Step 1

Step 2

Figure C–5. Disconnecting a low-loss fitting

Four-Valve Manifold Gauge Sets

Another popular manifold design is the four-valve, four-hose configuration shown in Figure C–6. The two center-type hoses can be individually shut with individual valves. This feature saves time.

Figure C–6. Four-valve, four-hose manifold

Example

With the four-valve manifold gauge set, you can connect one center hose to a refrigerant source and the second center hose to a vacuum pump. With the high-side hose connected to the high-side service port and the low-side hose connected to the low-side service port, the system and manifold (and hoses) can be evacuated together. Then, you can isolate the vacuum pump and use the refrigerant source to charge the system, all without any hose changes. This avoids accidental intrusion of air and other contaminants after evacuation, and it simplifies charging.

Pressure Ratings of Manifold Gauge Sets

The high-pressure gauge on a service manifold set has a continuous scale that is usually calibrated to read from 0 to 800 psig or 0 to 500 psig. ***The numbers on the scale don't mean the gauge set is actually rated for use up to these maximum pressures.*** On older gauge sets and/or hoses, a typical rating is only 340 psig, even though scales on the gauges can show values to 500 psig.

When you use R-410A, you must use a gauge set rated for at least 800 psig with a 4,000 psig burst pressure on the manifold and the hoses. R-410A requires recovery tanks and recovery/recycling machines rated for at least

400 psig. Table C–4 provides a comparison of the high-side pressure of an AC system operating with a 110 °F condenser and using various refrigerants.

Table C–4. Theoretical AC Performance Comparison[a]

	R-22	R-407C	R-410A
Compression ratio	2.66	2.83	2.62
Compressor discharge pressure	226 psig	241 psig	364 psig
Temperature glide	0°F	9°F	0°F

[a] Assuming 110 °F condenser, 45 °F evaporator, 5 °F subcooling, 15 °F superheat.

Table C–4 shows the higher discharge pressure of R-410A. Because older manifold gauge sets and recovery tanks were normally rated for 340 psig maximum operating pressure, they are inadequate for use with R-410A. Before working with R-410A, check your equipment to ensure it has been designed for use with that refrigerant.

Manifold Gauge Set Color Codes

Manufacturers often color code the exterior of gauges. On a typical manifold gauge set, the low-pressure gauge is color coded blue. The high-pressure gauge is red. Similarly, the hose that connects the low-pressure gauge to the low-pressure side of the system is blue, and the hose that connects the high-pressure gauge to the high-pressure side is red. The center hose is typically yellow.

Good Service Practices

Good service practices for conserving refrigerant include the following:

- Recover the refrigerant.
- Keep the system tight.
- Find and repair leaks.
- For larger systems, take an oil sample to check for contaminants when the unit has a leak or major component failure. An oil sample can test for moisture, acid, sludge, and waxing.
- Clean up the system after a burnout.
- Always draw a deep dehydration vacuum of at least 500 microns and if necessary use a triple evacuation method (discussed later) to achieve the deep vacuum. If the system has so much water contained in the system, and this moisture is preventing you from reaching at least a 500-micron vacuum, rather than ignoring the issue and charging the system anyway, at least add Qwik**Shot**® to remove the remaining water (after the system is charged and operating). Although this approach is ***NOT*** our recommended approach, it is far better than completely ignoring the moisture left in the system.

- Never flush the system with liquid refrigerant to clean field tubing; this is illegal. Instead, use a commercial, environmentally safe, non-aqueous (no water) flushing solution that is non-toxic and can remove oils, contaminants, acid, and water. Because Qwik **System Flush**® also removes moisture, it shortens the time required for a deep evacuation to at least 500 microns.
- To reduce the amount of flushing solution used, always clean out the tubing using nitrogen gas with a pressure regulator before and after using the flushing solution. Properly dispose of any flushing solution with the waste oil. Install both a liquid-line and suction-line filter drier if there was an acid burnout.
- When using dry nitrogen from a portable cylinder to pressurize, service, or install a refrigeration system, only use nitrogen vapor, and always use a pressure regulator with a relief valve inserted in the downstream line from the pressure regulator.

Caution

Using pressurized nitrogen from a nitrogen cylinder without a pressure regulator is dangerous because the pressure inside these cylinders is well over 2,000 psig. Putting this pressure inside a refrigeration system would cause the system to explode.

- Always change the filter drier any time the refrigeration circuit is opened for repair.
- When acid is detected in an operating system, always change the filter drier and use Qwik**Shot**® Refrigerant and Oil Treatment to remove moisture and flush the acid into the new fresh filter drier.
- On burnouts, always flush the system; replace the compressor, oil, and refrigerant; and use both a suction-line and liquid-line filter drier.

Tip

After a burnout, you can clean up the system by using proper flushing techniques, followed by installing suction-line and liquid-line filter driers, static pressure decay leak testing, and deep dehydration evacuation before recharging. A suction-line filter drier is used to prevent any acid in the system from returning back into the compressor suction (where it would acidify the new compressor oil).

Three Rs

When you remove refrigerant from a system, there are only four things you can do with the refrigerant:

- Recover and reuse
- Recycle and reuse
- Reclaim to new purity levels
- Send to an EPA-approved facility for destruction

The three Rs—recover, recycle, and reclaim—are obviously the three best choices. Sending refrigerant that can't be reused to be destroyed is expensive for you and worse for the environment.

Recover

When you recover refrigerant, you remove refrigerant in any condition from a system and then store the refrigerant in a container (or in some cases, inside the recovery unit) without necessarily testing or processing the refrigerant in any way.

Recovered refrigerant can be returned to the same system or other systems owned by the same person without restriction. You can't sell or give recovered refrigerant to another person because the used refrigerant might no longer meet the AHRI 700 standard for virgin refrigerant.

If the recovered refrigerant is to be disposed or returned to a reclamation facility, you must store the refrigerant in a Department of Transportation (DOT)-approved recovery cylinder. These tanks are painted gray with yellow tops as shown in Figure C–7.

Figure C–7. DOT-approved recovery cylinders

Recycle

When you recycle refrigerant, you clean the refrigerant for immediate reuse by oil separation and single or multiple passes through devices like replaceable core filter driers, which reduce moisture and acidity.

Oil separation is an important part of any good recycling effort. Oil is the real problem because oil contains the majority of the acid and water present in the system. Failure to remove contaminated oil results in very poor system clean up.

With recycling, an effort is made to clean the refrigerant, but there are no standards for how clean or how much cleaner the recycling must make the refrigerant before it is called recycled. Obviously, multiple passes through devices like filter driers clean the refrigerant more than a single pass, but both processes recycle the refrigerant.

Like recovered refrigerant, recycled refrigerant can’t be transferred to another owner. You can only use the refrigerant in the system you removed it from or in another system owned by the same person. You can’t sell or give away the recycled refrigerant except to a refrigerant reclamation company or waste disposer.

Reclaim

To reclaim refrigerant, a process is used to return refrigerant to new product specifications. This process requires chemical analysis to verify the refrigerant meets new product purity standards.

Refrigerant can't be called reclaimed unless it has been chemically analyzed and shown that the refrigerant meets the AHRI 700 purity standard.

Only reclaimed refrigerant can be transferred or sold to another individual. Typically, reclamation facilities don't reclaim your refrigerant and then return it to you. Instead, they purchase your used recovered refrigerant if they determine it can be reclaimed. They sell you other reclaimed refrigerant that they have already processed and certified as pure.

Tips

Using reclaimed refrigerant will never invalidate a system warranty because the reclaimed refrigerant has been tested and shown to meet new refrigerant purity specifications. However, there is no purity test for recycled refrigerant, and if you put dirty recycled refrigerant into a system, you could invalidate a system warranty. Clearly, with large systems under warranty, using new virgin or reclaimed refrigerant is safer.

Recovery Techniques

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 doesn't enter the waste stream with the charge intact.

What is Recovery?

When you recover refrigerant from a system, you are removing the refrigerant from the system and placing the refrigerant into a container. After the refrigerant is removed from the equipment, you can do one of the following:

- Return the refrigerant to the same system after the repairs are made or to another system owned by the same person.
- Recycle the refrigerant.
- Reclaim the refrigerant.
- Send the refrigerant to an EPA-certified refrigerant waste disposal facility.

If you are going to use the refrigerant in equipment other that the equipment from which it was removed and this other equipment is owned by someone else, the refrigerant must be reclaimed. Ownership of recovered or recycled refrigerant can't be transferred except when sold or transferred for reclamation or destruction.

Identifying the Refrigerant

Before beginning a refrigerant recovery procedure, you must ***always*** know the type of refrigerant that is in the system. Each refrigerant type has its own recovery evacuation requirements that you need to understand before you start the recovery procedure. You can check the nameplate on the system to identify the refrigerant used.

Note

The recovery machine must be specifically certified for the refrigerant being recovered.

Example

If you are servicing a system and you discover that some R-410A was added to an R-22 system, you can't recover the refrigerant into an R-22 cylinder. You must recover the refrigerant into a separate recovery tank for disposal because this contaminated mixture can't be reused or reclaimed. Instead, you have to send it to an EPA-approved facility to be disposed of, typically through a controlled incineration. You will receive no recycling credit for this contaminated refrigerant.

Use the Pressure and Temperature to Identify a 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 (Table C–5).

Note

Whenever you check system pressures, you should use hand valves or self-sealing hoses to minimize any release.

Table C–5 . Saturation Pressure–Temperature Chart for Common Refrigerants

Temp (°F)	Pressure (PSIG)								
	R-12	R-22	R-134a	R-404A	R-404A Liquid	R-407C Liquid	R-407C	R-410A	R-500
–15	2.4	13.2	–0.02	19.3	20.5	17.6	9.4	31.7	5.6
–10	4.52	16.49	2.02	23.2	24.6	21.3	12.5	36.8	7.85
–5	6.7	20.1	4.1	27.5	28.9	25.4	15.9	42.5	10.6
0	9.2	24	6.5	33.5	33.7	28.3	18.9	48.9	13.3
5	11.8	28.2	9.1	38.6	38.8	33.0	22.9	55.7	16.4
10	14.6	32.8	11.9	44.0	44.3	38.0	27.3	62.9	19.7
15	17.7	37.7	15.0	49.9	50.2	43.5	32.0	70.8	23.4
20	21.0	43	18.4	56.2	56.6	49.3	37.2	79.2	27.3
25	24.6	48.8	22.1	63.0	63.4	55.7	42.7	86.3	31.5
30	28.4	54.9	26.0	70.3	70.7	62.5	48.7	98.0	36.0
35	32.6	61.5	30.3	78.1	78.6	69.8	55.2	108.4	40.9
40	37.0	68.5	34.9	86.4	86.9	77.6	62.1	119.4	46.1
45	41.7	76.0	39.9	95.2	95.8	86.0	69.5	131.3	51.6
50	46.7	84.0	45.3	104.7	105.3	94.9	77.5	143.9	57.6
55	52.0	92.6	51.0	114.7	115.3	104.5	86.0	157.3	63.9
60	57.7	101.6	57.2	125.3	126.0	114.6	95.1	171.7	70.6
65	63.8	111.2	63.8	136.6	137.3	125.4	104.8	186.8	77.8
70	70.2	121.4	70.8	148.6	149.3	136.9	115.2	202.8	85.4
75	77.0	132.2	78.3	161.2	162.0	149.1	126.2	219.9	96.8
80	84.2	143.6	86.3	174.6	175.4	162.1	137.8	237.9	102.0
85	91.8	155.7	94.8	188.8	189.5	175.8	150.2	256.9	111.0
90	99.8	168.4	103.8	203.7	204.5	190.2	163.4	277.0	120.5
95	108.2	181.8	113.3	219.4	220.2	205.5	177.4	298.2	130.6
100	117.2	195.9	123.5	235.9	236.8	221.6	192.1	320.5	141.1

The pressure–temperature method has several flaws:

- The saturation pressure–temperature relationships of some refrigerants are similar and difficult to distinguish. For example, looking at Table C–5, you can see that at a given temperature, the pressure difference between R-12 and R-134a is very small. Given the errors you could make in both the pressure and temperature measurements, you can't reliably distinguish these two refrigerants by this method. However, it would be quite easy to distinguish between R-410A and R-134a.
- Non-condensable gases in the system 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-134a or R-410A.
- Non-azeotropic blends, which are the 400-series refrigerants, have pressure–temperature characteristics that 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 different, potentially making refrigerant identification impossible.

If you are unsure of the refrigerant in the system but know the correct refrigerant with which to recharge the system, the best practice would be to recover the refrigerant into a dedicated recovery cylinder and return the refrigerant to a reclamation facility. Then recharge the system with new or reclaimed refrigerant.

Alternatively, if you are simply trying to determine the refrigerant that should be in 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 and how the appliance is used affects the required level of evacuation. Evacuation requirements for each certification type are covered in greater detail in their respective sections of this manual. To facilitate the recovery of refrigerant from a system, EPA regulations require that all systems containing more than one pound of refrigerant must be equipped with some form of servicing aperture.

EPA has divided refrigerated appliances into five groups:

- Small Appliances (Type I)—Any appliance that is fully manufactured, charged, and hermetically sealed in a factory with five pounds or less of refrigerant. This includes but isn't 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 and packaged terminal air heat pumps), dehumidifiers, under-the-counter ice makers, vending machines, and drinking water coolers.
- Low-pressure appliances (Type III)—An appliance that uses a refrigerant with a liquid phase saturation pressure below 45 psia at 104 °F. This definition includes but isn't limited to appliances using R-11, R-123, R-113, and R-1233zd.
- Medium-pressure appliances (Type II)—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 isn't limited to appliances using R-114, R-124, R-12, R-401C, R-406A, R-500, R-1234ze(E), and R-1234yf.
- High-pressure appliances (Type II)—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 isn't limited to appliances using R-12, R-22, R-134a, R-401A/B, R-408A, R-409A, R-410A, R-411A/B, R-416A, R-500, R-502, R-404A, and R-507.
- Very high-pressure appliances (Type II)—An appliance that uses a refrigerant with a critical temperature below 104 °F or with a liquid-phase saturation pressure above 355 psia at 104 °F. This definition includes but isn't limited to appliances using R-13, R-23, and R-503.

Regulatory Requirements for Equipment Certification

EPA has established a certification program for refrigerant recovery and recycling equipment. All recovery and recycling equipment manufactured after 1993 must be certified to meet the EPA requirements, and those requirements have been detailed in Air Conditioning, Heating & Refrigeration Institute (AHRI) Standard 740. This is the industry protocol for testing recycling and recovery equipment.

An EPA-approved organization can certify equipment and test the certified recovery or recycling equipment (EPA requirement) based on the AHRI 740 Standard for the performance of recovery and recycling units. As part of this certification testing, the equipment is tested and certified for operation with one or more specific refrigerants and can be only used with those refrigerants.

To ensure that you are safely and properly recovering the refrigerant, you must use the recovery equipment according to the manufacturer's directions and only with the refrigerants for which the equipment was certified.

All manufacturers and importers of recycling and recovery equipment intended for use during the maintenance, service, or repair of appliances or during the disposal of appliances (except small appliances) must have the equipment certified by an approved equipment testing organization. This equipment will have an EPA label certifying that it is an EPA-approved unit.

Proper Equipment

Before you use any of the following recovery equipment, inspect the equipment for signs of damage, rust, corrosion, or deterioration. Don't use any equipment that has questionable integrity or that could be faulty. 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 refrigerant, you need the proper equipment:

- EPA-approved recovery unit
- 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 DOT refrigerant recovery tank (storage cylinder) rated for the pressure of the refrigerant to be recovered

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.

Tip

Have two recovery tanks for each refrigerant. You can use one tank to store dirty refrigerant that won't be returned to a system but instead turned over to a reclaimer. Use the second recovery tank for the temporary storage of recovered refrigerant while servicing a unit.

Caution

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

- ***Wear safety glasses with side shields.***
- ***Wear protective gloves.***
- ***Wear protective shoes.***
- ***Follow all safety precautions for the equipment.***

Recovery Unit

Recovery units remove the refrigerant either as a liquid or as a vapor. Liquid recovery is the fastest. The disadvantage is that all of the refrigerant can't be removed as a liquid, and you have to remove the remaining refrigerant as a vapor.

You can speed recovery by ensuring the hoses and valve ports are not restricted. Avoid using long hoses between the unit and the recovery machine because they cause excessive pressure drop, increase recovery time, and potentially increase emissions. Remove any unnecessary restrictions in the hoses including Schrader valve core depressors where they aren't needed.

If you only plan on servicing small appliances, hoses with ¼" flare fittings on the ends is all you should ever need. For larger systems, however, ⅜" or even ½" hoses are an excellent investment to reduce pressure drop and dramatically speed up recovery rates.

Heating the system or cooling the recovery cylinder also speeds up recovery. When the pressure in the system is increased by heating the system, the recovery is faster. In the inverse situation, when the pressure in the system is reduced, which is possibly caused by the evaporation of the refrigerant in the system (or low ambient temperatures), the vapor becomes less dense and the recovery is slower. Therefore, low-ambient temperatures increase recovery times.

Tip

To remove ice from a sight glass or viewing glass, the EPA recommends using an alcohol spray.

Recovery Cylinders

The cylinders you use for recovering refrigerant are specifically designed and DOT approved for recovery. ***Never*** use disposable refrigerant containers to recover refrigerant. Disposable refrigerant containers are used to supply virgin refrigerant and reclaimed refrigerant only.

A refrigerant cylinder that has a gray body and a yellow top indicates the cylinder is designed to hold recovered refrigerant. Figure C–8 shows the top of a typical recovery cylinder.

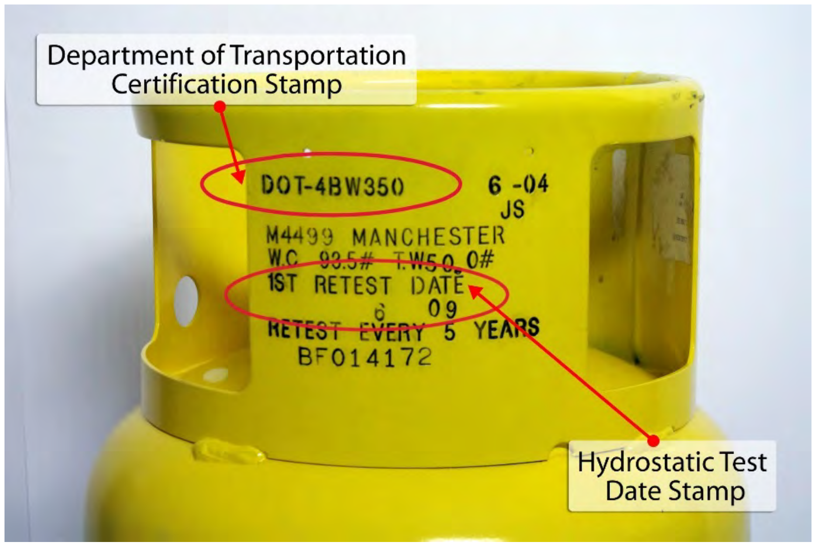


Figure C–8. Typical recovery cylinder

The recovery cylinder you use must have a DOT stamp of approval as shown in Figure C–8 and be rated for the refrigerant you are recovering. Because different refrigerants have different pressures, the recovery cylinder must be rated to handle the pressure of the refrigerant you are putting into the cylinder.

Refrigerant cylinders should be free of rust and damage. Before you use a recovery cylinder, inspect the cylinder for signs of damage, corrosion, or deterioration. Don't use any cylinder with questionable integrity.

You must also check the date on the cylinder. Reusable containers for refrigerants that are under high pressure (above 15 psig) at normal ambient temperature must be hydrostatically tested and date stamped every 5 years. Figure C–8 also shows the date stamp on a recovery cylinder. If the test date stamped on the shoulder of the cylinder is more than five years ago, you may not use that cylinder until you have it re-tested and date-stamped again by an approved testing laboratory.

Caution

You must ensure the cylinder isn't filled to more than 80 percent of its capacity. If overfilled and the temperature of the cylinder rises to levels common in storage areas during the summer, the

refrigerant inside could expand to the point that the cylinder would vent from the pressure relief valve or even explode.

Many refillable cylinders have internal magnetic-reed float valves that automatically shut the recovery unit off when the cylinder is 80 percent full. If you are using a refrigerant cylinder that doesn't have a mechanical float device or electronic shut-off device, you must use a scale to avoid overfilling.

Note

You can't use the sight glass on the system or the recovery unit to monitor the 80 percent fill level in a recovery tank because this tells you nothing about the volume of liquid stored in the recovery tank.

Cylinders that exceed 4.5" in diameter or 12" in length must have some type of pressure-relief device. Figure C–9 shows the pressure relief valve on a typical recovery tank. When you find corrosion buildup within the body of any relief valve, you must replace the valve.

Figure C–9. Pressure relief valve on a recovery cylinder

Because only one type of refrigerant may be recovered into the same cylinder, double check to be sure the recovery cylinder isn't filled with a different refrigerant. When recovering refrigerant, never mix different refrigerants in the same container because the mixture could then be impossible to reclaim.

If the mixture can't be reclaimed, it must be destroyed at an EPA-approved facility. If the recovery tank is empty, evacuate the tank before using. Always label the contents of the recovery tank, which is a DOT regulation. If emergency crews come across an unlabeled pressurized cylinder, they have to treat it as a worst-case scenario.

When you finish transferring liquid refrigerant, ensure that liquid refrigerant isn't trapped between service valves or in any way confined in the service hoses. Expansion of liquid refrigerant creates a high pressure and can rupture the service hoses.

After filling, you must verify that all cylinder valves are properly closed and capped to prevent leaks during subsequent handling and shipment. The recovery cylinder must also be properly labeled. The refrigerant recovery cylinder is labeled to avoid accidental mixing of recovered refrigerants, allow the recycler to identify the contents (without additional testing), and allow the technician's company to determine the amount of refrigerant recovered for recordkeeping purposes.

Caution

According to the American Society of Mechanical Engineers Pressure Vessel Code, the pressure rating must be 285 psig or higher for R-407C, and 400 psig or higher for R-410A. Do not use any storage or recovery cylinder with a maximum pressure rating less than 400 psig for R-410A. Recovery cylinders for R-410A should be specified as DOT 4BA400 or 4BW400.

Disposable Cylinders

Never refill a disposable cylinder. When scrapping a disposable cylinder, the internal cylinder pressure should be reduced to at least 0 psig, the cylinder rendered useless by puncturing or breaking off the service valve, and then the cylinder discarded (or recycled) as waste metal.

Repair

After a system has been properly evacuated, follow the additional good service practices described in this section.

Breaking the Evacuation Vacuum

Make all reasonable efforts to prevent the introduction of moisture to a system. Opening the system after it has been evacuated allows ambient air to enter the system and draws air and moisture into the system as the system stabilizes at atmospheric pressure. The preferred method is to introduce nitrogen into the evacuated system, raising the pressure to slightly above atmospheric pressure before opening the system.

After a Burnout or When Switching Refrigerants

When changing a system from a mineral oil to a synthetic ester-based lubrication system, you must remove all traces of the refrigerant and oil in the system. Because the refrigerant evaporates, it is removed during the recovery process, but the oil doesn't evaporate and can easily be trapped in the system. Acid and water that might have been in the system must also be removed.

When a compressor burnout has occurred, the burnout introduces high acid levels throughout the system. The compressor, refrigerant, and oil must be changed and the system flushed.

Identifying Causes of Post-Retrofit Breakdowns

Some contractors are experiencing compressor burnout problems with R-410A conversions soon after the systems are converted from R-22 refrigerant. The burnout is typically caused by improper flushing and residual acid, oil, moisture, or other contaminants being left in the system.

A refrigerant conversion should always include properly flushing components, except the compressor, filter drier, and expansion device, to remove residual oil, acid, water, and contaminants.

Poor on-site flushing methods and/or materials appear to be the main culprit in post-retrofit breakdowns because of the difficulty in getting all mineral oil, acid, and moisture traces out of the line sets in the old system. Combine the ongoing moisture battle that's commonly appearing in synthetic oil systems along with these damaging residuals and the result is either sludge that leads to the compressor seizing or inorganic mineral acid that leads to a compressor burnout.

Mainstream Engineering has performed several in-house tests proving that even miniscule amounts of residual impurities can result in mineral acid burnouts. If a newly converted HFC/POE burns out after just several months of operation, residual impurities are the main suspect.

Dehydration evacuation will never remove mineral oil or the acid trapped in the oil because the only removed contaminants are those that are capable of evaporating. Evacuation won't remove particulates or acid. Particulates, acid, and mineral oil left in a system can reach the compressor oil sump and can transform the oil into a sludge-like molasses. This sludge never boils off.

In the old days before CFC refrigerants were banned, service technicians used R-11 to flush lines. New EPA regulations now prohibit flushing any line set with any refrigerant.

To ensure the complete removal of the flushing compound, it too must vaporize. Therefore, any water-based liquid flushing solution is unacceptable because you are simply trading the oil and other non-evaporating fluids in the system with water and other liquid impurities. Given the complex chemical interactions of HFC refrigerants and synthetic oils, this is a really bad idea.

Because any good flushing agent removes both acid and water, these flushing solutions should never be purchased in an unpressurized container. Unless all the flushing solution is used immediately, the remaining flushing solution quickly becomes contaminated with moisture from the air that enters the container to replace the flushing solution that was removed. For this reason, Qwik **System Flush**® (QT1100 & QT1130) is only available in pressurized containers. In addition to flushing oil and impurities, Qwik **System Flush**® has patented acid and moisture removing additives to ensure both acid and moisture are flushed out of the system, which prevents future oil sludging issues and makes deep dehydration evacuations faster.

Tip

*Only use dry, non-aqueous flushing compounds that vaporize, which means they are packaged in a pressurized disposable cylinder or pressurized aerosol can, such as Qwik **System Flush**®.*

Qwik **System Flush**® (shown in Figure C–10) is a safe, biodegradable flushing agent originally developed for the U.S. Air Force to clean fighter jet oxygen breathing systems. Obviously, it's not a good idea to use a toxic cleaner for a system that distributes a pilot's oxygen at high altitudes. The success of the flushing agent later prompted Mainstream to market the cleaner to the HVAC/R industry, which also needed a safe, effective, environmentally friendly refrigerant flushing solution. Results from a third-party laboratory test are available at www.qwik.com/flush.

Figure C–10. Qwik System Flush®

Flushing agents are excellent for removing oil from line sets, but they should never be blown through a compressor because the flushing agent removes all lubricating oil from the sliding surfaces of the compressor, causing the compressor to seize.

Never flush the agent into a filter drier because the large number of particulates reduces its filtering capacity. Thermostatic expansion valve (TXV) apertures and capillary tubes would be clogged as well. These concerns aren't major because in a burnout/cleanup procedure, the compressor and filter drier are already removed from the system before flushing.

Checking for Acid

Another good practice for both burnouts and retrofits is to follow up the final assembly of the system with a Qwik**Check**® acid check on the operating system (Figure C–11).

Figure C–11. QwikCheck® testing for acid on an operating system

If acid is present, there are two types of acid removers:

- Neutralizing products that introduce an alkaline base to neutralize the acid

- Qwik**Shot**® Refrigerant and Oil Treatment, which removes acid and moisture by flushing the acid to the filter drier without neutralizing and without leaving residue or byproducts

Qwik**Shot**® Refrigerant and Oil Treatment is recommended because it leaves no residue like the neutralizing process. Any residue is a contaminant that can eventually damage the system. Also, if an acid neutralizer is used and too much is added, the system becomes basic, which is also corrosive. If too little neutralizer is added, all of the acid isn't neutralized.

Because the exact acid level is never known, you never know how much neutralizer to add to properly balance the acid present. Clearly, Qwik**Shot**® Refrigerant and Oil Treatment is a better approach. Qwik**Shot**® is added to an operating system using a Qwik**Injector**® as shown in Figure C–12.

Figure C–12. QwikShot® added to a system with a QwikInjector®

Preparing for Leak Checking

As a last step before leak checking, always change the liquid-line filter drier (anytime the system is opened). After a burnout, you should also add a suction-line filter drier to catch any residual acid in the system that might be sent back into the suction inlet of the compressor. This suction line filter drier should be located just upstream of the compressor inlet.

Leak Detection

This section describes several ways to find a leak in your system.

Oil Residue

Sometimes the simplest way to find the source of a refrigerant leak is to look for traces of oil on the exterior surface of an operating system (or a system that has been operating recently). This method is especially good for small systems that you can inspect closely. At the site of a refrigerant leak, the refrigerant vaporizes and enters the air while any entrained refrigerant oil is left at the surface of the leak because the oil can't vaporize.

One method to detect very small leaks is to use a fluorescent dye indicator such as Qwik**GlowPRO**® (QT2310). The dye can make the oil residue at the leakage site more noticeable. This technique is useful on small, hard-to-find leaks when you can look for the leak the next time the unit is serviced.

If a visual dye is used, you can see the dye with the naked eye. If an ultra-violet (UV) dye is used, you need a UV light to see the dye. This method doesn't work well in bright sunlight.

In either case, these techniques aren't useful for finding an immediate leak because after you add the dye to the system, you have to wait for an extended operating period until enough dye accumulates at the leak site. This approach is only recommended for detecting very small leaks that could not be found with other means.

Leak Testers

According to the EPA, the most effective way to detect the general area of a small leak is to use an electronic or ultrasonic tester.

Electronic Leak Detector

An electronic leak detector can detect leak rates of about 0.5 oz per year. After sampling the air, the electronic leak detector makes a sound or lights up if refrigerant is detected. Figure C–13 shows a typical leak detector.

Figure C–13. Electronic leak detector

This type of electronic leak detector works by drawing the vapor into the system and heating it. When the refrigerant vapor is heated, the positive ion concentration changes, affecting the electrical conductivity. To draw the air into the leak tester and test for trace amounts of refrigerant, a small air pump is used to draw the air into the leak tester probe. As the air sample is heated, the electrical conductivity increases, which is indicated by an increased clicking noise.

Caution

Electronic leak detectors are very sensitive, and the probe can be easily damaged by too much exposure to refrigerant in high concentrations. Never put the electronic leak detector probe near a high concentration of refrigerant, such as the direct refrigerant stream from a refrigerant bottle, to verify the detector is working. This can destroy the probe.

Soap Bubble Test

For small systems where you can coat all the potential leakage sites, a soap bubble test along with the use of dry nitrogen to pressurize the system can be effective. You coat the exterior surfaces where a leak is suspected with a liquid-soap solution and then look for signs of bubbles indicating the source of the leak.

Nitrogen Gas

Another way to check for leaks is to pressurize the system with dry nitrogen gas. Nitrogen is a colorless, odorless gas that makes up 78 percent of the air we breathe. It's nonflammable and won't support combustion. Although nitrogen is a relatively stable gas, it's not inert and reacts with oxygen to form nitric oxide and nitrogen dioxide. Nitrogen can also react with hydrogen to form ammonia and with sulfur to form nitrogen sulfide.

Nitrogen is available as both a gas and liquid. When supplied as a gas (sometimes referred to as GN or GN2), nitrogen is shipped in a high-pressure cylinder. When supplied as a liquid (referred to as LN or LN2), nitrogen is supplied as a liquid in a cryogenic Dewar.

For refrigeration applications, only use nitrogen gas with a nitrogen regulator to safely reduce the pressure of the gas to a controlled level.

Whenever you are pressurizing a system to check for leaks, always use dry nitrogen, which has very low water content. Nitrogen, like many substances, is available in various purity levels, and the higher the purity, the higher the cost. However, you need to ensure that the nitrogen you are using for flushing and leak testing is dry nitrogen and not contaminated with water vapor because water is easily absorbed by the synthetic oil, especially under pressure, and is very difficult to remove from a system.

After recovering refrigerant from a sealed system, you can use nitrogen to pressurize for leak checking or blow debris out of the system, but you should only use nitrogen vapor. Nitrogen may be vented to the atmosphere because nitrogen is a natural part of the atmosphere.

Never use compressed air, which contains oxygen that can explode (when mixed with compressor oil and some refrigerants) and contains lots of moisture.

It is legal to add a small quantity of the system refrigerant into the system before you pressurize it with nitrogen, and this leak check gas doesn't have to be recovered. However, using nitrogen without any refrigerant added is of course better for the environment.

Tip

After evacuating a system, never leave the system under a vacuum. An evacuated system could draw air, moisture, and other contaminants into the system when service valves are connected or if the system has a leak. Either charge the system immediately or store the system under a positive pressure with nitrogen.

Dry nitrogen causes essentially no damage to the environment when it is later vented because the atmosphere already contains approximately 78 percent nitrogen.

Caution

Do not use oxygen or compressed air to pressurize appliances to check for leaks because when mixed with compressor oil or some refrigerants, the oxygen can cause an explosion. Compressed air is also loaded with moisture.

Pressure Decay Leak Test

Another leak-checking procedure is a pressure decay leak test, also referred to as a static pressure decay leak test or standing pressure test, which is described in this section.

Why Not Use a Vacuum Test for Leak Checking?

Never use the system evacuation as a leak test. A vacuum test isn't the best method of leak testing a system for many reasons:

- A vacuum test allows air and moisture to enter the system if there is a leak.
- When you're working on a system, you can't determine from the vacuum where the leak is located, only the existence of a leak.
- When you check for a leak using a vacuum, you use a reverse pressure, which is the atmosphere trying to get into the system, of only 14.7 psi. However, under normal operating conditions, the system could be operating under an operating pressure of several hundred psig, which is 10 to 20 times the vacuum pressure difference.
- A vacuum test could actually hide a leak. For example, if a pin-sized hole is in a solder connection that has a flux buildup on it, the vacuum

could pull the flux into the pinhole so that a deep vacuum is achieved. However, when pressure is applied to the system, the flux will blow out of the pinhole, and the leak will be back.

Using a Pressure Decay Leak Test

Before you evacuate a system, you need to use a pressure decay leak test to verify no leaks exist. A simple method to determine the existence of a leak in the system is to pressurize using a pressure source that won't change an appreciable amount with temperature changes. Dry nitrogen is a good gas to use. If you plan to use an electronic leak detector, add a small amount of the system's normal refrigerant to the system before pressurizing with nitrogen, creating a leak trace gas.

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

Caution

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. Again, never use compressed air because of the risk of explosion with some refrigerants and the risk of system contamination. Compressed shop air is quite wet and contains trace amounts of mineral oil, which is incompatible with the newer synthetic oils.

With the pressure decay leak test, you pressurize the system to the pressure indicated on the system nameplate, record the pressure, and watch for pressure degradation over a sufficient time period.

The question is how long is sufficiently long? On a small appliance with a normal charge of five pounds or less, a sufficiently long time could be a lunch hour, but on a large 100-ton system, the unit might have to sit for a week to show any measurable drop in pressure.

Some natural changes in pressure occur due to temperature, which you must adjust for unless the temperature remains relatively constant. 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.

Pressure Decay Leak Test Procedure

1. If you are *not* going to use an electronic leak detector with this test, proceed to Step 2. If you are going to use a refrigerant leak detector, put a small trace amount of the system refrigerant into the system (bring the system pressure up to no more than 10 psig, far less for a Type III low-pressure system). Don't use mixtures of nitrogen and any other refrigerant as a leak test mixture. Only the system refrigerant can be used as the leak check refrigerant added into the system.

2. Use the nitrogen to increase the pressure to the maximum pressure of the system as indicated on the manufacturer's nameplate. To determine a safe pressure for leak testing, use the value on the low-side test-pressure data plate.

3. Isolate the system from the nitrogen source. Tap the gauge slightly to make sure the needle is free and record the pressure. If the pressure falls over time, the system has a leak. Any drop in pressure after compensating for temperature changes indicates a leak. If you see a pressure drop, remember it could be the manifold gauge and connections that are 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 refrigerant 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 are in the system. Evacuate to at least 500 microns.

Caution

Never use liquid nitrogen to pressurize a system; use only dry, clean, compressed nitrogen. Always use a pressure regulator with a pressure relief valve downstream when connecting to a nitrogen cylinder.

Do not pressurize any system above the working pressure of the system, which is written on the equipment nameplate.

To determine the maximum allowable pressure to use when leak checking a system, check the design pressure on the equipment nameplate. If no nameplate exists, use the normal operating condenser temperature and the saturation pressure–temperature table (see Table C–5) of the refrigerant to determine the normal operating condenser pressure and use that pressure.

Low-pressure systems typically have a pressure relief valve set at 15 psig and therefore are usually in-field pressure tested to only 10 psig.

Example

If you have an evacuated system designed for use with R-134a or R-410A and you want to leak check a system that has no nameplate that specifies the test pressure, use the normal operating condenser temperature to determine the normal working pressure. For example, use pressurized dry nitrogen with a regulator set to a pressure of no more than 125 psig for R-134a or 320 psig for R-410A.

Dehydration Evacuation

Refrigeration systems are designed to run with only refrigerant and oil circulating through them. Except for low-pressure systems, most systems have normal operating pressures that are above atmospheric pressure. Even if the system has a leak, air and non-condensables can't normally enter the system unless essentially all the charge has leaked out, or the charge is low enough so that the compressor is drawing the low-side pressure below ambient pressure. Therefore, dehydration of a system is only required if the system was opened up allowing air to enter the system. A deep vacuum to at least 500 microns is necessary to dehydrate a system.

Removing Trapped Water with a Deep Evacuation

You can remove the water or trapped refrigerant by repeating the deep vacuum draw-down process until all the water or refrigerant has been boiled off and the system holds the deep vacuum.

Heating a system helps to remove the trapped water by increasing the vapor pressure of the water and preventing the water from freezing. If the water freezes, evacuation is much slower. For this reason, if you use a vacuum pump that is too large, the vacuum in the system could drop too fast, potentially causing the evaporating water to cool and freeze, making further water removal much more difficult. Even if the water doesn't freeze, the lower temperature of the water lowers the boiling point of the refrigerant, making a deeper vacuum necessary to evaporate the remaining now cooler water.

Triple Evacuation Method

A triple evacuation is an evacuation method where the system is initially evacuated to the deepest vacuum possible, usually at least 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 or vented, typically through the vacuum pump and the system evacuated again. Recovery of the nitrogen isn't required. This process of evacuation followed by nitrogen pressurization is repeated (typically at least three total evacuations), and the final evacuation should achieve a vacuum of at least 500 microns.

Triple evacuation is an effective method for dehydration because it uses the dry nitrogen to sweep through the refrigerant lines to push out any residual moisture. Air is 78 percent nitrogen, so this process doesn't harm the environment.

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 doubtful because you've 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, this indicates that 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.

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 burst 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, regulator, and downstream pressure relief device), 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. A vacuum pump can consist of a single- or two-stage design, but a two-stage vacuum pump is necessary for HVAC/R work.

The vacuum pump can also have a gas ballast valve, which helps to prevent moisture that is being removed from the system from condensing into the vacuum pump oil and reducing the maximum achievable vacuum level. Anytime a two-stage vacuum pump can't easily achieve a deep vacuum of at least 500 microns (when isolated), the vacuum pump oil could be contaminated with water and the oil needs to be changed.

Figure C–14 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 condenses 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.

Procedure for using a gas ballast valve:

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

Figure C–14. 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 vacuum (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 C–15 shows a typical electronic micron gauge. The micron gauge is far more accurate at measuring deep vacuums (very low pressures) when compared to a manifold gauge.

Figure C–15. Electronic micron vacuum gauge

The compound (blue) low-side pressure gauge on a manifold set measures evacuation levels by 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 at the deeper vacuum levels, providing greater measurement resolution.

Example

There are 25,000 microns between 29 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 doesn't 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 doesn't reach a level that exceeds 500 microns. If the gauge reading doesn't exceed 500 microns during the waiting period, you know the system has been evacuated adequately.

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.

Piping connections 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 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.

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.

Removing Non-Condensable Gases

If air gets into the refrigeration system or into a recovery cylinder, the system doesn't function properly; at even the coldest temperatures, the air won't condense in any vapor-compression system. This means that the air or any other non-condensable vapors don't condense anywhere in the vapor compression system, leading to increased system pressures.

If you try to recharge the system without first removing the non-condensable gases, the system operates at condensing pressures that are higher than normal because of the air trapped at the top of the condenser. This air effectively reduces the capacity of the condenser to reject heat and raises the overall discharge temperature and pressure. As a result, the system not only loses efficiency, but also the components in the system, such as the compressor, have the potential to fail prematurely because of the extra load.

Non-condensable gases can also cause chemical reactions that produce acids, reduce oil lubricity, and carry moisture into the system. Water vapor inadvertently introduced into the system with the air that enters the system can harm the system because moisture accelerates the formation of acids in the refrigerant and oil. If the evaporator is operating below the freezing point of water, the water vapor in the refrigerant can freeze in the small passage of the expansion device, causing the system to stop cooling. This unique failure mode takes place when the system stops cooling after operating awhile (due to the ice-clogged expansion valve). But then after sitting idle, the system again operates normally because the ice clog melted. The system operates for a while again before ice forms in the expansion device again.

To prevent damage to the appliance, you need to ensure no non-condensable gases are in the system. One way to avoid introducing non-condensable gases into the system is to perform a proper system evacuation after the system has been repaired and pressure leak tested and before charging the system with refrigerant.

Never cross charge a system: if a system is charged with one refrigerant, never top it off with a different refrigerant.

You need to know if excessive air or other non-condensable gases exist in the recovery cylinder because you don't want to put refrigerant contaminated with non-condensable gases back into the appliance.

Because you know non-condensable gas causes the pressure to rise, if you knew what the pressure was supposed to be and you could measure what the actual pressure was, you might be able to tell if non-condensable gases were in the system. One simple method of checking for non-condensables is to use the pressure–temperature chart (Table C–5) for the refrigerant.

If you know the room temperature where the appliance or recovery cylinder is located and this temperature is stable and represents the temperature of the system, you can find out what the pressure should be if no non-condensables were in the system. Then you can compare that pressure with the actual pressure. If the actual pressure is higher, non-condensables could be present.

If you measure a pressure that is lower than the pressure indicated on the pressure–temperature chart, one of the following three reasons could be the cause:

1. The temperature or pressure readings are incorrect because of unstable conditions or measurement devices that are out of calibration. Allow the cylinder temperature to stabilize at room temperature before taking pressure readings.

2. The refrigerant is contaminated with another refrigerant.

3. The refrigerant is a blend that has fractionated and the more volatile component has leaked off.

When contamination, fractionalization, or the presence of non-condensables is suspected, don't use the refrigerant. The refrigerant must be reclaimed by a certified reclaimer or destroyed by an approved disposal company. The refrigerant can't be recycled.

Tip

When in doubt, don't use the refrigerant.

Lubricants and Evacuation Procedures

The evacuation procedures today have to be much better than in the past because of the new lubricants that are used with the HFC refrigerants. In the past, CFC and HCFC systems used mineral oil, which has a much lower water saturation limit than the new synthetic oils, which absorb much greater concentrations of water (at least 100 times more). With the potential for so much more water in the system, you have to avoid moisture entry into the system, and you have to follow evacuation methods rigorously.

Before recharging a refrigeration system and after adding a new filter drier and leak checking a system, evacuate the system to at least 500 microns to dehydrate the system (to remove any liquid water and/or water vapor). If you are working with flammable refrigerants, the recovery unit, the refrigerant cylinder, and the system must be grounded to avoid a potential explosion caused by an electrical spark. Triple evacuation of a system is the best method of dehydration.

Although the EPA claims the most effective way to *detect the general area* of a small leak is to use an electronic or ultrasonic tester, a standing-pressure leak check at the maximum system pressure is the *best way to verify a system is leak free.*

General Safety

The safety concerns usually associated with refrigerants are displacement of the oxygen in a room (asphyxia), toxicity, flammability, frostbite, and explosion (due to the high pressure or combustion of flammable refrigerants). All refrigerants pose one or more of these safety concerns but only if the refrigerant escapes the container or the system. You can safely use refrigerants if you consistently follow safety guidelines, use proper equipment, and know what to do if the refrigerant does escape.

Safety Concerns

Asphyxia

When refrigerants are released into the air, they displace the oxygen in the area (asphyxia) without you realizing it. Most refrigerants are heavier than air, odorless, tasteless, and invisible. Before you begin working with any refrigerant, ensure the area has adequate ventilation. The area should have at least four air changes per hour.

Caution

Avoid prolonged breathing of refrigerant vapors or mist. Inhaling refrigerant in high concentrations for prolonged periods is extremely dangerous and could cause heart irregularities or unconsciousness. Death can occur without warning.

In most refrigerant accidents where death occurs, the major cause is oxygen deprivation because the refrigerant displaced the air.

Non-toxic refrigerants (such as R-22) can still can cause asphyxia because, like other refrigerants, they are heavier than air and displace the air.

Preventing Asphyxia

If someone is overcome in a space with inadequate oxygen due to a high concentration of refrigerant, move the person into fresh air, seek medical help, and give oxygen if needed. Remember, unlike smoke, refrigerant vapor is generally heavier than air, so if the ventilation is poor, the vapor will concentrate in low areas.

If there is a large release of any refrigerant in a contained area, you must either use a self-contained breathing apparatus (SCBA) or vacate and ventilate the spill area. Ventilate closed spaces before you enter and avoid low areas as you leave.

If a large leak of refrigerant occurs, such as from a filled cylinder in an enclosed area, and no SCBA is available, evacuate the area at once.

Toxicity

ASHRAE 34 divides refrigerant compounds into either low-toxicity or high-toxicity groups. The toxicity group is assigned depending on the permissible exposure limit (PEL) of the compound (see Figure C–16).

- Refrigerants with lower toxicity have PELs of more than 400 parts per million (ppm) and are classified as type A.
- Refrigerants with higher toxicity have PELs of less than 400 ppm and are classified as type B.

Older refrigerants, such as CFC-11 and HCFC-22, have 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 classified along with ammonia and sulfur dioxide as higher in toxicity. Although R-245fa is currently classified as A1, this classification is provisional and will be reviewed as additional data becomes available.

Excessive heat can cause the refrigerant to decompose, potentially forming toxic vapors.

Flammability

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

- The number 1 is given to refrigerants with no flame propagation. Class 1 refrigerants don't show flame propagation when tested in air at 70 °F and atmospheric pressure (21°C and 101 kPa).
- The number 2 is given to refrigerants with low flammability. Class 2 refrigerants have a lower flammability limit of more than 0.10 kg/m3 at 70 °F and atmospheric pressure and a heat of combustion of less than 19 kJ/kg.
- The number 3 is given to refrigerants with high flammability. Class 3 refrigerants are highly flammable as defined by a lower flammability limit of less than or equal to 0.10 kg/m3 at 70 °F and atmospheric pressure or a heat of combustion greater than or equal to 19 kJ/kg.

A refrigerant with an ASHRAE refrigerant safety classification of A-1 would be the safest, meaning both low toxicity (A) and non-flammable (1), such as R-134a. Figure C–16 shows the flammability vs. toxicity of common refrigerants.

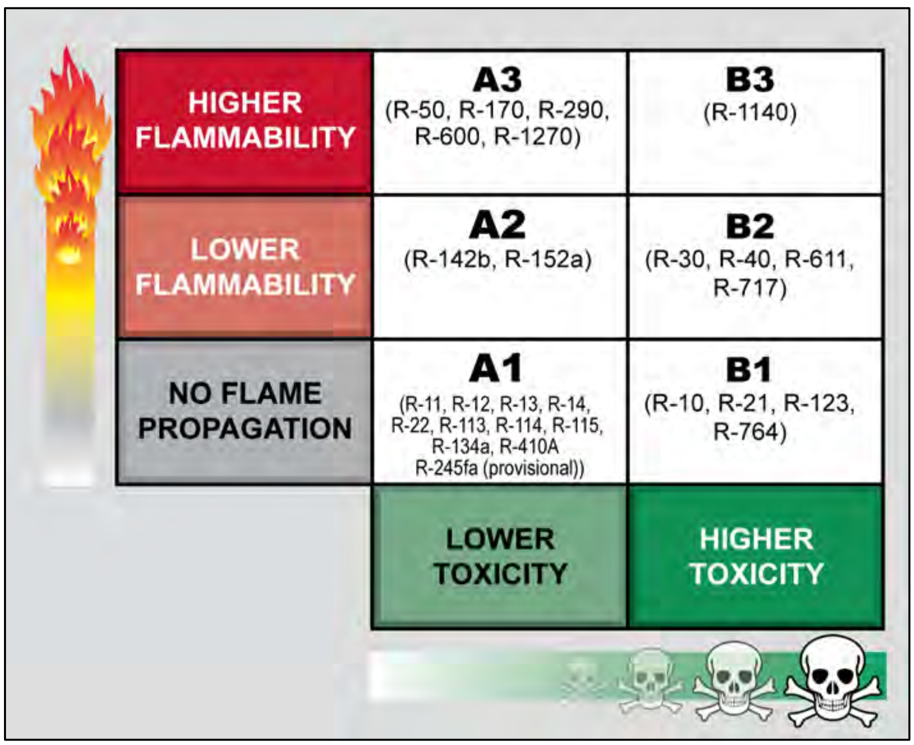


Figure C–16. ASHRAE safety classifications with some example refrigerants

Hydrocarbon Refrigerants

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. Some common hydrocarbon refrigerants are R-50 (methane), R-170 (ethane), R-290 (propane), R-441a (3% ethane, 55% propane, 42% isobutane), R-600 (n-butane), R-600a (isobutane), R601a (isopentane), R-1150 (ethylene, propylene).

Hydrofluoroolefin Refrigerants

HFO refrigerants are unsaturated HFCs that are heavily promoted as the next generation of refrigerants because of their environmental friendliness, although they aren't as green as the HC refrigerants. Although most HFO refrigerants are still flammable, they are less flammable than HC refrigerants. Because HFO refrigerants, like the HFC refrigerants, contain fluorine atoms, these fluorine atoms reduce the flammability.

Refrigerant manufacturers developed numerous HFO blends tailored to specific applications. HFO-1234yf, HFO-1234ze, and HFO-1233zd are furthest along in development. HFO-1234yf, HFO-1234ze are all classified as A2L, meaning they are "slightly" flammable (L for low) and HFO-1233zd is classified as A1(non-flammable).

Flammability Safety Precautions

Flammability risks are of particular concern to the EPA because, unlike Europe, refrigeration appliances in the United States traditionally have used refrigerants that aren't flammable. Without proper training, 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. Flammable Refrigerant Training is available at www.epatest.com.

Before you begin working on any refrigeration equipment, check the area for spilled or open containers of any flammable liquid or vapor such as gasoline and thinners. Don't operate any system where flammable liquids or vapors are present unless the system and any used tools are specifically designed for operation in flammable vapor locations. The sparks from contactors, relays, and motors in the system or the tools and equipment could cause a fire or explosion.

Caution

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

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

Never use EPDM (ethylene propylene diene monomer), natural rubbers, and silicone rubbers in HC or HFO refrigerant systems. These materials aren't compatible.

Marking of Systems Containing Flammable Refrigerants

Appliances containing flammable hydrocarbon refrigerants must have red marking on the area where the refrigerant will be accessed. The red marking 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 red 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. The purpose of the colored section of tubing is to inform the service technician that the system is charged with a flammable refrigerant so you can take additional precautions (e.g., reducing the use of sparking equipment) as appropriate to avert accidents, and particularly if refrigerant charge labels are no longer legible. Adding red coloring on tubing inside the appliance provides additional assurance that you will be aware that a flammable refrigerant is present.

This doesn't mean that the entire hose or process tube must be red. For process tubes, the tube must be red for at least one inch extending from the compressor as shown in Figure C–17. This way, if the process tube is cut for service, the red marking still remains after the tube is welded back together.

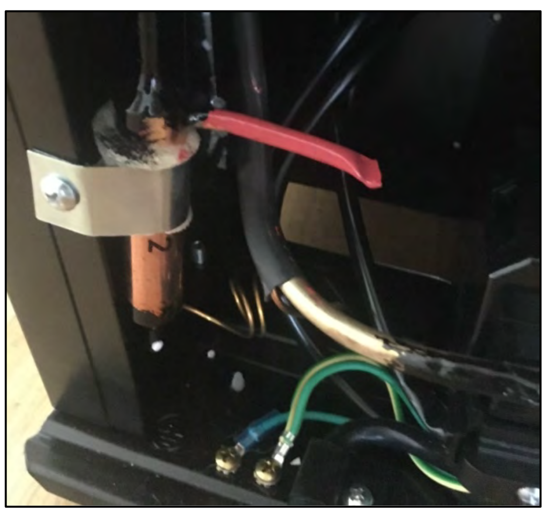


Figure C–17. Red tubing to inform the technician of a flammable refrigerant

If further servicing would leave the colored portion of the process tube less than 1 inch long, you must extend the red marking to at least 1 inch. If there isn't 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 don't allow the inclusion of service ports in finished products using flammable refrigerants; however, service ports can be added during servicing and the red marking requirement would still apply.

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

You can use a colored sleeve 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, if you remove a sleeve during servicing, you must replace that sleeve on the serviced tube with another sleeve.

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. 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 ¼" (6.4 mm) to make it easier for technicians, consumers, retail store owners, and emergency first responders to see the warning labels (see Shipping Labels on page 90).

All refrigerant containers that contain a flammable refrigerant or a refrigerant blend that could become flammable if there is a leak, must have a red band on the shoulder or top of the container.

Service ports aren't allowed in new household refrigerators or standalone retail food refrigerators that use flammable refrigerants, but Clean Air Act regulations still require a process tube when a service fitting isn't 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 is legal to install one), 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.

Caution

When working with flammable refrigerants, always follow these safety precautions:

- ***Never apply an open flame or live steam to a refrigerant cylinder.***
- ***Don't cut or weld any refrigerant line when refrigerant is in the unit.***
- ***Always refit the valve cap when the cylinder isn't in use.***
- ***To avoid any static electrical spark, ensure that the refrigeration cylinder, recovery unit, and system are grounded before beginning any service or refrigerant recovery.***
- ***Ensure the threads are clean and undamaged.***
- ***Never use oxygen or compressed air to purge the lines or pressurize the system.***
- ***Store and use cylinders in dry well-ventilated areas away from any fire risk.***
- ***Keep cylinders away from sources of heat.***
- ***Don't 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 and marked (red stripe) for use with flammable refrigerants.***
- ***Don't use EPDM, natural rubbers, or silicone rubbers in HC or HFO refrigerant systems. These materials aren't compatible.***

Frostbite

If the gas comes into contact with your skin, it could cause burns and frostbite. To avoid frostbite, always wear personal protective equipment when you work with refrigerants, the systems, and the cylinders that contain them.

Explosion

For flammable refrigerants, never use any equipment that isn't rated to handle flammable refrigerants. Only use recovery or recycling equipment that has been tested and EPA certified for use with the specific flammable HFO or HC refrigerant being recovered. These recovery units have been specifically designed to provide additional safeguards to avoid explosion and fire hazards.

Flammable refrigerants could pose an increased safety hazard if handled incorrectly. When the concentration of a flammable refrigerant is at any concentration above the lower flammability limit (LFL) and below the upper flammability limit (UFL) in the presence of an ignition source, an explosion or fire could occur. The ignition could come from many sources: a static electric spark resulting from closing a door, use of a torch during servicing, the spark from a contactor opening, nearby operation of a motor or switch that isn't explosion proof, or a short circuit in wiring that controls the motor of a compressor.

If you are working with flammable refrigerants, you must ground the recovery unit, the refrigerant tank, and the system to avoid a potential explosion caused by an electrical spark.

Never store refrigerant cylinders near highly flammable substances because they can explode and or discompose if there is a fire. Never heat any refrigerant storage tank with an open flame because the heat can over-pressurize the tank, resulting in refrigerant vented to the atmosphere or explosion of the tank, causing serious injury to people nearby.

Safety Data Sheets

Solvents, chemicals, and refrigerants come with a safety data sheet (SDS), which provides important information on the physical/chemical characteristics and first aid procedures. Always review the SDS information before working with any solvents, chemicals, or refrigerants.

Proper Equipment

Personal Protective Equipment

Given the risk that refrigerants could escape during a procedure, always wear personal protective equipment when you work with refrigerants, the systems, and the cylinders that contain them.

- Wear splash-proof safety glasses to guard against liquid refrigerant freezing the moisture of your eyes and causing permanent blindness. If you get refrigerant in your eyes, flush the area with water for at least 15 minutes.
- Wear protective gloves and shoes to guard against frostbite. If you get refrigerant on your skin, flush the area with water for at least 15 minutes.
- If you get refrigerant on your clothes, take your clothes off and flush your skin for at least 15 minutes.

In addition to protecting your body with protective gear, read and follow all safety precautions for the equipment you are using. Always read the safety data sheet for any substance you are working with including the refrigerants, lubricants, and any flushing or cleaning solutions.

Caution

Always follow these safety precautions:

- ***Never apply an open flame or live steam to a refrigerant cylinder.***
- ***Don't cut or weld any refrigerant line when refrigerant is in the unit.***
- ***Don't use oxygen or compressed air to purge lines or to pressurize a system. Use dry nitrogen gas only and use always use a pressure regulator and downstream pressure relief device.***

System Equipment

Before you maintain, service, or use any refrigeration equipment, inspect the equipment for signs of damage, rust, corrosion, or deterioration. Don't use any equipment with questionable integrity or any equipment that could be faulty. This equipment includes the compressor; all gauges, hoses, fittings, and valves; all cylinders and tanks; and all tools.

Cylinders

As you learned earlier in this study guide, the cylinders that are used to ship and store refrigerants must be DOT approved, and they must be handled carefully to prevent the refrigerant from leaking or the container from rupturing. Any time you use a cylinder, carefully inspect it. Refrigerant cylinders should be free of rust and damage, they must hold a current hydrostatic (pressure) test certification, and they must be secured.

The cylinders are also color coded to indicate the refrigerant contained. For example, sky blue is used for R-134a or rose for R-410A. A complete list of the color codes for cylinders of new or reclaimed refrigerant is shown in Table C–6.

In June of 2016, the AHRI declared that they will be doing away with color coding of refrigerant containers by the year 2020. This is unfortunate because color coding not only saves time but can help avoid accidently using the wrong refrigerant.

Approved refrigerant recovery cylinders are color coded with a gray body and a yellow top to indicate that the cylinder is designed to hold recovered refrigerant. The cylinder must also be labeled with the refrigerant it contains. Before adding refrigerant to a recovery cylinder, ensure the container is labeled and optionally also color coded for the refrigerant you are adding to the cylinder.

Caution

You may never use a disposable cylinder to recover refrigerant. Disposable refrigerant containers are used for supplying virgin or reclaimed refrigerant only and are only to be filled by the refrigerant manufacturer or EPA-certified reclaimer.

When using a recovery unit, you can control the fill level of the recovery cylinder by using a mechanical float switch or electronic shut-off device, or by weighing the cylinder on a scale.

Table C–6. Refrigerant Tank Color Coding

Tank Color		Refrigerant
	Orange	R-11
	White	R-12
	Sky Blue	R-13
	Light Green	R-22
	Light Blue/Gray	R-23
	Dark Purple	R-113
	Navy Blue	R-114
	Battleship Gray	R-116
	Light Blue/Gray	R-123
	Deep Green	R-124
	Tan	R-125

	Tank Color	Refrigerant
	Sky Blue	R-134a
	Coral	R-401A
	Mustard	R-401B
	Orange	R-404A
	Medium Brown	R-407C
	Tan	R-409A
	Pink	R-410A
	Yellow	R-500
	Light Purple	R-502
	Aqua	R-503
	Teal	R-507
	GrayBody/Yellow Top	Recovery Cylinder

Because any refrigerant cylinder could be shipped from one location to another, the Department of Transportation (DOT) has regulations you must follow, and all cylinders (including recovery cylinders) must meet these DOT regulations (as discussed in Shipping starting on page 90).

If you are recovering refrigerant, you can only use portable refillable tanks (cylinders or containers) that meet DOT standards and are designated "refillable" by DOT for transporting recovered pressurized refrigerant.

The DOT also requires that any pressure vessel, including refrigerant cylinders that normally have a pressure above 15 psig at room temperature, must be hydrostatically tested and date stamped every 5 years.

When heated, refrigerants used in systems or stored in tanks can build up very high pressures with the potential of causing serious injury.

Caution

Never fill a refillable refrigerant cylinder above 80 percent of its capacity by weight at 77 °F (24 °C). If you fill a cylinder more than 80 percent and then put the cylinder in an area that gets hot, the internal pressure of the cylinder could rise and vent the refrigerant through the pressure relief valve or rupture the burst disk. Either way, the refrigerant is lost to the environment.

Tip

Although R-410A is a high-pressure refrigerant, you can store it in the back of your service van as long as the temperature inside the vehicle doesn't exceed 125 °F. This is the same guidance given for R-22 and other common refrigerants.

If a refrigerant cylinder is overfilled with liquid refrigerant and the pressure relief value doesn't operate properly, the cylinder could rupture and cause an explosion. This is because as the liquid expands due to the increase in temperature, if there is insufficient vapor space, the expanding liquid has no room to expand, resulting in excessive pressures that can burst the cylinder.

Similarly, you must ensure no liquid is ever trapped in any space that isn't protected by a pressure relief valve. If the liquid expands in an unprotected, confined space, such as in refrigerant hoses, the expanding liquid will rupture the container, leading to an explosion of rapidly expanding vaporizing liquid.

These two-phase flashing refrigerant explosions are more violent than the explosion of an air cylinder, for example. This is because, as the pressure in the space drops due to the rupture, the compressed liquid refrigerant flashes (evaporates almost immediately) into vapor. The explosion is more violent because the liquid refrigerant continues to flash into a stream of vapor.

Shipping

Department of Transportation Regulations

Portable refillable recovery tanks or containers used to store or ship refrigerants obtained with recovery equipment must meet DOT standards to ensure they are safe.

If you want to ship any refrigerant, you have to follow the DOT standards to prepare the cylinders for shipping:

- Fill the cylinder only up to 80 percent of its capacity or less, which is the same as the EPA standard.
- Check the hydrostatic test inspection label on the cylinder and ensure the cylinder was certified within the last five years.
- Ensure the cylinder is rated for the refrigerant it contains and is properly labeled and color coded.

Shipping Labels

When transporting cylinders containing used refrigerant, you must attach DOT classification tags. A refrigerant recovery cylinder with a DOT classification tag is shown in Figure C–18. Place the refrigerant label directly on the refrigerant cylinder to be shipped. DOT regulations require the number of refrigerant cylinders of each refrigerant to be recorded on the shipping papers.

The DOT classification tag and shipping paperwork provide vital information to first responders after an accident by identifying the involved refrigerants so proper protective actions can be taken.

The shipping document contains the proper shipping name of the refrigerant, the hazard class, and the 4-digit United Nations Identification number preceded by the letters UN. The shipping document also displays a 24-hour emergency response telephone number.

Figure C–18. Photo of DOT classification tag

You must also properly complete the shipping paperwork as shown in Figure C–19.

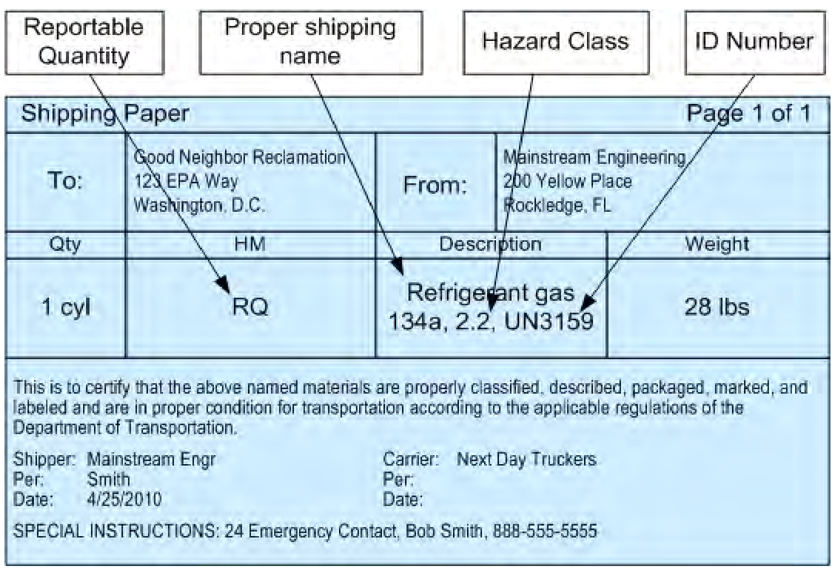


Figure C–19. Typical shipping paperwork

Cylinder Loading

It is a legal requirement that 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 can't move during transport.

Emergency Response Guidebook

DOT produces an Emergency Response Guidebook (ERG) for first responders to accidents involving dangerous or hazardous materials. The shipping label attached to the refrigerant cylinder tells first responders which section of the ERG to follow if an accident occurs.

The shipping label on the cylinders requires a 24-hour, 7-day emergency response telephone number. If called, information about the refrigerant, such as the safety data sheet, must be provided.

Emergency responders should keep unauthorized people at least 100 meters (330 ft) away from the spill and stay upwind if possible.

Type I—Small Appliance Certification

Type I Technician Requirements

This section will prepare you for the EPA Type I Certification online exam for technicians working with small appliances.

If you maintain, service, or repair small appliances (including the recovery of refrigerant), you must be properly certified by the EPA as a Section 608 Type I technician or Universal technician. The sale of refrigerants to service or install refrigeration and air conditioning equipment is restricted to technicians who are EPA certified in refrigerant recovery.

Regardless of the system charge, a motor vehicle air conditioner (MVAC) or MVAC-like air conditioner does not meet the requirements for Section 608 Type I certification. To service MVAC systems, EPA Section 609 MVAC certification is required (see www.EPAtest.com for Section 609 training and testing). To service MVAC-like equipment, either EPA Section 609 MVAC certification or Section 608 Type II (or Universal) certification is required.

What is a Small Appliance?

EPA defines a small appliance as a product that is fully manufactured, charged, and hermetically sealed in a factory with five pounds or less of refrigerant. The following is a list of common small appliances:

- Refrigerators and freezers designed for home use
- Room air conditioners (including window air conditioners and packaged terminal air conditioners[PTACs])
- Packaged terminal heat pumps
- Dehumidifiers
- Under-the-counter ice makers
- Vending machines
- Drinking water coolers

More than 8 million refrigerators, freezers, air conditioners, dehumidifiers, and other vapor compression small appliances are discarded each year in the United States, releasing an estimated four million pounds of refrigerant into the atmosphere annually. EPA believes that these releases contribute to one of today's greatest environmental threats—the destruction of the stratospheric ozone layer.

Household refrigerators and other small cooling appliances that combine to make up the small appliance category have very small charges and are rarely serviced. The relatively low cost of these units typically does not justify repair, and the equipment owner usually just replaces the item. When this equipment is disposed, it generally enters the waste stream with the charge intact. The charge must be removed before it is ultimately discarded.

EPA has special safe disposal requirements for small appliances, which have been enacted to ensure that the final person in the disposal chain (e.g., a scrap metal recycler) is responsible for properly recovering the refrigerant before the final disposal of the equipment. Anyone along the disposal chain can recover the refrigerant, but the final person in the disposal chain has the responsibility to ensure the refrigerant has been properly recovered.

Flammable Refrigerants

EPA Rules on Flammable Refrigerants

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.

EPA found that using R-600a (isobutane), R-290 (propane), and R-441A in household refrigeration is acceptable. The use of HFC-32 (difluoromethane) is acceptable in room air conditioning units.

R-450A is a zeotropic blend of R-134a and HFO-1234ze designed to serve as an alternative to R-134a, offering similar performance but with a lower global warming potential of only 547 (a reduction of almost 60% of GWP).

EPA established the following use conditions for flammable refrigerants:

- These specific flammable 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 are 57 g (2.0 ounces weight) for household refrigeration and 150 g (5.3 ounces weight) for retail food refrigeration end uses. For vending machines, the flammable refrigerant charge is limited to 150 g (5.3 ounces by weight). The charge size limitation

applies to each individual isolated refrigerant circuit in the device, not the charge in the entire appliance.

- Refrigeration units using HC refrigerants must be clearly labeled.
- To denote the system charge is a flammable refrigerant, 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. 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

UL Standards referenced in this rule don't allow the inclusion of service ports in finished products using flammable refrigerants; however, you can add service ports during servicing. If you do, the red line marking requirement still applies.

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

Odorization of Flammable Refrigerants

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 refrigerants as long as the refrigerant remains within purity specifications.

According to the EPA, however, the red exterior markings and adherence to UL Standards are designed to alert manufacturers, service personnel, and customers of the presence of a flammable refrigerant without the need to add odorant.

Tube Marking

Appliances containing hydrocarbon refrigerants must have red 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.

The purpose of the colored hoses and tubing is to enable service technicians to identify the use of a flammable refrigerant and to take additional precautions (e.g., reduce the use of sparking equipment) as appropriate to avert accidents. The red color is particularly important if labels are no longer legible. Adding red coloring on tubing inside the appliance provides additional assurance that technicians are 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 red for at least one inch extending 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 isn't 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 service port.

UL Standards referenced in this rule don't allow the inclusion of service ports in finished products using flammable refrigerants; however, as stated previously, you can add service ports 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.

You can use a colored sleeve or cap as long as you meet the requirements of the use condition (red color, location, and dimension). However, to remain in compliance with the use condition, if you remove a red sleeve or red marking during servicing, you are required to replace the red marking on the serviced tube.

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 until those involved in the disposal chain become familiar with flammable refrigerants. Labeling provides a warning of the presence of a flammable refrigerant.

Any small appliance that is using a flammable refrigerant must have **Danger** and **Caution** labels permanently attached at specified locations (on or near any evaporator, near the machine compartment, near any exposed refrigerant tubing, and on the exterior of the refrigerator). 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.

The following label must be placed on or near any evaporator that could be contacted by the consumer.

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

The following two labels must be placed near the machine compartment.

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

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.

The following label must be placed on the exterior of the refrigerator.

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

The following label must be placed near exposed refrigerant tubing.

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

Refrigerant Containers

All flammable refrigerant containers must have a red band on the shoulder or top of the container. The EPA does not require unique fittings on the refrigerant cylinders. 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

Only technicians specifically trained in handling flammable refrigerants may service refrigerators and freezers containing these refrigerants. To become a Type I certified technician, you must also understand the techniques and service practices that are used to minimize the risk of fire and understand how to use flammable refrigerants safely.

Training is an important way for you 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, the EPA has continued to list a variety of new refrigerants as acceptable. The EPA does not require that certified technicians be recertified as a result of the listing of the additional refrigerants. Furthermore, the goal of the Section 608 technician certification program is to reduce emissions during servicing, maintenance, repair, and disposal.

EPA certification training isn’t a substitute for the proper training that is normally provided through trade schools, apprenticeships, or other industry mechanisms. Although some limited flammable refrigeration training has been incorporated into this Mainstream EPA training course, far more information is available. The limited training in this course is meant to give you an awareness of the regulations, not give you a complete training program in the safe use of flammable refrigerants.

Although EPA does not require training as a use condition for these flammable substitutes, to ensure that the flammable refrigerants can be used as safely as other available refrigerants, you should also obtain field training on the safe handling of hydrocarbon refrigerants. Certification training is available at www.EPAtest.com.

Recovery Requirements

Small Appliance Evacuation Requirements

If you are opening small appliances for maintenance, service, or repair, the relative quantity of refrigerant you must recover depends on whether the compressor in the appliance is working or not. When you open a small appliance for maintenance, service, or repair, you must do one of the following:

- Recover 90 percent of the refrigerant in the appliance when the compressor in the appliance is operating (90 percent of the name plate charge)
- Recovery 80 percent of the refrigerant in the appliance when the compressor in the appliance isn't operating (80 percent of the name plate charge)
- Evacuate the small appliance to 4 inches of mercury vacuum, regardless of the operating condition of the compressor

You must meet one of these recovery requirements regardless of the type of recovery machine (passive or active) that you use. If the compressor of the system is functional, you can use the compressor to pump the refrigerant out of the system to meet the evacuation requirement of 90 percent or four inches of mercury vacuum.

A recovery bag can be used instead of a recovery tank. A recovery bag inflates as refrigerant is introduced so the pressure does not build up in the bag, allowing greater amounts of refrigerant to be recovered into the bag without a pressure increase.

If the compressor of the system is broken, the required amount of refrigerant recovery is lower (only 80 percent) because only the pressure difference between the system and the recovery vessel (typically a recovery bag or evacuated recovery tank) is available to force the refrigerant out of the system. In this case, you might need to cool the recovery vessel and heat the system to get the necessary recovery mass removed.

Example

You are changing out the compressor of a system containing three pounds of R-410A and the compressor of the system being recovered does not function. You must recover at least 80 percent of the refrigerant charge from the system (3 x 0.8 = 2.4 lbs.) or recover to a 4-inch of mercury vacuum.

Recovery Devices

Recycling and recovery equipment must be tested by an EPA-approved third party and be equipped with low-loss fittings. The low-loss fittings can be either manually closed or automatically closed when disconnected to prevent loss of refrigerant from hoses. The recovery equipment does not need to have an oil separator or be able to handle more than one refrigerant. As stated earlier in this manual, AHRI 740 has two equipment classifications, system-dependent equipment and self-contained equipment.

System-Dependent Equipment

System-dependent equipment depends on the operation of components of the system where the refrigerant is being recovered and can only be used on appliances with 15 pounds or less of refrigerant. You can use a system-dependent recovery device for refrigerant recovery from any small appliance because small appliances only have a charge of five pounds or less. You can't use a system-dependent recovery device for larger appliances (more than 15 pounds of charge) such as a centrifugal air conditioner, a reciprocating liquid chiller, or a large commercial walk-in freezer unless the system-dependent equipment is permanently attached to the appliance as a pump-down unit.

You can use a passive recovery device to recover refrigerant from small appliances. A passive recovery device is a subset of a system-dependent recovery device that captures the refrigerant in a non-pressurized container or recovery bag without the use of the system compressor to transfer the refrigerant. A passive recovery device can use heat (to raise the pressure in the system) or cooling of the recovery tank (to lower the recovery tank pressure).

Because passive recovery systems don't rely on the system compressor, you can use a passive recovery device on systems with an inoperative compressor. When using a passive recovery process with an inoperative compressor, you need to connect both the high and low side of the system to the passive recovery tank or bag to achieve maximum refrigerant recovery.

Tips

If you are recovering refrigerant into a non-pressurized container from a household refrigerator with an inoperative compressor, heating and striking the compressor with a rubber mallet is helpful. The vibration helps dislodge refrigerant from under the oil in the compressor crankcase.

If you open an appliance containing a refrigerant for maintenance, service, or repair, you must have at least one self-contained recovery machine available. The exception to this rule is if you're working on small appliances or systems with a charge of less than 15 pounds. For these systems, you can use system-dependent recovery devices.

Self-Contained Equipment

Self-contained **r**ecovery or recycling equipment does not require the help from or operation of any components in the system where the refrigerant is being recovered or recycled.

If you only hold a Type I certification, you don't need to have any certified recovery equipment. You can rely on system-dependent recovery, for example, using the system compressor if it works and refrigerant bags or an evacuated recovery tank. However, if you hold any EPA certification other than just Type I certification, you must have at least one piece of certified, self-contained recovery or recycling equipment available at your place of business.

Tip

Self-contained active recovery devices recover the refrigerant faster and can be configured to clean the refrigerant at the same time as you recover the refrigerant. Therefore, active recovery devices might be economically justified.

Many technicians use a self-contained recovery unit instead of wasting time with system-dependent recovery units for the following reasons:

- The recovery unit doesn't risk harming the system compressor due to overheating. You can connect the unit and leave it alone, which allows you to do other work without risking damage to the compressor during recovery.
- Recovery is simpler. You only need one service connection, so you only need to install one piercing access valve.

- Recovery is faster.
- Recovery is possible when the appliance has a leak. Recover to 4 "Hg, and you are done. You don't need to try to achieve 80 or 90 percent recovery (of the nameplate charge) when the charge is actually below that value because of leakage.

Example

If the system has leaked 30% of the charge, it would be impossible to recover 80% of the nameplate charge because only 70% of the nameplate charge is in the system.

Static Electricity Concerns

As shown in Figure I–1, when the concentration of a flammable refrigerant reaches or exceeds the lower flammability limit (LFL) and is below the upper flammability limit (UFL) 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 be this ignition source.

Example

For flammable refrigerant shown in Figure I–1, 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.

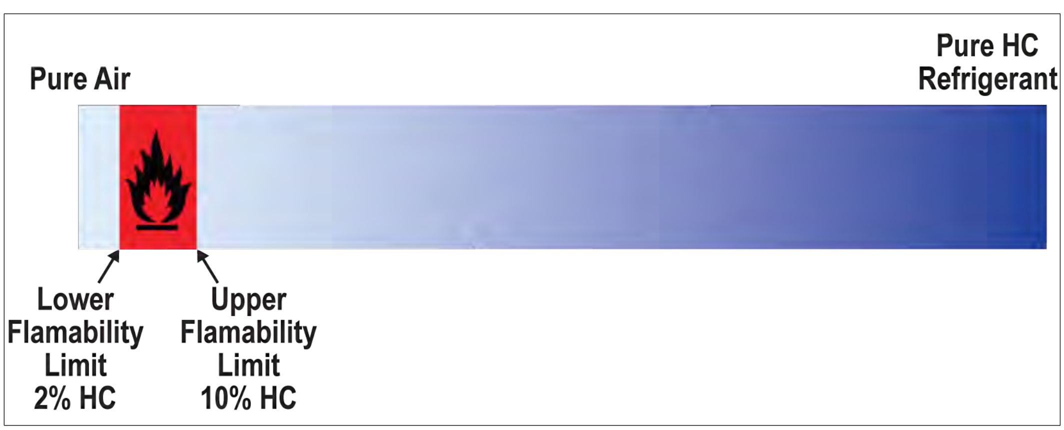


Figure I–1. Example of flammability limits of a possible hydrocarbon refrigerant

Caution

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.

Tip

If you smell a pungent odor during recovery and/or repair of a system, acid is probably in the system as a result of a compressor burnout, and a new compressor is necessary. This refrigerant is most likely highly acidic and can't be recycled; therefore, don't reuse this refrigerant.

If there was a compressor burnout, look for signs of contamination in the oil when recovering the refrigerant. If the oil is contaminated and you are planning to repair the system, you need to flush the system. Flush the remaining system components (not the compressor or expansion device) with a commercial flushing solution such as Qwik ***System Flush***®*. Then install a new liquid-line filter drier and a suction-line filter drier (to keep contaminates from returning to the oil sump of the new replacement compressor).*

Table I–1. Saturation Data for Potential Small Appliance Refrigerants

Temp (°F)	Pressure (PSIG)						
	R-32	R-134a	R-290	R-404A	R-410A	R-441A	R-1234yf
0	49	6	24	34	48	20	9
5	56	9	28	39	55	24	12
10	63	12	32	44	62	27	15
15	71	15	36	50	70	31	18
20	80	18	41	57	79	35	22
25	89	22	46	63	88	39	25
30	99	26	52	71	97	44	29
35	110	30	58	79	108	49	34
40	121	35	64	87	119	54	38
45	133	40	71	96	131	60	43

Temp (°F)	Pressure (PSIG)						
	R-32	R-134a	R-290	R-404A	R-410A	R-441A	R-1234yf
50	146	45	78	105	143	65	49
55	160	51	85	115	157	71	54
60	174	57	93	126	171	78	61
65	189	64	101	137	186	85	67
70	206	71	110	149	202	92	74
75	223	79	120	162	219	99	81
80	241	87	129	174	238	107	89
85	261	95	140	190	255	116	97
90	281	104	151	204	275	124	106
95	303	114	162	220	296	134	115
100	326	124	174	237	319	143	125

Equipment Certification

The recovery or recycling equipment you use for the maintenance, service, or repair of small appliances must have a label stating it was tested by an EPA-approved testing laboratory to ensure the equipment can achieve the required results.

For small appliances, your equipment must be certified to be capable of one of the following:

- Recovering 90 percent of the refrigerant in the system when the compressor of the system is operating, or recovering 80 percent of the refrigerant from the system when the compressor of the system isn't operating
- Achieving a 4-inch vacuum based on AHRI Standard 740

Refrigerants Not Recovered with EPA-Approved Recovery Devices

Some older appliances use refrigerants such as R-717 (ammonia), R-764 (sulfur dioxide), methyl chloride, and methyl formate, which can't be recovered with the recovery/recycling machines regulated by the EPA and don't have to be recovered. These substances are toxic and/or potentially carcinogenic. Therefore, you must use different types of equipment, procedures, and safety precautions. You also must take precautions to avoid inhalation of these substances.

For refrigerators, if the refrigerant is ammonia or sulfur dioxide, the thermodynamic cooling process typically is heat-driven absorption, not vapor compression. These systems can be heat powered, from natural gas for example, and could be both heat- or electrically driven (where either the fuel or the electric energy is converted to heat). Look on the back of the unit for a natural gas hookup.

Training to work with these refrigerants is outside the scope of this manual. See the specific equipment manufacturer for additional information and training.

Fortunately, very few of these units remain in the field. If you have to service one, however, read the safety data sheet (SDS) for the working fluid, and consult with the manufacturer for recovery, repair, or disposal methods. For these refrigerants, you don't need to use equipment currently regulated by the equipment certification requirements of the EPA under Section 608.

Hydrogen and water can also be present as components of refrigerants used in small appliances in campers or other recreational vehicles. These refrigerants don't need to be recovered either, and they also can't be recovered with current EPA-approved recovery devices.

Caution

Hydrogen is very explosive, so contact the equipment manufacturer for specific training and proper procedures. Do not use vacuum pumps or recovery machines on equipment that contains hydrogen unless the equipment is rated explosion-proof and rated for use with hydrogen. Never vent hydrogen in an enclosed space.

Small Appliance Equipment

Fittings, Connections, and Ports

EPA regulations require that all air conditioning and refrigeration equipment containing more than one pound of refrigerant be provided with a servicing aperture to facilitate removal of refrigerant when the unit is serviced or disposed of. For small appliances, this service port typically is a straight piece of tubing that is sealed at the end and typically referred to as a process stub or process tube as shown in Figure I–2.

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 because a service fitting isn't 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, which is allowable, the required red flammable marking must be applied at least one inch in both directions from the valve. Such fittings, if installed, should be designed specifically for flammable refrigerants.

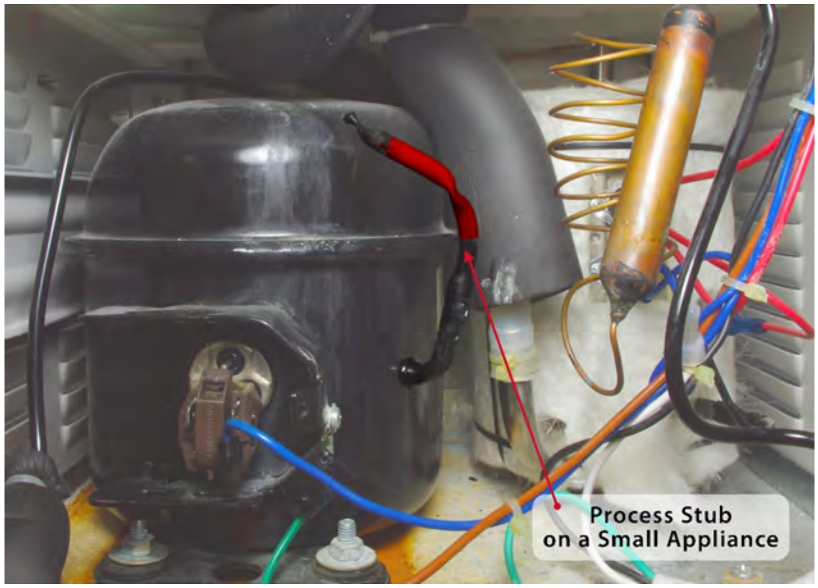


Figure I–2. Process stub on a small appliance with flammable refrigerant

The process stub is punctured with a piercing-type (or saddle) access valve that attaches temporarily, facilitating refrigerant recovery and recharging. The access valve shown in Figure I–3 is essentially clamped to the process stub tube (as far out on the tube as possible to allow subsequent attachments). The valve uses an O-ring face seal against the tube to prevent leakage.

Figure I–3. Piercing-type access valve on a small appliance with nonflammable refrigerant

When attached, the valve core punctures a small hole in the tube, allowing access to the refrigerant. You might be tempted to keep the access valve in place for future use, but this would be a mistake because the valve isn't a perfect seal. In time, all of the refrigerant will leak from the system. The proper procedure is to crimp the process tube up-stream of the valve essentially to seal the tube. Then remove the access valve and braze the crimped tube closed to ensure a leak-tight seal.

Graduated Charging Cylinders

A graduated charging cylinder is designed to be filled with refrigerant and used to charge a system accurately with refrigerant. Today, most technicians use a portable scale and the refrigerant tank to determine how much refrigerant has been added to a system. However, another accurate method is to use a charging cylinder. Graduated charging cylinders are able to hold only a relatively small amount of refrigerant, so they typically are only used with small appliance applications.

Graduated charging cylinders have a clear glass column running from the top to the bottom of the cylinder so you can see the refrigerant inside as shown in Figure I–4. They also have a pressure gauge at the top of the cylinder.

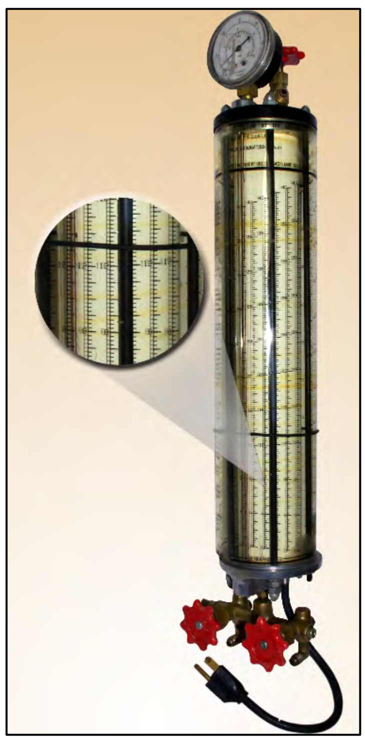


Figure I–4. Graduated charging cylinder

You can see the volume of liquid refrigerant in the cylinder through the glass column. By using the saturation pressure displayed by the pressure gauge, you can use the saturation temperature and the density of the refrigerant to convert the volume of refrigerant to the mass of refrigerant in the cylinder. Various scales are located on the clear glass column to make this task easy. When filled to the desired charge, you can use the electric heater in the graduated cylinder to pressurize the refrigerant and force it into the system being charged.

Because charging cylinders are designed to be refilled, you can use them to store recovered refrigerant temporarily during a service call and then recharge the refrigerant into the system.

Caution

Do not leave refrigerant in a charging cylinder for extended periods of time.

Never transport refrigerant in a charging cylinder.

Tip

Because small appliances have very small refrigerant charges, you can use the charging cylinder to store refrigerant during the service or maintenance until you return the refrigerant to the system after the service.

If you are going to use a graduated cylinder, be sure you use one that is large enough for the job. Also remember that when you fill a graduated charging cylinder, you must recover refrigerant that is vented off the top of the cylinder.

Recovery Methods for Small Appliances

You've already inspected your tools and equipment, and you have the necessary protective gear to keep yourself safe. Now you are ready to begin recovering refrigerant from the small appliance. These are the steps to follow:

1. Identify the refrigerant in the appliance.

2. Extract the refrigerant, storing it in a DOT-approved recovery cylinder, which has a gray body with yellow top. (The terms recovery cylinder and recovery tank are used interchangeably.) If the refrigerant is to be returned directly to the system after service, you can use a graduated charging cylinder.

3. Return the recycled or recovered refrigerant to the appliance, or recharge the system with new or certified (to meet AHRI 700 purity standards) reclaimed refrigerant.

4. Finish the job by verifying all valves are closed and capped or removed, and the system is resealed.

These steps are explained in more detail in the following section.

Identifying the Refrigerant

You could use an AHRI 700 purity test to determine the type of refrigerant. However, because this test is expensive, it isn't practical or cost effective for a small appliance. You might be able to use the saturation pressure–temperature characteristics of the refrigerant or the nameplate to verify the refrigerant (see Table I–1). For small appliances, the charge is small. If you're uncertain about contamination or cross charge of the refrigerant, change the charge.

To determine the type of refrigerant used in an appliance, first look at the identification tag attached to the unit. Figure I–5 shows the nameplate from a small appliance water cooler. The location of the nameplate varies depending on the manufacturer and appliance. Look for the name plate on the back of the unit inside the refrigerated compartment, on the side of the door, on the compressor unit, or under a faceplate or external body panel.

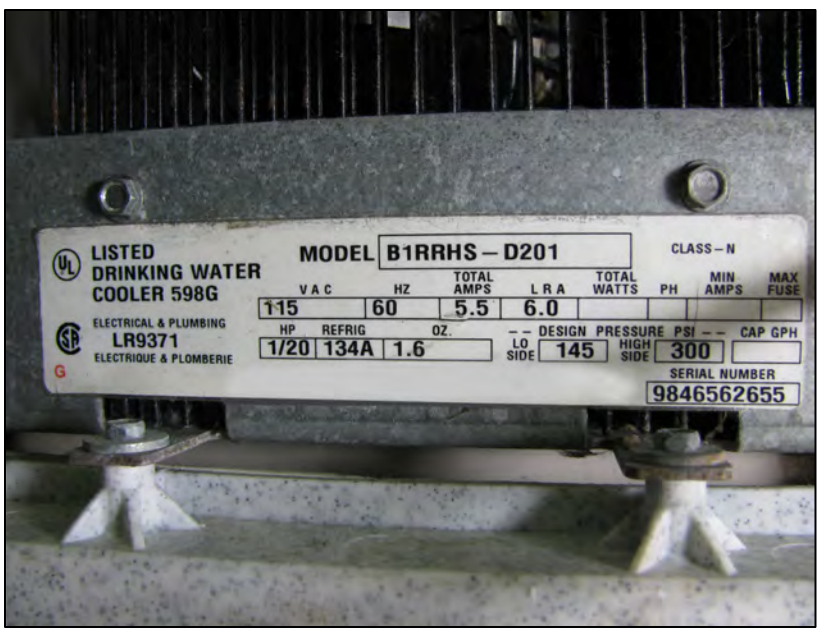


Figure I–5. Nameplate on a water cooler

As stated previously, for refrigerators, if the refrigerant is ammonia or sulfur dioxide, the thermodynamic cooling process typically is heat-driven absorption, not vapor compression. These systems can be heat powered, from natural gas for example, and could be both heat- or electrically driven (where either the fuel or the electric energy is converted to heat).

Look on the back of the unit for a natural gas hookup. Ammonia or sulfur dioxide refrigerants don't need to be recovered because they have no ozone depletion potential. However, these working fluids are toxic, and you must use different types of equipment, procedures, and safety precautions. Training for work with these refrigerants is outside the scope of this manual. See the specific equipment manufacturer for additional information and training.

Extracting the Refrigerant (Refrigerant Recovery)

Before beginning a refrigerant recovery procedure, you need to know the type of refrigerant that is in the system. After you've identified the type of refrigerant, you can select the proper DOT-approved refrigerant recovery machine and recovery cylinder for the refrigerant. Either select a new cylinder that has been properly evacuated or a recovery cylinder that currently holds the type of refrigerant in the appliance you are recovering.

Ensure the recovery cylinder has been properly labeled to indicate the refrigerant it contains. You can also use a graduated recharging cylinder if you are returning the refrigerant directly to the system after servicing.

Note

If you mix one refrigerant type with another refrigerant type, you can't reuse the refrigerant. Refrigerants should never be mixed. Separating accidently mixed refrigerants is only possible by a certified refrigerant reclamation facility, and many times the separation isn't possible or economically feasible. If the refrigerants can't be separated, the mixture must be sent to an approved EPA facility for destruction.

You need the following basic tools for recovering refrigerants from small appliances:

- Piercing access valve(s) if no service valves are on the system
- EPA-certified self-contained recovery unit (certified for the refrigerant being recovered) or a system-dependent recovery method
- Manifold gauge with hoses
- DOT-certified recovery cylinder rated for the refrigerant pressures of the refrigerant being recovered or some other means of storing the refrigerant such as a refrigerant bag

Example

Cylinders labeled DOT-4BA or DOT 4BW can be used for R-134a, R-12, R-22, R-404A, R-407C. Cylinders labeled DOT-4BA400 or DOT 4BW400 can be used for R-410A, as well as other lower pressure refrigerants such as R-134a, R-12, R-22, R-404A, and R-407C.

Tip

If the piercing valve is solderless, only use it temporarily on copper or aluminum tubing. When you have completed servicing the system, remove the valve and seal the tube to prevent leaking after the repair. If you are disposing of the refrigerant, you can put locking pliers-type piercing valves on the tube temporarily, as shown in Figure I–6, while the refrigerant is being recovered.

Figure I–6. Locking-pliers piercing access valve

As you learned earlier in this study guide, the recovery unit is either system-dependent or self-contained. System-dependent recovery can be used only on appliances containing 15 pounds or less of refrigerant and by definition needs the help of components inside the small appliance to evacuate the refrigerant (usually the compressor if it works or the pressure in the system). Self-contained units remove the refrigerant without any help from the appliance.

The following steps outline the general process for recovering the refrigerant. If these instructions differ from those of the equipment manufacturer, always follow the manufacturer's instructions for your recovery unit. When reading through this section, refer to Figure I–7 and Figure I–8 to see the basic components of a refrigeration system and how the refrigerant flows through the system.

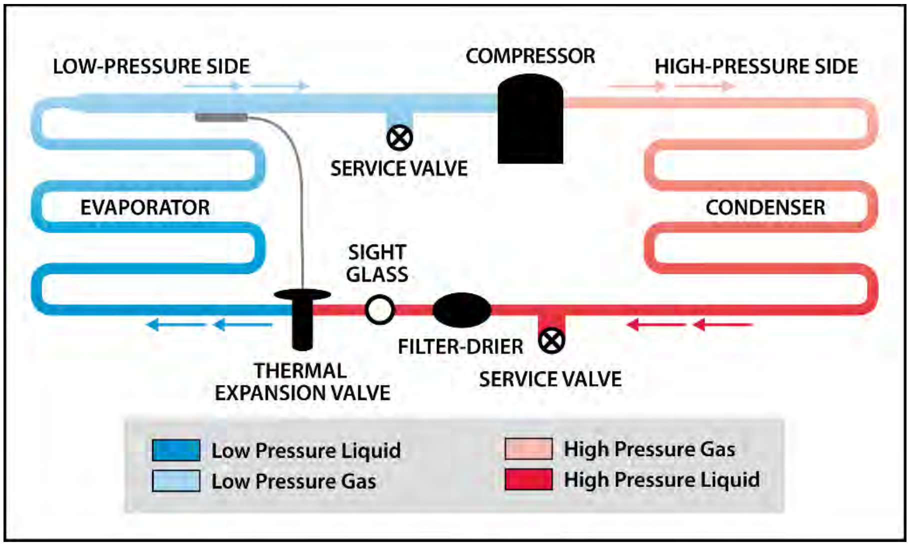


Figure I–7. Basic refrigeration diagram with two service ports

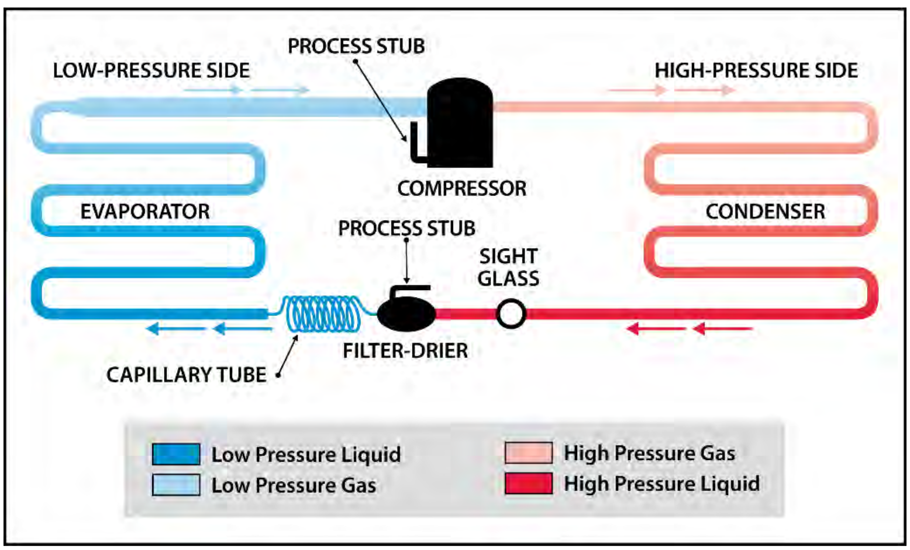


Figure I–8. Refrigeration diagram with process stubs shown

Figure I–9 shows a small appliance with a process tube. The low-side process stub is attached to the compressor can, which is common.

This system also has a high-side process stub attached to the filter drier. A high-side process stub is less common, but when available, this process stub is typically located on the filter drier as shown. Some filter driers use a Schrader-valve-type service port.

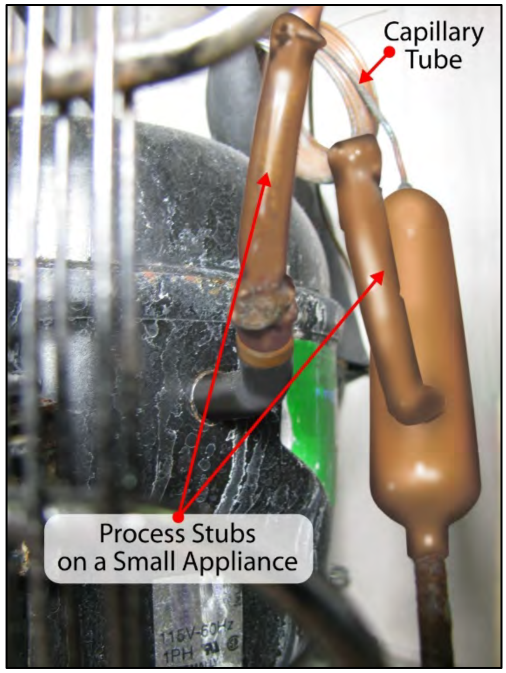


Figure I–9. Process stubs on a small appliance with nonflammable refrigerant

Connecting Service Hoses

The first thing you need to do when extracting the refrigerant is decide where to connect your service hoses. Manual or self-sealing valves on the ends of the gauge set hoses are required to minimize any release of refrigerant.

Caution

Be careful not to trap liquid refrigerant in the service hoses. If liquid refrigerant is trapped in the service hose, as the line warms, liquid refrigerant expands with no place to go. The pressure in the hose can get quite high and damage or burst the hose.

Using Two Service Ports

If the small appliance has both high- and low-side service ports as shown in Figure I–6, attaching to both ports is best. Not only is the recovery faster, but also you know that all the refrigerant will be recovered. If you only attach to a single side, the refrigerant recovery depends on the ability of the refrigerant to be drawn through the throttling device (thermal expansion device) and/or the compressor, which can make the recovery rate much slower.

Instead of having service valves, many small appliances have a process stub as shown in Figure I–8. To service this type of small appliance, you have to attach a piercing valve to the process stub. The recovery time saved (by using two access valves) might not be offset by the additional time required to install a second access valve because small appliances have a small charge.

If you are disposing of the system, locking-pliers-type piercing access valves as shown in Figure I–6 are fast to connect. It is a good idea to have two of these tools so you can connect to both the high side and low side to speed recovery before discarding the unit.

In larger systems, two service access points are always used because of the larger refrigerant charge and the faster recovery time. Of course, two service valves have other benefits when diagnosing system problems, such as the ability to determine both subcooling and superheat because both high- and low-side pressures can be monitored during operation.

Using One Service Port

To help you decide if you should connect only to a single side, consider the following issues:

- If the compressor isn't operating when connecting to the low-side service port, the compressor valves will prevent refrigerant from flowing backward through the compressor, and you must recover the high-pressure refrigerant as it flows through the throttling (thermal expansion) valve. However, after you finish the recovery, the low-side access port is better suited for recharging refrigerant.
- The high side operates at an elevated temperature and pressure relative to the recovery tank. If you want to be able to charge refrigerant at ambient pressure and temperature back into an operating system through only a high-side service connection, you must do one of the following:
  - Charge the refrigerant back into the system using the additional pressure head developed by the recovery machine.
  - Use a heated graduated charging cylinder.
  - Heat the refrigerant storage container (never use an open torch).

As you can see in Figure I–7, the high-pressure side of the system refers to any part of the plumbing system located between the compressor discharge (outlet) and the throttling (expansion) device inlet (shown as a thermal expansion valve in Figure I–7), but it could also be a capillary tube or orifice plate).

Figure I–8 shows a schematic of the system where a capillary tube is used instead of a thermal expansion valve. Figure I–9 also shows a typical configuration where the capillary tube expansion device is connected directly to the upstream spun-metal filter drier.

The low-pressure side of the system is any part of the plumbing system located between the throttling (expansion) device outlet and the compressor inlet.

- If you are using a system-dependent recovery process and the compressor *does* operate, recover the refrigerant from the high side because the compressor will pump the refrigerant to the high side (see the following Caution).
- If you are using a passive recovery device and the compressor *does not* run, you must access both the high and low sides of the system for refrigerant recovery.

Caution

Be careful when operating a system compressor with suction-side pressures below 0 psig. Remember, you only need to recover either 90 percent of the charge or recover to a vacuum of 4 "Hg vacuum, not both. Never operate the system compressor with a suction side pressure below 4 "Hg vacuum to avoid burning out the compressor.

Hermetic compressors, which are commonly used in small appliances, all rely on the flow of refrigerant through the compressor to cool the compressor motor windings. Therefore, *never* operate the system compressor when you are using a self-contained recovery machine.

When using a system-dependent recovery system, if the system compressor is used to evacuate the system, you must be careful to avoid damaging the compressor by overheating. The cooling to the compressor is reduced as the low-side pressure is reduced. Therefore, the refrigerant flow is reduced. If too deep a vacuum is drawn by the system compressor, the compressor will burn out in a matter of minutes.

If you are working on a sealed system with an operating compressor that has a completely restricted capillary tube and you plan on using only one piercing access valve, this valve must be located on the high side of the system so that the low-side refrigerant can be drawn through the compressor.

If you are using a self-contained recovery device that can't handle ingesting liquid refrigerant, you must restrict the initial flow of refrigerant (typically done by partially closing a valve in the supply line) so that the refrigerant flashes in the tubing leading to the recovery compressor and avoids compressor slugging. When the system pressure has dropped below the saturation pressure, you can remove the restriction (open the valve fully).

Installing an Access Valve

If you decide to access the system through the process stub, install a piercing-type access valve on the process stub, which is typically located on the suction side of the compressor. Sometimes both a high- and low-side process stub exists.

Install the access valve near the sealed end of the process stub to allow room for additional access valve connections after the initial access valve is crimped-off and sealed.

Caution

When installing any type of access fitting onto a sealed system, you must leak test the fitting before proceeding with recovery.

Recovering the Refrigerant

The following steps describe how to recover the refrigerant:

1. Attach the recovery hose or hoses to the recovery unit if not already connected. If the recovery unit has a suction side pressure gauge, connect the recovery hose(s) directly to the recovery unit without plumbing through a manifold gauge to reduce overall pressure drops and reduce recovery time.

2. If not already connected, attach an evacuated recovery cylinder (or a recovery cylinder containing the same refrigerant) to the outlet of the recovery machine using a self-sealing hose.

3. Attach the recovery hose or hoses to the service connection using self-sealing hoses.

Caution

After connecting to the system (installing and opening a piercing access valve or connecting to an existing service valve), if the system pressure is 0 psig, don't begin any recovery procedure because the system has a leak, and all the refrigerant has leaked out. Air and potentially moisture most likely have leaked into the system making refrigerant recovery impossible (there is little or no refrigerant to recover). If you were to recover the air and moisture in the system, you would contaminate any other refrigerant in your recovery tank.

4. Open the service valve connection, allowing refrigerant to flow naturally into the recovery tank.

5. When the natural pressure-driven flow has slowed or stopped, turn on the recovery machine. If you are using a system-dependent recovery unit and the compressor in the appliance is inoperative, the only way to recover the required amount of refrigerant (80% of nameplate charge) is to use a non-pressurized container, such as a refrigerant recovery bag or a chilled and/or evacuated recovery cylinder (as well as possibly heating the system). Alternatively, if you are using a system-dependent recovery unit and the compressor in the appliance is inoperative, the only way to recovery to 4 inches of mercury vacuum is to use an evacuated recovery cylinder along with potentially heating the system and cooling the recovery cylinder.

6. Evacuate the system to the required level. Recover the refrigerant according to EPA guidelines. Remember, if you are using a self-contained recovery machine, you can recover the system to 4 "Hg instead of the 80 or 90 percent requirement. This might be your only option if the refrigerant charge is low. You must recover 80 or 90 percent of the charge on the nameplate on the small appliance. If some of the refrigerant has leaked out, less than 80 percent of the charge could remain in the system, making 80 or 90 percent recovery impossible. In this case, your only alternative is to recover to 4 "Hg.

7. Shut off the recovery machine and disconnect all hoses.

8. After you finish making any repairs and have installed a new filter drier, leak check the system (using a static pressure decay test).

9. When the system is leak tight, use a vacuum pump to achieve a final deep vacuum of at least 500 microns (ideally 300 microns). To reach this level of evacuation, you might need to use a dry nitrogen source to perform a triple evacuation.

10. Recharge the system with either the recovered or recycled refrigerant from this system or from a system owned by the same person (if you know the refrigerant is clean). Alternatively, you can use new or reclaimed refrigerant.

Caution

Never use recovered or recycled refrigerant from the system if the system had a compressor burnout or any water, air, or other contaminant intrusion into the refrigerant. Never attempt to reuse or recycle highly acidic or moisture-laden refrigerant or oil.

11. After properly recovering the refrigerant, send the refrigerant to an approved recycler or waste refrigerant disposer if necessary. Never mix refrigerants.

Tip

A standard vacuum pump designed specifically for evacuation and dehydration can never be used as a recovery device in combination with a pressurized container.

When the Compressor Isn't Running

Sometimes the compressor isn't operating during recovery either because you are using a self-contained recovery machine or you are performing a passive recovery and the system compressor is broken. When the compressor isn't running, you must help release trapped refrigerant from the system compressor oil.

One way to release trapped refrigerant is to activate the compressor crankcase heater (if available), which heats the compressor oil and helps remove any refrigerant dissolved or trapped in the compressor oil. Another way (in addition to activating the crankcase heater if one exists) is to strike the compressor several times with a rubber mallet to help dislodge any refrigerant that could be trapped under the oil in the compressor oil sump.

To speed the recovery process and ensure that all refrigerant has been removed from a frost-free refrigerator, turn on the defrost heater to increase the vapor pressure in the system.

When Using a Passive Recovery Device

When using passive recovery devices to achieve the required refrigerant recovery amount (80 percent of the nameplate charge when the compressor is non-operational), you must help release trapped refrigerant from the compressor oil.

Note

If the recovery tank inlet valve (which is connected to the discharge of the recovery machine) has not been opened or if there is excessive air in the recovery tank, excessive pressure conditions result on the high side of the recovery device. This could cause the recovery unit to shut off on a high-pressure safety switch or the recovery tank to vent its contents (in the case of the air in the tank) to avoid over pressurization and risk of explosion.

Non-Condensable Gases

Appliances are designed to run with only refrigerant and oil circulating inside them. If air gets into the refrigeration system or into a recovery cylinder, the system won't function properly because the air won't condense. This means that the air or any other non-condensable vapors displace the refrigerant, leading to increased system high-side pressure as well as potentially trapping these non-condensables in the condenser, reducing the effective working area of the condenser for heat transfer.

On small appliances, because the charge is smaller, the negative effect of a small volume of air is worse. If you try to recharge the system without first removing the non-condensable gases, the system operates at a condensing pressure that is higher than normal. In addition to reducing the capacity of the condenser to reject heat, the non-condensables raise the overall discharge temperature and pressure. As a result, the system not only loses efficiency, but also the components in the system, such as the compressor, have the potential to fail prematurely due to the extra load.

Non-condensable gases also can cause chemical reactions that produce acids, reduce oil lubricity, and typically carry moisture into the system. Water vapor inadvertently introduced into the system with the air that enters the system harms the system because moisture accelerates the formation of acids in the refrigerant and oil.

If the evaporator is operating below the freezing point of water, the water vapor in the refrigerant can freeze in the small passage of the expansion device, causing the system to stop cooling. This type of failure is easily identified if the system stops cooling after operating for a while (due to the ice-clogged expansion valve) and after sitting idle, the system operates normally for a while again before ice forms in the expansion device.

Preventing Non-Condensable Gases

To prevent damage to your appliance, you need to ensure no non-condensable gases are in the system. One way to avoid introducing non-condensable gases into the system is to perform a proper system evacuation after the system has been repaired and pressure leak tested and before charging the system with refrigerant.

You also need to know if excessive air or other non-condensable gas exists in the recovery cylinder because you don't want to put refrigerant with non-condensable gas back into the appliance.

Because you know non-condensable gas causes the pressure to rise, if you knew what the pressure was supposed to be and you measure what the actual pressure was, you might be able to tell if non-condensable gases are in the system or the recovery cylinder.

If you know the room temperature where the appliance or recovery cylinder is located (and this temperature is stable and represents the temperature of the system), you can find out what the pressure should be if no non-condensables were in the system. Then you can compare that pressure with the actual pressure. If the actual pressure is higher, non-condensables could be present.

If the refrigerant is a blend, fractionization of the blend could change the pressure in the system, but fractionization typically leads to lower pressures. Because the more volatile (high-pressure) refrigerant tends to leak out more, the pressure is lowered, not increased, as would be the case with non-condensables in the refrigerant.

Checking for Non-Condensable Gases

When checking for air or other non-condensable contaminates inside a system or recovery cylinder, allow the temperature of the system or cylinder to stabilize to room temperature before taking a temperature and pressure reading. A comparison to a pressure–temperature chart is only valid if both the pressure and temperature of the refrigerant are stable and known.

When in doubt, don’t use the refrigerant. If you suspect the refrigerant in a recovery cylinder is contaminated, turn refrigerant in for reclamation. However, if a reclamation facility receives a tank of mixed refrigerant, it could refuse to accept the refrigerant or charge extra for processing.

Tip

As part of your regular recovery equipment maintenance, check the recovery equipment for refrigerant leaks. Depending on the location of the leak, the unit could lose refrigerant or introduce air into the recovery cylinder.

Replacement Refrigerants

According to EPA, there are no “drop-in” service replacements for any refrigerants. The term drop-in replacement means that the refrigerant provides exactly the same cooling, efficiency, pressure ratio, and other performance factors as the original refrigerant with no changes to existing equipment. Despite what some sales materials claim, every replacement refrigerant requires some change to the system. However, some changes are only minor, and the performance differences can be minimal.

R-404A was to be banned from use in new domestic refrigerators beginning January 1, 2021; however, the U.S. federal court has ruled that the Clean Air Act authority given to the EPA is limited to banning ozone-depleting substances. Because HFCs like R-404A have zero ODP, the EPA has no jurisdiction to ban any HFCs. Therefore, at this time, without new congressional legislation, there is no plan to ban any HFCs. Keep up to date on this evolving issue at the Mainstream website www.EPAtest.com.

R-22 is banned for use in new equipment and will be banned from production or import for use into any existing system in 2020. Reclaimed and recovered refrigerant can, of course, still be used.

Putting the Refrigerant Back into the Appliance

If you know the recovered refrigerant is clean, you can put this refrigerant back into the appliance from which you removed it or into another appliance owned by the same person.

Before charging the system, follow these guidelines:

- Always change the filter drier when replacing the refrigerant charge.
- Always leak check the system (under positive pressure).
- Always evacuate the system (deep evacuation to at least 500 microns) using a triple evacuation before charging the system.

Refrigerant Replacements

If the refrigerant you removed is an ozone-depleting refrigerant that was phased out (meaning it is no longer available for purchase as a new refrigerant) and you can’t reuse the refrigerant you removed, you have only two options.

- Purchase reclaimed refrigerant for use in the system.
- Modify the system to accommodate a replacement refrigerant.

Refrigerant 134a has been used for years as a replacement for R-12 in household refrigerators. R-134a does not deplete the ozone and its pressure–temperature characteristics are very similar to R-12. But R-134a has a very high GWP and could be phased out in the future if further legislation to ban HFCs is enacted by congress and becomes law.

Removing an Access Valve

If you have installed a solderless-type piercing valve, you have to remove the access valve after you charge the system to prevent a likely long-term leakage problem. To remove the piercing valve, crimp the process stub upstream of the valve, remove the access valve, and braze the process stub tube closed.

Note

When the compressor of a small appliance (such as a household refrigerator) does not run and a system-dependent (and passive) recovery is used, you should install both high- and low-side access valves to recover the refrigerant from the system. Not only will the recovery be faster, but both service connections might be necessary to achieve the required recovery efficiency, which is to remove 80 percent of the total charge or achieve a vacuum of 4 inches of mercury.

Leak Repairs

When a refrigeration system is low on refrigerant (the evaporator coil ices up) or the system has excessive superheat, you should check for leaks. Although it isn't mandatory to repair leaks in small appliances, it is highly recommended to do so whenever possible. Because the charge is so small, the tolerance for a leak is much less, and because the system is smaller, the odds of finding even a small leak is much better.

Note

After recovering refrigerant from a sealed system, if nitrogen is used to pressurize the system for leak checking or blow debris out of the system, you can vent the nitrogen to the ambient air.

Storing the Refrigerant

If your recovery machine has an internal storage tank or you recovered the refrigerant into a graduated charging cylinder and you don't plan to return this refrigerant to the system, transfer the refrigerant into a DOT-approved refrigerant recovery cylinder. Never fill the recovery cylinder to more than 80 percent of its capacity. You can determine the 80 percent fill level by using a mechanical float switch inside the cylinder, using an electronic shut-off device inside the cylinder, or weighing the cylinder on a scale.

Before adding refrigerant to a recovery cylinder, you must check the pressure rating for the cylinder to see if it is compatible with the refrigerant you are planning to recover. For example, R-410A requires recovery tanks rated for at least 400 psig. All recovery cylinders must be DOT approved and have a current hydrostatic test date stamped on them if they are to be used to contain a refrigerant with a pressure above 15 psig at room temperature.

Disposing of Small Appliances

You don't need to be a certified technician to remove refrigerant from small appliances when preparing them for disposal. However, the equipment used to recover refrigerant from appliances before their final disposal must meet the same performance standards as refrigerant recovery equipment used for servicing.

If you are involved in the final disposal of appliances, you must certify to your EPA Regional Office that you have obtained and are properly using EPA-certified refrigerant recovery equipment.

Safety

This section gives information to keep yourself safe and your equipment protected. The most important way to keep safe is to have the appropriate equipment for the task, know how to use the equipment correctly, know when you need to wear protective gear, and know which refrigerant you are recovering. Because different refrigerants have different pressures, you have to be sure you are using equipment designed to handle the type of refrigerant and the pressure of the refrigerant to be recovered.

- When working with any compressed gas, you need a pair of protective eye goggles with vented side shields to keep the goggles from fogging up and to keep you cool.
- If liquid refrigerant comes into contact with your skin, it can cause frostbite. Wear a pair of butyl-lined gloves and leather work boots to prevent frostbite when connecting and disconnecting hoses.
- Be sure the recovery equipment you use is EPA approved and rated for the refrigerant you are working.
- Be sure the manifold gauge set and service hoses are rated for the pressure of the refrigerant you are working with.
- Never use a flame to heat any component containing refrigerant. At high temperatures (i.e., open flames, glowing metal surfaces), R-12 and R-22 can decompose to form poisonous hydrochloric and hydrofluoric acids and phosgene gas.
- When using nitrogen, only use nitrogen vapor and always use a pressure regulator with a relief valve inserted in the downstream line from the pressure regulator. Using pressurized nitrogen from a nitrogen cylinder without a pressure regulator is very dangerous because the pressure inside these cylinders is over 2,000 psig.

Putting this pressure inside a refrigeration system would cause the system to explode.

- If there is a large release of any refrigerant in a contained area, you must either use a self-contained breathing apparatus (SCBA) or vacate and ventilate the spill area. The release of refrigerants in large quantities can cause suffocation because refrigerants are heavier than air and displace oxygen. Avoid low areas as you leave and ventilate closed spaces before you re-enter.
- Never recover flammable refrigerants in any recovery or recycling machine that has not been expressly certified to be used for that refrigerant.
- For flammable refrigerants, only use recovery cylinders that are specifically marked, including the red band on the shoulder or top of the container.
- Never remove the at least one-inch-long red marking on the tube to indicate flammable refrigerant. If this marking is removed or shortened, you must replace it with a new red mark that is at least one-inch long.
- For a system charged with a flammable refrigerant, if a service port or access valve is installed after manufacture, the required red flammable marking must be applied at least one inch in both directions from the service port. If you are installing fittings, be sure they are designed specifically for flammable refrigerants.
- When recovering flammable refrigerants, always ensure that the refrigeration system, recovery unit, and recovery cylinder are all properly grounded.

Tip

To use flammable refrigerants safety, minimize the presence of potential ignition sources. Also reduce the likelihood that the levels of these refrigerants will reach their lower flammability limits (LFLs).

Appendix 1: Conversion Factors

Appendix Table 1 shows the formulas for conversion.

Appendix Table 1. Conversion Formulas

From	To	Formula
PSIG	PSIA	**Add** 14.7 to the PSIG reading
PSIA	PSIG	**Subtract** 14.7 to the PSIA reading
Inches of Mercury	Millimeters of Mercury Absolute	**Multiply** the Inches of Mercury by 25.4 and **Subtract** the result from 760
Millimeters of Mercury Absolute	Inches of Mercury	**Subtract** the vacuum in mmHg Absolute from 760 and **Divide** by result by 25.4

The following table shows examples for converting vacuum units.

Appendix Table 2. Examples of the Conversion of Vacuum Units

PSIA Reading	Reading in Inches of Mercury (in. Hg)	Reading in Millimeters of Mercury Absolute (mmHg Absolute)	Microns
14.7 PSIA	0 "Hg	760 mmHg Absolute	760,000 microns
12.2 PSIA	5 "Hg	633 mmHg Absolute	633,000 microns
9.8 PSIA	10 "Hg	506 mmHg Absolute	506,000 microns
7.3 PSIA	15 "Hg	379 mmHg Absolute	379,000 microns
4.8 PSIA	20 "Hg	252 mmHg Absolute	252,000 microns
2.4 PSIA	25 "Hg	125 mmHg Absolute	125,000 microns
0.5 PSIA	28.9 "Hg	25 mmHg Absolute	25,000 microns
0.0 PSIA	29.9 "Hg	0 mmHg Absolute	0 microns

Appendix 2: Additional HVAC/R Certifications

This section describes additional training offered by Mainstream. However, all of these additional training programs require knowledge of the methods and procedures described in Mainstream's EPA Section 608 Training Program. This additional training is not intended to teach installation, troubleshooting, or repair of air conditioning or refrigeration systems.

Before obtaining any of Mainstream's additional certifications (with the exception of Section 609 training), the technician must have an EPA 608 certification from an EPA-approved certifying agency such as Mainstream.

HC/HFO Certification

Although, EPA certification isn't necessary for working with hydrocarbon (HC) or hydrofluoroolefin (HFO) refrigerants, Mainstream's HC/HFO certification covers the techniques and regulations for the safe handling of flammable hydrocarbon and hydrofluoroolefin refrigerants. Mainstream's HC/HFO Certification Manual is free to read at www.epatest.com/hc-hfo/.

R-410A Certification

EPA certification also isn't necessary for working with R-410A. Mainstream's Section 608 training includes training for all refrigerants including R-410A. However, because of the higher-pressure nature of R-410A, most manufacturers agree that additional specific R-410A training is a wise choice.

Toward this goal, Mainstream developed an R-410A training program for certified EPA Section 608 technicians. Mainstream's R-410A Certification Manual is free to read at www.epatest.com/R410A/.

Green Certification

Mainstream's Green Certification adds relevant new tools to your professional skills. This certification provides the fundamentals behind current energy-saving equipment options, energy auditing, effects of building infrastructure on efficiency, and energy-saving preventive maintenance.

Green Certification is not an EPA required certification. It is, however, becoming one of the most important concerns for building owners, home owners, and industry professionals in the United States. Becoming Green HVAC/R certified demonstrates to customers, peers, and potential employers that you are aware of and possess a basic understanding of the principles behind energy conservation and how it relates to the heating and cooling industry.

Mainstream's Green HVAC/R Certification Manual is free to read at www.epatest.com/Green/.

EPA Section 609 MVAC

EPA-approved Section 609 Certification is needed to service motor vehicle air conditioners and to purchase refrigerant in large containers at automotive supply houses. Mainstream's EPA Section 609 Certification Manual is free to read at www.epatest.com/609/.

Preventive Maintenance and Indoor Air Quality Technicians

Preventive maintenance and indoor air quality are fields of service that are quickly becoming imperative to the HVAC/R industry. This section describes these certifications.

Before obtaining any of Mainstream's preventive maintenance technician (PM Tech) or indoor air quality (IAQ) certifications, you must have an EPA 608 certification from an EPA-approved certifying agency such as Mainstream.

Only 608-certified technicians can obtain a PM Tech or IAQ Certification.

Preventive Maintenance Technician

Mainstream's PM Tech certification is free and covers all aspects of acid and moisture detection, acid removal, water removal, compressor maintenance, coil maintenance, proper refrigeration charging techniques, advanced diagnosis, and leak testing procedures. The exam consists of 25 questions related to preventive maintenance and proper use of QwikProducts to service, repair, and maintain air conditioning, refrigeration, and heat pump systems.

Indoor Air Quality Technician

Mainstream also offers IAQ certification for 608-certified technicians online in a format similar to the PM Tech certification. IAQ certification covers ventilation, mold detection/prevention/remediation, radon detection, air filtration, biological contamination, duct cleaning, humidity control, water damage remediation, and more.

Levels of PM Tech or IAQ Certification

The three levels of PM Tech or IAQ certification are described in this section.

Apprentice Certification

Apprentice Certification requires EPA 608 certification from Mainstream or another EPA-approved testing organization. You must successfully complete the online exam with a score of 84% or better. If you received EPA certification by any organization other than Mainstream, you must send valid documentation to Mainstream. For Mainstream 608 Certified Technicians, Mainstream automatically verifies your 608 certification.

Journeyman Certification

Journeyman Certification includes all the requirements of the apprentice plus at least 5 years of verifiable experience in the HVAC/R trades. Documentation to substantiate this experience is required.

Master Certification

Master Certification includes all the requirements of the apprentice plus at least 10 years of verifiable experience in the HVAC/R trades. Documentation to substantiate this experience is required.

Additional Information

Training

More information about all of Mainstream's QwikProduct Certifications and Training is available at www.EPATest.com. Our training is focused on improving your skills, improving your technical image, keeping you in compliance, and keeping you safe.

QwikProducts

Mainstream is a thermal control and energy conversion R&D-based manufacturer that focuses on transitioning its advanced U.S. military technology into high-quality and cost-effective products, QwikProducts, which are all made in the USA. We are engineers and service technicians who are deeply involved in the HVAC/R trade, and all our QwikProducts are designed to save you time and money.

Required Recordkeeping

The EPA has imposed significant and time-consuming recordkeeping requirement on HVAC/R professionals. These requirements have been outlined in this manual.

To ease the burden on HVAC/R service providers, the QwikProducts team offers a secure cloud-based ***free*** recordkeeping service that complies with all the EPA requirements. For security reasons, our secure password-protected HVAC/R QwikProducts community is only open to 608-certified HVAC/R service contractors. Further details about the community are available at www.qwik.com.

Acronyms and Definitions

AHRI—Air Conditioning, Heating, and Refrigeration Institute. Professional organization that maintains technical standards, certifies products, shares data, and conducts research.

AKB—Alkylbenzene. A synthetic refrigeration lubricant that better thermal stability compared to traditional mineral oil. They can be used in systems designed for CFCs and HCFCs.

Appliance—Device that contains and uses a refrigerant for household or commercial purposes, including any air conditioner, refrigerator, chiller, or freezer. EPA interprets this definition to include all air conditioning and refrigeration equipment except units designed and used exclusively for military purposes.

ASHRAE—American Society of Heating, Refrigerating and Air Conditioning Engineers. Publishes technical standards to improve the HVAC/R field.

Asphyxia—Displacement of the oxygen in a room by the denser refrigerant.

Azeotrope—Blend of two or more components whose equilibrium vapor phase and liquid phase compositions are the same at a given pressure. These refrigerants are given a 500-series ASHRAE designation and behave like a single refrigerant. They can be charged as a liquid or vapor.

Bubble point—Temperature at which the non-azeotropic blend first begins to evaporate (boil).

Capillary tube—Passive throttling device comprised of a very 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. The capillary tube doesn't actively control the pressure drop to maintain a prescribed superheat at the exit of the evaporator.

CFC—Chlorofluorocarbon. A family of refrigerants containing the elements chlorine, fluorine, and carbon. CFCs have characteristics that make them more likely to reach the stratosphere than most other compounds containing chlorine. Refrigerants that contain chlorine but not hydrogen are so stable that they don't breakdown in the lower atmosphere after being released.

cfm—cubic feet per minute. Unit of measure, often used for the volumetric capacity of vacuum pumps.

Chiller—Vapor compression system that cools or chills water rather than directly cooling the air in the building. This chilled water is then pumped to fan coil units (water-to-air heat exchangers with a fan) that condition the air in the appropriate sections of the building.

Class I refrigerant—Refrigerants that have an ozone depletion potential greater than 0.2. All chlorofluorocarbons (CFCs) are Class I refrigerants.

Class II refrigerant—Class II refrigerants are refrigerants that have an ozone depletion potential less than 0.2 and consist of all hydrochlorofluorocarbons (HCFCs). HCFCs were developed as transitional substitutes for Class I substances and are subject to a later phase-out schedule than Class I substances. Although there are currently 34 controlled HCFCs, only a few are commonly used. The most widely used have been HCFC-22, HCFC-141b (a solvent and foam-blowing agent), and HCFC-142b (a foam-blowing agent and component in refrigerant blends).

ClO—Chlorine monoxide.

Comfort cooling equipment—Any AC equipment used to control temperature and/or humidity in occupied facilities including, but not limited to, residential, office, and commercial buildings. Generally, chillers are considered comfort cooling appliances.

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. This type of equipment contains large refrigerant charges, typically more than 75 pounds.

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

Compressor—Refrigeration system component that changes a low-pressure vapor to a high-pressure vapor. The common types of hermetic compressors are reciprocating, rotary, and scroll compressors. Larger types of compressors include centrifugal and screw compressors.

Condenser—Refrigeration system component that changes a high-pressure vapor to a high-pressure liquid by rejecting heat from the refrigerant causing the refrigerant to condense.

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.

Dew point—Temperature at which the non-azeotropic blend first begins to condense.

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.

EPA—Environmental Protection Agency. Government agency formed in 1970 with the primary role of carrying out the laws of the Clean Air Act.

EPDM—Ethylene propylene diene monomer. Rubber-like material not compatible in HC or HFO refrigerant systems.

ERG—Emergency response guidebook. Book produced by the Department of Transportation for first responders to accidents involving dangerous or hazardous materials.

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

Evaporator—Refrigeration system component that changes (boils) the low-pressure two-phase mixture of liquid and vapor refrigerant into an all-vapor stream of refrigerant, drawing heat into the refrigerant (thus providing cooling) during the evaporation.

EXV—Electronic expansion valve. 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.

Exempt refrigerants—Refrigerant that has a 0 ozone depletion potential (0 ODP) and a global warming potential (GWP) equal to or lower than carbon dioxide that is a GWP of 1 or less. Some exempt refrigerants include carbon dioxide, hydrocarbon refrigerants, nitrogen, or water. Ammonia which is used in commercial or industrial process refrigeration or in absorption units is also exempt because it isn’t used in a vapor compression application.

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

GWP—Global warming potential. Measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO_2). The GWP was developed to allow comparisons of the global warming impacts of different gases. The GWP of carbon dioxide is 1.

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

Heat pump—Vapor-compression cooling system with a reversing valve so that the system can provide interior cooling during hot ambient temperature and interior heating during cold ambient temperatures.

High-pressure appliance—Appliance that uses a refrigerant with a liquid phase saturation pressure between 170 psia and 355 psia at 104 °F. This definition includes but isn't limited to appliances using the high-pressure refrigerants R-22, R-401A, R-409A, R-401B, R-411A, R-22, R-411B, R-502, R-402B, R-408A, R-410A, and R-402A.

HC—Hydrocarbon. Compound containing only the elements hydrogen and carbon. HC refrigerants are natural, nontoxic exempt refrigerants that have no ozone depleting properties and absolutely minimal global warming potential. However, they are all highly flammable. They are listed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) as safety group A3, meaning they have low toxicity(A) and are highly flammable (3).

HCFC—Hydrochlorofluorocarbon. A family of refrigerants containing hydrogen, chlorine, fluorine, and carbon. Because the hydrogen reduces the stability of the compound, these refrigerants have an increased deterioration potential before reaching the stratosphere, which means HCFCs have a low ODP, but their ODP isn't zero.

HFC—Hydrofluorocarbon. A family of refrigerants containing hydrogen, fluorine, and carbon, but no chlorine. HFC refrigerants won't damage stratospheric ozone they all have an ODP of zero. However, they have very high GWPs, typically in the thousands.

HFO—Hydrofluoroolefin. A family of refrigerants containing hydrogen, fluorine, and carbon, but more reactive than HFCs because of the reactivity of the carbon–carbon bond. This increased reactivity means they have GWPs that are lower and have shorter atmospheric lifetimes. HFOs are being promoted by the EPA as the next generation of refrigerants because of their environmental friendliness, although they aren't as green as the HC refrigerants. Most HFOs are flammable, but they are less flammable than HC refrigerants.

HVAC—Heating, ventilation, and air conditioning.

Hygroscopic—Affinity for water; hygroscopic oils are oils that readily absorb moisture.

Industrial process refrigeration—Complex customized appliances used in the chemical, pharmaceutical, and petrochemical industries and in manufacturing. This sector includes industrial ice machines and ice rinks.

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 rate—EPA approved method to determine the rate at which an appliance is losing refrigerant, based on extrapolating the measured leak over the next 12 months. The leak rate is expressed in terms of the percentage of the full (nameplate) 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. The rate is calculated using the following formula:

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

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

LFL—Lower flammability limit, which is the minimum concentration in air at which flame propagation occurs.

Line set—Piping used to connect the outdoor unit (typically referred to as the condensing unit) to the indoor unit (sometimes referred to as the fan coil unit). The line set consists of two lines; the smaller, high-pressure liquid refrigerant line (which brings condensed refrigerant to the evaporator) and the larger, insulated low-pressure line (which brings cooler evaporated refrigerant vapor back to the compressor).

Low-loss fitting—Device that is intended to establish a connection between hoses, appliances, or recovery/recycling machines, and 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—Appliance that uses a refrigerant with a liquid phase saturation pressure below 45 psia at 104 °F. This definition includes but isn't limited to appliances using low-pressure refrigerants R-11, R-123, and R-113.

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

Medium-pressure appliance—Appliance that uses a refrigerant with a liquid phase saturation pressure between 45 psia and 170 psia at 104 °F. This definition includes but isn't limited to appliances using R-114, R-124, R-12, R-401C, R-406A, and R-500.

Micron—One thousandth (1/1,000) of a millimeter of mercury vacuum.

Mixture—Blend of two or more components that don't 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).

Motor vehicle air conditioner (MVAC)—Mechanical vapor compression appliance used to cool the driver or passenger compartment of a motor vehicle that isn't using a high-pressure refrigerant (such as R-22, R-407C or R-410A) and has a refrigerant charge of less than 20 pounds. Section 609 certification is required for working on MVAC systems while either Section 608 Type II or Section 609 certification is required for MVAC-like A/C systems (e.g., farm equipment and other non-roads vehicles). This definition excludes any appliance that uses a high-pressure refrigerant, except carbon dioxide. Although carbon dioxide is also a high- pressure refrigerant, it is an exempt refrigerant, making it exempt from any certification requirements.

MVAC-like appliance—Mechanical vapor compression appliance used to cool the driver or passenger compartment of a non-road vehicle (including agricultural and construction vehicles) that isn't using a high-pressure refrigerant (such as R-22, R-407C or R-410A) and has a refrigerant charge of less than 20 pounds. Either Section 608 Type II or Section 609 certification is required for MVAC-like systems. This definition excludes any appliance that uses a high-pressure refrigerant, except carbon dioxide. Although carbon dioxide is also a high- pressure refrigerant, it is an exempt refrigerant, making it exempt from any certification requirements.

A key difference between MVAC and MVAC-like appliances is that persons who service MVACs are subject to the Section 609 equipment and technician certification requirements only if they perform "service for consideration," while persons who service MVAC-like appliances are subject to the equipment and technician certification requirements set forth in the Section 608 and 609 regulations regardless of whether they are compensated for their work.

Another difference is that persons servicing MVAC-like appliances have the option of becoming certified as Section 608 Type II technicians instead of becoming certified as Section 609 MVAC technicians under subpart B. Persons servicing MVACs don't have this choice. They must be certified as Section 609 MVAC technicians if they perform the AC service for compensation.

NASA—National Aeronautics and Space Administration

Non-azeotropic refrigerant—Synonym for zeotropic, which is the preferred term although less commonly used as a descriptor. See zeotropic.

Non-condensable gas—Gas that won't condense anywhere in the vapor compression system and typically accumulate in the condenser.

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

O_2—Oxygen.

O_3—Ozone.

ODP—Ozone depleting potential. Relative amount of degradation to the ozone layer that a refrigerant can cause.

ODS—Ozone depleting substance. Any substance that depletes the ozone layer.

Opening an appliance—Service, maintenance, or repair on an appliance that could be reasonably expected to release refrigerant from the appliance to the atmosphere unless the refrigerant was previously recovered from the appliance.

Orifice plate—Passive throttling device, comprised of a small opening located upstream of the evaporator that drops the pressure in the system, causing refrigerant to flash into a two-phase mixture. The orifice plate doesn't actively control the pressure drop to maintain a prescribed superheat at the exit of the evaporator.

PAG—Polyalkylene glycol oil. Type of synthetic oil primarily used in automotive air conditioning systems.

PEL—Permissible exposure limit. Maximum amount or concentration of a refrigerant that a worker can be exposed to under OSHA regulations.

Person—Individual or legal entity, including an individual corporation, partnership, association, state, municipality, political subdivision of a state, Indian tribe, and any agency, department, or instrumentality of the United States and any officer, agent, or employee thereof.

POE—Polyolester oil. Also referred to as ester oil, a synthetic lubricant commonly used with HFC refrigerants and HFC blends.

ppm—parts per million. Unit of measure.

Process stub—Length of tubing that provides access to the refrigerant inside a small appliance or room air conditioner that can be resealed at the end of repair or service.

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 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.

PTAC—Packaged terminal air conditioner.

PVE—Polyvinyl ether oil. Oil commonly used in newer MVAC systems.

Reclamation—To reprocess refrigerant to new product specifications or at least to the purity specified in the AHRI Standard 700, Specifications for Fluorocarbon Refrigerants, and to verify this purity using the analytical test procedures 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 or processing it in any way.

Recovery efficiency—Percentage of refrigerant in an appliance that is recovered by recycling or recovery equipment.

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 performing a recovery evacuation, the EPA required evacuation level must be determined based on the quantity and type of charge. 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.

Refrigerant—Any class I or class II substance used for heat transfer purposes, or any substance used as a substitute for such substances by any user in a given end-use, except for the following substitutes in the following end-uses:

- *Ammonia* in commercial or industrial process refrigeration or in absorption units
- *Chlorine* in industrial process refrigeration (processing of chlorine and chlorine compounds)
- *Carbon dioxide* in any application
- *Nitrogen* in any application
- *Water* in any application

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.

SCBA—Self-contained breathing apparatus.

SDS—Safety data sheet. Provides important information on the physical/chemical characteristics and first aid procedures for solvents, chemicals, and refrigerants.

Self-contained recovery—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 refrigerating or cooling appliance that is unitary, fully manufactured, charged, and hermetically sealed in a factory with five pounds or less of refrigerant. This includes but isn't limited to: refrigerators and freezers designed for home use, room air conditioners (including window air conditioners and packaged terminal air conditioners), packaged terminal heat pumps, dehumidifiers, under-the-counter ice makers, vending machines, and drinking water coolers.

SNAP—Significant New Alternatives Policy. EPA's program to evaluate and regulate the *safety* of substitutes for the ozone-depleting chemicals that are being phased out under the stratospheric ozone protection provisions of the Clean Air Act.

Subcooling temperature—Number of degrees the refrigerant is cooled to below the saturation temperature (at the same pressure).

Substitute—Chemical or product substitute, whether existing or new, used by any person as a replacement for a class I or II compound in a given end-use.

Superheat—Number of degrees the vapor is heated above the saturation temperature (at the same pressure).

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

Technician—Person who performs maintenance, service, or repair that could reasonably be expected to release refrigerant into the atmosphere, including but not limited to installers, contractor employees, in-house service personnel, and, in some cases, owners. Technician also means any person disposing of appliances except for small appliances.

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

Throttling device—Refrigeration system component that drops the pressure to lower the saturation temperature and allows the refrigerant to evaporate or boil in the evaporator, drawing heat into the refrigerant. Also called an expansion device or throttling valve.

TOMS—Total-ozone monitoring station.

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) and the system re-evacuated. Recovery of the nitrogen isn't required. This process is repeated additional times with the final evacuation down to at least 500 microns.

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

UFL—Upper flammability limit. Maximum concentration in air at which flame propagation occurs. At flammable refrigerant concentrations above the UFL, there is insufficient oxygen in the air to propagate the flame.

UV-B—Harmful ultraviolet rays from the sun.

Vacuum pump—Device used to pump the air, moisture, and other non-condensables out of a system and 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.

Very high-pressure appliance—Appliance that uses a refrigerant with a critical temperature below 104 °F or with a liquid phase saturation pressure above 355 psia at 104 °F. This definition includes but isn't limited to appliances using R-13, R-23 or R-503.

Zeotropic—Also referred to as Non-Azeotropic. Refrigerant 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.