

Environmentally Safe Refrigerant Service Tips & Techniques

Abridged* Free Version

*This manual contains all the information necessary to successfully study and pass the EPA Section 608 Type I Certification Exam, and is distributed free of charge. For readers desiring more information on the subject or to purchase the full version of the manual, visit www.epatest.com/608 for details.

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Preface

This manual contains all the information necessary to successfully study and pass the EPA Section 608 Type I Certification Exam, and is distributed free of charge. For readers desiring more information on the subject or to purchase the full version of the manual, visit www.epatest.com/608 for details.

The information in this course is intended for educational purposes only. Procedures described are for use only by qualified air conditioning and refrigeration service technicians. **This training course is not a substitute for any equipment Manufacturer's Operator Manual.**

Take safety precautions when using all HVAC equipment. Improper use of HVAC equipment can cause explosion and serious personal injury. Always read the entire Manufacturer's Operator Manual before turning on any equipment for the first time. Use extreme caution when working with refrigerants; hoses may contain liquid refrigerant under pressure. Use only approved refillable storage cylinders. Do not overfill any storage cylinder beyond its rated capacity. Always wear safety glasses. Protect the skin from flash freezing. **Never turn on any equipment if you do not understand its operation. Where procedures described in this manual differ from those of a specific equipment manufacturer, the equipment manufacturer's instructions should be followed.**

Do not 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 book is current as of the date of the manual's latest publication. Due to 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. Manufacturer's Operator Manuals must be consulted for the proper operation of any piece of equipment. The content of this course is limited to information and service practices needed to contain, conserve, and reuse refrigerants, and to prevent their escape into the atmosphere. **This manual is not intended to teach air conditioning–refrigeration system installation, troubleshooting, or repair.** Refrigeration technicians should already be well versed in these areas prior to taking this course.

Table of Contents

[PREFACE](#)

[TABLE OF CONTENTS](#)

[TABLES](#)

[FIGURES](#)

[Figures - Core Section](#)

[Figures - Type I Section](#)

[DOCUMENT CONVENTIONS](#)

[CERTIFICATION INFORMATION](#)

[Types of Technicians](#)

[Examination Details](#)

[DEFINITIONS](#)

[Core Section](#)

[OZONE DEPLETION](#)

[Earth's Atmosphere](#)

[Ozone](#)

[Legislative Action](#)

[The Monitoring of the Ozone Layer](#)

[Primary Sources of Chlorine in the Atmosphere](#)

[CFCs](#)

[HCFCs](#)

[HFCs](#)

[Effects on Human Health](#)

[CLEAN AIR ACT](#)

[EPA](#)

[Recordkeeping Requirements](#)

[Recovery and Recycling](#)

[Venting](#)

[The Sale of Used Refrigerant](#)

[Who Can Buy Refrigerants](#)

[Disposal](#)

[Enforcement](#)

[SUBSTITUTE REFRIGERANTS AND OILS](#)

[Refrigerant Blends](#)

[Changing to a Different Refrigerant](#)

[Using Synthetic Oils](#)

[REFRIGERATION PRINCIPLES](#)

[How Refrigerant Works](#)

[Required Tools](#)

[Good Service Practices](#)

[THREE RS](#)

[Recover](#)

[Recycle](#)

[Reclaim](#)

[RECOVERY TECHNIQUES](#)

[Identifying the Refrigerant](#)

[Evacuation Requirements](#)

[Proper Equipment](#)

[Customer Service](#)

[Refrigerants at High Temperatures](#)

[LEAK DETECTION](#)

[Nitrogen Gas](#)

[Pressure Decay Leak Test](#)

[DEHYDRATION EVACUATION](#)

[Triple Evacuation](#)

[Triple Evacuation Procedure](#)

[Cleanup After Major Repairs](#)

[GENERAL SAFETY](#)

[Asphyxia](#)

[Material Safety Data Sheet](#)

[Personal Protective Equipment](#)

[Release of Refrigerant into the Air](#)

[Flammability](#)

[Pressure](#)

[ASHRAE Refrigerant Safety Classifications](#)

[Cylinders](#)

[SHIPPING](#)

[Department of Transportation \(DOT\) Regulations](#)

[Shipping Labels](#)

[Cylinder Loading](#)

[Type I - Small Appliance Certification](#)

[TYPE I TECHNICIAN REQUIREMENTS](#)

[WHAT IS A SMALL APPLIANCE?](#)

[RECOVERY REQUIREMENTS](#)

[Small Appliance Evacuation Requirements](#)

[Recovery Devices](#)

[Equipment Certification](#)

[Refrigerants That Are Not Recovered with EPA-Approved Recovery Devices](#)

[SMALL APPLIANCE EQUIPMENT](#)

[Fittings, Connections, and Ports](#)

[Graduated Charging Cylinders](#)

[RECOVERY METHODS FOR SMALL APPLIANCES](#)

[SAFETY](#)

[Safety Gear and Protective Clothing](#)

Tables

[TABLE 1. THEORETICAL AC PERFORMANCE COMPARISON^A](#)

[TABLE 2. SATURATION PRESSURE-TEMPERATURE CHART](#)

Figures

Figures - Core Section

[FIGURE C - 1. COMPONENTS OF A COOLING SYSTEM](#)

[FIGURE C - 2. TWO COMMON STYLES](#)

[FIGURE C - 3. TWO-VALVE, THREE-HOSE MANIFOLD](#)

[FIGURE C - 4. TWO-VALVE, THREE-HOSE MANIFOLD PHOTO](#)

[FIGURE C - 5. DOT-APPROVED RECOVERY TANKS](#)

[FIGURE C - 6. TYPICAL RECOVERY TANK](#)

[FIGURE C - 7. PRESSURE RELIEF VALVE ON A RECOVERY TANK](#)

[FIGURE C - 8. PHOTO OF DOT CLASSIFICATION TAG.](#)

[FIGURE C - 9. TYPICAL SHIPPING PAPERWORK](#)

Figures - Type I Section

[FIGURE I - 1. PROCESS STUB ON A SMALL APPLIANCE](#)

[FIGURE I - 2. GRADUATED CHARGING CYLINDER](#)

[FIGURE I - 3. LOCKING-PLIERS PIERCING ACCESS VALVE](#)

Document Conventions

The following figures appear throughout this document:



Tip

Tips are designed to provide hints or shortcuts.



Note

Notes contain related information.



Example

Examples provide illustrations to enable you to practice your skills or test yourself on material.



Caution and Warning

Caution and Warning indicates the possibility of bodily harm or damage to your equipment.

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 the filter drier

Activities that are not 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 external electrical circuit
- Replacing insulation on a length of pipe
- Replacing a faulty capacitor or potential relay
- Tightening nuts and bolts on the appliance

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

A technician includes but is not 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). Once certified, your EPA Section 608 certification has no expiration date. If EPA regulations change after you become certified, however, it is your responsibility to comply with any future changes in the law.

Types of Technicians

The certification has three levels depending on the appliance you need to work on. A universal certification exists for technicians who work on all types of appliances. The types of EPA certification are described in the following section.

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 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 exam (with a higher score requirement for passing) or a closed-book proctored format. Only Type I certification is available in the open-book 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. The 25 Type I questions do not need to be repeated.

Type II Technicians

Type II technicians maintain, service, or repair medium-, high-, or very high-pressure appliances that do not qualify as small appliances. Individuals who dispose of medium-, high-, or very high-pressure appliances must also be certified properly as Type II technicians. Essentially, if you work on any system that does not qualify as a small appliance or a low-pressure system (or Motor Vehicle Air Conditioners (MVAC) or MVAC-like system), then you need Type II or Universal certification.

Technicians receiving a passing grade on the Type II (medium-pressure, high-pressure, and very high-pressure) 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 technicians.

Universal Technicians

If you hold Type I, Type II, and Type III certification, you will be issued a Universal certification card and will be eligible to maintain, service, or repair all appliances covered by each of those certifications. Universal certification does not 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.

Technicians who maintain, service, or repair MVAC-like equipment such as farm equipment and other off-road vehicles can be certified with either the Section 609 MVAC certification or Section 608 Type II (or Universal) certification.

The EPA definition for MVAC-like appliances is a mechanical vapor compression, open-drive compressor appliance used to cool the driver or passenger compartment of an off-road motor vehicle with a refrigerant charge (that is not HCFC-22) of less than 20 pounds. Currently, HCFC-22 systems cannot be classified as an MVAC-like device.



Note

Emerging electric vehicles will use hermetically sealed (not open-drive) compressors that are electric powered. Under current regulations, such systems cannot be serviced by MVAC technicians; you need Type I or Type II certification (depending on the refrigerant charge). If the system has less than five pounds of charge (which is most likely), you need Type I Small Appliance certification.

Apprentices

Apprentices are exempt from this certification requirement provided the apprentice is closely and continually supervised by a certified technician while performing any maintenance, service, repair, or disposal that could reasonably be expected to release refrigerant from appliances into the environment. The supervising certified technician is responsible for ensuring that the apprentice complies with this subpart.

Serviceable Systems

Certification Type	Systems/Appliances			
	Small Appliance ¹	Med/High & Very High Pressure ²	Low Pressure ³	Motor Vehicle
None	No	No	No	No
608 Type I	Yes	No	No	No
608 Type II	No	Yes	No	No
608 Type III	No	No	Yes	No
608 Universal ⁴	Yes	Yes	Yes	No
609 MVAC	No	No	No	Yes

¹Small Appliances (packaged terminal air conditioners, unitary systems) containing 5 lbs or less of refrigerant

²High-pressure and very high-pressure appliances including split systems and all other non-automotive systems not covered under the category of unitary small appliance or low pressure appliance.

³Low-pressure appliances such as chillers

⁴Universal certification is simply possessing a Type I, Type II, and Type III certification

Refrigerant Recovery

Certification Type	Permitted to Recover*		
	CFCs	HCFCs	HFCs
None	NONE*	NONE*	NONE*
608 Type I	Small Appliance	Small Appliance	Small Appliance
608 Type II	Med/High/Very High	Med/High/Very High	Med/High/Very High
608 Type III	Low	Low	Low
608 Universal ¹	All Above	All Above	All Above
609 MVAC	Only MVAC Refrigerants	Only MVAC Refrigerants	Only MVAC Refrigerants

¹Universal certification is simply possessing a Type I, Type II, and Type III certification

*All refrigerants are required to be recovered. Only certified technicians are permitted as per the table above.

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 R-410A Service Techniques, Green Certification, Preventative Maintenance Certification, and Indoor Air Quality Certification. Information on these other 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 proctored exam (per section) is 72 percent, which means you must answer at least 18 of the 25 questions correctly in each section.

For the Type I open-book format, the passing grade is 84 percent (21 of 25 correct).

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

If you take the proctored Universal exam but only pass the Core section and at least one of the Type sections, you will receive a certification card for the Type section(s) you passed.

The proctored exams are closed book. You cannot use your own papers, charts, or any other supplemental material. Calculators and cell phones may not be used during the test. All the necessary pressure/temperature charts are supplied during the test.

Definitions

Appliance - any 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.

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

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

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

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

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

Major Maintenance, Service, or Repair – a service or repair that involves removal of the compressor, condenser, evaporator, or auxiliary heat exchanger coil.

Motor Vehicle Air Conditioner (MVAC) - Mechanical vapor compression refrigeration equipment used to cool the driver or passenger compartment of any motor vehicle. This definition is NOT intended to encompass the hermetically sealed refrigeration system used on motor vehicles for refrigerated cargo or the air conditioning systems on passenger buses.

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).

Section 608 certification is required for working on hermetically sealed refrigeration systems used on motor vehicles for refrigerated cargo or the air conditioning systems on passenger buses.

Due to the similarities between MVAC and MVAC-like appliances, EPA recommends that technicians servicing MVAC-like appliances consider certification under Section 609.

Note that buses using CFC-12 or HFC-134a to cool the driver are MVACs. However, buses using HCFC-22 are not MVACs or MVAC-like appliances, but rather high-pressure equipment covered under by Section 608 certification. Therefore, if you service both the driver AC system (MVAC) and the passenger AC system, both a 609 MVAC and a 608 certification are required. Likewise, if you service the AC system for the cab of a truck (MVAC) as well as the refrigerated cargo container then again, you need both 609 MVAC and 608 certifications.

MVAC-Like Appliances - mechanical vapor compression, open-drive compressor appliances used to cool the driver or passenger compartments of a non-road vehicle, including agricultural and construction vehicles. This definition excludes appliances using HCFC-22 refrigerant or their substitutes, such as R-410A or R-407.

The regulations implementing sections 609 and 608 treat MVACs and MVAC-like appliances (and persons servicing them) slightly differently. A key difference 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 do not have this choice. They must be certified as Section 609 MVAC technicians if they perform the AC service for compensation.

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

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

Normal Charge - the quantity of refrigerant within the appliance or appliance component when the appliance is operating with a full charge of refrigerant.

Opening an Appliance - any 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.

Process Stub - a length of tubing that provides access to the refrigerant inside a small appliance or room air conditioner that can be resealed at the conclusion of repair or service.

Reclamation - to reprocess refrigerant to new product specifications or at least to the purity specified in the ARI 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.

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 - the fluid used for heat transfer in a refrigeration system, which absorbs heat during evaporation at low temperature and pressure, and releases heat during condensation at a higher temperature and pressure.

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 of the following products that are fully manufactured, charged, and hermetically sealed in a factory with five pounds or less of refrigerant: 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.

Substitute - any 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.

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

Technician - any 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.

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

their volumetric capacity, typically expressed in cubic feet per minute (cfm). Three to six cfm pumps are typically used in residential applications.

Very high-pressure appliance - 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 is not limited to appliances using R-13 or R-503. Very high-pressure refrigerants include R-13, R-23, and R-503.

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 above Earth is a fairly simple, yet unstable, molecule that is 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 CFCs contain a chlorine atom, when they enter the stratosphere, they can destroy ozone.

In fact, according to 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 chlorofluorocarbons (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, which is even more damaging than chlorine.

In September 1987, the United States and 22 other countries signed the Montreal Protocol on Substances That Deplete the Ozone Layer. 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. Every two years, the parties are required to assess the science, economics, and alternative technologies related to the protection of the ozone layer.

The Monitoring of the Ozone Layer

Scientists know that the best proof that CFCs are in the stratosphere is to take air samples from the stratosphere and measure the CFCs in the samples. On February 3, 1992, NASA released preliminary data acquired by the ongoing Arctic Airborne Stratospheric Experiment-II, a series of high-altitude instrument-laden plane flights over the northern hemisphere. Additional data were also obtained from the initial observations by NASA's Upper Atmosphere Research Satellite launched in September 1991.

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 measurements showed higher levels of chlorine monoxide over Canada and New England than were observed during any previous sampling done. In fact, 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 enhanced aerosol surface reactions due to emissions from the volcanic eruptions of Mount Pinatubo.

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

In addition, the levels of nitrogen oxides were also low, providing evidence of reactions that take place on the surface of aerosols that diminish the ability of the atmosphere to control the buildup of chlorine radicals. New observations of hydrogen chloride and nitrogen oxide implied 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

Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (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 show that chlorine in the stratosphere comes mainly from CFCs, which 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 CFC 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.

To stop damage to the stratospheric ozone layer, technicians in the United States are required to recover refrigerant and use good service practices to capture ozone-damaging CFCs and HCFCs. Through the use of alternative, non-ozone depleting refrigerants, this practice will ultimately eliminate the use of CFCs and HCFCs.

CFCs

Chlorofluorocarbons (CFCs) are 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 do not breakdown in the lower atmosphere after being released. Chlorine or bromine reacts with ozone (O₃), causing it to change back to oxygen (O₂), which destroys the ozone layer.

CFCs have a high ozone depletion potential (ODP). 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. Hydrofluorocarbons (HFCs) have a zero ODP but do contribute to global warming, another issue that is discussed later.

The following refrigerants contain CFCs:

- R-500
- R-12

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. HCFCs have been used to replace CFCs because they cause less depletion of the ozone, making them less harmful to stratospheric ozone than CFCs.

In January 1, 2010, a ban was placed on the production, sales, 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 January 1, 2010, but not to appliances or components manufactured before that date.

The Allocation Rule, along with existing EPA requirements, prohibits manufacturers from charging newly manufactured appliances with virgin HCFC-22 or HCFC-142b or blends containing these refrigerants.

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. These refrigerants have applications in retail food refrigeration, cold storage warehouses, industrial process refrigeration, and transport refrigeration.

On January 1, 2015, the HCFC ban will extend to all HCFCs for use in new systems and will only allow the use of HCFCs for special applications including the service and repair of existing equipment.

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

Most small commercial AC systems manufactured before 2010 use HCFC-22. However, due to 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.

The following refrigerants contain an HCFC:

- R-22
- R-123
- R-124

HFCs

Hydrofluorocarbons (HFCs) are a family of refrigerants containing hydrogen, fluorine, and carbon, but no chlorine. HFC refrigerants will not damage stratospheric ozone.

The following refrigerants are HFCs:

- R-134a
- R-410A

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.

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
- Damage to plants including crops and aquatic organisms
- Increased formation of ground-level ozone
- Increased weathering of outdoor plastics

Clean Air Act

The EPA is also responsible for setting regulations for all air-conditioning and refrigeration equipment using CFC, HCFC, or HFC refrigerants.

Halons were completely phased out by 1994. The phase-out schedule was accelerated so that the production and consumption of CFCs, halogenated CFC, carbon tetrachloride, and methyl chloroform would be complete in 1996. However, the EPA developed a proposal that would end the production of these chemicals by the end of 1995.

In addition to setting the schedule for the phase out of CFC/HCFC production, 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.

Under Section 608 of the Clean Air Act, EPA established regulations that require persons servicing or disposing of air-conditioning and refrigeration equipment to certify to EPA that they have acquired refrigerant recovery and/or recycling equipment and are complying with the requirements of the rule. EPA has set standards for the recovery of refrigerants, which are covered in more detail in the Type I, Type II, and Type III certification sections of this training guide. These 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.

Motor Vehicle Air Conditioning (MVAC) service technicians are governed under a different section, namely Section 609 of the Clean Air Act. If you are an MVAC technician, you must obtain a Section 609 MVAC certification.

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.

EPA has set maximum leakage rates for equipment that contains 50 pounds or more of refrigerant. When servicing systems that contain less than 50 pounds of refrigerant, you are not legally required to repair any leaks, but you should do so whenever possible. Since June 14, 1993, the EPA requires systems that contain 50 pounds or more of refrigerant to have “substantial leaks” repaired within 30 days. A substantial leak is a leak of 35 percent per year or more of the normal charge for industrial process and commercial refrigeration systems. For all other systems, a leakage rate of 15 percent loss of charge per year is defined as a substantial leak by the EPA.

Revocation of Your Certification

Currently, Section 608 technician certification does not expire. However, EPA may require technicians to demonstrate their ability to perform proper procedures for recovering and/or recycling refrigerant. If you fail to demonstrate or properly use the equipment, EPA can revoke your technician’s certificate. If you refuse to demonstrate your ability to use approved equipment properly or if you fail to use approved equipment properly, EPA is likely to issue an administrative order ordering you to demonstrate compliance with the statute and the regulations. Failing such demonstration, EPA would order revocation of your certificate.

Refrigeration technicians who violate the Clean Air Act may 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 appliances, and knowingly releasing refrigerants while repairing appliances.



Tip

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

Recovery and Recycling

EPA defines “appliance” as any device that contains and uses a class I or class II substance or their substitutes as a refrigerant and is used for household, commercial, or industrial purposes, including any air conditioner, refrigerator, chiller, or freezer. 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.

All refrigerants must be recovered before opening or disposing of any appliances. No matter what type of refrigerant a system contains, that refrigerant must be recovered when the system or appliance is opened for service/repair or prior to disposal. It is a good practice to “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 it is opened.

Equipment Types

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

- 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 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. Equipment intended to service air-conditioning and refrigeration equipment (except for small appliances) must be tested under EPA requirements based on the ARI 740 test protocol, which is the test procedure for recovery and recycling equipment.



form.

Note

Equipment used to dispose of refrigerant in small appliances, as well as other refrigeration or air-conditioning equipment, can be homemade (Regulatory Classification C and D), but this homemade equipment must still be certified to the EPA using this same EPA

Recycling

Recovered, recycled, and reclaimed refrigerants serve as a useful bridge while alternative refrigerants are developed. In the United States, production or importation of CFCs ended December 31, 1995. CFC refrigerant supplies to service existing units in the United States can only come from recovery and recycling.

Venting

Effective July 1, 1992, Section 608 of the Clean Air Act makes it illegal for individuals to intentionally vent ozone-depleting substances used as refrigerants into the atmosphere while maintaining, servicing, repairing, or disposing of air-conditioning or refrigeration equipment. Subsequent amendments have made it illegal to intentionally vent any refrigerant into the atmosphere.

Only four types of releases are permitted under the prohibition:

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.
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 (as discussed previously). A faulty purge unit that results in a substantial loss of refrigerant is still considered a substantial leak, and the purge unit must be repaired just like any other leaking source.
3. Releases of CFCs or HCFCs that are not used as refrigerants. For instance, mixtures of nitrogen and a small quantity of refrigerant (such as R-134a, R-410A, or even R-22) that are used as holding charges or as leak test gases may be released. However, the release of mixtures of nitrogen and refrigerant that result from adding nitrogen to a fully 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 check gas and avoid refrigerant recovery. To use a leak check gas, the refrigerant in the system must be recovered (to the required evacuation levels). Once any repairs are made, then a small quantity of refrigerant can be added 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 an electronic leak detector can be used to search for leaks. The leak check mixture does not need to be recovered and can be vented. Don’t use a leak check gas, but instead use pure nitrogen if you are not planning to use an electronic halide leak detector.

4. Small releases of refrigerant that result from purging hoses or from connecting or disconnecting hoses to charge or service appliances are not considered violations of the prohibition on venting. However, recovery and recycling equipment manufactured after November 15, 1993, must be equipped with low-loss fittings.

It has been illegal to vent class I and class II refrigerants since November 15, 1995. It has also been illegal to vent substitutes for CFC and HCFC refrigerants since November 1995. It is currently illegal to intentionally vent any refrigerant including HFCs because even though the HFC refrigerants have no ozone depletion potential (ODP), they do contribute to global warming and must not be vented.

The Sale of Used Refrigerant

Selling used refrigerant that is not reclaimed is prohibited. As a result, under EPA regulations you may only sell recovered refrigerant to reclamation facilities to be purified to the required ARI-700 level. (This is the industry-set purity standard 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.

Who Can Buy Refrigerants

The only people who can legally buy new or reclaimed ozone-depleting refrigerants (such as CFC-11, CFC-12, and HCFC-22) in any size container (except small cans of CFC-12, see paragraph below) 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. This sales restriction covers ozone-depleting refrigerants contained in bulk containers, such as cans, cylinders, or drums.

Disposal

Refrigeration and air-conditioning equipment that is typically dismantled on-site before disposal (e.g., retail food refrigeration, central residential air conditioning, chillers, and industrial process refrigeration) has to have the refrigerant recovered in accordance with EPA's requirements for servicing prior to disposal. Equipment that might enter the waste stream as a complete system with the charge intact (e.g., motor vehicle air conditioners, 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 cannot reuse a disposable refrigerant cylinder. When you are finished with a disposable cylinder, you are sure that all refrigerant has been recovered, and the cylinder is rendered useless, you can recycle the metal.



Tip

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



Caution

In
steel

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 shell that is unpainted on the inside. Even very little internal corrosion (rust) can severely weaken the structure even though 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, do not leave almost empty disposable cylinders lying around where they can be forgotten until they explode. Instead, recover any remaining refrigerant, render the disposable cylinder useless (puncture or break off the valve), and discard or recycle the metal.

Under EPA safe disposal requirements, the final person in the disposal chain (e.g., a scrap metal recycler or landfill owner) is responsible for ensuring that the refrigerant is recovered from any equipment before the final disposal of the equipment. If the final person in the disposal chain accepts appliances that no longer contain any refrigerant charge, that person is responsible for obtaining and keeping a signed statement from the person who removed the refrigerant, stating that the refrigerant was properly recovered. 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.

Enforcement

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 even offering rewards of up to \$10,000 for information about unreported violations. However, EPA does not 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

The American Society of Heating Refrigeration and Air Conditioning Engineers (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.

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

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

Non-Azeotropic or Zeotropic Blends

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

These blends cannot be treated like a pure refrigerant during servicing. You can only charge them as a liquid, and when the system has a leak, you cannot top off the refrigerant. The reason you cannot top off non-azeotropic blends is because these 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.

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

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 would not be able to detect it in the field. See the example below where the temperature glide of the non-azeotropic R-410A is only 0.2°F making R-410A a near-azeotropic refrigerant blend.

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, but they can be topped off, and this is a significant benefit.

Blended non-azeotropic refrigerants leak from a system in uneven amounts due to different vapor pressures, so these systems cannot be topped off. Instead, you need to recover all of the refrigerant and send it to a reprocessing (reclamation) facility. The system (after repairs) must be recharged using only liquid (not vapor) charging.



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, 400-series non-azeotropic blended refrigerants should be charged 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) will be charged into the system at a higher proportion than the other refrigerant components. The only way you can be sure the non-azeotropic blend is charged properly and does not 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.

Using Synthetic Oils

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 ester oil. The most common ester oil is polyolester (POE) oil. Although HFC refrigerants are typically compatible with most existing refrigeration and air-conditioning equipment parts, they are not compatible with the mineral oils that were used in a system. Instead of mineral oils, you can use any appropriate synthetic oil.



Caution

Do not mix ester-based oils with any other oils except in waste disposal containers. In general you should never mix different types of

oils in a system.

All synthetic oils (including POE ester, PVE and 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, while 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 follow triple evacuation methods.

Alkylbenzene and Mineral Oil

For HCFC refrigerant installations and conversions, you can use mineral oil, alkylbenzene (PAG) 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. PAG oils cannot 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.

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

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

Refrigeration Principles

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) 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 this evaporation.

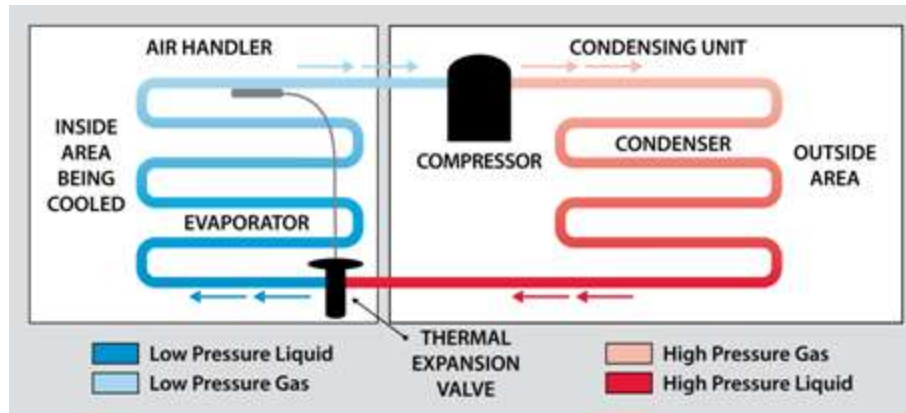


Figure C - 1. Components of a Cooling System

The next section explains how these components work together to cool an area.

How Refrigerant Works

A motor runs 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 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 to below the saturation temperature is referred to as the subcooling. Refrigerant 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:

1. The liquid refrigerant will soon flow through the expansion device, but because the expansion device has the smallest refrigerant passage in the system, all impurities must be removed before the refrigerant enters the expansion device.
2. The sudden drop in pressure associated with the expansion 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 expansion device.

As stated above, upon exiting the filter drier the liquid refrigerant enters the expansion 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 TXV or EXV) to maintain the superheat of the refrigerant at the exit of the evaporator.

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

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 is present in the refrigerant stream entering the compressor because a compressor cannot 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 oil sump, the refrigerant can dilute the oil, reducing its lubrication capability. This diluted lubricant can fail to adequately lubricate the compressor's wear surfaces and can result in premature compressor failure. To avoid this, a crankcase heater can be located on the exterior can of the compressor and can be activated anytime the compressor is not 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.



Caution

the

Never operate a hermetic compressor when there is a vacuum in 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 very 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 very carefully if it has a hermetic compressor to ensure that an excessive vacuum is not developed. Such a deep vacuum can quickly result in a system burnout, which will ruin the system's 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 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. Thus, to achieve a deep vacuum of 500 microns, we are achieving a vacuum of 0.5 mmHg absolute, or 0.0097 psia.

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.

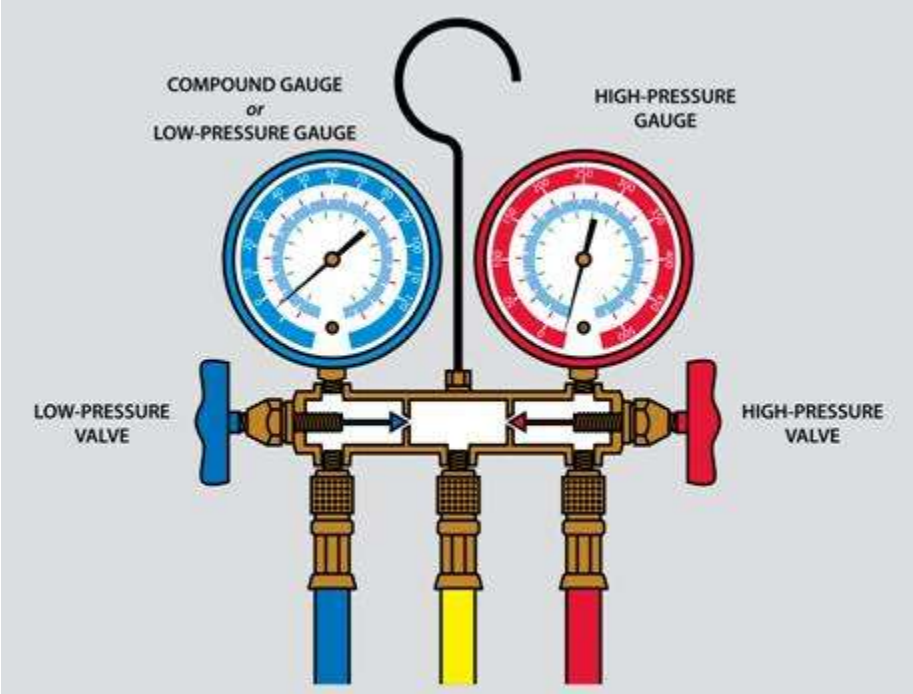


Figure C - 3. Two-valve, three-hose manifold



Figure C - 4. Two-valve, three-hose manifold photo



TIP

Since 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
cause

careful not to trap any liquid refrigerant in sealed hoses or the manifold gauge because increased ambient temperatures could cause all liquid refrigerant in these sealed components (which do not 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 will have room for expansion, which is the reason recovery tanks are never filled with liquid to more than 80 percent of their volume.

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 do not 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 may 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 1 provides a comparison of the high-side pressure of an AC system operating with a 110°F condenser and using various refrigerants.

Table 1. 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

^aAssuming 110°F condenser, 45°F evaporator, 5°F subcooling, 15°F superheat

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 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.
- Clean up the system after a burnout.
- Always draw a deep vacuum of at least 500 microns and use a triple evacuation method (discussed later).
- Never flush the system with liquid refrigerant to clean field tubing. Instead, use a commercial, environmentally safe, non-aqueous (no water) flushing solution that is non-toxic and can remove oils, contaminants, acid, and water. Qwik System Flush® is recommended. Clean out the tubing using nitrogen gas with a pressure regulator before and after using the flushing solution. Properly dispose of any flushing solution.
- 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. Using pressurized nitrogen from a nitrogen cylinder without a pressure regulator is very 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 anytime the refrigeration circuit is opened for repair.
- When acid is detected in an operating system, always change the filter drier and use QwikShot® Acid Treatment to 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 new 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 a suction-line and liquid-line filter driers, static pressure decay leak testing, and deep triple vacuum 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
- Recycle
- Reclaim
- Send to an EPA-approved facility for destruction

The three Rs - recover, recycle, and reclaim - are obviously the three best choices. Sending refrigerant that cannot be reused to be destroyed is not only expensive for you, but also 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 it in any way.

Refrigerant that is recovered can be returned to the same system or other systems owned by the same person without restriction. You cannot sell or give recovered refrigerant to another person.

If the recovered refrigerant is to be disposed of by returning it to a reclamation facility, you must store the refrigerant in a DOT-approved recovery tank. These tanks are painted gray with yellow tops as shown in Figure C - 5.



Figure C - 5. DOT-approved recovery tanks

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.

Reclaim

When you reclaim refrigerant, you use a process that returns refrigerant to new-product specifications. This process requires chemical analysis to verify the refrigerant meets new product purity standards.

Refrigerant cannot be called reclaimed unless it has been chemically analyzed, and the refrigerant meets the ARI-700 purity standard.

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 does not enter the waste stream with the charge intact.

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 should check the nameplate on the system to identify the refrigerant used, or you can use an ARI 700 purity test to determine the type of refrigerant. You may also be able to use the saturation pressure/temperature characteristics of the refrigerant to verify the refrigerant. The only reliable method of accurately determining the refrigerant type is to take a sample of the refrigerant and send it to a certified testing laboratory for analysis.



Note

If you are using a replacement refrigerant, the recovery machine must be specifically certified for the replacement refrigerant. Just because the recovery machine is certified for the original refrigerant does not mean you can use the machine with any replacement refrigerant.



Example

If you are servicing a system and you discover that some R-502 was added to an R-22 system, you cannot recover the refrigerant into an R-22 cylinder. You must recover the refrigerant into a separate recovery tank for disposal because this contaminated mixture cannot 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, and the disposal charges will be much greater than the cost of disposing contaminated refrigerant that was not mixed with other refrigerants.

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 2).



Note

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

Table 2. 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.

1. The saturation pressure–temperature relationship of some refrigerants is very similar and difficult to distinguish. For example, looking at Table 2, 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 cannot reliably distinguish these two refrigerants by this method. However, it would be quite easy to distinguish between R-410A and R-134a.
2. Non-condensable gases in the system will raise the system pressure making it difficult to determine the refrigerant, unless you are trying to select the refrigerant type from two very different choices such as R-134a or R-410A.
3. 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 very different, potentially making refrigerant identification impossible.

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

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

Evacuation Requirements

The recovery requirements for appliances are different depending on the classification of the equipment. The size of the appliance, how the appliance is used, and the date of manufacture of the recovery unit also affect the required level of evacuation. Evacuation requirements for each certification type are covered in greater detail in their respective sections of this manual.

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 (5) pounds or less of a class I or class II substance used as a refrigerant. This includes but is not limited to refrigerators and freezers (designed for home, commercial, or consumer use), medical or industrial research refrigeration equipment, room air conditioners (including window air conditioners 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 is not limited to appliances using R-11, R-123, and R-113.
- 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 is not limited to appliances using R-114, R-124, R-12, R-401C, R-406A, and R-500.
- 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 is not limited to appliances using R-22, R-134a, R-401A/B, R-408A, R-409A, R-410A, R-411A/B, R-416A, 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 is not limited to appliances using R-13, R-23, and R-503.

Proper Equipment

Before you use any of the following recovery equipment, inspect the equipment for signs of damage, rust, corrosion, or deterioration. Do not use any equipment with 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.

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



Caution

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

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

Recovery Unit



Tip

To remove ice from a sight glass or viewing glass, use an alcohol spray.

Heating the system or cooling the recovery tank will speed up recovery. When the pressure in the system is increased by heating the system, speeding the recovery. 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, the vapor becomes less dense and the recovery is slower.

During vapor recovery, the vapor is drawn from the appliance into the recovery system. The vapor passes through the recovery system's compressor and into the condenser of the recovery unit (which cools and condenses the recovered vapor). The condenser can be either air cooled or water cooled. Larger recovery units are typically water cooled and may use the domestic water supply for cooling.

Cooling the recovery tank lowers the pressure in the recovery tank, thus lowering the head pressure on the recovery machine and increasing the recovery rate. On hot days, using a recovery unit with a subcooling feature will increase the rate of recovery because it lowers the temperature of the recovery tank. If your recovery unit does not have a subcooling feature, you can place the recovery tank in water or ice water.

Recovery during low ambient temperatures, on the other hand, will slow the recovery process. Although the recovery tank is cooler, the system is also cooler. The fastest recovery is with a warm system and a cool recovery tank. The warmer the system, the warmer and more dense the vapor is. Therefore, the compressor in the recovery unit will be able to transfer more refrigerant per minute. Hence, any method to warm the system (via heat lamps or defrost heaters, or by raising the temperature in the equipment room, etc.) and cool the recovery tank will speed recovery.



Caution

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

If you suspect a burnout, take every precaution to avoid recovering the waste oil with the recovered refrigerant. Remember that “*oil is the real problem in an acid burnout.*”



Caution

Small amounts of the refrigerant have no odor. If you smell a pungent odor during a system recovery and/or repair, the refrigerant has become acidic and the compressor has probably burned out.

When recovering refrigerant from a burned-out system, both the oil and the refrigerant are contaminated. Both must be replaced.

Charging Hoses

As stated previously, you also need a set of service hoses with low-loss fittings or shut-off valves on the ends rated for the pressure of the refrigerant to be recovered. Typically, 1/4" or 3/8" charging hoses are used. You will want to have a variety of lengths of these hoses so you can use the shortest possible hoses for each job. Long hoses between the unit and the recovery machine should be avoided 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 are not needed.

Recovery Cylinders

The cylinders you use for recovering refrigerant are specifically designed and DOT approved for recovery. You may never use disposable refrigerant containers to recover refrigerant. Disposable refrigerant containers are used for 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 - 6 shows a typical Recovery Tank.



Figure C - 6. Typical Recovery Tank

The recovery cylinder you use must have a Department of Transportation (DOT) stamp of approval as shown in Figure C - 6 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. Do not 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 - 6 also shows the Date Stamp on a Recovery Tank. 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 tested by an approved laboratory.



Caution

You must also ensure the cylinder is not filled to more than 80 percent of its capacity. If 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 system off when the storage tank is 80 percent full. If you are using a refrigerant cylinder that does not have a mechanical float device or electronic shut-off device, you must use a scale to avoid overfilling.



Note

You cannot use the sight glass on the system or the recovery unit to monitor the 80 percent fill level in a recovery tank since 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 - 7 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 - 7. Pressure Relief Valve on a Recovery Tank

Because only one type of refrigerant may be recovered into the same cylinder, double check to be sure the recovery cylinder is not filled with a different refrigerant. When recovering refrigerant, never mix different refrigerants in the same container because the mixture may be impossible to reclaim. If a reclamation facility receives a tank of mixed refrigerant, it may refuse to process the refrigerant and return it at the owner's expense or agree to destroy the refrigerant but typically for a substantial fee. The mixed refrigerant typically has to be incinerated in a special furnace that controls emissions.

If the mixture cannot be reclaimed, it must be destroyed at an EPA-approved facility. If the recovery tank is empty, evacuate it before using.

Upon completion of refrigerant liquid transfer between the recovery unit and the refrigeration system, ensure that liquid refrigerant is not trapped between service valves or in any way confined in the service hoses. Expansion of liquid refrigerant will create a very high pressure and can rupture the hoses.

After filling, you must verify that all cylinder valves are properly closed and capped to prevent leaks during subsequent handling and shipment. The cylinder must also be properly labeled.



Caution

any

400 psig for R-410A. Recovery tanks for R-410A should be specified as DOT 4BA400 or 4BW400.

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 storage or recovery tank with a maximum pressure rating less than

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 (recycled) as waste metal.

Customer Service

When addressing consumer complaints regarding additional service expense due to recovery efforts, you need to explain to customers that recovery is necessary to protect human health and the environment. Tell your customers that recovery is required by law, and remind them that all professional service personnel are duty bound to follow the law and protect the environment.

Refrigerants at High Temperatures

At high temperatures (i.e., open flames, glowing metal surfaces), R-12 and R-22 can decompose to form hydrochloric and hydrofluoric acids and phosgene gas. If this happens in your system, you must do the following:

1. Evacuate all the refrigerant and oil into an isolated recovery cylinder (for disposal or reclamation).
2. Flush all remnants of the acidic oil from the system.
3. Add oil if necessary.
4. Replace the filter drier. Add a suction line filter drier.
5. Perform a Triple Evacuation to ensure complete dehydration
6. Recharge with new or reclaimed refrigerant.

7. Once the system is operational, test for residual acid with a QwikCheck[®] two-second acid test. If any residual acid is found, flush this acid out of the operating system with QwikShot[®] Acid Flush.

Leak Detection

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.

Nitrogen Gas

Nitrogen is a colorless, odorless gas that makes up 78 percent of the air we breathe. It is nonflammable and will not support combustion. Although nitrogen is a relatively stable gas, it is not inert and will react 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 GAN), nitrogen is shipped in a very high pressure cylinder. When supplied as a liquid (referred to as LIN or LN), 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.

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.



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 it 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.

Do



Caution

not use oxygen or compressed air to pressurize appliances to check for leaks because when mixed with compressor oil or some refrigerants, either oxygen or compressed air can cause an

explosion.

Pressure Decay Leak Test

Before you evacuate a system, you need to use a Pressure Decay Leak Test to verify no leaks exist. Whenever you evacuate a system with a leak, you will be drawing air, moisture, and other contaminants into the system, making subsequent deep evacuation much more difficult.

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 amount of HCFC-22 or an HFC refrigerant in the system and bring the system pressure up to about 10 psig (less for a Type III low pressure system). Do not use mixtures of nitrogen and any other CFC or HCFC (except HCFC-22) as a leak test mixture. Venting CFC or HCFC refrigerant from any appliance, hardware, or device is illegal. The release is presumed to be a refrigerant and is a violation of the EPA regulations and subject to fine. Only HCFC-22 or any HFC refrigerant can be used as the leak check refrigerant added into the system.
2. Use the nitrogen to increase the pressure to the normal working 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 the manifold gauge and connections could be leaking, not the system.
4. Check for leaks while the system is pressurized because the leaks are easier to detect. If refrigerant was added in Step 1 before the system was pressurized, then an electronic halide leak detector can be used. Otherwise, use soap bubbles, or an ultrasonic detector.
5. When you are convinced that the system is leak free, then dehydrate the system using the Triple Evacuation Method to ensure that no trapped air, refrigerant, and/or water is in the system.



Caution

Always use a pressure regulator on the nitrogen cylinder. Do not pressurize any system above the system's working pressure 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.



Example

If you have an evacuated system designed for use with R-134a or R-410A and you want to leak check the system, which has no nameplate that specifies the test pressure, then 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

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. However, removing the water out of the system is typically very difficult because the water can evaporate in one section of a large system and then condense in another section.

Heating a system will help to remove the trapped water by increasing the vapor pressure of the water and preventing the water from freezing. If the water freezes, recovery will be 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 rapidly, making further water removal much more difficult. Even if the water does not 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

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

- draw a deep vacuum,
- see if the vacuum can hold.
- refill the system with dry nitrogen and repeat until a deep vacuum is achieved and held

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

If you see an increase in pressure, the system could have a leak, but this is very doubtful since you have already passed the pressure decay leak test with the system at a much higher pressure, unless it was a low pressure system. 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).

Triple Evacuation Procedure

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

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

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

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:

13. 1. Isolate (shut-off) the service hose evacuating the system from the system.
14. 2. Break the vacuum in the line between the vacuum pump and the system.
15. 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 will draw vacuum pump oil into the system or hose, resulting in the contamination of the system or hose.
16. 4. Measure the final system vacuum with the system isolated and the vacuum pump turned off.
17. 5. After you isolate the vacuum pump from the system, wait 10 to 15 minutes to verify the vacuum gauge does not reach a level that exceeds 500 microns. If the gauge reading does not exceed 500 microns during the waiting period, you know the system has been evacuated adequately.



Tip

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

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

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

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

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

Evacuation can be a slow, tedious process. Rushing the process only leads to improper evacuation levels that will cause equipment to operate below peak efficiency and experience premature component failure. It is not possible to 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 will determine the length of dehydration time. During dehydration of a refrigeration system, the system may be heated to decrease dehydration time.

Cleanup After Major Repairs

A major repair always begins with recovering refrigerant to the necessary evacuation level for the refrigerant and size of the system. In many cases, the system is evacuated to some pressure below atmospheric pressure.

After repairs are made, the next steps are to:

1. Install a new liquid-line filter drier (in addition, install a suction line filter drier if there was a burnout or high acid in the system),
2. Pressure Decay Leak Check the system (repair leaks as necessary),

3. Dehydrate the system with the Triple Evacuation Method (achieve a deep vacuum of at least 500 microns), and
4. Charge the system with refrigerant and check for proper operation
5. If there had been high acid levels or a burn-out, introduce QwikShot® Acid Flush into the operating system.

If you cannot complete all of these necessary steps for servicing, then before you disconnect the service gauges, pressurize the system with dry nitrogen. You should never let a system sit in a vacuum because even accessing the service valves will introduce some air into the system as the vacuum draws air into the system.

Make every effort to minimize the introduction of contaminants and moisture into the system. Try not to leave a system open for any extended time. Instead, seal up the system, evacuate it (even if it is only a temporary evacuation), and then pressurize the system to a small positive pressure (like 10 psig) to keep out air, moisture, and contaminants until you are ready to finish the service.

Moisture in a system accelerates the formation of acid. Acids in the system can cause fouling of the oil, thickening of the oil (reduced viscosity), increased metal corrosion and wear, damage to the valves, and an electrical short in motor windings inside the compressor, which is called a compressor burnout. A burnout occurs when the acid actually etches off the electrical lacquer insulation on the wires of the hermetic compressor motor causing them to short. A burnout destroys the compressor and creates very high acid levels in the entire system, making system cleanup very difficult (see the section on System Flushing).

If you cannot seal up the system, at least tape the exposed ends to minimize the entry of contaminants.



Tip

Some technicians think that a deep vacuum is all that is necessary to dehydrate a system properly, but a triple evacuation to a deep vacuum is actually much more effective at removing trapped moisture.

Removing Noncondensable 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 will not function properly because at even the coldest temperatures, the air will not condense in any vapor-compression system. This means that the air or any other non-condensable vapors will not 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 will operate 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 due to the extra load.

Lubricants

The evacuation procedures today also have to be much better than in the past because of the new lubricants that must be 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. 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, you must always dehydrate the system by removing the water and drying out the system completely. Triple evacuation of a system is the best method of dehydration.

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). 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.

Asphyxia

When refrigerants are released into the air, they can replace the oxygen in the area without your 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 cause asphyxia because they are heavier than air and displace the air.

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 that refrigerant vapor is generally heavier than air, so if the ventilation is poor, the vapor will concentrate in low areas.

Material Safety Data Sheet

Solvents, chemicals, and refrigerants come with a material safety data sheet (MSDS), which provides important information on the physical/chemical characteristics and first aid procedures. Always review this information before working with a refrigerant.

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 cylinders that contain them:

- Wear splash-proof safety glasses to guard against liquid refrigerant freezing the moisture of your eyes and causing permanent blindness.
- Wear protective gloves and shoes to guard against frostbite.
- If you get refrigerant in your eyes flush the area with water for at least 15 minutes.
- 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 Material Safety Data Sheet (MSDS) for any substance you are working with including the refrigerants, lubricants, and any flushing or cleaning solutions.

Release of Refrigerant into the Air

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 they are heavier than air and displace oxygen. Avoid low areas as you leave and ventilate closed spaces before you enter.

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

Flammability

According to EPA, flammable hydrocarbon refrigerants as a replacement for CFC-12 pose a special challenge because air-conditioning and refrigeration systems in the United States have been designed to use nonflammable refrigerants. They are not designed to protect users, service technicians, and disposal personnel from the possibility of fire. Therefore, the use of flammable hydrocarbon refrigerants as a replacement for CFC-12 in existing systems may pose a risk not found with nonflammable fluids. EPA does not allow the use of flammable hydrocarbon refrigerants as a replacement for CFC-12 except for industrial process refrigeration.

This situation differs from Europe where hydrocarbon-based refrigerants such as R-290 (propane), R-50 (methane), and R-600 (butane) are commonly used. These hydrocarbon refrigerants, which have a low GWP and zero ODP that makes them green refrigerants, however, are flammable and not currently used in the United States.

As stated earlier, Honeywell and DuPont together have developed a new refrigerant (2,3,3,3-Tetrafluoroprop-1-ene), referred to as R-1234yf, to replace R-134a in automotive applications. It is a hydrofluoro olefin (fluorinated hydrocarbon) with a reduced flammability. Like hydrocarbon refrigerants, R-1234yf has the advantage of low GWP and zero ODP. More details are available at the company websites or at <http://www.1234facts.com>.

Refrigerants are divided into three groups according to flammability (see **Error! Reference source not found.**):

- Class 1 refrigerants do not show flame propagation when tested in air at 21°C and 101 kPa.
- Class 2 refrigerants have a lower flammability limit of more than 0.10 kg/m³ at 21°C and 101 kPa and a heat of combustion of less than 19 kJ/kg.
- Class 3 refrigerants are highly flammable as defined by a lower flammability limit of less than or equal to 0.10 kg/m³ at 21°C and 101 kPa or a heat of combustion greater than or equal to 19 kJ/kg.

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. Do not operate any system where flammable liquids or vapors are present unless the system and any tools used 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.

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 overpressurize the tank, resulting in refrigerant vented to the atmosphere or

explosion of the tank causing serious injury to people nearby. Excessive heat can cause the refrigerant in the tank to decompose, potentially forming toxic vapors.

Pressure

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



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 does not exceed 125°F. This is the same guidance given for R-22 and other common refrigerants.



Caution

80

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.

If the pressure relief valve did not operate properly, the cylinder could rupture and cause an explosion. As the liquid expands due to the increase in temperature, the vapor space diminishes. If insufficient vapor space is available, the expanding liquid has no room to expand, resulting in excessive pressures that could burst the cylinder.

Similarly, you must ensure no liquid is ever trapped in any space that is not 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 explosions are more violent than the explosion of an air cylinder, for example. As the pressure in the space drops due to the rupture, the compressed liquid refrigerant almost instantly flashes (evaporates almost immediately) into vapor. This makes the explosion much more violent because of the greater volume occupied by vapor refrigerant.

Before working on any piece of refrigerating equipment, use your manifold gauge set to check the pressure. If you are not sure of the type of refrigerant in the system (check the nameplate), test the refrigerant to determine its type, and then you may service the unit.

ASHRAE Refrigerant Safety Classifications

If you want to use the safest refrigerant, choose one with an ASHRAE refrigerant safety classification of A-1, such as R-12 or R-134a.

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.



Caution

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

If you are recovering refrigerant, you can only use containers 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.



Caution

Always follow these safety precautions:

- *Never apply an open flame or live steam to a refrigerant cylinder.*
- *Do not cut or weld any refrigerant line when refrigerant is in the unit.*
- *Do not use oxygen to purge lines or to pressurize the machine. Use dry nitrogen gas only, and use always use a pressure regulator.*

Shipping

Department of Transportation (DOT) Regulations

Portable refillable recovery tanks or containers used to store or ship refrigerants (obtained with recovery equipment) must meet Department of Transportation (DOT) standards.

Shipping Labels

When transporting cylinders containing used refrigerant, DOT requires that you attach DOT classification tags. Before shipping any used refrigerant in a cylinder, you must properly label the refrigerant container with the hazard class 2.2 as shown in Figure C - 8. Place the refrigerant label directly on the refrigerant cylinder to be shipped .



Figure C - 8. Photo of DOT classification tag.

You must also properly complete the shipping paperwork as shown in Figure C - 9.

Reportable Quantity	Proper shipping name	Hazard Class	ID Number
Shipping Paper			Page 1 of 1
To:	Good Neighbor Reclamation 123 EPA Way Washington, D.C.	From:	Mainstream Engineering 200 Yellow Place Rockledge, FL
Qty	HM	Description	Weight
1 cyl	RQ	Refrigerant gas 134a, 2.2, UN3159	28 lbs
<p>This is to certify that the above named materials are properly classified, described, packaged, marked, and labeled and are in proper condition for transportation according to the applicable regulations of the Department of Transportation.</p> <p>Shipper: Mainstream Engr Carrier: Next Day Truckers Per: Smith Per: Date: 4/25/2010 Date:</p> <p>SPECIAL INSTRUCTIONS: 24 Emergency Contact, Bob Smith, 888-555-5555</p>			

Figure C - 9. Typical shipping paperwork

The shipping paperwork provides vital information to first responders after an accident. This paper identifies the materials involved so protective actions can be taken for your own safety and the safety of the public.

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.

Cylinder Loading

It is a legal requirement that when you load the cylinders into the vehicle for shipping, place the refrigerant cylinders in an upright position and secure the cylinders so they cannot move during transport.

Type I - Small Appliance Certification

Type I Technician Requirements

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

If you maintain, service, or repair small appliances, you must be properly certified by the EPA as a Section 608 Type I technician or universal technician.

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 chlorofluorocarbons and hydrochlorofluorocarbons 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.

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, or PTACs)
- Packaged terminal heat pumps
- Dehumidifiers
- Under-the-counter ice makers
- Vending machines
- Drinking water coolers

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.

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 when your recovery equipment was manufactured and whether the compressor in the appliance is working. Whenever opening a small appliance for maintenance, service, or repair, you must do one of the following:

- When using recycling and recovery equipment manufactured before November 15, 1993, recover 80 percent of the refrigerant in the small appliance (80 percent of the name plate charge); or
- When using recycling or recovery equipment manufactured on or after November 15, 1993, recover 90 percent of the refrigerant in the appliance when the compressor in the appliance is operating (90 percent of the name plate charge), or 80 percent of the refrigerant in the appliance when the compressor in the appliance is not operating (80 percent of the name plate charge), or.
- Evacuate the small appliance to 4 inches of mercury vacuum.

Recovery Devices

As stated earlier in this manual, ARI 740 has two equipment classifications, system-dependent equipment and self-contained 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 (passive) recovery device for refrigerant recovery from any small appliance because small appliances only have a charge of five pounds or less. Therefore, you cannot 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.

Self-contained recovery 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 do not 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 will recover the refrigerant faster and can be configured to clean the refrigerant at the same time as you recover the refrigerant and therefore might be economically justified.

Equipment Certification

If the recovery or recycling equipment you use for the maintenance, service, or repair of small appliances was manufactured or imported on or after November 15, 1993, the equipment must have a label stating it was tested by an EPA-approved testing organization 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, using a system-dependent process, or recovering 80 percent of the refrigerant from the system when the compressor of the system is not operating
- Achieving a 4-inch vacuum based on ARI Standard 740–1993 or ARI Standard 740–1995

Refrigerants That Are Not Recovered with EPA-Approved Recovery Devices

Some older appliances use refrigerants such as ammonia, sulfur dioxide, methyl chloride, and methyl formate, which cannot be recovered with the recovery/recycling machines regulated by the EPA and do not have to be recovered. However, these substances are toxic and/or potentially carcinogenic. Therefore, you must take precautions to avoid inhalation.

Fortunately, very few of these units remain in the field. If you have to service one, however, read the Material Safety Data Sheet (MSDS) for the working fluid, and consult with the manufacturer for recovery, repair, or disposal methods.

For these refrigerants, you do not 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 do not need to be recovered either, and they also cannot 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 and manufactured after November 15, 1993, 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 - 1



Figure I - 1. Process stub on a small appliance

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 - 2. They also have a pressure gauge at the top of the cylinder.



Figure I - 2. 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. Once 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. Never transport refrigerant in a charging cylinder.



Do
time,

Caution

not leave refrigerant in a charging cylinder for extended periods of and do not transport refrigerant in these devices. Because small appliances have very small refrigerant charges, the charging cylinder can be used to store refrigerant during the service or maintenance until you return the refrigerant to the system after the service.



Tip

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, refrigerant that is vented off the top of the cylinder must be recovered.

Recovery Methods for Small Appliances

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, 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, locking pliers-type piercing valves, as shown in Figure I - 3, can be put on the tube temporarily while the refrigerant is being recovered.



Figure I - 3. 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). Therefore, the system-dependent recovery process must use a non-pressurized container to capture the refrigerant. Refrigerant bags or evacuated chilled recovery tanks are common methods.

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 (passive) 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.
- If you are using a system-dependent (passive) recovery device and the compressor *does not* run, you must access both the high and low sides of the system for refrigerant recovery (see the following Caution).

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

Be
side



Caution

very careful when operating a system compressor with suction-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.

- 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 cannot 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. Once the system pressure has dropped below the saturation pressure, the restriction can be removed (the valve can be opened fully).

Installing an Access Valve

If you have decided to access the system through the process stub, install a piercing-type access valve on the process stub, which is located typically 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.

you



Caution

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

After



Caution

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, do not begin any recovery procedure. If the system pressure is 0 psig, 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.



Tip

Only use a standard vacuum pump designed specifically for evacuation and dehydration as a recovery device in combination with a non-pressurized container—never with a pressurized container. If you are using a system-dependent recovery process and the appliance compressor operates, run the compressor.

Sometimes the compressor is not 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 is not running, you must help release trapped refrigerant from the system compressor oil. One way to do this (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 may be trapped underneath the oil in the compressor's 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.



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 will 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.

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 cannot reuse the refrigerant you removed, you have only two options.

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

Refrigerant 134a is most commonly used as a replacement for R-12 in new household refrigerators. R-134a does not deplete the ozone and its pressure–temperature characteristics are very similar to R-12, yet a refrigerator operating on R-12 will not operate on R-134a without so many changes that it is impractical to make such a conversion in any small appliance. For example, the lubrication oil must be changed, the thermal expansion valve (if used) must be changed, the compressor typically must be changed, and the filter drier must be changed. Even if you performed all the necessary changes, the cooling capacity would be different.



Note

If the small appliance has not been operated recently, the pressure within the system should be equalized, which means the high-pressure and low-pressure sides have the same pressure. When a small appliance (such as a household refrigerator) compressor 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 may be necessary to achieve the required recovery efficiency, which is to remove 80 percent of the total charge.

Safety

Safety Gear and Protective Clothing

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 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 (if manufactured after November 15, 1993) and rated for the pressure of the refrigerant with which you are working.