ENVIRONMENTALLY SAFE REFRIGERANT SERVICE TECHNIQUES FOR MOTOR VEHICLE AIR CONDITIONING TECHNICIANS

A Self Study Course for EPA 609 Motor Vehicle A/C Certification
in the Proper Use of Refrigerants, including Recovery, Recycling, and Reclamation

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Seventh Edition
June 2016

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by
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Preface

The information in this course is intended for educational purposes only. Procedures described are for use only by qualified Motor Vehicle Air Conditioning, (MVAC), service technicians. Improper use of any A/C equipment can cause personal injury. Like any other piece of equipment, always read your recovery equipment Operator's Manual before using the equipment. **This training course is not a substitute for the manufacturer's Operator's Manual. Never operate 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! Misuse of such devices can cause explosion and personal injury.

Use only approved refillable storage cylinders. Do not overfill any storage cylinder beyond its rated capacity.

Take proper safety precautions when using all A/C equipment. Wear safety glasses and insulated gloves. Protect the skin from flash freezing. Use extreme caution when working with refrigerants; hoses may contain liquid refrigerant under high pressure.

Technical and legislative information presented is current as of the date of the latest publication of this manual. Due to rapidly advancing technology and changing regulations in this field, no representation can be made for accuracy of this information into the future. Visit **https://www.epa.gov/mvac** for the latest details.

Mainstream Engineering Corporation assumes no liability for the use of the information presented in this publication. This information is presented for educational purposes only. Equipment operator's manuals must be consulted for the proper operation of particular equipment. The course content is limited to information and service practices needed to contain, conserve, and reuse refrigerants, preventing their escape to the atmosphere when servicing Mobile Motor Vehicle Air Conditioning Systems. This manual is not intended to teach air conditioning-refrigeration system installation, troubleshooting, or repair. The certified refrigeration technician should already be well-versed in these areas prior to taking this course.

EPA Examination Information

Since January 1, 1993, any person, repairing or servicing motor vehicle air conditioners for consideration must certify to the EPA that such person has acquired, and is properly using, approved equipment, and that each individual authorized to use the equipment is properly trained and certified under Section 609 of the Clean Air Act. In addition, only Section 609 Certified Motor Vehicle A/C technicians can purchase refrigerants in containers of 20 pounds or less. Mainstream is approved by the EPA as a certifying agency for 609 MVAC Technician Certification and 608 Type I, II, III, and Universal HVAC Technician Certification Exams.

This book is only for Section 609 Motor Vehicle A/C Technician Certification. Section 609 addresses the mobile motor vehicle air conditioning industry. The sale of small containers of refrigerant fewer than 20 lb., including the "one pound" cans, is restricted to only people certified in Section 609. The purpose of 609 (Mobile Vehicle Air Conditioning) certification, as established by EPA, is to teach technicians and test their ability to properly handle and recover refrigerants. Technicians will also learn about the laws enacted to protect the stratospheric ozone layer.

This manual contains all the information necessary for answering the questions on the EPA open-book exam. By carefully reading this manual, you will find the information necessary to correctly answer these questions.

To pass the examination you must:

1. Correctly answer 21 of the 25 questions, (84% passing), without any help from any other person. It is an open-book exam, you can use this manual to help you find the correct answers, and you can take as much time as you need, but you cannot get help from any other person. You will be asked to certify that you received no help from any other person.
2. Complete the Self-Certification Statement, where you pledge that you received no help from anyone in completing the test.

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Introduction

Effective since, August 13, 1992, no person repairing or servicing motor vehicles for consideration may perform any service on a motor vehicle air conditioner involving the refrigerant for such air conditioner; without properly using equipment approved by the EPA, unless such person has been trained and certified by an approved Section 609 certification program. This August 13, 1992, deadline could be extended to January 1, 1993, for small service shops (that serviced less than 100 A/C units in 1990). So, it has been illegal to service motor vehicle A/C units since, January 1, 1993, if you are not certified. To further prevent the servicing of motor vehicle A/C units by uncertified technicians, the EPA has mandated that since November 15, 1992, motor vehicle A/C refrigerants can only be sold to EPA Section 609 certified technicians. Furthermore, Section 609 certified technicians can purchase automotive refrigerant in any size container including containers with less than 20 pounds of refrigerant. EPA certified Section 608 technicians cannot purchase these smaller refrigerant containers.

This training manual was written to help educate the MVAC technician in all the requirements related to refrigeration conservation and EPA regulations, as well as recovery, recycling, and reclamation techniques. This manual was intended to serve as a reference manual, for future problems and as a training manual to help technicians successfully pass the enclosed EPA Section 609 MVAC certification examination. This training manual is limited to information and service practices needed to contain, conserve, and re-use refrigerants, thereby preventing their escape to the atmosphere. This manual is not intended to teach air conditioning system installation, troubleshooting, or repair. Experienced service technicians will notice that a lot of this information is not new on the topic of conservation and containment; most of the procedures for maintaining tight systems have been in use for years. However, these skills must now be applied more diligently than ever.

Some users of this manual will also be aware of available information that is not included here. The intent is to present a course concentrating on practical, basic information that is most needed and can be readily applied on the job with the most effective results.

This manual is in a continual state of evolution and revision, partly because of the changing EPA regulations and partly because of the information feedback from technicians in the field. If there are sections of this manual that require improvement, or there are missing areas that you believe to be important, please write us a short note and we will see that the improvements are incorporated into future editions. In the past, we have received very useful comments and suggestions from refrigeration technicians in the field, and to all those who have helped in the past we owe a sincere debt of gratitude. Suggestions on the improvement of this course or any Mainstream product will always be welcomed. To submit suggestions directly related to this course, please write to Robert P. Scaringe, Ph.D., P.E., 609 Refrigeration Certification Program, Mainstream Engineering Corporation, Pines Industrial Center, 200 Yellow Place, Rockledge, Florida 32955.

Definitions

Azeotrope	A blend of two or more components whose equilibrium vapor phase and liquid phase compositions are the same at a given pressure.
Barrier Hoses	A flexible rubber hose is not completely leak proof; refrigerant can actually “seep” through these hoses and into the atmosphere. There are new less permeable “barrier” hoses that reduce the amount of refrigerant that can seep through the hose and into the atmosphere. R-22 also referred to as HCFC-22 can seep through traditional hoses. Therefore, when using R-22 or any refrigerant blend containing R-22, the technician must ensure that the less permeable "barrier" hoses are used. When retrofitting to a refrigerant blend that includes R-22, these hoses must be installed if the system currently uses non-barrier hoses.
CFC-12	dichlorodifluoromethane, (R-12).
Class I Refrigerant	CFC refrigerants such as R-12.
Class II Refrigerant	HCFC refrigerants such as R-22.
Compound	A substance formed by a union of two or more elements in a definite proportion, by weight.
Disposal	The process leading to and including any of the following: (1) The discharge, deposit, dumping, or placing of any discarded appliance into or on any land or water. (2) The disassembly of any appliance for discharge, deposit, dumping, or placing of its discarded component parts into or on any land or water. (3) The disassembly of any appliance for reuse of its component parts.
Fractionation	The separation of a liquid mixture into separate parts by the preferential evaporation of the more volatile component.
Halocarbon	A halogenated hydrocarbon containing one or more of the three halogens: fluorine, chlorine, and bromine. Hydrogen may or may not be present. HCFC-22 chlorodifluoromethane, (R-22). HFC-134a 1,1,1,2,-tetrafluoroethane, (R-134a). HFO-1234yf: hydrofluoroolefin, (R-1234yf).
Hydrocarbon	A compound containing only the elements hydrogen and carbon. Hydrocarbon refrigerants are flammable.
Isomer	One of a group of substances having the same combination of elements, but these elements are arranged spatially in different ways.

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, minimizing the release of refrigerant from hoses, appliances, and recovery or recycling machines.
Mixture	A blend of two or more components that do not have a fixed proportion to one another and that no matter how well blended, still retain a separate existence (oil and water for example).
Motor Vehicle	Any vehicle which is self-propelled and designed for transporting persons or property on a street or highway, including but not limited to passenger cars, light duty vehicles, and heavy duty vehicles.
Motor Vehicle Air Conditioners (MVAC)	Is defined as mechanical vapor compression open-drive compressor air conditioning equipment used to cool the driver or passenger compartments 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 which use HCFC-22 refrigerant. Section 609 certification is required for working on MVAC systems while Section 608 certification is required for working on non-motor vehicle air conditioning systems. Note that 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 which use HCFC-22 refrigerant. MVAC-Like Appliance Mechanical vapor compression, open-drive compressor air conditioner used to cool the driver's or passenger's compartment of a non-road vehicle, including agricultural and construction vehicles. This definition excludes appliances using HCFC-22 refrigerant. 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, the latter being preferred though less commonly used descriptor.
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, repair, or disposal of an appliance that would release refrigerant from the appliance to the atmosphere unless the refrigerant was recovered previously from the appliance.
R-12	Another name for CFC-12.
R-22	Another name for HCFC-22.
R-134a	Another name for HFC-134a.
R-1234yf	Another name for HFO-1234yf.
Reclamation	To reprocess refrigerant to at least the purity specified in the Air-Conditioning Heating and Refrigeration Institute (AHRI) Standard 700-1988, 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 store it in a container without necessarily testing or processing it in any way.
Recovery Efficiency	The percentage of refrigerant in an appliance that is recovered by a piece of recycling or recovery equipment.
Recycling	To extract refrigerant from an appliance and 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. MVAC recycling machines must be certified to meet SAE standards for performance.
Refrigerant	Is any Class I or Class II substance used in a motor vehicle air conditioner and since November 15, 1995, refrigerant also includes any substitute substance." Note: Class I substances are CFCs such as R-12, and Class II substances are HCFCs such as R-22. Technically the refrigerant is the fluid used for heat transfer in a refrigerating system, which absorbs heat during evaporation at low temperature and pressure, and releases heat during condensation at a higher temperature and pressure.
Service for Consideration	Refers to the technician being paid to perform service, whether it is cash, credit, goods, or services. This includes all service except that done for free.
Service Involving Refrigerant	Refers to any service during which discharge or release of refrigerant from the motor vehicle's air conditioner to the atmosphere can reasonably be expected to occur.
Technician	Any person who performs maintenance, service, or repair that could reasonably be expected to release Class I (CFC) or Class II (HCFC) substances into the atmosphere, including but not limited to installers, contractor employees, in-house service personnel, and in some cases, owners.
Zeotropic	Blends comprising multiple components of different volatilities that, when used in refrigeration cycles, change volumetric composition and saturation temperatures as they evaporate (boil) or condense at constant pressure.

Units Conversions

The mass units typically encountered in the MVAC trade are the ounce (oz), pound (lb.), gram (gr) and kilogram (kg). There are 16 ounces (weight) in a pound, 457 grams in a pound and 0.457 kg in a pound. That is to convert ounces to pounds divide by 16, to convert grams to pounds divide by 457, and to convert kg to pounds divide by 0.457. Table 1 has some common conversions for your convenience.

Table 1. Units Conversion Table

Ounces (oz)	Pounds (lbs.)	Grams (gr)	Kilograms (kg)	Ounces (oz)	Pounds (lbs.)	Grams (gr)	Kilograms (kg)
1	0.063	28.6	0.0286	17	1.063	485.7	0.4857
2	0.125	57.1	0.0571	18	1.125	514.3	0.5143
3	0.188	85.7	0.0857	19	1.188	542.9	0.5429
4	0.250	114.3	0.1143	20	1.250	571.4	0.5714
5	0.313	142.9	0.1429	21	1.313	600.0	0.6000
6	0.375	171.4	0.1714	22	1.375	628.6	0.6286
7	0.438	200.0	0.2000	23	1.438	657.1	0.6571
8	0.500	228.6	0.2286	24	1.500	685.7	0.6857
9	0.563	257.1	0.2571	25	1.563	714.3	0.7143
10	0.625	285.7	0.2857	26	1.625	742.9	0.7429
11	0.688	314.3	0.3143	27	1.688	771.4	0.7714
12	0.750	342.9	0.3429	28	1.750	800.0	0.8000
13	0.813	371.4	0.3714	29	1.813	828.6	0.8286
14	0.875	400.0	0.4000	30	1.875	857.1	0.8571
15	0.938	428.6	0.4286	31	1.938	885.7	0.8857
16	1.000	457.1	0.4571	32	2.000	914.3	0.9143

Conversion Factors

Examples of the Conversion of Vacuum Units		
PSIA Reading	**Reading in Inches of Mercury [in. Hg]**	**Reading in Millimeters of Mercury Absolute [mm Hg Absolute]**
14.7 PSIA	0 "Hg	760 mm Hg Absolute
12.2 PSIA	5 "Hg	633 mm Hg Absolute
9.8 PSIA	10 "Hg	506 mm Hg Absolute
7.3 PSIA	15 "Hg	379 mm Hg Absolute
4.8 PSIA	20 "Hg	252 mm Hg Absolute
2.4 PSIA	25 "Hg	125 mm Hg Absolute
0.5 PSIA	28.9 "Hg	25 mm Hg Absolute
0.0 PSIA	29.9 "Hg	0 mm Hg Absolute

SECTION I:
Refrigerants, Past, Present, and Future

Introduction

In 1928, C. F. Kettering, a vice president of General Motors, decided that the refrigeration industry needed a new refrigerant if they ever expected to get anywhere. He asked Thomas Midgely to see if he could find one. Three days after getting the assignment, Midgely and his associates had synthesized dichlorodifluoromethane (CFC-12) and demonstrated that it was nonflammable and had unusually low toxicity. With this development, the fluorocarbon refrigerant industry was born, and rapid expansion of refrigeration and air conditioning was made possible.

The refrigerant industry has been changing and evolving since then. In the years of developing new refrigerants, concerns about global warming and the ozone began to emerge. As those issues have come to the forefront of the industry, newer and more environmentally friendly products have been introduced and approved by the Environmental Protection Agency (EPA), with the newest being R-1234yf, R-744 (carbon dioxide), and R-152a.

Molecular Structure and Terminology

Most refrigerants in current use are compounds containing carbon, fluorine, usually chlorine, and sometimes hydrogen, bromine, or iodine. When a refrigerant is referred to as a CFC, the refrigerant contains chlorine, fluorine, and carbon. When a refrigerant is referred to as a HCFC, the refrigerant contains hydrogen, chlorine, fluorine, and carbon. When a refrigerant is referred to as an HFC, the refrigerant contains hydrogen, fluorine, and carbon. HFO refrigerants also contain hydrogen, fluorine, and carbon atoms; however, the different configuration contributes to their reduced lifetime if released into the atmosphere.

CFCs

The refrigerants heard about the most are the chlorofluorocarbons (CFCs). As the name says, these refrigerants consist of chlorine, fluorine, and carbon, thus the abbreviation CFC. Because they contain no hydrogen, CFCs are chemically very stable, even when released into the atmosphere. Because they contain chlorine, CFCs are damaging to the stratospheric ozone layer high above the Earth's surface. The ozone layer is what shields us from excessive ultraviolet solar radiation. The combination of these two characteristics gives CFC refrigerants a high ozone-depletion potential, (ODP), and has made these refrigerants the target of legislation that will reduce their availability and use. Their manufacture was discontinued as of January 1, 1996! R-12 is a CFC and often referred to as CFC-12.

HCFCs

A second category of refrigerants currently available are the hydrochloro-fluorocarbons (HCFCs). Although they contain chlorine, which is damaging to the ozone layer, they also contain hydrogen, which makes them chemically less stable once they enter the atmosphere. These refrigerants, decompose when released in the lower atmosphere so very little ever reaches the ozone layer. The HCFCs therefore have a lower ozone-depletion potential, (ODP). HCFC-22, also known as R-22, has been in widespread use for many years in building and window air conditioning units.

HFCs

Hydrofluorocarbon (HFC) refrigerants, which contain no chlorine at all, have been developed. These refrigerants have an ozone-depletion potential of zero but probably still contribute to the global warming problem. HFC-134a (1,1,1,2-Tetrafluoroethane CF3CH2F) has replaced CFC-12 and HCF-22 in a large number of MVAC applications.

Replacement Refrigerants

Serious concerns involving depletion of the Earth's protective stratospheric ozone layer and the effects of CFC's on this depletion resulted in the phasing out of the production of all CFC refrigerants such as R-12 by January 1, 1996. Recent ozone depletion studies indicate that the current situation is far worse than originally thought.

Key considerations for any new refrigerant are chemical stability in the system, toxicity, flammability, thermal characteristics, efficiency, ease of detection when searching for leaks, environmental effects, compatibility with system materials, compatibility with lubricants, and cost. In general, HFC-134a has replaced CFC-12 in all automotive applications.

HFCs such as R-134a, do not lead to ozone depletion but do contribute to global warming due to the greenhouse effect, so refrigerant recovery and recycling are here to stay, regardless of the new refrigerants developed. Recycling also makes sense economically because of the cost of the new refrigerants and the taxes on the more traditional refrigerants. Since as early as 1992, automotive air conditioning has been using HFC-134a instead of CFC-12.

There are no “drop-in” substitute refrigerants for any equipment category. This means that some changes in a system's equipment or materials of construction are always necessary when converting to a replacement refrigerant. The existing refrigerant cannot simply be removed from a system and replaced with another refrigerant. Usually the changes amount to replacement of incompatible seals and changes in lubricant. Filter-driers, compressors, and seals that are compatible with CFCs, HCFCs, HFCs and their oils are currently being developed; however, the replacements are not without problems. **The new (POE), synthetic oils being used with HFC refrigerants are incompatible with as little as 1% residual oil, (PAG or traditional mineral), in the system.**

***NOTE*:** HFC-134a still carries some concern about compatible lubricants. Lubricants typically used with CFC-12 do not mix with HFC-134a. Polyalkylene glycols (PAGs) mix properly with 134a at low temperatures but have upper-temperature problems, as well as incompatibility with aluminum bearings and polyester hermetic motor insulation. **Ester-based synthetic, (POE), lubricants for HFC-134a resolve these problems but are incompatible with existing PAG or mineral oils.**

The thermodynamic properties of HFC-134a are similar to CFC-12, and with proper equipment redesign, efficiencies will be similar. In automotive applications, capacity suffers only minor reductions.

The EPA has recently listed HFO-1234yf, carbon dioxide, and HFC 152a as alternative refrigerants, given the appropriate conditions. These alternatives do not deplete the ozone layer nor do they impact our climate as strongly as CFC-12 or HFC-134a.

HFO-1234yf has a GWP of 4 and is mildly flammable but can be used safely. It can be used only in new passenger cars and light-duty trucks and is subject to use conditions. MVAC systems using HFO-1234yf must adhere to all the safety requirements of SAE J639, including requirements for a flammable refrigerant warning label, high-pressure compressor cutoff switch and pressure relief devices, and unique fittings. For connections with refrigerant containers for use in professional servicing, use fittings must be consistent with SAE J2844.

Carbon dioxide (CO_2) has a GWP of 1 and is acceptable, subject to use conditions, for new vehicles only. It operates at five to ten times higher pressure than other MVAC systems. CO_2 can be released into the environment, but it requires the use of certified refrigerant handling equipment, as serious injury and asphyxiation can occur with rapid expansion when it is released. Mitigation devices have to be available for use in the event that a refrigerant leak results in CO_2 concentrations that exceed the STEL of 30,000 ppm averaged over 15 minutes in the passenger-free space and the ceiling limit of 40,000 ppm in the passenger breathing zone. CO_2 use must adhere to the standard conditions identified in SAE J639.

HFC-152a has a GWP of 124 and is acceptable, subject to use conditions, for new vehicles only. It is moderately flammable and may be pursued more vigorously in the future. Mitigation devices have to be available for use in the event that a refrigerant leak results in R-152a concentrations that exceed the 3.7% v/v or above in any part of the passenger-free space for more than 15 seconds when the car is running. R-152a use must adhere to the standard conditions identified in SAE J639, including unique fittings and a flammable refrigerant warning label as well as SAE Standard J2773, “Refrigerant Guidelines for Safety and Risk Analysis for Use in Mobile Air Conditioning Systems.”

Disposable Refrigerant Cylinders

Size and Color Codes

Refrigerants are usually packaged in disposable containers for use by air conditioning and refrigeration service personnel. Disposables are manufactured in sizes from 1 to 50 pound capacities and should never be refilled. Refrigerant manufacturers and packagers voluntarily color code cylinders for their refrigeration products. The color code for R-12 is white and R-134a is light blue.

Regulations

Disposable cylinders are manufactured to specifications established by the U.S. Department of Transportation (D.O.T). The DOT has regulatory authority over all hazardous materials in commercial transportation. Disposable cylinders manufactured for CFCs are designed to meet or exceed DOT Specification 39.

Transportation of refilled DOT 39 cylinders is illegal and subject to a penalty of up to $25,000 fine and five years of imprisonment. The use of a refilled DOT 39 cylinder also violates OSHA workplace regulations and may also violate state laws.

Safety

Every cylinder is equipped with a safety-relief device that will vent pressure from the cylinder before it reaches the rupture point. Cylinders can become over-pressurized for several reasons; however, the primary cause is overheating. When temperatures increase, the liquid refrigerant expands into the vapor space above the liquid causing the pressure to rise gradually as long as a vapor space is available for expansion. However, if no vapor space is available due to an overfilled cylinder (and no pressure-relief valve is available), the liquid will continue to expand with no room for the expanding liquid and will result in the cylinder rupturing. When the cylinder ruptures, the pressure drop causes the liquid refrigerant to flash into vapor and sustains the explosive behavior of the rupture until all the liquid is vaporized. The rupture of a refrigerant cylinder containing liquid refrigerant that flashes into vapor is far worse than the rupture of a compressed-air cylinder of the same pressure.

Hazards of Reuse

Disposable cylinders are manufactured from steel. Rust can eventually weaken the cylinder to the point where the wall can no longer contain the compressed refrigerant. Cylinders must be stored and transported in dry environments. Cylinders exhibiting extreme rust should be emptied of contents and properly discarded.

Disposal

Empty disposable cylinders should be emptied (recover refrigerant until pressure has been reduced to a vacuum). The container's valve can be closed at this time and the container marked empty. The container is ready for disposal. We recommend (however it is not required by the EPA of Section 609 technicians), that the cylinder valve should then be opened to allow air to enter, and the cylinder should be rendered useless (with the valve still open) by breaking off the valve or puncturing the container. This will avoid misuse of the container by untrained individuals. Used cylinders can be recycled with other scrap metal. Never leave used cylinders with residual refrigerant outdoors where the cylinder can rust. The internal pressure of a cylinder with one ounce of liquid refrigerant is exactly the same as a full cylinder. An abandoned cylinder will eventually deteriorate and potentially explode.

Refillable Cylinders

Refillable cylinders also referred to as recovery cylinders or recovery tanks, are now available for the transportation of refrigerants used in the air conditioning and refrigeration industry. These refillable cylinders are used for the same refrigerants as are the disposable cylinders. In addition to the disposable and returnable cylinders, refillables also are regulated in their design, fabrication, and testing by DOT for use in the transportation of refrigerants.

Recovery cylinders are painted yellow in the shoulder area and 12 inches down the side. The remainder of the cylinder body is painted gray by the manufacturer. However, we recommend that a color-strip, be painted on the tank, in accordance with the color-coding convention for new refrigerant cylinders, (White for R-12; Light Blue for R-134a), to indicate the type of recovered refrigerant being stored in the tank and to minimize the potential for accidental refrigerant mixing. For refrigeration technicians using recycling machines, we further suggest that the refrigeration technician utilize a "CLEAN" recovery tank for recycled refrigerant and a "DIRTY" recovery tank for recovered, but not recycled refrigerant. Marking the recovery tanks as clean and dirty will avoid contamination of otherwise clean refrigerant by putting clean refrigerant into a recovery tank that once held dirty refrigerant. With the rising cost of refrigerant, the value of the refrigerant stored in a 50-lb. recovery tank is worth five times the cost of a recovery tank. Separating clean and dirty refrigerant will save you money very quickly.

Overfilling

Each cylinder contains a "warning decal" to caution the user against physical contact or exposure to the refrigerant and against using a refrigerant in the cylinder that has a vapor pressure in excess of 318 psig at a temperature of 130°F.

Cylinder Re-testing

The use of the various refrigerants, in cylinders that are exposed to the environment, is reason for concern, as previously discussed. Although the interior of these cylinders must be void of moisture, the exterior cannot avoid it. Thus, corrosion can and does occur, as well as damage due to mishandling. These are but a few of the reasons why the cylinders must be re-tested at five-year intervals.

The valves should be periodically examined, especially the relief valve. Check to be sure that nothing is obstructing the relief valve and that no visual deterioration or damage has occurred. If any damage is visible, empty the cylinder and have the tank repaired. Never use a cylinder with a faulty pressure-relief valve or with obvious structural impairments. SAE Standard J2296 “*Retest of Refrigerant Container*” provides the procedure to inspect a refrigerant cylinder used for refrigerant recovery/recycling and charging equipment when servicing mobile air-conditioning (AC) systems.

Refrigerant Safety

General Safety Considerations

Careful attention should be given to the following general safety considerations concerning fluorocarbon refrigerants. Before using or handling any refrigerant, personnel should be familiar with safety concerns for the specific product. This is particularly important for some of the new replacement refrigerants for which testing is not yet complete, or long-term health effects are not yet known! Specific product safety information is always available from the manufacturer.

Health Hazards

Skin or eye contact with fluorocarbon refrigerants can result in irritation and frostbite. Although the toxicity of traditional fluorocarbon refrigerants is low, (due to their chemical stability), the possibility of injury or death exists in unusual situations or if they are deliberately misused. The vapors are several times heavier than air. Good ventilation must be provided in areas where high concentrations of the heavy vapors might accumulate and exclude oxygen. Inhalation of concentrated refrigerant vapor is dangerous and can be fatal. Exposure to levels of fluorocarbons above the recommended exposure levels can result in loss of concentration and drowsiness. Cases of fatal cardiac arrhythmia have been reported in humans accidentally exposed to high levels. The exposure levels for some of the new replacement refrigerants are lower than for those with which you may be familiar.

First Aid

If inhaled, the victim should be moved to an area with fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Avoid stimulants. Do not give adrenaline (epinephrine) because this can complicate possible effects on the heart. Call a physician. In the case of eye contact, flush eyes promptly with plenty of water for at least 15 minutes. Call a physician. Flush exposed skin with warm water (not hot) or use other means to warm the skin slowly.

Other Hazards

Most halogenated compounds will decompose at high temperatures such as those associated with gas flames or electric heaters. The chemicals that result under these circumstances always include hydrofluoric acid. If the compound contains chlorine, hydrochloric acid will also be formed, and if a source of water, (or oxygen), is present, a smaller amount of phosgene will be formed. Fortunately, the halogen acids have a very sharp, stinging effect on the nose and can be detected by odor at concentrations below their toxic level. These acids serve as warning agents that decomposition has occurred. If they are detected, the area should be evacuated until the air has been cleared of decomposition products. Some other replacement refrigerants have lower exposure limits, so read the manufacturer's warnings carefully and take the precautions seriously.

Precautions

- Always read the product label and the product safety data sheet (MSDS).
- Always use with adequate ventilation.
- Never expose these products to flames, sparks, or hot surfaces.
- When handling refrigerants, wear side-shield safety glasses, impervious gloves, and other protective equipment or clothing as required by the employer or situation. Make sure that showers and eye wash fountains of the deluge type are readily accessible in case of contact with the skin or eyes.

- In readily accessible areas, store auxiliary breathing apparatus in case an abnormally high concentration of refrigerant vapor should develop in the storage, handling, or production areas.
- As with any chemical, if a spill occurs, clear the area immediately, and return wearing an approved respirator.
- Physicians: Do not use epinephrine to treat overexposure.
- Review SAE J2845 Technician Training for Safe Service and Containment of Refrigerants used in Mobile AC systems.
- Review SAE J2211 Recommended Service Practices for the Containment of HFC134a.

Safety for Refrigerant Cylinders

- Keep the outlet cap on the valve outlet, and keep the valve hood securely screwed onto the neck of the returnable cylinder at all times, except when discharging refrigerant.
- Keep the returnable cylinder secured in an upright position.
- Never drop the cylinder or hit it with a hammer or any other object.
- Never apply live steam or direct flame to the cylinder.
- Never lift a cylinder by the valve cover or valve.
- Never remove the valve from a cylinder or attempt to repair it.
- Do not tamper with the safety device.
- Never refill disposable cylinders.
- Do not remove or attempt to alter any permanent cylinder markings. (It is illegal!)
- Take care not to dent, cut, or scratch the cylinder or valve.
- Protect the cylinders from moisture, salt, or corrosive chemicals.
- Always open the valve slowly and close after each use.
- Do not attempt to use a cylinder that is in a rusted or otherwise deteriorated condition--contact appropriate personnel for disposal.
- Never leave an empty refillable or returnable cylinder open to the atmosphere because moisture might get inside and result in rapid internal rusting.

Review Topics

- Chlorofluorocarbon (CFC) refrigerants are so named because they contain the elements Chlorine, Fluorine, and Carbon.

- CFCs have the highest ozone depletion potential (ODP) and are the most harmful to stratospheric ozone.

- Hydrofluorocarbon (HFC) refrigerants contain Hydrogen, Fluorine, and Carbon. R-134a, also known as HFC-134a, is a chlorine-free refrigerant.

- HFC fluorocarbon refrigerants cause no harm to stratospheric ozone; they have a zero ODP.

- HFO-1234yf refrigerant is mildly flammable but does not deplete the ozone. It has a significantly lower impact on the climate system, with a GWP of only 4.

- Ester-based synthetic oils cannot be mixed with other oils.

- Whenever a technician is working with any unknown solvents, chemicals, or refrigerants, the technician should always review the material safety data sheets, which by law should be shipped by the manufacturer with these compounds.

- Refrigerant vapors or mist in high concentrations should not be inhaled because they have been demonstrated to cause heart irregularities or unconsciousness in some people. Note the warnings on the packaging. Refrigerants are also heavier than air and can displace the air in a room, leaving no breathing air in the room (leading to asphyxia). In most refrigerant accidents where death occurs, the major cause is oxygen deprivation.

- The **MOST IMPORTANT** reason why one should NEVER heat a refrigerant storage or recovery tank with an open flame is that the tank may explode, seriously injuring people in the vicinity.

- A refillable refrigerant cylinder must not be filled above 80% of its full capacity.

- At high temperatures (i.e., open flames, glowing metal surfaces, etc.), CFC-12, as well as HCFCs and HFCs, can decompose to form hydrochloric and hydrofluoric acids.

- 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, then the area should be vacated and ventilated.

- Every refrigerant cylinder is protected by some type of pressure relief device.

SECTION II: Stratospheric Ozone Depletion

Stratospheric Ozone

Ozone is a gas, slightly bluish in color, with a pungent odor. It consists of three atoms of oxygen in each molecule; the oxygen we breathe contains two atoms in each molecule. **Chemically, oxygen is O_2, and ozone is O_3.** The "ozone layer" consists of ozone in the stratosphere, high above the Earth at an altitude of between 7 and 28 miles. It is formed by ultraviolet light (UV) from the sun acting on oxygen molecules. The ozone layer absorbs and scatters ultraviolet light from the sun, preventing harmful amounts of ultraviolet light from reaching the Earth. For this reason, it is often referred to as the ozone or protective shield.

Atmospheric Ozone

Ozone is also found at times in the lower atmosphere where we breathe it. Here it is caused by ultraviolet radiation from the sun acting on smog and air pollutants on hot summer days. This situation should not be confused with the protective ozone layer in the stratosphere. Ozone at ground level is a harmful pollutant; in the stratosphere it is a protective shield.

Depletion of Stratospheric Ozone

In June 1974, Professor Sherwood Rowland and Dr. Mario Molina of the Department of Chemistry at the University of California at Irvine first proposed the theory that certain chlorine-containing compounds could pose a threat to the stratospheric ozone layer above the Earth. The Rowland-Molina theory states that CFCs would ultimately cause damage to the stratospheric ozone layer, which protects the Earth from harmful levels of ultraviolet radiation from the sun. What follows is a summary of the current theory held by the EPA.

Refrigerants that contain chlorine but not hydrogen are so stable that they do not break down in the lower atmosphere even one hundred years or more after being released. These chemicals gradually float up to the stratosphere, where the chlorine or bromine react with ozone, causing it to change back to oxygen.

The "Ozone Hole" is a thinning in the stratospheric ozone layer over Antarctica, which occurs during the Antarctic spring season (autumn in the Northern Hemisphere). It occurs over the Antarctic continent due to the unique climate in that part of the world. Powerful winds encircle Antarctica during its winter, isolating the continent from warmer winds that would otherwise migrate from lower latitudes on the Earth's surface. The continent is in darkness during the winter. These two effects combine to produce the coldest temperatures on Earth; colder than the Arctic. The stratosphere is normally too dry to form clouds, except at the bitterly cold temperatures reached during the Antarctic winter. At these frigid temperatures, clouds of ice and nitric acid, called polar stratospheric clouds (PSCs), form in the stratosphere over the continent of Antarctica. Chemical reactions take place on the surfaces of these clouds, converting chlorine and bromine from forms that do not react with ozone to other, less stable forms that readily break up in the presence of sunlight and go on to destroy ozone. Both cold temperatures and sunlight are critical to the stratospheric ozone depletion process. So it is in the spring, when the sun again rises and when the PSCs are still present, that the Antarctic ozone hole is found. As the sun warms the region in spring, the clouds dissipate.

This area is being carefully monitored for the degree to which the stratospheric ozone thins out because it has been found to lead to stratospheric ozone depletion in other parts of the world as well. Significantly reduced stratospheric ozone levels were detected in 1985, and high chlorine levels were found in 1986. Since that time, aircraft and ground-based instruments have indicated that the ozone depletion problem may be more serious than initially thought.

When stratospheric ozone depletion occurs, more UV radiation penetrates to the Earth's surface. Moreover, because of the long atmospheric lifetimes of CFCs, it will take many decades for the ozone layer to return to past concentrations. As stated earlier, bromine-containing compounds, which are contained in typical Halon fire extinguishers, react the same way as chloride atoms in destroying the ozone. In the years since the theory was first proposed, substantial scientific research has supported the general concern that increased concentration in the stratosphere of chlorine and bromine pose substantial risks of ozone depletion resulting in harm to human health and the environment.

The CFC refrigerants and the halons have been assigned a factor that represents their relative ability to destroy stratospheric ozone. Called the Ozone Depletion Factor, or **Ozone Depletion Potential (ODP)**, this scale is based on CFC-11 having been assigned a factor of 1. CFC-12 has an ODP of 1.0, HCFC-22 has an ODP of 0.05, and HFC-134a has an ODP of 0.0.

Health and Environmental Effects

Shielding the Earth from much of the damaging part of the sun's radiation, the stratospheric ozone layer is a critical resource safeguarding life on this planet. Should the ozone layer be depleted, more of the sun's damaging rays would penetrate to the Earth's surface. Some scientists have claimed that each 1% depletion of ozone increases exposure to damaging ultraviolet radiation by 1.5%–2%. EPA's assessment of the risks from ozone depletion focus on the following areas:

- Increase in skin cancers
- Suppression of the human immune response system
- Increase in cataracts
- Damage to agriculture and wildlife
- Damage to aquatic organisms
- Increases in ground-level ozone
- Increased global warming (See **https://www.epa.gov/ozone-layer-protection)**

Unlike many other environmental issues, stratospheric ozone protection is a global problem. CFCs and halons are used in many nations, and because of their long atmospheric lifetimes, they become widely dispersed over time. As a result, the release of these chemicals in one country could adversely affect the stratosphere above other countries and therefore the health and welfare of their citizens. Many developed and some developing countries produce CFCs and halons. Most consume the chemicals in a variety of different products. The United States, for example, consumed 29% of the world's CFCs. Other developing nations were significant users. To protect the ozone layer from the damage that may be caused by CFCs and halons, an international solution was critical.

Global Warming Potential

Hydrofluorocarbon (HFC) refrigerants such as HFC-134a, contain no chlorine and therefore have a zero ozone-depletion potential (ODP), however they can still contribute to the global warming problem caused by greenhouse gas emissions. The potential of a gas contributing to global warming is expressed in a relative scale, known as the Global Warming Potential or GWP. The GWP is reported relative to carbon dioxide; therefore, a refrigerant with a GWP of 1,000 has 1,000 times greater potential to contribute to global warming than carbon dioxide. Table 2 lists the GWP and ODP of several common refrigerants. Europe is currently taking steps to meet the Kyoto Protocol, which calls for quantitative reduction of greenhouse gases (including HFCs) for the period 2008–2012. Therefore, Europe will be restricting the use of any refrigerant with a Global Warming Potential (GWP) in excess of 150. The European Union has adopted regulations that ban the use of R-134a in all new vehicles by 2017. In the U.S., the Status Change Rule was finalized in July 2015. It states that HFC-134a will no longer be allowed in vehicles as of the model year 2021.

Table 2. Environmental Impact of Several Common Refrigerants

Refrigerant	GWP	Ozone Depletion Potential	Atmospheric Lifetime (Years)
CFC-12	10,900	1	100
HFC-134a	1,430	0	14
HFC-152a	124	0	1.4
HFO-1234yf	4	0	0.030
Carbon Dioxide (R-744)	1	0	100

R-134a

HFC-134a (R-134a) is the refrigerant that replaced R-12 in automotive air conditioning systems. The automobile industry has accepted R-134a because of its low hose permeability, along with satisfactory efficiencies. R-134a is a polar molecule, which contributes to its low solubility in non-polar lubricants such as mineral oils and therefore new lubricants had to be developed. R-134a is not corrosive on standard steel, aluminum, and copper samples. R-134a is regarded as one of the safest refrigerants yet introduced, based on current toxicity data. The chemical industry's Program for Alternative Fluorocarbon Toxicity Testing (PAFT) tested R-134a in a full battery of laboratory animal toxicity studies. The results indicate that R-134a does not pose a cancer or birth defects hazard.

OEM engineers and chemical manufacturers have examined the flammability and corrosiveness of each potential R-12 substitute. Like CFC-12, R-134a is not flammable at ambient temperatures and atmospheric pressures. However (as with all refrigerants), service equipment and vehicle AC systems should never be pressure tested or leak tested with compressed air. Such poor service practices introduce moisture and incompatible (air compressor) mineral oils into the system, but even more important is that some mixtures of air and R-134a have been shown to be combustible at elevated pressures. These mixtures could be potentially dangerous, causing injury or property damage.

Potential New Refrigerants

To address the global warming issues, researchers are looking at several potential refrigerant changes. These refrigerants would not be drop-in replacements for R-12 or R-134a (there are no drop-in replacements for these refrigerants) but instead would require completely new system designs. Because propane (R-290), n-butane (R-600), isobutene (R-600a), and propane/butane blends have a low GWP, they were at one time, considered as potential refrigerants; however, their flammability levels were unacceptable under the SNAP guidelines and are now illegal for use for use in MVAC systems in the United States. Some of the refrigerants that are being considered because of their low GWP (and zero ODP) are hydrofluoroolefin (HFO)-1234yf, carbon dioxide (R-744), and R-152a (difluoroethane).

HFO-1234yf has a GWP of 4, carbon dioxide has a GWP of 1, and R-152a has a GWP of 140. While HFO-1234yf and R-152a are flammable refrigerants, they are Significant New Alternatives Policy (SNAP) approved. Automobile manufacturers are currently considering HFO-1234yf, carbon dioxide, R-152a.

HFO-1234yf stands for a specific compound: 1—double bond, 2—hydrogens, 3—carbons, 4—fluorines, and yf—position of the fluorine atoms. HFO-1234yf is considered "*mildly flammable*" and has thermodynamic properties similar to R-134a. R-1234yf standards require service equipment and evaporators with safety features that cover this concern. In addition, new SAE J2843-compliant Recovery/Recycle/Recharge machines must feature integrated refrigerant identifiers or a USB port for connection with a hand-held identifier. Current identifiers cannot identify R-1234yf refrigerant. Vehicles equipped with R-1234yf and carbon dioxide refrigerant systems have unique low- and high-side service fittings, internal heat exchangers, and SAE standard J2842-compliant evaporator cores. The J2842 standard states that an evaporator from an AC system shall not be repaired or removed with the intention of using it again in the same or a different vehicle; that is, leaking evaporators must be replaced with a new evaporator. If an electronic leak detector is to be used with R-1234yf, it must be a SAE J2913-certified electronic leak detector; certain leak-detection devices could be an ignition source with even mildly flammable refrigerants. The HFO-1234yf refrigerant cylinder color is white with a red stripe per SAE J639; SAE J2844 list other container requirements that are specific to R-1234yf.

R-152a is 1,1-Difluoroethane, also called simply difluoroethane. R-152a is a chemical compound composed of carbon, hydrogen, and fluorine. Its molecular formula is $C_2H_4F_2$ and it is a flammable liquid and gas under pressure. Thermal decomposition yields toxic products which can be corrosive in the presence of moisture. There are no known toxicological effects and no known ecological damage caused by R-152a. At standard temperature and pressure, it is a colorless gas. It is classified as a halogenated aliphatic. In use as a refrigerant, it has a low global warming potential and has recently been approved for use in automobile applications as an alternative to R-134a. It is also commonly found in electronic cleaning products, and many consumer aerosol products that must meet stringent volatile organic compound (VOC) requirements. New HFC-152a MVAC systems are acceptable under the condition that MVAC systems must be designed to avoid concentrations in the passenger cabin that are above 3.7% for more than 15 seconds. Vehicles equipped with an R-152a refrigerant system have unique low- and high-side service fittings and a directed relief system. However, according to SAE J639, until mobile air-conditioning systems are developed to use R-152a, no SAE standards for system design, service equipment, or service procedures have been established. The R-152a service fitting standards were established as part of the industry's evaluation of replacement refrigerants and are maintained for future design guidance and to prevent potential refrigerant cross-contamination.

Carbon dioxide (R-744) is also a possible refrigerant, however the much higher pressures would preclude the use of flexible hoses, and the refrigerant would be operating above the critical point at the heat rejection temperatures. This translates into a much lower efficiency cycle. It is extremely unlikely that a shaft-driven traditional MVAC system would be developed if CO_2 were utilized as a refrigerant. It appears that R-152a is much more likely. However, if a CO_2 MVAC system were developed, the CO_2 system would be acceptable to the EPA under the condition that MVAC system was designed to avoid concentrations in the passenger cabin that are above 3% for more than 15 minutes. Systems using a CO_2 refrigerant system have unique low- and high-side service fittings. As with systems using R-1234yf, a leaking evaporator must be replaced with a new evaporator. The CO_2 refrigerant cylinder color is gray per SAE 2845.

Propane and butane is used in Europe for air conditioning applications. However, propane, isobutene, and all other flammable refrigerants, except HFO-1234yf and HFC-152a, have been found unacceptable under the SNAP program and are illegal to use in the U.S.

New systems can be designed to safely operate with flammable refrigerants, as evidenced by the use of HFO-1234yf, which is used currently in many cars. Demonstrating that a flammable refrigerant can be used safely in current systems, whether existing or new, requires a comprehensive, detailed, scientifically valid risk assessment. EPA has required a risk assessment for flammable refrigerants since the inception of the SNAP program in 1994. An assessment must address potential leak scenarios such as collisions, servicing errors, and disposal procedures. In addition, the assessment must consider ignition sources ranging from cigarette lighters or matches to sparks caused during a collision.

The Society of Automotive Engineers (SAE) has developed standards for recovery and recovery/recycling machines that are to be used with flammable refrigerants. The standards are J2843 "R-1234yf Recovery/Recycling/Recharging Equipment for Flammable Refrigerants for Mobile Air-Conditioning Systems," which is specific to HFO-1234yf. It requires that the equipment used to recover refrigerants and provide for accurate recharging of mobile air-conditioning systems is certified to meet all SAE performance requirements as well as international/regional construction and safety requirements. The pressurized leak check must be conducted with the HVAC blower on *low*, and the SAE J2913-compliant leak detector is set to high sensitivity (4 grams per year leak rate). The machines addressed in J2843 will not work with any other flammable refrigerant. J2851"Recovery Equipment for Contaminated Refrigerant from Mobile Automotive Air Conditioning Systems" provides minimum performance and operating requirements for equipment used to recover contaminated refrigerant or to recover refrigerant at facilities that do not service MAC systems. Any refrigerant recovered with this equipment must be returned to an EPA-approved refrigerant reclamation facility that will process or dispose of it properly. Refrigerant recovered with the equipment detailed in this standard cannot be recycled. SAE standard J3030, “Automotive Refrigerant Recovery/Recycling/ Recharging Equipment Intended for use with both R-1234yf and R-134a” establishes the minimum equipment requirements for equipment that uses both R1234-yf and R-134a in a common refrigerant circuit that has been directly removed from, and is intended for reuse in, mobile air-conditioning systems. This does not apply to equipment that has a common enclosure with separate circuits for each refrigerant, although some amount of separate circuitry for each refrigerant could be used. The equipment covered by J3030 enables smoother, more economical service during the transition period between R-134a and R-1234yf.

The pressure temperature saturation curves for potential new and existing refrigerants are presented in Figure 1. Table 3 contains the pressure temperature behavior of R-152, Table **4** contains the pressure temperature behavior for carbon dioxide, and Table 5 contains the pressure-temperature behavior of HFO-1234yf. The pressure-temperature behavior of HFO-1234yf is similar to R-134a, but this refrigerant is very different and “slightly flammable.” Clearly, HFO-1234yf will not be a drop-in replacement for R-134a. Even though the pressure of carbon dioxide is greater than 1000 psig at temperatures just slightly above 80° F, these systems are being pursued by several original equipment manufacturers (OEMs).

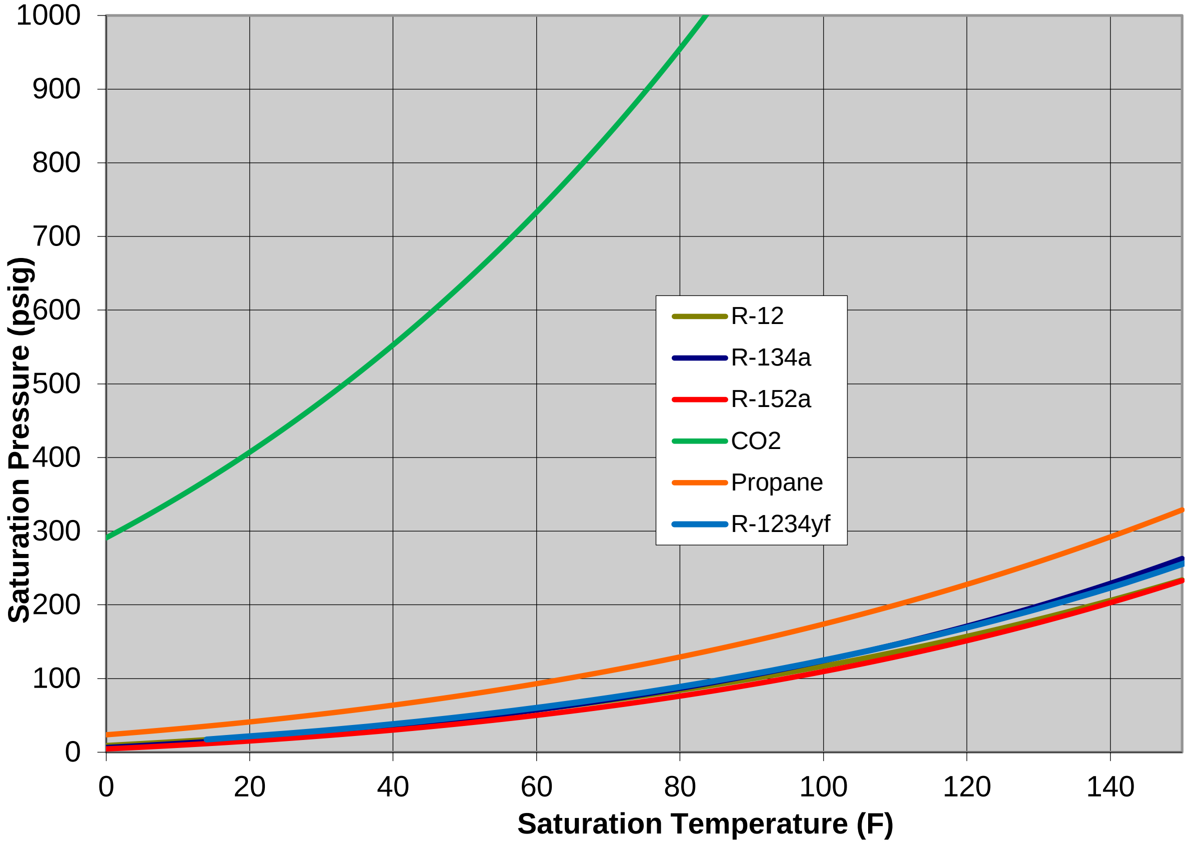

Figure 1. Saturation temperature pressure relationship for some possible refrigerants

Table 3. Saturation Pressure Temperature

Temperature (°F)	Pressure (psig)	Temperature (°F)	Pressure (psig)
20	15	80	76
25	19	85	84
30	22	90	92
35	26	95	100
40	30	100	110
45	35	105	119
50	39	110	129
55	44	115	140
60	50	120	151
65	56	125	163

70	62		130	175
75	69			

Table 4. Saturation Pressure Temperature Table for Carbon Dioxide (R-744)

Temperature (°F)	Pressure (psig)
20	407
25	441
30	476
35	513
40	553
45	594
50	638
55	684
60	733
65	784
70	838
75	895
80	955
85	1018
87.8 Critical Point Temp	

Table 5. Saturation Pressure Temperature Table for HFO-1234yf

Temperature (°F)	Pressure (psig)
14	17
32	31
50	48
68	71
86	99
104	133
122	174
140	223
158	282
176	350
194	431

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2. SAE Report # CRP1234-4, SAE International, **http://www.sae.org/standardsdev/tsb/cooperative/crp_1234-4_report.pdf**
3. Thundiyil, K. "US EPA MAC Regulatory Landscape," Alternative Refrigerant System Symposium, Phoenix, AZ, 2007. **http://www.sae.org/events/aars/presentations/2007thundiyil.pdf**
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11. Devotta, S., et al., "Comparative Life Cycle Testing of Hermetic Compressors with CFC-12 and HC-Blend," *Proceedings of the International Conference on Ozone Protection Technologies,* 194-202, 1997.
12. Granryd, E., "Hydrocarbons as refrigerants - an overview," International Journal of Refrigeration Vol. 24, pp. 15-24, 2001.
13. Maclaine-Cross, I.L., and Leonardi, E., "Comparative Performance of Hydrocarbon Refrigerants," I.I.F. - I.I.R. - Commissions E2, E1, B1, B2, Melbourne, Australia, February 1996.

14. Parmar, A. S., "Performance of Hydrocarbon Refrigerants in Motor Car Air-Conditioning," B.E. thesis, School of Mechanical and Manufacturing Engineering, The University of New South Wales, Sydney, 1995.

Review Topics

- Ozone in the stratosphere above the Earth consists of molecules containing 3 oxygen atoms (O_3).

- It is the chlorine and bromine in refrigerants that cause stratospheric ozone depletion.

- CFCs are chemically very stable, and they do not dissolve or break-down in water (so they are not removed by rain). Because of this chemical stability, they are able to reach the stratosphere.

- CFCs have the highest ozone depletion potential (ODP) and are the most harmful to stratospheric ozone.

- HFC-134a does not deplete the ozone, but it is a potent greenhouse gas.

- The ozone layer protects the Earth from ultraviolet radiation from the sun. Skin cancer, increased cataracts, and damage to crops are just some of the results of damage to the Earth's ozone layer.

- Capturing and ultimately eliminating the use of chlorofluorocarbons is being done in the United States to stop damage to the stratospheric ozone layer.

- When addressing consumer complaints regarding additional service expense due to recovery efforts, the technician needs to explain to the customer that recovery is necessary to protect human health and the environment and that is required by federal law.

- With some older equipment, turn off the recovery device after reaching the required recovery vacuum on a system (isolate the system), and wait for a few minutes to see if the system pressure rises, indicating that there is either refrigerant in liquid form, refrigerant trapped in the oil, or a leak in the system. With some newer equipment, these processes are programmed into the machine, and the appropriate action is performed or the operator is notified of any issues. The technicians may also be given the option of performing manual tests.

- Non-condensables in a refrigeration system result in a higher discharge pressure.

SECTION III: Regulations

Introduction

There is some confusion in the refrigeration industry as to what the current regulations are. This chapter will attempt to provide the background for the regulations and then specifically summarize the regulations.

The confusion arises because there are Montreal Protocol Regulations, which are not U.S. laws, but rather an agreement between nations to follow some rules. Each nation that agrees with the Montreal Protocol (signatory nations), must then pass its own laws to enforce the protocol ideals. The U.S. laws that apply to the refrigeration technicians in the United States are part of the U.S. Clean Air Act and subsequent revisions to the Clean Air Act. Then there are EPA proposed rulings, which are proposed rules by the EPA to enforce the Clean Air Act. However, the EPA first proposes these rules, and then after public comment refines these rules. Some people have incorrectly assumed that the proposed rulings were the law; they were not. Many of the proposed rules have been modified after public input, including input by equipment manufacturers and technical groups. The actual laws that must be followed concerning stratospheric ozone protection, (including venting, recovery, recycling, equipment certification, technician certification, disposal, record keeping, and enforcement), have finally been completed and are discussed in the Code of Federal Regulations Sections Title 40 Parts 82.30 to 82.42 and are commonly referred to as the Clean Air Act Section 609 Requirements for Motor Vehicle A/C (MVAC) systems and technicians. For convenience the key requirements have been summarized in the subsection on Clean Air Act Section 609 Requirements in this Section.

Early Controls on CFCs

During the early 1970s, CFCs that were used as aerosol propellants constituted over 50% of total CFC consumption in the United States. Following concerns initially raised by the Rowland-Molina theory in 1974, the EPA and the Food and Drug Administration in 1978 banned the use of CFCs as aerosol (spray can) propellants in all but a few essential (mostly medical) applications. Two new factors brought CFCs back into public concern in 1986. One was the connection between CFCs and the theory of global warming, or greenhouse effect. The other was new scientific evidence that CFCs deplete stratospheric ozone and that a "hole" had developed in the ozone layer over Antarctica.

The Montreal Protocol

Recognizing the global nature of the problem, on September 16, 1987, in Montreal, Canada, 24 nations and the European Economic Community (EEC) signed the Montreal Protocol on Substances that Deplete the Ozone Layer. Most of the major CFC and Halon producing and consuming nations signed the agreement. On August 1, 1988, the U.S. EPA enacted the provisions of this agreement into regulations for the United States.

Clean Air Act Section 609 Requirements

Introduction

The Clean Air Act (CAA) of 1990 directs EPA to establish requirements to prevent the release of ozone-depleting substances. The sections dealing with preventing the release of ozone-depleting substances are Sections 608 and 609. Other sections of Title VI of the CAA address other aspect of ODS, such as the phase-out. These CAA regulations and subsequent revisions are codified in the Code of Federal Regulations, specifically 40 CFR 80 Subpart B.

- Prohibitions and required practices are located in 40 CFR 82.34.
- Approved refrigerant handling equipment is discussed in 40 CFR 82.36.
- Certification, recordkeeping, and public notification requirements are located in 40 CFR82.42.
- Standards for the service and repair of MVAC and MVAC-like appliances is covered in 40 CFR, Subpart B, Appendices A–F.
- An overview of the Section 608 certification program is located in 40 CFR 82.161.

Section 608 deals with the building and stationery air-conditioners and requires technicians to be certified in Type I, II and III or Universal. Over-the-road refrigeration units and R-22 (HCFC) air conditioning, such as that found in buses, also requires Section 608 certification. The issue in this section that is relevant to MVAC technicians involves proposed updates that require self-sealing valves on small cans sold for MVAC servicing. This rule will go into effect in 2016.

Section 609 addresses the mobile motor vehicle air conditioning (MVAC) industry. MVAC technicians can only service motor vehicle A/C systems used to cool passenger compartments. The sale of small containers of refrigerant under 20 lbs., including the one pound cans, are restricted to only people certified in Section 609. Technician certification, as established by EPA, is to teach technicians and test their ability to properly handle and recover refrigerants. Technicians will also learn about the laws enacted to protect the stratospheric ozone layer.

Technicians who repair or service any MVAC system must be trained and certified by an EPA-approved organization. If a technician is already trained and certified to handle CFC-12, he does not need to be re-certified to handle HFC-134a.

Servicing Farm and Heavy-Duty Equipment

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.

Refrigerant Purity Standards

Recycled R-12 (CFC-12) that has been directly removed from, and intended to be returned to, a mobile air-conditioning system cannot exceed the level of contaminants as specified by the SAE J1991 standard:

- Moisture: 15 parts per million (ppm) by weight.
- Refrigerant oil: 4,000 ppm by weight.
- Non-condensable gases (air): 330 ppm by weight.

Purity specification of new, recycled or reclaimed R–12 refrigerant supplied in containers from other recycle sources, for service of mobile air-conditioning systems, must meet Air-Conditioning Heating and Refrigeration Institute (AHRI) Standard 700–2006:

- Moisture: 10 parts per million (ppm) by weight.
- Air and other Non-condensables: Less than 1.5% by volume
- All Other Volatile Impurities: Less than 0.5% by weight.
- High-Boiling Residue: 0.01% by volume
- Chloride Content: Less than 3 ppm
- Acidity: 1 ppm by weight (as HCL)
- Boiling Point Range: Less than 0.5°F
- Unsaturated Impurities: Less than 40 ppm

Recycled R-134a (HFC-134a) that has been directly removed from, and intended to be returned to, a mobile air-conditioning system cannot exceed the level of contaminants as specified by the SAE J2099 standard:

- Moisture: 50 parts per million (ppm) by weight. Note: R-134a and its oils have a much higher affinity for water and are harder to keep dry
- Refrigerant Oil: 500 ppm by weight.
- Non-Condensable gases (air): 150 ppm by weight.

Purity specification of new, recycled or reclaimed R–134a refrigerant supplied in containers from other recycle sources, for service of mobile air-conditioning systems, must meet AHRI Standard 700–2006 (Air Conditioning and Refrigeration Institute):

- Moisture: 10 parts per million (ppm) by weight.
- Air and other Non-condensables: Less than 1.5% by volume
- All Other Volatile Impurities: Less than 0.5% by weight.
- High-Boiling Residue: 0.01% by volume
- Chloride Content: Less than 3 ppm
- Acidity: 1 ppm by weight (as HCL)
- Boiling Point Range: Less than 0.5°F
- Unsaturated Impurities: Less than 40 ppm

Recycled HFO-1234yf (R-1234yr) that has been directly removed from, and intended to be returned to, a mobile air-conditioning system cannot exceed the level of contaminants as specified by the SAE J2099 standard:

- Moisture: 50 ppm by weight
- High Boiling Residue (lubricant): 500 ppm by weight
- Non-condensable Gasses (air): 1.5% by volume at 23.9°C

Prior to the removal of R-1234yf from a MAC system, the refrigerant must be at least 98% pure and must have been directly removed from and intended to be returned to an MVAC system that uses R-1234yf. Purity specification of new, recycled, or reclaimed R–1234yf refrigerant supplied in containers from other recycle sources, for service of mobile air-conditioning systems, must meet AHRI 700-2006 and SAE J2844:

- Moisture: 25 ppm by weight.
- Air and Other Non-Condensables: Less than 1.5% gas phase by volume at 23.9°C
- All Other Volatile Impurities: Less than 0.5% by weight.
- High-Boiling Residue: 0.01% by volume
- Chloride Content: No visible turbidity
- Acidity: 1 ppm by weight (as HCL)
- Boiling Point Range: N/A
- Unsaturated Impurities: N/A

Unsaturated Impurities Specification

In 2006 both the Society of Automotive Engineers (SAE) and the Air-Conditioning Heating and Refrigeration Institute (AHRI) have approved more stringent refrigerant purity standards which limit the level of unsaturated impurities in the refrigerant HFC-134a and are reflected in the new AHRI-700 purity standard for new and reclaimed refrigerants. The AHRI standard now contains the new specification to limit unsaturated impurities in HFC-134a to a maximum level of 40 ppm. SAE standard J2776 also contains this provision. The term "unsaturated" refers to the types of bonds within some molecules contained in the refrigerant. Molecules that contain double bonds are called unsaturated. Double bonds in unsaturated molecules are more chemically reactive than single bonds and therefore increase the chance of chemical instability and the likelihood that the refrigerant will contain contaminants that often contribute to the formation of sludge or tar. The SAE has also developed a new standard, J2683, to specify the refrigerant purity and container requirements for carbon dioxide (CO_2 R-744) used in mobile air-conditioning systems.

Prohibitions

1. Since August 13, 1992, no person repairing or servicing motor vehicles for consideration, may perform any service on a motor vehicle air conditioner involving the refrigerant for such air conditioner without properly using approved recycling equipment (equipment must meet SAE Standards) and unless such person has been properly trained and certified by an EPA-approved 609 certification program. These requirements did not apply until January 1, 1993 for small entities (persons or companies who performed less than 100 A/C service jobs in 1990), if they filed the proper certification with the EPA. However since January 1, 1993, this law applies to all regardless of the size of their organization or the number of service jobs performed in the past, if any.
2. Since November 15, 1992, no person may sell or distribute, or offer for sale or distribution, any Class I or Class II substance that is suitable as a refrigerant in a motor vehicle air conditioner and that is in a container which contains less than 20 pounds of refrigerant to any person unless that person is properly trained and holds a 609 certification. The only exception to this sales restriction is if the purchaser is a re-seller of the refrigerant, and the re-seller has certified to the seller, in a form satisfactory to the EPA, his re-seller status. R-12 is a Class I Substance; R-22 is a Class II Substance. Containers of refrigerant which contain more than 20 pounds of refrigerant can be sold to a person who holds either Section 608 or Section 609 certification.
3. Since November 15, 1995, it has been illegal to vent substitutes for CFC and HCFC refrigerants.
4. Since January 29, 1998, it has been mandatory to recycle HFC-134a as well as any other automotive refrigerant before returning to that MVAC or sold.

NOTE: Section 608 HVAC/R Technicians cannot buy refrigerant in quantities less than 20 lbs.

Record-keeping Requirements

The Clean Air Act establishes the following rules for record keeping:

1. Any person who owns approved refrigerant recycling equipment certified for MVAC use must maintain records of the name and address of any facility to which refrigerant is sent.
2. Any person who owns approved MVAC refrigerant recycling equipment must retain records demonstrating that all persons authorized to operate the equipment are 609 Certified.
3. Any person who sells or distributes any Class I or Class II substance (in a container of less than 20 pounds of such refrigerant) must verify that the purchaser is Properly Trained and 609 Certified and must retain a record. The seller must have a reasonable basis for believing that the information presented by the purchaser is accurate.
4. All records must be maintained for 3 years. Entities which service MVAC systems must keep the records on-site and must allow a representative of the EPA access to all required records.
5. Public Notification is also required. Any person who conducts any retail sales of a Class I or Class II substance, for MVAC units, and that is in a container of less than 20 pounds, must prominently display a sign that reads: "It is a violation of federal law to sell containers of Class I and Class II refrigerant of less than 20 pounds of such refrigerant to anyone who is not properly trained and certified to operate approved refrigerant recycling equipment."
6. New service shops must certify to their regional EPA office that they have acquired and are properly using approved refrigerant handling equipment. The form is available at **https://www.epa.gov/mvac/mvac-servicing-certification-form;** addresses for the EPA regional offices can be found on the second page of that form. This is a one-time requirement. If a shop has certified ownership of a piece of CFC-12 or HFC-134a equipment at any time in the past, the shop *is not required* to re-submit certification to EPA when they purchase new equipment. This applies even if the shop purchases equipment for a different refrigerant, such as HFO-1234yf.

Evacuation Requirements for Systems Being Serviced

This applies to all Class I and Class II refrigerants and their substitutes that are used in MVAC systems.

The refrigerant must be recovered until the system pressure drops to a vacuum of 4" (or 102mm) of mercury. The service technician must assure that the vacuum level holds (for at least 5 minutes the first time you check it and at least 2 minutes for any rechecks). That is the MVAC technician must verify that there is no remaining refrigerant being vaporized off to raise the pressure above ambient pressure.

Evacuation Requirements for Systems Being Disposed

Prior to the EPA's January 29, 1998 Final Rule the EPA regulations had not addressed how refrigerant recovered from a motor vehicle located at a salvage yard, scrap recycling facility, landfill or other motor vehicle disposal facility could be reused after it was recovered. Many service technicians and motor vehicle disposal facility operators have believed, incorrectly, that the EPA required that a refrigerant removed from a motor vehicle bound for disposal must be sent to a reclaimer rather than recycled prior to reuse.

The Final Rule contains provisions designed to clarify that motor vehicle disposal facility operators and certified automotive service technicians can recycle and resell refrigerants recovered from motor vehicles destined for disposal. Specifically, the rule explicitly allows Section 609 certified technicians who recover refrigerant (whether CFC-12 or a substitute) from motor vehicles located at disposal facilities to take the refrigerant off-site and recycle that refrigerant at their service facilities for reuse in other motor vehicles. In addition, owners or operators of motor vehicle disposal facilities are permitted to sell refrigerant recovered from such vehicles to Section 609 certified technicians for re-use in MVACs. By promoting markets for used refrigerant recovered from these vehicles, the Agency hopes to provide incentives for the recovery and reuse of refrigerants. Note that these changes do not affect refrigerant recovered from home appliances, such as refrigerators, that are destined for disposal; refrigerant from these sources must still be sent to a reclaimer before it can be sold (or transferred in any way to another owner).

Under EPA's rule, equipment that typically enters the waste stream with the charge intact, (such as motor vehicle air conditioners), are subject to special safe-disposal requirements. Under these safe disposal requirements, the final person in the disposal chain, (e.g., a scrap metal recycler), is responsible for ensuring that the refrigerant is recovered from the equipment before the final disposal of the equipment. However, persons "upstream" could remove the refrigerant and provide documentation of its removal to the final person.

Prior to scrapping MVAC equipment the refrigerant must be recovered to a minimum vacuum of 4 inches of mercury, (102 mm of mercury). The service technician must assure that the vacuum level holds at 4 inches of mercury. That is the MVAC technician must verify that there is no remaining refrigerant being vaporized off to raise the pressure above 4 inches of mercury.

If the recovered refrigerant is to be sent to an MVAC service facility for charging, or recharging into an MVAC or MVAC-like appliance without prior reclamation then the refrigerant must be recovered using approved refrigerant recycling equipment dedicated for use with MVAC and MVAC-like appliances. This recovery must be performed by either a 609 certified technician or an employee, owner, or operator of the disposal facility.

An EPA fact sheet entitled "Recovering Refrigerant at Motor Vehicle Disposal Facilities," (available through the EPA website https://www.epa.gov/mvac) provides more details about this portion of the rule.

Evacuation/Disposal Requirements for Empty or Near Empty Disposable Tanks

This applies to all Class I and Class II refrigerants and their substitutes which are contained in disposable tanks, (of less than 20 pound original capacity), by MVAC service technicians.

- **A.** The refrigerant must be recovered until the system pressure drops to a vacuum. No specific vacuum level must be achieved. But the service technician must assure that the vacuum level holds. The container's valve can be closed at this time.
- **B.** The container must be marked "EMPTY".
- **C.** The container is ready for disposal.

We recommend, (however it is not required by the EPA of Section 609 technicians), that the cylinder valve then be opened to allow air to enter, and the cylinder should be rendered useless, (with the valve still open), by breaking off the valve or puncturing the container. This will avoid misuse of the container by untrained individuals. Used cylinders can be recycled with other scrap metal. They can never be reused for any purpose.

Never leave used cylinders with residual refrigerant outdoors where the cylinder can rust. **The internal pressure of a cylinder with one ounce of liquid refrigerant is exactly the same as a full cylinder.** An abandoned cylinder will eventually deteriorate and potentially explode if the cylinder wall weakens.

Evacuation Requirements for Empty Refillable External Recovery Transfer Tanks

This applies to all refillable external recovery tanks for use by MVAC technicians which are being switched from one refrigerant to another, or are being brought into service and may be contaminated with air or other non-condensable gasses.

The empty refillable tank must be evacuated to a minimum vacuum of 27 inches of mercury, (686 mm of mercury), before being filled with refrigerant. (A vacuum pump not a recovery device is typically used.) The service technician must assure that the vacuum level holds at 27 inches of mercury. That is the MVAC technician must verify that there is no moisture being vaporized off to raise the pressure above 27 inches of mercury.

Recovery Equipment Evacuation Requirements

Recovery Equipment Requirements for R-12 are described completely in SAE Standard J1990, “Extraction and Recycle Equipment for Mobile Automotive Air-Conditioning Systems.” Recovery Equipment Requirements for R-134a are described completely in SAE Standard J2810, “HFC-134a (R-134a) Refrigerant Recovery Equipment for Mobile Automotive Air-Conditioning Systems.” Recovery/Recycling/Recharging Equipment Requirements for R-134a are described completely in SAE Standard J2788, “HFC-134a (R-134a) Recovery/Recycling Equipment and Recovery/Recycling/Recharging for Mobile Air-Conditioning Systems.” Details of these requirements are discussed in greater detail in Section 4 of this manual.

Sales Restrictions

Right now, there is no restriction on the sale of HFC-134a, so anyone may purchase it. However, as of April 2016, the EPA issued a proposed rule in which only technicians certified under Section 608 and Section 609 of the Clean Air Act may purchase refrigerant.

SAE Standards

The Society of Automotive Engineers, Inc, has developed standards that apply to the recovery and recycling of motor vehicle refrigerant as well as service guidelines for MVAC technicians.

SAE J051: Automotive Air Conditioning Hose

SAE J639: Safety and Containment of Refrigerant for Mechanical Vapor Compression Systems used for Mobile Air-Conditioning Systems

SAE J1627: Performance Criteria for Electronic Refrigerant Leak Detectors

SAE J1629 Cautionary Statements for Handling HFC-134a During Mobile Air Conditioning Service

SAE J1657: Selection Criteria for Retrofit Refrigerants to Replace R-12 in Mobile Air Conditioning Systems

SAE J1660: Fittings and Labels for Retrofit of R-12 Mobil Air-Conditioning Systems to R-134a

SAE J1661: Procedures for Retrofitting R-12 Mobil Air-Conditioning Systems to HFC-134a

SAE J1662 Compatibility of Retrofit Refrigerants with Air Conditioning System Materials

SAE J1732: HFC-134a Extraction Equipment for Mobile Automotive Air-Conditioning Systems

SAE J1771: Criteria for Refrigerant Identification Equipment for use with Mobile Air-Conditioning Systems

SAE J1989: Recommended Service Procedure for the Containment of R-12.

SAE J1990: Extraction and Recycle Equipment for Mobile Automotive Air-Conditioning Systems.

SAE J1991: Standard of Purity for Use in Mobile Air-Conditioning Systems

SAE J2064: R-134a Refrigerant Automotive Air Conditioning Hose

SAE J2099: Standard of Purity for Recycled HFC-134a for use in Mobile Air-Conditioning Systems

SAE J2196: Service Hose for Automotive Air-Conditioning

SAE J2197: Service Hose Fittings for Automotive Air-Conditioning

SAE J2209 CFC-12 Extraction Equipment for Mobile Automotive Air-Conditioning Systems

SAE J2788: HFC-134a (R-134a) Recovery/Recycling Equipment and Recovery/Recycling/Recharging for Mobile Air-Conditioning Systems

SAE J2211: Recommended Service Procedure for the Containment of HFC-134a

SAE J2810: HFC-134a (R-134a) Refrigerant Recovery Equipment for Mobile Automotive Air-Conditioning Systems.

SAE J2843: R-1234yf Recovery/Recycling/Recharging Equipment for Flammable Refrigerants for Mobile Air-Conditioning Systems

SAE J2851: Recovery Equipment for Contaminated Refrigerant from Mobile Automotive Air Conditioning Systems

SAE J3030: Automotive Refrigerant Recovery/Recycling/Recharging Equipment Intended for Use with Both R-1234yf and R-134a

CFC Refrigerant Tax

The 1990 federal budget contained provisions for federal excise taxes on new production, floor stocks, and imports of CFCs and halons. The taxes were effective

January 1, 1990, and apply to CFC 12. The Energy Policy Act of 1992, section 1931 of Public Law 102-486 revised and further increased the excise tax, (in effect since January 1, 1993). The government's intent is to provide additional financial incentives to increase recycling and promote the shifting-away from these substances. This excise tax is imposed when the CFC is sold or used by the manufacturer or importer. Recycled and reclaimed refrigerants are exempt from the tax. A floor tax also applies to anyone holding 400 lb. or more of the regulated CFCs.

The tax payment must be deposited with Form 8109, Federal Tax Deposit Coupon, at an authorized depository or a Federal Reserve Bank. In addition, a return must be filed on Form 720, the Quarterly Federal Excise Tax Return with the Environmental Tax Form 6627 attached. Contact the IRS for further details.

Enforcement

Under Section 608 of the Clean Air Act, intentional release (venting) of any refrigerant is illegal unless the refrigerant is specifically exempt from the prohibition. CO_2 is exempt under section 608, meaning that it can be legally vented. However, section 609 still requires that all MVAC systems be serviced through the proper used of EPA-certified refrigerant handling equipment. This requirement applies regardless of the refrigerant used in the MVAC system. Therefore, anyone servicing an MVAC system that uses CO_2 as the refrigerant would need to properly use EPA-certified refrigerant handling equipment.

EPA responds to tips reporting venting. Under the Clean Air Act, EPA is authorized to assess fines of up to $37,500 per day per violation for any violation of the act. These dollar amounts are maximum figures and are not necessarily the amount that will be assessed in all cases.

State and Local Regulations

Individual states cannot pass laws to lessen federal requirements or invalidate federal law; however, state and local governments can establish laws that contain stricter regulations than the Clean Air Act/EPA regulations. For example:

- Although EPA does not require a leak to be repaired prior to recharging a motor vehicle air conditioning system, some states do have state laws requiring leak repairs.
- Propane, isobutene, and all other flammable refrigerants, except HFO-1234yf and HFC-152a, have been found unacceptable under SNAP and are illegal to use in the U.S.
- The U.S. EPA does not characterize used refrigerants as hazardous waste. Most states share this view and, consequently, require no special procedures for used

refrigerant shipments. However, any individual state may require special shipping procedures.

Technicians must check state and local regulations and licensing requirements.

For information concerning regulations related to stratospheric ozone protection, please visit https://www.epa.gov/mvac.

Review Topics

- Capturing and ultimately eliminating the use of chlorofluorocarbons is being done in the United States to stop damage to the stratospheric ozone layer.

- Since August 13, 1992, no person repairing or servicing motor vehicles may perform any service on a motor vehicle air conditioner involving the refrigerant for such air conditioner without properly using approved recycling equipment, (equipment must meet SAE Standards), and unless such person has been properly trained and certified by an EPA-approved 609 certification program.

- Since November 15, 1992, no person may sell or distribute, or offer for sale or distribution, any Class I or Class II substance that is suitable as a refrigerant in a motor vehicle air conditioner and that is in a container which contains less than 20 pounds of refrigerant, to any person unless that person is properly trained and certified. (R-12 is a Class I Substance, R-22 is a Class II Substance).

- Any person who owns approved refrigerant recycling equipment, certified under the Clean Air Act, must maintain records of the name and address of any facility to which refrigerant is sent.

- Any person who owns approved MVAC refrigerant recycling equipment must retain records demonstrating that all persons authorized to operate the equipment are Section 609 certified. All equipment must be registered with EPA regional offices.

- Any person who sells or distributes any Class I or Class II substance, (in a container of less than 20 pounds of such refrigerant), must verify that the purchaser is properly trained and certified. The seller must retain a record of this for a period of three years.

- Public Notification is also required. Any person who conducts any retail sales of a Class I or Class II substance must prominently display a sign that reads: "It is a violation of federal law to sell containers of Class I and Class II refrigerant of less than 20 pounds of such refrigerant to anyone who is not properly trained and certified to operate approved refrigerant recovery equipment."

- State and local governments may establish laws that contain stricter regulations than the Clean Air Act/EPA regulations.
- MVAC systems must be evacuated to a vacuum before servicing.
- External Recovery Tanks must be evacuated to 27 inches of mercury before being put into service.
- MVAC systems being disposed must be evacuated to 4 inches of mercury before being scrapped.
- Disposable Refrigerant Tanks, (under 20 pounds), must be evacuated before being scrapped.
- Service technicians who violate Clean Air Act provisions can be fined, lose their certification, and face federal charges.
- Violation of the Clean Air Act, including the knowing release of refrigerant during the maintenance, service, repair, or disposal of appliances, can result in fines up to $37,500 per day per violation for anyone venting refrigerant except for carbon dioxide (CO_2), which can be vented.
- Since January 1, 1996, it is no longer legal for CFCs to be manufactured or imported into the United States. Supplies of CFC refrigerant for equipment servicing can ONLY come from recovery, recycling, and reclamation.
- Since November 15, 1995, it is illegal to vent substitutes for CFC and HCFC refrigerants.

SECTION IV: Service Practices

Basic Vapor-Compression A/C Principles

It is not the intent of this section to teach basic air-conditioner theory; however, a simple discussion of the basic cycle is useful for describing the effects of non-condensable gases, moisture, and contaminates on the air-conditioning system.

The most basic vapor-compression air conditioning system consists of four major components: compressor, evaporator, condenser, and expansion device. As every technician knows, actual practical hardware contains many other critical components for reliable, trouble-free operation, such as a control system, high-pressure and low-pressure safety controls, liquid receiver, accumulator, oil separator, etc. However, the four basic components are all that is needed to illustrate the point of this section.

Refrigerant adsorbs energy, (provides cooling), as it is evaporated, that is, as it boils and turns from liquid to vapor. For pure refrigerants, if the refrigerant evaporates at a constant pressure, then the evaporation occurs at a constant temperature while both liquid and vapor are present. Likewise, refrigerant rejects energy, (gives off heat), as it condenses from vapor to liquid. For pure refrigerants and azeotropic mixtures, if the condensation occurs at a constant pressure, then the condensation will occur at a constant temperature until all the vapor has condensed to a liquid. Therefore, for evaporation, or condensation, the temperature and pressure are related by the pressure/temperature saturation curve. Table 6 presents saturation temperature/pressure data for CFC-12, and HFC-134a.

If a technician has an unknown refrigerant in a recovery cylinder, and both liquid and vapor are present in the recovery cylinder, then he/she can verify the refrigerant type by comparing the pressure and temperature with the saturation pressure temperatures curves for the various refrigerants. Unfortunately, the temperature pressure relationship of R-12, R-134a, and R-1234yf, are too close to distinguish. For example, suppose the unknown refrigerant has a tank temperature of 80°F. If the refrigerant is HFC-134a, then the tank pressure would be 86 psig, (referring to Table 6), and if the refrigerant was CFC-12, the tank pressure would be 84 psig, because of gauge inaccuracy and non-condensable gas effects this is too close to call. However, accurate refrigerant gas analyzers are commercially available to determine refrigerant types and to verify that there is no refrigerant contamination during a refrigerant change-over.

A brief discussion of the operating vapor-compression cycle is helpful to indicate other potential air-conditioning problems in real systems. In the basic cycle, slightly subcooled refrigerant leaves the condenser at high pressure, and the pressure is dropped via the throttling device, (capillary tube, TXV, etc.), before it enters the evaporator. It enters the evaporator as two-phase mixture (liquid and vapor) and evaporates or boils at low temperature, adsorbing heat. Slightly superheated refrigerant vapor exits the evaporator and enters the compressor where the pressure and temperature are increased as the compressor, compresses the refrigerant vapor. The vapor, leaving the compressor, is superheated, and the compressor discharge is the hottest point in the cycle. This refrigerant is cooled and condensed in the condenser where heat is rejected and the refrigerant is condensed to liquid. Refrigerant actually leaves the condenser slightly subcooled to assure condensation has been complete. Any non-condensable vapors in the system will be unable to condense in the condenser and will appear as gas bubbles in the condensed liquid stream. These non-condensables may collect in the condenser and displace refrigerant from the condenser heat exchanger, thereby reducing the effective surface area of the condenser.

Any water in the system will most likely freeze in the expansion valve, because this is the point where refrigerant is cooled by the evaporation occurring as a result of the sudden pressure drop, and the expansion device also represents the smallest passage way in the overall system. It is this reason why filter-driers are typically located just upstream of the expansion device.

Table 6. Pressure/Temperature Saturation Relationship for Common Refrigerants

Temperature [°F]	Pressure[psig]	
	CFC-12	**HFC-134a**
0.0	9.2	6.3
10.0	14.6	11.6
20.0	21.0	18.0
30.0	28.5	25.6
40.0	37.0	34.5
50.0	46.7	44.9
60.0	57.7	56.9
70.0	70.2	70.7
80.0	84.2	86.4
90.0	99.8	104.2
100.0	117.2	124.3

Leak Testing

Automotive systems naturally leak small amounts of refrigerant. This slow leakage comes from the inherent minor permeability of the soft, flexible hoses in the system, and the shaft seal on the compressor. Another possible source of leaks are at the threaded connections for the hoses, the gasketed face seals and any location where the soft, flexible hoses are crimped and join harder metal tubing. EPA does not require a leak to be repaired prior to recharging a motor vehicle air conditioning system, but it is highly recommended! Some states do have state laws requiring leak repairs. (Note: states can impose laws that are stricter than federal laws.) In a proposed change to Section 608, the leak repair requirements will extend to HFCs; therefore, motor-vehicle-like appliances will be covered once the rule is finalized. In addition, EPA does not require that the refrigerant be recovered and cleaned prior to recharging the system with additional refrigerant; that is, you can legally top off A/C systems. However, some replacement refrigerant blends cannot be topped-off for thermodynamic reasons. When there is a leak in a system with a non-azeotropic refrigerant blend the more volatile refrigerants leak more than the other refrigerants in the blend. This changes the proportions of the blend and alters the blend's properties. For these non-azeotropic blends (refrigerants with an R-5XX designation), the refrigerant must be recovered and replaced rather than topped off. This is a significant drawback of these non-azeotropic blends. R-1234yf, R-134a, R-152a, R-12, and carbon dioxide are pure refrigerants and can therefore be topped off. In addition, azeotropic blends (refrigerants with an R-4XX designation) behave as a pure refrigerant and can also be topped off.

A service technician’s major responsibility is to minimize the amount of refrigerant that escapes into the atmosphere. One of the worst things a service technician can do is service an automotive air conditioning system and then discover that the system has large leaks.

The technician should give the vehicle a thorough visual inspection before starting any service procedures, including inspecting the entire refrigerant circuit while watching for signs of oil leakage, corroded or damaged lines, hoses, or other components. The technician should also look for uncapped Schrader valves, dust caps, or missing and/or damaged O-rings. Topping off a system that leaks refrigerant lets harmful refrigerants escape into the atmosphere.

In addition to the environmental benefits of keeping systems properly charged and leak-free is that it will improve the efficiency of the MVAC, saving the owner the additional cost of refrigerant, and improve the reliability and longevity of the unit. The refrigerant charge must be correct; adding more change than is necessary can cause compressor damage and decrease efficiency.

A vacuum test is not the best method of leak testing a system. This method allows air, and thus moisture, to enter the system, and the technician cannot determine from the vacuum where the leak is, but only that there is a leak. Also, when a vacuum is used for leak checking, it is only proving that the system will not leak under a pressure difference of 14.7 psi. (If all of the atmosphere is removed from a system, there is only the atmosphere's pressure trying to get back into the system, therefore a 14.7 psi pressure difference.)

When checking for a leak using a vacuum, the technician is using a reverse pressure, (the atmosphere trying to get into the system), of only 14.7 psi; however, under normal operating conditions, the system may be operating under a pressure of more than a hundred psig, that is, many times the vacuum pressure difference. Always leak check with dry nitrogen to a pressure of approximately 130 psig, and never more than 150 psig.

Using soap bubbles to indicate a leak can be a simple and effective approach. However, some very small leaks are difficult to find. In this case, an electronic leak detector could be useful. Always follow the directions provided with the detector. SAE document J1628, provides general guidelines for the use of electronic leak detection devices.

If an electronic leak detector cannot identify the source of very small leaks, then the introduction of an ultraviolet (UV) fluorescent leak detection dye or simply a visible dye is another alternative. The dye mixes with the oil, and at a leak, the liquid oil and dye residue, which do not evaporate, are more noticeable than simply looking for oil alone. Because the UV dye fluoresces when a UV light is shined on the area, it can be easier to see than a simple visible dye. SAE document J2298 provides general procedures for the use of ultraviolet leak detection dyes, J2297 provides the stability and compatibility criteria of the fluorescent dye for R-134a systems, and SAE J2299 provides the performance requirements for fluorescent refrigerant leak detection dye injection equipment for aftermarket service of mobile A/C.

This technique is useful on small, hard to find leaks, where the technicians can look for the leak the next time they are servicing the unit. The additive will show as a bright yellow-green or blue glow under the ultraviolet lamp at the source of the leak. The area can be wiped clean with a general purpose cleaner after the leak has been repaired and the area can then be re-inspected. If a new leak is suspected at a later date, the leak can be located by the fluorescent color under the ultraviolet light. Always verify that the dye being used is compatible with the oil and refrigerant in the MVAC system.

Always locate and fix the leak before adding the proper refrigerant charge. Only the refrigerant that is specified for the system should be used for leak checking. This prevents any chemical contamination from one refrigerant to another.

Never use pure oxygen or air for leak checking. Air contains 18 percent oxygen, which when mixed with many refrigerants, (as would be done in a leak checking procedure), could cause an explosion if a flame is encountered. The pure oxygen and/or the oxygen in the air can combine with the refrigerant or oil and make an explosive mixture. Pure oxygen and oxygen in the air will oxidize system oil, very rapidly. In a closed system, pressure from the oxidizing oil can build up rapidly and may generate pressures to a point of exploding**.** The use of air for leak checking will also introduce a tremendous amount of moisture into the system. Typical ambient air can contain thousands of ppm of moisture.

NOTE: Contained, recovered or recycled liquid refrigerant, contaminated with a small amount of air, does not constitute a flammability hazard. Use, however, of refrigerant contaminated with air will result in abnormally high operating system pressures, excess superheat, and possible major system damage. Use the Non-Condensable Gas Determination and Removal method described later in this section to determine if non-condensable gases are present and to remove these non-condensables.

If the system's refrigerant is to be used for leak checking, at least 50 psig of pressure is needed in both high and low sides of the system for leak checking. This means that the system does not have to be fully charged to leak check; also, **leak checking should be done with the engine off.** Even though a minimum of 50 psig is required for leak checking, it is not enough refrigerant to determine if the system will produce useful cooling. If the compressor is to be operated, refrigerant will have to be added to the system so the service technician can systematically troubleshoot and detect problems.

Refrigerant that is used for leak checking must be recovered and cannot be released into the atmosphere. To knowingly release refrigerant into the atmosphere is a violation of the Clean Air Act with fines up to $37,500 per occurrence [except carbon dioxide (CO_2), which can be vented.]

No one method should be relied on to detect refrigerant leaks. Electronic leak detectors are designed to find leaks of just fractions of an ounce per year. Some electronic detectors can detect multiple refrigerants, where others detect only one refrigerant. R-134a has no chlorine in its molecule and is harder to detect. The leak detector has to have a higher sensitivity to detect the more elusive fluorine molecule in R-134a. When purchasing a leak detector for mobile air conditioning service, make sure it will find the refrigerant you are trying to detect. The more modern leak devices can detect both R-12, R-134a, and R-1234yf refrigerants. SAE document J1628 should be used by mobile air conditioning service technicians when leak-checking any vehicle. This document explains the use of a certified electronic leak detector according to SAE J1627 specifications. SAE standard J2791 provides the minimum performance requirements for electronic leak detectors to be used with HFC-134a and SAE J2913 provides the minimum performance requirements for electronic leak detectors to be used with R-1234yf; these leak detectors may also detect R-12, R-134a, and other contaminants.

Some leaks are very hard to find. In fact, a service technician will often finish checking a vehicle and find that there are no detectable leaks. However, just because the technician didn't find any leaks doesn't mean that the system doesn't leak. Some leaks are vibration dependent, temperature dependent, pressure dependent, or a combination of the three. Conversely, in systems using CO_2 (R-744), leak detection equipment could sense a leak when one does not actually exist because CO_2 occurs naturally and artificially in the environment. This is why it is important to practice good service procedures and workmanship. Always double check the system before closing the hood.

Leak Repairs

Once a leak is discovered, common sense will typically dictate the proper repair method. If a rubber hose is leaking it must be replaced. The entire plumbing assembly can be replaced or the rubber hose can be replaced. Never reuse a leaking hose. Likewise, leaking fittings can be tightened, however if that does not repair the leak, then the o-ring or face seal must be replaced. Use a small drop of compressor lubricant on the o-ring or face seal before reassembly. If a compressor shaft seal is leaking the compressor must be replaced or rebuilt.

Some aftermarket products are sold that claim to seal leaks by reacting inside the system at the source of the leak and plugging the leak (by forming a solid reside). In addition, some products are sold as "O-ring sealants" that are claimed to cause o-rings to swell to stop leaks. Avoid all such products. It is never a good idea to add any foreign substance into an air conditioning system due to potential unforeseen chemical incompatibilities with the lubricant, refrigerant or materials of construction. Furthermore, the introduction of a chemical that is specifically designed to form a solid residue, (to plug a leak), is an especially bad idea. They will also invalidate a manufacturer’s warranty. If tubing assemblies, or heat exchangers are leaking they must be replaced.

System Flushing

Today, the Clean Air Act prohibits the use of CFCs and/or methylchloroform in any flushing procedure in which the flushing agent is vented to the atmosphere. R-11 and R-113 have been used successfully for many years in flushing out mobile air conditioning systems. These refrigerants are CFCs, and are no longer produced. Also residual chlorine from any CFC, (including R-11, R-12, or R-113), left in the air conditioning system will cause serious chemical stability problems in R-134a systems. Use of any flushing fluid, other than the refrigerant prescribed for the MVAC system is not recommended.

Some solvents on the market are supposedly designed for system flushing. However, these solvents might not vaporize and come out of the system when a deep vacuum is pulled on it. If residual solvents remain in the active air conditioning system, the chemical stability of the refrigerant and oil could be affected. This is why some mobile air conditioning manufacturers recommend not flushing after a mechanical failure. SAE Standard J2670 provides the stability and compatibility criteria for additives and flushing materials intended for aftermarket use in R-134a (HFC-134a) and R-1234yf (HFO-1234yf) vehicle air-conditioning systems.

Mainstream does not recommend the use of any cleaning or flushing fluid other than Qwik System Flush™ for MVAC systems. Qwik System Flush™ has been shown (in independent third-party laboratory tests) to effectively flush acid, oil, water and other impurities without leaving any residue.

Filter-Driers

Using a filter-drier, just before the expansion valve or orifice tube, has proven to be a more effective method for catching particle residue, moisture, and debris from failed parts and/or components. There are in-line filters designed to catch the harmful particles and still not restrict the vehicle's air conditioning system.

Refrigerant Blends

Introduction

In 1994, the EPA established the SNAP program to evaluate and regulate substitutes for the ozone-depleting chemicals that have been phased out under the stratospheric ozone protection provisions of the Clean Air Act. In **Section 612(c)** of the **Clean Air Act**, the Agency is authorized to identify and publish lists of acceptable and unacceptable substitutes for **class I** or **class II** ozone-depleting substances. The EPA identified alternative refrigerants that reduce overall risk to human health and the environment. The purpose of the program is to allow a safe, smooth transition away from ozone-depleting compounds by identifying substitutes that offer lower overall risks to human health and the environment. The SNAP program does not certify the suitability of any alternative refrigerant as a replacement for a phased out refrigerant.

Understanding the meaning of *"acceptable subject to use conditions"* is important. EPA believes such refrigerants, when used in accordance with the conditions, are safer for human health and the environment than CFC-12. This designation does not mean that the refrigerant will work in any specific system, nor does it mean that the refrigerant is perfectly safe regardless of how it is used. The EPA does not approve or endorse any one refrigerant that is acceptable subject to use conditions over others also in that category. The EPA does not test refrigerants under the SNAP process. Rather, they review information submitted by manufacturers and various independent testing laboratories. Additional considerations about substitute refrigerants can be found in EPA's fact sheet titled "**Ten Questions to Ask Before You Purchase An Alternative Refrigerant**."

To provide a historical perspective into replacement refrigerants, all CFC refrigerants, including CFC-12 were banned in the USA because of their ozone depletion potential. As a result, CFC-12 was replaced by HFC-134a for new MVAC applications. Now, new vehicle manufacturers and the MVAC industry have been investigating improved refrigerants to potentially replace HFC-134a because of its high global warming potential. Several HCFC blends are acceptable under SNAP, but none of these have been commercialized.

Blends

Refrigerant blends are mixtures of refrigerant that have been formulated to provide a similar pressure/temperature relationship to the original refrigerant. HFO-1234yf will most likely be the long-term replacement for certain CFCs and HCFCs, as several million vehicles on the road worldwide are using this refrigerant.

Many blends also use a flammable component (such as propane or butane) as one of their components. All flammable refrigerants are unacceptable for use in MVAC except HFO-1234yf and HFC-152a. The use conditions required by the SNAP listing for these two substitutes are in place to allow for the safe use of the flammable refrigerants in an MVAC system. Table 7 lists refrigerants that have been found to be unacceptable in MVAC applications and are therefore illegal. SNAP approval does not mean that the alternative refrigerant is compatible with the materials (or lubricant) used in the MVAC system or that the performance of the unit will be similar. SNAP approval only means the environmental and human health effects of the refrigerant are acceptable and the refrigerant has been tested to determine flammability. The EPA has made it illegal to use flammable refrigerants in motor vehicle air conditioning systems except for HFO-1234yf and HFC-152a in new MVAC equipment. Each potential new refrigerant must be tested according to the American Society of Testing Materials (ASTM) E-681 testing method to determine flammability. Table 8 lists the acceptable MVAC substitute refrigerants.

Table 7. Unacceptable Substitute MVAC Refrigerants as of July 2015

Substitute	Trade Name	Retrofit/New	SNAP Listing Date	Use Conditions
Free Zone (HCFC Blend Delta)	Free Zone/RB-276	R/N	May 22, 1996; July 20, 2015	Unacceptable in New Light-Duty Systems as of MY 2017. Detailed conditions apply - see Rule.
Freeze 12	Freeze 12	R/N	October 16, 1996; July 20, 2015	Unacceptable in New Light-Duty Systems as of MY 2017. Detailed conditions apply - see Rule.
GHG-HP (HCFC Blend Lambda)	GHG-HP	R/N	October 16, 1996; July 20, 2015	Unacceptable in New Light-Duty Systems as of MY 2017. Detailed conditions apply - see Rule.
GHG-X5	GHG-X5	R/N	June 3, 1997; July 20, 2015	Unacceptable in New Light-Duty Systems as of MY 2017. Detailed conditions apply - see Notice.
HFC-134a	134a	R/N	March 18, 1994; July 20, 2015	Unacceptable in New Light-Duty Systems as of Model Year (MY) 2021, except where allowed under a narrowed use limit through MY 2025. Acceptable, subject to narrowed use limits, for vehicles exported to countries with insufficient servicing infrastructure to support other alternatives, for MY 2021 through MY 2025. Unacceptable for all newly manufactured vehicles as of MY 2026. Detailed conditions apply - see Rule.
R-406A	GHG	R/N	October 16, 1996; July 20, 2015	Unacceptable in New Light-Duty Systems as of MY 2017. Detailed conditions apply - see Rule.
R-414A	GHG-X4, HCFC Blend Xi, Autofrost, Chill-it	R	October 16, 1996; July 20, 2015	Unacceptable in New Light-Duty Systems as of MY 2017. Detailed conditions apply - see Rule.

R-414B	Hot Shot, Kar Kool	R/N	October 16, 1996; July 20, 2015	Unacceptable in New Light-Duty Systems as of MY 2017. Detailed conditions apply - see Rule.
R-416A	FRIGC FR-12, HCFC Blend Beta	R/N	June 13, 1995; July 20, 2015	Unacceptable in New Light-Duty Systems as of MY 2017. Detailed conditions apply - see Rule.
R-426A	RS-24	R/N	September 28, 2006; July 20, 2015	Unacceptable in New Light-Duty Systems as of MY 2017. Detailed conditions apply - see Notice.
SP34E	SP34E	R/N	December 18, 2000; May 23, 2001; July 20, 2015	Unacceptable in New Light-Duty Systems as of MY 2017. Detailed conditions apply - see Notice; Use of new fittings for small refrigerant cans required.

Table 8. Acceptable MVAC Refrigerant Alternatives as of July 2015

Substitute	Trade Name	Retrofit/New	SNAP Listing Date	Use Conditions
Evaporative Cooling		N	March 18, 1994	
HFC-152a		N	June 12, 2008	Detailed conditions apply - see Rule
HFO-1234yf		N	March 29, 2011	Detailed conditions apply - see Rule
Ikon A	Ikon-12, Blend Zeta	R/N	May 22, 1996	Detailed conditions apply - see Rule
R-401C		R/N	June 13, 1995	
R-744 (Carbon Dioxide, CO2)		R/N	June 6, 2012	Detailed conditions apply - see Rule
Small auxiliary power units that include an engine, electrical alternator, water pump, air conditioning compressor and a heat exchanger used in tractor trailers in conjunction with passenger compartment climate control systems that already use an acceptable substitute refrigerant.		R/N	June 19, 2000	
Stirling Cycle		N	March 18, 1994	

There are no drop-in refrigerant replacements. Some refrigerant blend manufacturers have chosen trademarks that could give the impression their "new" refrigerant is a drop-in for R-12 and have even incorporated the "12" as part of their name (FREEZE-12 for example). However, using any substitute refrigerant requires as a minimum that the high-side and low-side service ports be permanently changed to the SNAP-designated fittings (Table 9) and the system be re-labeled to indicate the replacement refrigerant contained in the MVAC system (Table 10). That means no refrigerants can simply be charged into a CFC-12 or HFC-134a system without any hardware changes!

Even though replacement blends are on the market that will supposedly replace R-12 with minimal retrofitting, Mainstream is not aware of any automotive manufacturer to this date that has approved a refrigerant blend for an R-12 system. R-134a is still recognized as the refrigerant of choice for new mobile air conditioning systems. While no single refrigerant or blend is a direct drop-in for R-12 in automotive air conditioning systems, R-134a is still the choice for R-12 retrofit systems. There is always the need for some retrofitting of the system including labels and fittings. The new climate-friendly alternatives are not approved for use as retrofits—they are only approved for new systems. Finally, most blends and their lubricants are not compatible with existing R-12 or R-134a systems and will require separate service equipment. Recharging a blend is also quite different, you must always recharge as a liquid.

System Retrofits

Introduction

Never attempt to put any retrofit refrigerant into an existing R-12 automotive system without first retrofitting the system. Retrofit changes may include larger condenser surface areas to control head pressures, a high-pressure cut-out device for safety concerns, different style hoses, newly designed filter-driers, a new compressor, and different internal seals in the compressor and/or other internal parts. Always follow the original equipment manufacturer's recommendations to avoid injury and voiding a warranty. Always use the retrofit refrigerant that has been approved by the original vehicle air conditioning manufacturer.

Although section 609 of the Clean Air Act does not govern retrofitting, Section 612 of the Clean Air Act (which describes the agency's SNAP program), does require that when retrofitting a CFC-12 vehicle for use with another refrigerant, the technician must first extract the CFC-12, must cover the CFC-12 label with a label that indicates the new refrigerant in the system, and must affix new fittings that are unique to the new refrigerant.

In addition, if a technician is retrofitting a vehicle with a refrigerant that contains R-22, the technician must ensure that only barrier hoses are used in the A/C system and if the system includes a pressure relief device, the technician must install a high pressure compressor shutoff switch to prevent the compressor from increasing pressure until the refrigerant is vented.

More information about the SNAP program and about retrofitting procedures is available in an EPA fact sheet, “Choosing and Using Alternative Refrigerants,” which is available through the EPA website **https://www.epa.gov/mvac**. The Society of Automotive Engineers (SAE) also has several useful documents including SAE Document J1660, “Fittings and Labels for Retrofit of R-12 Mobile Air Conditioning Systems to R-134a” and SAE Document J1661, “Procedures for Retrofitting R-12 Mobil Air Conditioning Systems to HFC-134a.” The EPA has additional materials available on retrofit procedures at **https://www.epa.gov/mvac/choosing-and-using-retrofit-refrigerant-cfc-12-motor-vehicle-air-conditioner-mvac**.

Other changes could also be necessary such as new seals, hoses, lubricant, and additional safety devices. The EPA has several publications available on their website (**https://www.epa.gov/mvac**) that discuss compressor replacements, retrofit procedures, sources for retrofit training, and common questions and answers. Temporary adaptors to override the unique fittings on MVAC systems should never be used. If a system is properly reworked to accommodate a new replacement refrigerant, the fittings and labels on the system must be permanently changed to alert future technicians that might be servicing the system.

SNAP Requirement for Unique Service Fittings

As part of the SNAP regulations, the EPA requires that each new refrigerant must be used with a unique set of fittings to prevent the accidental mixing of different refrigerants. These unique service fittings are required at the high- and low-side service ports on the car itself, on all recovery and recycling equipment, and on the refrigerant containers. If the car is being retrofitted, any service fittings not converted to the new refrigerant must be permanently disabled. Unique fittings help protect the consumer by ensuring that only one type of refrigerant is used in each car and are used in new systems as well as retrofit systems. They also help protect the purity of the recycled supply of CFC-12, which means it will last longer, so fewer retrofits will be necessary nationwide. These fittings are attachment points on the car itself, on all recovery and recycling equipment, on can taps and other charging equipment, and on all refrigerant containers. An adapter should not be used to convert a fitting.

Unique fittings are a general SNAP requirement for MVAC refrigerants and are listed in Table 9. They are an important part of the retrofitting process, but the requirements also apply to new systems.

Table 9. Fitting Sizes for Motor Vehicle A/C Refrigerants

	High Side Service Port		Low Side Service Port			30-lb. Cylinders				Small Cans		
Refrigerant	Diameter (inches)	Pitch (threads/inch)	Thread Direction	Diameter (inches)	Pitch (threads/inch)	Thread Direction	Diameter (inches)	Pitch (threads/inch)	Thread Direction	Diameter (inches)	Pitch (threads/inch)	Thread Direction
CFC-12 (post-1987)	3/8	24	Rt.	7/16	20	Rt.	7/16	20	Right	3/8	24	Right
CFC-12 (pre-1987)	7/16	20	Rt.	7/16	20	Rt.	7/16	20	Right	7/16	20	Right
FREEZE 12	7/16	14	Left	1/2	18	Rt.	1/2	18	Right	3/8	24	Right
Free Zone/RB-276	1/2	13	Rt.	9/16	18	Rt.	9/16	18	Right	3/8	24	Left
Hot Zone	5/8	18	Left	5/8	18	Rt.	5/8	18	Right	Not sold in small cans.		
GHG-X4	.305	32	Rt.	.368	26	Rt.	.368	26	Right	14mm	1.25mm spacing	Left
GHG-X5	1/2	20	Left	9/16	18	Left	9/16	18	Left	Not sold in small cans.		
R-406A	.305	32	Left	.368	26	Left	.368	26	Left	1/2	20	Left
GHG-HP	Not yet developed											
IKON	Not yet developed											
HFC-134a	Quick-connect			Quick-connect			1/2	16 Acme	Right	1/2	16 Acme	Right
FRIGC	Quick-connect, different from HFC-134a			Quick-connect, different from HFC-134a			1/2	20	Left	7/16	20	Left
HFO-1234yf	Outside diameter 17 +0/-0.2mm Quick-connect consistent with J639 (2011 version)			Outside diameter 14 +0/-0.2mm Quick-connect consistent with J639 (2011 version)			1/2 Quick-connect consistent with SAE J 2844 (2011)	60	Left^	Not yet developed *		

R-152a	Outside diameter 15 +0/-0.2mm Quick-connect consistent with J639 (2011 version)	Outside diameter 14.1 +0/-0.2mm⁺ Quick-connect consistent with J639 (2011 version)	Not yet developed*	Not yet developed*
R-744 CO_2	Outside diameter 18.1 +0/-0.2 mm⁺ Quick-connect consistent with J639 (2011 version)	Outside diameter 16.6 +0/-0.2 mm Quick-connect consistent with J639 (2011 version)	20.955 +0/-0.127 mm (0.825 +0/-0.005 inches) and right-hand thread direction	Not yet developed *

^ This unique fitting applies to containers of HFO-1234yf for professional servicing only (77 FR 17344)

* Unique fittings have not yet been developed. Additional information must be submitted to the EPA, and unique fittings must be approved prior to commercialization.

⁺ HFC-152a and R-744 service fittings are provisional pending final production, commercialization, and use of the refrigerant.

Label Requirements for Retrofits

When a new refrigerant is retrofitted, the technician must apply a detailed label giving specific information about the retrofitted refrigerant. The label's background color is chosen by the refrigerant manufacturer to be unique, and the label colors for each refrigerant are listed in an EPA fact sheet titled "Fitting Sizes and Label Colors for Motor Vehicle Refrigerants." The label for the old refrigerant must be covered or removed. The retrofit label shows:

- the name and address of the technician and the company performing the retrofit;
- the date of the retrofit;
- the trade name, charge amount, and, when applicable, the ASHRAE numerical designation of the refrigerant;
- the type, manufacturer, and amount of lubricant used; and
- if the refrigerant is or contains an ozone-depleting substance, the phrase "ozone depleter."

Table 10 provides a list of refrigerant label background colors. Historically, EPA established a specific label color for each refrigerant as part of its SNAP approval. Table 10 includes only those refrigerants for which EPA required use of a specific label color as part of the listing decision. This table does not include all MVAC refrigerants, such as those for which labeling was never developed. Also, the use conditions for HFO-1234yf, R-744 (CO_2), and HFC-152a require compliance with SAE J639, which specifies the marking required on labels, but not unique label colors. These refrigerants are not included in Table 10 but must be labeled in accordance with SAE J639.

Table 10. Refrigerant Label Background Colors

Refrigerant	Background Color
CFC-12	White
HFC-134a	Sky Blue
Freeze 12	Yellow
Free Zone / RB-276	Light Green
Hot Shot	Medium Blue
GHG-X4	Red
R-406A	Black
GHG-X5	Orange
GHG-HP	not yet developed*
Ikon-12 / Ikon A	not yet developed*
FRIGC FR-12	Grey
SP34E	Tan
R-426A (RS-24, new formulation)	Gold
R-420A	Dark green (PMS #347)

* These refrigerants have not been marketed yet; therefore, label colors have not been developed.

The information required for each label is listed in EPA's fact sheet Choosing and Using Alternative Refrigerants for Motor Vehicle Air Conditioning.

Lubricant Change-Over

One of the most important system changes is the lubricant. The lubricant used in a system should always be identified on the unit because of potential lubricant incompatibilities. The mineral oils used with R-12 are not adequately circulated through the A/C system when R-134a is the refrigerant. Automobile manufacturers have tested both PAGs and esters for refrigerant/lubricant miscibility, lubricity, chemical stability and materials compatibility. In the process of developing recommendations, they also considered the additives and conditioners present in the oils. Most of the compressor manufacturers chose to use PAG lubricants in new vehicles equipped with R-134a. Some compressor manufacturers are shipping new compressors with PAGs, some with esters, and some are shipping them empty.

PAG oils are hygroscopic, which means that they will draw water from the atmosphere when exposed. Many aftermarket A/C specialists are choosing to use ester lubricants (POE oils) instead of PAGs, because they believe that the hygroscopic characteristics of PAGs may limit their lubricating ability and introduce corrosion into the A/C system. POE lubricants are also hygroscopic (although less so than PAGs), and care must still be taken to ensure that excess moisture does not go into the system.

It is good practice to use PVC-coated gloves and safety goggles when handling these lubricants, since prolonged skin contact or even brief eye contact can cause irritations such as stinging and burning sensations. You should also avoid breathing any vapors produced by the lubricants, and make sure to use them in well ventilated areas. Keep both PAGs and POE's in tightly sealed containers, both so that humidity does not contaminate the oil, and so that the vapors do not escape.

The amount of mineral oil that can safely remain in a system after retrofitting, without affecting performance, is still being debated. It was originally thought that 1 to 5% of mineral oil left in the system was acceptable and that any more mineral oil than that could cause compressor failure. Removing the mineral oil may require draining certain components. Unless the vehicle manufacturer recommends flushing the system during the retrofit procedure, a service technician can assume that flushing is not necessary. (Although the SAE J1661 procedure for retrofit includes flushing, according to the EPA's website, SAE no longer believes that flushing is critical to a successful retrofit.)

Hoses and O-Rings

When R-134a was first introduced, it was thought that all non-barrier/nitrile hoses would have to be replaced during an AC retrofit. Early laboratory tests showed that the small R-134a molecules leaked through the walls of non-barrier hoses more readily than the larger R-12 molecules did. In the laboratory, this caused unacceptably high leakage rates. More recent testing, however, has shown that oils used in automotive MVAC systems are absorbed into the hose to create a natural barrier to R-134a permeation. Therefore, R-12 system hoses will perform well, provided they are in good condition. Procedures for numerous hose tests are detailed in SAE J2064 for R-134a systems and in SAE J2888 for R-1234yf systems. Cracked or damaged hoses should always be replaced with new barrier hoses. Most retrofit instructions call for lubricating replaced O-rings with mineral oil to provide this natural barrier protection.

Desiccants Change-Out during R-134a Retrofit

An MVAC system, like any other vapor compression A/C system, utilizes a filter/drier to remove moisture and acid from the system. These filter/dryers also known as desiccants in the MVAC industry no longer function when they are saturated with moisture or acid. R-12 systems typically use an XH-5 desiccant, while R-134a systems use either an XH-7 or XH-9 desiccant. Some manufacturers recommend routine replacement of the drier to one containing XH-7 or XH-9 during the retrofit procedure. (Any systems with silica gel desiccant MUST be switched to XH-7 or -9 desiccant during the R-134a retrofit.) Manufacturers generally agree desiccant or filter/drier should be replaced if the vehicle has over 70,000 miles or is older than five years, and is opened up for major repair. In that case use the R-134a-compatible desiccants.

Misleading Use of "Drop-in" to Describe Refrigerants

Many companies use the term "drop-in" to mean that a substitute refrigerant will perform identically to CFC-12, that no modifications need to be made to the system, and that the alternative can be used alone or mixed with CFC-12. However, EPA believes the term confuses and obscures several important regulatory and technical points. First, charging one refrigerant into a system before extracting the old refrigerant is a violation of the SNAP use conditions and is, therefore, illegal. Second, the fittings and labels on a system must always be changed if the refrigerant type is changed. Third, certain components may be required by law, such as new hoses and compressor shutoff switches. For all of these reasons, EPA does not use the term “drop-in” to describe any alternative refrigerant.

Barrier Hoses for R-22 Retrofit Blends

R-22 also referred to as HCFC-22 can seep out through traditional hoses. Therefore, when using any refrigerant blend containing R-22, the technician must ensure that new less permeable "barrier" hoses are used. These hoses must be installed if the system currently uses non-barrier hoses.

Compressor Shut-Off Switches

Some MVAC systems have a pressure relief device that automatically releases refrigerant to the atmosphere to prevent extremely high pressures. When retrofitting any system with such a device to use a new refrigerant, the technician must also install a high-pressure shutoff switch. This switch will prevent the compressor from increasing the pressure to the point where the refrigerant is vented.

For More Information on Retrofitting

EPA's website (**https://www.epa.gov/mvac**) provides numerous fact sheets and brochures to help you better understand how to choose and use retrofit refrigerants.

Lubricants

The majority of HFC-134a automotive air conditioning systems use polyalkylene glycols, (PAG), as the lubricant. The conventional R-12 systems used mineral oil lubricants. However, more and more polyol ester (POE) lubricants are being researched and used in mobile applications and are quickly becoming the second generation lubricant with automotive air conditioning systems incorporating R-134a as the refrigerant. PAGs and POEs are very different from the mineral oil lubricants used in conventional R-12 automotive air conditioning systems of the past.

Ever since R-134a/PAG and R-134a/POE automotive air conditioning systems have entered the market, the service technician has had to pay close attention to which PAG or POE lubricant package is specified for a particular vehicle. Even though most automotive R-134a systems may use a PAG or POE-based stock lubricant, not all lubricant additive packages are the same, and may not be compatible from vehicle to vehicle. Whether the system is new or retrofitted, the service technician must use only the air conditioning manufacturer or vehicle's specified lubricant package. If the system is a newer one, the specified lubricant will be identified on an identification tag located in the engine compartment or on the air conditioning system itself. Never mix lubricants in a system, and be careful to avoid unintentional mixing of lubricants in the recovery equipment, cylinders, hoses, and manifold sets. Mixing lubricants can cause serious air conditioning system problems. The proper amount of lubricant is also a very important consideration. If overcharged with lubricant, the system will become oil logged and less efficient, delivering warmer air, or may result in premature compressor failure. Many individuals believe the high incidence of compressor failure in the automotive industry is at least in part caused by lubrication overcharge.

When servicing R-134a systems, it is imperative that care be taken to assure that air and moisture contamination to PAG and POE oils be kept to an absolute minimum. Keep the oil containers closed and hoses sealed-off when not in use. PAG and POE lubricants readily absorb moisture when left exposed to the air. By SAE standards, different hoses are used for R-12 and R-134a systems thereby making it harder to cross contaminate refrigerants. But R-134a systems could be using POE or PAG oils and cross contamination of the oil can result in unwanted chemical reactions in the system and refrigerant breakdown and material corrosion. Always use the lubricant specified by the manufacturer to avoid cross contamination of the oil. If you routinely use more than one type of HFC-134a lubricant, then in order to prevent cross contamination from the oil in the hoses, we suggest using designated separate manifold gauge sets for R-134a with PAG oil and R-134a with POE oils. Remember to always tag the system with the refrigerant and oil being used in the system.

PAG lubricants are used with HFO-1234yf. According to SAE J2843, the lubricant should be PAG ISO 100, PAG ISO 46-55, or equivalent and should contain no more than 1,000 ppm by weight of moisture. POE lubricants are used in some hybrid vehicles. Only new lubricant can be installed in a MVAC system. Lubricant removed from the system and/or the equipment must be disposed of in accordance with the applicable federal, state, and local regulations.

PAG and POE lubricants can be used in R-152a systems, as R-152a is very similar to R-134a. However, HFC refrigerants, such as R-152a, may benefit from using polyvinyl ether (PVE) lubricants. Using traditional POE lubricants in CO_2 systems may result in significantly reduced viscosity, while non-traditional POEs may cause problems with the air conditioning components over time. The optimal lubricant has yet to be designed to meet the needs of a CO_2 system.

Removing Moisture

As stated above, the new synthetic oils have a much higher attraction for water than did the mineral oils of yesteryear. Moisture in a system, if not removed by the water absorption material in the filter-drier, can freeze at the expansion device and clog the system. Always replace the filter-drier when opening-up a system for repair and never reuse lubricant.

When moisture is excessive a vacuum pump is used to remove moisture from a system before the lubricant and refrigerant is replaced into the system. Moisture can be in either a vapor or liquid state in the system. When the moisture is in the vapor state, it is easy to remove; however, when the moisture is in the liquid state, it is much harder to remove because it must be vaporized, and the vaporization of water in the system further reduces the remaining water temperature, which makes further evaporation more difficult.

For example, if liquid water in the system is initially at 80°F, then the saturation pressure of the water is 28.87 inches of mercury. The vacuum pump must therefore achieve a pressure of at least 28.87 inches of mercury for this liquid water to boil off. As the water cools to 70°F the saturation pressure of the water becomes 29.16" Hg and the vacuum pump must achieve a pressure of 29.16" Hg for the remaining water to boil off. Once again, however, the further evaporation of water will further cool the remaining water. If the water is cooled to 50°F, then the vacuum pump must achieve a pressure of 29.54 for the remaining water to boil off. As you can see, it becomes very difficult to remove liquid water from the system, and if the water evaporates too fast, it will cool below the freezing point of water and freeze, essentially halting vaporization.

If moisture must be removed, the following guidelines may be helpful.

1. Use a vacuum pump with clean vacuum pump oil. (Dirty vacuum pump oil will limit the vacuum achievable by the vacuum pump.)
2. Do not add the air conditioner's compressor oil back into the system until after the evacuation. If you add it earlier, the oil may become wet and hard to evacuate. The new POE oils have a very high affinity for water.

3. Use a heat lamp to apply heat to the system. The entire system, including the interconnecting piping, must be heated to a warm temperature or the water will boil to a vapor where the heat is applied and condense where the system is cool. If this happens the water is just being moved around, but not being removed.
4. Start the vacuum pump and observe the oil level in it. As moisture is removed, some of it will condense in the vacuum pump's crankcase. Some vacuum pumps have a feature called gas ballast, which introduces some atmosphere between the first and second stages of the two-stage pump. (This is typically not necessary in automotive applications.) This prevents some of the moisture from condensing in the vacuum pump's crankcase. Regardless of the vacuum pump, watch the oil level. Over a period of time, water in the vacuum pump will displace the oil and raise the oil out of the pump. Eventually, water may be the only lubricant in the vacuum pump crankcase, and damage may occur to the vacuum pump. Since automotive systems typically do not have tremendous quantities of water in the system, if you change the vacuum pump oil on a periodic basis, you will avoid this problem. (Check the vacuum pump oil for water when you replace the oil.)
5. Isolate the system, and crack the line to the vacuum pump, before turning the vacuum pump off. This allows air to enter the line thereby keeping vacuum pump oil from being drawn into the hose.

Non-condensable Gas Determination and Removal

If the refrigerant temperature is known and the measured pressure is above the saturation pressure (for that temperature), then the refrigerant is contaminated with either non-condensable gases or another refrigerant. SAE has developed a Recycled Refrigerant Checking Procedure to determine if non-condensable gases are present in refrigerant contained in a portable recovery cylinder. This procedure is not to be used on refrigerant that is still located in the A/C unit. The procedure is discussed in detail in SAE Standard J1990 and key features are repeated below.

1. To determine if the recycled refrigerant, in a recovery container, has excess non-condensable gases (air), the container must be stored at a relatively constant temperature of 65°F, or above for at least 12 hours and protected from exposure to direct sun.
2. Install a calibrated pressure gage, with 1 psig divisions, to the container and determine the container pressure.
3. With a calibrated thermometer, measure the air temperature within 4 inches of the container surface.
4. Compare the observed container pressure and air temperature to values on the Non-Condensable Determination Table, to determine if the container exceeds the pressure limits found on the appropriate table. If the refrigerant is R-12 use Table

11, if the refrigerant is R-134a use Table 12 (For Example: for a measured air temperature 70°F, the pressure of a R-12 recovery tank must not exceed 80 psig).

5. If the container pressure is less than the appropriate table value the non-condensable gas limit has not been exceeded for the refrigerant.
6. If the measured pressure is greater than the appropriate table value, very slowly recover, from the top of the container, a small amount of vapor into the recycle equipment, until the pressure is less than the pressure shown on the appropriate table. (Recovery must be performed very slowly; otherwise, the container will cool itself and alter the refrigerant temperature.) If this self-cooling does occur, the container must be given time to reach a stable temperature again, that is repeat the procedure from Step 1.)
7. If the container still exceeds the pressure shown on the appropriate table, the entire contents of the container must be recycled.

Table 11. R-12 Non-condensable Determination Table

Temp °F	PSIG	Temp °F	PSIG	Temp °F	PSIG
65	74	**79**	94	**93**	115
66	75	**80**	96	**94**	116
67	76	**81**	98	**95**	118
68	78	**82**	99	**96**	120
69	79	**83**	100	**97**	122
70	80	**84**	101	**98**	124
71	82	**85**	102	**99**	125
72	83	**86**	103	**100**	127
73	84	**87**	105	**101**	129
74	86	**88**	107	**102**	130
75	87	**89**	108	**103**	132
76	88	**90**	110	**104**	134
77	90	**91**	111	**105**	136
78	92	**92**	113	**106**	138

Table 12. R-134a Non-Condensable Determination Table

Temp °F	PSIG	Temp °F	PSIG	Temp °F	PSIG
65	69	**79**	90	**93**	115
66	70	**80**	91	**94**	117
67	71	**81**	93	**95**	118
68	73	**82**	95	**96**	120
69	74	**83**	96	**97**	122
70	76	**84**	98	**98**	125
71	77	**85**	100	**99**	127
72	79	**86**	102	**100**	129
73	80	**87**	103	**101**	131
74	82	**88**	105	**102**	133
75	83	**89**	107	**103**	135
76	85	**90**	109	**104**	137
77	86	**91**	111	**105**	139
78	88	**92**	113	**106**	142

Automotive Hose Assemblies

SAE standards J2064, J2196, J2197, and J2888 provide the necessary information for hose assemblies and repairs. All parts used should be stamped as being SAE compliant.

Basic Design of Automotive Hose Assemblies

Automotive air conditioning systems utilize a combination of metal tubing and rubber hoses. The rubber hoses are connected to the metal tubing with a barbed tubular section that is inserted into the rubber hose. The barbs are necessary to keep the metal tube from sliding out of the hose, when the system is pressurized. The rubber hose with the barbed tube inserted inside is then clamped with a metal ferrule. The ferrule is crimped to a smaller diameter thus clamping the rubber hose to the metal tube. The refrigeration hose is a special barrier type hose that is compatible with refrigerants in the system, capable of sustaining the worst case system pressures, and has low refrigerant permeability.

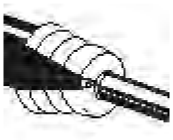
Leak Checking

When leak checking any part of the system, always look for oil deposits, since an oil residue typically indicates a source of leaks. This is because both oil and refrigerant leak out, but the refrigerant vaporizes leaving an oil residue. If a leak is discovered in the rubber hose or at the point where the rubber hoses attaches to the metal tube, the hose assembly should be repaired or replaced. In many cases the metal tubing portion of the plumbing assembly is not damaged, rather it is the flexible hose that is leaking. In this case the rubber hose can be replaced, provided the same type of hose can be obtained. Many aftermarket suppliers offer replacement barrier refrigerant hoses along with the necessary hose clamping tools and instructions. Always verify that the replacement hose is compatible with the actual refrigerant being used in the A/C system. HCFC-22, a component in some blends, and can seep out through many common traditional hoses. Therefore, when using a blend, verify that the new, less permeable barrier hoses developed specifically for HCFC-22 are used. These hoses must also be installed if the system currently uses old, non-barrier hoses and the refrigerant is being changed.

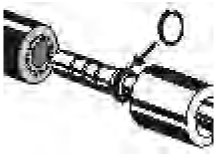
Hose Repairs

To replace the rubber hose on an A/C plumbing assembly requires a hose repair kit. Never attempt to crimp the metal ferrule with a vice or pliers, and never use a radiator hose clamp on the refrigeration hoses. Never use air hoses for refrigerant. Always, follow the hose repair crimping tool instructions supplied with the actual kit. The hose repair procedure can be generally described in a four step process.

Step 1. Cut the original ferrule, so that the ferrule can be spread open and removed from the hose.



Step 2. Remove the barbed tube from inside the rubber hose. This may require cutting the rubber hose to free the barbed tube. If the hose is cut, be careful not to scribe a line in the tube while cutting the hose free. If the barbed tube does get scratched, it will be a source of leaks and the tube will have to be replaced. The barb must be cleaned of any old hose debris before reusing. Inspect the barb to be sure there are no rough edges, replace the metal tube assembly, if necessary.



Step 3. Install a new replacement ferrule onto the metal hose as well as a new retaining ring. Then slide the barbed section of the tube into the new rubber hose. Never reuse an old hose. Be sure that the hose is slide all the way onto the barb.

Step 4. Using the crimping tool (supplied for the ferrule and hose diameter being used), crimp the ferrule onto the hose.

Step 5. After replacing the tubing assembly, leak check the system with nitrogen, before recharging the system with refrigerant.

Key Recommended Recovery/Recycle Service Procedures

1. Verify the vehicle air conditioner has refrigerant pressure. (If no pressure is present in the system, do not use the recovery unit.)
2. Reduce system pressure until a vacuum is reached and held.
3. Heat, (from a heat lamp), may be applied if the system shows evidence of icing. Never heat with an open flame.
4. Determine the amount of lubricant removed during the refrigerant removal process and add new lubricant. (Discard used lubricant, Never Reuse Lubricant)

Recommended Service Procedures for Using a Manifold Gauge Set

1. High-, low- and center-service hoses must have shut-off valves within 12 inches (30 cm) of their service ends. These valves must be closed prior to hose removal from the air conditioning system. This will reduce the volume of refrigerant that would otherwise be vented to the atmosphere.
2. During all service operations, the valves should be closed until connected to the vehicle air conditioning system or the charging source to avoid introduction of air and to contain the refrigerant, rather than vent to the atmosphere.
3. When the manifold gauge set is disconnected from the air conditioning system or when the center hose is moved to another device that cannot accept refrigerant pressure, the gauge set hoses should first be attached to the recovery/recycling equipment, to recover the refrigerant from the hoses.
4. Never trap liquid refrigerant in a hose. As the refrigerant heats up during the day, the increase in pressure can cause the hose to burst.

Recovery-Only Equipment Requirements

R-12 Recovery-Only Equipment

Refrigerant recovery equipment must be certified by to meet the appropriate recovery standard. Equipment that recovers but does not recycle CFC-12 refrigerant must meet SAE standard J2209. The key functions are described below.

1. The recovery equipment must be capable of removing a minimum pressure of 102 mm of Mercury below atmospheric pressure.
2. The equipment must be capable of continuous operation in ambient temperatures between 50°F and 120°F.
3. The equipment must be able to separate lubricant from recovered refrigerant and accurately indicate the amount removed from the system.
4. Since January 1, 1992, all recovery hoses must meet SAE J2196 specifications and must have a shut-off device within 12 inches (30 cm), of the connection point to the MVAC.
5. The equipment must have an 80% full shut-off device and a mechanical pressure relief valve.
6. The equipment must meet be certified to meet the SAE J2209 standard.
7. The EPA will maintain a list of approved equipment by manufacturer and model.

R-134a Recovery-Only Equipment

Since October 31, 2008, equipment that recovers but does not recycle HFC-134a refrigerant must be certified to meet EPA requirements as set forth in SAE standard J2810, HFC-134a (R-134a) Recovery Equipment Mobile Air-Conditioning Systems. The following key functions are described:

1. The recovery equipment must be capable of removing a minimum of 95% of the refrigerant from the test system in 30 minutes or less.
2. The equipment must be capable of continuous operation in ambient temperatures between 50°F and 120°F.
3. The equipment must be able to separate lubricant from recovered refrigerant and accurately indicate the amount removed from the system.
4. Since January 1, 1992, all recovery hoses must meet SAE J2196 specifications and must have a shut-off device within 12 inches, (30 cm), of the connection point to the MVAC.
5. The equipment must have an 80% full shut-off device and a mechanical pressure relief valve.
6. The equipment must meet be certified to meet the SAE J2810 standard.
7. The EPA will maintain a list of approved equipment by manufacturer and model.

The purpose of SAE standards for the recovery equipment is to provide minimum performance and operating feature requirements for the recovery machines used to recover refrigerant that is to be returned to a refrigerant reclamation facility that will process it to the appropriate AHRI 700 Standard or allow for recycling of the recovered refrigerant to SAE specifications by using certified recovery and recycling equipment.

Refrigerant removed from a MVAC system with recovery equipment cannot be returned to a mobile A/C system because recycling (with a certified unit) is required before used refrigerant can be returned to a system.

Recovery/Recycling Equipment Requirements

R-12 Recovery/Recycling Equipment

Refrigerant recovery/recycling equipment must be certified by the EPA Administrator or an independent organization approved by the Administrator to meet the appropriate recovery standard. Equipment that recovers and recycles CFC-12 refrigerant must meet SAE standard J1990. The following key functions are described:

1. The recovery equipment must be capable of removing a minimum pressure of 102 mm of Mercury below atmospheric pressure.
2. The equipment must be capable of continuous operation in ambient temperatures between 50°F and 120°F.
3. The equipment must be able to separate lubricant from recovered refrigerant and accurately indicate the amount removed from the system, in 30mL units.
4. Since January 1, 1992, all recovery hoses must meet SAE J2196 specifications and must have a shut-off device within 12 inches, (30 cm), of the connection point to the MVAC.
5. The equipment must have an 80% full shut-off device and a mechanical pressure relief valve.
6. The equipment must meet be certified to meet the SAE J1990 standard.
7. The equipment must purify refrigerant to SAE J1991 Standard.
8. The EPA will maintain a list of approved equipment by manufacturer and model

R-134a Recovery/Recycling or Recovery/Recycling/Recharging Equipment

Since January 1, 2008, equipment that recovers and recycles HFC-134a refrigerant and equipment that recovers and recycles HFC-134a refrigerant and recharges systems with HFC-134a refrigerant must be certified to meet EPA requirements as set forth in SAE standard J2788, HFC-134a (R-134a) Recovery/Recycling Equipment and Recovery/Recycling/Recharging for Mobile Air-Conditioning Systems.

In the past, recovery/recycling equipment for MVAC applications was designed to meet SAE standard J2210. However, an industry sponsored research project has shown that equipment that was designed to meet this SAE standard (J2210) would not recover all the refrigerant from MVAC systems. This study indicated that as much as 30% of refrigerant remained in an MVAC system, while the SAE J2210 certified recovery equipment indicated all refrigerant had been recovered. While the “proper” procedure to follow after opening a system for repair is to perform a triple evacuation of the system to remove residual moisture or refrigerant, many MVAC service technicians skip this step, electing instead to rely on the recovery machine to completely evacuate the system.

It appears that in cases where only the refrigerant charge was being removed and replaced, the MVAC recovery recycling machine was being used to recover the system, evacuate the system and recharge the system. In these cases, if the MVAC service technicians relied on the refrigerant recovery recycling machine to assure complete recovery, a failure to properly recovery all the refrigerant could lead to a system overcharging by as much as 30%.

To remedy this potential problem, the SAE has revised its requirements for recovery recycling machines. The SAE replaced standard J2210 with standard J2788 in October 2006. SAE standard J2788 encompasses all of the features of J2210, while adding additional standards on recharging of MVAC systems, and adding performance standards to improve equipment refrigerant recovery performance. SAE Standard J2788 includes a recharge accuracy requirement of 0.5 ounce and requires approved designs to be tested to ensure they recover 95% of the refrigerant from an MVAC system.

The EPA has updated the recovery recycling requirements reference from J2210 to J2788 for recovery/recycling equipment and for recovery/recycling/recharging equipment. In addition, for purposes of clarity, EPA has added a clause to Section 82.34 (prohibitions and required practices), which specifies that equipment manufactured or imported must meet the SAE standards.

Currently the EPA regulations under Sec. 82.36 (Approved refrigerant recycling equipment) encompass more than just refrigerant recycling and includes refrigerant recovery. Therefore, to more accurately reflect the provisions outlined in that section, EPA is revising the title of Sec. 82.36 from “Approved refrigerant recycling equipment'' to “Approved refrigerant handling equipment.''

While the EPA has updated the refrigerant handling equipment requirements, it did not require an immediate replacement of previously certified MVAC recovery and recovery/recycling equipment with new J2788 certified equipment. Rather, all new MVAC recovery/recycling and recovery/recycling/recharging equipment for MVAC systems manufactured after December 31, 2007 must be certified to J2788. MVAC shop owners are not required to replace their old J2210 certified equipment; however, they might decide to replace old J2210 equipment with the new J2788 equipment because of the additional refrigerant savings that translate into a cost savings. According to the January 2007 Mobile Air Conditioning Society Worldwide (MACS) Service Report, the new J2788 equipment will result in a 30% to 50% refrigerant savings because the equipment will recover more refrigerant from an MVAC system. The recovered refrigerant can be recycled for future use, rather than buying new refrigerant.

The complete functional description of recovery/recycling and recovery/recycling/recharging equipment for MVAC applications is more fully explained in SAE Standard J2788 (section 7, page 4); however, the key functions are described below.

1. The recovery equipment must be capable of removing a minimum of 95% of the refrigerant from the test system in 30 minutes or less.
2. The equipment must be capable of continuous operation in ambient temperatures between 50°F and 120°F.
3. The equipment must be able to separate lubricant from recovered refrigerant and accurately indicate the amount removed from the system.
4. The refrigerant recovered, after oil separation, must be measured and the quantity displayed. The quantity displayed, which represents the actual refrigerant removed, must be accurate to within plus or minus one ounce (30 grams).
5. Since January 1, 1992, all recovery hoses must meet SAE J2196 specifications and must have a shut-off device within 12 inches, (30 cm), of the connection point to the MVAC.
6. The equipment must have an 80% full shut-off device and a mechanical pressure relief valve.
7. The equipment must meet be certified to meet the SAE J2788 standard.
8. The equipment must purify refrigerant to SAE Standards.
9. The EPA will maintain a list of approved equipment by manufacturer and model.

R-1234yf Recovery/Recycling Equipment

Recharge equipment and procedures for R-1234yf are different from those used for other systems. Refrigerant recovery/recycling equipment must be certified by the EPA administrator or an independent organization approved by the administrator to meet the appropriate recovery standard. Equipment that recovers and recycles R-1234yf refrigerant must meet SAE standards J2843 and J2851. The following key functions of the equipment are described:

1. The equipment must have a desiccant package that is to be replaced before saturation with moisture and whose mineral acid capacity is at least 5% by of the dry desiccant.
2. The equipment must incorporate an in-line filter that will trap particulates of 15 micron spherical diameter or greater.
3. The equipment must feature an integrated refrigerant identifier or USB port for connection with a handheld identifier.

4. Service couplers must be designed to SAE J2888 specifications to avoid cross connection with non-R-1234yf vehicle ports.
5. The equipment must be capable of continuous operation in ambient temperatures between 50°F and 120°F (10°C and 50°C).
6. Pressure-indicating devices used to identify non-contaminant gas levels must have readable division of 7 kPa.
7. The equipment must be able to remove a minimum of 95% of the refrigerant from the test system in 30 minutes or less, without prior engine operation (previous eight-hour minimum) or external heating or use of any device (such as shields, reflectors, special lights, et.) that could heat components of the system. Ambient temperature should be 21°C to 13°C (70°F to 75°F).
8. The equipment must be able to remove a minimum of 85% of the refrigerant from the test system in 30 minutes or less at an ambient temperature of 10°C to 13°C (50°F to 55°F).
9. The equipment must separate oil from the refrigerant, measure the amount recovered to an accuracy of 10 ml (0.3 oz) to provide an accurate basis for adding oil to the system.
10. The equipment must be able to separate oil from recovered refrigerant and accurately indicate the amount removed from the system to within ±30 g (±1 oz).
11. Any component that normally releases small amounts of R-1234yf vapor into the cabinet must have the vapor directed away from any potential ignition sources and be dispersed from the cabinet by the ventilation system.
12. All flexible hoses must meet SAE J2888 specifications and must have shutoff valves at the connection point to the system being serviced. Any hoses or lines to refrigerant storage/holding containers on or in the machine, must have shutoff valves at the connection points to permit tank replacement of charging with refrigerant, without loss of refrigerant. A tank that is a permanent installation is exempt from this requirement.
13. The equipment must purify refrigerant to SAE standard J2912.

Topping Off Regulations

The January 29, 1998 Final Rule clarifies an existing provision of the Section 609 EPA Clean Air Act regulations. The rule explains that Quick-Lubes and other facilities that charge refrigerant into vehicles but do not perform any other kind of refrigerant servicing or repair (i.e., facilities that "top off" only) are still considered to be performing service involving refrigerant, and are therefore subject to all the requirements of the Section 609 regulations, including the requirement that they must purchase approved equipment and the service performed by MVAC certified technicians.

In addition, the EPA does not require recovery and recycling of the refrigerant contained in a system prior to topping off the system with additional refrigerant.

Dual-Refrigerant Recovery Equipment

Refrigerant recovery equipment which can recover two different refrigerants is available. The concern with the use of such dual refrigerant recovery devices is the potential for cross-contamination of the refrigerant which is being recovered. The EPA has adopted SAE Standard J1770 which incorporates many safeguards to prevent cross contamination. For example any single-circuit dual-refrigerant equipment must contain special features to prevent cross contamination in the refrigerant circuit. The equipment must prevent the initiation of the recovery operation if the equipment is not set up properly. If an operator action is required to clear the unit prior to reconnecting for a different refrigerant, the equipment shall be provided with a means which indicates which refrigerant was last used. The equipment is also required to prevent recovery from two different refrigerant sources concurrently. The standard also specifies that the transfer of recycled refrigerant for recharging and transfer must be from the liquid phase only; this is to allow proper recharging of refrigerant blends which must be charged from the liquid phase.

Recycling Blends

Once recovered, only uncontaminated CFC-12 or HFC-134a should be recycled on-site; all others must be sent to a reclaimer. Recovering contaminated R-12 or R-134a refrigerant into recycling equipment may damage the equipment, and recovery equipment can only filter and dry refrigerant it cannot remove other gaseous impurities such as air or other refrigerants. Furthermore, EPA regulations prohibit technicians from recycling blend substitute refrigerants whether they are contaminated or not. This is because a blended refrigerant could have lost one or more of the volatile components of the blend (due to system leaks), and this can dramatically change the performance characteristics of the blend. Recycling cannot replace the lost constituents of the blend.

Refrigerants in Use

Recovery, recycling and recharging of automotive A/C systems is a lot more complicated than it used to be. In the past, all automotive A/C systems used CFC-12; however, this is clearly not the case anymore. Even when R-12 was the only refrigerant in town, many A/C techs discovered systems that had been contaminated with air, HCFC-22 or even hydrocarbons like propane and butane.

In addition to the new vehicles that are using HFC-134a refrigerant, an astonishing number of R-12 substitutes are in the market. Clearly, the variety of refrigerants that technicians can encounter is making A/C service more complicated, with all the new refrigerants entering the marketplace in newly manufactured vehicles.

The EPA requires that when any vehicle is retrofitted from R-12, a label identifying the new refrigerant in the system must be placed under the hood, and new unique fittings must be attached to the high- and low-side service ports of the A/C system (see Table 9). Of course, you could encounter a vehicle that has been retrofitted to another refrigerant but has not been properly relabeled, or a vehicle that has the right label, but has been charged with highly contaminated refrigerant. Propane is not a legal automotive refrigerant, so if this refrigerant is used, chances are little warning will be provided.

Checking refrigerant pressures does not guarantee that you will recognize that refrigerant is contaminated or is a brand that is unfamiliar to you. Unusual head pressures can indicate an improperly labeled system; however, a contaminated system can result in a similar pressure temperature dependence.

Purchasing a refrigerant identifier unit can help pinpoint many refrigerant identification problems, and EPA strongly recommends, but does not require, this equipment. Some identifiers are simple go/no-go devices that only tell you if the refrigerant is HFC-134a or not (or CFFC-12 or not). Alternatively, more sophisticated and expensive diagnostic units identify the constituents and even identify flammable working fluids. SAE Standard J1771 applies to refrigerant identification equipment to be used for identifying refrigerant CFC-12 (R-12) and HFC-134a (R-134a) refrigerant when servicing MVAC systems. SAE standard J2912 applies to refrigerant identification equipment to be used with R-1234yf.

In general however, even the most sophisticated portable diagnostic units on the market today cannot properly identify all combinations of chemicals used in refrigerant blends. Diagnostic identifiers being sold today typically can identify potential R-12 and R-134a contaminants such as air, R-22, and flammable hydrocarbons, but many were not designed to identify chemicals that are components in R-1234yf, R-152a and CO_2 or to recognize particular chemical combinations as a specific commercial blend.

Whether you are interested in purchasing a "go/no-go" unit or a diagnostic unit, check that the unit meets the SAE J1771 standard, which is an indication that the unit accurately identifies refrigerants. When claiming to meet this standard, manufacturers of identifier equipment are <u>required</u> to state the accuracy of the unit.

Finally, beware of contaminated refrigerants or incorrect refrigerants being sold as new pure refrigerant. There have been cases where refrigerant has been falsely packaged, sometimes leading to explosion and injury. A certified refrigerant identification unit will prevent this from happening. It is, of course, always a good practice to only purchase refrigerant from reputable sources.

Charging of MVAC Systems

The most accurate method of charging a MVAC system (after repairing and leak checking the system) is to:

1. Leak-check the system with dry nitrogen at a pressure of 100 to 150 psig.
2. Properly evacuate the system to at least 29 inches of mercury,
3. Add the lubricant to the system
4. Re-evacuate the system to at least 29 inches of mercury
5. Charge the system using a refrigerant charging scale or other accurate refrigerant metering device (accuracy should be at least 0.5 ounce of charge)

When charging directly from a refrigerant cylinder, connect a manifold gauge to both the high and low side service ports of the MVAC, and initially introduce the refrigerant into the both the high- and low-side of the system. Once the pressure of the system is above the saturation pressure at 40°F, start the compressor and continue to add charge to the low-side of the system until the proper quantity of refrigerant has been added to the system (as determined from the charging scale or charging meter).

When charging the MVAC system with a pure refrigerant such as R-134a, R-12, or R-152a then you should charge as a vapor to avoid refrigerant slugging and to slow the charging process (and avoid over charging).

When charging the MVAC system with a blended refrigerant, instead of a pure refrigerant, then you must remove the refrigerant from the storage tank as a liquid. This may involve inverting the storage container or using a different connection to the tank. The refrigerant must be removed from the storage tanks as a liquid. The manifold valve should be almost completely closed, so the liquid from the refrigerant tank flashes across the valve on the charging manifold and the refrigerant actually enters the MVAC system as a vapor. The refrigerant should be slowly introduced into the compressor, if any unusual noise (slugging) is heard, immediately shut off the flow of refrigerant (at the manifold valve) and resume charging at an even slower rate (with the manifold valve closed even more).

If a properly operating HFC-134a recovery/recycling/recharging machine is being used and the machine was manufactured after January 1, 2008, then it has been certified to meet EPA requirements as set forth in SAE standard J2788 (HFC-134a Recovery/Recycling Equipment and Recovery/Recycling/Recharging for Mobile Air-Conditioning Systems). This system will recover at least 95% of the refrigerant in a MVAC system and provide a re-charging accuracy of at least 0.5 ounce. Follow the manufacturer’s instructions for using the unit. If you are using an older machine (that is not certified to meet SAE standard J2788), they have been shown to leave as much as 30% of the refrigerant charge in the system and this can result in system over charging, compressor slugging and added refrigerant expense. For these older machines, it is suggested that you manually override the automatic recovery operation to assure complete refrigerant recovery and proper system recharge.

Incorrect Calculation of Charge

Vapor compression air conditioning systems, like those used in MVAC systems, have several options for the configuration of the throttling expansion valve. The expansion valve can be a feedback type control valve that adjusts the opening to accurately control evaporator exit superheat, such as a Thermostatic Expansion Valve (TXV) or it can be a fixed orifice, such as an orifice plate or capillary tube. The advantage to the TXV type valve is that it closely controls evaporator exit superheat, even if the operating charge is not perfect. Fixed orifices on the other hand, have the evaporator superheat closely related to the system charge.

If too much refrigerant charge is added to a fixed orifice MVAC system the desired superheat will be lost and liquid refrigerant could be returning to the compressor, resulting in compressor slugging and premature compressor failure.

If too little refrigerant charge is added to a fixed orifice MVAC system, the superheat will be excessive, resulting in reduced cooling capacity and if the charge is far too low, it will lead to icing of the evaporator coil (typically on cooler or rainy days).

Most of today's MVAC systems use a fixed orifice type expansion (to save cost) and therefore maximum cooling capacity and proper system life is highly dependent on having the proper charge.

If the system is properly evacuated and charged with an SAE standard J2788 or J2843 certified recovery/recycle/recharge machine, an accurate charge should be introduced.

If the MVAC system is being topped off, then the total quantity of charge in the system cannot be determined. For this reason alone, Mainstream does not recommend topping off the refrigerant charge in a system. The time necessary to top off the refrigerant, wait for the system to equalize, measure the evaporator superheat and condenser subcooling (to determine if the charge is correct), and then repeat the process until the proper charge is obtained will take much more time than simply recovering, recycling, and recharging the system. There is no economic incentive to top off the system if you plan on doing it right! Of course, if the refrigerant is a blend, it can never be topped off because the composition of the blend is altered when some refrigerant leaks out of a system, so the refrigerant must be replaced. Blended refrigerants cannot be recycled; they must be recovered and returned to a refrigerant recycling site.

If a system is being recharged without an automated recharging machine, then a charging scale, charging cylinder or other accurate refrigerant measuring device (accurate to 0.5 ounce of charge) is necessary. Always completely evacuate the system to a vacuum of at least 29 inches of mercury before any manual charging operation.

Calibration of Recovery and Recharging Machines

Equipment Requirements

R-134a recovery/recycling/recharging systems must be certified to meet SAE Standard J2788, and this standard requires that the equipment must be capable of indicating and recharging the system to within 15 grams (0.5 oz.) of the vehicle manufacturer's specifications. The standard also requires that if a scale is used by the recharging equipment to determine the quantity of refrigerant recharged, then the equipment manufacturer must provide a method or service procedure for the technician to use to check the accuracy and calibrate the machine. Similarly, if a mass flow system is used for charge determination, the equipment manufacturer must provide a method for checking the accuracy and include any necessary accuracy testing devices with the machine.

In general, to verify or calibrate a refrigerant recovery or recharging scale, the procedures in the next subsections can be used.

Procedure to Verify the Accuracy of a Recharging Unit

1. Place an empty approved refrigerant recovery tank on a platform scale. The platform scale must have the capacity for measuring the weight of an external recovery tank plus an additional 1000 grams (35 ounces). The scale must have an accuracy of at least ±3 grams (±0.006 lb.).
2. Connect the hoses to the recovery tank from the recharging machine, as if the recovery tank were a MVAC unit.
3. Open the access valve on the recovery tank
4. Record the Initial Weight of the recovery tank
5. Set the Recharging unit to recharge 457 grams (16 ounces) of refrigerant.
6. When recharging is complete, record the Final Weight of the recovery tank
7. Subtract the Final Weight of the Recovery tank (step 6) from the Initial Weight (step 4); the difference is the quantity of refrigerant recharged by the Recharging machine.
8. The quantity of refrigerant recharged should be between 442 grams (15.5 ounces) and 472 grams (16.5 ounces). If the actual recharged amount as determined in the previous step is more than 472 grams or less than 442 grams the machine must be recalibrated, following the manufacturer's recommendations or returned to the manufacturer or other calibration company for recalibration.

Procedure to Calibrate a Recovery or Recharging Unit

As stated above, SAE J2788 certified recovery/recycle/recharge machines are required to provide calibration tools and instructions, and these instructions will supersede anything presented here. If no other calibration information is available, the general procedures provided in this section should be used.

A) Inspect the scale and/or the manufacturer's literature to determine if the recharging system has a recharging calibration adjustment mechanism.

B) If a Calibration Adjustment Mechanism is available on the Equipment, then;

1. Continuing from the Accuracy Check Procedure above, the actual quantity of refrigerant recharged was determined in Step 7. If the actual recharged amount is greater than 457 grams (16 ounces), then adjust the calibration scale to decrease the quantity of refrigerant recharged. Similarly, if the actual recharged amount is less than 457 grams, then adjust the calibration scale to increase the quantity of refrigerant recharged. Turn the adjusting mechanism as little as possible during the initial adjustment, to get a feel for the sensitivity of this adjustment.
2. Repeat the Accuracy Test. If the actual recharged amount (from the repeated test) is now within the allowable range of 442 grams (15.5 ounces) to 472 grams (16.5 ounces) then calibration is complete. If it is outside this range repeat these calibration Steps B-1 and B-2.

C) If a Calibration Adjustment Mechanism is NOT available on the Equipment and the Equipment uses a Platform Scale, then;

1. Continuing from the Accuracy Check Procedure above, the actual quantity of refrigerant recharged was determined in Step 7. If the actual recharged amount is greater than 457 grams, then subtract 457 from the actual amount, to determine the amount of weight (in grams) to add to the platform scale (or the tank on the scale) being calibrated. For example if the actual recharged amount was 477 grams, the amount of weight to add to the scale would be 477-457, or 20 grams. Alternatively, if the actual recharged amount is less than 457, then subtract the actual recharged amount from 457 to determine the amount of weight (in grams) to remove from the platform scale (or the tank on the scale) being calibrated. It may not be possible to remove weight, if this is the case simply set the equipment to recharge the additional weight calculated above. For example, if you set the equipment to recharge 457 grams but the actual recharged amount is 427 grams, the amount you need to take off the scale is 457-427, or 30 grams. If you cannot remove 30 grams from the scale or tank, simply set the equipment to recharge 487 grams, or 457+30.
2. Add or remove the required weigh to/from the Platform scale or the Recovery Tank

3. Repeat the Accuracy Test. If the actual recharged amount (from the repeated test) is now within the allowable range of 442 grams (15.5 ounces) to 472 grams (16.5 ounces) then calibration is complete. If it is outside this range repeat calibration steps C-1 through C-3.

D) If a Calibration Adjustment is NOT available on the Equipment and the Equipment uses a Mass Flow Transducer, then the unit cannot be calibrated in the field and must be returned to the manufacturer for recalibration.

R-1234yf Equipment Calibration

For R-1234yf recharging equipment validation, the equipment manufacturer is responsible for ensuring that the system evacuation process leaves the system 98% free of refrigerant and/or non-contaminated gasses before recharging, following recovery and recycle provisions of SAE standard J2843.

All charge programming should be entered in SI units and should display in kg to three decimal places. The equipment must be able to indicate and charge the system to within 15 g (0.5 oz) of the vehicle manufacturer’s specifications.

If a scale is used in the machine, the equipment manufacturer has to provide a method or service for the technician to check scale accuracy. In addition, the manufacturer has to include any necessary accuracy-checking device, such as calibration weights, with the machine. If the accuracy-testing device for the scale includes a consumable, the manufacturer must include a quantity of replacement or refill devices for five years of periodic testing as recommended.

If a mass flow system is used for charge determination, it must maintain accuracy equal to the 15 g (0.5 oz) specification. The equipment manufacturer must provide a method for checking accuracy and include any necessary accuracy-testing devices with the machine. If the accuracy-testing device for the scale includes a consumable, the manufacturer must include a quantity of replacement or refill devices for five years of periodic testing as recommended.

If any other system is used for charge determination, such as a positive pump, the equipment manufacturer must provide a method and any needed device(s) to check accuracy that is/are appropriate for its method of operation, including temperature-compensating trim, if used.

The equipment manufacturer must make a calibration service available to owners of the equipment as a means of maintaining the charge amount accuracy and precision within the allowable tolerances. A fee may be charged for these services.

Prevention of Cross-Contamination

One of the largest sources of cross-contamination is incorrect top-off by do-it-yourselfers or another service technician, any of whom might top off R-1234yf refrigerant with small cans of R-134a. Measures must be taken by the service technician to assure cross contamination does not occur while servicing an automotive air conditioning system or recovering refrigerant. Cross-contamination can result in chemical reaction of substances within the system, lubrication problems leading to component damage, and decreased performance. During system charging, the specified weighed in amount and approved type of refrigerant for the system must be installed without substitution. Likewise, when replenishing oil, the specified oil for a given refrigerant, and specified by the manufacturer, must be charged into the system.

In service practice, if a recovery machine is attached to a cross contaminated system and that crossed refrigerant charge is recovered, the recovery machine must be cleaned and filter-driers replaced. If the recovered refrigerant is not marked as cross contaminated and properly disposed of, it could be accidentally used again thereby contaminating other air conditioning units. The contaminated, recovered refrigerant must be labeled as Cross Contaminated Refrigerant and picked up for incineration at an approved destruction site, (at significantly increased cost). On-site detection of cross contamination of an AC system before adding the recovered refrigerant to your stored refrigerant is an excellent precaution to prevent contaminating the entire batch of recovered refrigerant. Accurate refrigerant and oil identification prior to any system service procedure is a very important first step in prevention of cross contamination. Different service hose fittings have been specified by SAE to prevent the mixing of R-12 and R-134a; however, vehicles coming into today’s shops could have any number of strange blends, including flammable gasses, as discussed in the prior Refrigerants in Use section.

Refrigerant and oil, left in the gauge manifold and service hoses, can be a major source of system contamination. When servicing R-134a systems, it is imperative that care be taken to assure that air and moisture contamination to PAG and POE oils be kept to an absolute minimum. Keep the oil containers closed and hoses sealed-off when not in use. PAG and POE lubricants readily absorb moisture when left exposed to the air. By SAE standards, different hoses are used for R-12 and R-134a systems thereby making it harder to cross contaminate refrigerants. <u>But R-134a systems could be using POE or PAG oils and cross contamination of the oil can result in unwanted chemical reactions in the system and refrigerant breakdown and material corrosion</u>. Always use the lubricant specified by the manufacturer to avoid cross contamination of the oil. In order to prevent cross contamination from the hoses, we suggest using designated separate manifold gauge sets for R-134a with PAG oil and R-134a with POE oils.

Used Refrigerant

Recharging Used Refrigerant

The EPA's definition of MVAC "service involving refrigerant" states that MVAC technicians must recycle refrigerant prior to recharging it into an MVAC or MVAC-like appliance, even if the refrigerant is to be replaced back into the same AC unit from which it was removed. For equipment that only recovers refrigerant, proper use includes recycling the refrigerant on-site or sending the refrigerant off-site for reclamation before it can be recharged into an MVAC system. This is quite different from the HVAC Section 608 requirement for stationary (non-MVAC) air conditioning and refrigeration applications, which allows technicians to transfer refrigerant back into the unit it was removed from or into any other unit owned by the same person without recycling or processing the refrigerant in any way. This requirement is not new and has in fact been clarified in the January 1998 Final Rule summary. This requirement does not apply if the service is not for consideration, as in the case of do-it-yourselfers.

Purchasing Used Refrigerant

EPA regulations prohibit the sale of any used refrigerant, with the exceptions of refrigerant used and intended for use in MVAC or MVAC-like appliances, unless it has been reclaimed by an EPA-certified reclaimer (Sec. 82.154(g)). In the December 30, 1997, amendments to the MVAC recycling regulation explicitly permitted refrigerant recovered from MVACs and MVAC-like appliances at disposal facilities to be reused (after recycling in 609-certified recycling equipment) in MVACs and MVAC-like appliances without being reclaimed.

These requirements, also apply to any working fluid which is a SNAP approved substitute refrigerant for any MVAC or MVAC-like appliances.

R-12, R-134a, and other air conditioning refrigerants are used in other non-MVAC appliances in addition to being used in MVAC systems. Refrigerant from non-MVAC equipment should never be recycled and recharged into MVAC systems because non-MVAC systems have many different contaminants not normally present in MVAC systems. For the same reason, MVAC recycle/recharge equipment should never be used with refrigerants obtained from non MVAC equipment. However, reclaimed refrigerant from any source can be used in MVAC systems because reclaimed refrigerant must be tested to verify it meets the AHRI 700 purity standard for new refrigerant.

Specifically:

- Only section 609-certified technicians or disposal facility owners or operators may recover the refrigerant.

- The refrigerant recovered from the MVACs and MVAC-like appliances may not be mixed with refrigerant from any other sources.
- Only section 609-certified recovery equipment may be used to recover the refrigerant.
- The refrigerant can only be reused in MVAC or MVAC-like appliances.
- The refrigerant can only be sold to 609-certified technicians.
- The section 609-certified technicians must recycle the refrigerant in section 609-certified recycling equipment before charging it into the MVAC or MVAC-like appliance.

These restrictions are intended to ensure that the exemption from the reclamation requirement for refrigerant removed from and charged into MVACs and MVAC-like appliances does not compromise the purity of refrigerant flowing into the MVAC and MVAC-like appliance service sectors.

Disposal facilities must retain signed statements attesting to the removal of the refrigerant from the MVAC or MVAC-like appliance.

Refrigerant Transfer

Any portable container used for transfer of reclaimed or recycled refrigerant must meet DOT and UL standards. Prior to the initial introduction of refrigerant into an approved storage cylinder, (or the changing of refrigerant), the cylinder must be evacuated to at least 27 inches of mercury vacuum. Also, cylinder safe filling level must be controlled by measured weight and liquid net weight must not exceed 80 percent of the cylinder's internal volume.

Service Equipment and Specifications

Technicians repairing or servicing CFC-12 MVACs must use either combination recovery-and-recycling machines or recover-only equipment approved by EPA. Recover/recycle equipment cleans the refrigerant so that oil, air, and moisture contaminants reach acceptably low levels.

One of the major drawbacks of PAG lubricants is their incompatibility with chlorine and other lubricants. Because of this, service facilities must dedicate separate recovery and recycling equipment along with service hoses and manifold sets for individual refrigerants such as R-12, R-134a, and R-1234yf. If this is not done, any residual chlorine and/or mineral oil from the R-12/mineral oil system can contaminate the R-134a/PAG system.

Because R-1234yf is a flammable refrigerant, the recovery or recovery/recycling machine must be specifically designed and approved by the EPA for use with this flammable refrigerant.

Because R-134a has a smaller molecular size than R-12, it tends to leak out of service hoses more quickly than R-12. For this reason, SAE has mandated different service hose specifications for different refrigerants.

R-12 Service Hoses

The hose, for connecting to the high side of an R-12 MVAC system, will be solid red or black with a red stripe. The hose, for connecting to the low-side of a MVAC R-12 system, will be solid blue or black with a blue stripe. Utility hoses, for R-12, will be either solid yellow or white, or black with a yellow or white stripe. All hoses designed for R-12 use will be marked SAE J2196.

R-134a Service Hoses

The hose, for connecting to the high-side of an R-134a MVAC system, will be solid red with a black stripe. The hose, for connecting to the low-side of an R-134a MVAC system, will be solid blue with a black stripe. The utility hose will be solid yellow with a black stripe. All hoses designed for R-134a use will be marked SAE J2196/R-134a. ONLY R-134A HOSES HAVE A BLACK STRIPE.

R-1234yf Service Hoses

SAE Standard J2888 “HFO-1234yf Service Hose, Fittings and Couplers for Mobile Refrigerant Systems Service Equipment” establishes specific and unique fittings, couplers, and hoses for service equipment used in maintaining HFO-1234yf systems. Hoses must be stamped with “SAE J2888,” and the manufacturer and assembler identification must be located on the external surface of the hose, 180 degrees from the SAE marking. High side hoses are red, low side hoses are blue, and supply hoses are yellow.

Service Hose Fittings

Different service hose fittings have been specified by SAE to prevent the mixing of R-12 and R-134a during service operations. SAE J2197 standard specifies that R-134a service hose fittings to have a 1/2 inch, 16 ACME thread for connection to manifold gauge sets or to recovery/recycling/charging equipment. While the R-12 hose fittings are 7/16 inch, 20 thread for connection to the manifold gauge set or recovery/recycling/charging equipment.

The service hose ends that connect to the motor vehicle air conditioning system are also different for R-134a and R-12. This is regulated by SAE standard J639. R-12 service fittings which connect to the vehicles air conditioning system are threaded fittings for both the low and high sides of the system. R-134a systems use a SAE approved quick-connect that doesn't have external threads, which couples the service hose to the vehicle. To avoid confusing the low side from the high side service fitting, the high side R-134a fitting has a 16 mm Outside Diameter, (OD), and the low side fitting has a 13 mm OD.

Per SAE J2888, the hoses that connect the high- and low-side fittings and the recovery equipment include a high- or low-side coupling, as defined in SAE J639, and at the shutoff device of the connection to the serviced system or equipment, an M12 x 1.5-6g male thread on both ends.

Safety Precautions

1. Always wear protective goggles when working with refrigerant. If liquid refrigerant gets in your eye, permanent blindness may result.
2. Do not allow refrigerant to come in contact with your skin. The refrigerant has a very low boiling point, which will cause frostbite.
3. All refrigerant handling, charging, and recycling operations should be performed in locations with adequate ventilation of at least four air changes per hour. Avoid prolonged breathing of the vapor. Prolonged inhalation of refrigerant is extremely dangerous; death can occur without warning.
4. Do not use the recovery unit in the vicinity of spilled or open containers of gasoline, thinners, or any other flammable liquid or vapor unless your equipment is expressly designed, (explosion proof designs), for such environments. Do not operate where flammable vapor is present.
5. Do not leave any recovery or recycling machine on and unsupervised.
6. Do not attempt to fill any vessels, containers, cylinders, charging equipment, or storage tanks that are not DOT-approved and equipped with a safety-vent valve.
7. Do not transfer refrigerant to non-refillable cylinders.
8. Do not fill any storage tank or vessel with refrigerant beyond 80% of its capacity.

9. The internal pressure of a cylinder with one ounce of liquid refrigerant is the same pressure as a full cylinder. The explosive damage potential of a cylinder of liquid refrigerant is much worse than a cylinder of compressed air at the same pressure. This is because unlike the compressed air pressure which will quickly drop, the saturated liquid refrigerant will boil-off from liquid to vapor and maintain the high pressure until all the refrigerant is vaporized. You have all experienced the boil-off from a car radiator as the cap is removed. The pressure is only about 15 psig, but it maintains that pressure until essentially all the water in the radiator has boiled off. Imagine that same process occurring at over 100 psig, and with very cold liquid refrigerant which can cause eye damage, frostbite, and skin cold-burns - now you have the idea.

Cylinder Inspection

Prior to filling, a cylinder should be inspected for signs of damage, such as dents or corrosion. Do not fill a damaged cylinder. A recovery cylinder should not be filled if the present date is more than five years after the test date that is stamped on the shoulder of the cylinder. The test date will look similar to the example below:

A1

12 **89**

23

The designation in the example above indicates that the cylinder was re-tested in December 1989 by re-tester number A123. If a cylinder is out of date, it must not be filled; promptly return it to the cylinder owner for re-testing by an approved test laboratory. As stated earlier in this course, liquid refrigerant will expand as its temperature increases. If the cylinder is overfilled, thermal expansion of the liquid could rupture the cylinder. After filling, it is important to verify that all cylinder valves are closed properly and capped; this will prevent leaks during subsequent handling and shipment.

Review Topics

- The system vacuum level is measured with the system isolated.
- Always isolate the system and relieve the vacuum on the vacuum pump (by loosening the hose connections), for example, before turning the pump off. Otherwise, vacuum pump oil may be sucked out of the vacuum pump and into

the lines or system. Vacuum pump oil may not be compatible with the MVAC system's oil.

- During dehydration of a refrigeration system, the refrigeration system can be heated to decrease dehydration time.

- Whenever a technician is working with any unknown solvents, chemicals, or refrigerants, the technician should always review the material safety data sheets, which by law should be shipped by the manufacturer with these compounds.

- Refrigerant vapors or mist in high concentrations should not be inhaled because they have been demonstrated to cause heart irregularities or unconsciousness in some people. Note the warnings on the packaging. Refrigerants are also heavier than air and can displace the air in a room, leaving no breathing air in the room (leading to asphyxia). In most refrigerant accidents where death occurs, the major cause is oxygen deprivation.

- When corrosion build up is found within the body of a relief valve, the valve must be replaced, NOT repaired.

- Never use oxygen or compressed air to leak-check hardware because some refrigerants, when mixed with air or oxygen, can explode. The oil present in shop air, (even in small concentrations), will also contaminate the system.

- The MOST IMPORTANT reason why one should NEVER heat a refrigerant storage or recovery tank with an open flame is that the tank may explode, seriously injuring people in the vicinity.

- When filling a graduated charging cylinder, refrigerant that is vented off the top of the cylinder must be recovered.

- 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, then the area should be vacated and ventilated.

- When first inspecting a system known to be leaking, you should look for traces of oil because this is an excellent indication of leaks.

- The rotating shaft seal on an open-type automotive compressor is likely to leak if the unit is not used for several months.

- If a system is opened for servicing, the filter drier should always be replaced.

- Non-condensables in a refrigeration system result in a higher discharge pressure.

- Every refrigerating system and refrigerant cylinder must be protected by a pressure-relief device.
- All devices used for refrigerant recovery must meet EPA standards.
- Hygroscopic means affinity for water, so hygroscopic oils are oils with a high affinity for water. POE and PAG oils are hygroscopic oils.
- Recycling is defined as the cleaning of refrigerant for reuse by oil separation, non-condensable gas removal and single or multiple passes through filter/moisture absorption devices.
- Reclamation is defined as processing refrigerant to a level equal to new product specifications as determined by chemical analysis (testing to AHRI 700).
- Recovery is defined as transferring refrigerant in any condition from a system to a storage container without testing or purifying the refrigerant in any way.
- When addressing consumer complaints regarding additional service expense due to recovery efforts, the technician needs to explain to the customer that recovery is necessary to protect human health and the environment. Explain to the customer that recovery is required by federal law, remind the customer that all professional service personnel are duty-bound to follow the law and protect the environment. Point out that there are substantial fines of $37,500/occurrence/day for anyone venting refrigerant except for carbon dioxide (CO_2), which can be vented.
- When recovering refrigerant, it is important not to mix different refrigerants because the mixture will be impossible to reclaim. In cases where the refrigerant cannot be reclaimed, it must be destroyed. Only one refrigerant type can be recovered into a cylinder at a time.
- A system is not evacuated until a vacuum gauge shows that you have reached and HELD the required finished vacuum.
- After completing the transfer of liquid refrigerant between the recovery unit and the refrigeration system, you must be careful to avoid trapping liquid refrigerant between service valves of the refrigerant hose because pressure can build up in the line and burst the hose.
- All refrigerant tanks, including recovery tanks, should be labeled to indicate their contents.
- A refillable refrigerant cylinder must not be filled above 80% of the cylinder’s rated volume.

- Removal of the refrigerant charge from a system can be conducted more quickly by cooling the recovery tank.

- Recycling or recovery equipment that use hermetic compressors have the potential to overheat when drawing deep vacuums because the compressor motor relies on the flow of refrigerant through the compressor for cooling.

- With some older equipment, turn off the recovery device after reaching the required recovery vacuum on a system (isolate the system), and wait for a few minutes to see if the system pressure rises, indicating that there is either refrigerant in liquid form, refrigerant trapped in the oil, or a leak in the system. With some newer equipment, these processes are programmed into the machine, and the appropriate action is performed or the operator is notified of any issues. The technicians may also be given the option of performing manual tests.

- Non-condensables in a refrigeration system result in a higher discharge pressure.

SAE Standards

Over the years, SAE International J Standards have been referenced by regulatory authorities, such as J639 Safety Standards for Motor Vehicle Refrigerant Vapor Compression Systems, which cover system design, components, and service equipment for refrigerants used in MAC systems.

The following documents are available on the SAE International website:

- J639_201102 Safety Standards for Motor Vehicle Refrigerant Vapor Compression Systems
- J1627 Performance Criteria for Electronic Leak Detectors
- J2064_201102 R134a Refrigerant Automotive Air-Conditioned Hose
- J2099_201102 Standard of Purity for Recycled R-134a (HFC-134a) and R-1234yf (HFO-1234yf) for Use in Mobile Air-conditioning Systems
- J2196 Service Hose for Automotive Air-Conditioning
- J2197 HFC-134a Service Hose Fittings for Automotive Air-Conditioning Service Equipment
- J2296 Retest of Refrigerant Container
- J2297_201102 Ultraviolet Leak Detection: Stability and Compatibility Criteria of Fluorescent Refrigerant Leak Detection Dyes for Mobile R-134a and R-1234yf (HFO-1234yf) Air-Conditioning Systems
- J 2298 Ultraviolet Leak Detection: Procedure for Use of Refrigerant leak Detection Dyes for Service of Mobile Air-Conditioning Systems
- J2299 Ultraviolet Leak Detection Performance Requirements for Fluorescent Refrigerant Leak Detection Dye Injection Equipment for Aftermarket Service of Mobile Air-Conditioning Systems
- J2670_201102 Stability and Compatibility Criteria for Additives and Flushing Materials Intended for Aftermarket Use in R-134a (HFC-134a) and R-1234yf (HFO-1234yf) Vehicle Air-Conditioning Systems
- J2683 Refrigerant Purity and Container Requirements for Carbon Dioxide (R-744) Used in Mobile Air-Conditioning Systems
- J2762_201102 Method for Removal of Refrigerant from Mobile Air Conditioning System to Quantify Charge Amount
- J2772_201102 Measurement of Passenger Compartment Refrigerant Concentrations Under System Refrigerant Leakage Conditions
- J2773_201102 Standard for Refrigerant Risk Analysis for Mobile Air Conditioning Systems
- J2776 Refrigerant Purity and Container Requirements for New HFC-134a 1,1,1,2-Tetrafluoroethane Refrigerant used in Mobile Air-Conditioning Systems
- J2791HRC-134a Refrigerant Electronic Leak Detectors, Minimum Performance Criteria
- J2842_201102 R-1234yf and R744 Design Criteria and Certification for OEM Mobile Air Conditioning Evaporator and Service Replacements

- J2843_201102 R-1234yf [HFO-1234yf] Recovery/Recycling/Recharging Equipment for Flammable Refrigerants for Mobile Air-Conditioning Systems
- J2844_201102 R-1234yf [HFO-1234yf] New Refrigerant Purity and Container Requirements for Use in Mobile Air-Conditioning Systems
- J2845_201102 R-1234yf [HFO-1234yf] and R-744 Technician Training for Service and Containment of Refrigerants Used in Mobile A/C Systems
- J2851_201102 Recovery Equipment for Contaminated Refrigerant from Mobile Automotive Air Conditioning Systems
- J2888_201102 HFO-1234yf Service Hose, Fittings and Couplers for Mobile Refrigerant Systems Service Equipment
- J2911_201102 Procedure for Certification that Requirements for Mobile Air Conditioning System Components, Service Equipment, and Service Technician Training Meet SAE J Standards
- J2912_201102 R-1234yf Refrigerant Identification Equipment for Use with Mobile Air Conditioning Systems
- J2913_201102 R-1234yf [HFO-1234yf] Refrigerant Electronic Leak Detectors, Minimum Performance Criteria
- J2927_201102 R-1234yf Refrigerant Identifier Installed in Recovery and Recycling Equipment for Use With Mobile A/C Systems

These and other SAE International standards can be purchased at **http://standards.sae.org/**. For more information on these technical standards, contact **pr@sae.org** .