REFRIGERANT RECOVERY TRAINING MANUAL

Professional Service Association

AHAM
ASSOCIATION OF HOME APPLIANCE MANUFACTURERS

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PRESERVING OUR ENVIRONMENT

Refrigerant Recovery Training Manual

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Section 1 - Ozone Depletion

Introduction

Appliances that are designed to cool indoor temperatures and provide safe storage of our foods and beverages are a common fixture in homes. We take for granted that these “cold appliances” will add to our comfort and enjoyment in different North American climates and expect that they will provide for the safety of our foods. However, it was not always so. The conversion of either blowing air over a block of ice in the home or using a block of ice in a cabinet to keep our milk cold is not even a hundred years old.

The widespread use of chemical refrigerants began in the early 1930s with the introduction of dichlorodifluoromethane (R-12). In 1928, C. F. Kettering, a vice president with General Motors, commissioned Thomas Midgely and his associates to develop a refrigerant that was nonflammable and low in toxicity. Three years later, R-12 was born and, on Nov. 24, 1931, the original patent for chlorofluorocarbon refrigerants was granted.

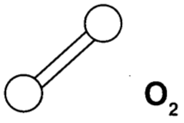
Over the next five years, additional patents were secured. Most notable of these were R-11 (1932) and R-22 (1936). Thus, refrigeration and air conditioning as we know it today was made possible by the introduction of these and other chlorofluorocarbon refrigerants (CFCs). In addition, these chemicals were also highly energy efficient.

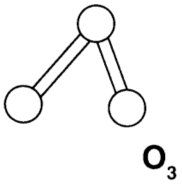
For the next 40 years, little or no thought was given to the possibility that CFCs might pose a threat to the environment. Venting of refrigerants to the atmosphere was common. In fact, in 1943, R-11 and R-12 were introduced as aerosol propellants in many household chemical products. As a result of this intentional venting, millions of tons of CFCs were introduced into our environment. Further, there was unintentional venting of refrigerants (primarily from automobile air conditioners and, to a lesser degree, other air conditioning and refrigeration equipment including refrigerators, freezers, and dehumidifiers) as well as the slow degradation of refrigeration foam blowing materials and the foam-blowing agents.

Then, in 1974, Prof. Sherwood Rowland and Dr. Mario Molina of the University of California at Irvine Department of Chemistry proposed the theory that certain chlorine-containing compounds might be destroying the ozone layer above Earth. The Rowland-Molina theory stated that chlorine-based fluorocarbons, when carried to the outermost part of the atmosphere (the stratosphere), substantially depleted the protective layer of ozone that blocks harmful levels of the sun’s ultraviolet radiation from reaching Earth’s surface. Since that time, extensive research has confirmed that stratospheric ozone depletion is taking place. Over the years, more was learned about how CFCs and other compounds interact with the ozone layer and how the destruction of the ozone layer occurs.

This training manual will explore not only the sequential history of different refrigerant chemicals but also how the refrigerant service industry can help maintain the safety of the environment.

Stratospheric Ozone



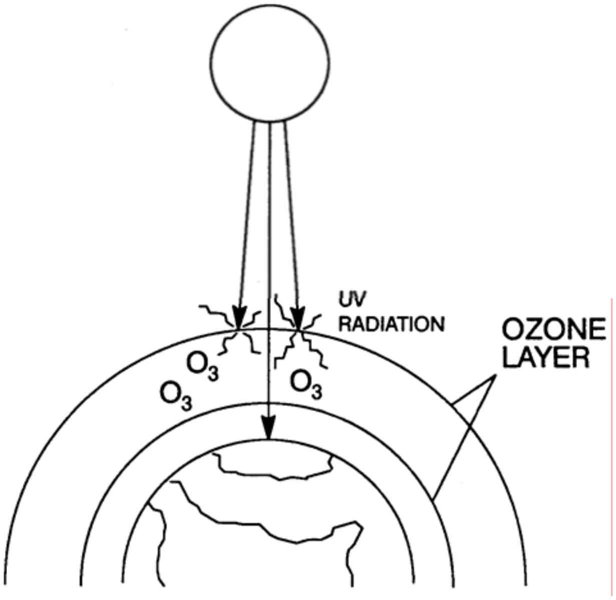


Ozone is a slightly bluish gas formed when an extra oxygen atom is added to the molecular oxygen we breathe. The normal composition of airborne oxygen is two oxygen atoms in each molecule (O_2). Ozone consists of three oxygen atoms in each molecule (O_3).

The ozone molecule can be formed in several ways. At ground level, ozone is created when ultraviolet radiation from the sun acts on smog and air pollutants on hot summer days.

At higher elevations, ozone is formed by ultraviolet light (UV) acting on oxygen molecules. At ground level, ozone is a harmful pollutant. In the stratosphere, ozone acts as a protective shield.

The ozone shield circles the earth at an altitude of 7 to 28 miles and protects us from harmful UV radiation by scattering and absorbing ultraviolet light.



Causes of Ozone Depletion

Although theories concerning the causes of ozone layer depletion abound, specific chemicals are either known to aid, or are strongly suspected of aiding, the destruction of this critical layer. Some of these factors are due to natural occurrences. Others are human made.

The best-known source of natural ozone depletion is the sun. The very element that creates ozone also destroys it. Over the course of a single day, sunlight alternately creates and destroys this gas. A fine balance is maintained between the number of ozone molecules created and destroyed. As long as no external factors are introduced, this balance is preserved. The reduction of the ozone layer is a problem for all animal and plant life on Earth.

One of the external factors that can create an imbalance is the introduction of volcanic dust. When a volcano becomes active, millions of tons of ozone-destroying particles and gases are introduced into the stratosphere. Not only do the gases begin to break the 0_3 molecules down to molecular oxygen, but the particles reduce the sunlight needed to create new ozone as well.

Among man-made chemicals that may contribute to ozone destruction, chlorofluorocarbon (CFC) and hydrochlorofluorocarbon (HCFC) refrigerants are suspected of being among the worst offenders. The chlorine atoms in these refrigerants systematically combine with ozone to break the more complex 0_3 molecule down to its simpler, more stable 0_2 form. **And, because CFCs and HCFCs neither dissolve in water nor break down into compounds that dissolve in water, they do not rain out of the atmosphere.**

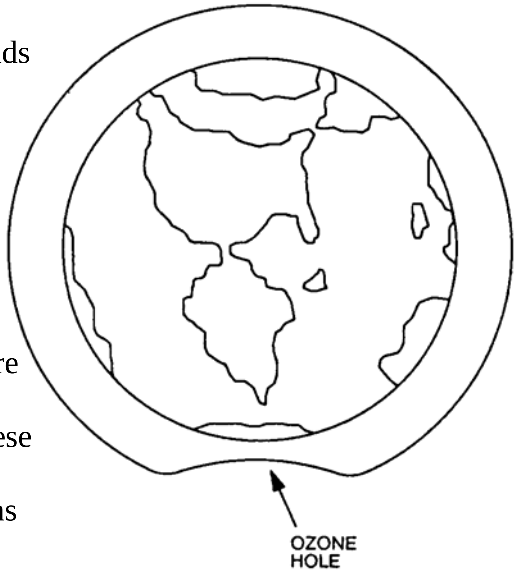
It is believed for several reasons that chlorine in the stratosphere comes primarily from CFCs and HCFCs rather than from natural causes (such as volcanoes). First, the rise in the amount of chlorine measured in the stratosphere over the past two decades matches the rise in the amount of fluorine. Since fluorine has different natural sources than chlorine, the conclusion can be drawn that they are both introduced from the CFC and HCFC emissions. Second, the rise in the amount of chlorine measured in the stratosphere over the past two decades corresponds to a similar rise in the emissions of CFCs and HCFCs over the same period. Finally, samples of air taken from the stratosphere over erupting volcanoes show that very little chlorine is emitted by volcanoes. In comparison, CFC and HCFC emissions contribute a much greater quantity of chlorine.

The "Ozone Hole"

Chlorine-based refrigerants are so stable that they do not break down in the lower atmosphere, even decades after being released. When these chemicals are swept up to the stratosphere by wind currents, the chlorine systematically destroys ozone. The chlorine atom reacts with the ozone molecule and breaks it down to its simpler molecular oxygen state. Because the chlorine atom remains active, it continues to cause more and more ozone-to-molecular oxygen conversions. Each chlorine atom can go on to destroy as many as 100,000 ozone molecules. Furthermore, because of the long atmospheric lifetimes of CFCs and HCFCs, it will take many decades for the ozone layer to return to past concentrations.

The effects of ozone depletion can best be seen by the study of the ozone hole over Antarctica. This thinning of the ozone layer occurs every year during the Antarctic spring season (autumn in the Northern Hemisphere). It occurs because of the unique climate in this part of the world.

During the Antarctic winter, powerful winds encircle the continent, isolating it from the winds that would otherwise migrate from warmer latitudes. Because the sun is above the equator during this season, the continent is also in darkness. These two factors combine to make Antarctica the coldest place on earth; temperatures as low as -126° F have been recorded.



Clouds do not normally form in the stratosphere because the air is too dry. Above Antarctica, however, ice and nitrous oxides combine at these bitterly cold temperatures to form polar stratospheric clouds (PSCs). Chemical reactions on the surface of the PSCs deplete ozone by converting the chlorine that is present in the air from forms that do not react with the ozone layer to other, less stable forms that readily break up in the presence of sunlight and go on to destroy ozone.

As the sun warms the region in spring, the combination of sunlight and the less stable chlorine molecules act to thin the ozone layer. Thus, as the PSCs dissipate every Antarctic spring, the chlorine molecules systematically break down the 0_3 molecules in the stratosphere until a large area is depleted of ozone, creating a thinning of the ozone layer that has come to be known as the ozone hole.

In 1991, a similar thinning of ozone was discovered over the Arctic. Moreover, increased concentrations of chlorine monoxide have been detected over both the Arctic and the Equator (chlorine monoxide is an indicator of CFC activity). The strongest evidence that CFCs are present in the stratosphere, however, comes from measurements of air samples taken from the stratosphere that show the presence of CFCs.[ii] The inescapable conclusion is that further thinning of the ozone layer is inevitable, this time overpopulated areas of the world. ***When ozone depletion occurs, more UV radiation penetrates to the earth's surface and health and environmental risks increase.***

Other Ozone-Depleting Chemicals

Besides chlorofluorocarbons, other chemicals are known to aid in the depletion of the ozone layer. Bromine-containing compounds, such as those found in halon fire extinguishers, react with ozone in the same manner as chlorine-based compounds. (Bromine is chemically related to chlorine.)

CFC or HALON	OZONE DEPLETION POTENTIAL
CFC-11	1.0
CFC-12	1.0
HALON-115	3.0
HALON-1301	10.0
HALON-2402	6.0

CFCs and halons have been assigned a factor which 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 (R-11), having been assigned a factor of one. Note that bromine-containing halons have factors many times those of CFC refrigerants.

Health and Environmental Concerns

The ozone layer is essential to the well-being of most living things. Without the protection of the ozone layer, much more of the sun's ultraviolet radiation would reach Earth's surface.

It is estimated that each 1% depletion of the ozone layer increases exposure to UV radiation by as much as 1.5 to 2%. Increased UV radiation has many risks. Among these are:

- Increased skin cancers
- Increased cataracts
- Suppression of the human immune response system
- Damage to crops
- Damage to marine life
- Increased ground level ozone
- Increased global warming

Human Health Effects

Since the impact of the radiation from the sun is greatest around the equator, the farther the distance from the equator, the greater the effectiveness of the ozone layer as a shield. Thus, the farther from the equator, the fewer number of damaging UV rays that reach the earth's surface. Therefore, as long as the ozone layer is intact, UV radiation hazards are minimal in the heavily populated Northern Hemisphere. An increase in ozone-depleting chlorine molecules, however, could sharply increase UV radiation hazards for millions of people worldwide.

The most common effect of increased UV radiation is a rise in skin cancer occurrences. Depletion of the ozone layer could result in an increase in three types of skin cancer. Squamous and basal cancers are the most common types and already affect about 500,000 Americans every year. If detected early, only 1% of these cases result in premature death. Malignant melanoma is less common but has a higher death toll associated with it. Out of the 25,000 cases that reported annually, about 20% (5,000) are fatal.

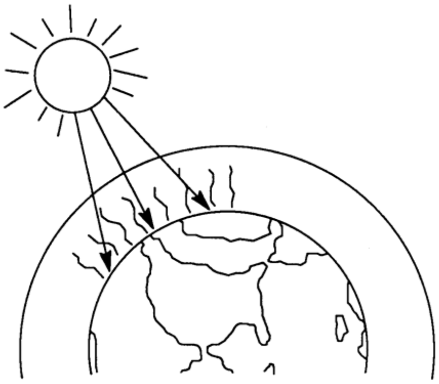
The number of cataracts (the clouding of the lens in the eye) may also increase with further reduction of the ozone layer. It is estimated that over 18 million new cases of cataracts (among individuals living or who will be born prior to the year 2075) could have been expected if the previous trend of CFCs and halon usage were to have continued.

The study of the human immune system is a relatively new medical development. Weakening of the immune system reduces the body's ability to fight disease. Although test results are inconclusive at this time, research suggests that exposure to UV radiation may give rise to the occurrence rate of certain types of diseases. Further research is needed to verify the exact results of UV radiation on the immune system, but in the meantime, a great natural experiment is taking place. The risks were too great to continue the use of ozone-depleting gases.

Research also seems to indicate that increased UV radiation may have adverse effects on crops and other terrestrial ecosystems. In studies of crops grown in greenhouses, almost two thirds of the crops that were exposed to high levels of UV radiation showed significantly reduced yields. As an example, soybeans that were exposed to a 25% increase in UV radiation had a 20% reduction in yield.

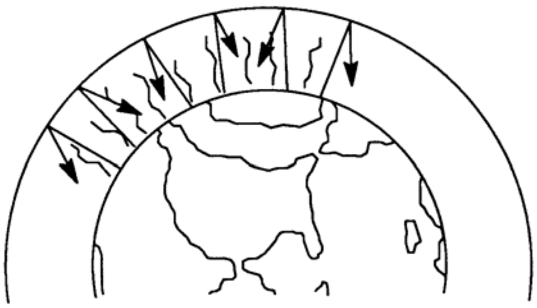
Marine organisms, such as phytoplankton and the larvae of many species, may also be sensitive to increased exposure to UV radiation. These microorganisms spend much of their existence near the surface of the water and are more susceptible to the changes that are created by ozone depletion. The marine food chain is very dependent on these organisms and any significant reduction in the productivity and diversity of these organisms is bound to have a serious effect on the world food supply.

Increased UV radiation has other impacts as well. Ground-level ozone (tropospheric ozone) increases when more of the sun's harmful rays reach the surface. The same UV radiation that creates ozone in the stratosphere will create tropospheric ozone. This ozone combines with pollutants in the air to form smog. Smog, as most of us know, is especially harmful to the elderly and to individuals with breathing disorders. Upper-atmospheric ozone depletion also accelerates the weathering of polymers (plastics). Materials like plastics, paint, and rubber compounds, which are an integral part of our daily lives, deteriorate more quickly when exposed to higher concentrations of UV radiation.



Finally, CFCs are thought to be greenhouse gases; this means that they have many of the same properties as upper-atmosphere carbon dioxide. Greenhouse gases allow the higher light frequencies to pass through the atmosphere and block lower light frequencies. Thus, more light from the sun penetrates the atmosphere, causing additional heating of Earth's surface during daylight hours.

At night, the lower infrared frequencies that are given off by the warm surface and would normally escape into space are reflected back to earth. Greenhouse gases reduce the cooling that normally takes place at night.



A rise in Earth's average temperature over the last couple of decades could have serious implications. Less freezing would then raise the temperature of seawater, which, in turn, would further increase the amount of heat that would have to be given off during the night hours. Many scientists believe that the cumulative effect of this increase in solar radiation and less effective cooling at night, may be related to the shrinking of the polar ice caps. Sea levels could rise to a point where a significant loss of usable land is probable. In addition, dependency on the very system that contributed to the rise in temperature (cooling and air conditioning) would also be increased. Others have pointed to the increase in major climate events, such as droughts, flooding, severity of hurricanes, and other weather phenomena as possibly related to even small amounts of earth's temperature increase.

Global Impact of Ozone Depletion

Unlike many other environmental concerns, stratospheric ozone depletion is a global problem that must be dealt with by all nations. Unfortunately, when one nation fails to reduce its usage of CFCs and halons, all nations suffer the consequences. Given their long atmospheric lifetimes, these gases become widely dispersed over time. As a result, the actions of one nation could seriously affect the health and welfare of individuals far from the source of those actions.

CFCs, HCFCs and HFCs are used by all countries, both developed and developing. Since developed nations were the largest users of these chemicals, they bore the responsibility of instituting the policies needed to minimize damage to the ozone layer. The ultimate solution, however, requires the combined efforts of all parties, both developed and developing nations.

Section 2 - Climate Change and Global Warming

Background

Since approximately the mid-1990s, the debate has intensified over the role of the replacement chemicals used in refrigeration systems and about the use of refrigerants that contain chlorine or fluorine. Following global restrictions over the use of CFC chemicals, most refrigerator and air conditioner manufacturers opted for HFC refrigerants, such as R-134a and R-410A. From 2010 to 2015 many of the companies began debating the use of HFC refrigerants as both the cooling chemical and the foam blowing agents in refrigeration and air conditioning appliances.

In North America, the U.S. EPA banned the use of CFC and then HCFC refrigerants. In the ensuing decades, governments around the world have restricted the manufacture and use of products with HFC refrigerants in household refrigeration and air conditioner products, among others. The Montreal Protocol, discussed below, has been amended to include HFC regulations and phase-out, although such amendments have not been ratified in the U.S.

In the United States, there were efforts by EPA to regulate and phase-out many HFC uses but they have been stymied by court decisions. Some states are enacting similar legislation.

Despite their political, legal and policy debates, the appliance industry is rapidly moving, where feasible, to non-HFC alternative refrigerants. The appliance market is global in nature and manufacturers have market and global sustainability realities and commitments, which require more uniform refrigerant choices.

Beginning in 2010 many new appliances started to appear on the market using replacements for the HFC chemicals. Segments of the “cold” appliance industry must weigh GWP of refrigerants against such aspects as the performance, energy efficiency, toxicity, availability, approval by governmental bodies, availability of components and service. As noted, many chemical companies, environmental advocates and manufacturers have been studying hydrocarbon refrigerants, such as R-600a and /or R-290 propane. These materials are more energy efficient than HFC refrigerants and show less environmental hazards when released into the atmosphere. Both of these materials are considered flammable refrigerants and are rated by ASHRAE standard 34 as A3 refrigerants. Even though the charge amounts are very small, less than 150 grams (5.3 oz) in household refrigerators and small air conditioning products, there are risks to the consumer and service technician if these materials are not treated with care during installation, service, and end-of-life disposal.

Another class of refrigerants with more use in air conditioning products, known as difluoromethane and having a rating by ASHRAE standard 34 of A2L refrigerants started to be used in North America in the years following 2015. One of the most well-known refrigerants in this class is R-32. Because these chemicals contain fluorine, they still have been identified as having a moderate global warming factor. These refrigerants have a lower burning velocity and higher ignition point than the A3 refrigerants. The American national safety standards for appliances such as household refrigeration, dehumidification, and air conditioning recognize that these A2, A2L and A3[1] refrigerants can be used safely in small

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[1] The designation of flammability classes such as A2, A2L, and A3 are referenced in ASHRAE Standard 34 which includes additional details on the individual refrigerants, including ignition temperatures and burning

quantities, usually under 150 grams (5.3 oz) per refrigerant loop. With certain restrictions over the design of appliances using these A2L and A3 refrigerants, the American national safety standards organized and published by Underwriters Laboratories (UL) allow for appliances to use these A2, A2L, and A3 refrigerants. Products such as these have maximum refrigerant charge amounts restricted by the applicable UL safety standards. It is important to remember that servicing of appliances using these flammable refrigerants requires additional safety measures. For this reason, service technicians working on appliances containing these flammable refrigerants must receive and follow specialized training. **We encourage all service technicians to become aware of the specialized requirements for safe servicing of products containing flammable refrigerants. Contact the individual manufacturers and also consult the industry information, such as found at:** http://www.aham.org/AHAM/Safety/Safe_Servicing_of_Cold_Appliances/AHAM/Safety/Safe_Servicing_of_Cold_Appliances.aspx

Whereas HCFC R-22, HFC-R-134a, and HFC R-410A have global warming potentials of 1810, 1430, and 2090, respectively, some of the third-generation chemicals have GWPs of 675 for R-32, 675 for R-452B, and 4 for R-1234yf. In addition, hydrocarbon refrigerants such as R-290 and R-600a have GWP values of 3.[2] Measurements of GWP are based on CO_2, which is given a relative GWP value of zero (0).

Progression of Refrigerants

First generation – The first documented, systematic search for a refrigerant offering a practical design with improved performance came in the 1920's, with examination of refrigerant for chillers. The first generation of refrigerants included substances such as hydrocarbons, ammonia, and carbon dioxide.

Second Generation – This Generation was distinguished by a shift to fluorochemicals for safety and reliability. The second generation of refrigerants included chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), which became widely used because they were efficient, non-flammable, and non-toxic.

In the 1980s, CFCs and HCFCs were determined to play a major role in depleting the stratospheric ozone layer. Beginning in the 1990s for ozone protection, the industry phased out CFCs and HCFCs in favor of a third generation of refrigerants: hydrofluorocarbons (HFCs). HFCs have zero ozone depletion potential.

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characteristics.

[2] Global Warming Potential values are obtained from the Intergovernmental Panel on Climate Change (IPCC) and currently use the 5th Assessment Report values. See www.ipcc.ch

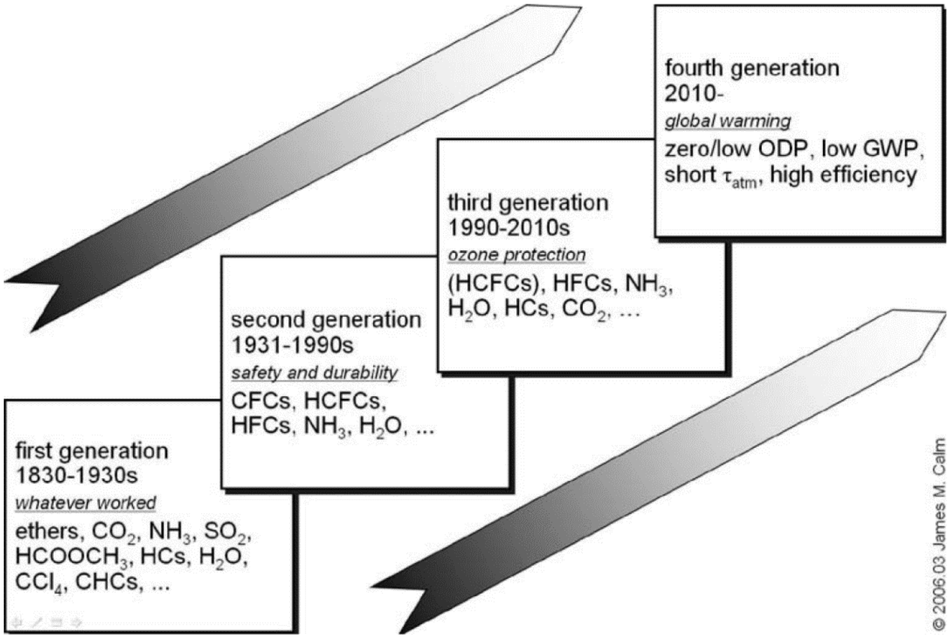

Figure 2.1. One representation of the changeover in refrigerants, often referred to as "generations."

However, it was later realized that when HFCs are released to the atmosphere, they have significant global warming potential (GWP). Global Warming Potential is a relative measure that describes the amount of heat trapped by a particular gas, when released into the atmosphere, compared to the amount of heat trapped by an equivalent mass of carbon dioxide gas. In this report, we refer to GWP values calculated over a 100-year time interval. The GWP value of carbon dioxide is defined as 1. For example, a GWP value of 500 for a particular gas indicates that the gas would trap 500 times more heat than the equivalent mass of carbon dioxide over a 100-year time period. The growing international emphasis on global warming mitigation has stimulated interest in a fourth generation of low-GWP refrigerants – ammonia, carbon dioxide, hydrocarbons and water.

The transition from HCFCs occurred between 1990 and 2010 in North America. The Montreal Protocol limits production of HCFCs in steps in 1996, 2004, 2010, 2015, and 2020 with full production phase-out by 2030 in non-Article 5 countries and imposes a freeze starting in 2016 and cessation of production in 2040 in Article 5 countries. Individual countries adopted different response approaches. Most western- and central-European countries accelerated HCFC phase-outs, while the majority of other developed countries set limits by phasing out propellant and blowing agent (especially R-141b) uses early, requiring phase-out of R-22 (the most widely used refrigerant today) by 2010 in new equipment, and then banning all HCFC use in new equipment by 2020. This resulted first in the change to HFC refrigerants such as R-134a and R-410a. In the years following 2015, many manufacturers of household refrigeration appliances have begun using R-600a and many air conditioning product manufacturers have begun using blends such as R-32. The chart above (Figure 2.1) shows one example of the progression of generations of refrigerants.

Section 3 - Refrigerants

Refrigerant Types

A refrigerant can be a solid, liquid or vapor substance that acts as a heat-absorbing agent. Its purpose is to transfer heat from one place to another. In a refrigerator, for instance, heat is transferred from the interior of the product and released on the outside by the movement of refrigerant through the sealed system. Refrigerants most commonly used today have liquid/vapor characteristics (i.e., liquid when pressurized and vapor at atmospheric pressure).

Until 1950, a variety of refrigerants were used in small appliances. Refrigerants such as sulfur dioxide, methyl chloride and methyl formate were phased out of existence because they exhibited toxic, flammable or corrosive characteristics. A few products with these refrigerants may still be in use, however. Ammonia, another corrosive refrigerant with a pungent odor, was used in household refrigeration during the 1930s and is still used in recreational vehicle refrigerators. Due to the toxic, flammable and corrosive nature of these refrigerants and their incompatibility with today's commonly used recovery equipment, it is not recommended that these refrigerants be captured. Contact the original equipment manufacturer for disposal recommendations.

REFRIGERANT	CLASS	APPLICATION IN SMALL APPLIANCES
R-12	CFC	Refrigerators, freezers, dehumidifiers, small ice machines
R-500	CFC	Dehumidifiers
R-22	HCFC	Room air conditioners, Dehumidifiers, PTAC's
R-11	CFC	Blowing agent for foam insulation
R-134a	HFC	Household refrigerators and freezers
R-410A	HFC	Small appliance room air conditioners, portable air conditioners, and dehumidifiers
R-600a	HC	Household refrigerators and freezers
R-32	HFC	Small air conditioners, portable air conditioners

For years, refrigerants used in small appliances have come from the CFC, HCFC or HFC classes. The table attached as Annex 2 gives the refrigerants, their characteristics, and their application:

Except for ammonia and a few other less commonly used substances, most refrigerants in use today are compounds containing chlorine, fluorine, carbon and sometimes hydrogen. They can be identified either by their "R-number" or by their "class/number" designation. As you can see in the following table, they are the same refrigerants. To keep things simple, the "R-number" designation is used when referring to a specific refrigerant (i.e., R-12, R-22, etc.).

The Refrigerant Numbering System

Because of the complex chemical names of refrigerants, DuPont developed a method of referring to refrigerants by number. The numbering system was released to the industry in 1956 and has become a standard. The logic behind DuPont's numbering system is as follows:

first digit on the *right* = number of fluorine atoms
second digit from the *right* = number of hydrogen atoms +1
third digit from the *right* = number of carbon atoms –1 *(not used when = 0)*

Notice that the numbering system begins with the number to the right. Additional numbers are added to the left of the first number.

Example 1: R-22		**Example 2: R-115**	
Chemical Formula:	**$CHClF_2$**	**Chemical Formula:**	**$CClF_2CF_3$**
Number of F atoms =	**2**	**Number of F atoms =**	**5**
Number of H atoms +1	**2**	**Number of H atoms +1**	**1**
Number of C atoms -1	**0**	**Number of C atoms -1**	**1**

Figure 3.1 Examples of Chemical Formulas for Refrigerants

In this training manual, we will concentrate on refrigerants used in appliances, and not other refrigerants for such applications as motor vehicle air conditioning (MVAC) or large commercial air conditioning systems. In addition, new chemical refrigerants are entering the market each month and we have concentrated on the ones most likely to be used by appliance manufacturers under the Type 1 Certification program.

CFCs

As the name implies, chlorofluorocarbon refrigerants (CFCs) consist of chlorine, fluorine and carbon compounds. Refrigerant 12, for example, is made up of 1 carbon, 2 chlorine and 2 fluorine atoms (Dichlorodifluoromethane, CCI2F2). R-12, however, is just one of several CFCs that share these elements in varying concentrations:

CHLOROFLUOROCARBONS (CFCS)		
R-11	**Trichlorofluoromethane**	**CCl_3F**
R-12	**Dichlorodifluoromethane**	**CCl_2F_2**
R-500[iii]	**Dichlorodifluoromethane/ Difluoroethane azeotropic**	**CCl_2F_2/CHF_2CH_3**

Figure 3.2 Examples of Chemical Names of Refrigerants

Because of their chlorine content, CFCs are very stable and have the greatest potential of ozone depletion. These properties combined made CFCs the target of legislation limiting their use and availability. As a result, all of these refrigerants came under control of the Montreal Protocol as of July 1989 and the Clean Air Act in November 1990. Their production has been banned in the United States since January 1, 1996. Use of recycled or stockpiled materials by properly certified technicians is still allowed in the United States. Following the effective date of the Clean Air Act, properly certified service technicians, using certified equipment and following the required guidelines may continue to service appliances with refrigerants that may have been phased out.

HCFCs

A second category of refrigerants in the field is the hydrochlorofluorocarbon (HCFCs) family of chemicals. Because hydrogen has been added to the formula, these chlorine-containing refrigerants are less stable and therefore less harmful to the ozone layer. HCFCs decompose more quickly when released to the troposphere (lower atmosphere) and are much less stable than CFCs. This instability makes the ozone depletion potential of HCFCs very low when compared to CFCs.

Refrigerant 22 was the most common HCFC in production for many years. Today, most residential and small commercial air conditioning equipment now use the HFC R-410A and are now converting to new refrigerant blends. Today, most residential refrigeration and freezer products use R-134a, an HFC refrigerant. Many of these refrigeration products are beginning to change to R-600a, a hydrocarbon refrigerant.

HYDROCHLOROFLUOROCARBONS (HCFCs)		
R-22	**Chlorodifluoromethane**	**CHCIF$_2$**

HFCs

An additional class of refrigerants known as hydrofluorocarbons (HFCs) have been available for over 25 years. These refrigerants contain no chlorine and have an ODP of zero. The most notable of these is R-134a.

HYDROFLUOROCARBONS (HFCs)		
R-134a	**Tetrafluoromethane**	**CF3CH2F**

R-134a refrigerant replaced R-12 in the sealed-systems of some small appliances produced in North America after December 31, 1995. Although R-134a and R-12 have somewhat similar operating characteristics, R-134a is very susceptible to minute quantities of contamination. R-134a and other refrigerants can never be mixed or substituted for each other in a small appliance. The same is true of R-410A in air conditioning products. **Totally separate and dedicated recovery cylinders are required to eliminate residual cross contamination.** Follow recommended guidelines for manufacturers' maintenance of hoses, manifold sets, and recovery machines. R-134a refrigerant is only compatible with ester-based compressor oil. Because R-134a is not compatible with mineral and alkyl benzene oils (used in R-12, R-500: and R-22 systems) and is very susceptible to trace chlorine contamination, it cannot be used as a drop-in replacement for any existing CFC, HCFC or HFC small appliance refrigeration systems. Manufacturers of small residential air conditioning appliances are beginning to change over to refrigerant blends. Manufacturers of household refrigeration appliances are beginning to change over to hydrocarbon (HC) refrigerants.

Replacement Refrigerants

Key considerations for any new refrigerants are:

- Chemical stability in the system
- Flammability
- Thermal characteristics
- Compatibility with lubricants
- Compatibility with system material
- Ability to recycle or reclaim
- Field serviceability
- Energy efficiency
- Toxicity
- Environmental effects
- Cost
- Ease of leak detection
- Compliance with applicable codes, standards and regulations
- Moisture solubility
- Availability

In an ideal world, replacement refrigerants would simply "drop-in"[vi] to existing systems.

Unfortunately, it’s not that simple. In almost every case, the new system must be designed around the new refrigerant, and the old system must be properly prepared or modified to eliminate any compatibility problems with the new “drop-in” refrigerant.

Necessary modification to the system may require changing the oil in the compressor, the filter drier or the compressor itself. Flushing out the entire system may also be required to eliminate traces of the old refrigerant or oil that is considered a contaminant to the new refrigerant. Because the refrigeration system is designed to specific and critical tolerances, only the refrigerant and lubricant specified for the system should be used.

No “drop-in” replacements for R-12, R-22, R-134a, or R-410A are available at this time. However, the following table summarizes currently known replacement refrigerants that are not “drop-in” replacements. These are targeted for use in the aftermarket service segment as alternatives to the diminishing supply of CFC and HCFC refrigerants originally specified for older equipment:

Window air conditioning packaged terminal air conditioning and dehumidifiers will continue to use R-410A for some years to come. HCFCs have begun to be phased out, and have been largely replaced by HFC refrigerants, such as R-410A.

Finally, not all new refrigerants have the same cooling capacity of those presently in use. The consideration of energy usage and cooling efficiency play an important role in the selection of the replacement refrigerants used in new products.

While refrigerant service technicians have long desired to have one or more refrigerant “drop-in” replacements for those refrigerants being replaced or withdrawn, none exist. For example, R-410A has been discussed as a replacement for R-22, but it is not a “drop-in” replacement for current R-22 systems. R-410A operates at approximately 50% higher pressure than R-22. A few refrigerant systems may be retrofitted or converted from one refrigerant to another, but this should only be conducted according to the individual manufacturer’s instructions and approval.
Another common refrigerant used by itself or in combination with other materials is difluoromethane (R-32). This HFC chemical refrigerant has a zero ozone depletion potential and a global warming potential of 675. R-32 is considered as an A2L refrigerant by ASHRAE Standard 34. Additional mixtures of R-32 with other refrigerants may have different GWP or different flammability ratings according to ASHRAE 34.

Refrigerant Pressure Classification

Beyond categorizing refrigerants by their chemical compositions, they can be further classified by their relative pressures.

LOW PRESSURE REFRIGERANTS	MEDIUM PRESSURE REFRIGERANTS	HIGH PRESSURE REFRIGERANTS
R-11 **R-113** **R-123**	**R-12** **R-134a** **R-600a** **R-1234yf** **R-1234ze**	**R-12 R-407C** **R-22 R-410A** **R-134a** **R-404A R-500** **R-502** **R-744** **R-290**

Figure 3.3 Pressures of Common Refrigerants

Refrigerant 134a

As the replacement for R-12 in many refrigeration product applications, it is critical that certain properties of R-134a be thoroughly understood. Although they are comparable in their health effects and demand the same safety precautions, system requirements are completely different for R-134a from those of R-12.

Perhaps the most significant difference is that the two refrigerants are not compatible. In fact, even the slightest trace of chlorine is enough to cause premature failure of R-134a sealed systems. Thus, it is imperative that equipment be dedicated to R-134a and never be interchanged with CFC, HCFC or other HFC refrigerants. Even though most appliances that use R-12 were redesigned to operate with R-134a, the two refrigerants are not interchangeable. Never attempt to use R-134a as a “drop-in” for R-12 or R-22 or vice versa.

Another difference between the two is that R-134a does not mix well with mineral oils in lubricants and requires the use of polyol ester oil (known simply as ester oil). When mineral oils are used with R-134a, lubrication of compressor components drops off tremendously and premature compressor failure occurs. For that reason, mixing of esters and other oils is not permitted. Ester oils, and their special properties, will be discussed in greater detail later in this chapter.

HFO Refrigerants

These are considered fourth-generation replacement chemicals. They may be used as a possible refrigerant and blowing agent material. HFO-1234yf and HFO-1234ze are classified by ASHRAE safety standard as A2L refrigerants. They have lower GWP and some are mildly flammable but have some concerns attached to them in the form of breakdown into TFA and in presence of high heat or ignition and may form acids that can be caustic or could cause injuries. HFO refrigerants are not compatible with silicone-based elastomers used in seals and gaskets.

Azeotropes and Blends

It is important to understand the difference between azeotropes and blends. Although they can both be classified as mixtures, they behave differently under certain conditions and require different diagnostic and charging procedures.

An azeotrope is a mixture of two refrigerants that combines into a third refrigerant with its own properties. Once combined, the refrigerants cannot be easily separated and remain combined in both their liquid and vapor states. Since an azeotrope is essentially another refrigerant, it behaves pretty much like any other refrigerant. No change from the normal diagnostic and charging procedures is necessary.

A blend, on the other hand, is a mixture of two or more refrigerants that do not combine to form a new refrigerant. Rather, the refrigerants mix and behave like a new refrigerant, but only as long as the mixture remains in a liquid state. As soon as the blend assumes a vapor state, each refrigerant reverts back to its original chemical composition and remains a separate chemical until it recombines with the other refrigerants to reform a liquid. This rather unique property of a blend presents some challenges to the technician in both system diagnosis and system charging.

To better understand how blends behave in a, sealed system, let’s examine what occurs whenever a blend changes its state. Keep in mind that each refrigerant has a unique vapor pressure point. That is, at a given temperature, each refrigerant boils at a different pressure. Conversely, if the pressure is held constant, each refrigerant boils at a different temperature. This is known as the pressure/temperature relationship of a refrigerant.

For the sake of simplicity, we will consider only the effect that changing the pressure has on the blend. Thus, if refrigerant A has a vapor pressure of 10 psig at a given temperature and refrigerant B has a vapor pressure of 5 psig at the same temperature, refrigerant A will vaporize first if the pressure is reduced below 10 psig. This process continues until all of refrigerant A has changed from a liquid into a vapor. And as long as the pressure does not drop below 5 psig, refrigerant B will remain in its liquid state. It is possible, therefore, for the two refrigerants to exist in the system, one as a liquid, the other as a vapor. If the pressure is further reduced to a point below 5 psig, the second refrigerant will vaporize as well. This is why refrigerant blends should only be charged into an appliance as a liquid. Eventually, both refrigerants change into a vapor and exist as unique chemical compounds.

The same concept applies when the refrigerant changes back into a liquid. The refrigerant with the lower liquid pressure (lowest condensing point) will liquify first, leaving the other refrigerant in its vapor state until the pressure is increased further, and the condensing point of the second refrigerant is reached. Once both refrigerants are liquified, the two mix together to form the desired blend.

Of course, if the pressure is held constant, then a change in temperature will accomplish the same thing. Keep in mind that there are two ways to effect a change of state. One, you can lower or raise pressure. Two, you can increase or decrease the temperature. When either pressure or temperature is changed, however, the change of state of a blend may not be complete. One part of the blend may remain in liquid state while the other part exists as a vapor. Normal pressure/temperature relationships do not hold true as long as refrigerant can exist in two states within the same system.

System diagnosis is complicated by these abnormal pressure/temperature relationships. For example, as a liquid blend changes into a vapor, it is not uncommon for the temperature of the vapor to drop below that of the liquid temperature. This is contrary to everything that we’ve ever experienced with non-blends and can confuse anyone who is accustomed to determining system performance by comparing vapor temperatures and pressures. The range of boiling and condensing points (sometimes called bubble or dew points) that exist within the system (as measured at the evaporator and condenser of the system respectively) is known as the ***temperature glide*** of the blend.

As can be seen by the table on page 12, some alternative refrigerant blends are made up of three refrigerants. **This is known as a three-part mixture or a *ternary* blend.** Blends of two refrigerants are known as two-part mixtures or binary blends. The ratio of each refrigerant within a mixture is critical and any change in the ratio greatly affects the performance of the blend. As a result, leaks present a special problem. Since the vapor pressure of each refrigerant is different within the blend, **blended refrigerants leak from the system at uneven amounts.** When the ratio of the remaining refrigerant changes, the system performance deteriorates.

Keep in mind that the blend exists only as a liquid, and anytime that one part of the mixture is vaporized, the original blend no longer exists. For this reason, charging a system with a blend must be done with great care. The charge must be introduced into the high side of the system ***as a liquid***. This is the only way that we can be sure that the integrity of the blend is maintained. If we try to introduce the charge as a vapor, there is a chance that the ratio of refrigerants will be altered. This not only affects the temperature glide of the blend, but the overall performance of the system as well. In addition to these characteristics, refrigerant manufacturers must consider the compatibility with metals, elastomers, and plastics with which they may come in contact.

Zeotropic Refrigerant Blends

These refrigerant blends are sometimes called “non-azeotropic blends” and are a mixture of components that have different boiling points. Individual substances within the blend do not evaporate or condense at the same temperature as one substance. Examples of this may be R-450A, which is a blend of R-134a and R-1234ze, or R-452b, which is a blend of R-32, R-125 and R-1234yf. Another example is R-407C which is a mixture of R-32, R-125 and R-134a. This particular zeotropic blend is sometimes called a ternary blend (3 chemicals) and requires a polyol ester oil lubricant.

Flammable Refrigerants—IMPORTANT SAFETY INSTRUCTIONS

As the appliance and air conditioning industry changeover to newer refrigerants such as HFO, HC, and blends containing flammable chemicals, service technicians need to be extremely aware of these new chemicals, particularly the safety aspects. Technicians need to be aware of special safety markings on the appliances, compressors, and literature available. The information in this training manual is general but specific service information on each piece of equipment must be followed carefully. Not only are some of these chemical refrigerants flammable, but the presence of chemicals after an ignition event may also be hazardous to the service technician.

It is critical that service technicians are trained on the equipment necessary to service appliances with flammable refrigerants. This includes having mechanical equipment to cut into the refrigerant lines, a flammable gas leak detector, as well as Personal Protective Equipment (PPE) for the technician’s safety.

Technicians should read and follow all training materials in order to work safely on appliances with flammable refrigerants, including the warning markings, exact types of refrigerants, and safety guidelines.

Safety Warning Markings

Manufacturers’ operating instructions, service training manuals and many other documents for appliances containing refrigerants will have several important safety instructions. Service technicians must read these and follow all instructions. In addition, service technicians should look for safety warning symbols and markings on the appliance. Technicians should look for these on the back of the appliance, near the rating label, near or on the machine compartment, or near or on the compressor of the appliance.

One example of a safety marking on an appliance:

Figure 3.4: Marking safety figure found on appliances with flammable refrigerants.

Service technicians should read and follow all instructions contained in the AHAM "Safe Servicing of Appliances with Flammable Refrigerants, Recommended Practices." The 2019 Edition of these practices are available free-of-charge on the AHAM website at:
http://www.aham.org/AHAM/Safety/Safe_Servicing_of_Cold_Appliances/AHAM/Safety/Safe_Servicing_of_Cold_Appliances.aspx
The brochures with these practices are available in English, French and Spanish.

Hydrofluoroolefin Refrigerants (HFO)

Within the last five years we have seen the addition of a class of refrigerants called hydrofluoroolefins (HFO). These chemicals are non-ozone depleting chemicals with very low (single digits) global warming potentials. An example is HFO R-1234yf. Some of these chemicals are mildly flammable, depending on the makeup of the blend. Many of these are emissible in POE lubricants. Because of the presence of fluorine, EPA has designated that these chemicals must be recovered and may not be vented to the atmosphere. Most, if not all, of the HFO refrigerants are mildly flammable and require very careful handling, similar to the hydrocarbon refrigerants. Just as with Hydrocarbon refrigerants, appliances with these chemicals are not only different in the refrigerant but also in the electrical components, wiring, compressors, fittings, seals, lubricants and many other design aspects. It is for these reasons that service technicians should **NEVER** use an HFO refrigerant to substitute in a non-HFO system. In addition, the service technician working on an HFO (and HC) appliance must use the exact type and model number of all electrical components and follow strict protocol in the service methods.

Hydrocarbon Refrigerants (HC)

Cold appliances in many countries have been using hydrocarbon refrigerants for over 20 years. These chemicals have only recently been used in domestic refrigerators and some sealed-system small air conditioning products. Because of the ASHRAE 34 safety standard listing of A3 category for these chemicals, additional safety requirements are necessary. Products with these chemicals are not only different in the refrigerant but also in the electrical components, wiring, compressors, fittings, seals, lubricants and many other design aspects. It is for these reasons that service technicians should NEVER use a hydrocarbon refrigerant to substitute in a non-HC system. In addition, the service technician working on a HC appliance must use the exact type and model number of all electrical components and follow strict protocol in the service methods.

Hydrocarbon refrigerants are non-ozone depleting chemicals and have very low (single digit) global warming values. Because of these values, EPA has determined that it is permitted to vent into the atmosphere the charge quantities of hydrocarbon refrigerants from small residential appliances.[3] Two examples of these HC refrigerants are R-600a and R-290. Several product lines of small appliances are utilizing HC refrigerants.

ASHRAE 34 Flammability Ratings

Classification of Safety through ASHRAE 34

ASHRAE Standard 34 classifies hundreds of refrigerants and blends according to many characteristics. One characteristic important for service technicians is the flame or fire properties. The main types of refrigerants used by household appliances are classified as A1, A2, A2L or A3. See page 36 for additional information.

Chemical Type	ASHRAE 34 Designation	Flammability Rating	Examples
CFC	A-1	Low—No Flame Propagation	R-11, R-12
HCFC	A-1	Low—No Flame Propagation	R-22
	B-1	Low—No Flame Propagation	R-121
HFC	A-1	Low—No Flame Propagation	R-404A, R-134a, R-407C, R-422B, R-410A
	A-2L	Lower Flammability	R-32
HC	A-3	Higher Flammability	R-441A, R-170, R-290, R-600a
Blend	A-1	Low—No Flame Propagation	R-502
Others	B-2L	Lower Flammability	R-717
	A-1	Low—No Flame Propagation	R-744

Figure 3.5 Flammability Designation of Common Refrigerants

ASHRAE 34 Designated Refrigerants A2 and A2L

Refrigerants determined to be in the ASHRAE 34 categories of A2 and A2L are slightly less flammable than A3 refrigerants. They should still be treated with

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[3] Refer to https://www.epa.gov/snap/refrigeration-and-air-conditioning for other acceptable refrigerants (the lists on the SNAP website include the ASHRAE 34 safety classification where available). Within the United States, these refrigerants are exempt from the venting prohibition under the Clean Air Act and are exempt from EPA's hazardous waste regulations (RCRA) when contained in a consumer-owned (rather than commercially owned

caution.

All appliance service work deserves special attention for the safety of the technician and the homeowner, however the use of A2, A2L and A3 refrigerants demand additional care. These materials are flammable. However, in order for there to be an ignition or explosion, there needs to be the right mixture of refrigerant, oxygen, and a source of ignition. In addition, higher humidity increases the burning velocity of A2, A2L refrigerants. In order for ignition to occur and be maintained, concentration of the refrigerants need to be between the lower flammability limit (LFL) and the upper flammability limit (UFL).

Oils Used with Refrigerants

For years, technicians have been maintaining and servicing refrigeration equipment without giving much thought to the oils that were used in the system. With the introduction of HFCs and blends, the importance of the oils used have taken on a greater degree of importance. We can no longer take the oil for granted since the oil plays an integral role in the operation of the system.

There are three types of oil currently in use in refrigeration products:

- Mineral oils are used with HCs, CFCs and HCFCs.
- Ternary blends containing HCFCs require the use of alkyl benzene oils. Also known as AK oils, are synthetic oils that can also be used with CFCs and HCFCs.
- Polyol ester (POE) oils are used with HFC refrigerants, such as R-134a, R-410A, and R-407C.
- **HFCs require the use of ester lubricants.** Esters are hygroscopic oils. **This means that they have a high affinity for water.** When left open to the atmosphere, they act as moisture sponges. Most manufacturers limit the amount of time that the oil can be exposed to the atmosphere before the oil is rendered useless. HFCs are miscible with polyol ester oils.
- The biggest problem with moisture is that it combines with the oil to form salts and gels that travel through the system and eventually plug the capillary tube. This forces replacement of expensive system components. Technicians should familiarize themselves with the special requirements of these and other oils. Since these new oils are used primarily with new and alternate refrigerants, always follow the manufacturer's recommendations when servicing these systems.
- As you can see by the descriptions of these many chemical refrigerants as well as the safety and performance, refrigerants should never be mixed.

Note: Service technicians should always check with the manufacturer of the refrigerant or compressor to determine the proper oil for that refrigerant.

Section 4 - EPA & CFC Regulations

Much has been said and written about the regulation and control of CFCs within the last few years. Yet, the control of CFCs began in 1978 when the EPA and the Food and Drug Administration banned the use of CFCs as aerosol propellants in all but a few (mostly medical) applications. This ban significantly reduced the U.S. production and use of both R-11 and R-12. (Prior to the ban, aerosol propellants constituted over 50% of the total CFC consumption in the U.S.) Unfortunately, very few countries followed the U.S. lead in this ban.

In 1980, the EPA announced that it was considering further restrictions on CFC production for other, non-aerosol uses. Two regulatory approaches were proposed at that time: mandatory regulations, and economic incentives that included the sale of required permits. Because scientific concerns about ozone depletion were diminishing at the time, regulations were not immediately pursued within the U.S. The EPA began to focus instead on developing international agreements.[4]

By 1986, the recognition of CFCs as contributors to global warming brought the issue back into the public limelight. Additionally, new scientific evidence connected CFCs with ozone depletion and the ozone hole that had been discovered over Antarctica. It was generally accepted at that time that the solution to the CFC problem lay with stronger regulatory measures and, to be effective, international cooperation.

The Montreal Protocol

In 1987, 24 nations and the European Economic Community (EEC) met in Montreal, Canada to discuss the ozone depletion problem. On September 16 of the same year, the Montreal Protocol on Substances that Deplete the Ozone layer was signed by most of the large halon and CFC producer and consumer nations. To date, more than175 nations representing virtually all of the world’s production capacity for CFCs and halons, have signed the protocol. This treaty among the member nations came to be known as the Montreal Protocol.

ORIGINAL MONTREAL PROTOCOL SIGNATORIES

Belgium
Canada
Denmark
Egypt
European Economic Community
Federal Republic of Germany
Finland
France
Ghana
Italy
Japan
Kenya
Mexico
Netherlands
New Zealand
Norway
Panama
Portugal
Senegal
Sweden
Switzerland
Togo
United Kingdom
United States
Venezuela

Figure 4.1

Compounds Controlled by the Montreal Protocol

The chemical compounds that were eventually controlled by the Montreal Protocol fell into two distinct categories. Under the first category are the fully halogenated chlorofluorocarbons and hydrochlorofluorocarbons (CFCs and HCFCs). The second

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[4] Refrigerants used in the United States are subject to approval by the U.S. Environmental Protection Agency under the Significant New Alternatives Policy (SNAP). See Rules 17, 19, and 21 and any other applicable rules at https://www.epa.gov/snap/snap-regulations

category includes all of the halons. Each group is treated differently under the Protocol since halons are produced in far smaller quantities and less is known about their production volume. Although halons are substantially more potent ozone-depleting chemicals, they will not be discussed in detail in this manual.

Reductions in both CFCs and halons were mandated to go into effect by July of 1989. The Protocol called for a freeze in CFC production to 1986 levels. Since consumption had grown since 1986, this was actually a cutback. A further reduction of 20% was required by July 1, 1993 and a 50% reduction was required by July 1, 1998.

COMPOUNDS CONTROLLED BY THE MONTREAL PROTOCOL	
CFC OR HALON	**DEPLETION WEIGHT**
CFC-11	**1.0**
CFC-12	**1.0**
HALON-1211	**3.0**
HALON-1301	**10.0**
HALON-2402	**6.0**

Figure 4.2

On February 11, 1992, President Bush announced the U.S. would unilaterally accelerate the phase-out schedule for ozone-depleting substances. Virtually all Class I substances, such as CFC-12 (R-2) and CFC–11, **were phased out of production by January 1, 1996**. That is, these refrigerants were no longer manufactured or imported into the U.S. after December 31, 1995.

International Trade Agreements

In an effort to entice non-signatory countries to join the Protocol, trade provisions were written into the Protocol that minimize any potential adverse economic effects that could come about as a result of affiliating with the Protocol. Except for developing countries that presently use little of the chemicals, each country must, within one year of affiliation, ban bulk imports from countries that are not signatories to the agreement and are not subject to production restrictions. Developing countries, however, are exempted from this ban for the first ten years of affiliation. In addition, production restrictions on participating countries would be lifted by 10 to 15% to allow for export to these qualified developing countries. Thus, the growth of developing countries that enter into the agreement will not be impaired.

Further restrictions on the trade of controlled substances apply and periodic reassessments are scheduled. The first of these reassessments took place in London in June of 1990.

Copenhagen Revisions to the Protocol

The Fourth Meeting of the Montreal Protocol convened in November of 1992. The parties adjusted the previously established phase out of schedules for CFCs (Class I substances) to required 75% reduction in production and consumption from 1986 baseline levels for 1994 and 1995 and a complete phase out by 1996. They also established criteria for identifying essential uses and a process for exempting limited production and consumption following the CFC phase out.

The Parties also adopted amendments to the Protocol setting maximum consumption levels of HCFCs beginning in 1996. Consumption will be reduced by 65% by 2010, 90% by 2015, 99.5% by 2020 and 100% by 2030. Reporting requirements for HCFCs were also established by the parties.

The Clean Air Act

In 1990, the U.S. Clean Air Act was amended to include regulation and control of CFCs used by both the automotive and appliance industries. Signed into law by President Bush on November 15, 1990, these amendments establish a National Recycling and Emissions Reduction Program to regulate the use and disposal of both CFCs and HCFCs. Title VI is entitled “Stratospheric Ozone Protection” and contains the “National Recycling and Ozone Reduction” program.

The overall objectives of Title VI are to reduce the use and emissions of CFCs and HCFCs to the lowest achievable level and to encourage the capture and recycling of such substances. The amendments also establish new standards for the safe disposal of these substances and institute federally mandated certification procedures for those engaged in servicing any equipment (such as automotive air conditioning and commercial and residential refrigeration) or appliances that contain refrigerants.

Under Section 608 (c) of the 1990 Clean Air Act Amendments:

> “(1) Effective July 1, 1992, it shall be unlawful for any person, in the course of maintaining, servicing, repairing or disposing of an appliance or industrial process refrigeration, to knowingly vent or otherwise knowingly release or dispose of any Class I or Class II substance used as a refrigerant in such appliance in a manner which permits such substance to enter the environment. *De minimis* releases associated with good faith attempts to recapture and recycle or safely dispose of any such substance shall not be subject to prohibition set forth in the preceding sentence.
>
> (2) Effective 5 years after the enactment of the Clean Air Act Amendments of 1990, paragraph 1 shall also apply to the venting, release, or disposal of any substitute substances for Class I or Class II substance by any person maintaining, servicing, repairing, or disposing of an appliance . . .”

By November of 1995, all refrigerants, including present and future replacements, **were subject to these regulations.** Intentional violators of the Act could face very stiff penalties and fines. Unless the EPA determines that venting substitute refrigerants does not pose a threat to the environment, it is also illegal to vent substitutes for CFC and HCFC refrigerants.

The revised Clean Air Act mandated that beginning ***July 1, 1992 all CFCs, HCFCs, including later HFCs and HFO’s used as refrigerants must be recovered.*** In the process of recovering, a “good faith attempt” must be made to ensure that none of these controlled refrigerants are allowed to vent to the atmosphere. The *de minimis* release clause of the Act allows “unavoidable” or “accidental” releases of minute amounts of refrigerant that occur during the recovery operation (such as the refrigerant that accidentally escapes when a hose is removed from a sealed system when refrigerant recovery equipment is properly used).

EPA Regulations

Based on the Montreal Protocol and the subsequent amendments to the Clean Air Act, the Environmental Protection Agency has been charged with establishing and enforcing regulations that govern the recovery, recycling and reclamation of refrigerants. The “Final Rule on Protection of Stratospheric Ozone; Refrigerant Recycling” was published in the Federal Register on May 14, 1993. The final rule establishes the guidelines and effective dates that are to be used during the service, maintenance and repair of "any device which contains and uses a Class I (CFC) or Class II (HCFC) substance as a refrigerant, and which is used for household or commercial purposes, including any air conditioner, refrigerator, chiller or freezer."

The final rule further defines "***small*** appliances" as:

"Any of the following products that are fully manufactured, charged and hermetically sealed in a factory with five pounds or less of refrigerant: refrigerators and freezers designed for home use, room air conditioners (including window air conditioners, portable air conditioners) and packaged terminal air conditioners), packaged terminal heat pumps, dehumidifiers, under-the counter ice makers, refrigerated vending machines, and drinking water coolers."

After August 14, 1993, EPA requires:
- That persons recovering refrigerant from small appliances must register with the EPA Administrator.
- That they have acquired recovery equipment meeting EPA standards, and that they are complying with EPA regulations.
- That all recovery equipment shall be used in accordance with the manufacturer's directions unless such directions conflict with requirements of the regulations.

In the manufacturing sector, effective November 15, 1993:
- No person may sell or distribute, or offer for sale or distribution, any small appliance unless the appliance is equipped with a process stub to facilitate the removal of refrigerant at servicing or disposal. Process stub is defined by EPA as a "length of tubing that provides access to the refrigerant inside a small appliance or room air conditioner and that can be resealed at the conclusion of the repair or service." For most small appliances, this is the tubing entered using a piercing access valve. According to the applicable UL safety standards, this process stub must be marked in red color and must extend at least one inch in both directions from a service connection.
- All recovery equipment used in the capture of refrigerants must be approved by the EPA.

Furthermore, effective November 14, 1994:
- No person may open a small appliance for repair, service or maintenance unless the person has been certified as a Type I or Universal technician.
- Only those training/testing programs which comply with all EPA standards and have been granted approval will be allowed to issue certificates pursuant to the regulations.
- No person may sell or distribute, or offer for sale or distribution, any Class I or Class II substance for use as a refrigerant to any person unless:

1. The buyer has been certified as a Type I, Type II, Type III or Universal technician
2. The refrigerant is sold for eventual resale to certified technicians or to an appliance manufacturer[vii.]

Likewise, any organization distributing HCFC, HFC or HFO refrigerants must verify that the organization employs at least one Section 608 certified technician.

Required Practices

Persons opening small appliances for maintenance, service or repair must:

1. When using recycling and recovery equipment manufactured before November 15, 1993, recover at least 80% of the refrigerant in the small appliance; **or,**
2. When using recycling or recovery equipment manufactured on or after November 15, 1993, recover at least 90% of the refrigerant in the appliance if the compressor in the appliance is operational, or 80% of the refrigerant if the compressor in the appliance is not operational; **or,**
3. Evacuate the small appliance to 4 inches of vacuum mercury (per AHRI 740 standard).

Certification of Recovery and Recycling Equipment

Manufacturers and importers of recycling and recovery equipment used during the maintenance, service or repair of small appliances must have such equipment certified by an independent, EPA- approved equipment testing organization (such as Underwriters Laboratories (UL) or the Air-Conditioning, Heating and Refrigeration Institute-AHRI) to meet regulatory requirements specified under "Required Practices" of the final rule. The recovery efficiency requirements for equipment used with small appliances are summarized in the table on the next page.

Those persons not in business at the time of publication of the final rule, or anyone opening a new business, must, within 20 days of opening a business, register with the EPA administrator that they have acquired recovery or recycling equipment and that they are complying with the applicable requirements of this regulation.

RECOVERY EQUIPMENT EFFICIENCY REQUIREMENTS FOR SMALL APPLIANCES		
REQUIRED RECOVERY EFFICIENCY	**PERCENT TO BE RECOVERED**	**INCHES OF HG VACUUM**
Recovery efficiency for new active and passive equipment manufactured after November 15, 1993 used for service or at disposal with working compressor.	**90%**	**4***
Recovery efficiency for new active and passive equipment manufactured after November 15, 1993 used for service or at disposal with non-working compressor.	**80%**	**4***
Recovery efficiencies for "grand-fathered" active and passive equipment manufactured before November 15, 1993 used for service or at disposal with or without working compressor.	**80%**	**4***

Figure 4. Per AHRI 740 standards

Technician Certification Requirements[5]

As mentioned earlier, November 14, 1994 is the effective date for mandatory certification of all technicians involved in the service, repair and maintenance of small appliances containing Class I and Class II substances. Certifying programs must issue to individuals a wallet-sized card to be used as proof of certification, upon successful completion of the appropriate test(s).

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[5] https://www.epa.gov/section608/section-608-technician-certification

Programs providing Type I certification for small appliance certification, which use the mail-in format, must issue a permanent identification card to technicians no later than 30 days after the program has received the exam and any additional required material. The applicant must receive a passing score of 84% on both the general and small-appliance specific sections of the test (21 of 25 questions in each section must be answered correctly). An applicant who passes one section of the test and not the other may retake only the section failed. Each card must include, at minimum, the name of the certifying program, the date the organization became a certifying program, the name of the person certified, the type of certification, a unique number for the certified person, and the following text:

[Name of Person] has been certified as a [Type I, Type II, Type III and/or Universal, as appropriate] technician as required by 40 CFR part 82 subpart F.

Authorized representatives of the EPA may require technicians to demonstrate their ability to perform proper procedures for recovering and/or recycling refrigerant. Failure to demonstrate or failure to properly use the equipment may result in revocation of the technician's certification. The technician then would need to recertify before maintaining, servicing or repairing any appliance. Technicians certified under this regulation must keep a copy of their certificate at their place of business. Any technician who loses their Section 608 certification card may contact the certifying organization for a replacement.

For a summary of EPA Section 608 certification level definitions, refer to this table:

CERTIFICATION LEVEL	LEVEL DEFINITION	CERTIFICATION LEVEL	LEVEL DEFINITION
TYPE I	Persons who maintain service or repair small appliances (products that are fully manufactured, charged and hermetically sealed in a factory with 5 pounds or less of refrigerant).	**TYPE III**	Persons who maintain, service, repair or dispose of low-pressure appliances, such as chillers.
TYPE II	Persons who maintain, service, repair or dispose of high or very high-pressure appliances with charges greater than 5 pounds, such as central air conditioning units.	**UNIVERSAL**	Persons who maintain service or repair equipment, all three levels (Type I, II and III)

Figure 4.4

Disposal of Appliances

Persons who take the final step in the disposal process of a small appliance must either:

1. Recover any remaining refrigerant from the appliance in accordance with the regulation.
2. Verify that the refrigerant has been evacuated from the appliance previously. This verification must include a signed statement from the person from whom the appliance is obtained that a refrigerant not leaked previously has been recovered from the appliance. This statement must include the name and address of the person who recovered the refrigerant and the date the refrigerant was recovered or a contract that refrigerant will be removed prior to delivery.
3. The final person in the disposal chain of handling is responsible to ensure that the refrigerants have been properly removed and documentation kept.

COMPLIANCE DATES AT A GLANCE	
MAJOR COMPLIANCE EFFECTIVE DATES	**REGULATORY REQUIREMENTS**
July 1, 1992	Persons maintaining, servicing, repairing or disposing of a refrigerator are prohibited from knowingly venting CFC and HCFC refrigerants.
August 12, 1993 or within 20 days of opening a new business	Persons using recovery equipment to recover refrigerant from small appliances must register (or certify) with EPA that they have equipment capable of removing 80% of the refrigerant or achieving a 4-inch vacuum under conditions of AHRI 740.
November 15, 1993	Recycling and recovery equipment used during maintenance, service or repair of small appliances must be certified by an EPA approved laboratory if manufactured effective this date.
November 14, 1994	All technicians must be certified. The sale of CFC, HCFC, HFC and HFO refrigerants will be restricted to technicians who are certified in refrigerant recovery by an EPA approved testing organization.
December 31, 1995	The Clean Air Act requires that the production of CFCs be discontinued after this date.

Figure 4.5

Penalties

Section 113 of the Clean Air Act authorizes EPA to obtain injunctions, assess fines, withdraw the certification of a technician, or commence criminal proceedings against anyone violating the servicing regulations described in this section. The following are among the violations subject to these penalties:

- knowingly releasing CFCs, HCFCs or HFCs the air while repairing appliances
- servicing appliances without proper certification or certified equipment
- falsifying or failing to keep required records
- failing to reach required evacuation levels before opening, or disposing of appliances
- selling refrigerant to uncertified persons

As of 2017, the EPA may impose fines of up to $44,539 per day for the violation of any of the requirements or prohibitions.[i] In addition, criminal penalties and/or prison terms of up to 5 years may be assessed against offenders. Second offenders may receive up to 10 years. Criminal fines and imprisonment may also be assessed against any person who makes false material statements or representations in any report, notice or application required by EPA for purposes of administering these regulations.

EPA performs random inspections, responds to tips and pursues potential cases against violators. In order to encourage others to report violations of the Act, EPA is authorized to pay an award of up to $10,000 to any person who furnishes information or services which leads to a criminal conviction or a judicial or administrative civil penalty of violators of the EPA refrigerant regulations. Such payment is NOT AUTOMATIC and is subject to available appropriations for such purposes as provided to EPA annually by Congress.

Effective July 1, 1992, every technician must be aware of and follow all service and repair procedures applicable to appliances containing refrigerants. All service providers must also institute procedures to ensure that they are in compliance with these EPA regulations.

State and Local Regulations

As local governments attempt to establish further restrictions on CFC and HCFC usage, state and local legislation will be enacted. State and local regulations will likely go beyond the scope of EPA regulations and it is important that each technician be aware of and comply with all federal, state and local regulations.

In addition, some states and local governments may have regulations on the servicing of and requirements on the service technician using flammable refrigerants. Service technicians should check with the state and local agencies in the jurisdictions in which they operate.

Section 5 - Our Role

The Clean Air Act regulations present a unique opportunity for anyone involved with maintaining, servicing, repairing or disposing of any appliance that contains and uses refrigerants. Compliance with these regulations is mandatory. No company or individual has the option of disregarding these regulations. There is too much at stake, both from a global impact and a financial perspective.

Whether or not we personally accept fluorocarbons as an environmental threat is irrelevant. Scientific evidence supports that it is and, as long as the possibility of a threat exists, we have a responsibility to react. Besides, the financial burden of noncompliance is too great.

Noncompliance of the fluorocarbon regulations is costly to any individual who chooses to ignore them. **The responsibility of compliance lies with both the individual performing the service or repair and his or her employer.** As the first line of compliance, it is up to the technician to follow all applicable state and federal mandates that are presently in force or that may come into play at a future date.

In recent years, federal court decisions have invalidated some of EPA's regulatory scheme as applied to HFCs and substitutes, such as the new generation of flammable refrigerants. The exact nature of appropriate federal regulation of HFCs and substitutes are uncertain, but it does not change the view that proper management, servicing and disposal practices are important from a safety and environmental point of view. In addition, numerous states are filling in the gaps where EPA regulation may be restricted so the practices stated in this guide are still appropriate and will help users comply with state as well as federal laws.

Economic Considerations

Thus far, we have concentrated on environmental and legislative reasons for refrigerant recovery. There is, however, another reason why refrigerants are recovered. From a purely economic standpoint, recovery makes good business sense. The steady demand for CFC, HCFC and HFC refrigerants, coupled with the mandatory cutbacks in production and increased taxes, will drive the price of new (virgin) refrigerants upward. However, by recovering, recycling, and reclaiming these refrigerants, we will be able to continue servicing the millions of appliances already in use. Without such refrigerant containment, consumers may be forced to replace appliances before their useful life has expired.

Conservation of Refrigerants

Recovery, Recycling, and Reclamation

Unless something is done to preserve supplies of refrigerants, the cost of repairing present systems will probably rise beyond the point of affordability for most consumers. The only game in town, therefore, is to **conserve**, **recover** and **reclaim** the ozone-depleting refrigerants that are already in use. Proper detection of system leaks and repairs to the system will help conserve existing stocks of refrigerant. Furthermore, recovered refrigerant can be reclaimed and reused at a much lower cost to the consumer.

Reclamation should not be confused with recycling or recovery. In the past, these terms have been used interchangeably. Each term, however, has its own meaning.

Recovery is the process of removing refrigerant from a system and storing it in an external container without testing or processing it in any way.

Recycling is accomplished when refrigerant is removed from a system and is passed through filters to separate the oil and reduce the moisture, acid and particulate matter content that may be present. In most cases, the refrigerant is then reinstalled in the system that it came out of without the benefit of testing. Due to the sensitivity of small appliance sealed systems to contamination, most small appliance manufacturers presently discourage the use of recovered refrigerant that has not been reclaimed. Typically, only the automotive air conditioning repair industry utilizes recycling equipment since their systems are not subject to the contamination that occurs when a compressor burns out.

In the process of **reclamation**, the used refrigerant is brought back to new product by a chemical process, which may include distillation. The term usually applies to procedures available at a reprocessing or manufacturing facility. Chemical analysis of the reclaimed refrigerant is required, and the reprocessed refrigerant must meet EPA standards based upon AHRI Standard 700. Regardless of the purity levels achieved in the reprocessing method, the refrigerant is not considered “reclaimed” until the chemical analysis shows it to meet this standard.

EPA regulations ban the sale of used refrigerant, unless the refrigerant has first been reclaimed by an EPA-certified refrigerant reclaimer.

Maintaining purity levels is important for several reasons. The most important of these is that once refrigerants are mixed, they become a new compound that behaves differently and has different properties than the base refrigerants. Thus, in a sealed system, a mixture of R-12 and R-22 will have different characteristics than either R-12 or R-22.

Systems using HFCs, such as R-134a, are especially vulnerable to cross-contamination from CFCs, HCFCs and HFCs. Chlorine, even in minute quantities, will cause premature failure of system components.

Although reclamation of such mixtures may one day be possible, they are not reclaimable at this time. Mixing refrigerants, therefore, may make them unusable waste that is difficult to separate for subsequent use as a refrigerant. If a reclaimer receives mixed refrigerant from a servicer, it could be refused, returned, or with the servicer’s approval, destroyed at the servicer's expense. It’s important, therefore, ***that separate refrigerant containers are used for each refrigerant during recovery and charging*.**

Educational Requirements

This training program has been developed to assist you in meeting the certification requirements of the Clean Air Act and the EPA regulations. Certification will require that you prove your competency in proper refrigerant handling by taking and passing an EPA approved test.

Continual Education

Certification will be an ongoing process. Once certified, technicians will only remain certified as long as they are in compliance with the rules and regulations that are put in place. As changes are enacted, it will be your responsibility to comply with those changes. Furthermore, if you are found to be in violation of either present or future regulations, you will, at the very least, be subject to losing your certification (and thus your right to maintain and repair refrigeration equipment). In a worst-case scenario, you could be subject to fines and even imprisonment.

Unfortunately, ignorance of the law will not exempt you from compliance. Therefore, every technician must make an effort to stay current on any changes that come about.

Consumer Awareness

Besides the legal and economic ramifications just described, there is one additional reason to be fully aware of all the aspects of the refrigerant issue. Consumers deserve accurate and sincere responses to their questions and concerns.

While many consumers will be familiar with the refrigerant issue, it is likely that many concerns will still arise. Opinions vary and every customer is entitled to his or her own view. Both positive and negative feelings about the refrigerant issue will be encountered. Customers may have questions about such things as the safety of equipment you use, the adequacy of your recovery efforts, whether recovery requirements will cause your service fees to increase, and the need for recovering refrigerants. Not all of your customers will be sold on the idea that refrigerant recovery is necessary.

As the front-line representative who deals directly with the consumer, you will be confronted with their concerns. The customer will look to you for answers. When addressing consumer concerns, remind the customer that recovery is necessary to protect the environment and thus, human health. Inform them that the procedures and equipment you use are safe and are highly regulated by the U.S. EPA, and that recovery is the law and all service professionals are legally bound to follow the law.

Having read thus far in this training manual, you have no doubt become aware that the world of appliance refrigerants is changing often and changing rapidly. It is the responsibility of service technicians to be trained on servicing equipment containing these new refrigerants used today and in the years to come. Conducting service on equipment in the future will require constant updated training. This is not only true of the performance of the equipment but especially in the safety of the equipment, the service technician and the consumers.

Section 6 – Refrigerant Handling & Safety

Refrigerant handling and cylinder safety are primarily regulated by Department of Transportation (DOT) guidelines. There is also an OSHA (U.S. Occupational Safety and Health Administration) requirement that compressed gas cylinders should only be handled by individuals who are trained in the proper handling procedures and safe use of these cylinders.

General Refrigerant Safety

Although future safety standards may be implemented to encompass replacement refrigerants (such as R-123 and 134a), there are general safety considerations that should be heeded regardless of the refrigerant being handled. Before handling any refrigerant, personnel should be familiar with the general and specific safety concerns for that product. This is especially true of any new refrigerant that has not been fully tested and for which specific test data is not yet available.

Safety Data Sheets

Every refrigerant manufacturer publishes and makes available **Safety Data Sheets** (SDS) for the various refrigerants it produces. The SDS for each refrigerant lists all the pertinent material and safety information that is required knowledge for anyone handling that refrigerant.

The front page from a typical SDS is shown on the right. Every technician is required to carry a separate SDS for each refrigerant being transported or handled. The SDS sheets must be available for inspection upon request by authorized individuals. Each manufacturer also publishes important safety recommendations for the use and handling of its products. As a handler of hazardous chemicals, you should be familiar with and follow all of the recommended safety precautions that are outlined in these sheets. Safety Data Sheets are also available for solvents and other chemicals. Safety Data Sheets should be reviewed whenever a technician works with refrigerants or other chemicals with which he or she is not familiar.

Health Hazards of Improper Refrigerant Use

Even though the toxicity of many refrigerants is low, deliberate misuse of refrigerants can cause serious injury or even death**. Refrigerant vapor is generally several times denser than air and displaces available oxygen. Thus, good ventilation is a must whenever refrigerants are being handled.**

Intentional and accidental inhalation of concentrated vapor is extremely dangerous. Exposure to levels of refrigerants beyond the recommended levels can result in loss of concentration and drowsiness. Refrigerant vapors or mist in high concentrations should not be inhaled since **they may cause, among other things, heart irregularities and unconsciousness.**

Refrigerants are also asphyxiants. This means that refrigerants displace air and reduce available oxygen for breathing. **In most fatal accidents involving refrigerants, the major cause is oxygen deprivation (asphyxia).**

Of course, the exposure levels for replacement refrigerants will not be known until the test data for each is released. Care should be taken to limit exposure at all times since replacement refrigerants may have higher toxicity levels than current refrigerants. ***Read and follow all safety recommendations found on the SDS for the refrigerant being handled.***

Another consideration is the refrigerant's ability to cool. Frostbite and skin irritation are always major causes for concern. Protective gloves and safety goggles should be worn when contact with liquid refrigerant is possible. If skin contact occurs, first flush with water and then treat for frostbite (if necessary) by gently warming the affected area.

Lastly, most chlorofluorocarbons (CFC) refrigerants decompose at high temperatures. Deliberate or accidental exposure of refrigerants to open flames (such as working around standing pilot gas water heaters, furnaces and ranges) creates toxic gases and acids. Hydrofluoric and, if the compound contains chlorine, hydrochloric acids can be formed. Hydrofluoric acid can cause internal injuries if inhaled, but can also cause burns of the skin. In the presence of water or oxygen, a small amount of phosgene gas may be created. This is also true of some A2L replacement refrigerants which contain hydrogen and fluorine, such as R-32, R-452b, HFO-1234yf and HFO-1234ze.

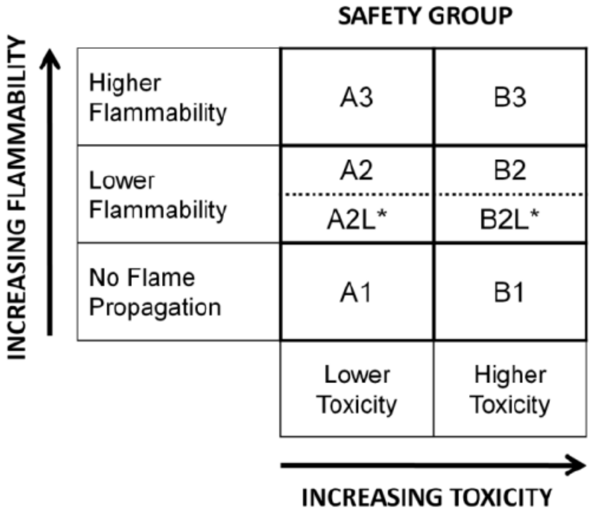
Fortunately, these acids and gases are very pungent and have a stinging effect on the nose. Detection is therefore easy and should serve as a warning that decomposition has occurred. When they are detected, the affected area should be evacuated immediately until all of the toxic agents have been purged. ***Small pets, children, the elderly and individuals with respiratory and heart conditions are especially susceptible to harm from these agents*.**

Of course, the general safety outlines just described are based on experience with known refrigerants. As test results are made available for replacement refrigerants, additional safety standards may be established.

ASHRAE Refrigerant Safety Classifications

The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) has developed safety classifications for refrigerants. The table below indicates safety levels related to toxicity and flammability according to ASHRAE 34.

As can be seen from the table, safety group A1 presents the least risk to the technician. Safety group B3 presents the highest risk since the refrigerant has the highest flammability and toxicity. Technicians should be familiar with these classifications.



Higher Flammability	A3	B3
Lower Flammability	A2 A2L*	B2 B2L*
No Flame Propagation	A1	B1
	Lower Toxicity	Higher Toxicity

* A2L and B2L are lower flammability refrigerants with a maximum burning velocity of ≤ 10 cm/s

Figure 6.1: Refrigerant safety groupings in ASHRAE Standard 34-2013

Preparing the area for service

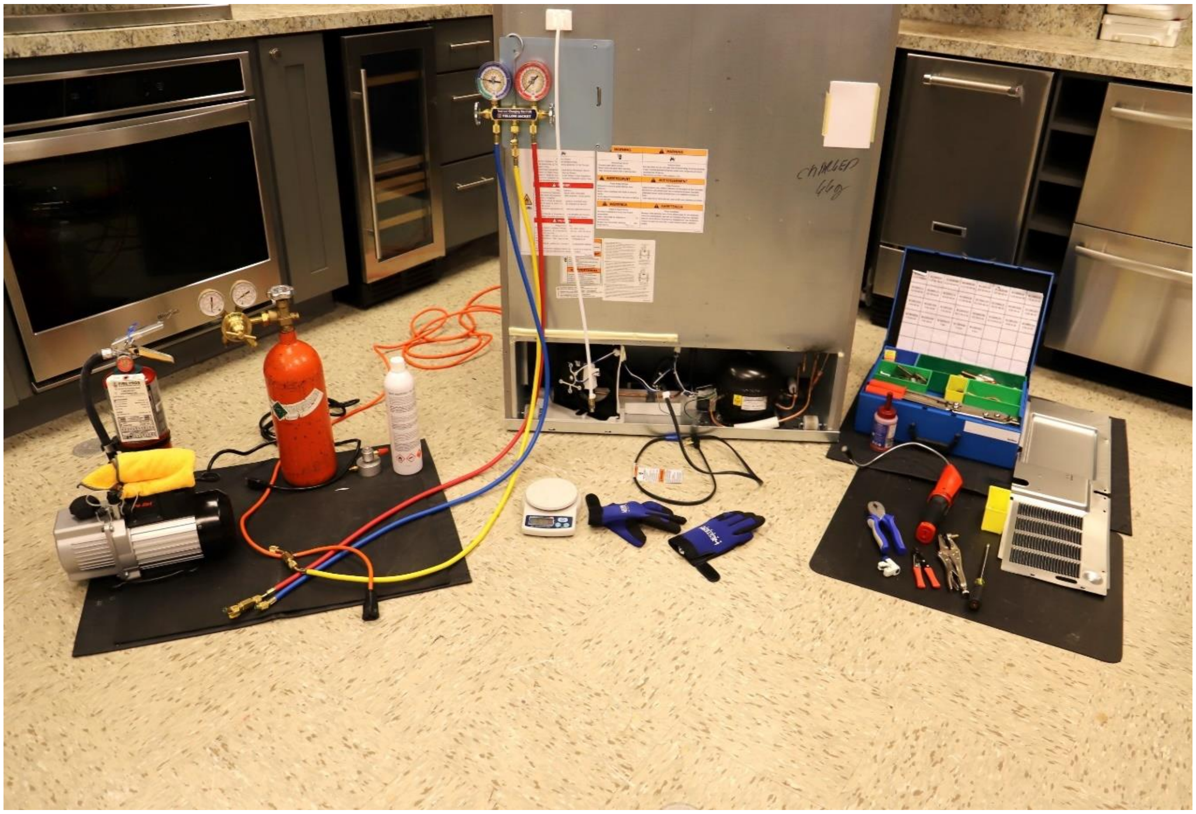


Figure 6.2

General Precautions When Handling Refrigerants

- An appropriate fire extinguisher should be near the work site at all times.
- A combustible gas sensor should be used whenever the marking on the product indicates that the refrigerant is flammable.
- Always read the product label and Safety Data Sheet.
- Always use with adequate ventilation.
- Never expose these products to flames, sparks or hot surfaces.
- Always wear side-shield safety glasses, safety shoes and impervious gloves and any other provided protective equipment or clothing that may be required for the situation when handling refrigerants.

Many of these refrigerants are extremely cold and may cause burns when in contact with the skin. Use gloves, eye protection and proper clothing at all times.

- Always be aware of the location of the nearest water supply before proceeding. Should refrigerant come in contact with eyes or skin, it may be necessary to deluge affected areas with water.
- The refrigerated appliance and all pumps or refrigeration evacuation units should be grounded.
- Never intentionally misuse the product or allow its misuse.
- Avoid contact with clothing.
- Store refrigerant only in approved containers.

- Secure cylinders properly during transport.
- Always store and transport cylinders in the upright (vertical) position.
- Never apply open flames, live steam or excessive heat to a refrigeration cylinder (cylinder may explode causing serious bodily harm or death to anyone in the vicinity).
- Never cut or weld any refrigerant line that is filled with refrigerant.
- Never use oxygen or compressed air to purge lines or to pressurize a sealed system for leak testing purposes because oxygen and oil can explode when mixed.
- In the case of refrigerant systems involving HFC or blends containing HFC (such as HFO) refrigerants, if the appliance shows signs of burning or charring of components in the machine compartment, stop and contact the manufacturer before proceeding.

Figure 6.3

Handling Refrigerant Spills or Releases

Caution: Large spills and releases should only be handled by trained emergency responders and rescue workers. All persons in the area who are not trained and who are not equipped with an SCBA must vacate the area immediately.

If a large spill or release of refrigerants occurs, a self-contained breathing apparatus (SCBA) must be used since these refrigerants displace oxygen available for breathing. A SCBA is a respiratory device used for emergency and rescue work in the event of an accident involving hazardous materials that may produce toxic gases and/or displace oxygen. This device has a face mask which is connected by hoses to compressed air cylinders or canisters which supply oxygen to the emergency/rescue worker. The SCBA enables the emergency responder or rescue worker to enter the contaminated or oxygen-deficient atmosphere, up to limits specified on the cylinder or canister.

In the case of a spill or release (i.e., an enclosed area where filled cylinder(s) have ruptured and leaked), all occupants should immediately vacate the area and the area must be ventilated (especially low places where heavy vapors might collect). If cylinders rupture and contents are released under fire conditions, the SCBA device must also be used by responders and workers in the area.

Cylinder Safety

As a small appliance technician, you will rarely deal with larger than 50-pound refrigerant cylinders. Be aware that regulations differ for the various size cylinders. For the purpose of this manual, however, we will concentrate on the types of refrigerant containers that you are most likely to encounter.

Disposable Refrigerant Cylinders

Virgin refrigerants are normally packaged in disposable cylinders that are color coded to indicate the type of refrigerant that is contained in the cylinder. These cylinders are manufactured to specifications established by the U.S. Department of Transportation (DOT). The DOT regulates the transportation of all hazardous materials.

COLOR CODING	
R-11	Orange
R-12	White
R-22	Green
R-500	Yellow
R134a	Light Blue
R410A	Rose

Disposables built to transport CFCs are manufactured to Specification 39 and are often referred to as DOT 39's. The DOT 39 specification stipulates that all cylinders manufactured for refrigerants must withstand the highest pressure CFC (R-502). R-502 cylinders must be rated to withstand a service pressure of 260 PSI and are leak tested at 325 PSI. One out of a thousand cylinders is tested to the point of failure and must not rupture below 650 PSI. The purpose of these tests is to assure that end users receive a safe and leak-free container.

Each cylinder is equipped with a safety relief device that is intended to vent the refrigerant should an over-pressure situation arise. The primary reason for over-pressurization is overheating of the cylinder. When the cylinder is exposed to temperatures that exceed 125° F, the compressed gas can expand to liquid-fill the cylinder. This is known as a hydrostatic condition. At this point, even the slightest temperature increase can cause the internal pressure of the liquid to rise very rapidly. If the refrigerant is not allowed to vent, the cylinder can explode, causing serious damage, personal injury and even death. **Never tamper with safety relief devices on any pressurized container and never intentionally heat a cylinder.**

DOT 39 makes it very clear that ***reuse of disposable cylinders is illegal.*** Under no condition should a disposable cylinder be reused for any reason. Since the cylinders are manufactured from steel, rust can eventually weaken cylinder walls to the point where normal refrigerant pressures can cause the walls to rupture. Thus, anyone transporting refilled disposable cylinders is subject to a severe monetary penalty and possible imprisonment. In addition, refilling disposable cylinders may violate OSHA workplace regulations and some state laws as well. Once the cylinder is used, the refrigerant should be recovered and the cylinder rendered useless and returned for proper recycling. ***Always read and follow the safety warnings that are printed on every cylinder.***

Residual refrigerant must be evacuated and recovered (pressure reduced to at least 0 psig) from disposal cylinders before they are discarded. Cylinders that are filled or partially filled may eventually deteriorate to the point where the walls could rupture before the safety relief device activates. After the residual contents are recovered, the valve(s) must be removed, and the tank marked "EMPTY." These steps are taken to ensure that the entire refrigerant is recovered, and the disposal cylinder is rendered useless before the metal is recycled.

Recovery Cylinders

Recovery cylinders must also comply with DOT specifications. Recovery cylinders are painted yellow in the shoulder area. The remainder of the cylinder body is painted gray.

The cylinder of choice for most residential recovery applications is a 30 lb. tank. Regardless of the size, however, a recovery cylinder must **not be filled beyond 80% of its capacity.** The 80% maximum is a DOT requirement. State and local laws may set more stringent requirements. Filling beyond 80% can cause an excessive pressure condition which may pose an explosion hazard.

Each cylinder is stenciled or stamped “MAX. GROSS WT_.LB.” This weight represents the total weight of the cylinder and its contents.

There are several methods of monitoring 80% fill levels in recovery cylinders. One method uses a ball or float switch device to provide an electro-mechanical means of controlling the level of refrigerant inside the cylinder. The ball floats atop the liquid and actuates a switch when the liquid reaches the 80% full mark. This switch, which is connected to the recovery device through a wire cable, automatically shuts off the recovery device. Another method uses two thermistors to monitor the temperature of both the bottom of the tank and the 80% fill mark. The bottom thermistor registers liquid temperature while the top thermistor monitors the warmer vapor temperature. When the liquid level reaches the upper thermistor, the temperatures of the two thermistors equalize and the recovery device shuts off.

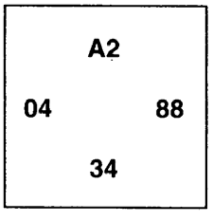
The recovery cylinder contents can also be monitored by placing the cylinder on a scale during each refrigerant addition, or the cylinder can remain on a dedicated scale from the initial transfer of refrigerant to the final addition. The tare (empty) weight of the cylinder must be known prior to beginning transfer of refrigerant into the cylinder. This weight is typically stamped on the collar of the cylinder.

The “MAX. GROSS WEIGHT” of the tank and contents is based on water weight. Thus, the density of the refrigerant must be known in order to determine the correct weight of the refrigerant that can be added (in order not to exceed the 80% capacity). This method of regulating the fill level requires close monitoring by the operator.

Regardless of the method used to determine the maximum fill level, a cylinder should be inspected prior to filling for signs of damage such as dents, gouges, bulges, cuts or other imperfections which may render the cylinder unsafe to hold refrigerant for storage or transportation. ***Never fill a damaged cylinder and use only refillable DOT-approved recovery cylinders that meet safety requirements.***

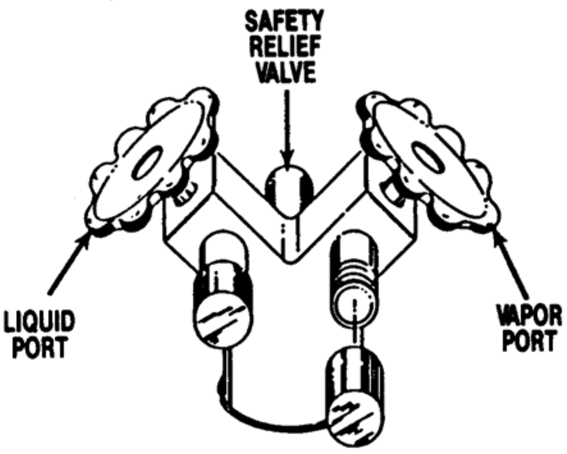
If the refrigerant in the recovery cylinder is suspected to be contaminated, the pressure of the cylinder should be checked against the stable ambient temperature and known values of the refrigerant in question. These can be compared against a pressure temperature chart for the applicable refrigerant. Any recovery cylinder suspected of being contaminated should be returned for reclamation.

A refillable (reusable) cylinder for refrigerants that are under high pressure (above 15 psig) at normal ambient temperatures must be hydrostatically tested and date stamped every 5 years to meet DOT safety requirements. The cylinder should not be filled if the present date is more than 5 years past the test date that is stamped on the shoulder of the cylinder. The test date will look similar to the example to the right. In this example, the cylinder was retested in April of 1988 by re-tester number A234.



Valves

Refillable cylinders designed to be used in the capture of refrigerants are equipped with a “Y” configured combination valve that provides access to either liquid or vapor while the tank is in the upright position. One of the valves is ported to the top of the cylinder and the other is ported to a dip tube that draws from the bottom. Each valve handle is marked to denote the “VAPOR” and “LIQUID” port.



These valves also include a spring-actuated safety relief valve for over-pressurization protection and are set to discharge at pressures between 1.5 and 2.0 times the design pressure of the cylinder. Use manual or self-sealing valves on the end of the gauge set hose to reduce the likelihood of releasing refrigerant.

After filling, verify that all cylinder valves are closed properly to prevent leaks during subsequent handling and shipment.

Leak testing should be done with a bubble soap solution or electronic leak detector capable of sensing the refrigerant being recovered.

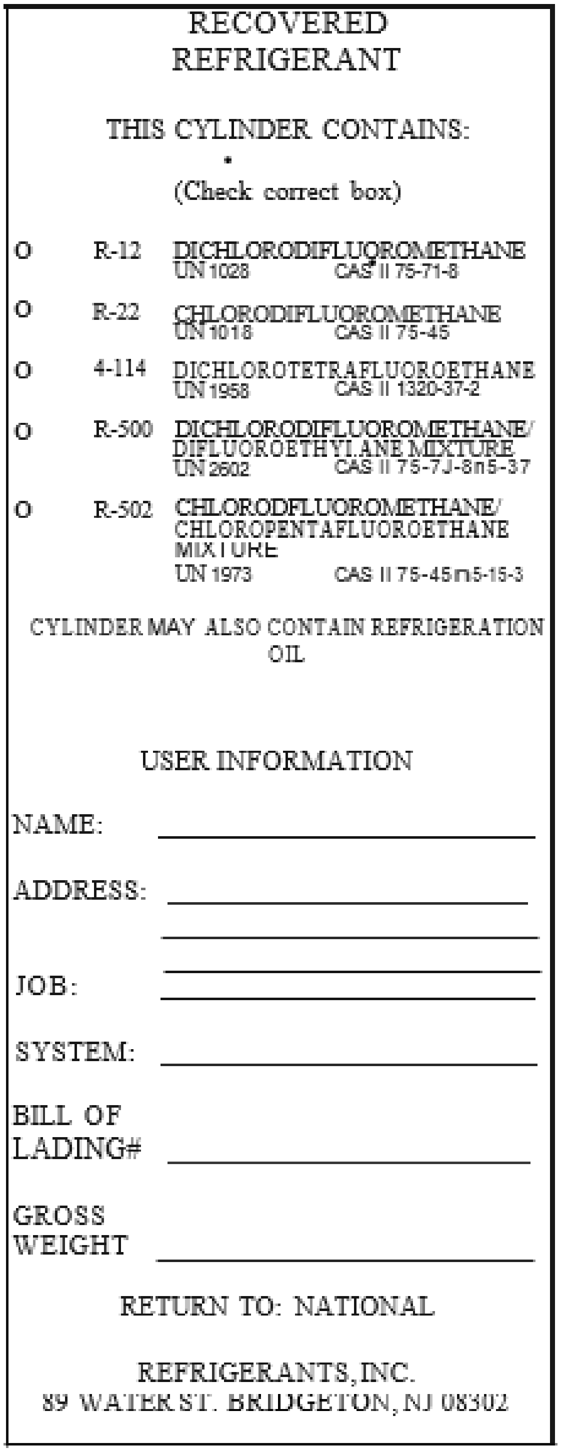
Figure 6.4

Transportation of Refrigerant Cylinders

Although the U.S. EPA does not characterize used refrigerants as hazardous waste, all refrigerant containers must be properly labeled for identification and transportation purposes (DOT requirement). Because of their pressurized state, all refrigerant containers are classified as hazardous materials and thus require this special labeling. A DOT label or tag should be attached to the cylinder to indicate its contents. Stick-on labels and/or tags are normally provided by the reclaimer. A typical tag is shown on the following page. One side of the tag allows the user to denote the type of refrigerant stored in the cylinder by checking the appropriate box. The other side contains the required “NON-FLAMMABLE” green label and all of the cautions and safety information that should be used with the cylinder and its contents.

Figure 6.5

The tag and/or labels should be affixed and marked prior to filling the tank. This prevents inadvertent mixing of refrigerants. Unlabeled containers in your truck are not only potentially dangerous but are also illegal. (In the event of an accident, most emergency personnel are instructed to avoid unidentified containers or cylinders. They must wait for a hazardous materials response team to arrive and identify the contents of the containers before cleanup action can be taken.)



RECOVERED REFRIGERANT

THIS CYLINDER CONTAINS:

(Check correct box)

○ R-12 DICHLORODIFLUOROMETHANE
UN 1028 CAS # 75-71-8

○ R-22 CHLORODIFLUOROMETHANE
UN 1018 CAS # 75-45

○ 4-114 DICHLOROTETRAFLUOROETHANE
UN 1958 CAS # 1320-37-2

○ R-500 DICHLORODIFLUOROMETHANE/ DIFLUOROETHYLANE MIXTURE
UN 2602 CAS # 75-7J-8n5-37

○ R-502 CHLORODFLUOROMETHANE/ CHLOROPENTAFLUOROETHANE MIXTURE
UN 1973 CAS # 75-45n5-15-3

CYLINDER MAY ALSO CONTAIN REFRIGERATION OIL

USER INFORMATION

NAME: ____________________

ADDRESS: ____________________
____
____

JOB: ____________________

SYSTEM: ____________________

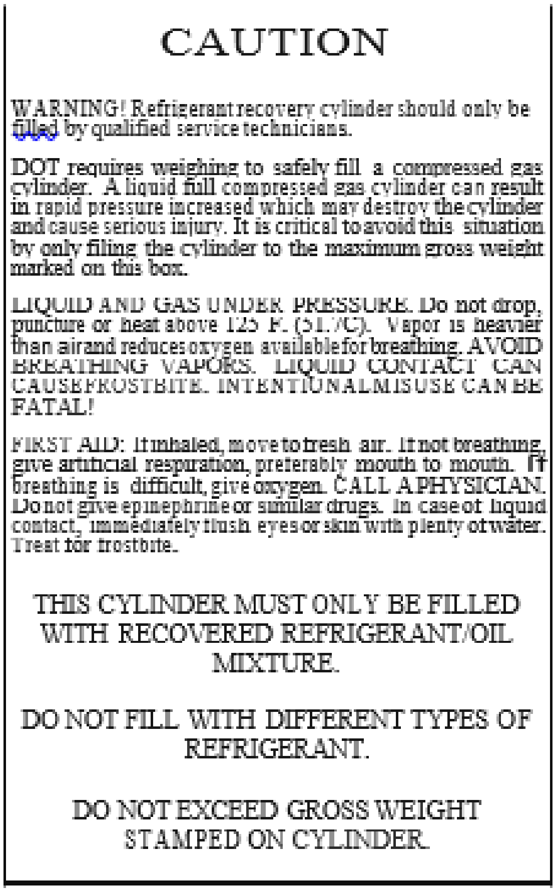
BILL OF LADING# ____________________

GROSS WEIGHT ____________________

RETURN TO: NATIONAL

REFRIGERANTS, INC.
89 WATER ST. BRIDGETON, NJ 08302

(FRONT)



CAUTION

WARNING! Refrigerant recovery cylinder should only be filled by qualified service technicians.

DOT requires weighing to safely fill a compressed gas cylinder. A liquid full compressed gas cylinder can result in rapid pressure increased which may destroy the cylinder and cause serious injury. It is critical to avoid this situation by only filing the cylinder to the maximum gross weight marked on this box.

LIQUID AND GAS UNDER PRESSURE. Do not drop, puncture or heat above 125 F. (51.7C). Vapor is heavier than air and reduces oxygen available for breathing. AVOID BREATHING VAPORS. LIQUID CONTACT CAN CAUSE FROSTBITE. INTENTIONAL MISUSE CAN BE FATAL!

FIRST AID: If inhaled, move to fresh air. If not breathing, give artificial respiration, preferably mouth to mouth. If breathing is difficult, give oxygen. CALL A PHYSICIAN. Do not give epinephrine or similar drugs. In case of liquid contact, immediately flush eyes or skin with plenty of water. Treat for frostbite.

THIS CYLINDER MUST ONLY BE FILLED WITH RECOVERED REFRIGERANT/OIL MIXTURE.

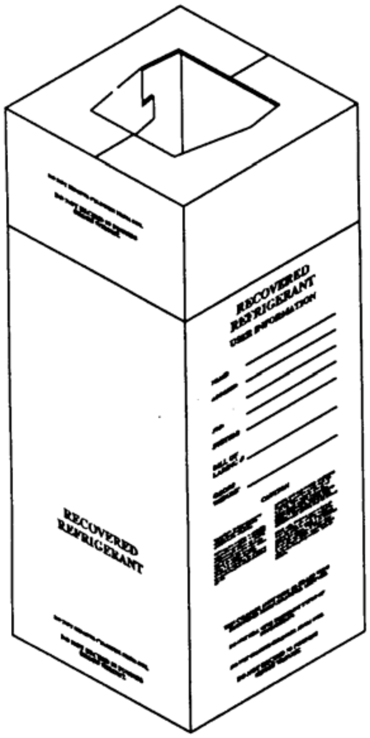
DO NOT FILL WITH DIFFERENT TYPES OF REFRIGERANT.

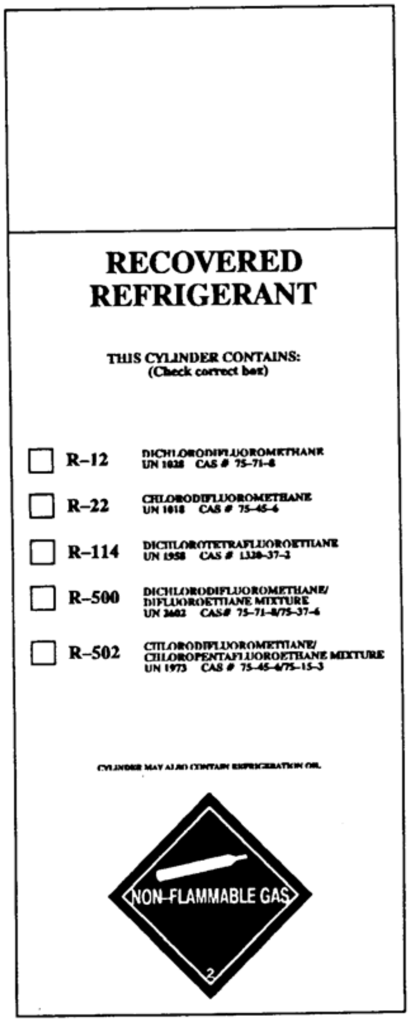
DO NOT EXCEED GROSS WEIGHT STAMPED ON CYLINDER.

(BACK)

Instead of tags, a carton (cardboard box) system may be used. When a box system is used, tags are not needed since the cylinder is placed in the carton and all of the information that normally appears on the tag is printed on the carton. In addition, the recovery cylinder is not required to be painted gray and yellow since these colors appear on the box. Thus, the recovery cylinder may be one solid color (such as white or cream).

When this system is used, the recovery cylinder must remain in the carton at all times (since there are no markings on the cylinder itself). **Once the cylinder is removed from the carton, it is difficult to identify the contents of the cylinder and the possibility of mixing refrigerants is increased. In addition, it is illegal to transport unmarked tanks.**



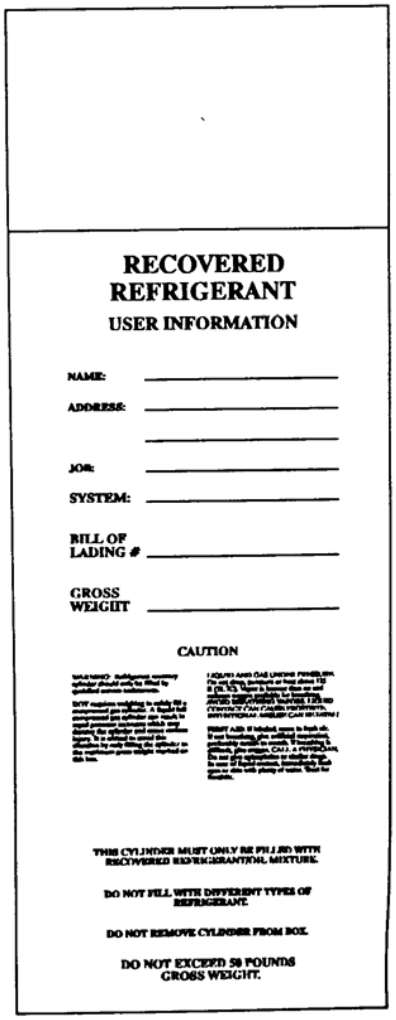


RECOVERED REFRIGERANT

THIS CYLINDER CONTAINS:
(Check correct box)

☐ R–12 DICHLORODIFLUOROMETHANE UN 1028 CAS # 75–71–8
☐ R–22 CHLORODIFLUOROMETHANE UN 1018 CAS # 75–45–6
☐ R–114 DICHLOROTETRAFLUOROETHANE UN 1958 CAS # 1320–37–2
☐ R–500 DICHLORODIFLUOROMETHANE/ DIFLUOROETHANE MIXTURE UN 2602 CAS# 75–71–8/75–37–6
☐ R–502 CHLORODIFLUOROMETHANE/ CHLOROPENTAFLUOROETHANE MIXTURE UN 1973 CAS # 75–45–6/75–15–3

CYLINDER MAY ALSO CONTAIN REFRIGERATION OIL.



RECOVERED REFRIGERANT

USER INFORMATION

NAME: ____________
ADDRESS: ____________
____
JOB: ____________
SYSTEM: ____________
BILL OF LADING # ____________
GROSS WEIGHT ____________

CAUTION

[illegible]

THIS CYLINDER MUST ONLY BE FILLED WITH RECOVERED REFRIGERANT/OIL MIXTURE.

DO NOT FILL WITH DIFFERENT TYPES OF REFRIGERANT.

DO NOT REMOVE CYLINDER FROM BOX.

DO NOT EXCEED 50 POUNDS GROSS WEIGHT.

Shipping Papers

In addition to affixing the appropriate tags or labels to each refrigerant cylinder, a shipping paper must accompany each cylinder or group of cylinders of refrigerant. The regulations do not differentiate between refrigerants and other pressurized gases. All pressurized containers, whether being shipped from one location to another or being transported in a service vehicle, must be identified correctly on the shipping paper.

Even though the EPA has exempted recovered refrigerant destined for reuse (either recycling or reclaiming) from hazardous waste status, DOT does regulate these "used" refrigerants as hazardous materials for transportation purposes. They are classified as a non-flammable compressed gas which is DOT hazard class 2.2, under Department of Transportation Regulations, 49CFR. Using October 1, 1993 DOT regulations, a cylinder of refrigerant is entered on the shipping paper first by the proper shipping name, second by the hazardous class and third by the UN (United Nations) identification number. Thus, the shipping paper entry for R-12 must appear as follows on the shipping paper:

Dichlorodifluoromethane, 2.2, UN 1028

Also, shipping papers must show the number of cylinders of each gas. This information is used by emergency responders to react appropriately to the particular hazardous materials involved in an accident. **This information must be entered accurately and *in the correct sequence.***

The above DOT system has now been adopted by the UN international system; therefore, if an accident occurs in the U.S. or Australia involving R- 12, the shipping paper entries will be identical.

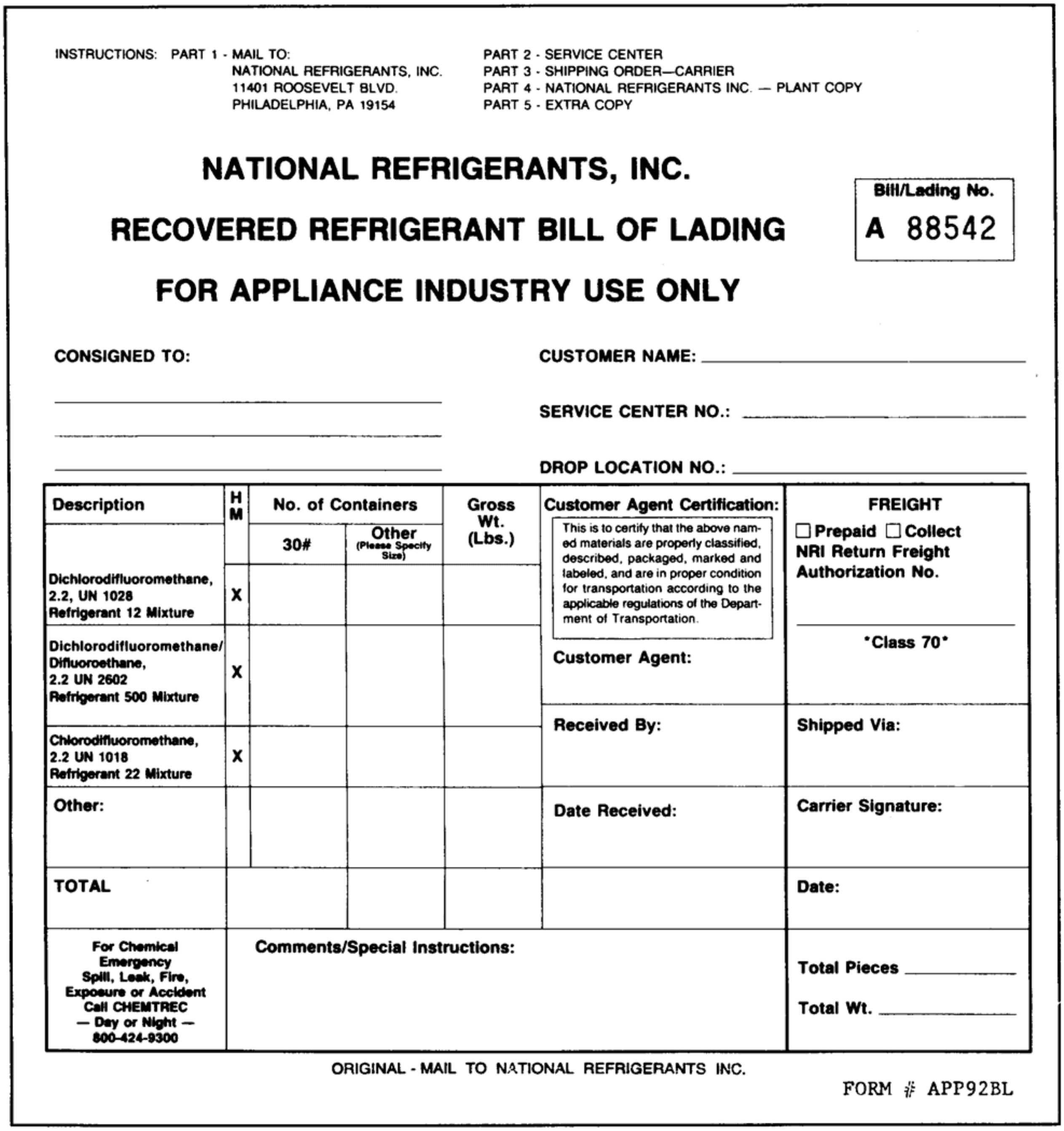
Note: EPA regulations stringently restrict and in some cases ban the import of CFC and HCFC refrigerants.

Bill of Lading

A common shipping paper used to transport compressed materials via common carrier is the bill of lading. In addition to the above-listed information describing the type of compressed gas being shipped, the following information is generally required to appear on a bill of lading:

- Company name of the carrier
- Date
- Company name and address of the shipper
- Signature of the shipping Company's representative
- Shipping destination
- Identity of the compressed material (i.e., R-12, R-22, Oxygen) listed per the DOT requirement above
- Number of containers being shipped
- Gross product weight, in pounds
- Shipping information
- Emergency contact information (phone number that is manned 24 hours a day) that can be used by the emergency responders to learn about the chemicals being shipped

In many cases, the bill of lading, complete with all of the required information, is provided to the shipper by the reclaimer. An example of such a bill of lading is shown on the following page.



INSTRUCTIONS: PART 1 - MAIL TO:
NATIONAL REFRIGERANTS, INC.
11401 ROOSEVELT BLVD.
PHILADELPHIA, PA 19154

PART 2 - SERVICE CENTER
PART 3 - SHIPPING ORDER—CARRIER
PART 4 - NATIONAL REFRIGERANTS INC. — PLANT COPY
PART 5 - EXTRA COPY

NATIONAL REFRIGERANTS, INC.

RECOVERED REFRIGERANT BILL OF LADING

FOR APPLIANCE INDUSTRY USE ONLY

Bill/Lading No.
A 88542

CONSIGNED TO: ______________________

____

____

CUSTOMER NAME: ______________________

SERVICE CENTER NO.: ______________________

DROP LOCATION NO.: ______________________

Description	H M	No. of Containers		Gross Wt. (Lbs.)	Customer Agent Certification:	FREIGHT
		30#	Other (Please Specify Size)			
Dichlorodifluoromethane, 2.2, UN 1028 Refrigerant 12 Mixture	X				This is to certify that the above named materials are properly classified, described, packaged, marked and labeled, and are in proper condition for transportation according to the applicable regulations of the Department of Transportation.	☐ Prepaid ☐ Collect NRI Return Freight Authorization No. ____________
Dichlorodifluoromethane/ Difluoroethane, 2.2 UN 2602 Refrigerant 500 Mixture	X				Customer Agent:	*Class 70*
Chlorodifluoromethane, 2.2 UN 1018 Refrigerant 22 Mixture	X				Received By:	Shipped Via:
Other:					Date Received:	Carrier Signature:
TOTAL						Date:
For Chemical Emergency Spill, Leak, Fire, Exposure or Accident Call CHEMTREC — Day or Night — 800-424-9300	Comments/Special Instructions:					Total Pieces ____________ Total Wt. ____________

ORIGINAL - MAIL TO NATIONAL REFRIGERANTS INC.

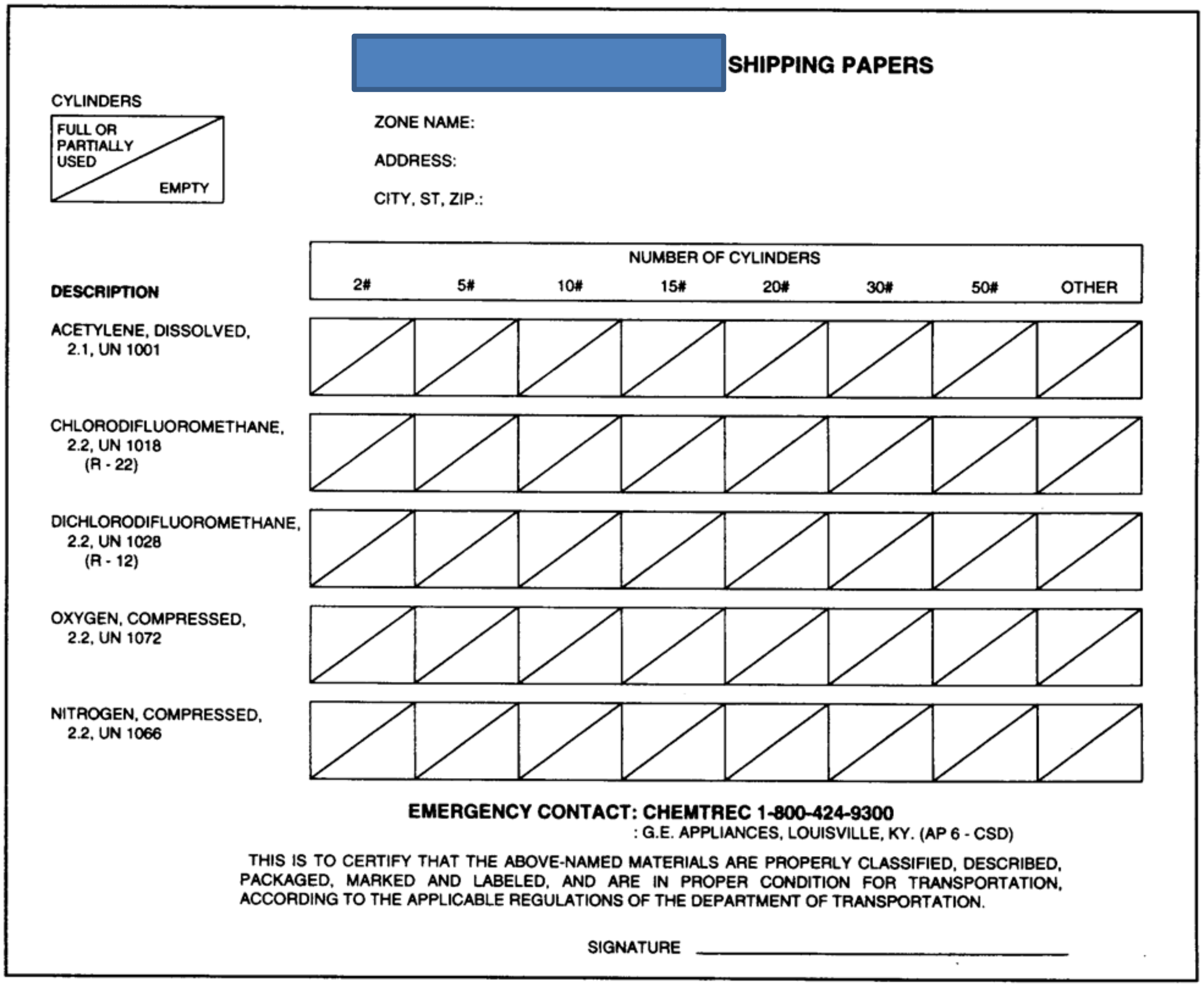
FORM # APP92BL

Typical Bill of Lading

Some carriers, such as UPS, have developed their own shipping papers that cancel the need for the bill of lading. Since a shipping paper is required, the shipper should *check with the carrier to ensure that the proper paperwork accompanies all refrigerants being shipped.*

Other Shipping Papers

The shipping paper requirement for compressed gases is not new to the refrigeration industry. All pressurized containers, including such commonly transported items as acetylene, oxygen and compressed air, must be accompanied by a shipping paper whenever they are transported. Thus, some companies have developed customized shipping papers that list the commonly used materials transported by their technicians.



[redacted] **SHIPPING PAPERS**

CYLINDERS

FULL OR PARTIALLY USED / EMPTY

ZONE NAME:
ADDRESS:
CITY, ST, ZIP.:

DESCRIPTION	NUMBER OF CYLINDERS 2#	5#	10#	15#	20#	30#	50#	OTHER
ACETYLENE, DISSOLVED, 2.1, UN 1001								
CHLORODIFLUOROMETHANE, 2.2, UN 1018 (R - 22)								
DICHLORODIFLUOROMETHANE, 2.2, UN 1028 (R - 12)								
OXYGEN, COMPRESSED, 2.2, UN 1072								
NITROGEN, COMPRESSED, 2.2, UN 1066								

EMERGENCY CONTACT: CHEMTREC 1-800-424-9300
: G.E. APPLIANCES, LOUISVILLE, KY. (AP 6 - CSD)

THIS IS TO CERTIFY THAT THE ABOVE-NAMED MATERIALS ARE PROPERLY CLASSIFIED, DESCRIBED, PACKAGED, MARKED AND LABELED, AND ARE IN PROPER CONDITION FOR TRANSPORTATION, ACCORDING TO THE APPLICABLE REGULATIONS OF THE DEPARTMENT OF TRANSPORTATION.

SIGNATURE ________________________

Customized Shipping Paper

Every technician is required to carry an up-to-date and completed shipping paper in his or her service vehicle anytime that pressurized containers are transported. Several states may impose special shipping procedures based on their own waste classification. Check with your appropriate state authority for additional regulations that may apply.

Section 7 - Basic Refrigeration and Dehydration Principles

The Clean Air Act, and in particular, the rules and regulations that control the capture and recycling of refrigerants, have brought an unparalleled awareness to the refrigeration industry. From the time that a refrigeration product is manufactured, to its disposal at the end of its useful life, no facet of the handling of that product can be taken for granted.

Nowhere is this more evident than in the refrigeration service industry. A thorough understanding of the refrigeration system and proper refrigerant recovery and dehydration procedures is essential before recovery should be attempted.

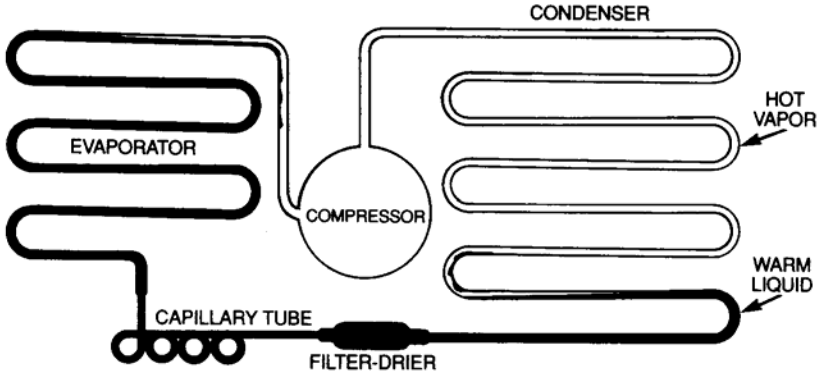
While it is assumed that any technician taking the EPA certification test has the necessary experience to perform sealed system repairs, a short review of basic refrigeration systems and components will reinforce some of the principles that make the recovery process more efficient and recovery concepts easier to understand.

The Basic Refrigeration System

Regardless of the size or function of the appliance, the basic refrigeration system that is used in most small appliances is known as a ***direct-expansion, vapor-compression system*****.** As with other types of systems, cooling **only takes place when liquid refrigerant turns into a vapor.**

To understand how these systems convert liquid refrigerant into a vapor, let's take a closer look at the five major components of the system and how they interact. The major components of a direct-expansion, vapor compression system are:

1. Compressor
2. Condenser
3. Filter-drier or strainer
4. Metering or expansion device
5. Evaporator



Each of these five components affects the refrigerant in some manner as it travels through the system. Some affect pressure, others affect temperature.

Pressure and temperature changes cause the refrigerant to alternately boil and condense. In effect, the refrigerant changes its state, from a liquid to a vapor and back to a liquid again. Each time that a change of state occurs, heat is either absorbed or given up. Without a change of state occurring, no significant heat can be absorbed or released.

It is the compressor and metering device that establish the pressure differentials required to cause the refrigerant to flow through the system and to condense or vaporize. Remember that even though both pressure and temperature have an effect on the state of a refrigerant, it is changes in pressure within the system that produce the greatest effect.

Vapor enters the compressor as a low-pressure, superheated[viii] vapor. Through compressor action, **the low-pressure vapor is transformed into high-pressure vapor** and propelled into the inlet of the condensing coil (condenser). At the outlet of the condenser, a metering or expansion device restricts the flow of refrigerant through the condenser.

One such metering device is the capillary tube found in most small appliances. Being much smaller in diameter than the condenser, the capillary tube reduces the flow of refrigerant as it leaves the condenser. And because the vapor enters the condenser at a faster rate than it can leave, vapor molecules begin to “bunch up” at the outlet.

As more and more vapor is introduced, the pressure within the condenser rises, forcing the vapor molecules closer and closer together. This makes it easier for the vapor molecules to recombine into a liquid. Because the condenser is exposed to ambient temperatures, cooling of the refrigerant takes place. The combination of increased pressure and reduced temperature causes the refrigerant to condense. In the process, the refrigerant gives up its heat. The temperature of the liquid entering the capillary tube, therefore, is reduced to ambient (or very close to ambient) temperature. In effect, ***the condenser changes the high-pressure vapor into a reduced temperature, high-pressure liquid.***

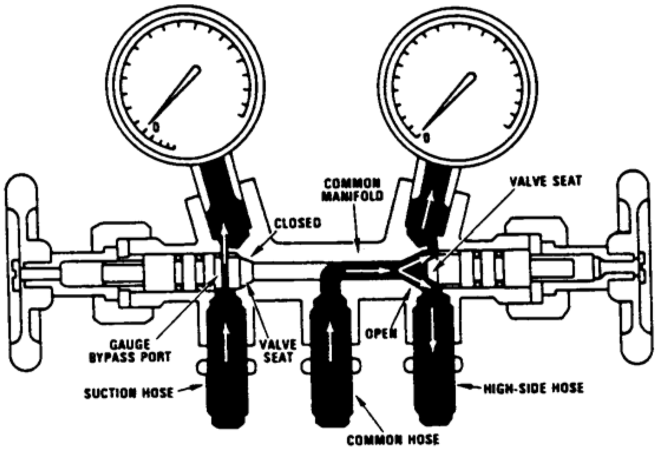
As the liquid makes its way from the condenser to capillary tube, it passes through the filter drier. This device does not affect pressure or temperature and acts only to trap any debris and moisture that may be traveling with the refrigerant. After the drier, the high-pressure liquid is forced through the capillary tube and into the evaporator coil.

Because the evaporator outlet is coupled directly to the suction side of the compressor, the pressure within the evaporator is very low (when compared to that of the condenser). As the high-pressure liquid exits the capillary tube and enters this reduced pressure area, the lower pressure causes the refrigerant to boil violently. As it boils, the refrigerant absorbs heat, and cooling of the evaporator coil takes place.

This process is ongoing. The refrigerant travels through the system, leaving one component and entering another. With the exception of the drier, pressure and/or temperature is altered every time the refrigerant travels through a component. As the refrigerant changes its state, it alternately absorbs and releases heat. In effect, all that any refrigeration system does is to move heat from an area where it is not wanted (such as the freezer compartment of a refrigerator) to an area where the added heat won’t matter (such as the kitchen).

Compound Gauges

The tool that is used to measure refrigerant pressures and partial vacuums in a sealed system is the ***gauge manifold*** (sometimes called the compound gauge). This combination gauge and valve assembly allows the technician to measure system pressures and to control the flow of refrigerant to and from the sealed system.



Manifold gauge sets are easily identified by the two color-coded gauges found atop a common manifold. The gauge on the left reads both pressure and partial vacuums and is color-coded blue. This gauge is calibrated to read pressures typically from 250 psig to 30 inches of mercury. Because of its ability to measure pressures below atmospheric pressure (partial vacuums), the blue gauge of the gauge manifold set is used to monitor the pressures found in the low side of a refrigeration system. The gauge on the right is color coded red and is used to monitor pressures on the high side of the system. This gauge is calibrated to read pressures typically from 0 psig (atmospheric pressure) to 800 psig.

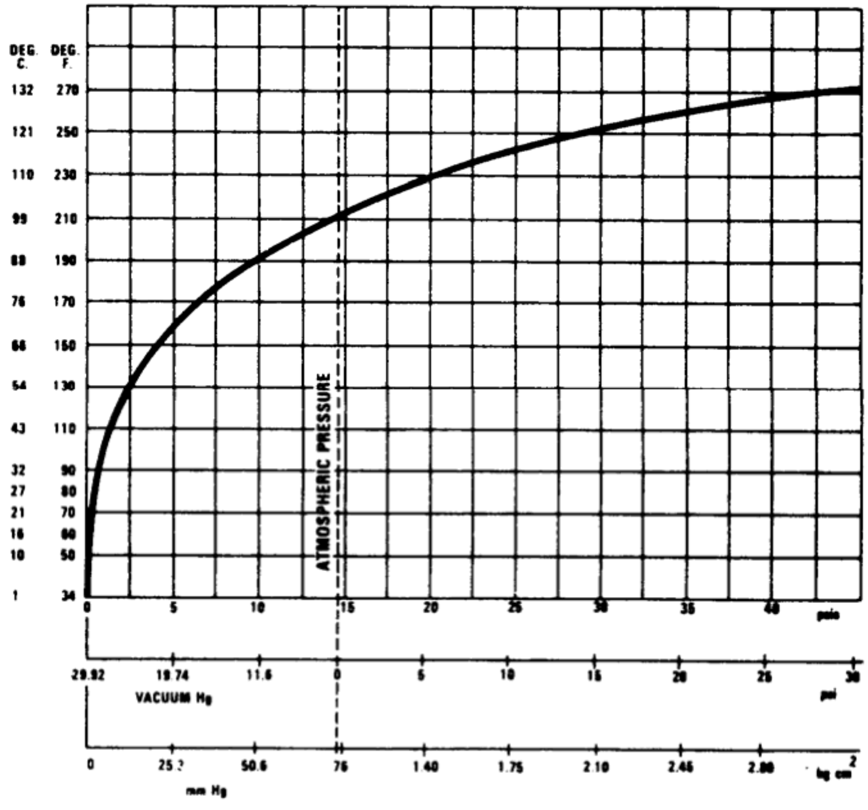
The gauges are coupled to a three-port manifold. Each of these three ports is designed to accept a refrigeration hose. When hoses are attached, refrigerant flow through the manifold can be controlled by the internal valves found on each side. The hand valve on the left controls flow to and from the low side of the system. The hand valve on the right controls flow of refrigerant to and from the high side of the system. A bypass port in each valve allows the gauges to read system pressures even when the valves are closed.

The center hose connection of the manifold is common to both the low and high side valves. By opening and closing each valve, the manifold gauge allows control of refrigerant flow from each side of the system to the center port or hose.

This arrangement of valves, gauges and hoses allows the technician to measure and monitor system conditions during system repair. By attaching both the low and high side hoses to the low and high sides of the system respectively, the valves can be opened or closed to allow control of refrigerant to the center port of the manifold during recovery, evacuation and charging of the system. When attaching gauges & hoses, manual or self-sealing valves on the ends of the hoses must be used to reduce the risk of leaking the refrigerant charge.

Evacuation and Dehydration Moisture, when mixed with refrigerants, can wreak havoc on any refrigeration system. Water mixes with the refrigerants to form ***hydrochloric*** and ***hydrofluoric acids.*** These acids travel through the system and systematically destroy compressor components. In addition, the moisture can collect at the end of the capillary tube. There, the moisture freezes and plugs the small-diameter tubing. Of course, once refrigerant ceases to travel through the system, cooling stops.

PRESSURE EFFECT ON BOILING WATER



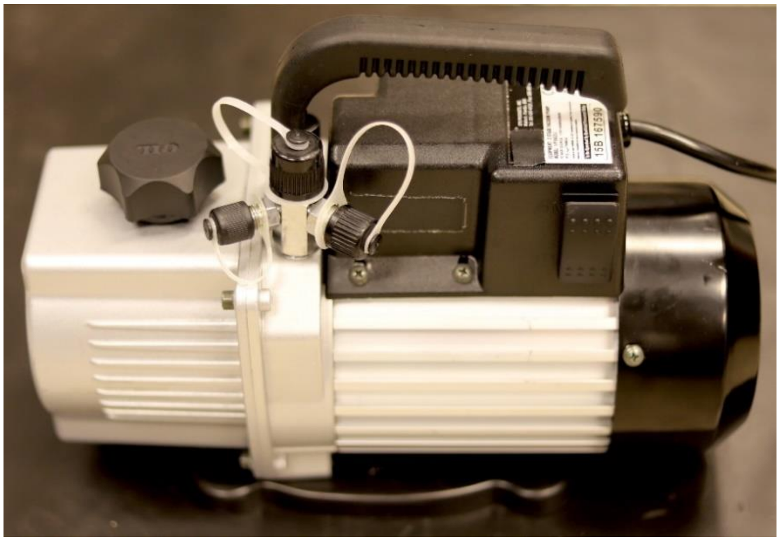
Even though the filter-drier is designed to trap moisture, it cannot absorb more than trace amounts of water vapor. Thus, it is imperative that the water be removed from the system (dehydrate the system) after the system is evacuated and before the new refrigerant charge is added.

Although there are two acceptable methods of dehydrating a system, the more commonly employed method involves the use of a vacuum pump (the other is the sweep charge method). Because of the challenges involved with the use of a vacuum pump, however, we will review some of the basic concepts and address some of the concerns that arise when the vacuum pump is not used properly (or is not sized correctly for the job).

As stated before, pressure has a tremendous effect on the change of state of any liquid. This holds true for water as well as refrigerant. By reducing pressure over water, the boiling point of the water can significantly be reduced.

As pressure approaches 29.92 inches of mercury (which is actually 0 pounds per square inch atmospheric or the absence of all pressure), the boiling point drops. In a perfect vacuum, water boils at approximately 34° F. The device used to reduce pressure within the refrigeration system is the vacuum pump.

Remember that the only reason a vacuum pump is used to evacuate a system is to dehydrate it (remove water and water vapor). It's important to understand that the vacuum pump is not designed to be used in the recovery of refrigerant. Vacuum pumps do not work well against pressure and cannot be used to pump refrigerant into a pressurized cylinder. Therefore, the vacuum pump should only be used after the recovery process is completed (using the recovery procedures outlined in the next section of this manual). In fact, the EPA requires that system pressure be at 0 psig (atmospheric pressure) or below, depending on equipment used and conditions encountered, before the vacuum pump can be attached.



Another effect of using the vacuum pump is that it will also remove any residual refrigerant that is trapped in the compressor oil. During off cycles of the compressor, refrigerant migrates to the crankcase of the compressor and is absorbed by the oil. This migration is caused by the difference in ***vapor pressure*** between the oil and the refrigerant. Removing residual refrigerant may be required before the introduction of certain alternative blends.

Normally, once the compressor restarts, the combination of reduced crankcase pressure and the heat generated by the running compressor acts to release the refrigerant from the oil. If the system compressor is not functional or the system has been turned off for some time prior to evacuation, the vacuum pump will free the refrigerant, along with any moisture, from the oil.

Note that when evacuating refrigeration systems employing hydrocarbon refrigerants, those refrigerants with ASHRAE rating A3, such as isobutane, R-600a, or refrigerant propane, R-290, or mildly flammable refrigerants with ASHRAE rating A2 or A2L, standard vacuum pumps may not provide the level of safety necessary. Vacuum pumps that are certified for use with hydrocarbon refrigerants and provide additional levels of safety from sparking switches or controls are necessary and must be used.

Some large refrigeration systems may contain a sight glass that can indicate the presence of moisture by changing color. In colder climates, it may be necessary to use a small amount of isopropyl alcohol spray to remove any ice build-up on the sight glass.

Factors Affecting System Dehydration

When a vacuum pump is used to evacuate the system, the reduced pressure created by the pump causes the water to boil (evaporate) at a temperature well below 212° F. Boiling will occur at room temperatures and below if the pressure is dropped sufficiently. By sustaining reduced pressure over a period of time, most of the water can be vaporized and drawn out of the system by the action of the pump. How quickly and effectively dehydration takes place depends on several factors among these are:

1. **The size of the system being evacuated**: the larger the system, the more moisture it holds and the longer it will take to remove the moisture.
2. **The amount of moisture present**: a fairly dry system will dehydrate quickly. Larger amounts of moisture require additional evacuation time.
3. **Ambient temperature**: as temperature is increased, so is the rate at which evaporation takes place. An increase in temperature, when coupled with reduced pressure, causes the water to evaporate very quickly in the system. Conversely, evacuation of the system in low ambient temperature environments may increase the time it takes to recover all the refrigerant.
4. **The capacity of the pump**: the greater the capacity, the greater the volume of gas the pump will move and the deeper the vacuum that can be achieved. Deep vacuums reduce the boiling point of water significantly and increase the rate at which the water evaporates.
5. **The size of the vacuum lines (hoses)**: the larger the inside diameter of the hose, the greater amount of gas it can move. As the size of the hose is reduced, so is the rate of gas flow through the hose. For this reason, ***the size of the hose should be equal to or greater than the pump intake connection.***
6. **The length of the vacuum lines (hoses)**: the amount of restriction that the hoses present to the flow of a gas is determined by its diameter and by its length. The longer the hose, the more friction it introduces to the flow and the slower the rate of dehydration, the more pressure drop and the longer the recovery time. ***Piping connections to the vacuum pump should be as short in length and as large in diameter as possible. Vacuum lines (hoses) should be equal to or larger than the pump intake connections.***

Counteracting Evacuation Problems

Over-evacuation of a system is not possible and does not occur. Using too large a pump (too much capacity) can cause problems, however. Keep in mind that as a perfect vacuum is approached, the boiling point of water drops very close to its freezing point (32° F). As water boils, it absorbs heat and, if the pressure is dropped too quickly, enough heat can be removed from the water (and its immediate surroundings) to cause it to freeze. Once frozen, the water will not vaporize, and dehydration is effectively stopped.

For this reason, it is wise to size the pump to the system under evacuation. Unfortunately, most technicians do not have the luxury of carrying more than one vacuum pump. Besides, how would a technician determine which size pump would be most effective?

There are ways to counteract this problem. The simplest method is to add heat to the system while evacuating. This not only prevents freezing, but also significantly reduces the time required to dehydrate the system. A heat lamp or portable steamer can be used to warm the different components of the system while the vacuum pump is attached. **Note**: Heat guns should never be used on a system that contains a flammable refrigerant.

Adding heat, rather than running the system compressor, is the preferred method of removing moisture that is trapped in the compressor oil. This is especially true with hermetically sealed compressors since these units require refrigerant flow for both cooling and lubrication (the oil trapped in the refrigerant lubricates the compressor components as the refrigerant travels through the compression chamber). Since the vast majority of the refrigerant is removed before the vacuum pump is attached, running the compressor while the vacuum pump is attached will destroy the compressor in very short order. ***A hermetic compressor must never be operated while there is a dehydration (deep) vacuum in the system.***

Determining State of Dehydration

A system is said to be dehydrated when the vacuum indicator shows that the system has reached the required finished vacuum. Normally this is 29.9 inches of vacuum as measured by an acceptable system vacuum gauge. Among these measuring devices are manifold gauges, manometers and micron gauges. Manifold gauges do not offer a great deal of accuracy and should not be relied upon to determine system dehydration. Manometers offer a great deal of accuracy, but if they are filled with mercury, they present an environmental hazard. For this reason, micron gauges are becoming very popular among refrigeration technicians. These small units work electronically and are very easy to use and read.

Regardless of the vacuum gauge used, ***it is important that the vacuum reading be taken with the vacuum pump turned off.*** Obviously, if the pump is running, the true evacuation picture cannot be determined since the vacuum pump maintains the system in an artificially high state of vacuum. Once the pump is turned off, any water left in the system will continue to vaporize. This vapor will show up as an increase in system pressure.

The vacuum gauge should be connected as far downstream from the vacuum pump as possible. While the pump is operating, system pressure will always be lowest at the pump inlet. By having the vacuum gauge near the pump, a false reading is obtained, and the technician may turn the pump off before the system is even close to being dehydrated.

It is normal procedure to continually check the evacuation gauge while the pump is running. Once the required vacuum is reached, the pump is shut off and the gauge checked to see if system pressure rises. If the vacuum holds, dehydration is complete. It is suggested that dehydration should be continued until a reading of 500 microns is reached before charging the system. If the system pressure rises, either there is still water in the system, or the system has a leak. For this reason, ***the use of a vacuum pump is one suggested method of leak checking and dehydration.***

Sweep Charge

A “sweep charge” is sometimes used after the refrigeration system has been opened for service. A typical sweep charge procedure for a household refrigerator is as follows:

1. Two access valves are installed, one on the suction line and one on the discharge line of the compressor.
2. After repairs are made, four ounces of liquid refrigerant is metered into the sealed system.
3. A leak check is performed on the system, as well as any newly brazed joints.
4. The compressor is started and allowed to run and circulate the 4 ounces of refrigerant through the system for 3 minutes.

5. With the compressor still running, the discharge valve is opened, and the refrigerant and contaminants are allowed to flow into a recovery bag for 5 minutes. If you are working with a system that had a low side leak or a compressor burnout, it is advisable to apply additional heat to the evaporator coil to help purge non-condensables and moisture from the sealed system.

Section 8 - Service Procedures

Conservation of refrigerants means that ***many past practices will have to be abandoned, others will have to be applied more carefully, and some new practices will have to be learned.*** Among good service practices for conserving refrigerant are recovering and recycling refrigerant, keeping systems tight, and finding and repairing leaks.

Recovery of such refrigerants as the older CFC (example R-12) chemicals that have very high ODP as well as the substitute chemicals of HCFC (example R-22), HFC (example R-134a or R-410A) or HFO (example R-1234yf) are required to be recovered by the U.S. EPA. Refrigerants sometimes denominated as "natural refrigerants," such as R-600a and R-290 may be vented to the atmosphere because they are considered to have Zero ODP and extremely low GWP. However, these materials do have flammability levels much greater than standard HFC and HCFC refrigerants. They must have special handling and care procedures by service technicians. We recommend that all service technicians read and follow the service instructions of the particular manufacturer's equipment and the safety guidelines published by the Association of Home Appliance Manufacturers (AHAM) as "Safe Servicing of Household Appliances with Flammable Refrigerants, Recommended Practices." The latest edition of these practices are available free-of-charge on the AHAM website at www.aham.org/AHAM/Safety.

The brochures with these practices are available in English, French and Spanish.

Responsible technicians must be ready to minimize waste. **They must maintain their recovery and system processing equipment to prevent leaks and ensure that every system repaired is leak free. Refrigerants must only be used in approved ways and never in irresponsible ways such as blowing dust and dirt from condensing coils.**

Remember that no refrigerant will harm the environment as long as it is contained. Thus, every effort must be made to minimize venting. By using proper brazing and leak detection techniques, refrigerant losses can be minimized. Even common practices, such as purging of charging hoses, must be done with greater care to reduce the amount of refrigerant that enters the atmosphere. To be effective, we must all make an effort to use only approved service techniques, tools and equipment that maximize recovery efforts:

- Quick couplers, self-sealing hoses or hand valves should be used to reduce the amount of emissions from hoses as they are coupled to and uncoupled from the sealed system.
- Leak testing should become habit and no system repair should ever be pronounced "complete" until all brazed joints are tested.
- Recovery equipment, gauges, hoses and other fittings should be leak tested on a daily basis and prior to attempting recovery.
- Only EPA-approved recovery equipment should be used, and the technician should be familiar with the equipment and procedures before attempting recovery.
- Wear safety glasses and protective gloves (impervious or butyl-lined).

Any person opening the sealed system of an appliance for maintenance, repair or service must have at least one operational self-contained recovery machine in their place of business. The only exception to this is technicians solely working on small appliances.

Recovery Equipment

Recovery equipment is classified as **system-dependent** (passive) or **self-contained** (active). **System-dependent equipment captures refrigerant without the use of an external pump or compressor. Self-contained equipment uses a compressor or pump to aid in the removal of refrigerant from a system.**

System-Dependent Recovery Equipment

Any device suitable for containing refrigerants can be considered a system-dependent recovery device. Also known as "passive" recovery systems, these devices are nothing more than non-pressurized storage vessels that capture the refrigerant by allowing the system pressure and/or the system compressor to "push" the refrigerant from the sealed system into the vessel. In small appliances, this is more likely to be found in a refrigerator or freezer. Anyone who has ever transferred refrigerant from one cylinder to another by cooling the receiving cylinder was utilizing the principle that makes a system-dependent device work. System- dependent equipment can only be used on an appliance that has a normal charge of 15 pounds or less of refrigerant.

Figure 8.1

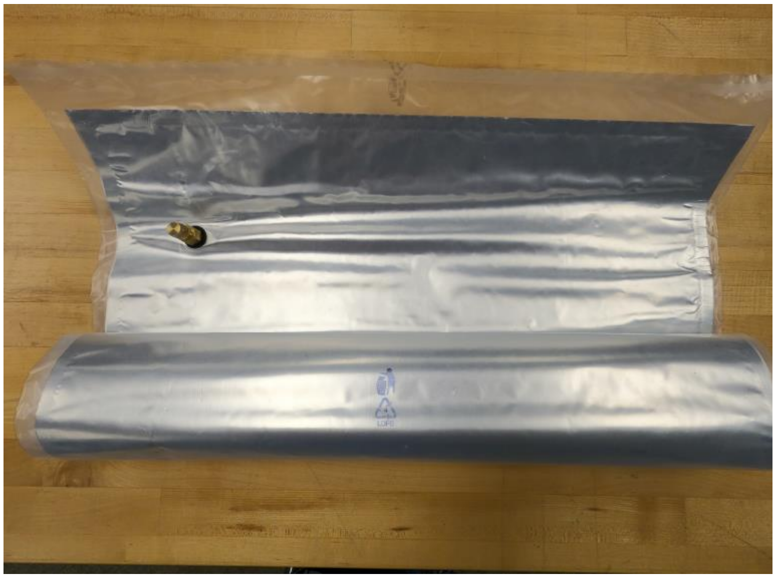


Figure 8.2

One commonly used system-dependent device is the temporary multi-layered storage bag (hereafter referred to as a recovery bag), which expands as refrigerant enters it. This can be used with an appliance such as a residential refrigerator. Because the recovery bag expands, the pressure inside never rises above one pound per square inch. Thus, the recovery bag will continue to accept refrigerant, much like a balloon accepts air, until the system pressure equalizes with the bag. Of course, just like a balloon, the recovery bag expands and will eventually burst if enough refrigerant is introduced. But as long as the capacity of the recovery bag is not significantly exceeded, there is no danger of the bag bursting. This device is not intended to be more than a temporary holding vessel for the recovered refrigerant. The refrigerant must be transferred to a more permanent storage vessel such as a refillable cylinder or vented externally if allowed. Review the quantity of refrigerant in the system before connecting to this type of recovery bag.

Self-Contained Recovery Equipment

As the name implies, self-contained recovery equipment uses an external device such as a pump or a compressor to remove the refrigerant from the system. For this reason, most technicians refer to these devices as “recovery pumps.” While the system compressor may be used to aid in the removal of the refrigerant, recovery pumps operate independently of the system compressor or system pressure. In fact, most self-contained recovery devices evacuate the system into a partial vacuum (any vacuum less than 29.9 inches Hg). Service technicians who open the sealed system of an appliance containing CFC, HFC, HCFC, or HFO refrigerants are required to have a self-contained recovery machine available. The only exception to this is technicians working specifically on small appliances.

The recovered refrigerant is pumped directly into a refillable DOT-approved recovery cylinder. In many instances, the liquid level sensor in the cylinder connects directly to the recovery pump. The recovery pump then shuts off when the liquid level in the tank reaches 80% full. Both electronic sensors (thermistors) and mechanical float switches (float/ball and switch) are commonly used to control liquid level in recovery tanks. The two systems are not compatible, and the correct cylinder must be matched to the recovery pump (unless an adaptor is used). If a tank without a sensor is used, the refrigerant must be weighed before and after each transfer to prevent overfilling. By logging all transfers, leaks in the cylinder can easily be detected. **Regardless of the system used, whenever refrigerant is transferred to a pressurized cylinder or container, the safe filling level must be controlled by one of the methods described above.**

As with all refrigerant recovery devices, self-contained recovery units must be equipped with low-loss fittings to connect the recovery device to the appliance. Low-loss fittings may be designed to close either manually or automatically when disconnected from the system or recovery device/tank to prevent loss of refrigerant from the hoses.

Vacuum Pumps

Because of their similarity to self-contained recovery devices, technicians sometimes attempt to use a vacuum pump (see illustration, p. 40) to recover refrigerant into a cylinder. Vacuum pumps are not designed to pump against pressure. When attached to a high- pressure device, such as a recovery cylinder, the pump destructs. Vacuum pumps should only be used in conjunction with very low-pressure recovery devices such as the recovery bags.

When used with this system-dependent recovery device, the vacuum pump can greatly enhance the recovery efficiency, especially when recovering from a system with an inoperative compressor. The low pressure created by the vacuum pump assists in separating the trapped refrigerant from the oil in the system compressor and removes it from the system.

When Not to Recover

As a general rule, anytime the sealed system of a small appliance is going to be opened to the atmosphere, the refrigerants required by EPA must be recovered. But there are times when recovery is not recommended. Remember that only CFCs, HCFCs, HFCs, HFO’s and all present and future blends of these refrigerants are required to be recovered by the Clean Air Act. This does not apply to hydrocarbon refrigerants, which may be vented to the atmosphere, following recommended guidelines for safe discharge.[6]

Current recovery equipment should not be used with the following:

- Refrigerants such as ammonia, hydrogen and water that are found in small appliances like those used in campers or other recreational vehicles.
- Refrigerants used before 1950, such as sulfur dioxide, methyl chloride and methyl formate.
- Empty systems. Contemporary systems containing CFCs, HCFCs, HFO’s or HFCs do not need to be recovered if the refrigerant has leaked out. If, after installing and opening an access valve, the system pressure is found to be 0 psig, all recovery efforts should be discontinued. There is nothing to be gained by recovering the air and non-condensables that are present in a “flat” (0 psig) system.
- Nitrogen that is sometimes used to blow debris out of a contaminated or restricted system (after the refrigerant is recovered) and as a holding charge in replacement compressors. Nitrogen is a naturally occurring gas that is present in the atmosphere and is totally benign to the environment when vented. **Note: If nitrogen is mixed with refrigerant, it must be recovered.**

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[6] Refer to https://www.epa.gov/snap/refrigeration-and-air-conditioning for other acceptable refrigerants (the lists on the SNAP website include the ASHRAE 34 safety classification where available). Within the United States, these hydrocarbon refrigerants are exempt from the venting prohibition under the Clean Air Act and are exempt from EPA’s hazardous waste regulations (RCRA) when contained in a consumer-owned (rather than commercially owned) appliance.

Recovery Procedures

The first step in any recovery process is to be thoroughly familiar with the system under repair, the type of refrigerant to be recovered, and the recovery equipment to be used. Although many of the steps are common to both system-dependent and self-contained equipment, certain procedures vary with the type of equipment used. We will begin by looking at those steps that are common to both.

Before the system is entered, it is important to look at the model number plate to determine

1) The type of refrigerant to be recovered (so that mixing of refrigerants does not take place.
2) The original system charge.
3) That all recovery equipment is labeled is EPA certified.

Knowing the system charge is especially critical to ensure that the equipment being used has the capacity to capture all refrigerant in the system. Once recovery has begun, it is too late to decide that the recovery cylinder is too full to contain the entire charge (or that the charge is greater than can be captured by the last empty recovery bag in the truck). Unless the equipment is capable of containing the entire charge, the recovery procedure should not be attempted, and the service should be rescheduled for a later time.

It is important to take an accurate pressure reading of the recovery cylinder to determine if there may be excess air or non-condensables in the cylinder.

Gaining Access to the System

Access to hermetically sealed systems is accomplished by the use of either **clamp-on** or **solder-on** (braze-on) valves. Both pierce the system tubing to gain access to the refrigerant.

Note: Prior to using any valve, fitting, or tubing, the parts should be leak tested.

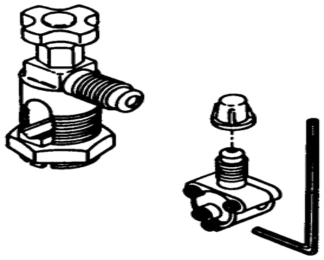

Figure 8.3: Self-piercing valve.

Figure 8.4

Solder-on valves and self-piercing type valves must NOT be installed on refrigeration systems containing A2, A2L or A3 flammable refrigerants unless all of the refrigerant has been removed, including the amount remaining in the compressor and compressor oil.

Clamp-on valves (also known as “solder-less piercing valves”) should be used only when temporary access is desired on aluminum or copper refrigerant lines. These valves must be removed once recovery is completed. If left in place, the Neoprene seal will eventually deteriorate from heat and the system charge will be lost. Of course, the hole that is created by the piercing needle of the valve must be repaired before the system can be recharged (unless the compressor is replaced, and the pierced tubing is removed with the compressor). Solder-on valves, on the other hand can be left in the system (as long as the proper precautions are taken when they are installed). Remember that nothing is gained by recovering the refrigerant if the system is left with a leak and the replacement refrigerant escapes to the atmosphere.

When installing a permanent, solder-on valve, it’s a good idea to check the solder joint for leaks before the steel piercing pin is driven into the tubing. Check for flaws in the brazed joint with an inspection mirror and then pressurize the valve body with refrigerant. Test for leaks with an electronic leak detector or with a bubble solution.

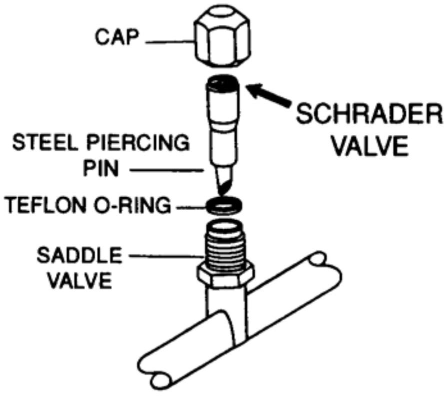

Figure 8.2 Schrader valve.

The heart of the solder-on valve is the “Schrader” spring-loaded core that allows the refrigerant to flow when the core is depressed by the hose connection. When the hose is removed, the spring pushes the core back into its seat, sealing the valve and preventing refrigerant from escaping. As a result, the Schrader valve core should be inspected for bends or breakage and should be replaced if defective. Many manufacturers now suggest that once a Schrader valve is installed, and if it shows no leak after charging, it should be left in place.

Once the repair is completed, the cap must be installed on the valve to prevent accidental depression of the valve core. Common sense dictates that all devices equipped with Schrader valves, such as recovery pumps and cylinders, must be inspected for leaks periodically.

Note: *When capping the solder-on valve in a refrigeration system using CFC, HCFC, or HFC chemicals, always use two wrenches (one on the valve body, the other on the cap) to prevent the valve from twisting. Wrenches should not be used on systems containing flammable refrigerants and caps should be finger-tightened only.*

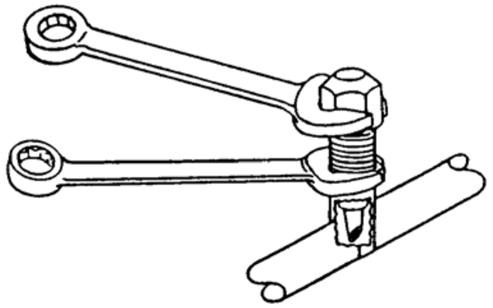

Figure 8.5: Tools used with solder-on valve on CFC, HCFC, or HFC refrigerant. systems.

Self-Contained Recovery

Recovery with **self-contained equipment** is often referred to as active recovery because a “recovery pump” is used to remove refrigerant from the system.

There are two basic types of recovery pumps. Most pumps intended for use with larger refrigerant charge appliances, such as window air-conditioners and window heat pumps, are designed to capture both vapor and liquid. Those used with lower volume charges, such as refrigerators and freezers, are often vapor-only pumps.

Although recovery pumps vary in design, units intended to recover both liquid and vapor are normally equipped with two ports. One port is designed to be attached to the liquid side of the system; the other is intended to be attached to the vapor side of the system. When used to recover both liquid and gas, the vapor port of the pump is attached to the low side of the system and the liquid port is attached to the high side. Using both ports will speed recovery. Thus, when using this type of recovery pump, it is necessary to install access valves on **both the high and low sides of the system.** Consult your pump manufacturer’s recommendations for more information. Self-contained recovery equipment should be checked regularly for any refrigerant leaks.

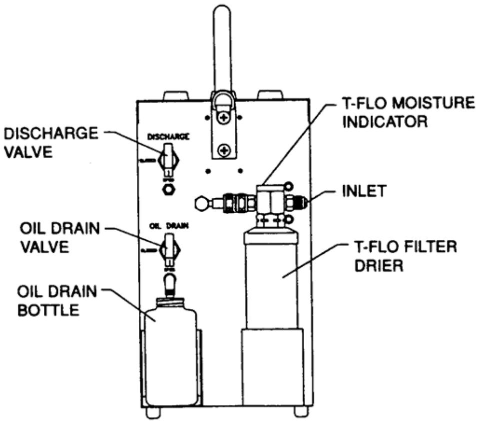

Figure 8.6: Example of a self-contained or recovery pump system.

When non-condensables are present in the refrigerant being recovered, this can cause excessive pressure conditions on the high side of a self-contained (active) recovery device.

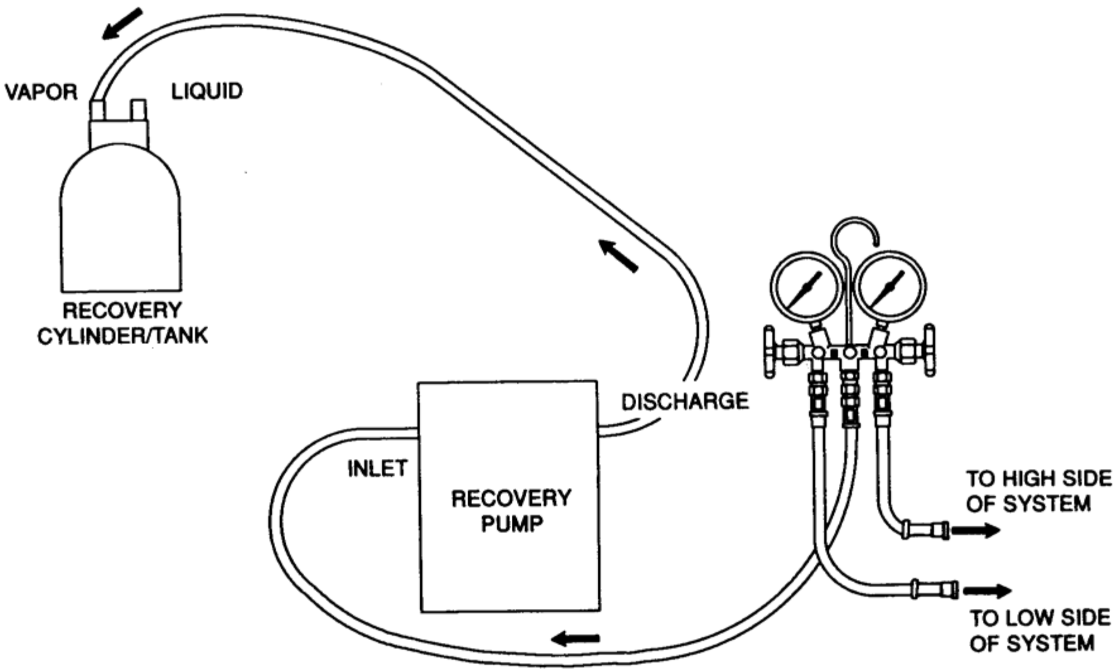

Figure 8.7: Example of connections when using recovery pump.

Vapor-only pumps should never be used to recover liquid ***directly*** from a system. In these units, refrigerant flows through the recovery compressor or pump. Since liquid does not compress, the recovery unit will be damaged if liquid is allowed to enter the pump’s compression chamber. For this reason, **only one access valve is required.** The valve should be installed at the system condenser inlet (high side of the system). This process may be used in situations where the compressor is operating but a blockage occurs in the capillary tubes.

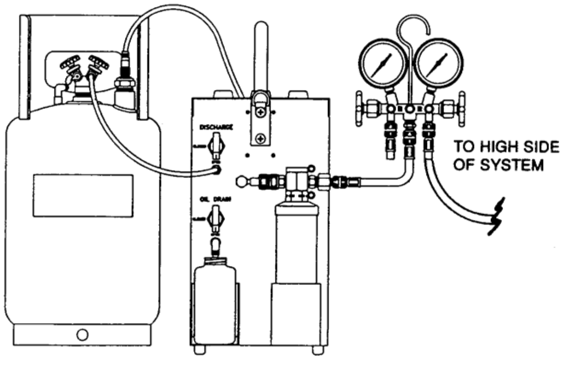

Figure 8.8 Connection to High Side of System

Some vapor-only recovery pumps can be used to recover-liquid by using the pump to pressurize the system and allowing the liquid refrigerant to flow directly from the system into the recovery tank. The pump attaches ahead of the system and uses vapor from the recovery tank to build pressure within the system. The pressure, introduced to the low side of the system, pushes the liquid into the recovery tank (from the high side). Once the liquid is purged, the pump is shut off and attached to the low side to draw the remaining vapor.

Regardless of the type of recovery pump being used, the technician MUST read and follow the recommended procedures outlined in the operating and maintenance manual that accompanies each pump.

System-dependent Recovery (with Operational Compressor)

Also known as passive recovery, system-dependent recovery relies on system pressure and the system compressor (if the compressor is operational) to capture the refrigerant in the system.

When using the recovery bag, recovery efficiency is greatly enhanced by utilizing the system compressor to aid in the recovery process. The bag is attached directly to the system through **one high side solder-on access valve.** The system compressor is then energized, establishing a pressure differential between the low and high sides of the system.

Regardless of whether or not the system is clear or restricted, only one valve is required to capture the refrigerant as long as the system compressor is operational.

Once the low side of the system goes into a partial vacuum, any refrigerant that is trapped in the compressor oil is “boiled” off and forced into the high side and the recovery device. As a result, recovery efficiencies of 90 to 95% or greater are achieved.

System-dependent Recovery

(Non-operational Compressor, Recovery Bag)

If the system compressor is not operational and the recovery bag is being used, additional steps must be taken to ensure the proper recovery efficiency. Unless the refrigerant that is trapped in the compressor oil is removed, the required 80 to 90% recovery efficiency will not be achieved.

To begin with, **both low and high side valves must be installed.** The refrigerant then enters the recovery device from both sides of the system. During the 15-minute purging process, **a 1500-watt heat source, such as a heat gun*, is directed at the bottom half (base) of the compressor.** The heat helps remove the refrigerant that has migrated into the compressor oil. The longer the compressor has been off before the repair is made, the more refrigerant will have migrated into the oil.

****Note: A heat gun, open wire element heater, or torch should NEVER be used on a refrigerant system which uses a flammable refrigerant.***

After the system has purged the refrigerant into the recovery device for 12 minutes, the compressor must be **struck sharply at the base three times with a hammer or plastic mallet.** Heat is then applied for an additional 3 minutes. [***Note: Heat from a source such as a heat gun should never be applied to a compressor and appliance that uses a flammable refrigerant.***] In the case of a frost-free refrigerator, it may be possible to energize the defrost heater or use a portable steamer to slightly increase the temperature and recover all the refrigerant. The combination of heat and/or the vibration of the oil may act to release the remaining refrigerant, allowing it to purge into the recovery device.

A vacuum pump can also be used to enhance the efficiency and speed of recovery when using a recovery bag. The vacuum pump eliminates the need to strike or heat the compressor. After system pressure has purged the majority of the refrigerant into the recovery bag, the vacuum pump is attached between the system and the bag and run for at least five minutes. The pump removes most of the remaining refrigerant by lowering the pressure over the oil and allowing the refrigerant to “boil” off. Of course, heating and striking the compressor will speed up the recovery process, even if a vacuum pump is used. Heat should never be applied to a compressor for a refrigeration system containing flammable refrigerants. A combustible gas leak detector should be used at all times when servicing the refrigerant system which employs a flammable refrigerant.

When recovering refrigerant from an appliance equipped with a defrost system and where the refrigerant is non-flammable, the defrost heater might be energized if the evaporator is frosted at the start of the recovery. Refrigerant naturally migrates to the coldest area of the system and a frosted evaporator can hold the majority of the system refrigerant charge in liquid form. When heat is introduced, the refrigerant vaporizes, the system pressure increases, and the recovery process is accelerated. When dealing with a manual defrost system (or an inoperative defrost system), a heat source can be used to accomplish the same thing. Care should be used, however, when applying heat around plastic liners and components to prevent damage to the appliance. Open element heat sources, heat guns and other potential sources of ignition should NEVER be used with appliances that contain flammable refrigerants. Manufacturers recommend the use of a portable steam cleaner to provide heat to defrost frozen lines in appliances using flammable refrigerants. For systems containing flammable refrigerants, if the refrigerant lines are frozen, the system and area should be checked with a combustible gas leak detector following removal of the refrigerant from the lines.

Flushing a System of Contaminants

Both mechanical and electrical failures of hermetically sealed compressors can result in contamination of the system. When a burnout is suspected or the unit has had a leak or a major component failure, the refrigerant oil should be inspected for signs of contaminants. This can easily be done if recovering into a bag. A certain amount of oil usually enters the recovery bag along with the refrigerant.

When a self-contained recovery device is used, it will be necessary to wait until the recovery is completed and the compressor is cut out of the system before the oil can be inspected. By tipping the compressor and pouring a few drops of oil onto a clean white cloth or paper towel, the burnout residue can be observed against the white background. Contaminated oil also has a distinctive odor. Since small amounts of both CFC, HCFC, and HFC refrigerants have no odor, a pungent aroma is a clear indication that a burnout has occurred. In such cases, the evidence of the burnout is obvious by the odor, and the oil test is not necessary. In addition, refrigerant oil can be examined or sent for testing if the oil is found to contain moisture, acid, a thickening of the oil, waxing or other degradations. While sampling and testing the oil may be often conducted in large systems, this is rarely done in a sealed-system appliance.

If contaminants are present, it may be necessary to flush the system. In the past, it was common to use R-11 refrigerant to clean the system of contaminants. Some manufacturers recommend installation of a new filter-drier or using a commercial system flushing solution. Other manufacturers recommend the use of oxygen-free dry nitrogen (OFN, or OFDN) to blow out contaminated systems since this naturally occurring gas need not be captured. Mixtures of OFDN and CFCs, HCFCs, or HFCs, however, must be recovered but pure OFDN used for a sweep charge may be vented to the atmosphere. Never add OFDN to a fully charged system since subsequent releases of this mixture violate the Clean Air Act.

OFDN can be under extremely high pressure and thus must always be equipped with a pressure regulator and a relief valve downstream of the regulator. Always read and follow safety instructions for any compressed gas. Read all SDS sheets that accompany any chemical.

Recovering Mixed Refrigerants

There will be times when a technician encounters a system that has been inadvertently tampered with and may contain mixed refrigerants. Perhaps someone has added R-22 to an R-12 system, R-134a or R-410a to an R-22 system. Whenever mixed refrigerants are suspected, the refrigerant in the system should be recovered into a separate tank. Do not recover suspected mixtures into tanks that are otherwise dedicated to "pure" refrigerants. Remember that mixed refrigerants may be impossible to reclaim. For the most part, a reclaimer can remove most other contaminants from the recovered refrigerant. At present, however, no one has perfected a method to separate azeotropes. Since there is no way for the technician to determine if mixed refrigerants have formed an azeotrope, only one type of refrigerant (or recognized blend) should be recovered per cylinder.

Other Recovery Considerations

The efficiency of any recovery attempt is affected by factors that range from the length of the hoses used to the ambient temperature during recovery. Just as hose length and size affected the efficiency of evacuation, recovery can be slowed if the hoses are too long or of insufficient diameter. Ambient temperature can also affect the speed of recovery. Increasing the temperature of the system will greatly speed up the process.

Once you have completed the transfer of the refrigerant liquid between the recovery unit and the refrigeration system, you will need to prevent trapping of liquid refrigerant in the service hoses.

Recovering Refrigerant from a Charging Cylinder

In systems using CFC, HCFC, HFC, and HFO refrigerants, even the vapor that would normally be vented while filling a charging cylinder, should be captured. Using self-sealing hoses (or hand valves), attach the recovery device to the vapor port of the charging cylinder. As liquid is introduced into the cylinder, pressure within the cylinder can be lowered by allowing some of the vapor to escape into the recovery device. The illustrations below show how this is done.

Figure 8.11. Recovery of refrigerant from charging cylinder.

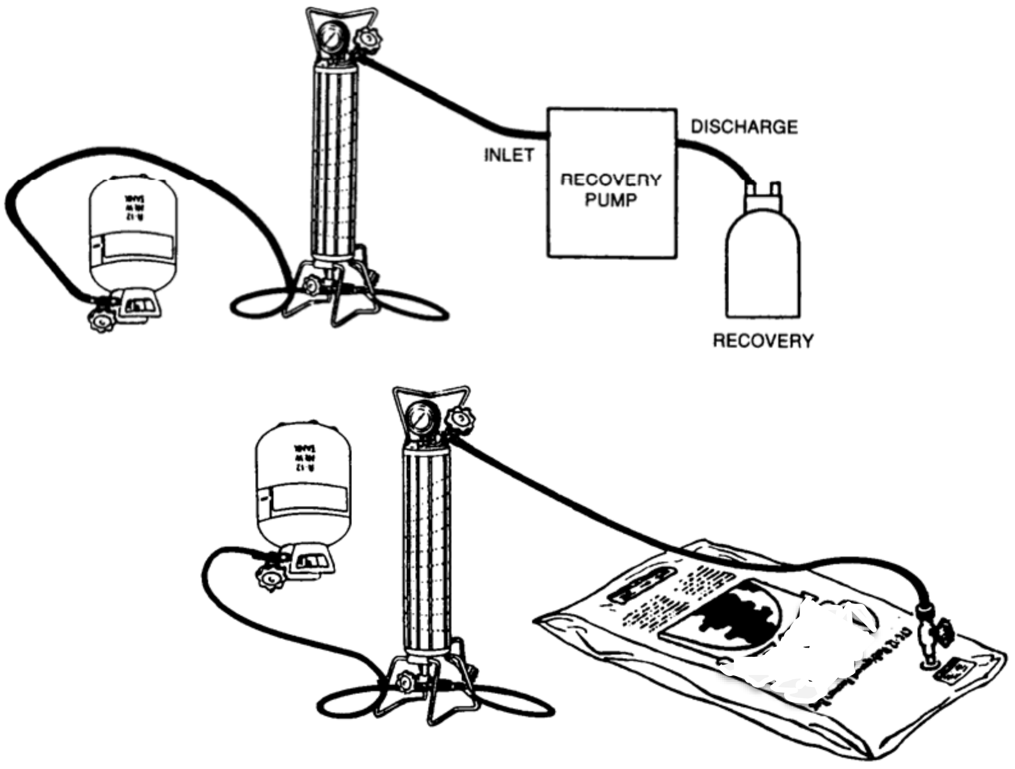

Figure 8.9 Connections to Recovery Cylinder or Recovery Bag

Purging Non-condensables from Recovery Tanks

As non-condensables are introduced into the storage tank, tank pressure increases. If enough non-condensables are present, the pressure may rise to a level that prevents the tank from filling to the 80% mark or may cause excessive pressure on the high side of a self-contained recovery device. Non-condensables must be purged from the tank if the tank is to be filled to the allowable level.

See Annex 1.

If the pressure/temperature relationship of the tank exceeds the maximums listed in the table to the right, non-condensables are present. Follow the procedures below to purge the non-condensables from the tank:

1. Let the tank stand at room temperatures for 10 hours to stabilize tank pressure.[ix]
2. Modify a 1/4" flare cap by drilling a 1/16" bleed hole at the center of the cap. Attach the modified cap to the center connection of a standard manifold gauge set.[x]
3. Connect the high side of the manifold to the vapor valve on the tank.
4. Open the manifold valve so that a small amount of air or vapor escapes through

MAXIMUM GAUGE PRESSURE (PSI)				
TEMP (F)	**R-12**	**R-22**	**R-500**	**R-502**
50	**57**	**94**	**67**	**107**
55	**62**	**103**	**74**	**117**
60	**68**	**112**	**81**	**121**
65	**74**	**121**	**88**	**126**
70	**80**	**131**	**88**	**126**
75	**87**	**142**	**103**	**142**
80	**94**	**154**	**112**	**154**
85	**102**	**166**	**121**	**166**
90	**110**	**178**	**130**	**178**
95	**118**	**192**	**140**	**192**
100	**127**	**206**	**151**	**206**
105	**134**	**221**	**162**	**221**
110	**146**	**236**	**174**	**236**
115	**157**	**253**	**186**	**253**
120	**168**	**270**	**199**	**270**
125	**178**	**288**	**213**	**288**

the 1/16" orifice.

Note: Because non-condensables do not liquify, only minimal amounts of refrigerants are released through this procedure. This is considered a de minimis release under Clean Air Act regulations. Good customer relations, however, dictates the purging be done as cautiously as possible to avoid customer misinterpretations.

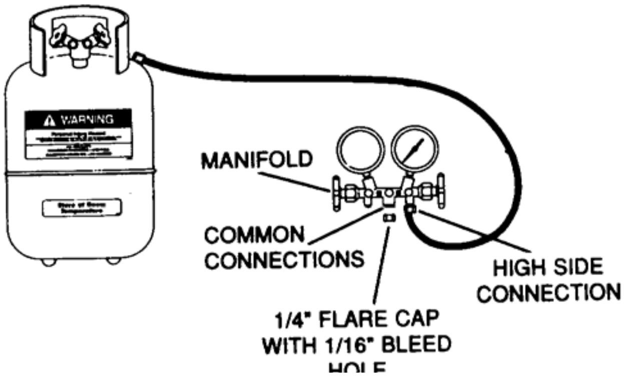

Figure 8.10: Purging non-condensables.

5. Continue to bleed off from the tank until the tank pressure stabilizes at the pressure that corresponds to the pressure indicated on the chart.
6. Allow the tank pressure to stabilize for ten minutes and recheck the pressure.
7. Repeat the process, if necessary.

Records

It is the responsibility to keep and store records of all recovery situations. A service technician who disposes of appliances with between 5 and 50 lbs. of refrigerant must maintain the following records:

- **The amount and type of refrigerant, date sent for destruction or reclamation, and the person or organization to which it was sent.**
- **The location, type of refrigerant, and date or recovery for each appliance.**
- **The amount of refrigerant by type, recovered from each appliance sent for disposal in each month.**

Leak Testing and Repair

Although the repair of leaks in small appliances is not addressed in the final EPA rule, it would be foolhardy and anti-environmental to go through the trouble of capturing only to allow the refrigerant to escape through shoddy workmanship or carelessness. Hoses, manifold gauge sets and recovery equipment should be inspected, and leak tested on a regular basis. Although both electronic (ultrasonic) leak detectors and bubble solution can be used for this purpose, it is generally accepted that the electronic leak detectors (testers) are the most effective at localizing the general area of a small leak.

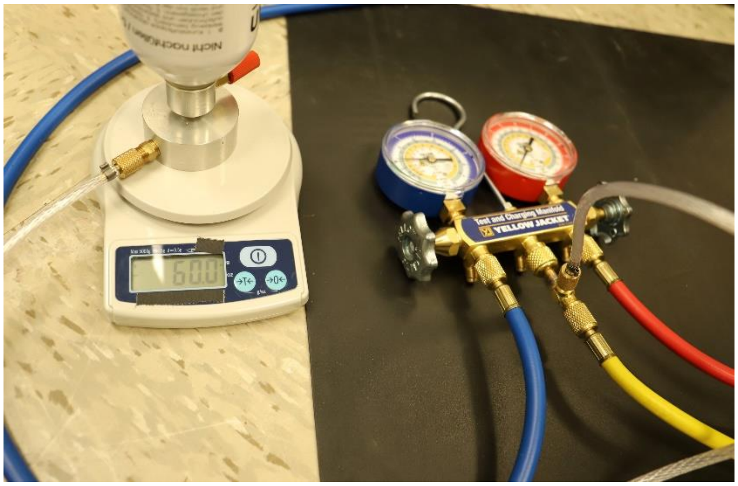

Figure 8.11

In addition, the AHAM "Safe Servicing of Household Appliances with Flammable Refrigerants: Recommended Practices" states that service technicians "**Use a combustible gas leak detector to perform a background check and monitoring around the appliance." [See Figure 6.3]** ***CAUTION: To avoid a risk of injury, do NOT use leak detectors with an arc or spark module to check for leaks in and around appliances that use A2, A2L or A3 refrigerants.*** The leak detector must be certified for use with the specific refrigerant class being serviced. If flammable refrigerant is detected, immediately ventilate the room, evacuate the area, and notify the owner or customer. Recheck with a combustible gas leak detector before proceeding."

Likewise, all brazed joints should be checked with an inspection mirror for obvious defects. Before the final charge is added, a test charge should be used for leak detection purposes. If the system charge was intact before the repair, it is the technician's responsibility to ensure a leak-free system when the repair is completed.

There will be times, however, when a technician encounters a low or empty system. As part of the service call, every effort should be made to locate and, with the consent of the owner, repair the leak. If the customer objects, the technician should take the time to inform the customer of the environmental and economic reasons that make repairing leaks a beneficial choice.

In order to determine the safe pressure for leak testing, a service technician should refer to the low-side test pressure found on the data-plate or nameplate of the appliance.

If refrigerant is used to test for leaks, it must be recovered. Never use compressed air or oxygen to pressurize a system. When oxygen mixes with refrigerant oil, a violent explosion can occur.

If a system contains a flammable refrigerant, combustible gas leak detectors that are certified for use with these refrigerants must be used. Leak detectors using open heating elements are not acceptable.

Leak Detection with Oxygen-Free Dry Nitrogen (OFDN)

Although not commonly used by small appliance technicians, OFDN has recently gained popularity among some because of its high pressure and inert qualities. OFDN is perceived as being the least environmentally damaging method of leak detection. While it is not the intent of this manual to endorse or indict one method of leak detection over another, there are some concerns associated with the use of OFDN that should be understood by anyone who uses it.

Nitrogen is an extremely high-pressure gas. Storing and transporting this gas requires special care. Ensure that cylinders are secure at all times, especially when transporting them in a service vehicle. Accidental discharge of the gas presents a serious missile hazard that could cause serious bodily harm or death.

Likewise, ***never pressurize a refrigeration system with nitrogen unless the nitrogen tank is equipped with a pressure regulator.*** Prior to pressurization, check the safe pressure limit of the system by reading the low-side test-pressure data-plate value on the unit. The design pressure of the system is sometimes listed on the equipment nameplate. If the test pressure is not listed, nitrogen should not be used since the design pressure could be exceeded and cause equipment damage and serious bodily harm. Where the design test pressure is known, *a pressure relief valve should be installed to ensure that the design pressure is not exceeded. These valves are normally installed in the downstream line. Relief valves should be inspected before installation and any valve showing signs of corrosion must be discarded and replaced with a new valve.*

Figure 8.12

Section 9 – Appendices

Glossary of Terms

ACTIVE RECOVERY (See SELF-CONTAINED RECOVERY EQUIPMENT.)

AHAM Association of Home Appliance Manufacturers. A trade association and accredited ANSI standards development organization of manufacturers of residential home appliances such as residential refrigerators, freezers, dehumidifiers, room and portable air conditioners.

AHAM Guidance on the Safe Servicing of Appliances with Flammable Refrigerants.

Guidance document was developed by the members of AHAM to better equip service technicians working with flammable refrigerants in cold appliances. The link to the document is found here:

http://www.aham.org/AHAM/Safety/Safe_Servicing_of_Cold_Appliances/AHAM/Safety/Safe_Servicing_of_Cold_Appliances.aspx

Note: This guidance document will be updated over time without refreshing the AHAM-PSA-NARDA Refrigerant Training Manual. Please consult the AHAM web site for the latest edition. The guidance document is made available in English, French, and Spanish.

APPLIANCE Any device that contains and uses a Class I (CFC), Class II (HCFC), or other substitute refrigerants and is used for household or commercial purposes. (See also EPA Designation "SMALL APPLIANCE.")

ASHRAE American Society of Heating, Refrigeration and Air-Conditioning Engineers. ASHRAE is an ANSI accredited standards development organization.

ALKYLBENZENE OIL Synthetic oil that mixes well with CFCs and ternary blends.

AHRI Air-Conditioning Heating and Refrigeration Institute. AHRI is a trade association and ANSI accredited standards development organization representing manufacturers of larger air conditioning and commercial refrigeration appliances.

ANSI American National Standards Institute is the private, third-party accreditation organization for standards development organizations operating in the United States.

ASPHYXIANTS Chemicals or gases that displace oxygen and cause suffocation.

ATOM Smallest particle of an element.

AZEOTROPE A mixture of two refrigerants that combine to form a third refrigerant with its own properties. Once combined, the refrigerants cannot be easily separated and remain combined in both their liquid and vapor states.

BLEND A mixture of two or more refrigerants that do not combine to form a new refrigerant. Rather, the refrigerants mix and behave like a new refrigerant, but only as long as the mixture remains in a liquid state. As soon as the blend assumes a vapor state, each refrigerant reverts to its original chemical composition and remains a separate chemical until it recombines with the other refrigerants to form a liquid.

CFCs Chlorofluorocarbons: Family of chemicals made up of chlorine, fluorine and carbon.

CHLORINE An element that is one of the prime ingredients in CFCs, HCFCs, and HFCs.

CHLOROFLUOROCARBON (See CFCs.)

CONSORTIUM Group of people, companies or nations that meet to work toward a common goal or resolution.

DEHYDRATION Process of removing water and water vapor.

DEMINIMUS RELEASES Small, unintentional release of refrigerant during recovery or repair of a refrigeration product (i.e., when a hose is removed from a sealed system).

DISPOSAL Discarding of an appliance or the disassembly of an appliance for recycling.

DEPARTMENT OF TRANSPORTATION (DOT) Agency of the U.S. federal government that is responsible for regulating transportation of chemicals and other materials.

EPA (Environmental Protection Agency) Agency of the, U.S. federal government that is responsible for implementing federal laws by developing and enforcing regulations that are designed to protect the environment. See https://www.epa.gov/section608/section-608-clean-air-act

ESTER OILS Synthetic oils which mix well with HFC refrigerants. Esters have a high affinity for water and act as a moisture sponge when exposed to air.

EVACUATION The removal or withdrawal of refrigerants, moisture and contaminants from a sealed system.

FINAL RULE Abbreviation used to describe, in this case, "40 CFR, The Final Rule on Protection of Stratospheric Ozone; Refrigerant Recycling." The Final Rule outlines all the regulatory requirements associated with recovery and recycling of refrigerants as mandated by the Clean Air Act. See https://www.epa.gov/clean-air-act-overview

FLUORINE Element that is one of the prime ingredients in CFCs, HCFCs and HFCs.

FLUOROCARBONS Family of compounds made up of fluorine and carbon.

GLOBAL WARMING Phenomenon that is believed to occur when certain greenhouse gases, such as carbon dioxide (CO_2), prevent cooling of the earth during night hours. The higher the concentration of these gases, the less cooling that occurs and the greater the heat that is retained by the earth. If sufficient heat is retained, the earth's average temperature could rise, causing the polar ice caps to melt and sea levels to rise.

GREENHOUSE GASES Any gas that allows certain light frequencies to pass and blocks other light frequencies, thus acting like a greenhouse. During the day, these gases allow the higher frequencies to penetrate to the surface and warm the earth. At night, the lower light frequencies are given off as the earth cools, and the greenhouse gases reflect them back to ground level.

GROUND LEVEL OZONE Ozone that is created near the earth's surface when, for example, sunlight reacts with pollutants and smog.

GWP Global Warming Potential. Relative potential of a chemical or compound to act as a greenhouse gas. The GWP of refrigerants are based on CO_2 at 1 and are published by the International Panel on Climate Change (IPCC). The most recent published Assessment Report (AR) on refrigerants was 2014 as the 5th AR. The 6th AR is due for release in 2022 and will contain many of the new refrigerants and blends. For reference, refrigerant CO_2 is known as R-744.

HALONS Bromine-containing substances found in certain fire extinguishers. Because of their bromine content, halons have a very high Ozone Depletion Potential (ODP).

HYDROCARBONs Family of refrigerants made up of hydrogen and carbon. These materials have essentially zero Ozone Depletion Potential (ODP) and very low (single digit) Global Warming Potential (GWP). Examples of these refrigerants would be R-600a (isobutane) and R-290 (refrigerant propane).

HCFCs Family of hydrochlorofluorocarbon refrigerants made up of hydrogen, chlorine, fluorine and carbon. Because of their hydrogen content, these refrigerants are not as stable as CFCs and consequently have a lower Ozone Depletion Potential (ODP).

HFCs Family of hydrofluorocarbon refrigerants made up of hydrogen, fluorine and carbon. Because of their zero potential for ozone depletion, they have been used as replacements for CFCs.

HYDROCHLOROFLUOROCARBONS (See HCFCs.)

HYDROCHLORIC ACID (HCl) Acid formed when moisture enters a refrigeration system and reacts with chlorine in CFC or HCFC refrigerants.

HYDROFLUOROCARBONS (See HFCs.)

HYDROFLUORIC ACID (HF) Acid formed when moisture enters a refrigeration system and reacts with fluorine in CFC, HCFC, HFC, or HFO refrigerants. In some mildly flammable HFO refrigerants, this may occur when the refrigerant is consumed in a fire. Hydrofluoric Acid can remain on surfaces after an ignition of a refrigerant. It is considered colorless, highly acidic, and highly corrosive. It is considered a highly toxic contact poison and any contact with breathing or skin should be treated professionally immediately.

HYGROSCOPIC Property of having an affinity for water; acting as a moisture sponge.

IMMUNE SYSTEM Human body's mechanism for fighting disease.

LOW-LOSS FITTING Connecting device on hoses or recovery equipment that is designed to be closed manually or close automatically when disconnected, minimizing the release of refrigerant.

SAFETY DATA SHEETS (SDS) Literature which defines the hazardous nature of chemicals and lists their technical and safety specifications.

MICRON Unit of length in metric system; one thousandth part of a millimeter.

MICRON GAUGE Instrument used to measure vacuums that are very close to a perfect vacuum.

MOLECULES Smallest particle of a substance that retains all the properties of the substance and is composed of two or more atoms.

MONTREAL PROTOCOL Treaty signed by many nations that regulates the production and venting of CFCs and HCFCs.

OSHA (U.S. Occupational Safety and Health Administration) An agency of the federal government responsible for regulating safety in the workplace.

OZONE Slightly bluish gas that is formed when sunlight reacts with oxygen (by adding an extra atom to the normal 2-atom molecular configuration).

OZONE DEPLETION POTENTIAL (ODP) Substance's relative potential for depletion of stratospheric ozone.

OZONE HOLE Localized thinning of the stratospheric ozone layer.

OZONE LAYER Region of the atmosphere where ozone occurs naturally. This region spans between 9 and 18 miles above the earth and serves as a protective shield against harmful ultraviolet radiation by scattering and absorbing the sun's ultraviolet light before it reaches the earth's surface.

PASSIVE RECOVERY (See SYSTEM-DEPENDENT RECOVERY EQUIPMENT.)

PROCESS STUB Straight length of tubing that provides access to the refrigerant inside a small appliance and that can be resealed at the conclusion of repair or service. According to the applicable UL safety standards, this process tube area must be marked in a red color, Pantone Matching System (PMS) 185.

PTAC (Packaged Terminal Air Conditioner) A self-contained air conditioner or heat pump unit that is used primarily by motels and hotels to cool and heat individual rooms; included among products defined as small appliances by EPA.

RECLAIM System to reprocess refrigerant to new product specifications by such means as distillation and chemical analysis. Reclaimed refrigerant must be analyzed and meet AHRI 700 specifications.[7]

RECOVER Ability to capture refrigerant in any condition from a system without necessarily testing or processing it in any way.

RECOVERY PUMP (See SELF-CONTAINED RECOVERY EQUIPMENT.)

RECYCLE Using portable recycling equipment to clean refrigerant for reuse at the job site without meeting all of the requirements of reclamation. This may involve oil separation, single or multiple passes through devices such as replaceable core filter dryers, in order to reduce moisture and acidity. Analysis is not required unless the refrigerant changes ownership.

REFRIGERANT Chemical substance used inside a sealed system to absorb heat and transfer it from one area to another.

SELF-CONTAINED RECOVERY EQUIPMENT Device also referred to as "Active" recovery equipment or as "recovery pumps." Equipment that is capable of removing the refrigerant from an appliance without the assistance of components contained in the appliance.

SERVICING APERTURE (See also, PROCESS STUB.) According to the Clean Air Act, all refrigeration systems are required to have a servicing aperture or an equally effective design feature which will facilitate the capture of refrigerants. This can be a valve or process tube on a compressor. This process stub or servicing area must be colored red (PMS 185) according to the requirements of the applicable UL safety standards.

SMALL APPLIANCE EPA Section 608 classification of appliances, specifically household or domestic appliances, which are manufactured, charged and are hermetically sealed in the factory with five pounds or less of Class I or Class II substances as a refrigerant. These appliances are refrigerators, freezers, dehumidifiers, vending machines, water coolers, room or window air conditioners, packaged terminal air conditioners and heat pumps and drinking water coolers.

SIGNIFICANT NEW ALTERNATIVE PROGRAM (SNAP) A regulatory activity of U.S. EPA to phase-out of and/or ban on the production or sales of refrigerants that are known to cause damage to the ozone layer.

STRATOSPHERE Portion of the atmosphere that ranges from 7 to 28 miles above the earth.

STRATOSPHERIC OZONE That layer which occurs naturally high above the earth's surface. (See also OZONE LAYER.)

SYSTEM-DEPENDENT RECOVERY EQUIPMENT This may also be referred to as "Passive" recovery equipment. Equipment that requires the assistance of components contained in an appliance to remove the refrigerant from the appliance. The maximum normal charge is 15

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[7] See https://www.epa.gov/section608/epa-certified-refrigerant-reclaimers for information on EPA certified reclaimers.

pounds of refrigerant in an appliance using system-dependent recovery.

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

TEMPERATURE GLIDE Term used to describe the range of temperatures that can exist at the condenser and evaporator for a given pressure, when a blend is used as a refrigerant.

TOXIC Substance that is hazardous or poisonous.

TROPOSPHERE That part of the atmosphere that is closest to the earth's surface.

TROPOSPHERIC OZONE Ozone that is created when sunlight reacts with pollutants at ground level to create "smog." Tropospheric ozone is a potentially hazardous compound that causes difficulty in breathing in some people and accelerates decomposition of rubber products and certain plastics.

UL (Previously referred to as Underwriters Laboratories) An independent organization that tests electrical and mechanical equipment and certifies its compliance with the requirements in the applicable safety standard. UL safety certification compliance operates under the accreditation of the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Nationally Recognized Testing Laboratory (NRTL) program. [Note: there are several safety certification organizations that certify compliance with safety standards under OSHA NRTL.] UL also has a separate organization that administers the development of safety standards under accreditation of the American National Standards Institute (ANSI).

VAPOR PRESSURE Pressure imposed by either a vapor or a gas; pressure exerted by a vapor in equilibrium with its solid or liquid state.

ZEOTROPE A **blend** of refrigerants that behaves normally as a mixture of refrigerants. The physical and chemical properties are a combination of the individual component properties. The vapor composition is different from the liquid, which promotes fractionation and temperature glide effects. An example is R-450A, which is a blend of R-134a and R-1234ze.

Pressure-Temperature

Charts for Selected Appliance Refrigerants in PSIG at Atmospheric Pressure (14.7 PSIA)

		A1	**A1**	**A1**	**A1**	**A2L**	**A3**	**A3**
Deg F	**Deg C**	**HCFC**	**HFC**	**HFC**	**HFC**	**HFC**	**HC**	**HC**
		R-22	**R-410A**	**R-404A**	**R-134a**	**R-32**	**R-290**	**R-600a**
-50	-45.6	14.7	4.95	0.47	-9.2	5.16	-2.11	-11.59
-45	-42.8	-1.3	7.7	2.585	-8.29	7.95	-0.43	-11.09
-40	-40	0.56	10.75	4.92	-7.27	11.03	1.42	-10.54
-30	-34.4	4.92	17.82	10.33	-4.84	18.19	5.66	-9.22
-29	-33.9	5.41	18.6	10.93	-4.56	18.98	6.13	-9.07
-28	-33.3	5.9	19.4	11.54	-4.28	19.79	6.61	-8.92
-27	-32.8	6.4	20.21	12.16	-3.99	20.61	7.09	-8.76
-26	-32.2	6.92	21.04	12.79	-3.7	21.45	7.58	-8.6
-25	-31.7	7.44	21.88	13.435	-3.4	22.30	8.085	-8.44
-24	-31.1	7.98	22.74	14.09	-3.095	23.17	8.6	-8.28
-23	-30.6	8.5	23.61	14.76	-2.78	24.06	9.11	-8.11
-22	-30.0	9.07	24.50	15.44	-2.46	24.96	9.46	-7.94
-21	-29.4	9.63	25.41	16.13	-2.14	25.88	10.18	-7.76
-20	-28.9	10.2	26.33	16.83	-1.80	26.81	10.72	-7.58
-19	-28.3	10.79	27.27	17.54	-1.46	27.76	11.28	-7.40
-18	-27.8	11.38	28.22	18.27	-1.115	28.73	11.84	-7.21
-17	-27.2	11.99	29.19	19.01	-0.76	29.71	12.42	-7.02
-16	-26.7	12.6	30.18	19.765	-0.398	30.71	12.999	-6.83
-15	-26.1	13.23	31.18	20.53	-0.03	31.73	13.59	-6.63
-14	-25.6	13.87	32.20	21.31	0.35	32.77	14.19	-6.43
-13	-25.0	14.52	33.24	22.10	0.72	33.82	14.805	-6.23
-12	-24.4	15.18	34.30	22.905	1.12	34.90	15.43	-6.02
-11	-23.9	15.85	35.37	23.72	1.52	35.99	16.06	-5.80
-10	-23.3	16.53	36.47	24.56	1.93	37.10	16.699	-5.58
-9	-22.8	17.23	37.58	25.40	2.35	38.22	17.35	-5.36
-8	-22.2	17.93	38.71	26.26	2.77	39.37	18.01	-5.14

-7	-21.7	18.65	39.85	27.135	3.20	40.54	18.685	-4.91
-6	-21.1	19.38	41.02	28.02	3.645	41.72	19.37	-4.67
-5	-20.6	20.12	42.21	28.925	4.09	42.925	20.06	-4.43
-4	-20.0	20.88	43.41	29.84	4.55	44.15	20.76	-4.19
-3	-19.4	21.65	44.635	30.77	5.02	45.39	21.48	-3.94
-2	-18.9	22.43	45.88	31.72	5.49	46.66	22.205	-3.69
-1	-18.3	23.22	47.14	32.68	5.98	47.94	22.94	-3.43
0	-17.8	24.03	48.43	33.665	6.47	49.25	23.69	-3.17
1	-17.2	24.85	49.73	34.65	6.97	50.57	24.45	-2.9
2	-16.7	25.68	51.06	35.65	7.485	51.92	25.22	-2.63
3	-16.1	26.53	52.40	36.675	8.01	53.29	26.000	-2.35
4	-15.6	27.39	53.77	37.71	8.54	54.68	26.79	-2.07
5	-15.0	28.26	55.16	38.77	9.08	56.09	27.60	-1.78
6	-14.4	29.15	56.57	39.84	9.63	57.52	28.41	-1.49
7	-13.9	30.05	58	40.92	10.19	58.98	29.24	-1.20
8◦F	-13.3◦C	30.96	59.45	42.025	10.76	60.455	30.08	-0.89
9	-12.8	31.89	60.92	43.13	11.34	61.96	30.93	-0.59
10	-12.2	32.83	62.42	44.28	11.93	63.48	31.80	-0.27
		A1	**A1**	**A1**	**A1**	**A2L**	**A3**	**A3**
Deg F	**Deg C**	**HCFC**	**HFC**	**HFC**	**HFC**	**HFC**	**HC**	**HC**
		R-22	**R-410A**	**R-404A**	**R-134a**	**R-32**	**R-290**	**R-600a**
11	-11.7	33.79	63.94	45.43	12.53	65.025	32.67	0.04
12	-11.1	34.77	65.48	46.6	13.14	66.59	33.56	0.37
13	-10.6	35.755	67.05	47.79	13.76	68.19	34.465	0.695
14	-10	36.76	68.635	48.99	14.395	69.80	35.58	1.03
15	-9.4	37.775	70.25	50.21	15.04	71.44	36.305	1.37
16	-8.9	38.81	71.88	51.45	15.69	73.11	37.245	1.715
17	-8.3	39.86	73.54	52.71	16.36	74.80	38.20	2.07
18	-7.8	40.92	75.22	53.98	17.04	76.51	39.16	2.42
19	-7.2	42.00	76.93	55.27	17.72	78.25	40.14	2.79
20	-6.7	43.095	78.66	56.58	18.42	80.015	41.13	3.15
21	-6.1	44.21	80.42	57.91	19.135	81.80	42.14	3.53
22	-5.6	45.33	82.2	59.26	19.86	83.62	43.16	3.91

23	-5.0	46.68	84.005	60.63	20.59	85.46	44.19	4.30
24	-4.4	47.64	85.84	62.01	21.34	87.33	45.24	4.69
25	-3.9	48.81	87.69	63.42	22.10	89.22	46.30	5.09
26	-3.3	50.01	89.58	64.84	22.87	91.14	47.37	5.495
27	-2.8	51.22	91.49	66.29	23.66	93.09	48.46	5.91
28	-2.2	52.445	93.42	67.75	24.45	95.06	49.56	6.325
29	-1.7	53.69	95.38	69.23	25.26	97.06	50.68	6.75
30	-1.1	54.95	97.37	70.735	26.08	99.09	51.81	7.18
31	0.6	56.23	99.39	72.26	26.92	101.15	52.95	7.62
32	0	57.53	101.43	73.80	27.77	103.23	54.11	8.065
33	0.6	58.84	103.5	75.365	28.63	105.34	55.29	8.52
34	1.1	60.17	105.6	76.95	29.50	107.48	56.48	8.975
35	1.7	61.525	107.73	78.555	30.39	109.65	57.68	9.44
36	2.2	62.89	109.88	80.18	31.29	111.85	58.90	9.91
37	2.8	64.28	112.07	81.83	32.21	114.08	60.14	10.39
38	3.3	65.69	114.28	83.50	33.14	116.34	61.39	10.88
39	3.9	67.11	116.52	85.19	34.08	118.63	62.65	11.37
40	4.4	68.555	118.79	86.90	35.04	120.95	63.94	11.87
41	5.0	70.02	121.09	88.64	36.01	123.30	65.23	12.38
42	5.6	71.5	123.42	90.39	37.00	125.68	66.55	12.90
43	6.1	73.001	125.78	92.17	38.00	128.09	67.87	13.42
44	6.7	74.52	128.17	93.97	39.02	130.53	69.22	13.95
45	7.2	76.06	130.59	95.8	40.05	133.00	70.58	14.49
46	7.8	77.62	133.04	97.64	41.095	135.50	71.96	15.035
48	8.9	80.80	138.03	101.4	43.23	140.61	74.76	16.15
50	10.0	84.06	143.15	105.26	45.43	145.84	77.63	17.30
52	11.1	87.41	148.4	109.21	47.70	151.21	80.57	18.48
54	12.2	90.83	153.78	113.26	50.025	156.71	83.575	19.69
55	12.8	92.58	156.52	115.32	51.21	159.51	85.10	20.31
56◦F	13.3◦C	94.35	159.29	117.41	52.42	162.35	86.65	20.93
58	14.4	97.95	164.94	121.65	54.88	168.13	89.80	22.21
60	15.6	101.63	170.72	126.00	57.405	174.04	93.01	23.525
62	16.7	105.41	176.64	130.45	60.00	180.10	96.30	24.87

64	17.8	109.28	182.70	135.00	62.67	186.31	99.67	26.26
65	18.3	111.24	185.79	137.32	64.03	189.47	101.38	26.96
		A1	**A1**	**A1**	**A1**	**A2L**	**A3**	**A3**
Deg F	**Deg C**	**HCFC**	**HFC**	**HFC**	**HFC**	**HFC**	**HC**	**HC**
		R-22	**R-410A**	**R-404A**	**R-134a**	**R-32**	**R-290**	**R-600a**
66	18.9	113.24	188.91	139.66	65.41	192.66	103.11	27.68
68	20.0	117.29	195.26	144.43	68.22	199.17	106.62	29.13
70	21.1	121.43	201.75	149.31	71.105	205.82	110.21	30.63
72	27.2	125.67	208.40	154.3	74.065	212.64	113.87	32.16
74	23.3	130.01	215.20	159.40	77.10	219.61	117.62	33.73
75	23.9	132.22	218.66	161.99	78.65	223.15	119.52	34.53
76	24.4	134.45	222.16	164.61	80.22	226.73	121.44	35.34
78	25.6	138.99	229.27	169.94	83.41	234.02	125.35	36.99
80	26.7	143.63	236.54	175.39	86.69	241.48	129.34	38.68
82	27.8	148.37	243.97	180.96	90.04	249.10	133.41	40.41
84	28.9	153.22	251.56	186.65	93.48	256.90	137.56	42.185
85	29.4	155.68	255.42	189.54	95.23	260.86	139.67	43.09
86	30	158.17	259.33	192.46	97.01	264.86	141.80	44.00
88	31.1	163.23	267.26	198.4	100.62	273.00	146.12	45.86
90	32.2	168.39	275.36	204.46	104.31	281.32	150.53	47.76
92	33.3	173.67	283.64	210.66	108.10	289.82	155.03	49.71
94	34.4	179.06	292.09	216.98	111.97	298.50	159.61	51.70
95	35	181.80	296.38	220.19	113.95	302.91	161.94	52.71
96	35.6	184.56	300.72	223.44	115.94	307.37	164.29	53.73
98	36.7	190.18	309.54	230.03	120.00	316.42	169.06	55.815
100	37.8	195.91	318.54	236.76	124.15	325.67	173.92	57.94
102	38.9	201.76	327.73	243.63	128.40	335.11	178.87	60.12
104	40	207.73	337.11	250.63	132.74	344.75	183.92	62.345
105	40.6	210.76	341.87	254.19	134.95	349.64	186.48	63.48
106	41.1	213.82	346.68	257.79	137.19	354.59	189.06	64.62
108	42.2	220.03	356.46	265.08	141.73	364.63	194.30	66.94
110	43.3	226.36	366.43	272.53	146.37	374.88	199.64	69.31
112	44.4	232.82	376.60	280.12	151.12	385.34	205.08	71.74

114	45.6	239.41	386.98	287.87	155.97	396.01	210.61	74.21
115	46.1	242.75	392.25	291.8	158.44	401.43	213.42	75.47
120	48.9	259.95	419.40	312.05	171.16	429.34	227.84	81.95
125	51.7	277.99	447.94	333.31	184.58	458.67	242.92	88.77
130	54.4	296.88	477.92	355.64	198.71	489.47	258.68	95.94
135	57.2	316.67	509.42	379.09	213.58	521.82	275.13	103.46
140	60	337.38	542.51	403.71	229.22	555.77	292.31	111.36
145	62.8	359.04	577.30	429.59	245.66	591.40	310.23	119.64
150	65.6	381.68	613.88	456.8	262.91	628.81	328.92	128.31
155	68.3	405.34	652.38	485.47	281.03	668.10	348.40	137.39
160	71.1	430.05	692.82	515.78	300.03	709.39	368.70	146.88
165	73.9	455.86	*	*	319.95	752.87	389.85	156.80

Above Critical Temperature

Characteristics of Common Refrigerants

[Note: Lines with flammable refrigerants are shaded yellow.]

Reference No.	Type[8]	Name/ Composition	Ozone Depletion Potential (ODP)	Refrigerant Generation[9]	Global Warming Potential (GWP)[10]	Common Use; Lubricants[11]	EPA Pressure Range	ASHRAE 34 Class	Boiling Point °F/°C	
R-11	CFC	Trichloro-fluoromethane	1.0	II	4660[12]	Refrigeration & Air Conditioning; Lubricants: MO	Low	A1	74.8	23.8
R-12	CFC	Dichloro-difluoro-methane	1.0	II	10200	Refrigeration & Air Conditioning; Lubricants: MO	Medium	A1	-21.6	-29.8
R-22	HCFC	Monochloro-difluoromethane	0.05	II	1760	Air Conditioning; Lubricants: MO, POE	High	A1	-41.4	-40.8
R-32	HFC	Difluoro-methane	0	IV	675	Residential and Commercial A/C; Lubricants: MO, AB, POE and PVE	Medium	A2L	-61.6	-52
R-123	HCFC	Dichloro-trifluoroethane	0.06	II	77	Replacement for R-11, large air conditioners;	Low	B1	81.7	27.6

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[8] Type: CFC (Chlorofluorocarbon), HCFC (Hydrochlorofluorocarbon), HFC (Hydrofluorocarbon), HC (Hydrocarbon), NH3 (Ammonia), Carbon Dioxide (CO2)

[9] Refer to Table (drawing) on Page XXX

[10] IPCC AR5 5th Assessment Report 2014 100 year timeline (where available)

[11] Lubricants: Mineral Oil (MO), Alkyl Benzene (AB), Polyol ester (POE), Poly vinyl ether (PVE), Poly alkene glycol (PAG)

[12] AR5-100 yrs.

						Lubricants: MO, AB				
Reference No.	**Type**	**Name/ Composition**	**Ozone Depletion Potential (ODP)**	**Generation**	**Global Warming Potential (GWP)[13]**	**Common Use; Lubricants[14]**	**EPA Pressure Range**	**ASHRAE 34 Class**	**Boiling Point ◦F/◦C**	
R-502	Blend CFC + HCFC	Monochloro-pentafluoroethane/ Monochloro--difluoromethane	0.23	II	4657		High	A1	-49.5	-45.3
R-404A	HFC	Pentafluoro-ethane, Trifluoro-ethane, Tetrafluoro-ethane	0	II	3922	Blend used in commercial refrigeration equipment. Requires POE lubricant.	High	A1	-51.2	-46.2
R-134a	HFC	Tetrafluoro-ethane	0	II	1300	Air Conditioning and Refrigeration. Requires POE lubricant.	Medium	A1	-15.3	-26.3
R-407C	HFC	Difluoromethane, Pentafluoro-ethane, Tetrafluoro-ethane	0	II	1774	Air conditioning R-22 retrofit. Requires POE lubricant	Medium to High	A1	-46.5	-43.6
R-422B	HFC	Pentafluoro-methane, Trifluoroethane, Isobutane	0	III	2525	Retrofit for medium & low-temp, R-22, R-407C, R-502, & HCFC Blends; Lubricants	High	A1	-42.4	-41.3

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[13] IPCC AR5 5th Assessment Report 2014 100 year timeline (where available)

[14] Lubricants: Mineral Oil (MO), Alkyl Benzene (AB), Polyol ester (POE), Poly vinyl ether (PVE), Poly alkene glycol (PAG)

						include MO, AB, POE				
Reference No.	**Type**	**Name/ Composition**	**Ozone Depletion Potential (ODP)**	**Generation**	**Global Warming Potential (GWP)[15]**	**Common Use; Lubricants[16]**	**EPA Pressure Range**	**ASHRAE 34 Class**	**Boiling Point ◦F/◦C**	
R-410A	HFC	Difluoro-methane, Pentafluoro-methane	0	III	2088	Residential and Commercial Air conditioning; Requires POE lubricants	High	A1	-55.3	-48.5
R-441A	HC	Ethane, Propane, Butane, Isobutane	0	IV	3.6	Self-contained commercial refrigerators and freezers; Requires MO lubricant	High	A3	-31.5	-35.3
R-170	HC	Ethane	0	IV	5.5	Manufacturing processes, very low temp refrigeration; Lubricants MO, AB, POE	Very high	A3	-12.6	-24,8
R-290	HC	Refrigerant propane	0	IV	3.3	Commercial and industrial process refrigeration, vending machines, bottle coolers; Lubricants MO, AB, POE	High	A3	-43.8	-42.1

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[15] IPCC AR5 5th Assessment Report 2014 100 year timeline (where available)

[16] Lubricants: Mineral Oil (MO), Alkyl Benzene (AB), Polyol ester (POE), Poly vinyl ether (PVE), Poly alkene glycol (PAG)

Reference No.	Type	Name/ Composition	Ozone Depletion Potential (ODP)	Generation	Global Warming Potential (GWP)[17]	Common Use; Lubricants[18]	EPA Pressure Range	ASHRAE 34 Class	Boiling Point ◦F/◦C	Reference No.
R-600a	HC	Isobutane	0	IV	3	Household refrigeration, commercial & industrial process refrigeration; Lubricants MO, AB, POE	Medium	A3	10.4	-12
R-744	CO2	Carbon Dioxide	0	III	1	Commercial and Industrial Process Refrigeration; Lubricants specific to application	Very high	A1	-108	-78
R-717	NH3	Ammonia	0	III	0	Air conditioning, commercial and industrial processes, commercial refrigeration; Lubricants specific to application	High	B2	-28	-33
R-1234yf	HFO	Blend: Hydrogen, Fluorine, Carbon	0	IV	4	Automotive air conditioning; Lubricants restricted to PAG oils	Medium	A2L	-22	-30

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[17] IPCC AR5 5th Assessment Report 2014 100 year timeline (where available)

[18] Lubricants: Mineral Oil (MO), Alkyl Benzene (AB), Polyol ester (POE), Poly vinyl ether (PVE), Poly alkene glycol (PAG)

Reference No.	Type	Name/ Composition	Ozone Depletion Potential (ODP)	Generation	Global Warming Potential (GWP)[19]	Common Use; Lubricants[20]	EPA Pressure Range	ASHRAE 34 Class	Boiling Point ◦F/◦C	Reference No.
R-1234ze	HFO	Blend: Hydrogen, Fluorine, Carbon	0	IV	<1	Chillers, heat pumps, vending machines; Lubricants: POE, PVE, POE	Medium	A2L	49.6	9.8
R-1233zd	HFO	Blend: Hydrogen, Fluorine, Carbon	0	IV	1	Low pressure centrifugal Chillers and Foam Blowing Agent; Uses mineral oil as lubricant.	Low	A2L	65	18.3

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[19] IPCC AR5 5th Assessment Report 2014 100 year timeline (where available)

[20] Lubricants: Mineral Oil (MO), Alkyl Benzene (AB), Polyol ester (POE), Poly vinyl ether (PVE), Poly alkene glycol (PAG)

Footnotes

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[i] Source – ASHRAE *Journal*, December 1992

[ii] Source – ASHRAE *Journal*, December 1992

[iii] R-500 is an *azeotrope.* Azeotropes are formed when two refrigerants are mixed to form a new refrigerant that has its own properties. Although not a true CFC, R-500 is made up of approximately 74% R-12. Because of its high ODP, it's classified as a CFC.

[iv] An alternate refrigerant is a non-CFC refrigerant – approved by the EPA for use in new product or existing refrigeration system. EPA – approved alternatives are documented in the EPA Significant New Alternatives Program for SNAP documents.

[v] A blend is a mixture of several HCFC and HFC refrigerants that may be used as an alternate refrigerant in new product sealed systems or as a "drop-in" replacement in existing refrigeration systems. A blend of three refrigerants is also called a "ternary" blend.

[vi] A *drop-in* refrigerant is a non-CFC refrigerant designated for use as a replacement refrigerant in existing refrigeration systems. A drop-in refrigerant may consist of a single HFC refrigerant or a blend of several HCFC and HFC refrigerants.

[vii] See http://www.epa.gov/ozone/title6/608/sales/sales.html for discussion of the sales restriction.

[viii] ***Superheated vapor*** – As refrigerant boils and turns into a vapor, it absorbs heat. During this change of state, however, the boiling liquid and the emitted vapor are at the same temperature. As the refrigerant travels toward the compressor, it continues to absorb heat. This additional heat that is absorbed is referred to as *superheat* and the vapor is known as superheated vapor.

[ix] Since there is no way to accurately measure temperature inside of a tank, you must let the tank's contents come to room temperature in order to know a tank's internal temperature.

[x] A high-pressure gauge equipped with a quick coupler and depressor can also be used to purge.

XI (Reference AHAM Guidelines on Safe Servicing)

[ii] As of November 2, 2015, this amount applies to penalties assessed after January 15, 2017. This amount escalates each year according to the Civil Monetary Penalty Inflation Adjustments and is published in the Federal Register.