United States Environmental Protection Agency

EPA 430-R-11-012

The GreenChill Advanced Refrigeration Partnership

GreenChill Best Practices Guideline

Commercial Refrigeration Retrofits

U.S. Environmental Protection Agency
Stratospheric Protection Division

August 2011

Disclaimer

The authors of this Guideline and the organizations to which they belong do not assume responsibility for any omissions or errors, nor assume liability for any damages that result from the use of the Guideline. Always check with your component manufacturers before undertaking any action that may affect your equipment.

History of Revisions

Version	Date Posted Online	Summary of Changes
1	September 2008	Original version.
2	April 2009	Updated recovery container table and performance data on Arkema Forane R-427A. Added a case history on R-427A.
3	July 2009	Added R-407A case histories.
4	August 2011	Updated information on phaseout of HCFC-22. Added information on ICOR R-422B and R-422C. Added Honeywell performance data, case histories, and checklist for R-407F. Added Arkema performance data on R-407A and DuPont information on R-438A. Added all new chemicals to the recovery container table. Added a reference to the AHRI Guideline Q-2010. Added Appendix 3 and additional data and guidance from National Refrigerants.

Table of Contents

I. Introduction

Mission

GreenChill's mission in developing this document is to assist food retailers with an orderly, low-cost transition option from HCFC-22 to a substitute refrigerant, and to provide food retailers with a set of best practices related to the conversion process.

Purpose and Scope of this Guideline

The purpose of this Best Practices Guideline is to provide food retailers with fact-based, neutral information on best practices for every aspect of the HCFC-22 conversion process, including:

- Reasons to consider retrofitting refrigeration equipment that uses HCFC-22;
- HFC retrofit options currently available to food retailers;
- Factors to consider when assessing substitute chemicals;
- Current best practices for transitioning to HFC refrigerants and improving leak tightness;
- Recovery techniques for HCFC-22;
- HCFC-22 disposal and reclamation options; and
- Case studies that provide real-life examples from retrofits in the field.

Different sections of this Guideline will be of value to various people within a food retail organization. The document is designed to assist a wide range of stakeholders in the food retail market including, but not limited to, strategic decision-makers, store managers, and technicians participating in the HCFC-22 conversion process.

The scope of this document is limited to the conversion from HCFC-22 to non-ozone-depleting, HFC-based substitutes in commercial refrigeration systems. Our goal is to include every non-ozone-depleting HFC substitute that is readily available on the market for use by food retailers in place of HCFC-22. Its only limitations are that the chemicals must be on the U.S. Environmental Protection Agency (EPA) Significant New Alternatives Policy Program (SNAP)'s list of acceptable substitutes, and they must be non-ozone-depleting. Under the SNAP program EPA has reviewed these refrigerants for their health, safety, and environmental effects and has found that their overall health and environmental risks are comparable to, or less than, those of other available substitutes. The list of acceptable substitutes for use in retail food refrigeration is found at http://epa.gov/ozone/snap/refrigerants/lists/foodref.html.

This Guideline is meant to be a living document. EPA's GreenChill team will make every effort to include all relevant substitute refrigerants and to update this Guideline as future substitutes are found acceptable by the SNAP Program.

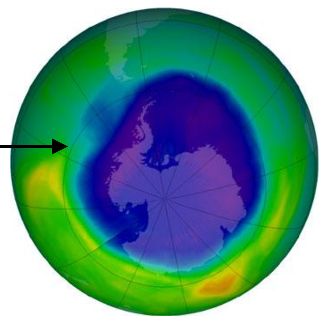
II. The HCFC Situation – Why Retrofit?

Ozone Layer Protection and the Montreal Protocol

HCFC-22 retrofitting is relevant to food retailers due to the phaseout of HCFC-22 under an international treaty, the *Montreal Protocol on Substances that Deplete the Ozone Layer*, and requirements under the Clean Air Act to protect the Earth's stratospheric ozone layer.

Stratospheric ozone depletion is caused by the release of chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and other ozone-depleting substances, which were and are used widely as refrigerants, as solvents, and in insulating foams. When these substances reach the stratosphere, the UV radiation from the sun causes them to break apart and release chlorine atoms which react with ozone, starting chemical cycles of ozone destruction that results in significant thinning of the protective ozone layer. One chlorine atom can break apart more than 100,000 ozone molecules.

Ozone Hole
[Source: NASA 2007]



Dark blue and purple correspond to thinnest ozone; light blue, green, and yellow indicate progressively thicker ozone.

As a result of ozone layer depletion, more UV radiation reaches the Earth's surface. In fact, average UV radiation levels increased by up to a few percent per decade between 1979 and 1998. This means more sunburns, skin cancer, cataracts, and other skin and eye damage. Some research even shows that exposure to doses of UV radiation that are only 30-50% as high as what is required to cause detectable sunburn can suppress human immune systems. A weakened immune system means more colds, sick days, and other diseases. Increased UV can also reduce crop yields and disrupt the marine food chain.

The Montreal Protocol is an agreement to protect the Earth's ozone layer and protect future generations from the harmful effects of ultraviolet (UV) radiation. The U.S. signed the Montreal Protocol in 1987. The Montreal Protocol and its amendments and adjustments have mandated the complete phaseout of CFCs, and the eventual phaseout of HCFCs, according to a schedule agreed upon by the signing parties, including the U.S. Today, the treaty has achieved universal participation and represents a truly world-wide effort, involving both developed nations and developing nations, to protect the ozone layer. Title VI of the Clean Air Act incorporates the requirements of the Montreal Protocol. EPA regulations at Title 40, Part 82 of the Code of Federal Regulations implement these requirements. EPA's Stratospheric Protection Division, home of the GreenChill program, manages these regulations.

While the Antarctic ozone hole (pictured above) still exists, it is slowly recovering as a result of positive efforts to date. The World Meteorological Organization predicts that Antarctic ozone will recover by the year 2060, assuming that the Montreal Protocol signatories continue to fulfill their obligations under the treaty.

Ozone layer recovery means fewer cases of skin cancer and cataracts. EPA uses its Atmospheric and Health Effects Framework (AHEF) model to estimate the U.S. health benefits of stronger ozone layer protection policies. EPA estimates that the improved ozone layer protection afforded by amendments and adjustments to the Montreal Protocol to date will avert millions of skin cancer and cataract cases for Americans born between the years 1985 and 2100.

Montreal Protocol Implementation in the United States

The U.S. is reducing HCFC production and consumption in several stages to meet the Montreal Protocol requirements. The chart shows the stepwise reductions required by the Protocol and EPA's regulatory requirements to meet these expectations. Beginning on January 1, 2010, EPA banned the production and import of HCFC-22 for use in new equipment (equipment manufactured after December 31, 2009). HCFC-22 may still be used for servicing equipment manufactured before this date (the so-called "servicing tail"), up until January 1, 2020, when all production and import of virgin HCFC-22 will be banned.

HCFC Phaseout Plans: Montreal Protocol and U.S. EPA Regulations

Montreal Protocol		U.S. (under EPA Regulations)	
Implementation Year	**% Reduction in Consumption and Production, Using Cap as Baseline**	**Implementation Year**	**Implementation of HCFC Phaseout Through Clean Air Act Regulations**
2004	35%	2003	No production or import of HCFC-141b
2010	75% (reduced from 65% in 2007)	2010	No production or import of HCFC-22 or HCFC-142b, except for use in equipment manufactured before 1/1/2010 (no new production or import for *new* equipment using these refrigerants)
2015	90%	2015	No production or import of any HCFCs except for use as refrigerants in equipment manufactured before 1/1/2020
2020	99.5%	2020	No production or import of HCFC-22 or HCFC-142b
2030	100%	2030	No production or import of any HCFCs

HCFC-22 Supply and Demand

As discussed above, the U.S. must meet an annual HCFC consumption cap under the Montreal Protocol. As of 2010, the United States needed to reduce the amount of HCFCs it consumed and produced by 75% from its baseline cap (the baseline cap is roughly the level of HCFC allowed in 1996-2003, and is calculated as the amount of HCFCs, plus 2.8% of the amount of CFCs, consumed in 1989). By 2015, the supply of HCFCs will be reduced by 90%.

HCFC-22 users need to be aware of the upcoming HCFC-22 constraint due to the reduction in total USA rights to consume ozone-depleting products. To address these concerns, there are several options to move away from HCFC-22 use. Included in these options are opportunities to repair leaky equipment, reclaim used HCFC-22, retrofit to new HFC products, and replace old equipment. This Guideline specifically addresses retrofitting to new HFC products and the reclamation of used HCFC-22.

EPA has estimated the continued demand for HCFC-22. The table below shows the projected HCFC-22 demand (including that used in blends) in 2010, 2015, and 2020. These estimates were developed based on EPA's Vintaging Model, which takes into account recent industry input (EPA, December 2009). EPA estimates that in 2010, approximately 62,500 metric tons of HCFC-22 were required to service AC and refrigeration equipment, of which the majority—41,700 metric tons (67%)—were used to service AC systems. In 2015, servicing demand is projected to reach approximately 38,700 metric tons of HCFC-22 for AC and refrigeration equipment, and in 2020, the projected demand declines to 18,200 metric tons.

Projected HCFC-22 Servicing Demand (2010-2020) (Metric Tons)

Equipment Type	2010	2015	2020
Total AC	41,700	25,900	11,300
Total Refrigeration	20,800	12,800	7,000
Overall Total	**62,500**	**38,800**	**18,200**

HCFC consumption is capped as described below. Both the 2015 and 2020 projections of HCFC-22 servicing demand exceed the U.S. consumption cap for all virgin HCFCs for these years. However, a portion of the servicing needs are expected to be met by using recovered and reclaimed refrigerant, thus decreasing the need for virgin HCFC-22. HCFC users should be planning for this transition to avoid costly investments and uncertainty in the future availability of the chemical.

HCFC Consumption Phaseout Targets Under the Montreal Protocol

Date	Consumption Cap	Quantity Expressed in R-22 Metric Tons
Jan 1, 1996	Consumption freeze capped at 2.8% of the 1989 ODP-weighted CFC consumption plus 100% of the 1989 ODP-weighted HCFC consumption	277,091 metric tons
Jan 1, 2004	35% reduction of the cap	180,109 metric tons
Jan 1, 2010	75% reduction of the cap	69,272 metric tons
Jan 1, 2015	90% reduction of the cap	27,709 metric tons

Jan 1, 2020	99.5% reduction of the cap	1,385 metric tons*
Jan 1, 2030	100% reduction of the cap	0 metric tons

* based on EPA regulation, no virgin HCFC-22 may be produced or imported starting January 1, 2020.

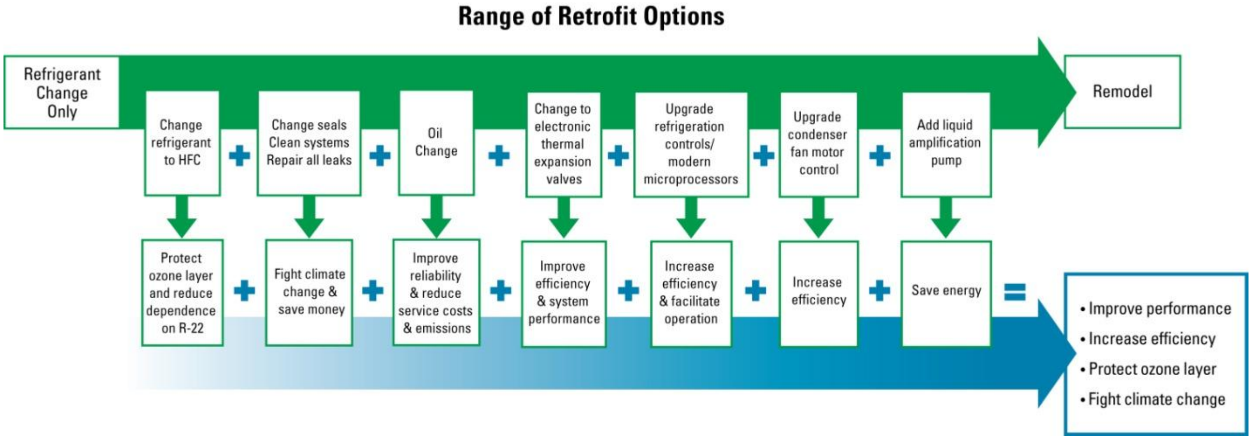
Reasons to Retrofit HCFC-22 Systems

Owners and operators of HCFC-22 systems need to evaluate their future need for the chemical in light of the limited supply as described above. Although EPA expects that an increasing amount of refrigerant need will be met by utilizing reclaimed HCFC-22, the supply of reclaimed material remains uncertain. What is known is that the availability of virgin HCFC-22 will continue to decrease, and production and import to the U.S. will be eliminated by January 1, 2020. Equipment owners can avoid the uncertainty regarding future HCFC-22 supplies and costs by replacing their equipment with new equipment utilizing a different refrigerant. New equipment, however, can be a costly investment. Instead, owners may choose from many SNAP-acceptable refrigerants that can be used in their existing equipment, often with only minor modifications. Performing a "refrigerant-only" retrofit allows an owner to transition away from HCFC-22 while avoiding the capital outlays and development time required to install new equipment.

This Guideline provides neutral technical information to assist food retailers who choose to retrofit their commercial refrigeration systems from HCFC-22 to ozone-friendly refrigerants.

III. HFC Refrigerant Retrofits

HFC Retrofit Options



There are two main approaches to retrofitting supermarkets from HCFC-22 to HFCs:

1. Replacing only the refrigerant, with minimal adjustment to the mechanical system.
2. Using new mechanical systems, which may include compressors, condensers, and refrigerated cases, along with a change to an HFC refrigerant.

There are advantages and disadvantages to each approach, as explained in the following section.

Once a CFC, HCFC, or HFC refrigerant is emitted, it is only a matter of time before it damages the atmosphere. As discussed earlier, CFCs and HCFCs are not only ozone-depleting substances but are also potent greenhouse gases. HFCs do not deplete the ozone layer but are still greenhouse gases. Therefore food retailers should use the retrofit conversion process as an opportunity to prevent refrigerant emissions and tighten up the leak rates of their systems. Regardless of the approach chosen, a retrofit should always include leak tightness improvements to the refrigeration system. This makes sense for the environment, but it also makes sense economically. It costs money to replace refrigerant lost to leaks.

HFC Refrigerant-only Retrofit

A refrigerant-only retrofit allows conversion to a non-ozone-depleting fluid while minimizing retrofit costs and store disruption. HFCs have a solid track record of performance and reliability. Mechanics have been working with HFC-containing refrigerant blends for years, and the handling of these fluids has become commonplace.

The type of installed system and the chosen HFC or HFC/hydrocarbon blend will determine the amount of mechanical, lubricant, and control changes required to accomplish an HFC-only retrofit. Selecting a refrigerant with mass flows within 30% of those of HCFC-22 may allow for

the use of the existing thermal expansion valves (TXVs). Retrofit refrigerants with low-side operating pressures close to those of HCFC-22 will assist in proper TXV operation.
Another advantage of retrofitting existing equipment to an HFC is the benefit of lower discharge temperatures inherent to some of the R-400 series blends and R-507A as compared to HCFC-22. If the discharge temperature is sufficiently low, issues associated with desuperheaters, liquid injection, and oil coolers are eliminated, which may lead to reduced maintenance costs. A side benefit of deactivating these devices may be a gain in system capacity and efficiency. If the existing system uses heat recovery to heat air or water, then too low a discharge temperature may necessitate changes to these systems.

One major disadvantage of retrofitting HCFC-22 equipment to some of the current commercial HFC options is the potential efficiency decrease relative to HCFC-22. As noted above, reduced discharge temperatures, particularly in low-temperature systems, with some of the available substitutes can lead to efficiencies that match HCFC-22. The decrease in efficiency can be aggravated or alleviated by system design, geographic location, and choice of refrigerant. Certain blends benefit from sub-cooling more than others, and this technique can bring some HFCs very close to performing like HCFC-22.

Caution is necessary when introducing a new refrigerant to an older system, and in addition to the criteria listed here, an evaluation of the resultant operating pressures is in order.
If the choice is made to continue the use of mineral-based lubricants, an evaluation of the system's oil separating technology should be made. The mineral oil-compatible HFC/hydrocarbon blends may be ineffective if the oil carryover ratio to the low side of the system is excessive. Systems without oil separators should not consider a non-miscible refrigerant/oil approach.

Gasket materials used in an older installation should be evaluated, since shrinking may occur after the HCFC-22 is removed. Valve and equipment suppliers are aware of this and can supply suitable replacements to be installed during the retrofit. Elastomeric seals should be replaced regardless of the retrofit path chosen.

The retrofit refrigerant should be selected after evaluating the current system's performance and evaluating the selection criteria listed in this section.

Even for a refrigerant-only retrofit, the retrofit process is a good opportunity to examine your refrigeration system and focus attention on performance to incur additional benefits by changing seals, repairing leaks, and cleaning the system.

Retrofitting with New Mechanicals and HFC Refrigerant

Retrofitting with new mechanical systems as well as an HFC refrigerant is likely to be more costly in the short term but could offer significant long-term savings. Such a retrofit enables a retailer to convert a store to ozone-friendly refrigeration and adopt advances in mechanical design concepts and control strategies. A food retailer can address existing mechanical shortcomings due to age or store layout, change display cases, and remove leaky equipment or piping.

A mechanical and refrigerant retrofit allows a retailer to consider such factors as:

- Improved control strategies such as floating head pressure control, liquid amplification, ambient and mechanical sub-cooling, and multiple suction groupings;
- Advances in compressor and motor design; and
- Improved microprocessor-based controllers, variable frequency drives, and flow controls, which have also shown to contribute to energy savings.

Replacing equipment during a retrofit results in a system with known operating characteristics, capacity, and performance values. For example, manufacturers and designers are familiar with systems designed to use polyolester (POE) lubricants and HFC refrigerants, a lubricant/refrigerant combination that reduces oil return problems and enhances compressor longevity.

Equipment changes, of course, present the disadvantage of higher equipment purchase cost and potential disruption of store operations. Retrofit costs are highly store-specific, reflecting the type of installation, display case upgrades and change-outs, store piping layout, and refrigerant selected. The location of the equipment room also affects the difficulty and cost of replacing compressor systems. Other considerations include the following:

- On-grade outdoor mechanical rooms often can be retrofitted or completely changed with minimal sales floor or rooftop disruption.
- Distributed systems may offer the opportunity to locate the new equipment closer to the loads, for example on the rooftop; they also allow electrical hookup and pre-piping with little sales floor interruption until final case tie-in.
- If the remodel calls for only back room mechanical changes with no case changes or modifications, then selecting an HFC with mass flows similar to HCFC-22 will minimize work on the sales floor.
- If the refrigerant chosen has less capacity than HCFC-22, more compressor displacement can be added during the retrofit.

In summary, purchasing new equipment for a retrofit may be more expensive initially than a refrigerant-only retrofit, but it provides the long-term advantage of matching the mechanical system to the chosen HFC, which may maximize the performance of the mechanical system. On the other side, some disruption to store operations is unavoidable.

Leak Tightness Improvements during Retrofits

EPA estimates that a typical supermarket refrigeration system holds a refrigerant charge of about 4000 pounds.[1] Since the average leak rate for a typical supermarket is about 25% per year, on average a supermarket emits approximately 1,000 pounds of refrigerant into the atmosphere annually. If nothing is done during a retrofit to repair leaks in a refrigeration system, that system will continue to emit 1000 pounds of a potent greenhouse gas into the atmosphere annually. The

[1] Revised Draft Analysis of U.S. Commercial Supermarket Refrigeration Systems (EPA, 2005)

retrofit conversion process presents an opportunity to tighten leak rates and prevent the emission of a potentially dramatic amount of refrigerant.
Reducing leaks is economically sensible as well as environmentally sensible. Leaks cost money, regardless of which refrigerant is used.

Factors to Consider When Assessing Retrofit Options

Before beginning the retrofit process, a retailer should evaluate which refrigerant is right for a particular store by assessing factors such as the following:

- Cooling capacity
- Efficiency
- Mass flow of refrigerant
- Lubricant compatibility
- Compressor manufacturer's approval of substitute chemicals
- GWP of refrigerant candidates
- Estimated retrofit cost
- Store disruption

Cooling Capacity

A retrofit can only be deemed successful if the refrigeration system can maintain case and product temperatures – that is, if the installed condensing unit capacity is compatible with the case load. This necessitates survey of the refrigeration system's available capacity. Then the retailer can survey commercially available HFCs, using thermodynamic data and variables such as design suction, discharge temperatures, and available sub-cooling and superheat settings. Some compressor manufacturers have evaluated retrofit HFCs, and they may have capacity data available. It is important to understand how capacity is defined, since compressor manufacturers normally include the "non-useful" heat picked up in the return line and the return gas temperature is often quoted at 65° F, which overstates the capacity. The evaporator capacity will determine whether the case temperature can be met. For systems that are running close to 100% of the design capacity with R-22, such as a rack system that is running all compressors most of the time, the installation of a lower-capacity fluid may lead to elevated case temperatures, particularly on summer design days. Systems that are not currently running at 100% capacity may be able to use a lower capacity refrigerant, which would translate into increased run times, although other factors such as valve/case capacities must be evaluated. Anecdotal information and even field trial data can be misleading indicators for a particular selection; thorough analysis upfront helps to ensure a successful retrofit.

Efficiency

As in the analysis of capacity referenced above, the coefficient of performance (COP) of a retrofit fluid can be determined using thermodynamic analysis or published compressor manufacturers' data for selected fluids. Again, care should be taken in understanding whether the

COP is truly based on evaporator load. In some cases the current commercial retrofit candidates will be less efficient than HCFC-22. System efficiency may be enhanced by technology upgrades.

Mass Flow of Refrigerant

The mass flow of refrigerant in a system depends on the installed compressor displacement and the density of the suction vapor entering the compressor at the design conditions. In some cases thermal expansion valves (TXVs) may need to be replaced, depending on the initial valve selection, the low-side operating pressures of the selected refrigerant, and the mass flow relative to HCFC-22. If the retailer determines that certain valves need to be replaced, he or she should consult valve manufacturers before beginning the retrofit to determine the extent of modifications required. Appendix 3 provides an analysis by one valve manufacturer for R-22 valve capacities used with various alternative refrigerants in a retrofit scenario. It should also be noted that supermarket systems with electronic expansion valves can automatically compensate valve capacities by a software correction.

Higher mass flows can also lead to greater pressure drop in refrigerant piping, decreasing system efficiency. An analysis of the installed piping system with particular attention to suction line piping will identify piping runs that may need to be replaced with larger diameters. While this situation is rare with the use of current retrofit fluids, some instances have been reported.

Equipment Change

Equipment changes for a given DX system are determined at three points:

- Compressor: evaluate installed compressor capacity and efficiency
- Evaporator: evaluate flow rate required per ton of cooling, evaporator pressure and suction line capacity
- Condenser: evaluate flow rate required for the heat rejected, condensing pressure and liquid line capacity

No refrigerant is a “drop in” for HCFC-22. The more a replacement differs from HCFC-22 with respect to compressor capacity, efficiency, mass flow per ton of cooling, evaporator and condenser pressures, and suction and liquid line capacities, the more the system’s operation could be affected. Equipment owners should consult with manufacturers before retrofitting to determine the extent of modifications required.

Lubricant Compatibility

HCFC refrigerants are partially miscible with mineral-based lubricants, while HFCs use more polar synthetic lubricants. The addition of hydrocarbons to HFCs may enhance the ability of some systems to use mineral-based lubricants. Oil separators and proper piping practices are essential for satisfactory oil return when using a non-miscible combination.

Compressor Manufacturer Approval

Compressor manufacturers supply and often extend warranties on compressors, the most expensive components of supermarket mechanical systems, and retailers should take advantage of manufacturers' experience and testing when selecting a retrofit fluid. Some installed compressors on older mechanical packages may not be suitable for use with HFCs or may require modification to use HFCs with synthetic lubricants. [2]

Global Warming Potential

While not a factor in refrigeration capacity, efficiency, or other physical parameters, a selection based on global warming potential is a prudent environmental choice.

Disruption to Store Operations

During the retrofit planning process the retailer should account for effects on store operations such as time spent emptying and restocking cases, potential for lost sales, and interference with customer shopping experiences. It is important, however, not to overestimate these effects, since the losses associated with the time spent retrofitting cases can be offset by refrigerant and energy savings.

[2] For example, Copeland R22 to R407C guidelines, form no. 95-14 R2, state that compressors manufactured prior to 1973 should not be retrofitted with new refrigerants and oil.

Value/Cost Calculation

Total cost of ownership should be considered when choosing a retrofit refrigerant. Total cost of ownership consists of two elements: first cost and future operating costs.

First cost:

- Labor
    - Engineering
    - Installation & follow up for leak checks
- Materials
    - Refrigerant
    - Charge size (lbs.)
    - Seals, gaskets, and O-rings
    - Filter driers
    - Oil changes if necessary
    - Expansion valves if necessary
    - Line changes if necessary
    - Ball valves if necessary
    - Distributor nozzles if necessary

Future operating costs:[3]

- Energy consumption for medium-temperature refrigeration
- Energy consumption for low-temperature refrigeration
- Compressor life
- Service refrigerant

  (= Refrigerant Charge Size (lbs) x Leak Rate (%/yr) x Refrigerant Cost ($/lb))
- Service labor

[3] [3] Future operating costs should be discounted to present value. Some supermarkets use an 8% discount rate for an 8 year period.

Lab Tests on Retrofit Refrigerants: Performance Data vs. HCFC-22

The following laboratory data have been provided by GreenChill's current retrofit chemical manufacturing partners: Honeywell, DuPont, Mexichem Fluor, and Arkema, and ICOR. Because each company uses different equipment and methodologies to conduct its laboratory tests and analyses, it was impossible to do a valid side-by-side comparison of the chemicals. GreenChill does not endorse any of the following chemicals, and EPA has not verified the accuracy of the following information. Please contact the appropriate chemical manufacturer with any questions you may have about the lab data and analyses that are contained in this section of this Guideline.

Please note: all global warming potentials are taken from the IPCC 4th Assessment Report, 2007. In some cases, the numbers are rounded to the nearest hundred.

Lab Tests on Retrofit Refrigerants: Honeywell Performance Data vs. HCFC-22

Honeywell has evaluated all of the commercially available and American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)-listed HFC and HFC/HC refrigerants using thermodynamic, system, and calorimeter testing. Below is a partial list of these refrigerants being considered as candidates for retrofitting HCFC-22 systems. The range of capacities and efficiencies for each fluid is the result of using the three evaluation tools. The first table is meant as a guide using the operating conditions listed in the table below it. Since many supermarkets use mechanical sub-cooling, capacity and efficiency values for sub-cooled low-temperature liquid are included to demonstrate the effect of this technique on the fluids. It should be noted that the increased sub-cooling load is generally moved to the medium-temperature systems and these systems should be evaluated when considering this technique. More information about these test results is available from Honeywell Refrigerant Technical Services.

	Refr.	Main Parameters					Standard Performance		Added Subcooling Performance		Retrofit Issues	
		GWP	Evap Glide	Comp. Ratio	Diff. Disch. T	Mass Flow	Capacity	Efficiency	Capacity	Efficiency	Preferred Lubricant (optional)	Equipment Evaluation
		#	°F	%	°F	%	%	%	%	%		
Low Temperature	R407A	2107	7.2	112	-56	105	90 to 96	89 to 95	96 to 102	94 to 100	POE	TXV adjustment
	R407C	1774	7.6	116	-44	92	86 to 92	91 to 97	91 to 97	94 to 100	POE	TXV adjustment
	R407F	1824	7.6	111	-35	101	98 to104	92 to 97	102 to 108	94 to 100	POE	No Change
	R422D	2729	4.8	108	-106	123	76 to 82	83 to 89	86 to 92	93 to 99	POE (MO,AB)	No Change
	R507A	3985	0.0	94	-106	151	93 to 99	81 to 87	106 to 112	92 to 98	POE	Change TXV
	R404A	3922	0.8	95	-103	143	91 to 97	82 to 88	103 to 109	92 to 98	POE	Change TXV
Medium Temperature	R407A	2107	7.7	107	-29	112	100 to 106	93 to 99	NA	NA	POE	TXV adjustment
	R407C	1774	8.4	108	-22	99	96 to 102	94 to 100	NA	NA	POE	TXV adjustment
	R407F	1824	8.0	106	-17	107	107 to 113	94 to 100	NA	NA	POE	No Change
	R422D	2729	4.9	104	-57	129	87 to 93	90 to 96	NA	NA	POE (MO,AB)	No Change
	R507A	3985	0.0	97	-57	150	100 to 106	87 to 93	NA	NA	POE	Change TXV
	R404A	3922	0.7	97	-56	143	98 to 104	88 to 94	NA	NA	POE	Change TXV

Operating Conditions			
Parameter	Medium Temperature	Low Temperature	Low Temperature Added Subcooling
Condensing Temperature	105°F	105°F	105°F
Degree of Subcooling at TXV Inlet	10°F	10°F	55°F
Evaporation Temperature	20°F	-25°F	-25°F
Superheat at Evaporator Outlet	10°F	10°F	10°F
Superheat gain in the Suction Line	15°F	40°F	40°F
Compressor Isentropic Efficiency	60%	60%	60%
Compressor Volumetric Efficiency	100%	100%	100%

Lab Tests on Retrofit Refrigerants: ISCEON® Performance Data vs. HCFC-22

DuPont has completed extensive compressor calorimeter tests on the leading R-22 replacement refrigerants to help supermarket retailers make educated choices. The table below summarizes the performance of several retrofit refrigerant options relative to R-22. More detail about the actual test results for both Copeland® brand and Carlyle® brand compressors is available to customers upon request.

Potential Alternatives	**Unit**	**HCFC-22**		**R-404A**		**R-407C**		**R-438A**		**R-422A**		**R-422D**	
Condenser Temp	°F	80	105	80	105	80	105	80	105	80	105	80	105
Relative Med Temp Capacity (20 °F)[a]	BTUH	1	1	1.17	1.11	1.01	0.96	1	0.94	1.13	1.08	1.01	0.96
Relative Low-Temp Capacity (-25 °F)[b]	BTUH	1	1	1.25	1.17	0.98	0.91	0.96	0.92	1.24	1.19	1.06	0.97
Relative Med-Temp EER (20 °F)[c]	BTUH/W	1	1	1	0.97	0.97	0.96	1.01	1	0.92	0.94	0.99	1.00
Relative Low-Temp EER (-25 °F)[d]	BTUH/W	1	1	1.03	1.03	0.98	0.93	1.03	1.02	1.06	1.07	1.04	1.04
Copeland Compressor Retrofit Approval		Yes		Yes		Yes		Yes		Yes		Yes	
Keep TXV		Yes		No		Yes		Yes		No		Evaluation	
Keep Line Sets		Yes		Evaluation		Yes		Yes		Evaluation		Evaluation	
UL Listed		Yes		Yes		Yes		Yes		Yes		Yes	
GWP	AR4	1810		3920		1760		2260		3140		2730	
Use Mineral Oil		Yes		No		No		Yes		Yes		Yes	
Medium-Temp Discharge Temp	°F	186	225	149	177	170	204	155	183	144	169	148	172
Low-Temp Discharge Temp	°F	230*	230*	201	225	225	230*	206	226	192	214	195	218

* Liquid Injection required to maintain 230 °F discharge temperature

[a] 65 °F return gas; Sub-cooled liquid 10 °F below average condenser temperature

[b] 65 °F return gas; Sub-cooled liquid 10 °F below average condenser temperature for 80 °F condenser conditions; Sub-cooled liquid 15 °F below average condenser temperature for 105 °F condenser conditions

[c] 65 °F return gas; Sub-cooled liquid 10 °F below average condenser temperature

[d] 65 °F return gas; Sub-cooled liquid 10 °F below average condenser temperature for 80 °F condenser conditions; Sub-cooled liquid 15 °F below average condenser temperature for 105 °F condenser conditions

Lab Tests on Retrofit Refrigerants: Klea® 407A Performance Data vs. HCFC-22

The following table provides system performance data for Klea®407A. The data is derived from laboratory tests and calorimeter data using compressors from a major manufacturer. More information is available from Mexichem Fluor upon request.

Medium-Temperature Condition	Units	R-407A	R-22	R-407A	R-22
Average condenser temperature	°F	80	80	105	105
Average evaporator temperature	°F	20	20	20	20
Liquid temperature at expansion valve	°F	70	70	95	95
Evaporator superheat	°R	10	10	10	10
Compressor suction gas temperature	°F	45	45	45	45
Evaporator capacity	BTU/hr	100624	93186	82023	78523
Evaporator EER	BTU/hr.W	15.85	15.85	9.99	10.25
Discharge temp without demand cooling	°F	139.5	162.7	176.2	207.8

Low-Temperature Condition	Units	R-407A	R-22	R-407A	R-22
Average condenser temperature	°F	80	80	105	105
Average evaporator temperature	°F	-25	-25	-25	-25
Liquid temperature at expansion valve	°F	70	70	95	95
Evaporator superheat	°R	10	10	10	10
Compressor suction gas temperature	°F	25	25	25	25
Evaporator capacity	BTU/hr	28867	27604	21627	17535
Evaporator EER	BTU/hr.W	6.50	6.67	4.48	4.30
Discharge temp without demand cooling	°F	213.2	264.5	256.9	319.5

R-407A performance relative to R-22					
Condition Evap/cond	Evaporator Capacity	Evaporator EER	Change in discharge temp (°F)	Mass flowrate at compressor	Change in evaporator pressure (psia)
20°F/80°F	108.0%	100.0%	-23	115.8%	+4.3
20°F/105°F	104.5%	97.5%	-32	115.8%	+3.7
-25°F/80°F	104.6%	97.5%	-51	114.9%	+0.5
-25°F/105°F	123.3%	104.2%	-63	123.7%	+0.2

Points in red denote that liquid injection was used to limit R-22 discharge temperature to 270°F and the EER/capacity adjusted accordingly

Lab Tests on Retrofit Refrigerants: Arkema Forane® 427A / Forane® 407A Performance Data vs. HCFC-22

Arkema completed testing of R-427A and R-407A as leading medium-to-low-temperature R-22 refrigeration retrofits. The tables below summarize their physical / performance properties. More information is available from Arkema Technical Service upon request.

Physical Properties

PROPERTIES	HFC-427A	HFC-407A	HCFC-22
Average Molecular Weight (g/mol)	90.4	90.1	86.5
Normal Boiling Point (NBP) (^{o}F)	-44.8	-49.0	-41.3
Latent Heat of Vaporization at NBP (BTU/lb)	102.0	101.3	100.5
Critical Temperature (^{o}F)	185.6	180.1	204.8
Critical Pressure (psia)	637.1	654.9	722.3
Density of Saturated Vapor @ NBP (lb/ft^3)	0.30	0.30	0.29
Density of Saturated Liquid at 77 ^{o}F (lb/ft^3)	71.9	71.5	74.5
Specific Heat of Saturated Vapor at NBP (BTU/lb. ^{o}R)	0.18	0.18	0.14
Specific Heat of Saturated Liquid at 77 ^{o}F (BTU/lb. ^{o}R)	0.38	0.36	0.30
Ozone Depletion Potential (ODP) (CFC-11 = 1.0)	0	0	0.055
ASHRAE Safety Group Classification	A1	A1	A1
Occupational Exposure Limits (8 hr time/wt. Avg.) (ppm)	1,000	1,000	1,000
Global Warning Potential (GWP)	2,130	2,100	1,810

Performance Properties – Medium-Temperature Application

Test Conditions

105 °F Condensing Temperature
20 °F Evaporator Temperature
R-22 TXV, Optimized Charge

	HFC-427A	HFC-407A	HCFC-22
Capacity (%)	91.1	97.3	100.0
COP (%)	94.2	94.2	100.0
Mass Flow Rate (%)	101.1	110.6	100.0
Discharge Pressure (psig)	216	242	211
Discharge Temperature (°F)	183	191	216

Lab Tests on Retrofit Refrigerants: ICOR R-422B and R-422C Performance Data vs. HCFC-22

The following table summarizes the laboratory tests of R-422B and R-422C on low-temperature applications. More information is available from ICOR International upon request.

70°F Box Start Temperature	R-422B	R-422C	R-22
Time to achieve 0 °F (minutes)	74	76	69
Time to achieve -10 °F (minutes)	101	101	96
Time to achieve -15 °F (minutes)	128	121	129
Lowest Box Temperature (°F)	-19	-31	-18
Time to achieve -10 °F after defrost (minutes)	26	22	16
Time to achieve -15 °F after defrost (minutes)	35	25	43
AMPs	4.4	4.6	4.8
Compressor Suction (psig)	3	7	7
Evaporator Suction Line Temp (°F)	-24	-27	-23
Evaporator Temp Supply (Air) (°F)	-22	-26	-21
Evaporator Temp Return (Air) (°F)	-16	-19	-15
Evaporator Delta T (°F)	6	7	6
Evaporator TD (°F)	18	11	11
Liquid (psig)	164	200	185
Liquid Temperature (°F)	82	84	90
Liquid Subcooling (°F)	6	5	6
Discharge (psig)	173	206	191
Discharge Temperature (°F)	110	114	119
Compression Ratio	10.4:1	10.1:1	9.6:1

IV. Best Practices for Transitioning to HFC Substitute Chemicals

Conversion Guidelines for HFC Substitute Chemicals

This section lists conversion procedures that a typical retailer will likely undertake to retrofit equipment that was designed to use HCFC-22. It also provides general guidance on a typical conversion process. Appendix 2 contains retrofit checklists that are specific to each HFC substitute refrigerant.

1. Determine alternative refrigerant to be used.
2. Determine oil type based on recommendations from refrigerant manufacturer, original equipment manufacturer (OEM), and contractor.
3. Determine whether existing elastomer types are suitable for the proposed refrigerant.
4. Ensure all material is on hand before starting the retrofit.
5. Record performance of existing system using the System Datasheet in Appendix 1.
6. Analyze the condition of the lubricant and refrigerant to identify any pre-existing issues that may prevent a successful retrofit like high moisture, acidity, non-condensibles, or compressor wear issues.
7. Check for, and repair, any existing leak before proceeding with the retrofit. (See GreenChill's leak repair guideline at http://www.epa.gov/greenchill/downloads/leakpreventionrepairguidelines.pdf)
8. If a change of oil type from mineral oil to POE oil is required, complete this step. If no change of oil is required, skip to step 9.
    a. Isolate the refrigerant to avoid refrigerant losses during the oil flush. Pull a vacuum on the system to minimize the amount of refrigerant dissolved in the oil.
    b. Drain the oil from the system into suitable containers, paying particular attention to the compressor sump, suction line accumulator, oil separator, long runs of piping, and any low spots. Measure the amount of oil removed. Dispose of oil properly.
    c. Replace filter-drier with one that is compatible with the new refrigerant and POE oil.
    d. Add the recommended POE oil to the system.
    e. Evacuate system to 500 microns to remove air and moisture. Hold vacuum to check for leaks.
    f. Restart system and check oil level. Adjust oil level if needed. Run system for a minimum of 24 hours to ensure time for the POE and residual oil to mix. Longer running times will allow more complete mixing and oil return, particularly for larger systems.
    g. Check amount of mineral oil content in the system using a refractometer or other commercially available device. If mineral oil content is above the recommended level, repeat step 8.

9. Remove HCFC-22 refrigerant from system.
    a. Use an approved recovery machine and recovery cylinders.
    b. Do not vent refrigerant to atmosphere.
    c. Remove refrigerant to a target vacuum level of 15 inches Hg. The lower the vacuum level achieved, the lower the refrigerant emission when the system is opened and the higher the amount of potentially valuable refrigerant recovered.
    d. Weigh amount of refrigerant recovered.
10. Break the vacuum.
11. Replace equipment as required for new refrigerant and as desired to reduce the potential for leaks in subsequent operation.
    a. Replace filter/drier, compatible with new refrigerant.
    b. Replace thermal expansion valves (TXVs) if it has been determined necessary in the initial system selection process.
    c. Replace any seal on a joint that was opened. Replace all seals on the rack system. This will reduce the likelihood of a leak even on joints that would not normally be broken as part of a retrofit.
    d. Replace old ball valves and repair/replace solenoid valves as necessary, as these are sources of leaks.
    e. If original oil type is to be used (step 8 was omitted), check condition of mineral oil and replace if needed.
12. Reset the pressure controls and other equipment as required for the new refrigerant.
13. Pull a vacuum on the system.
    a. Target is 500 microns.
    b. Hold vacuum and check for leaks.
14. Charge system with new refrigerant.
    a. Charge level will be based on refrigerant manufacturer's recommendation.
    b. For blend refrigerants in the ASHRAE 400 series, remove liquid from the cylinder to ensure correct composition. Ensure liquid is vaporized before reaching the compressor to avoid equipment damage.
15. Check system for any refrigerant leak.
    a. Check low-pressure side of system with compressor off, as the higher vapor pressure will enhance leak detection.
16. Adjust TXV setting as needed for new refrigerant.
    a. For ASHRAE 400 series refrigerants, there will be temperature glide in the condenser and evaporator, i.e. a difference in dew point and bubble point for a given pressure. Consult refrigerant manufacturer for correct dew point / bubble point information.
    b. When calculating sub-cooling, use the bubble point as the reference temperature.
    c. When calculating superheat, use dew point as the reference temperature.
17. Monitor oil level in compressor.
    a. Check oil level in system and adjust as needed.
    b. If oil return is not adequate or if oil level is unstable, refer to specific guidelines from the refrigerant manufacturer for corrective action.
18. Properly label the system with refrigerant and lubricant type and charge.

Material Compatibility

Generally, the same seal materials can be used in HCFC-22 and HFC service, but there are exceptions, since the swelling characteristics for HCFCs differ from those for HFCs. For example, Viton® does not perform well with R134a, a base component of certain HFC blends. Different grades of the same material can behave differently. The type of lubricant can also affect material choice. Consult refrigerant and equipment manufacturers to confirm material suitability. Older systems manufactured before the development of HFCs in the early 1990s may have compatibility issues.

Differences in Retrofit Procedures for Substitute Chemicals

The following chart shows some potential differences in the HCFC-22 conversion process for all SNAP-approved, non-ozone-depleting, retrofit chemicals. This is a general guide, and the procedures and requirements for your specific system may vary, so please check with equipment manufacturers and refrigerant manufacturers. Appendix 2 provides a detailed, step-by-step conversion checklist for each refrigerant.

Step	Pure HFC Blends					HFC/Hydrocarbon Blends			
	R-404A	R-407A	R-407C	R-407F†	R-427A	R-422D	R-422B	R-422C	R-438A
Change oil to POE	Yes	Yes	Yes	Yes	No*	No*	No	No	No
Flush with POE oil again until residual mineral oil is below recommended level	Yes	Yes	Yes	Yes**	No*	No*	No	No	No
Change TXVs	Normally yes	No	Normally no	No	Normally no	Normally no	Normally no	Normally No	No
Change seals	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Change powerhead	Yes	No	No	No	No	No	No	Yes	No
Significant equipment changes due to mass flow and pressure drop	Yes	No	No	No	No	No	No	No	No

*A change to POE oil may not required for R-422D and R-427A if the system has an oil separator and the oil circulation rate is acceptable; if the system does not have an oil separator, the oil must be changed to POE.

** Conversions from R-22 to R-407F have shown a high tolerance for residual mineral and alkyl benzene lubricants. Check with the system or compressor manufacturer for residual maximums.

† Pending.

V. Best Practices - End of Life

End-of-Life Options for Refrigerants and Equipment

When refrigeration equipment reaches its end of life, the HCFC-22 refrigerant must be recovered and either recycled, reclaimed, or destroyed. EPA's GreenChill Partnership recommends recycling or reclamation wherever possible, since HCFC-22 is a valuable resource that will likely become more valuable as it continues to be phased out. Foam insulation from refrigeration equipment, especially commercial refrigerators and freezers, can be recovered for additional environmental benefits. This section describes end-of-life best practices for HCFC-22 refrigerant.

Other Factors

Before entering into any agreement with a reclamation service provider, the equipment owner should make sure he or she understands all of the costs involved. There may be separate charges for identifying the material, transporting it, and reclaiming or destroying it. If the equipment owner is responsible for shipping the refrigerant, he or she should make sure the reclamation service provider explains how to comply with any applicable U.S. Department of Transportation (DOT), state, and local requirements for shipping.

The specific options and methods for recovery, recycling, and reclamation depend on the application and refrigeration equipment size. Since reclamation requires specialized machinery not available at a supermarket job site, an HVAC professional typically processes recovered refrigerant for reuse on site or (in the case of retrofit) sends it to a reclaimer or back to the refrigerant manufacturer. Regardless of which method is used, all personnel must be properly trained to handle refrigerants.

Best Practices – Refrigerant Recovery

Recovery is the removal of refrigerant from a system and storage in properly rated recovery cylinders without necessarily testing or processing it in any way. The following is a list of best practice recovery techniques. Proper handling and recovery will prevent inadvertent mixing of refrigerants and the accompanying handling and disposal fees.

- Do not mix refrigerants of different ASHRAE numbers either in the system or in a recovery cylinder. Refrigerants that are mixed during recovery are much more costly to reclaim, since they require a specialized separation process that few reclaimers provide. Mixed material may need to be destroyed, which is costly and wasteful.
- Tag the recovery cylinder with the identity of the refrigerant.
- Do not overfill recovery cylinders. Weigh each cylinder once refrigerant is recovered from a system and check this weight against maximum fill weights.

- A vacuum level of 10-15 inches Hg (50-67 kPa) is necessary to remove the charge (15 inches is recommended), relative to standard atmospheric pressure of 29.9 inches Hg.
- Recover the existing refrigerant charge from the system into proper pressure-rated recovery cylinders (see the table below). Return recovered refrigerant to your refrigerant wholesaler or reclaim service provider.

Recovery Containers for Used Refrigerant Products

Container	Water Capacity	Used Refrigerant Types	Weight (lb)	
			Avg. Tare	Max. Gross
4BA300 Cylinder 4BA350 Cylinder 4BA350 Cylinder	123 lb 26 lb 48 lb	R-12, R-114, R-123, R-124, R-134a, R-22, R-401A (MP39), R-401B (MP66), R-404A, R-407C, R-408A, R-409A, R-417A, R-422A, R-422B, R-422C, R-422D, R-423A, R-500, R-502, R-507, R-427A, R-407A, R-438A (MO99) , R-407F (Performax LT)	55 14 26	150 34 64
4BW400 Cylinder 4BA400 Cylinder 4BA400 Cylinder	123 lb 26 lb 48 lb	R-402A (HP80), R-402B (HP81), R-410A	62 14 26	150 34 64
3AA2400 3AA1800 3AA2265	96 lb or smaller	R-13, R-23, R-503, R-508B (Suva 95)	81	135
4BW260 Half-ton	1,000 lb	R-12, R-22, R-114, R-123, R-124, R-134a, R-401A (MP39), R-401B (MP66), R-409A, R-417A, R-500, R-502, R-427A	370	1,150
4BW400 Half-ton	1,000 lb	R-402A (HP80), R-402B (HP81), R-404A, R-407C, R-408A, R-410A, R-422A, R-422B, R-422C, R-422D, R-507, R-407A, R-407F (Performax LT)	560	1,360
Drum	55 gal, 20 gal, 10 gal	R-11, R-113, R-123, R-141b	N/A	N/A

One manufacturer has provided the weight chart on the next page, which provides similar information in a different format. This chart recognizes that different recovery cylinders could have different tare weights but the same water capacity, and lists the water capacity and the maximum refrigerant weight allowed for each size cylinder (which is a calculation of the refrigerant density and water capacity). The actual tare weight of the cylinder should be used to determine the gross weight.

Guidelines for Maximum Shipping Weights for Recovered Refrigerant Containers

Cylinder Size	30 lb.	One Shot 30 lb.	40 lb	50 lb.*	125 lb.	½ ton	1 ton
Water Capacity	26.2 lbs.	29.7 lbs.	38.1 lbs.	47.7 lbs.	123 lbs.	1000 lbs.	1600 lbs.

* includes 50F and 50HP

Maximum Refrigerant Weight Allowed

Refrigerant	Min service pressure							
R-12	260 psig	24	28	36	45	117	952	1523
R-22	260 psig	22	25	32	40	103	839	1342
R-500	260 psig	21	25	31	39	102	836	1337
R-502	260 psig	22	25	32	40	103	842	1347
R-114	260 psig	28	32	41	51	133	1088	1740
R-134a	260 psig	22	25	32	41	106	864	1382
R-401B	260 psig	22	25	32	40	103	857	1334
R-402A	350 psig	21	24	31	39	99	809	1294
R-402B	300 psig	21	24	30	38	97	792	1267
R-403B	300 psig	19	22	28	35	91	736	1177
R-404A	300 psig	18	20	26	22	85	688	1100
R-407A	300 psig	21	24	31	39	99	808	1292
R-407C	300 psig	21	23	30	38	97	790	1264
R-407F	300 psig	23	26	34	42	110	896	1433
R-408A	300 psig	19	22	28	35	90	735	1176
R-409A	260 psig	23	26	34	42	109	888	1420
R-410A	400 psig	19	22	28	35	89	726	1162
R-416A	260 psig	25	29	37	46	120	979	1566
R- 417A	260 psig	20	22	29	36	94	770	1231
R- 422A	350 psig	18	21	27	34	88	723	1157
R- 422B	350 psig	21	24	30	38	98	793	1268
R- 422C	350 psig	20	23	29	36	93	758	1213
R- 422D	350 psig	20	23	30	37	96	777	1243
R-427A	260 psig	24	27	34	43	111	904	1446
R- 507	350 psig	18	20	26	33	85	688	1100

Low Pressure Containers

Refrigerant	Drum size	Max Allowable Refrigerant Weight	Avg Drum Tare Weight	Max Gross Shipping Weight
R-11, R-113, R-123	100 lbs	90 lbs	10 lbs	100 lbs
	200 lbs	180 lbs	20 lbs	200 lbs
	650 lbs	585 lbs	65 lbs	650 lbs

(Continued on next page.)

Guidelines for Maximum Shipping Weights for Recovered Refrigerant Containers (cont.)

Very High Pressure Cylinders

Refrigerant	Ref Wt / Ship Wt		Ref Wt / Ship Wt		Ref Wt / Ship Wt	
R-13	14	34	19	49	74	211
R-23	11	31	15	45	58	198
R-503	12	32	16	46	64	206
R-508B	12	32	17	47	65	205
R-13B1	17	37	12	52	89	229

IMPORTANT: The tare weights listed in this guideline are only average weights. In order to determine actual gross shipping weight of each individual cylinder must be used.
Always use a scale when filling any cylinder. DO NOT OVERFILL.

SOURCE: National Refrigerants, 2011.

Best Practices – Recycling and Reclamation

Recycling

Before refrigerant is reused it must be recycled or reclaimed. Recycling refers to the recovery of refrigerant from a system and cleaning for reuse without necessarily meeting all of the requirements for reclamation. In general, recycled refrigerant is refrigerant that is cleaned using oil separation and single or multiple passes through devices, such as replaceable core filter-driers that reduce moisture, acidity, and particulate matter.

Recycled refrigerant may be stored and used by the same equipment owner. It may not, however, be sold for use or used in a different equipment owner's facility.

Reclamation

Reclamation is the processing of a recovered refrigerant, through such mechanisms as filtering, drying, distillation and chemical treatment, to restore the substance to the original purity specification indicated in AHRI Standard 700. Reclamation ensures that contaminated or mixed refrigerants do not enter the marketplace, where they could cause equipment damage or leaks. Reclamation by an EPA-certified reclaimer is required when recovered refrigerants will be charged into a different owner's equipment.

To be properly reclaimed, used refrigerant must be reprocessed to at least the purity level specified in Appendix A to 40 CFR Part 82, Subpart F.[4] Reclaimed refrigerant must be verified to meet AHRI-700 standards using analytical methodology prescribed in section 5 of Appendix A.

[4] See http://epa.gov/ozone/title6/608/reclamation/index.html

Reclaimers' business practices vary. Some might charge the material owner a fee and return the material to the owner. Others might buy used material from the owner, reclaim the material, and retain ownership and resell**.** In some cases, where the owner of material does not intend to retain ownership, the reclaimer may even charge for taking the material. Some reclaimers offer refrigerant "banking," under which an equipment owner ships recovered refrigerant to the reclaimer who then typically restores the refrigerant to AHRI Standard 700 condition. The reclaimer then packages and holds the reclaimed refrigerant in storage for the equipment owner until the equipment owner releases material from the "bank." The reclaimer would charge for processing, packaging and storing the refrigerant.

See www.epa.gov/ozone/title6/608/reclamation/reclist.html for a list of EPA-certified refrigerant reclaimers. You should check with a prospective reclaimer to verify its service area, its technical capability to process recovered refrigerant to AHRI Standard 700, its capability to separate mixed refrigerants or destroy contaminated refrigerant, and service options such as banking. EPA requires that reclaimed refrigerant attain AHRI 700 standards prior to resale. Reclamation facilities and processes should be designed to minimize emissions.

The following GreenChill partners offer refrigerant reclamation services through their wholesale distributors. For more information, contact:

i. Arkema – (800) 245-5858
ii. DuPont – (800) 235-7882
iii. Honeywell – (800) 631-8138
iv. Mexichem Fluor – (800) 424-5532
v. ICOR International – (800) 497-6805
vi. National Refrigerants, Inc. – (800) 262-0012

Best Practices – Destruction

Refrigerant that cannot be reclaimed to AHRI 700's purity standard must be destroyed. In this case, the reclamation service provider will most likely incinerate the refrigerant in an EPA-approved facility. Be aware that not all reclaimers have the technology to handle all contaminated or mixed refrigerants. Check with your reclamation service provider to verify that it is equipped to dispose of refrigerant in an environmentally acceptable manner with required permits (e.g., an incinerator equipped to decompose refrigerant into CO_2 and acid gases and scrub the acid gases from the vent stream).

Best Practices – Insulation Foam

CFC, HCFC, and HFC blowing agents are used in insulating foam contained in commercial refrigerators and freezers. ODS foam recovery presents a significant opportunity to reduce emissions of ODS and GHGs. Although not required by law, as a best practice, ODS foam can be recovered from commercial refrigerators and freezers at end of life and sent for reclamation or destruction.

To avoid the harmful release of ODS and GHGs, insulating foam should be removed from all parts of refrigerators and freezers at time of equipment disposal. Foam can be recovered from refrigerators and freezers either manually or through a fully automated process. Once foam is recovered it should be sent for either (a) destruction (e.g., to a municipal solid waste incinerator or waste-to-energy boiler) or (b) further processing to recover the blowing agent from the foam matrix and ultimately reclaim or destroy the concentrated blowing agent. Several dedicated appliance recycling facilities offer these types of foam removal and processing services across the U.S. In addition, EPA's voluntary Responsible Appliance Disposal (RAD) Program, designed to promote these types of best practices, serves as a technical clearinghouse on the development and implementation of responsible disposal programs.

Safety Information

CFC, HCFC, and HFC refrigerants are safe when handled properly. However, any refrigerant can cause injury when mishandled. Please review the following guidelines before using *any* refrigerant.

Do not work in areas with high concentrations of refrigerant vapors. Always maintain adequate ventilation in the work area. Do not breathe vapors. Do not breathe lubricant mists from leaking systems. Ventilate the area well after *any* leak, before attempting to repair equipment.

Do not use handheld leak detectors to check for breathable air. These detectors are not designed to determine if the air is safe to breathe. Use oxygen monitors to ensure adequate oxygen is available to sustain life.

Do not use flames or torches to search for leaks. Do not use flames in the presence of high concentrations of refrigerant. Open flames release large quantities of acidic compounds in the presence of all refrigerants and these compounds can be hazardous. Do not use torches as leak detectors. Old halide torches detect chlorine, which may not be present with new refrigerants. Use an electronic leak detector designed to find the refrigerants you are using.

If you detect a visible change in the size or color of a flame when using torches to repair equipment, **stop work immediately and leave the area**. Ventilate the work area well, and stop any refrigerant leaks before resuming work. These flame effects may be an indication of very high refrigerant concentrations, and continuing to work without adequate ventilation may result in injury or death.

Again: Any refrigerant can be hazardous if used improperly. Hazards include liquid or vapor under pressure, and frostbite from the escaping liquid. Overexposure to high concentrations of vapor can cause asphyxiation and cardiac arrest. Please read all safety information before handling any refrigerant.

Safe Handling Practices for Non-Reusable and Returnable Cylinders:

- Ensure valve is closed.
- Ensure cylinder remains in the original carton when transporting.
- Dispose of cylinders properly – check local requirements for disposal regulations. Recover the refrigerant heel to a minimum 15" prior to recycling the metal cylinder.
- Return empty cylinders using DOT guidelines for proper transporting.

Refer to AHRI Guideline Q-2010 for Content Recovery & Proper Recycling of Refrigerant Cylinders for more information on content recovery and recycling of cylinders.[5]

Filling Recovery Containers

When loading used refrigerant into recovery containers, particular care is necessary with respect to the following:

- **Container Pressure**
  Recover the refrigerant charge into proper pressure-rated recovery cylinders. Do NOT put a higher-pressure refrigerant such as R-507 into a lower-pressure recovery cylinder.

- **Container Integrity**
  Prior to filling, inspect the recovery container and valve for signs of damage such as dents or corrosion. Do NOT fill a damaged recovery container.

- **Test Date**
  Recovery cylinders and half-ton tanks should not be filled if the present date is more than five years past the test date that is stamped on the unit. The test date, which will look similar to the example below, is stamped on the shoulder of the cylinder or the collar of the half-ton tank.

	AO	
12		09X
	37	

  This designation indicates that the unit was retested in December 2009 by retester number AO37.

  If a recovery container is out of date, it must not be filled. Return it promptly for retesting.

  Containers filled prior to five years from test date may be shipped full to the recovery/evacuation facility.

- **Liquid Overfilling of Cylinders**

[5] Available online at www.ahrinet.org/ARI/util/showdoc.aspx?doc=1792>

Liquefied refrigerant expands when exposed to high temperatures. If the container is overfilled, the thermal expansion of the liquid could cause release of refrigerant through the relief valve, or rupture or bulge the container.

The maximum gross weight (total weight of the container and its contents) MUST NOT be exceeded.

- **Vapor Overpressuring: Recovery Half-Tons and Cylinders**
  When a compressor is used to recover refrigerant, the pressure of the recovery half-ton or cylinder must be monitored closely. Overpressurizing the cylinder could cause release of refrigerant through the relief valve, or rupture or bulge the container.

Note: Only use designated recovery cylinders for used refrigerant.

VI. Case Studies for Typical Low- and Medium-Temperature Conversions

Case History Profiles 1-4: R-427A

	Case 1	Case 2	Case 3	Case 4
Supermarket owner	Sherm's Thunderbird, Oregon	Geant Casino, France	Tutt OK supermarket, Italy	Fiesta Food Warehouse, Fontana, CA
Compressor models	Copeland 4DB2200, 4DC2200, 4Ds2200, 6DT3000, 4TD2200	5 Copeland, D6DJ3400AWM/D	Med Temp - 3 Copeland Low Temp – 2 Copeland	12 Copeland
Compressor capacity loading Before retrofit, After retrofit	N/A	N/A	N/A	N/A
Original refrigerant	HCFC-22	HCFC-22	HCFC-22	HCFC-22
Retrofit Refrigerant	HFC-427A	HFC-427A	HFC-427A	HFC-427A
Retrofit Lubricant	POE	Alkyl Benzene	POE	Alkyl Benzene
Change Date:	6/2008	4/2007	2004	2008
TXV's changed	No	No	No	No
Seals Changed	Not initially	No	No	No
Energy Use Comparison	7% reduction	5% less power consumption	Comparable to HCFC-22	N/A
Comments		For comparable suction temperature, the discharge temp is over 10 °C below with R-427A	Oil return is good despite a high residual mineral oil level (15% medium-temp unit and 5% low-temp unit)	Discharge temperatures are lower and the compressors are running cooler

Case History Profiles 5-10: R-422D

	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
Supermarket owner	Pathmark, Massapequa, NY	National Retailer – Houston TX	Northeast Retailer, Quincy MA	Northeast Retailer Latrobe, PA	National Retailer, Long Beach, CA	Midwest Retailer
Compressor models	Copeland, 3DB3-0750, 3DB3A-075E, 3DS3-1000, 3DS3A-100E, 3DB3-1000, 3DS-1500, 3DB-1000, 3DB3R12MO	Caryle 06CC228, 06CC337, 06CC550, 06CC665, 06CC675, 06DR228, 06DM337, 06EM450, 06EM475, 06DR724	Copeland 4DH3-250L, 3DS3A-150L, 3DP3-100L	Copeland 4DL-150E, 4DT-220E, 4DT-2200	Copeland Carlyle	Copeland 06DM-316, 06DR-228, 06DM-337. 06DM-316, 06DR-228, 06DM-337, 06DR-820. 06DM-337, 06ER-175, 06ER-337. 4DT3-220E-TSK, 4DL3-150E-TFD
Compressor capacity loading Before retrofit, after retrofit	N/A	N/A	N/A	95%, 334,000 BTUH 387,000 BTUH	N/A	0.92, 0.83, 0.92, 0.9, 0.9, 0.66, 0.83
Original refrigerant	HCFC-22	HCFC-22	HCFC-22	HCFC-22	HCFC-22	HCFC-22
Retrofit Refrigerant	R-422D	R-422D	R-422D	R-422D	R-422D	R-422D
Retrofit Lubricant	Mineral Oil	Mineral Oil	Mineral Oil	Mineral Oil	Alkyl Benzene	Mineral Oil
Change Date:	2/27/2007	8/14/2006	8/20/2006	10/9/2007		10/23/08
TXV's changed	No	No	No	No	No	No
Seals Changed	Yes	Yes	Yes	Yes	Yes	Yes
Energy Use Comparison	N/A	Comparable to HCFC-22	Comparable to HCFC-22 – Medium Temp	12% reduction in energy efficiency - low temp	N/A	Energy Impact appeared similar based on temps., pressures, (no KWH monitoring was used).
Comments	Store was remodeled, confusion about TXV sizing in cases due to new refrigerant	Proceeding with additional systems	Proceeding with confidence with additional systems	No reported leaks after startup. Turned off demand cooling modules	Operating properly	Operating properly, more stores scheduled

Case History Profiles 11-15: R-407A

	Case 11	Case 12	Case 13	Case 14	Case 15
Supermarket owner	K-VA-T Food Stores, Inc	Food Lion #1453	Food Lion #1490	Food Lion #1577	Food Lion #1585
Compressor models	MT: Copeland: 2DA-0750, 3DA-0750, 3DF-0900, 3DF-1200, 4DL-1500 LT: Copeland: 2DC-0500, 2DA-0750, 3DB-1000, 3DS-1500	4DE3-200L-TSK, 4DK3R22MO-TSK, 4DH3-250L-TSK, 4DJ3-300L-TSK, 4DR3R28ME-TSK, 4DJ3-300L-TSK, 4DJ3-300L-TSK	4DS3-220L-TSK, 4DS3-220E-TSK, 4DT3-220L-TSK, 4DT3F76KE-TSK, 4DT3-220L-TSK, 4DR3-300E-TSK	4DL3-150E-TSK, 4DP3-150L-TSK, 4DT3F76KE-TSK, 4DT3F76KE-TSK, 4DT3-220E-TSK, 4DT3F76KE-TSK, 4DT3-220E-TSK, 4DJ3-300L-TSK	4DK3-2500-TSK, 4DK3-2500-TSK, 4DJ3-300L-TSK, 4DR3-3000-TSK, 4DJ3-300L-TSK
Relative compressor capacity loading after retrofit	MT: ~85% & 94% LT: ~90%	99.6%	98.1%	98.0%	99.6%
Original refrigerant	R-22	R-22	R-22	R-22	R-22
Retrofit Refrigerant	R407A	R407A	R407A	R407A	R407A
Retrofit Lubricant	ICI Emkarate RL68-H (Original: Mineral Oil)	POE	POE	POE	POE
Change Date:	March 2008	6/24/08	5/12/08	2/26/08	5/13/08
TXV's changed	No	No	No	No	No
Seals Changed	Yes	Yes	Yes	Yes	Yes
Energy Use Comparison	NA	-24.63%	-10.63%	6.67%	-18.24%
Comments	All packing glands developed leaks during the first week after the oil was changed. This was easily correctable by retightening them. It does require unloading display cases to get to the TEVs. Technicians are not trained to use refrigerants with appreciable glides. How to set valves and staging has to be explained and reinforced several times during and after the conversion. When a new technician is hired the training process has to be repeated. One-on-one sessions are more effective than bulletins or classroom presentations.	The relative compressor capacity loading is based on published performance data. The change in energy use may also be due to other changes made at the store.	The relative compressor capacity loading is based on published performance data. The change in energy use may also be due to other changes made at the store.	The relative compressor capacity loading is based on published performance data. The change in energy use may also be due to other changes made at the store.	The relative compressor capacity loading is based on published performance data. The change in energy use may also be due to other changes made at the store.

Case History Profiles 16-21: R-407A

	Case 16	Case 17	Case 18	Case 19	Case 20	Case 21
Supermarket owner	Food Lion #1608	Food Lion #2340	Food Lion #2376	Food Lion #2392	Food Lion #2514	Food Lion #2759
Compressor models	4DA3-200L-TSK, 4DH3-250L-TSK, 4DR3A300E-TSK, 4DR3-300E-TSK, 4DR3R28ME-TSK, 4DJ3-300L-TSK	4DT3-22OL-TSK-205, 3DB3-075L-TFC-227, 2DA3-060L-TFC-227	4DH3-2500-TSK-406, 4DK3-2500-TSK, 3DB3-1000-TFC, 3OS3-1000-TFC	3DS3-150L-TFC	06EA565300, 06EA565300, 06EM475300, 06EM475300	4DL3A150L-TSK, 4DL3A150L-TSK, 4DL3A150L-TSK
Relative compressor capacity loading after retrofit	99.6%	97.6%	98.0%	96.6%	93.0%	97.2%
Original refrigerant	R-22	R-22	R-22	R-22	R-22	R-22
Retrofit Refrigerant	R407A	R407A	R407A	R407A	R407A	R407A
Retrofit Lubricant	POE	POE	POE	POE	POE	POE
Change Date:	4/16/08	8/12/08	6/30/08	9/16/08	4/2/08	12/4/08
TXV's changed	No	No	No	No	No	No
Seals Changed	Yes	Yes	Yes	Yes	Yes	Yes
Energy Use Comparison	3.45%	-11.29%	-5.64%	-5.64%	-3.79%	6.56%
Comments	The relative compressor capacity loading is based on published performance data. The change in energy use may also be due to other changes made at the store.	The relative compressor capacity loading is based on published performance data. The change in energy use may also be due to other changes made at the store.	The relative compressor capacity loading is based on published performance data. The change in energy use may also be due to other changes made at the store.	The relative compressor capacity loading is based on published performance data. The change in energy use may also be due to other changes made at the store.	The relative compressor capacity loading is based on published performance data. The change in energy use may also be due to other changes made at the store.	The relative compressor capacity loading is based on published performance data. The change in energy use may also be due to other changes made at the store.

Case History Profiles 22-25: R-407F

	Case 22	Case 23	Case 24	Case 25
Supermarket owner	Sprouts Farmers Market #4 Phoenix, AZ	Albertsons #169 Boise, Idaho	Weavers Markets Adamstown, Pa	Sprouts Farmers Market #2 Phoenix, AZ
Compressor models	<u>Medium Temp</u> 06DM-316 06DR-724 06DR-820 06DR-337 06DA-824 <u>Low Temp</u> 2DB3-0600 4DF3A-1500	<u>Medium Temp</u> 3DA3-0750-TAC 3DS3A-1500-TFC 3DS3A-1500-TFC <u>Low Temp</u> 3DS3-1000-TFC 3DS3-1000-TFC 3DS3-1000-TFC Singles 2DA3-0750-TFC 2DB3-060L-TFC	<u>Medium Temp</u> 3DA3-0750-TFC 3DS3-1500-TFC 4DA3-2000-TFC 2DL3750 <u>Low Temp</u> 3DB3-750-TFC 4DA3-100E-TSK 4DL3-150-TSK 4DL3-150-TSK 4DL3A1500E-TSK	3DA3-0600 3DL3-1500 3DB3-1000 3DS3-1500 3DF3-1200 3DE3-0750 3DK3-1200
Original refrigerant	R22	R22	R22	R22
Retrofit Refrigerant	R407F	R407F	R407F	Performax LT R407F
Retrofit Lubricant	EMKARATE POE	POE	EMKARATE POE	EMKARATE POE
Resultant Lubricant Composition	80/20%	90/10%	100% LT, 80/20% MT	85/15
Change Date:	4/26/2010	6/23/2010, 7/26/2010	3/23/2011, 3/29/2011	2/17/2011
TXV's changed	0	0	0	0
TXV's Adjusted	1		0	1
Seals Changed	All "O" ring seals @ rack	"o" rings @ rack Solenoid gaskets	Solenoid valve gaskets	All "O" ring seals @ rack
Energy Use Comparison	100%	105%	89%	100%
Comments	One oil change, no issues		Dramatic power reduction is partly due to low superheat during R22 operation. No adjustment to any txv's during retrofit corrected this situation.	

Case History Profiles 26-28: R-407F

	Case 26	Case 27	Case 28
Supermarket owner	Sobey's	Rouses #28	Bi-Lo #93
Compressor models	3DS1500 3DS1500 3DS3 15L 3DS1500 3DA3 750 3DS31500 2D3 750E	<u>Medium Temp</u> HSN 5352 25 SHL2 2500 TWK 200 HSN 646150 HSN ? <u>Low Temperature</u> HSK 5353 35 2NU SHM2 3500 TWK 200 HSK 5363 40 SHM2 3500	06DR3370DA3250 06DR3370DA3200 06DR3370DA3200 06DR3370DA3200 06DR3370DA3200
Original refrigerant	R22	R22	R22
Retrofit Refrigerant	Performax LT R407F	Performax LT R407F	Performax LT R407F
Retrofit Lubricant	POE	Solest 170	POE
Resultant Lubricant Composition	100%	90/10%	85/15%
Change Date:	N/A	N/A	5/24/2011
TXV's changed	0	0	0
TXV's Adjusted	0	0	0
Seals Changed	All "O" ring seals @ rack	All "O" ring seals @ rack	All "O" ring seals @ rack
Energy Use Comparison	100%	100%	100%
Comments	Chose to upgrade compressors per copeland	Bitzer Screws, Running synthetic lube, water cooled oil	Customer chose to ignore Carlyle recommendations pertaining to valve plate and oil pump modifications to accommodate synthetic lube.

VII. Appendices

Appendix 1: System Data Sheet

System Data Sheet

Type of System/Location: ______________________________

Equipment Mfg.: ______________________ Compressor Mfg.: ______________________

Model No.: ______________________ Model No.: ______________________

Serial No.: ______________________ Serial No.: ______________________

Original Charge Size: ______________________ Lubricant Type: ______________________

______________________ Lubricant Charge Size: ______________________

Drier Mfg.: ______________________ Drier Type (check one):

Model No.: ______________________ Loose Fill: ______________________

______________________ Solid Core: ______________________

Condenser Cooling Medium (air/water): ______________________

Expansion Device (check one): Capillary Tube: ______________________

Expansion Valve: ______________________

If Expansion valve:

Manufacturer: ______________________

Model No.: ______________________

Control/Set Point: ______________________

Location of Sensor: ______________________

Other System Controls (ex.: head press control), Describe: ______________________

____

(circle units used where applicable)

Date/Time				
Refrigerant				
Charge Size (lb, oz/g)				
Ambient Temp. (°F/°C)				
Relative Humidity				
Compressor:				
Suction T (°F/°C)				
Suction P (psi/kPa/bar)				
Discharge T (°F/°C)				
Discharge P (psi/kPa/bar)				
Box/FixtureT (°F/°C)				
Evaporator:				
Refrigerant Inlet T (°F/°C)				
Refrigerant Outlet T (°F/°C)				
Coil Air/H_2O In T (°F/°C)				
Coil Air/H_2O Out T (°F/°C)				
Refrigerant T at Superheat Ctl. Pt. (°F/°C)				
Condenser:				
Refrigerant Inlet T (°F/°C)				
Refrigerant Outlet T (°F/°C)				
Coil Air/H_2O In T (°F/°C)				
Coil Air/H_2O Out T (°F/°C)				
Exp. Device Inlet T (°F/°C)				
Motor Amps				
Run/Cycle Time				
Comments: ______________________				

Appendix 2: Conversion Checklists for HFC Substitute Chemicals

Retrofit Checklist for DuPont™ ISCEON® Refrigerants MO99 (R438A) or MO29 (R422D)

________ 1. Establish baseline performance with existing refrigerant.

- Use the System Data sheet given in Appendix 1
- Note oil type used and system operating data (if system is operating properly).
- Check for existing leaks and repair.

________ 2. Remove existing refrigerant charge from system. (Need 10-15 in. Hg [50-67 kPa] vacuum to remove charge.)

- Use recovery cylinder (DO NOT vent to atmosphere).
- Weigh amount removed if possible): ______________
- Break the vacuum with dry nitrogen.

________ 3. Replace the filter dryer and seals.

- Change elastomeric seals (O-rings. sight glasses. etc.).
- Check that oil is in good condition; replace if necessary.

________ 4. Evacuate system and check for leaks.

- Does the system hold a vacuum?
- Break vacuum with dry nitrogen, pressurize to below system design pressure.
- Does the system hold pressure?
- Check for any leaks.

________ 5. Charge system with ISCEON® refrigerant.

- Remove liquid only from cylinder.
- The initial charge amount should be approximately 85% of the standard charge for R-22 and the final charge amount will be approximately 95%.

________ 6. Adjust TXV and/or refrigerant charge to achieve the same superheat as the original system. If adjustment is not adequate, replace TXV.

________ 7. Monitor oil levels in compressor. If necessary add original oil to attain normal operating level (mid-sight glass).

- If a sudden surge in oil level occurs (e.g., during/just-after defrost) remove a small (approximately 10%) quantity of the mineral oil and replace with POE oil. Repeat if necessary.
- If oil level falls below the minimum, top-up to minimum level.
- If the oil level continuously falls or large oscillations occur during operation, add a sufficient amount of an equivalent POE until oil return becomes normal.

________ 8. Label system clearly. Ensure System Data sheet is completed and filed securely. Retrofit is complete!

Retrofit Checklist for Mexichem Fluor Klea®407A

________ 1. Before converting R22 systems to Klea®407A, check OEM recommendations to ensure compatibility with equipment and seal materials. Klea®407A is a HFC refrigerant and POE oil will be required. The older the system the greater the possibility of incompatibility with HFCs or POE oil. Follow all regulatory and safety requirements for handling refrigerants.

________ 2. Record system performance to obtain a baseline prior to the retrofit, eg. suction and discharge pressures, discharge temperature, temperatures in and out of condenser and evaporator, energy usage.

________ 3. Check and repair any existing leaks in the system.

________ 4. Remove mineral oil from system. Most of the mineral oil can be removed by draining the compressor sump, suction line accumulators, oil float, oil separators, etc. Record the amount of oil removed.

________ 5. Replace oil drier and oil screens.

________ 6. Add the compressor OEM recommended POE oil.

________ 7. Evacuate system and check for any leaks.

________ 8. Restart system and check for any leaks. Check oil level.

________ 9. Run system for at least 24 hours to allow for mixing of POE and remaining mineral oil. Larger systems may require more time. Check mineral oil concentration in POE using a refractometer. Historically, a target of less than 5% mineral oil in POE has been used for HFCs and the normal practice was three flushes to achieve this. However, systems have run satisfactorily after a single flush of POE. Contact Mexichem Fluor for more information.

________ 10. Remove refrigerant from system. Record weight removed.

________ 11. Replace equipment as required. Install a HFC compatible filter drier. Replace all seals on joints that have been opened and on the receiver. Replace receiver float seal. Replace or repair old solenoid valves and ball vales to minimize future leaks.

________ 12. Reset pressure controls for Klea®407A. Temperature/pressure data is available at www.mexichemfluor.com or call 1-800 ASK KLEA.

________ 13. Remove air in system by pulling a vacuum to 500 microns. Hold vacuum and check and repair any leaks.

________ 14. Charge system with Klea®407A with a target level of 95% of the R22 charge amount. The concentration of the blend components will be different than the liquid. Remove liquid from the cylinder to ensure the correct composition. To avoid equipment damage, vaporize the liquid before entering a running system.

________ 15. Start system and check for any leaks.

________ 16. Set TXV settings. For calculating sub-cooling, use the bubble point as the reference temperature. For calculating superheat, use the dew point as the reference temperature.

________ 17. Monitor refrigerant and oil levels and adjust as needed.

________ 18. Record performance data.

________ 19. Label the system to indicate refrigerant and oil type and amount.

Retrofit Checklist for Honeywell Genetron 407C

Genetron 407C is an HFC blend and a close match to R22 but will require an oil change to a synthetic lubricant. Consult the original equipment manufacturer for recommended lubricants. The mass flow of Genetron 407C is very close to that of R22 and in most cases the existing thermal expansion valves can remain although adjustment may be necessary. Genetron 407C is a refrigerant blend having glide which requires the technician to use dew point values for checking superheat and bubble values for checking sub-cooling. A pressure temperature chart is available at Genetron.com or by contacting Honeywell Refrigerants Technical Service.

Retrofit Checklist

________1. Record baseline data on original system performance.

________2. Recover HCFC-22 refrigerant charge using appropriate recovery equipment.

________3. Record the amount of HCFC recovered.

________4. Choose compressor lubricant.

________5. Drain the existing lubricant from the compressors, separators and oil reservoirs.

________6. Measure amount of lubricant removed.

________7. Change lubricant filters if present.

________8. Recharge the system with polyol ester lubricant, use the same amount that was removed.

________9. Traditionally at this point the R22 would be returned to the system and the system run for at least 24 hours to return as much of the residual mineral oil in the system to the compressors and oil management system. Typically an acceptable residual mineral oil content of 5% was the target. Recent field data suggests the possibility of a successful retrofit with only one oil change performed before the addition of Genetron 407C. Consult Honeywell Refrigerants for guidance.

________10. Evaluate the expansion devices; consult the valve manufacturers for recommendations. No change is necessary in most cases.

________11. Evaluate and replace all elastomer seals including receiver float, alarm and level control gaskets.

________12. Replace filter driers and suction filters.

________13. Leak check the system.

________14. Evacuate the system.

________15. Charge the system with Genetron 407C. Remove only liquid from the charging cylinder. Initial charge should be approximately 85% of the R22 charge by weight. Record the amount of refrigerant charged.

________16. Check system operation and adjust TXV's and operating controls. The discharge pressure of R407C is slightly higher and condenser fan and ambient controls may require adjustment.

________17. Adjust refrigerant charge if necessary, final charge should not exceed 95% of the original R22 charge.

________18. Label components and the system with the type of refrigerant and lubricant.

Retrofit Checklist for Honeywell Genetron® Performax™ LT (407F)[6]

Genetron Performax LT is an HFC blend and a close match to R22, but will require an oil change to a synthetic lubricant. Consult the original equipment manufacturer for recommended lubricants. The mass flow of Genetron Performax LT is very close to that of R22 and, in almost all cases, the existing thermal expansion valves can be utilized without adjustment. Genetron Performax LT is a refrigerant blend having glide, which requires the technician to use dew point values for checking superheat and bubble values for checking sub-cooling. A pressure temperature chart is available at www.genetron.com, or by contacting Honeywell Refrigerants Technical Service.

Retrofit Checklist

______1. Record baseline data on original system performance (Amp draw, suction pressure, discharge pressure, superheat, sub cooling).

______2. Run each circuit through a defrost cycle to return as much lubricant as possible to the condensing unit.

______3. Recover HCFC-22 refrigerant charge using appropriate recovery equipment.

______4. Record the amount of HCFC recovered.

______5. Choose compressor lubricant. Consult compressor manufacturer for lubricant recommendations. Note that lubricants from various manufacturers must not be mixed.

______6. Drain the existing lubricant from the compressors, separators and oil reservoirs.

______7. Measure amount of lubricant removed.

______8. Change lubricant filters if present.

______9. Recharge the system with synthetic lubricant, using the same amount that was removed.

______10. Traditionally at this point the R22 would be returned to the system and the system run for at least 24 hours to return as much of the residual mineral oil in the system to the compressors and oil management system. Typically an acceptable residual mineral oil content of 5% was the target. Recent field data suggests the possibility of a successful retrofit with only one oil change performed before the addition of Genetron Performax LT. Consult Honeywell Refrigerants for guidance.

______11. Evaluate the expansion devices; consult the valve manufacturers for recommendations. No change or adjustment is necessary in most cases.

______12. Evaluate and replace all elastomer seals including receiver float, alarm and level control gaskets.

______13. Replace filter driers and suction filters.

______14. Check the system for leaks and make repairs as required.

______15. Evacuate the system.

______16. Charge the system with Genetron Performax LT. Remove only liquid from the charging cylinder. Initial charge should be approximately 85% of the R22 charge by weight. Record the amount of refrigerant charged.

______17. Check system operation and operating controls. The discharge pressure of Genetron Performax LT is slightly higher. Condenser fan and ambient controls may require adjustment.

______18. Adjust refrigerant charge if necessary. Final charge should not exceed 95% of the original R22 charge.

______19. Label components and the system with the type of refrigerant and lubricant.

______.20. Monitor the system and pay particular attention to the condition of the lubricant. Change lubricant filters or suction filters if necessary. Synthetic lubricants are good solvents and may clean up and return material to the condensing unit.

---

[6] Pending

Retrofit Checklist for Arkema Forane® 427A

________ 1. Establish baseline performance with existing refrigerant.
- Use the System Data sheet in Appendix 1.
- Note the oil type in use and system operating data (if system is operating properly).
- Check for existing leaks and repair.

________ 2. Remove existing refrigerant charge from system. (Need 10-15 in. Hg [50-67 kPa] vacuum to remove charge.)
- Use recovery cylinder (DO NOT vent to atmosphere).
- Weigh amount removed if possible: ________________
- Break the vacuum with dry nitrogen.

________ 3. Replace the filter-drier and seals.
- Change elastomeric seals (O-rings, sight glasses, etc.).
- Check that oil is in good condition; replace if necessary.

________ 4. Determine oil change requirements.
- If an oil separator is currently used, replacement of original mineral oil or alkylbenzene is often not needed (skip to step 6).
- If no oil separator is present, drain existing mineral oil or alkylbenzene from the compressor sump, suction line accumulators, etc. Record the amount of oil removed.

________ 5. Add an equivalent amount of OEM recommended POE oil.
- In most cases, no flushing is required. Only one oil change is required with up to 15% residual AB or mineral oil accommodated.

________ 6. Evacuate system and check for leaks.
- Does the system hold a vacuum?
- Does the system hold pressure?
- Check for any leaks.

________ 7. Charge system with Forane® 427A refrigerant.
- Remove liquid only from cylinder.
- The initial charge amount should be approximately 95% of the standard charge for HCFC-22, topping up to 100% if necessary

________ 8. Adjust TXV setpoint and/or refrigerant charge to achieve the same superheat as the original system.

________ 9. Monitor oil levels in the compressor. If necessary, add/remove oil to attain normal operating level (mid sight glass).
- If original mineral oil or alkylbenzene used, and oil level surges (e.g. after defrost), falls below minimum, or large oscillations in oil level are observed, replace small amounts (≈ 10 %) of original oil with equivalent POE until satisfactory oil return is achieved.

________ 10. Label system clearly. Ensure System Data sheet is completed and filed securely.

Retrofit Checklist for ICOR International R422B "NU-22B" and R422C "ONE SHOT"

Change from CFC and HCFC to HFC refrigerants may cause a retraction in o-rings and elastomers. Be sure to repair or replace after recovery of the original refrigerant. Failure to address this at this time may cause unnecessary loss of refrigerant. ICOR International also recommends verification of the metering device sizing with the distributor or manufacture of the device.

________ **1. Record System Pre-Conversion Data:** Prior to converting, the system should be monitored and all system and component operating conditions recorded for future reference.

________ **2. Recover the R-22:** 100% of the refrigerant must be recovered from system in accordance with EPA guidelines.

________ **3. Perform Oil Analysis:** Check system oil for acidity, water and solids (metal shavings). If detected perform a complete system oil change using the OEM specified type and amount of oil.

________ **4. Install New Filter Drier and Oil Filter:** The oil analysis will tell you what type of filter drier you need to use. Systems with coalescent oil separators and/or compressor oil filters need to be changed, too. If converting the system to 422C the expansion valve power element will need to be changed.

________ **5. Leak Check System:** Pressure test system with dry nitrogen. DO NOT exceed the equipment's design pressure. 422B/422C can be detected with any standard leak detection designed to detect HFC refrigerants

________ **6. Evacuate System:** To remove non-condensables and moisture in the system, a minimum 500 micron vacuum must be achieved.

________ **7. Charge System:** Remove LIQUID ONLY from 422B/422C cylinder. When initially charging the system, 422B/422C can be added directly into the receiver or high side of the system with compressor(s) off. The initial charge of 422B/422C should be 95% of the original R-22 charge.

________ **8. Run System:** Check pressures, subcooling and superheat. Use ONLY 422B/422C P/T chart. If additional 422B/422C needs to be added, do so in 5% increments and DO NOT exceed 115% of the original charge of R-22. If system performance is inadequate, call ICOR International at 866-433-8324 or e-mail: tech2tech@icorinternational.com

________ **9. Properly Label System:** Avoid mixing refrigerants by properly labeling your system.

________ **10. Post conversion Leak Check:** After operation of system begins, do a thorough system leak check.

________ **11. Record System Post-Conversion Data:** Monitor and evaluate system performance and record data. This information can be compared to your pre-conversion data for a full conversion evaluation and can be used if technical support is required.

Appendix 3: Valve Capacities for Alternatives in Retrofits

This Appendix provides an analysis by one valve manufacturer for R-22 valve capacities used with various alternative refrigerants in a retrofit scenario. It should also be noted that supermarket systems with electronic expansion valves can automatically compensate valve capacities by a software correction.

TXV Rating Example

The nominal capacity of a Thermostatic Expansion Valve (TXV) is simply the capacity at the conditions it is rated. For high pressure refrigerants, such as R-22 or its alternatives, the AHRI industry standard rating point is: 40˚F evaporator temperature, 100˚F liquid temperature, and a 100 psi pressure drop across the TXV port. If any of these conditions change, the valve's capacity will also change.

Table 1 shows the capacities of a nominal 2 ton R-22 TXV when used with R-22, R-407A, and R-407C. Capacities are shown at varying evaporator temperatures, but in each instance the standard rating conditions of 100˚F liquid temperature and a 100 psi pressure drop across the TXV port are used in conjunction with the various evaporator temperatures. Note the highlighted nominal capacities for the three refrigerants listed and how they differ. This is the result of differing thermodynamic properties between the three refrigerants.

Table 1. Nominal TXV Capacities

Valve Type	Nominal Capacity	Refrigerant																	
		R-22						R-407A						R-407C			R-407F		
		Recommended Thermostatic Charges																	
		VC, VCP100, VGA			VZ, VZP			VC, VCP100, VGA			VZ, VZP40			NC, NCP100, NGA			VZ,VZP40		
		40°	20°	0°	-10°	-20°	-10°	-10°	-10°	0°	-10°	-20°	-40°	40°	20°	0°	-10°	-20°	-40°
G	2	2.00	2.18	1.91	1.96	1.75	1.31	1.87	2.00	1.71	1.74	1.54	1.12	1.84	1.97	1.70	1.63	1.20	1.11

If a specific application is utilizing a liquid temperature or pressure drop across the TXV port which is different than the AHRI rating condition, the correction factors in Table 2 and/or Table 3 would be applied to the capacity listed in Table 1 to determine the actual TXV capacity.

Table 2. Liquid Correction Factors

Valve Type	Liquid Temperature Entering TXV °F											
	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°
	Correction Factor, CF Liquid Temperature											
R-22	1.56	1.51	1.45	1.40	1.34	1.29	1.23	1.17	1.12	1.06	1.00	0.94
R-407A	1.75	1.68	1.61	1.53	1.46	1.39	1.31	1.24	1.16	1.08	1.00	0.92
R-407C	1.69	1.62	1.55	1.49	1.42	1.35	1.28	1.21	1.14	1.07	1.00	0.93
R-407F	1.72	1.65	1.58	1.51	1.44	1.37	1.30	1.22	1.15	1.08	1.00	0.92

Table 3. Pressure Drop Correction Factors

Evaporator Temperature (°F)	Pressure Drop Across TXV (PSI)										
	30	50	75	100	125	150	175	200	225	250	275
	Correction Factor, CF Pressure Drop										
40°	0.55	0.71	0.87	1.00	1.12	1.22	1.32	1.41	1.50	1.58	1.66
20° & 0°	0.49	0.63	0.77	0.89	1.00	1.10	1.18	1.26	1.34	1.41	1.48
-10° & -20°	0.45	0.58	0.71	0.82	0.91	1.00	1.08	1.15	1.22	1.29	1.35
-40°	0.41	0.53	0.65	0.76	0.85	0.93	1.00	1.07	1.13	1.20	1.25

For example: An R-22 application, operating at +20˚F is being retrofitted to R-407C. The evaporator capacity is 24,000 Btu/hr and the evaporator has a nominal 2 ton R-22 TXV installed. The application is designed to operate at 100˚F condensing, with a 90˚F liquid temperature.

The nominal capacity of the TXV for R-407C can be calculated as follows:

- Nominal capacity at +20˚F (from Table1): 1.97 tons.

- Corrected for liquid temperature at 90˚F (from Table 2): 1.97 x 1.07 = 2.10 tons.

To determine the correct pressure drop across the TXV port, the difference between the corresponding pressures at the condensing temperature and evaporator pressure must be used:

- 223 psi (100˚F condenser saturation) - 37 psi (20˚F evaporator saturation) = 186 psi.

The pressure drop through the refrigerant distributor and feeder tubes, the evaporator, and the frictional line loss in the piping between the condenser (where the pressure value is determined based on the condenser saturation temperature) and the TXV inlet must also be considered when determining the actual pressure drop across the TXV port.

For this example, we will assume the above mentioned pressure drop to be 36 psi.

- The actual pressure drop across the TXV port will be: 186 psi - 36 psi = 150 psi.

- Actual TXV capacity at the design condition for this application: 2.10 tons (corrected for liquid temperature) x 1.10 (from Table 3) = 2.31 tons.

- This would represent the TXV capacity at the design condition in the summer time.

To ensure that the TXV has sufficient capacity, a similar sizing exercise must be undertaken at the low ambient condensing temperature expected in the winter months. If the system utilizes fan cycling or head pressure control valves and fixes the minimum condensing temperature at 70˚F (137.5 psi), the TXV capacity will also need to be considered at this condition.

For most applications the correction factors listed in Table 4 can be used to determine if the existing R22- TXV will have sufficient capacity when used with the retrofit refrigerant of choice.

Table 4. Capacity Multipliers for R-22 Alternative Refrigerants

Evaporator Temp (°F)	Condensing Temp (°F)	Liquid Temp (°F)	R-22	Capacity Multiplier *							
				R-417A	R-422B	R-422D	R-424A	R-438A	R-407A	R-407C	R-407F
40	105	95	1.00	0.75	0.74	0.72	0.72	0.88	1.04	1.07	0.96
20	105	95	1.00	0.72	0.71	0.69	0.69	0.85	1.01	1.04	0.95
	70	60	1.00	0.82	0.83	0.83	0.83	1.00	1.20	1.22	0.99
0	105	95	1.00	0.69	0.68	0.66	0.66	0.81	0.98	1.00	0.95
	70	60	1.00	0.77	0.77	0.77	0.77	0.92	1.11	1.13	0.99
-20	105	95	1.00	0.67	0.66	0.64	0.64	0.79	0.96	0.97	0.94
	70	60	1.00	0.74	0.74	0.74	0.74	0.88	1.06	1.07	0.98

* Apply Capacity Multiplier to the TXV's R-22 rating to determine approximate TXV rating with the service retrofit replacement refrigerant. A total 40 psi pressure loss across the TXV from the refrigerant distributor and liquid line is assumed in the capacity multiplier calculation.

Thermodynamic data provided by NIST Refprop v8.0.

Capacity and correction factors courtesy of Sporlan Division - Parker Hannifin.

Source: Adapted from National Refrigerants, Inc., *Retrofit Handbook: R-22 Retrofit Guidelines and Procedures.* 2009.

VII. Acknowledgments

GreenChill is an EPA partnership with food retailers and other stakeholders to reduce refrigerant emissions and decrease the retail food industry's impact on the **ozone layer** and **climate change**.

Working with EPA, GreenChill Partners:

- Transition to environmentally friendlier refrigerants;
- Lower refrigerant charges and eliminate leaks; and
- Adopt green refrigeration technologies, strategies, and practices.

Original authors:

Keilly Witman, U.S. EPA
Craig Thomas, Arkema
Kevin O'Shea and Nick Strickland, DuPont
Ron Vogl, Honeywell
Sean Cunningham, Mexichem Fluor

Other contributors:

Dave Godwin, U.S. EPA
Patti Conlan, Arkema
David Callender, ICOR International
Jim Lavelle and Maureen Beatty, National Refrigerants
Stephen Spletzer, Arkema

Expert reviewers:

Jon Perry, Farm Fresh / SUPERVALU
George Ronn, SUPERVALU
Michal Shepard, Harris Teeter
Ed Estberg, Raley's
Steve Sloan, Publix Super Markets
Steve Millard, Food Lion
Scott Martin, Hill PHOENIX
Steve Hagler, Hussmann
Buzz Schaeffer, Hussmann
Travis Lumpkin, Kysor Warren
Bruce Hierlmeier, Zero Zone
Pat Murphy, NATE
Jerry Weis, HVAC Excellence
Warren Beeton, Emerson
Charles Allgood, DuPont.