Quick Reference to Refrigerants

	CFC	HCFC	HFC	"Natural"
R12	✔			
R502	✔			
R22		✔		
R123		✔		
R404A			✔	
R507			✔	
R134a			✔	
R410A			✔	
R407C			✔	
Propane				✔
Ammonia				✔
CO_2				✔

Copeland HFC Scroll Compressor Availability

Models	R22	R407C	R134a	R410A
1.5 - 4.0 Ton	Now	Now	Now	Now
4.0 - 6.5 Ton	Now	Now	Now	Now
7.0 -12.0 Ton	Now	Now	Now	2000/1
7.5 - 15.0 Ton	Now	Now	Now	2001
18.0 - 25.0 Tons	2001	2001	TBD	2001/2

Note: R410A Projected As Long Term Refrigerant of Choice

Section I - Background

Scientific data supports the hypothesis that chlorine from refrigerants is involved in the depletion of the earth's ozone layer. The air conditioning and refrigeration industry has supported global efforts to protect the environment by introducing non-chlorine-containing refrigerants. The Montreal Protocol, first established in 1987 and revised several times since then, established guidelines for evaluating refrigerant alternatives and setting appropriate timetables for the phase-out of chlorine containing refrigerants.

The effort began with an emphasis on reducing CFC refrigerants. The late 1980s and early 1990s centered on the elimination of CFCs primarily used in foam blowing, cleaning and refrigeration applications and centrifugal chillers for air conditioning. At the end of 1995, the production of CFCs came to a halt in developed countries (i.e., United States, Europe, Japan), and it is no longer used in new equipment today. These actions have proven to significantly reduce atmospheric chlorine and are starting to reduce ozone depletion.

Today there is increased attention on global warming, and on reducing the impact of refrigerants on this environmental hazard. The successful transition from CFCs to HCFCs and HFCs over the past decade has given our industry and regulatory agencies confidence, and supports the general belief that moving from HCFCs to HFCs is an achievable, next important step.

Many countries around the world support ozone depletion concerns by working actively to reduce HCFC consumption in air conditioning and refrigeration applications. Current regulations and other initiatives are focused on the transition from R-22 to longer-term HFC alternatives.

In 1997, a major international testing program under the leadership of the Air Conditioning and Refrigeration Institute (ARI), referred to as AREP (Alternative Refrigerants Evaluation Program), was completed. The AREP reports indicate that there is not just one replacement for R-22, but rather, at least three distinct alternatives that need to be evaluated before a decision is made.

While viable candidates have been identified, several have substantially different operating characteristics than R-22, including higher pressures and higher glide characteristics. Regardless of which refrigerant is selected to replace R-22, they all eliminate chlorine and potential ozone depletion, leaving climate change as the focus for future regulations and control.

Section II - Regulation Update

While CFC usage has reduced significantly, it is still being used in new and service equipment worldwide in developing countries and will not be completely phased out of production until 2010. Additionally, HCFCs continue to support air conditioning and refrigeration equipment in a majority of applications. Regulations have been developed to manage consumption of these refrigerants as the world moves toward full adoption of non-chlorine-containing compounds.

The Montreal Protocol was adopted by all developed countries and has resulted in their phase out of CFCs. It placed an initial cap on HCFC production in 1996. As shown in *Figure 1*, allowable HCFC production levels continue to reduce with time, with the next significant reduction planned in 2004.

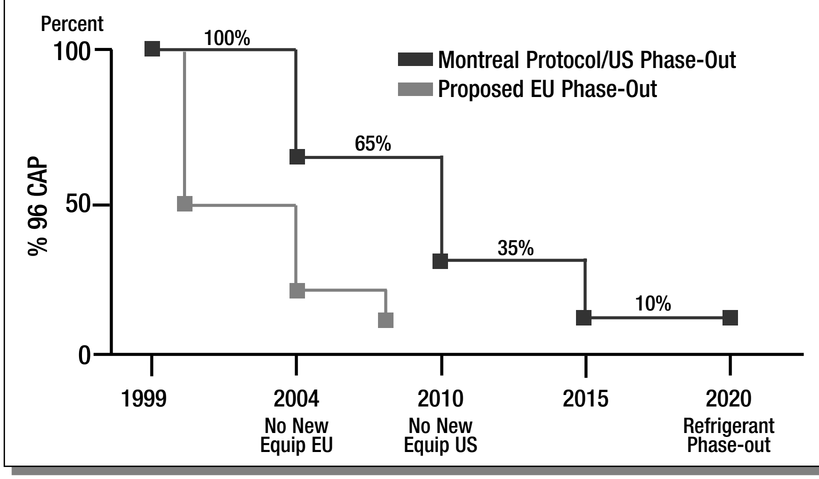
The Kyoto Protocol was established in 1997 in response to increased global warming concerns. By 2008 to 2012, developed countries are challenged with reducing greenhouse gases by an average of 5.23% from 1990 levels. A total of six gases are considered and controlled as a total package versus one gas. Only a few nations have ratified the Kyoto Protocol to date, but many countries are reacting to it.

The U.S. program currently plans to phase out HCFCs for new equipment in 2010 and for service applications in 2020. In 1998, HCFC production jumped to 92% of the cap, and some people in the industry believe that this may trigger new allocation or control regulations sooner than 2004.

Other developed countries like Japan and the European Union are already operating under accelerated phase-out schedules. At the same time, many less developed countries (i.e., China, India, Mexico) are still using CFCs and are only in the beginning stages of moving to HCFCs.

Refrigerant decisions are also impacted by other regulations related to product design and application. For example, Underwriters Laboratories recently changed the pressure standard for refrigerants within air conditioning and refrigeration systems, making it easier to apply the new, higher-pressure refrigerant alternatives.

Figure 1 HCFC Phase-Out Timeline



As the world moves away from CFCs and HCFCs to new, more environmentally safe refrigerants, the industry will place an even greater emphasis on global warming and the potential negative impact of these alternatives. Measurements for climate change, like Total Equivalent Warming Impact (TEWI), have become increasingly important tools.

Because most global warming is indirect, TEWI provides a more accurate measure of the overall climate change impact by taking into account a variety of variables. In fact, TEWI may be replaced by a new term to reflect the global warming impact of manufacturing the refrigerant. It is also likely that global warming will also play an important role in driving the trend to more efficient refrigerants, as energy consumption is the main contributor to overall global warming by most equipment.

Section III - Types of Refrigerants

In the air conditioning industry, virtually all of the refrigerant experience has been limited to single component ("pure") refrigerants.

However, as we search for acceptable replacements for these compounds, refrigerant manufacturers have been unsuccessful in developing single component replacements which meet all of the required or highly desirable characteristics for a widely used refrigerant. These requirements include:

- environmental acceptability
- chemical stability
- materials compatibility
- good refrigeration cycle performance
- nonflammable and nontoxic (per UL guidelines)
- boiling point

Many of the R-22 refrigerant replacements under consideration are not a single component, but are azeotropes, near-azeotropes, or zeotropes of two or more compounds. Fortunately, the commercial refrigeration industry has already had considerable experience with each type.

Definitions

CFC Refrigerant: A chlorofluorocarbon.

HCFC Refrigerant: A hydrochlorofluorocarbon.

HFC Refrigerant: A hydrofluorocarbon.

Natural Refrigerant: Compounds found in nature, such as air, water, ammonia, hydrocarbons, etc.

Pure Compound: A single compound, which does not change composition when, changing phase.

Blends (Mixtures): Refrigerants, which consist of two or more different chemical compounds, often used individually as refrigerants for other applications.

Azeotrope: Blends, which act as pure compounds, that do not change volumetric composition or saturation temperature appreciably as they evaporate (boil) or condense at constant pressure.

Zeotrope: Blends, when used in refrigeration cycles, that change volumetric composition and saturation temperatures to varying extents as they evaporate (boil) or condense at constant pressure.

Glide: The absolute value of the difference between starting and ending temperatures of a phase-change process by a refrigerant blend, exclusive of any subcooling or superheating at constant pressure. This term usually describes condensation or evaporation of a zeotrope, the temperature difference between the bubble and the dew point.

Near-Azeotrope: A zeotrope blend with a small temperature and composition glide at constant pressure over the application range, and no significant effect on system performance, operation and safety.

Fractionation: A change in composition of a blend by preferential evaporation of the more volatile component(s) or condensation of the less volatile component(s) at constant pressure.

GWP: Global Warming Potential. This calculation considers only the direct effect of the refrigerant as a greenhouse gas when it escapes into the atmosphere. It is referenced against CO2 where CO2 is equal to 1.

HGWP: Halocarbon Global Warming Potential is similar to GWP but uses CFC-11 as the reference gas where CFC-11 is equal to 1.

Total Equivalent Warming Impact (TEWI): TEWI integrates the global warming impacts of equipment's energy consumption and refrigerant emissions into a single number, usually expressed in terms of CO2 mass equivalents. The calculated TEWI for any given piece of air conditioning and refrigeration equipment is based on estimates for (1) the quantity of energy consumed by the equipment over its lifetime, (2) the mass of carbon dioxide produced per unit of energy consumed, (3) the quantity of refrigerant released from the equipment over its lifetime, and (4) the global warming potential of that refrigerant, expressed in terms of CO2 mass equivalent per unit mass of refrigerant.

Components of Mixtures

A mixture's components are chosen based on the final characteristics desired. These characteristics could include vapor pressure, transport properties, lubricant and material compatibility, thermodynamic performance, cost, flammability, toxicity, stability, and environmental properties. The proportions of the components are chosen based on the exact characteristics desired in the final product.

Behavior of Mixtures

When an azeotrope, near-azeotrope, or zeotrope is in the **pure liquid** or **pure vapor** state, the composition is totally mixed and all properties are uniform throughout.

However, **when both liquid and vapor are present** (such as in the evaporator, condenser, or perhaps receiver), a mixture's behavior depends upon whether it is an azeotrope or zeotrope.

The percentage composition of the liquid and vapor of an **azeotrope** will always be virtually the same when both liquid and vapor are present. If a leak occurs, there will not be a substantial change in composition of the refrigerant left in the system.

The composition of the vapor and liquid of a zeotrope are different when both liquid and vapor are present. If a leak occurs in this region of a system and only vapor leaks out, there can be a change in the composition of the refrigerant left in the system. Also, if the system uses a **flooded evaporator or multiple evaporators**, the composition of the liquid can be substantially different from the vapor, resulting in changes in the circulating refrigerant.

Since a **near-azeotrope** is still a zeotrope, the composition of the vapor and liquid will be different when both liquid and vapor are present, but to a small extent. If a leak occurs in this region and only vapor leaks out, there can be a small change in the composition in the refrigerant left in the system.

Since the composition of the liquid and vapor of a zeotrope (and near-azeotrope) can be different, it is important **to charge a system** with these types of refrigerants with liquid leaving the cylinder. If vapor is charged from the cylinder, the composition of the refrigerant in the system will not be the same as that in the cylinder because of the **fractionation** of the refrigerant in the cylinder as vapor alone is removed.

Additional information regarding pure compounds, azeotropes, zeotropes, and near- zeotropes can be found in the Copeland publication "Introduction to Refrigerant Mixtures," Publication Number 92-81.

Section IV - Evaluation of Refrigerant Alternatives

The AREP program was established in 1992 by ARI and controlled by an Executive Committee, comprised of senior executives from ARI member companies. The program was focused primarily on identifying possible alternatives to R-22 and R-502 refrigerants. Tests were conducted with 19 refrigerants identified as potential replacements for R-22. Individual test reports issued included compressor calorimeter, system drop-in, heat transfer, and soft-optimized system tests for most of these refrigerants.

AREP tested many types of compressors and systems. Reciprocating, rotary, screw and scroll compressors were evaluated. In addition, system performance was tested across a range of applications, including split system heat pumps, both air- and water-cooled packaged heat pumps, window units and condensing units. Over 180 AREP reports were approved and released to the public when the committee completed its testing in 1997.

As the industry evaluates HFC alternatives to replace R-22, we find that many of the likely candidates are not as close to the characteristics of R-22 as the HFC alternatives were for R-12 and R-502 in refrigeration. A list of alternatives has been identified as shown in Table 1. As the exhibit shows, the characteristics of these alternatives vary dramatically. R-290 (propane) and R-717 (ammonia), while having the benefit of almost zero direct global warming potential, have not been applied in the U.S. and Japan. Because of the unique risks and costs associated with litigation in the United States, U.S. companies are not pursuing flammable refrigerant options, since the likely solution requires a secondary loop configuration that adds cost and reduces efficiency.

Of the options identified, there are three basic categories of refrigerants that have emerged as leading candidates for R-22 replacement. These HFC alternatives were confirmed as viable options through the AREP studies:

1. A higher-pressure near-azeotrope mixture of R-32 and R-125, designated as R-410A.
2. A lower pressure alternative known as R-134a.
3. Several R-22 look-alike candidates that are mixtures of R-32, R-125 and R-134a. Of all the blends in this category, the ternary blend designated as R-407C has equivalent pressure and appears to be the most likely blend to be utilized in replacing R-22 in air conditioning applications.

Table 2 identifies some of the key characteristics of the three options discussed above, in addition to the characteristics of the natural refrigerant options, propane and ammonia. A summary of the advantages and disadvantages of each is discussed briefly on the next page.

Table 1
Chlorine Free R-22 Replacements

Identification	Ingredients	Glide° C	HGWP	Toxic/ Flammable
R-410A	32/125	0.11	0.44	No
R-407C	32/125/134a	5.40	0.37	No
R-134a	134a	0	0.28	No
R-290	Propane	0	0.02	Yes
R-717	Ammonia	0	0	Yes

R-410A

R-410A is a near-azeotrope composition of 50% R-32 and 50% R-125. This option differs significantly as it operates at 50% higher pressures than R-22. To date, optimized system testing has shown that R-410A delivers higher system efficiency than R-22. R-410A evaporates with a 35% higher heat transfer coefficient and 28% lower pressure drop compared to R-22. Since R-410A has lower pressure drop, additional system performance gain has been demonstrated by sizing for equal pressure drop through reducing the number of coil circuits to increase the mass flux.

R-410A systems should offer cost advantages, depending on the equipment size and appropriate maintenance. The higher density and pressure also allows the use of smaller-diameter tubing while maintaining reasonable pressure drops. This, along with reduced refrigerant charge and better cyclic performance, make R-410A potentially more cost effective. Several years ago, manufacturers believed it would be necessary to perform significant redesign for R-410A equipment to accommodate the higher pressures. However, the change in UL pressure standards have made it possible to use R-410A, in some cases, without major component redesigns.

R-134a

R-134a has the benefit of being a single component refrigerant and, therefore, does not have any glide. In addition, the direct global warming potential (HGWP) of R-134a is low relative to other options that have been evaluated. The disadvantage of R-134a lies in its relatively low capacity compared to R-22. To utilize this refrigerant, all of the tubing within the heat exchangers and between the components of an air conditioning system would need to be significantly larger to minimize pressure drops and maintain an acceptable operating efficiency. This, combined with the greater compressor displacements required, results in a system that will be more costly than R-22 systems today. The heat transfer coefficient of R-134a is also lower, and preliminary data suggests system performance would degrade with its use. In summary, manufacturers would need to invest significant time and capital to redesign from R-22 to R-134a and ultimately have a design with inherently lower performance or higher cost. Therefore, for residential and smaller commercial systems where R-22 has traditionally been used, we feel R-134a is the least likely of the three candidates.

This may not be the case in larger commercial systems where large screw or centrifugal systems have been traditionally used, and refrigerants like R-11 and R-12 were common. Here, R-134a may offer the best solution for a relatively low investment, simple redesign to HFCs.

Table 2

Key Characteristics

	R-134a	R-407C	R-410A	Propane
Glide	0	5.4˚C	0.11˚C	0
HGWP	.28	.37	.44	.02
Pressure at 54.5˚C (kPa)	1,476	2,262	3,406	1,887
Compressor EER (% R-22)	101%	95-101%	92-101%	98-100%
Capacity (% R-22)	65%	98-105%	149%-155%	85%
Heat Transfer	Less	Less	Higher	Same
Pressure Drop	Higher	Same	Less	Less
Tubing Size	Larger	Same	Smaller	Same
System Performance (% R-22)	97-98%	95-100%	98%-105%	100-103%
System Cost	Slight Increase	Same	Slightly Lower	Large Increase*
Redesign Required	Significant	Moderate	Significant	Significant*

* To address safety issues of flammable refrigerant

R-407C

R-407C is a ternary blend of R-32, R-125, and R-134a. Of the three options, R-407C was designed to have operating characteristics similar to R-22. The major concerns surrounding R-407C are in its relatively high glide (approximately 10˚F and the efficiency degradation when compared to R-22. However, the use of this refrigerant provides the simplest conversion of the three alternatives. We believe that in systems where glide is acceptable, R-407C will become a popular option for manufacturers who want to quickly move to an HFC alternative. Although in the long term, the lower efficiency performance of this refrigerant may make it a less attractive alternative when compared to R-410A.

Care should be taken when applying R-407C in any applications where glide can impact system performance by fractionization in flooded

Table 3

Comparison of TEWI for Three Cases

GWP	Case 1: Leakage Rate 25% Per Year Direct + Indirect = Total	Case 2: Leakage Rate 5% Per Year Direct + Indirect = Total	Case 3: Leakage Rate 25% Per Year 10% Improved Efficiency Direct + Indirect = Total
0.0	0 + 700 = 700	0 + 700 = 700	0 + 630 = 630
0.3	250 + 700 = 950	50 + 700 = 750	50 + 630 = 680
0.6	500 + 700 = 1,200	100 + 700 = 800	100 + 630 = 730

evaporator or multi-evaporator designs. Also, we must be careful in viewing R-407C as a drop-in for R-22 systems or applications. Like all HFCs, R-407C requires the use of polyol ester lubricants, and other system design modifications may be required for R-407C to operate acceptably in R-22 systems.

Natural Refrigerants

Propane has the benefits of zero direct global warning potential and high system performance; however, its flammability disqualified it as a R22 replacement. The safety issues of a flammable refrigerant requires significant system adders and re-design which may include secondary loop configurations that reduce efficiency.

Ammonia has the benefit of zero direct global warming potential; however, its high toxity limits its application to industrial refrigeration. Due to its system chemistry challenges, Ammonia was not a serious R22 alternative candidate in the AREP program.

Global Warming Impact

Another key consideration in the selection of future refrigerants is global warming. A disadvantage of R-410A is the slightly higher direct global warming potential versus R-134a or R-407C. However, it is our view that direct global warming alone can be misleading in understanding the overall effect of various refrigerant alternatives. TEWI helps to fairly assess the climate change impact, as it accounts for both the direct (refrigerant) and indirect (system power consumption/efficiency) effects in evaluating global warming. Most analysis shows that R-410A has the lowest TEWI for an equivalent cost system. In fact, today's HFC refrigerants appear to be very good options when comparing the total global warming impact to that of natural refrigerants.

We support the use of TEWI, and expect this measurement tool will become the representative criteria in selecting future refrigerants. As shown in *Table 3*, the indirect effect for global warming – that which can be most effectively dealt with through the use of higher-efficiency refrigerants and the design of higher-efficiency systems – can have a far greater impact than the direct component. TEWI highlights the importance of effectively controlling leaks in order to reduce the global warming from the refrigerant itself. Refrigerant that does not get into the atmosphere does not cause global warming.

As we consider the refrigerants available to manufacturers and the potential global warming impact of each, we believe it is likely that residential and commercial applications up to 100 tons will move to a higher-pressure option like R-410A in the long run. Initial results support the belief that the efficiency performance and cost advantages of this refrigerant outweigh the disadvantages associated with higher pressure and direct global warming potential. Further testing by OEMs and efforts to optimize systems using R-410A are essential in validating these preliminary conclusions.

Section V - Timing

The Montreal Protocol was revised to call for a complete production phaseout of refrigerant applications by 2020. However, with the HCFC production cap approaching, many OEMs are considering the proximity of current production to the cap and the potential acceleration of the protocol. Many OEMs are now working on system redesigns to eliminate the use of HCFC refrigerant. Design and testing cycles may be extensive, especially in the case of R-410A.

Regardless of regulations, several OEMs have already launched environmentally friendly systems in response to competitive pressures.

For more than four years now, Copeland has developed and released a series of new HFC products to support the industry's need for chlorine-free systems. A range of products is designed to operate with R-134a, R-407C or R-410A. There are a wide variety of displacements available for both residential and commercial air conditioning. Compressors up to 90 horsepower in size are available today, with future models planned up to 140 horsepower.

Scroll compressor technology has an inherent ability to adapt to higher pressure refrigerants like R-410A and more standard pressure refrigerants like R-407C. Although the design challenge is serious, scrolls are more easily adapted to higher pressures and are inherently more efficient than other compressor technologies. Most reciprocating designs will require extensive retooling and redesigning to handle the higher pressures.

For availability information on any Copeland HFC released compressor, please contact your local Copeland sales representative or application engineer.

Section VI - Compressor Selection

As system manufacturers consider new equipment designs to operate with HFC refrigerants, they are impacted by many other changes occurring throughout the industry. Specifically, the efficiency regulations established in recent years are driving equipment redesigns today, and these standards will become even more important in the next five years.

In 2006, the U.S. Department of Energy is planning to raise the minimum SEER (Seasonal Energy Efficiency Ratio) for residential equipment from a minimum of 10.0 to an expected 12.0 SEER or higher. New ASHRAE standards (ASHRAE 90.1) will also mandate an increase of up to 20% in efficiency levels across a variety of commercial equipment. There are also efficiency standards emerging throughout Asia and Europe. The room air conditioning market in Japan, for example, is charged with achieving 63% better efficiency performance than 1997 models by 2004.

Because the timing of these new efficiency standards coincides with the R-22 phase-out schedule, several air conditioning system manufacturers are developing HFC models for the higher efficiency systems in their product line. This strategy is reinforced by the fact that these new refrigerants cost more than R-22 initially, and the polyol ester oil required in these designs also adds system cost. The higher efficiency (12.0+ SEER) U.S. markets are the most likely segments where OEMs can promote environmentally-friendly products and earn a premium to overcome these initially higher costs.

Compressor technologies have also been evaluated for best overall performance relative to the new high efficiency, HFC applications. Today, over half of all U.S. residential air conditioning equipment has moved from reciprocating technology to scroll technology, particularly in these higher-efficiency segments. As existing manufacturers introduce scroll products, adoption in other segments will grow even further.

All analysis and testing to date confirms that R-410A is the best-cost, long-term solution for residential and smaller commercial designs. Recent field tests have confirmed that scroll systems with R-410A are more reliable than R-22. Results have also demonstrated that R-410A scroll products deliver system sound reductions when compared to R-22. Additionally, the refrigerant offers cost advantages *(see Section IV).* Residential systems achieve higher efficiency with R-410A, and it also delivers high reliability.

As we begin to see R-410A designs in commercial systems, we find they can perform well with this refrigerant. More testing is being done, and results indicate commercial systems with R-410A benefit from high efficiency, superior reliability and reduced refrigerant charge. R-410A systems with scroll in rooftops and other light commercial equipment also receive similar cost advantages as realized with residential equipment.

Based on our experience with this refrigerant and the results we have recorded to date, Copeland's HFC program is focused on developing R-410A scroll products. However, we also offer other HFC products, as these refrigerants may be necessary in some applications.

The Montreal Protocol was revised to call for a complete production phaseout of R-22 by 2020. However, with the first caps on R-22 quickly approaching, OEMs need to begin working on system re-designs now *(see Section II)*. Design and testing cycles may be extensive, especially in the case of R-410A.

Regardless of regulations, several OEMs have already launched environmentally friendly systems in response to competitive pressures.

For more than four years now, Copeland has developed and released a series of new scroll models to support the industry's need for chlorine-free systems. A range of products is designed to operate with R-134a, R-407C or R-410A. There are a wide variety of displacements available for both residential and commercial air conditioning. Compressors up to 15 horsepower in size are available today, with future models planned up to 25 horsepower.

This demonstrates the unique flexibility of scroll technology, with its inherent ability to adapt to higher pressure refrigerants like R-410A and more standard pressure refrigerants like R-407C. Although the design challenge is serious, scrolls are more easily adapted to higher pressures and are inherently more efficient than other compressor technologies. Most reciprocating designs will require extensive retooling and redesigning to handle the higher pressures.

For availability information on any Copeland HFC released compressor, please contact your local Copeland sales representative or application engineer.

Section VII - System Design Considerations

Regardless of which HFC refrigerant an OEM is considering, care must be taken in the design and handling of systems utilizing these new refrigerants. While they provide an ozone-friendly solution to the industry, HFCs do present new challenges:

- We believe polyol ester oils are an important requirement to ensure the reliability of the compressor when used with HFCs. However, when using polyol ester oils, care must be taken to keep the oil dry because of its hygroscopic characteristics. Proper precautions must be taken in both the manufacture of the system and its ultimate installation in the field to prevent excess moisture from entering the system. The use of a properly selected filter-drier is strongly recommended. (See Section IX for more information on polyol ester oils.)
- R-410A and R-407C are blends and, therefore, exhibit glide characteristics (particularly R-407C). The impact of glide must be considered both in the system design and in servicing the system. Manufacturers must understand and convey to the field the impact of leaks on non-azeotropic mixtures. Systems containing a non-azeotropic refrigerant must be liquid-charged to ensure the proper component mixtures are added.
- In residential and light commercial air conditioning split systems, it is common to replace the high side only (condensing unit). When replacing a high-side unit which was R-22 with a new unit using an HFC, extreme care must be taken to make sure the indoor unit and expansion device are compatible with the new refrigerant, and that most residual mineral oil is removed from the system. When the replacement system contains R-410A the manufacturer of the indoor coil must be contacted to determine if the coil burst pressure is adequate for the higher pressures encountered with this refrigerant. The safest solution is to replace either the indoor coil or the entire air handler.
- R-410A refrigerant has higher operating pressures and is significantly different from R-22. Therefore, R-410A systems require special considerations to maximize performance and benefits of the refrigerant. Precautions must be taken to ensure that the heat exchangers and components being used are designed to handle these higher pressures especially where heat pumps are concerned. The fact that R-410A has a much lower critical temperature (162.5˚F compared to 204.8˚F for R-22) must be considered when using this refrigerant in units designed for high ambient applications.

Please contact your Copeland application engineer or sales manager for further assistance.

Section VIII - Safety

As the air conditioning and refrigeration industries move away from the relatively few CFC and HCFC refrigerants, the issue of safety naturally arises. Of course, safety of new refrigerants is paramount when considering which HFC refrigerant to adopt.

Refrigeration safety issues typically fall into four major areas, including:

Pressure – Virtually all of the new refrigerants operate at higher pressure than the refrigerants they replace. In some cases, the pressure can be substantially higher, which means that the refrigerant can only be used in equipment designed to use it and not as a retrofit refrigerant.

Material Compatibility – The primary safety concern here is with deterioration of materials such as motor insulation (which can lead to electrical shorts) and seals (which can result in leaks).

Flammability – Leakage of a flammable refrigerant could result in fire or explosions. In addition, many of the new refrigerants are zeotropes, which can change composition under certain leakage scenarios. Consequently, it is important to completely understand the flammability of the refrigerant blend, as well as what it can change into under all conditions. Using flammable refrigerants exposes individuals and the environment to unnecessary hazards, and Copeland does not approve of the use of flammable refrigerants in Copeland compressors.

Toxicity – In the course of the refrigerant transition, some countries have explored and/or applied toxic refrigerant options such as ammonia. These alternatives may offer system performance benefits, but they can also be highly dangerous. Copeland sees no reason to risk utilizing refrigerant options like ammonia, when HFCs can deliver equivalent or better efficiency and overall performance.

The major refrigerant manufacturers, equipment manufacturers, and safety standard setting agencies (such as Underwriters Laboratories and ASHRAE) have extensively studied and then rated the safety aspects of the proposed new refrigerants according to each of the factors listed above. The intent is to use only refrigerants that are at least as safe as those being replaced.

Safety should not be a concern with any of the HFCs currently applied in the air conditioning and refrigeration industry, as long as the guidelines and recommendations of the manufacturers and standards agencies are followed. Of course, it is important to remember that refrigeration systems have high pressure equipment (containing either old or new refrigerants) and require technically competent individuals to design and service them. It is critical that the common safety practices accepted by our industry are adhered when handling CFC, HCFC or HFC refrigerants.

Section IX - Lubricants

Most manufacturers of hermetic and semi-hermetic compressors have determined that polyol esters (POEs) are the best choice of lubricants for the chlorine-free HFC refrigerants like R-407C, R-134a and R-410A. However, there is ongoing work by several organizations to develop ways of using mineral oils and alkylbenzene with HFCs.

Polyol esters are a family of synthetic lubricants that have been used primarily to lubricate jet engines. They are manufactured by several companies. There are many types and grades. It is important to understand that all POEs are not the same. As a result, it is crucial that equipment manufacturers use POEs specifically recommended by the compressor manufacturer.

Important areas where POEs can differ include lubricity, miscibility and solubility with refrigerant, viscosity, viscosity index, additive packages, pour point, and moisture content. Unlike natural mineral oils, POE is completely wax free.

POEs are made from more expensive base stock materials than mineral oils and cost considerably more. However, their advantages with HFC refrigerants include:

- miscibility with the HFCs, CFCs, and HCFCs
- backwards compatibility enables the POE to be added to a system containing mineral oil
- lubricity of POEs can be designed to be as good or even better than those of mineral oils
- better oil return characteristics and improved heat transfer characteristics in the comparison to mineral oils

Other areas of difference are:

- POEs are far more hydroscopic than mineral oil, which means they will absorb more moisture. As a result, POE oil must be handled more carefully, and compressor and system processing procedures must be more rigorous to avoid absorbing moisture. POE packaging is also important, as POEs stored in some plastic containers can actually absorb significant moisture through the wall of the container. Copeland only approves POEs which are packaged in metal cans.
- POEs are better solvents which means they will dislodge and carry debris through a system to a far greater extent than do mineral oils. Because of these characteristics, it is more important than ever to pay particular attention to adequate

use of filters and dryers in the design and service of equipment with POEs.

- Copeland has implemented a POE based Assembly Oil for all HFC compressors which replaces a Paraffinic Assembly Oil. This new POE based Assembly Oil is hydrolytically stable and is optimized for HFC refrigerants to avoid problems with expansion devices.

Copeland has developed a new POE for air conditioning scroll compressors, called 3MA. The 3MA lubricant is optimized for refrigerants containing HFC32, such as R-410A and R-407C. The 3MA lubricant has improved miscibility and oil return characteristics. In addition, it is deposit-free, hydrolytically more stable, and optimized for lubricity characteristics.

Section X - The Future

The next generation of refrigerants has been established. As reviewed here, R-134a, R-407C and R410A have ozone depletion advantages over R-22; however, they still have some global warming potential. A larger percentage of applications are moving to R-410A in air conditioning, and it appears this will be the HFC of choice for a majority of residential and light commercial systems.

It is important to recognize this is an evolutionary process. R-134a, R-407C and R-410A are the next steps, but they are not the last steps in the process. As technologies develop and new applications and system designs continue to emerge, other refrigerants may be applied in the future.

No HFC refrigerant can cause direct global warming if it is properly contained. Within the HVAC/R industry and in others, we expect to see increased emphasis on refrigerant recovery and preventing leaks in the coming years. As we move into a new century where the potential for climate change is more and more a concern, Copeland will work closely with refrigerant manufacturers, system manufacturers, all industry organizations and regulations to improve compressor performance and reliability while reducing environmental impact.

For more information, the following suggested reading materials are available from Copeland

	Form No.
• Copeland Accepted Refrigerants/Lubricants	93-11
• Introduction to Refrigerant Mixtures	92-81
• New Refrigerant Smorgasbord	92-83
• Refrigeration Oils	AE-1248
• Application Guidelines for ZP**K*E Scroll Compressors for R-410A	AE-1301
• 134a Application Engineering Bulletin	AE-1295
• Refrigerant Changeover Guidelines	
(CFC) R-12 to (HCFC) R-401A	93-02
(CFC) R-12 to (HCFC) R-401B	93-03
(CFC) R-12 to (HCFC) R-134a	93-04
(CFC) R-502 to R-402A/R-408A	93-05
(CFC) R-502 to R-404A/R-507	94-15
(HCFC) R-22 to R-407C	95-14