PLANNING FOR THE USE OF ALTERNATIVE REFRIGERANTS IN AIR-CONDITIONING AND REFRIGERATION

Glenn C. Hourahan, P.E.
Research Manager
Research and Technology Department
Air-Conditioning and Refrigeration Institute
4301 N. Fairfax Drive, Suite 425
Arlington, VA 22203

SUMMARY

Required equipment changes have kept design engineers busy, and it has confused and confounded many who have to apply and maintain air-conditioning and refrigeration equipment. The purpose of this paper is to try to alleviate some of this confusion and also illustrate options or policies that equipment planners need to consider.

INTRODUCTION

The air-conditioning and refrigeration industry is a microcosm of America. Many of the big issues that are discussed today impact cooling and refrigeration products: the environment, conservation, public health, international competitiveness, a trained labor force, and the economy. Of course, these days environmental factors dominate the industry — particularly the role of refrigerants in depleting the stratospheric ozone layer.

The depletion of stratospheric ozone has led to phase-out dates for chlorofluorocarbons (CFCs) as well as hydrochlorofluorocarbons (HCFCs), the refrigerants used in most air-conditioning and refrigeration systems in U.S. service today. International agreements for the banning of CFCs are in place and the era of CFC production is swiftly drawing to a close. The collective goal of these agreements is to lower the amount of chlorine in the stratosphere. Figure 1 shows an estimate of the level of chlorine in the stratosphere over the next six decades, the so-called "chlorine loading" factor. Due to the relatively long atmospheric lifetimes of some of these compounds, it is predicted to require decades for the chlorine loading level to drop back to its pre-1979 level of two parts-per-billion — even after factoring in a CFC production ban starting 1 January 1996.

Refrigerants that do not contribute to the stratospheric chlorine levels could contribute to the global warming effect. In referring to Figure 2, it can be seen that trade-offs between

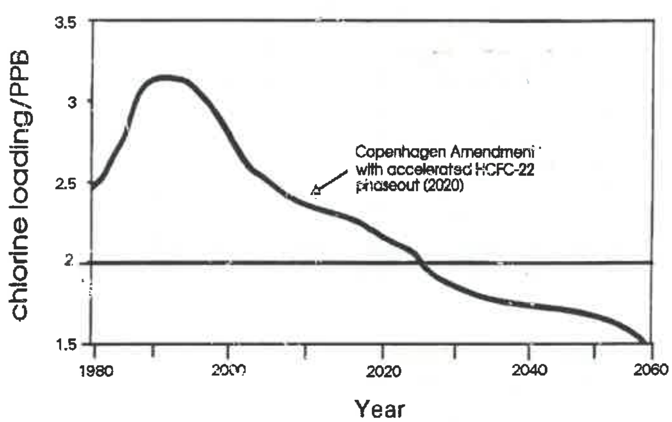

FIGURE 1. STRATOSPHERIC CHLORINE LOADING (EXISTING COMPOUNDS - ACCELERATED SCHEDULES)[1]

ozone depletion and global warming potentials are required. Yet, one more complication of the global warming issue is that policy makers must differentiate between direct emissions of global warming gasses (i.e., refrigerants that leak and find their way to the stratosphere) and indirect emissions, such as the CO_2 spewed from the powerplant that is producing electricity to drive the cooling equipment.

CFC AND HCFC PHASEOUT

Within the U.S., by 1 January 1994, only 25% of 1986 CFC production levels will be made. Two years later, by 1 January 1996, all CFC production will cease. In response to this, nearly all

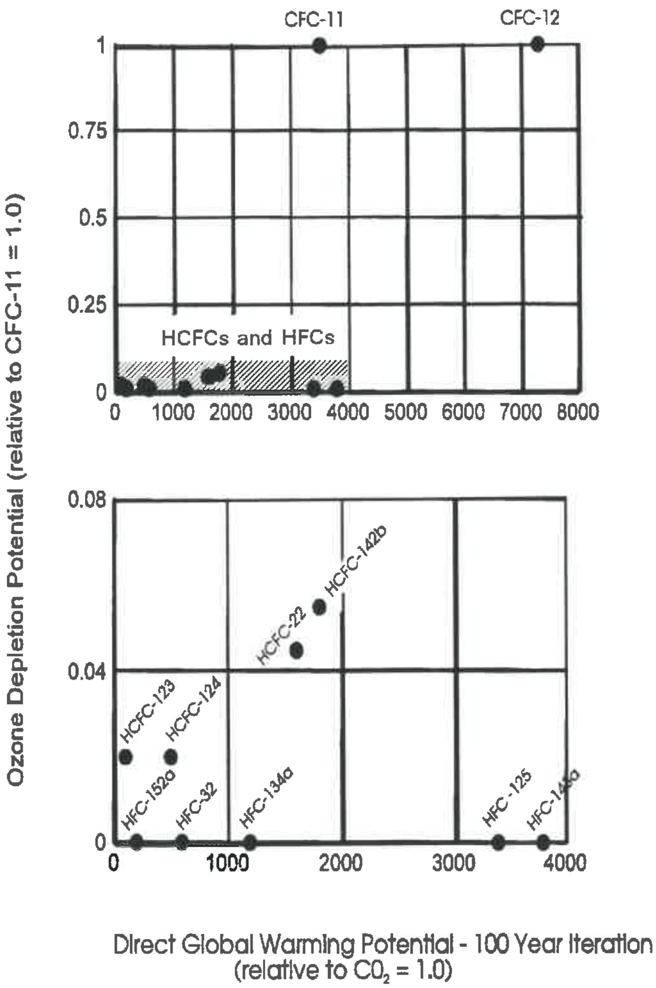

FIGURE 2. ENVIRONMENTAL IMPACT OF REFRIGERANTS[2]

equipment manufacturers offer non-CFC equipment and most no longer produce CFC equipment at all.

For all intents and purposes, CFCs are out of the picture. On the positive side, however, established alternatives are performing well. For example, equipment containing HCFC-22, HCFC-123, and HFC-134a are offered for many CFC applications.

HCFCs will play an important role as transitional refrigerants, but it can be seen that they too are destined for phaseout (refer to Figure 3). As currently proposed by the U. S. Environmental Protection Agency (EPA), longer atmospheric life refrigerants such as HCFC-22 will not be used in new equipment after 2010, and their production will be phased out in 2020. Shorter atmospheric life HCFCs, like R-123, are not scheduled for use in new equipment after 2020, and their production will cease in 2030.

CHILLER REPLACEMENT/CONVERSION

The phaseout of CFC production is causing owners of chillers to plan for the conversion or replacement of their units. However, at the current rate of conversions or replacements, severe CFC shortages in the future are expected. Figure 4 estimates the number of CFC chillers that chiller manufacturers expect to convert or replace in the next few years. At this rate of conversion and replacement, only 13,000 of the estimated 80,000 CFC chillers in the U.S. will be converted or replaced by the end of 1995.[3] Hence, at the beginning of 1996 an estimated 67,000 CFC chillers will still be in the field.

It is anticipated by the Congressional Research Service of the Library of Congress that these 67,000 chillers will require 3 - 8 million pounds of CFC refrigerants for servicing in 1996. However, no CFC refrigerant will be produced in 1996. Other competing applications will require 41 to 65.2 million pounds of CFCs. Automotive air-conditioning alone will require 30 to 50 million pounds of CFC-12 and commercial refrigerants will require 11-12 million pounds (see Table 1).[4]

Competition for CFCs will be fierce in 1996, and in successor years as well. The recently-released Library of Congress report, utilizing industry and EPA input, says some observers "predict a state of real chaos in late 1995 and the first several years after phaseout is complete."[4]

It is believed that tightening system leaks and better service practices may make the predicted need for 73 million pounds of CFCs a high-end estimate. Furthermore, it is hoped that recovery and reclamation programs will be sufficient to satisfy the CFC needs for the equipment still in the field. At this point, however, these hopes and beliefs may be a bit optimistic.

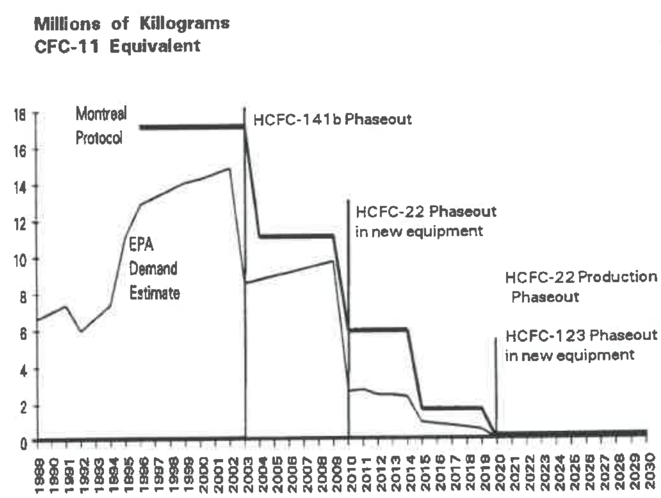

FIGURE 3. HCFC PHASEOUT SCHEDULE

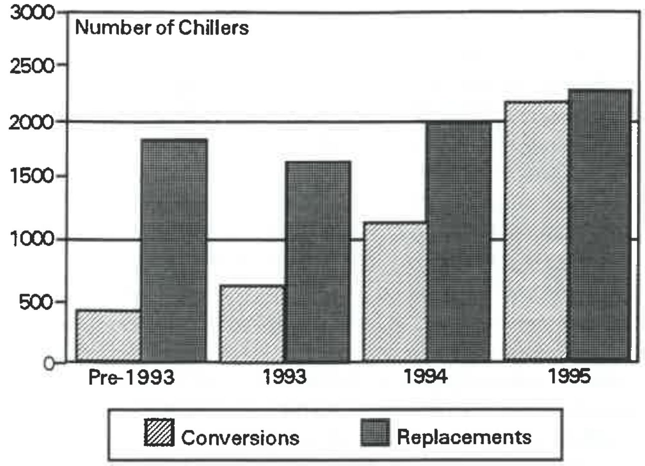

FIGURE 4. CFC CENTRIFUGAL CHILLERS, CONVERSION VS. REPLACEMENT, CFC TO NON-CFC[3]

NO SILVER BULLETS

The questions that are often asked are:

- What is being done by industry to find alternatives for CFC and HCFC refrigerants?
- When will equipment utilizing them be widely available?
- Should building operators delay CFC phaseout activities until then?

In referring to Figure 6, it can be seen that the criteria for selecting alternative refrigerants are much broader than a refrigerant's ozone depletion potential. Industry has to take into consideration a number of safety, environmental, performance concerns, and a host of infrastructure issues -- including availability of refrigerants, training of service personnel, equipment serviceability, and retooling of product lines.

Much research is currently ongoing by chemical producers, equipment manufacturers, and by private and national laboratories -- both here and abroad -- to resolve these issues. However, once likely candidates are identified, it still takes 8-12 years before they can be offered in full-scale manufacturing of new products.

The message here is that there are no magic compounds just around the corner. The air-conditioning and refrigeration options that will be available in the next decade are essentially the same as those that are currently available. This is especially true for CFC chiller applications. Equipment decisions should not be predicated on the supposition that a silver bullet is on the horizon. Planning must start today for servicing the existing equipment base and managing future equipment requirements.

The EPA has stated that it expects that many owners of refrigeration and air-conditioning equipment will face immediate shortages of CFCs in 1996 and thereafter. Refrigerant management programs must be implemented today if continuous cooling or refrigeration for buildings or food supply systems is to be maintained. If building owners implement refrigerant management today, they have an excellent opportunity to minimize the effects of the CFC shortage.

REFRIGERANT OPTIONS

Table 2 details a number of applications that utilize alternative refrigerants available today. As an example, HCFC-123 and HFC-134 are replacing CFC-11 and CFC-12 in low and high pressure chillers, respectively, either by equipment conversions or outright replacement. R-502 refrigeration equipment is being replaced by new HCFC-22 equipment, or is being converted to accept HCFC-22 blends.

Unitary rooftop equipment that utilizes HCFC-22 will continue using HCFC-22. Longer-term, it is anticipated that candidates will be blends of two or more fluids. As an example, the air- conditioning and refrigeration industry is collectively investigating ten possible alternatives for HCFC-22 and three for R-502. Of these, over 70% of them are blends, with most of these having a flammable constituent (e.g., HFC-32) as a component. At this point, it is considered unlikely that

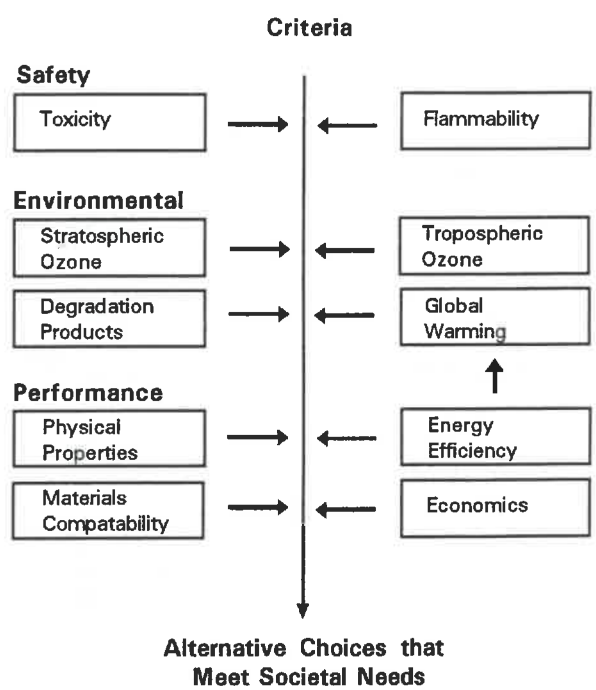

FIGURE 6. CRITERIA FOR SELECTING ALTERNATIVE REFRIGERANTS[5]

one single candidate will emerge as the obvious contender to replace HCFC-22 in all its applications. It is expected that multiple refrigerants will be needed to span all of R-22's existing applications and duty-cycles.

It should be reiterated that, based on the current phaseout schedules, the near-term refrigerant alternatives will be around for the next 25-35 years. Hence, equipment purchased today will satisfy requirements for many years. It is anticipated that the longer-term candidates (for example, HFC- 245ca) may be viable in 10 or more years, if found acceptable after testing for compatibility, toxicity, and other factors.

EQUIPMENT OPTIONS

There is a large selection of non-CFC equipment offered by many suppliers. In looking at CFC chillers, a number of manufacturers are offering centrifugals designed for operation with HCFC-22, HCFC-123, or HFC-134a. Additionally, screw, scroll, and reciprocating chillers utilizing HCFC-22 are available over a wide span of applications. Alternative cycle equipment, such as absorption and direct-fired absorption chillers, are also available over a wide tonnage range.

It should be noted that some of these alternatives may require special accommodations to comply with state and local codes. To minimize potential operator exposure levels, equipment leaks must be minimized and equipment room monitors and ventilation systems installed.

OPTIONS FOR BUILDING OWNERS

For existing equipment, the picture is a bit more complicated. One option is to contain the existing CFC charge by preventing emissions, fixing leaks, and, for low-pressure chillers, by replacing the existing incondensibles purge unit with a new, high-efficiency purge unit. Additionally, whenever service work is performed or the chiller is finally decommissioned, the CFC refrigerants should be recovered, recycled, and reclaimed.

For much field-installed equipment, it is possible to convert the existing CFC charge to a HCFC or HFC refrigerant. Careful planning is advised as the lubricant charge and some components also will need to be upgraded. Ideally, this option would be exercised on that equipment which is relatively new and has a good service record. To minimize the costs, conversion activities may be scheduled in conjunction with a major overhaul. The benefit of conversion is that future refrigerant availability has been assured for the balance of the equipment's useful life.

The third option is to replace the equipment with a new HCFC or HFC chiller, or even with an alternative cycle machine. For those sites with multiple CFC units, the oldest or most unreliable units can be decommissioned and the refrigerant banked for the needs of the remaining units. This action, coupled with a sound maintenance program that maximizes refrigerant containment, can aid in spreading the costs of unit replacement over a longer time period.

CFC phaseout may provide owners with the opportunity to achieve energy savings when conversion or replacement includes efficiency components.

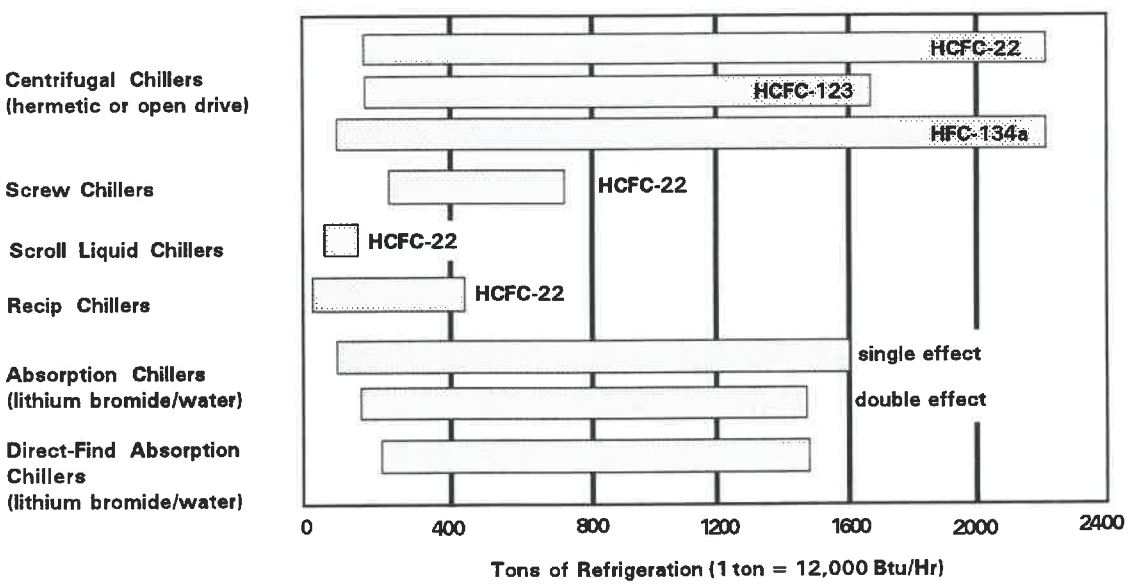

FIGURE 7. CHILLER OPTIONS

INDUSTRY RECOMMENDATIONS

The selected option is dependent on many factors. Key factors are the required current and future duty of the equipment, total installed and operating costs for both the conversion option and the replacement option, and a review of local regulations to determine code requirements.

If it is decided to convert existing equipment to operate on alternative refrigerants, the technical support of the equipment manufacturer must be sought. To attempt to perform the overhaul without the guidance of the equipment manufacturer is a blueprint for disaster. There are many materials, performance, and system considerations that need to be addressed. Additionally, the original equipment manufacturer has the proper conversion hardware required for a given machine, and can recommend service technicians that are properly trained and equipped.

To successfully avoid the chaos that will result from refrigerant phaseouts and subsequent shortages, the first order of business is to designate a knowledgeable person as a facility refrigerant manager to prepare and execute a refrigerant management program. This person should be knowledgeable about the facility's equipment, industry standards and practices, relevant federal, state and local codes, and most importantly, authorized to make the necessary decisions.

This manager will need to conduct an inventory of all equipment, including the types of refrigerants both in the equipment and in storage. This assessment should also address equipment age and operating histories. With this data, a sound refrigerant management program can be developed that will address maintenance, retrofit, and replacement considerations and timing. Other elements of a refrigerant management plan include training for service personnel utilizing certified refrigerant recovery and recycling equipment.

CONCLUSION

Although the CFC production ban is just around the corner, there is adequate time to lessen the impact if actions are taken now. Plans must be developed to introduce non-CFC technologies and, ultimately, to decommission existing CFC equipment. Refrigerant recovery, recycling, and reclamation are key components of refrigerant management plans as these activities will allow well-maintained CFC equipment to operate throughout the current decade.

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3. ARI Survey, March 1993.
4. David E. Gushee, *CFC Phaseout: Future Problem for Air-Conditioning Equipment?*, Congressional Research Service Report for the Library of Congress, 1 April 1993
5. F. A. Vogelsberg, Jr., *Key Factors in Phasing Out Ozone Depleting Substances*, Beijing International Conference on CFCs & Halon Alternatives, Beijing, China, 20 April 1993
6. ARI Table of Alternative Refrigerant Applications, April 1993.

Equipment Category	# of Units	CFC Inventory (million lbs)	Leak Rate	Make-Up Rate (million lbs)
Commercial Refrigeration	2-3 Million	50	22-25%	11-12
Commercial Chillers	67,000	80	<10%	5-8
Domestic Refrigerators	150 Million	80	2-4%	0-3.2
Auto Air Conditioners	100 Million	200	15-25%	30-50

TABLE 1. INVENTORY AND SERVICE NEEDS IN 1996[4]

Applications	Present Refrigerants	Near-Term Alternatives	Long-Term Candidates
Chillers (low pressure)	CFC-11	HFCC-123	HFC-245ca*
Chillers (low pressure)	HCFC-22 CFC-12 R-500	HCFC-22 HFC-134a HFC-134a	HFC-32 blends* HFC-134a HFC-134a
Rooftop/Commerical Air Conditioners and Heat Pumps, Residential Air Conditioners and Heat Pumps	HCFC-22	HCFC-22	HFC-32 blends*
Walk-In Coolers, Frozen Food Storage, Transport Refrigeration, and other Low-Temp Refrigeration	CFC-502 CFC-12	HCFC-22, HCFC-22 blends HFC-134a, HFC-22 HCFC-22 blends	HFC-134a HFC-125 blends* HFC-134a blends* HFC-125 blends* HFC-143a blends*
Industrial Cooling	CFC-12	HCFC-22, HCFC-22 blends	HFC-32 blends*
Low-Medium-Temp Refrigeration and Air Conditioning, Cascade Systems	CFC-13		HFC-23*
Auto Air Conditioning	CFC-12	HFC-134a	HFC-134a
Home Refrigerators	CFC-12	HFC-134a	HFC-152a, HFC-152a blends*
Marine Chillers	CFC-114	HCFC-124	

* numerous potential alternatives under investigation and development.

TABLE 2. ALTERNATIVE REFRIGERANT APPLICATIONS[6]