

# Equipment for alternative refrigerants

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Although equipment using alternative refrigerants is available, ideal refrigerants and drop-in substitutes do not exist. Accordingly, this article briefly discusses the options and considerations for the near-term use of alternative refrigerants in chillers for air-conditioning systems.

The term alternative refrigerants (as used herein) refers to those identified as substitutes for CFC refrigerants. The acronyms CFC, HCFC and HFC refer to the composition of fluorocarbon refrigerants. CFC (chlorofluorocarbon) indicates the presence of chlorine, HCFC (hydrochlorofluorocarbon) indicates the additional presence of hydrogen and HFC (hydrofluorocarbon) indicates the presence of hydrogen, but no chlorine.

The use of CFCs is being phased out under the Montreal Protocol and even more restrictive national requirements, such as the Clean Air Act Amendments of 1990 in the United States.

New alternatives include R-123 (an HCFC) and R-134a (an HFC) as replacements for R-11 and R-12 (both CFCs, respectively). To the extent that broader use of conventional refrigerants, including R-22 (an HCFC) and ammonia (R-717), can be used in place of CFCs, they are viewed as additional alternatives.

Ammonia can be used both in vapor-compression machinery and as the refrigerant in the ammonia/water, absorption-cycle pair. Water in water/lithium bromide absorption chillers also may be viewed as an alternative. Table 1 summarizes the attributes of these alternative refrigerants and the most widely applied CFC refrigerants, R-11 and R-12.

## Equipment options

Both R-11 and R-123 are low pressure refrigerants with comparatively high theoretical efficiencies. That of R-123 is approximately 2% lower than for R-11, which is currently the most common refrigerant in chillers with centrifugal (turbo) compressors.

Actual efficiencies with R-123 use may be as much as 5% lower than for R-11, with capacity reductions of 20% rather than 3% calculated for ideal cycles. The higher losses stem primarily from heat transfer characteristics, which are largely attributable to differences in surface tension.

Reductions by 5% in efficiency and 20% in capacity would be typical of retrofits, whereas 2% and 3% are targets as heat exchanger surfaces and compressors are reoptimized for R-123. Retrofit of R-11 chillers also requires replacement of components that are incompatible with R-123, primarily due to differences in solvency and, for hermetic compressors, coil fabrication.

Extensive efforts were made by manufacturers of R-11 chillers with materials suppliers to overcome the materials compatibility issues. As a result, both hermetic and open centrifugal chillers are now marketed using R-123. Use of R-123 offers a reduction in both ozone depletion and global warming potentials (by factors exceeding 50) as compared to R-11.

This reduction in global warming potential (GWP) refers only to direct effect, namely the impact of the refrigerant as a greenhouse gas. The net global warming impact also includes the much larger indirect effect, which is attributable to greenhouse gases from powering the equipment. The indirect component is a function of the equipment, application and service practices rather than an intrinsic property of the refrigerant.

Recommended maximum concentrations of R-123 (based on chronic exposure toxicity tests) require added attention to safety in handling and use of this refrigerant. Manufacturers recommend installation of leak sensors, external venting of purges, and increased provisions for ventilation.

R-134a offers similar capacity and efficiency to R-12, for which it is the primary substitute. While the ideal cycle efficiencies of these medium pressure refrigerants are lower than those of R-11 and R-123, the superior heat transfer of R-134a enables design of competitive machines.

Achieving comparable performance to R-12 requires a change in the impeller size and/or speed. Depending on the discrete

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Table 1. Attributes of Alternative Refrigerants\*

Attribute	R-11	R-123	R-12	R-134a	R-22	Ammonia (R-717)	Absorption Water/LiBr
<b>Environmental</b>							
efficiency (ideal COP)	7.78	7.63	6.91	6.77	7.06	7.28	1.4 to gas
(ideal kW/ton 40/100)	0.45	0.46	0.51	0.52	0.50	0.48	gas fired
greenhouse gas (GWP)	1,500	29	4,500	420	510	~ 0	~ 0
(GWP 100 yr)	3,500	85	7,300	1,200	1,500	~ 0	~ 0
ozone depletion (ODP)	1.00	0.02	1.00	0.00	0.05	0.00	0.00
<b>Safety</b>							
flammability (LFL %)	none	none	none	none	none	14.8	none
toxicity (TLV or =)	1,000	5-10	1,000	1,000	1,000	25	1,000
safety group (Std 34)	A1	B1	A1	A1	A1	B2	A1
<b>Cost (OEM)</b>							
current (relative \$/lb)	2.00	3.75	2.40	9.50	0.90	0.40	—
estim 1995 (1991 \$/lb)	3.75	2.75	4.25	4.75	0.90	0.40	—

\*The safety groups indicated are based on the public review draft of ASHRAE Standard 34-1989R; this revision has not been approved yet.



choices and the resultant optimization of the R-12 design, the reoptimized R-134a version may actually enjoy a slight performance and capacity advantage compared to R-12.

Ester-based lubricants generally have proven more suitable than mineral oils due to the reduced miscibility (related to the absence of chlorine) of R-134a. As for other HFCs, the ozone depletion concern is eliminated, and the global warming potential for R-134a is less than one-tenth that of R-12.

An option available for near-term use of equipment optimized for R-134a (until the cost of this refrigerant falls to projected levels) is interim charging with R-500. Use of this azeotropic blend of R-12 and R-152a (an HFC) is not viewed as viable for the long-term. Nevertheless, it offers a near-term option to limit efficiency and capacity degradation in R-134a optimized equipment, with approximately 25% lower ozone depletion and global warming potentials as compared to R-12.

The HCFC refrigerant R-22 already is widely used. It is, in fact, the most common refrigerant for many applications including window and unitary air conditioners and heat pumps as well as for very large chillers. Broader use of R-22 as an alternative is possible.

R-22 offers comparatively low ozone depletion and global warming potentials. Although suitable substitutes for R-22 have not been identified yet, its use already is restricted in some countries (notably Germany and Sweden), and production phase-out by 2030 is scheduled in the United States.

Propane (R-290, a hydrocarbon or HC), propane blends, and ammonia offer additional near-term options. While propane and ammonia are flammable, both are used in industrial applications.

The high lower-flammability limit and dispersion rate for ammonia reduce, but do not eliminate, this concern. In fact, ammonia is generally viewed as the refrigerant of choice in beverage and food processing plants due to its favorable performance (particularly at low temperatures) and competitive cost.

There are additional safety concerns with both fluids, including both the toxicity and irritant levels of ammonia and propane's potential as an asphyxiant. However, the distinctive, sharp odor of ammonia may serve as a warning of leaks in occupied areas. Materials issues also are involved because ammonia is incompatible with copper, zinc, and some plastics and elastomers.

Wider use of ammonia and of propane blends is anticipated, particularly in chillers and refrigeration equipment that are isolated from public and high-occupancy applications.

Absorption chillers, both ammonia/ water (refrigerant/absorbent) in small capacities and water/lithium bromide in larger sizes, have been used for many years. Their characteristically low efficiencies and high first-costs limit practical applications to areas where very favorable gas rates, (relative to those of electricity) are available. Rebates are offered by some gas utilities to increase usage.

Heat-driven variants (powered by steam or high-pressure hot water) also are available and are particularly attractive when otherwise wasted heat can be used. Use of absorption equipment may reduce peak electric demands, as would vapor-compression chillers integrated with thermal storage.

Whereas absorption-cycle chillers eliminate ozone depletion concerns, their net contribution to global warming (at least for direct-fired systems) is 50% to 100% higher than for vapor-compression chillers. While their refrigerants are not of concern as greenhouse gases, their low efficiency results in high indirect effect contributing to net global warming.

*Figure 1* summarizes the approximate capacities for which equipment using alternative refrigerants addressed herein are

available. Enormous investments are being made by equipment manufacturers as well as chemical and component suppliers. As shown, options for using one or more alternative fluids are commercially available in all sizes in which equipment nor-

mally is applied. Additional products will be introduced in the future.

### Conclusions

Environmental concern with ozone depletion and greenhouse gas impacts stems

from refrigerant emissions, not from actual use of these vital fluids. The primary option for environmental protection remains controlling refrigerant releases. Rational selection and use of refrigerants will mitigate the cited problems, as well as those associated with resource use and indirect global warming.

Equipment using alternative refrigerants is available, but neither ideal refrigerants nor drop-in substitutes exist; it is unlikely that these perfect solutions will be found.

This review of refrigerants and equipment options provides information on alternatives presently available. These options will change as technical advances are made and the uncertain environmental, political and regulatory outlooks unfold. □

*Author's note: This article summarizes the author's presentation at the "Consultants' Options on CFCs and Alternative Refrigerants Conference." A significant portion of the original presentation consisted of equipment illustrations, which are not included in this summary.*

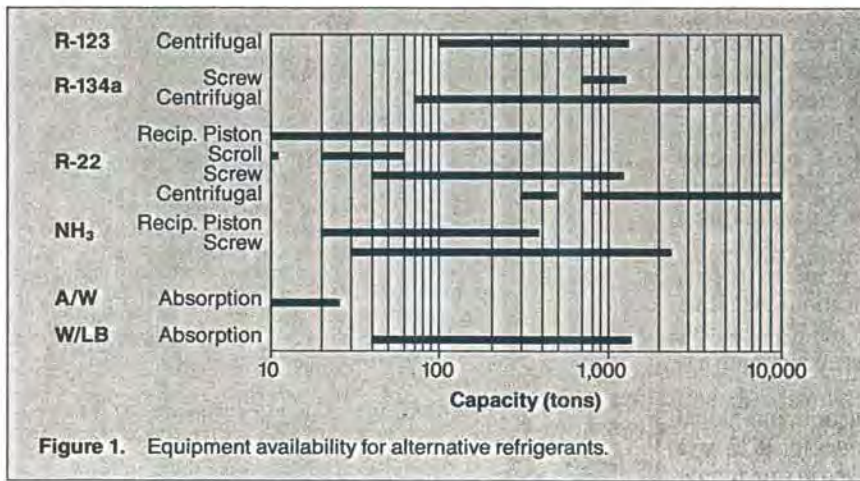


Figure 1. Equipment availability for alternative refrigerants.

## Selecting equipment and refrigerants

Because of this, it is almost impossible for every engineer in every company to

recommendations to the same client on similar projects.

months ago does not assure being well informed today.

received his B.S. in mechanical engineering from the Georgia Institute of Technology.

assume some additional risk to minimize further environmental damage. Every new