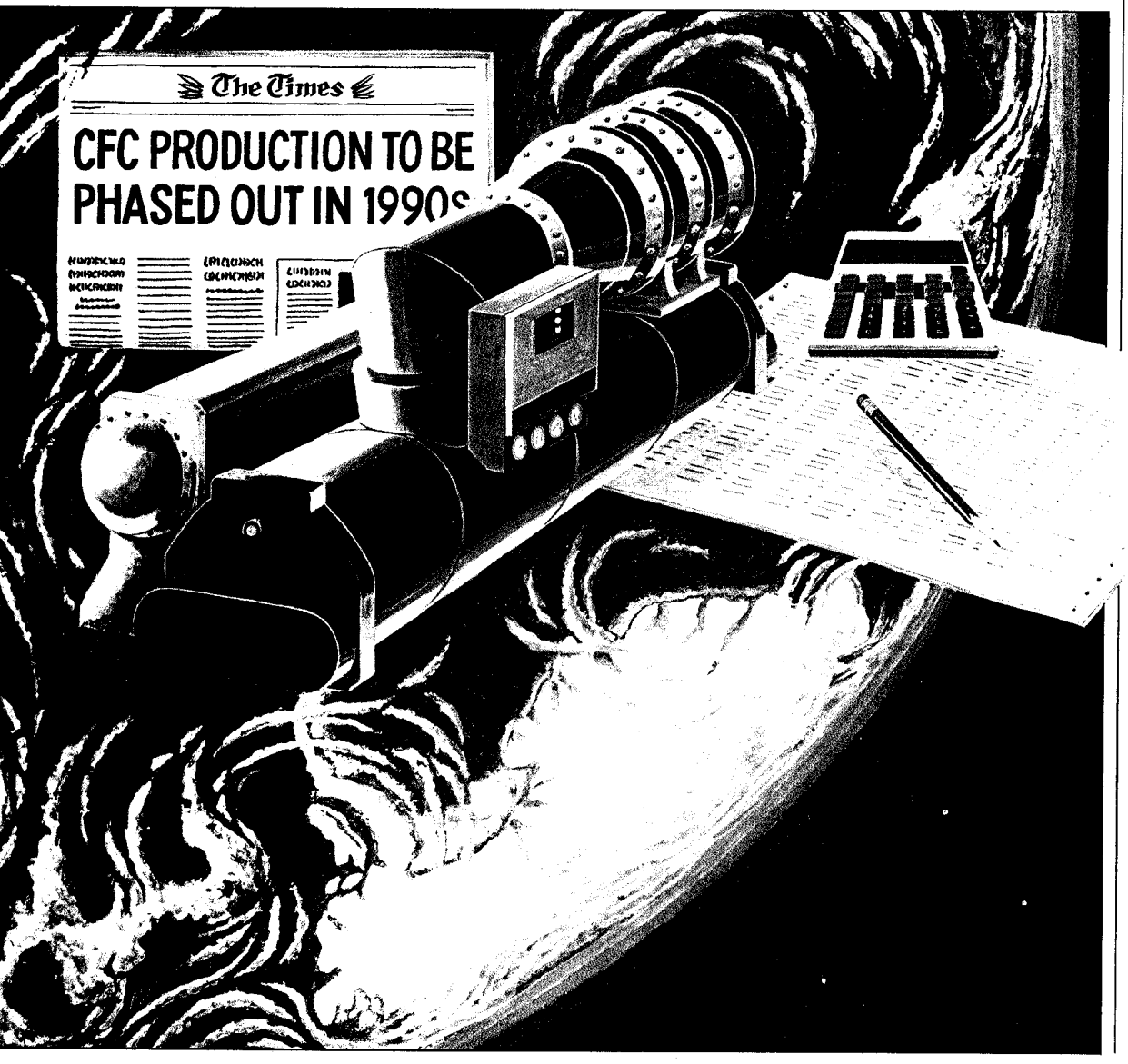
CFCs and Electric Chillers

Selecting Large Water Chillers as CFCs are Phased Out

EPRI



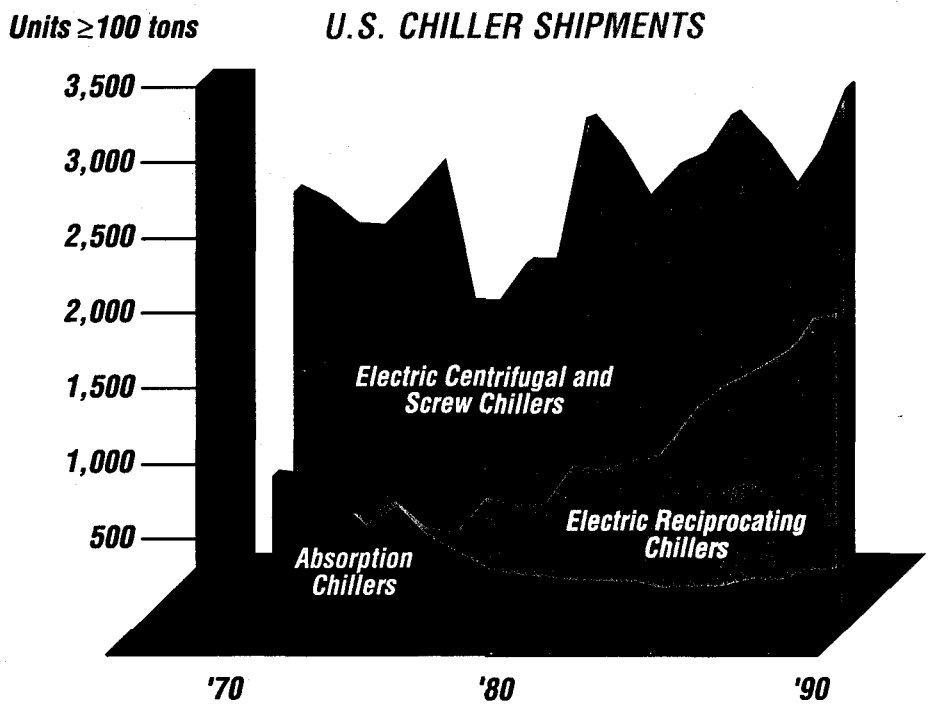
ELECTRIC
POWER
RESEARCH
INSTITUTE

Although Time-Honored Refrigerants Must Go...

Electric water chillers have always dominated the market for large commercial cooling systems because they are reliable and economical. Although several ozone-depleting refrigerants are being phased out, promising new refrigerants have been developed for use in new chillers. For the vast majority of chiller applications, electric chillers will remain the most economic choice for many decades.

For more than fifty years, electric chillers have been the technology of choice for large commercial cooling applications. In 1989, over 97% of large liquid chillers (≥100 tons) shipped in the United States used electric compressors. With low installed and operating costs and a long-standing reputation for high reliability, electric centrifugal chillers are the most popular chiller type.

Virtually all centrifugal chillers use CFCs, or chlorofluorocarbons, as refrigerants. CFCs make ideal refrigerants because they are efficient, nonflammable, nontoxic, and relatively inexpensive to produce. CFC-11 refrigerant is used in 80% of centrifugal chillers. CFC-12 refrigerant, which is used widely in supermarket refrigeration and automobile air conditioning, is also used in about 15% of centrifugal chillers. Other CFCs used as chiller refrigerants in very limited applications include CFC-500 and CFC-114.



The stability and efficiency that make CFCs such ideal refrigerants have become a cause for concern. CFC molecules are so extraordinarily stable that they do not break down until they are affected by ultraviolet rays in the upper atmosphere. Once released, however, the chlorine atoms disrupt the cycle of ozone creation and destruction in the stratosphere: A single chlorine atom may be able to destroy 100,000 ozone molecules. CFCs have also been implicated in global warming, due to their ability to trap heat in the atmosphere.

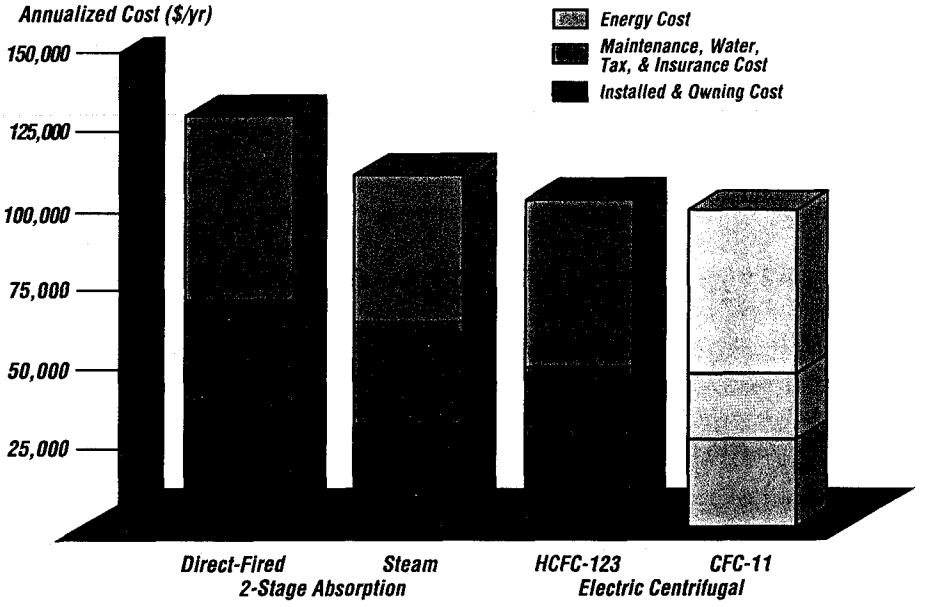
Because of these serious issues, many nations have agreed to phase out the production of CFCs and certain other ozone-depleting chemicals. The new agreement, known as the London Amendment to the Montreal Protocol, calls for industrial nations to stop producing CFCs by the year 2000.

This new international agreement only confirms the course already taken by the United States and many other industrial nations. Although these dramatic steps pose serious challenges to many industries, the purchasers of electric chillers need not be overly concerned.

...Electric Chillers Remain the Most Efficient and Economic Choice

In most large commercial applications, electric centrifugal chillers are still the least expensive chiller alternative.

- The installed cost of electric centrifugal chillers is significantly lower than for absorption chillers, because the heat-driven chillers require larger cooling water pumps and cooling towers. Even an electric centrifugal chiller sized slightly larger—to offset the possible lower capacity with HCFC-123 refrigerant—would have an installed cost lower than an absorption chiller with equivalent capacity.
- Maintenance costs for centrifugal chillers are about 30-40% lower than for absorption chillers, as the latter require more frequent replacement of mechanical components and have more tubes to replace. The use of HCFC-123 refrigerant will have a minimal impact on maintenance costs.
- Operating costs depend on relative electricity and gas rates in different regions. Even in areas with high on-peak electric rates, electric chillers using HCFC-123 can still remain the economic choice if they are installed with a cool storage system.
- All chiller cost evaluations should include the applicable costs of make-up water, property and sales taxes, and insurance. These often overlooked costs are critical in obtaining a realistic comparison between chiller alternatives.



Using conservative assumptions (listed below), overall costs for chiller operation with HCFC-123 remain significantly lower than the other non-CFC options. For a site-specific evaluation, contact your consulting engineer.

Cool storage can further reduce operating costs, ensuring the competitiveness of electric chillers in the vast majority of applications.

- During off-peak hours, chillers in cool storage systems refrigerate a storage medium such as water, ice, or eutectic mixtures. During on-peak periods, building cooling loads are served by circulating chilled liquid from storage while minimizing chiller operation.
- By deferring most or all chiller operation to off-peak periods, cool storage allows building owners to reduce peak electricity demand charges and take advantage of low, off-peak electric rates typically offered to large commercial customers.

COST ANALYSIS ASSUMPTIONS:
500-ton water-cooled chiller; 44°F leaving chilled water; 85°F entering condenser water; 1,277 equivalent full-load operating hours/year; 2,300 annual chiller operating hours

Electricity	Demand ($/kW/mo)	Energy ($/kWh)
Summer On-Peak (12h/d; M-F; 4mo/yr)	$9.00	$0.08
Summer Off-Peak	$0.00	$0.05
Winter On-Peak (12h/d; M-F; 8mo/yr)	$5.00	$0.06
Winter Off-Peak	$0.00	$0.05

Natural Gas-$0.35/therm; Water-$4.00 per 1000 gallons; Taxes/Insurance-1% of installed cost per year; Owning Cost-12% interest for 20 years

	2-Stage Absorption		Centrifugal	
	DF	Steam	CFC-11	HCFC-123
Chiller (full-load per ton)	13000 Btuh	11830 Btuh	.60 kW	.62 kW**
Chiller Auxil. (kWh/ton-op.hr.)	.024	.021	---	---
System Auxil. (kW/ton)	.239	.207	.127	.127
Water (gal/ton-hr)	6.2	6.2	4.0	4.0
Installation ($/ton)	570*	530*	422	444
Maintenance ($/ton-yr)	29	26	18	19

* after $100 / ton rebate

** chiller optimized for CFC-11 use

form within 5% of the efficiency of CFC-11, when used in a chiller optimized for CFC-11 performance. Safety testing by several manufacturers has demonstrated that the use of HCFC-123 should pose no health hazards under normal conditions.

Although HCFC-123 is a more aggressive solvent than CFC-11, new chillers that are designed for use with either refrigerant utilize component materials that are compatible with both refrigerants. Users of existing chillers designed only for CFC-11 may eventually choose to overhaul their chillers to enable the use of HCFC-123, or replace older chillers with those that are compatible with HCFC-123 refrigerant.

Several chemical manufacturers are now producing limited quantities of HCFC-123 and have announced that they will soon begin producing this refrigerant in commercial quantities. For example, DuPont is building a plant in Ontario, Canada, that will begin producing large quantities of HCFC-123 in the near term.

Because they do contribute to ozone depletion—although on a very small scale—HCFC refrigerants will also be phased out eventually. The eventual phase-out of HCFC-123 and other HCFC refrigerants should not be a factor in deciding which chiller to purchase during the 1990s.

HFC-134a: A Chlorine-Free Alternative to CFC-12 and CFC-500

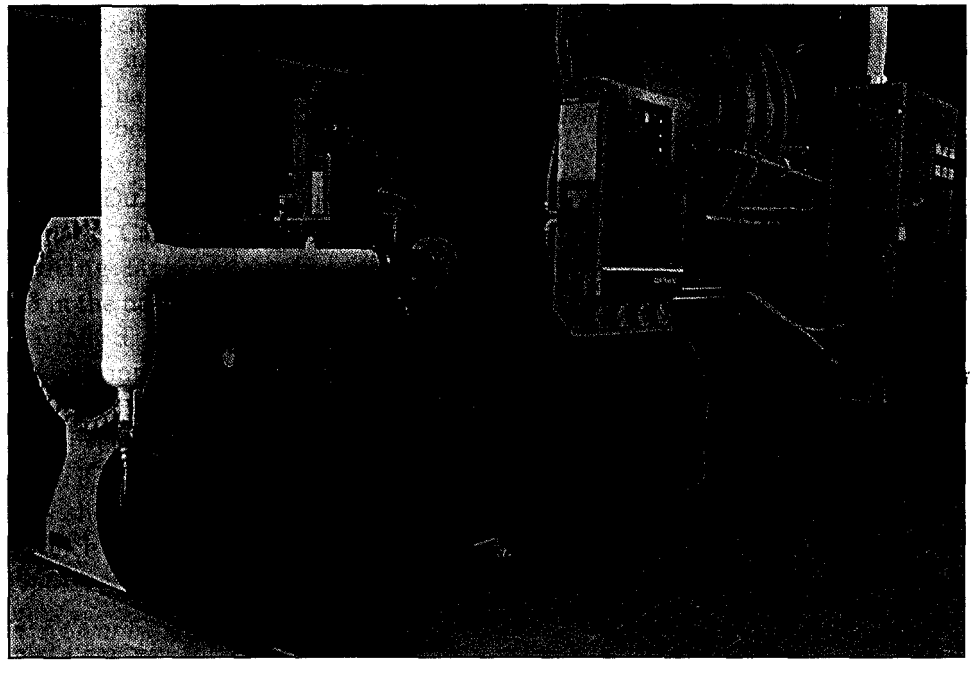
One of the most promising new refrigerants, HFC-134a was developed to replace CFC-12 in centrifugal chillers, home refrigerators, and automobile air conditioners. HFC-134a is very similar to CFC-12 in its thermodynamic and efficiency characteristics. No health or safety issues are associated with this refrigerant.

HFCs, or hydrofluorocarbons, contain no chlorine and have no effect on the ozone layer. For this reason, the London Agreement does not address HFC production. HFCs also have much lower global-warming potential than CFCs. In the long term, HFCs may become the dominant family of refrigerants, as there are no plans to restrict their production or use.

Chillers are being built today that can use HFC-134a as well as either CFC-12 or CFC-500. Users of existing chillers designed for CFC-12 will be able to switch to HFC-134a refrigerant when necessary, after making simple hardware changes.

When switching to HFC-134a, the oil may need to be changed as well—the traditional mineral-based oils are not soluble in HFC-134a. Polyalkaline glycol (PAG)-based and ester-based oils have been identified as suitable for use with HFC-134a.

DuPont has already opened its first HFC-134a manufacturing plant and is working on three more. Other refrigerant manufacturers are also designing production facilities in the United States and overseas.



This CFC-11 chiller will also accept HCFC-123 refrigerant.

...Effective Refrigerants Will Still Be Available

Conventional refrigerants will still be usable for many years.

CFC-11 and -12: Many More Years of Use

Although production of CFC refrigerants is being phased out, centrifugal chillers can continue to use them for many years. As new servicing and leak repair practices reduce CFC losses, less refrigerant will be needed to keep these chillers in operation. Also, the recovery and recycling of CFC refrigerants from retiring chillers will soon become routine practices, extending the supply of these refrigerants beyond the 1990s. This means that well-maintained CFC-11 and -12 chillers can continue to operate economically and efficiently for many more years without modifications or replacement.

	EFFICIENCY	ENVIRONMENT		PRODUCTION	
	Ton/hp	Ozone Depletion	Global Warming	Freeze	Ban
CFC-11	1.24	1.00	1.00	1989	2000
HCFC-123	1.24[1]	0.02	0.02	2015[2]	2030[2]
CFC-12	1.10	1.00	3.05	1989	2000
HFC-134a	1.10[1]	0.00	0.26	- no restrictions -	
HCFC-22	1.13	0.05	0.34	2015[2]	2030[2]

1. Estimated for systems optimized for HCFC-123 or HFC-134a
2. U.S. legislation passed November 1990

New and Existing Electric Chillers: Flexibility is the Key

Older CFC-11 and -12 chillers can be modified to accept the new alternative refrigerants. For new applications, comparably priced flexible-refrigerant chillers are now available from the major chiller manufacturers. These chillers can be charged with today's CFC refrigerants, but can also be switched to the appropriate alternative refrigerants when desired. New chillers designed to use CFC-11 will accept HCFC-123, with only small reductions in cooling capacity and efficiency. And new chillers designed for CFC-12 can use the newer HCFC-134a with little effect on capacity and efficiency.

HCFC-22: A Long Production Future

Although its very high operating pressures make it unsuitable for most centrifugal chillers, HCFC-22 is the predominant refrigerant used in screw and reciprocating chillers. As the chart on the previous page shows, reciprocating chillers in particular are an increasingly important share of the market.

HCFC-22 has only 5% of the ozone-depletion potential of CFC-11 and -12. It is now expected to be produced for another 40 years. Buyers of chillers relying on this refrigerant can be assured of its continuing availability for the expected life of these chillers.

Environmentally acceptable refrigerants are now available.

Alternative refrigerants have been developed that can replace CFC refrigerants in centrifugal chillers, with only slight changes in chiller design and minimal effects on efficiency. The new refrigerants are closely related to CFCs, but do not share their ozone-depletion potential.

HCFC-123: A Proven Alternative to CFC-11

HCFCs, or hydrochlorofluorocarbons, have only a fraction of the ozone-depletion and global-warming potential of CFCs. The added hydrogen atom makes the substance less stable, so it will break down in the lower atmosphere and have little effect on stratospheric ozone.

HCFC-123 has been identified as a suitable replacement for CFC-11 refrigerant. Similar to CFC-11 in its thermodynamic and efficiency characteristics, HCFC-123 is expected to per-

Commercial Program
Customer Systems Division

Related EPRI Publications:

Ozone: One Gas, Two Environmental Issues EPRI brochure EN.3003.12.88

The Greenhouse Effect... To What Degree? EPRI brochure EN.2003.9.89.

"CFCs: The Challenge of Doing Without." EPRI Journal, September 1989.

"Concern Over Ozone." EPRI Journal, June 1989.

"The Politics of Climate." EPRI Journal, June 1988.

For further information, contact:
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, CA 94303
(415) 855-2411

About EPRI

The Electric Power Research Institute, EPRI, was formed to apply advanced science and technology to the benefit of member utilities and their customers.

Funded through annual membership dues from some 660 member utilities, EPRI's work covers a wide range of technologies related to the generation, delivery, and use of electricity, with special attention paid to cost-effectiveness and environmental concerns.

At EPRI's headquarters in Palo Alto, California, more than 350 scientists and engineers manage some 1600 ongoing projects throughout the world. Benefits accrue in the form of products, services, and information for direct application by the electric utility industry and its customers.

EPRI — Leading Innovation in Science and Technology

EPRI

ELECTRIC POWER RESEARCH INSTITUTE

CU-2039 (1) 90