

# update

## The Refrigerant Shift in Centrifugal Chillers: From HCFCs to HFCs

### Overview

*In 1987, the Montreal Protocol mandated a phase-out schedule for chlorofluorocarbons (CFCs), a family of refrigerants linked to ozone depletion. This agreement was later amended with a phase-out schedule for another class of refrigerants – hydrochlorofluorocarbons (HCFCs). Then on September 21, 2007, twenty years after the Montreal Protocol was authored, the protocol's signatories agreed to accelerate the end of HCFCs.*

Over 80% of centrifugal chillers currently manufactured employ HFC-134a.

*The acceleration was possible because, in the intervening years, environmentally responsible alternatives to HCFCs had been developed, namely hydrofluorocarbons (HFCs). Because HFCs address ozone-depletion, global-warming, and safety issues, accelerating the phase-out of HCFCs became both economically and environmentally beneficial. Consequently, over 80% of centrifugal chillers currently manufactured employ HFC-134a, the proven alternative to HCFC-123, HCFC-22, CFC-11 and CFC-12 in centrifugal chillers.*



In the centrifugal-chiller marketplace, customers are turning away from HCFC-123 and choosing HFC-134a refrigerant instead.

### The Montreal Protocol's HCFC phase-out picks up speed

In 1987, an international gathering of governmental representatives signed the Montreal Protocol, an environmental agreement that ended production of CFC refrigerants in 1996. This mandate was based on findings that chlorine molecules from CFCs depleted stratospheric ozone.

In 1992, the Copenhagen Amendment to the Montreal Protocol extended the phase-out to another class of refrigerants – HCFCs – because they also contain chlorine and have an ozone-depletion potential (ODP). This amendment has been implemented in the U.S. by the Environmental Protection Agency (EPA) under Title VI of the Clean Air Act.

The HCFC phase-out schedule included HCFC-22, which is used in screw and scroll chillers, and HCFC-123, which is used in centrifugal chillers. The HCFC family had been designated by the Montreal Protocol as “transitional refrigerants” to be used until refrigerants with zero ODP could be developed.

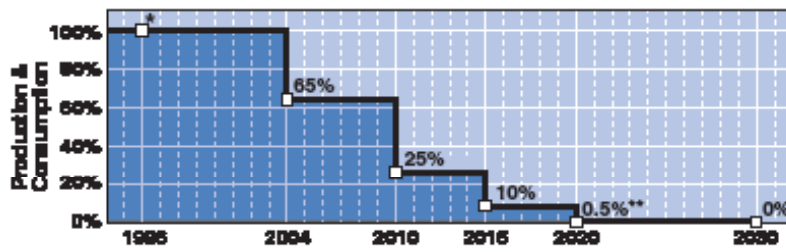
Since then, environmentally responsible alternatives have been developed in a new category – hydrofluorocarbon (HFC) refrigerants. Therefore, on September 21, 2007, twenty years after the Montreal Protocol was signed, representatives from 191 countries met and decided to accelerate the phase-out of HCFCs.



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The new schedule is aggressive. In 2010, developed countries will reduce HCFC production and consumption from 35% to 25% of the cap, and in 2015 to 10%. In 2020, HCFCs can no longer be used in new equipment. The only HCFC production allowed after that is a "service tail" of 0.5% of the cap (Figure 1). The necessity of a "service tail" will be reconsidered in 2015, so there is no guarantee of a service supply of HCFCs past 2020.

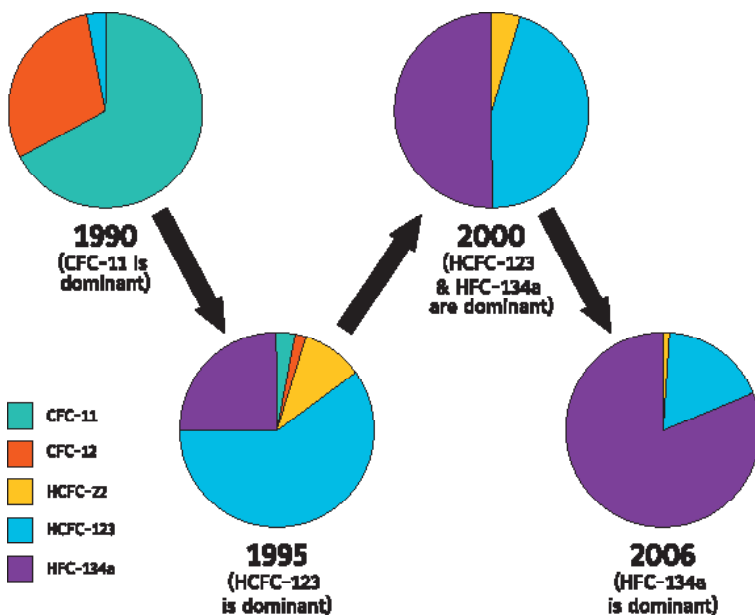
**Figure 1: 2007 Revised Phase-out Schedule for Production and Consumption of HCFCs in Developed Countries**



\* 100% = 2.8% of CFCs in 1989 plus 100% of HCFCs in 1989  
 \*\* Necessity of 0.5% "service tail" to be reconsidered in 2015

Within many developed countries, however, the phase-out of HCFC refrigerants is actually proceeding faster than the 2007 accelerated schedule. The European Union ended HCFC refrigerant production and consumption in new equipment in 2001 and plans to totally cease HCFC use, including service, in 2015. In the U.S., the EPA adopted an accelerated schedule to end HCFC-22 production and consumption in new equipment by 2010.

**Figure 2: Refrigerant Shift for Centrifugal Chillers**



**Impact of HCFC phase-out on centrifugal chillers**

The early move away from HCFC refrigerants has been made possible by the development of HFC refrigerants. In centrifugal chillers, the most popular choice is HFC-134a.

There is no guarantee of a service supply of HCFCs after 2020.

Figure 2 shows the shift in market share for centrifugal-chiller refrigerants since 1990. Over 80% of centrifugal chillers now being manufactured employ HFC-134a. Moreover, all major manufacturers now offer HFC-134a centrifugal models. As a result, HFC-134a production has reached over 200,000 metric tons annually and is increasing. In comparison, HCFC-123 production is estimated to be 4,000 to 6,000 metric tons annually and is decreasing.

**Why HFC-134a is the superior refrigerant choice**

Ever since a link was established between refrigerant chemistry and its impact on the environment, refrigerants have been evaluated not just by performance metrics, but also by their ODP, global-warming potential (GWP), and safety. After evaluating these parameters, the market has chosen HFCs over HCFCs.

*Ozone-depletion issue*

The ODP metric is the amount of degradation to the ozone layer caused by a substance compared to trichlorofluoromethane (CFC-11), which was given an ODP rating of 1.0.

The continued pressure to accelerate the HCFC phase-out is due to their ODP ratings. HCFC-123 contains chlorine and has an ODP rating of 0.02. HFC-134a contains no chlorine and has zero ODP, indicating no affect on ozone layer (Figure 3).

**Figure 3: Refrigerant ODP values**

Refrigerant	ODP
HCFC-22	0.05
HCFC-123	0.02
HFC-134a	0

Because HFC-134a has zero ODP, accelerating its substitution for HCFCs is believed to speed up benefits to the environment.

Writing in the *New York Times*, Keith Bradsher reported, "The accelerated phase-out of HCFC refrigerants could speed up the healing of the ozone layer by five years."<sup>1</sup>

DuPont, the only North American manufacturer of HCFC-123, supports acceleration of the HCFC phase-out. According to Mack McFarland, Environmental Manager of DuPont Fluoroproducts, "Done properly, this acceleration can yield significant environmental benefits for both the ozone layer and climate."<sup>2</sup>

In this view, hastening the adoption of the HCFC-123 alternative – HFC-134a – is a move that brings positive environmental results.

#### *Global-warming issue*

Scientists see a linkage between ozone-depleting substances (ODS) and global-warming. They believe that addressing ODP also addresses global warming (also known as "climate change").

A March 2007 study, published in the *Proceedings of the National Academy of Sciences*, found that "the Montreal Protocol will have reduced the net global-warming-potential-weighted emissions from ODS in 2010 by 5-6 times the reduction target of the first commitment period of the Kyoto Protocol (2008-2012), an international effort to cut emission of carbon dioxide and other greenhouse gases."

A 2007 United Nations Environmental Program (UNEP) publication, *Achievements in Stratospheric Ozone Protection, Progress Report 1987-2007*, indicated: "The reduction in ODS between 1990 and 2000 has yielded a net integrated reduction of approximately 25 billion tons of weighted global-warming gases. These significant reductions make the Montreal protocol one of the prime contributors in the fight against global warming."

So, reducing the supply of ODS in the atmosphere also has a beneficial effect on global-warming. What, then, is the impact of the GWP rating? To find out, we need recognize that a refrigerant's total effect on global warming has both a "direct" effect and an "indirect" effect.

**Figure 4: Refrigerant GWP values**

Refrigerant	GWP
HCFC-22	1700
HFC-134a	1300
HCFC-123	120

The direct effect of a refrigerant on global warming is its interaction in the atmosphere. It is represented by a GWP rating (Figure 4). GWP is a measure of how much a given mass of greenhouse gas is estimated to contribute to global warming. The GWP metric is the ratio comparing the results of emissions from one kilogram of a greenhouse gas to one kilogram of carbon dioxide over 100 years.

However, the direct effect can only occur if the refrigerant leaks out of chiller. In daily operation, leakage is miniscule. Accordingly, the direct effect is very small. That is because chillers manufactured today are tighter, thereby minimizing leakage, regardless of refrigerant.

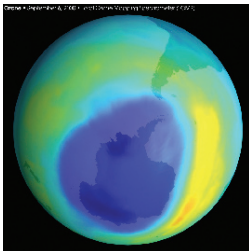
The indirect effect of a refrigerant on global warming is a result of how much carbon dioxide is produced by the fossil-fuel power plant to generate electricity to run the chiller. The less efficient the chiller, the more electricity it consumes, and the more carbon dioxide produced. The amount of electricity a chiller consumes has a huge impact on greenhouse gas emissions. Accordingly, the indirect effect is the most important global-warming factor, comprising 95-98% of the total effect.

There were proposals made at the September 2007 meeting to exempt HCFC-123 from early phase-out. The claim was that HCFC-123 would produce less global warming because of its theoretical thermal-efficiency advantage of about 3% compared to HFC-134a, and the full-load efficiency of the HCFC-123 chiller. This is quite misleading, and the protocol's signatories rejected those proposals.

Chiller efficiency is determined by mechanical efficiency, driver efficiency, heat-transfer efficiency, refrigerant efficiency, and control technologies. Though HCFC-123 theoretically has a better thermal efficiency than HFC-134a, its volumetric efficiency and heat-transfer efficiency are both worse. While refrigerant efficiency does have an impact on chiller efficiency, it is only one factor. In general, chillers of equal efficiency can be supplied, regardless of the refrigerant used.

Based upon the actual sales of equipment for many years, there is no difference in efficiency between HCFC-123 or HFC-134a chillers actually purchased for any given building. This is not a surprise. It is an expected outcome since both are competitively sold to meet a specified energy performance demanded in a particular project. Hence, the indirect effect of a refrigerant on global warming is essentially the same for all centrifugal chillers, regardless of the refrigerants used.

### There is no difference in efficiency between HCFC-123 or HFC-134a chillers actually purchased.



The Montreal Protocol signatories believe the accelerated phase-out of HCFC refrigerants will have a positive impact on the Earth's ozone hole, shown in blue.

(Image courtesy the TOMS science team and the Scientific Visualization Studio, NASA GSFC)

For all these reasons, the GWP ratings of the various refrigerants play a minimal role in climate change. In theory, the differences look large but, in practice, they have little impact on global warming.

#### Safety issue

Just as important as the global environment is the environment inside the equipment room. On this matter, HFC-134a is actually safer than HCFC-123. It has a toxicity classification of A1, compared to the B1 classification for HCFC-123.

#### Conclusion

On September 21, 2007, the Montreal Protocol signatories again showed their commitment to treating ozone depletion as the environmental problem at the "head of the line" for international

### All major manufacturers offer HFC-134a centrifugal chillers in their product line.

action. They accelerated the phase-out of HCFCs. The shift away from the use of HCFC-123 in centrifugal chillers is being made possible because the alternative – HFC-134a – addresses ozone-depletion, global-warming, and safety issues. Over 80% of centrifugal chillers manufactured today are successfully using HFC-134a. Consequently, all major manufacturers offer HFC-134a centrifugal chillers in their product line.

Your investment in a new centrifugal chiller should account for the continuing move away from HCFC-123. These chillers have a 30-year lifespan. The accelerated phase-out schedule adds a high degree of uncertainty in purchasing an HCFC-123 chiller. Therefore, for our customers, Johnson Controls continues to support the use of HFC-134a as a proven alternative to HCFC-123 in centrifugal-chiller specifications.

#### References

1. Bradsher, Keith. "Push to Fix Ozone Layer and Slow Global Warming." *New York Times* 03 15 2007 1-3. 05 29 2007 <http://www.nytimes.com/2007/03/15/business/worldbusiness/15warming.html?ex=1331611200&en=a7b2322b5540e4fd&ei=5088&partner=rssnyt&emc=rss>
2. Mack McFarland, Environmental Manager, DuPont Fluoroproducts, in a public letter to Dan Reifsnnyder, Deputy Assistant Secretary for Environment, Bureau of Oceans and International Environmental and Scientific Affairs, May 4, 2007.
3. *Proceedings of the National Academy of Sciences*, The importance of the Montreal Protocol in protecting climate," <http://www.pnas.org/cgi/reprint/0610328104v1.pdf>

