P-04398 28224 PDF

HCFC-123'S USE IN CHILLERS

By Eugene L. Smithart, PE
Director of Marketing for Heavy Refrigeration
Centrifugal and Absorption Business Unit
Commercial Systems Group, The Trane Company, La Crosse, WI

Without question, there has been a tremendous amount of information...and misinformation...surrounding one of the industry's most volatile topics: The CFC Issue. This paper provides answers to critical questions about one specific aspect of the CFC issue, **"The use of the alternative refrigerant HCFC-123 in centrifugal chillers."**

1. Have the HCFC-123 refrigerant compatibility issues been solved?
2. Is HCFC-123 commercially available?
3. If so, at what price?
4. Is HCFC-123 safe to use and handle?
5. How can microprocessor-based technology improve the safety of all refrigerants?
6. What affect will increased emphasis on global warming have on the refrigerant issue?

Compatibility

Compatibility was one of the most difficult challenges early in the process of converting to alternative refrigerants. HCFC-123 was compatible with the traditional lubricating oils, but was not compatible with seals, gaskets, etc. HFC-134a was compatible with most seals, gaskets, etc., but was not miscible with the traditional mineral oils.

In three short years, essentially all of these problems have been solved by all major centrifugal chiller manufacturers. The centrifugal chillers that ship today typically have dual capabilities, which means they are compatible with both traditional as well as alternative refrigerants. That dual capability allows chillers to either be shipped with the alternative refrigerant or to be converted to the alternative refrigerant at some time in the future. While the latter typically requires a change in a refrigerant metering system's impellers and a gear-driven system's gear set, the conversion costs are significantly reduced when compared to the conversion of noncompatible machines.

Availability

The availability of the alternative refrigerants was a major concern even as little as a year and a half ago. Today, that concern is also a thing of the past. What helped bring about this change? A number of things. However, most notable is the opening of chemical plants specifically built to produce alternative refrigerants. For example, in early 1991 Du Pont announced the opening of their Maitland, Ontario, Canada, plant for HCFC-123 and their Corpus Christi, Texas, plant for HFC-134a. With the opening of these plants, and others like them built by other chemical manufacturers, the alternative refrigerants are now available not only through direct ship from OEM's but also through local refrigerant distribution channels. Availability is no longer a road block to the acceptance of alternative refrigerants.

Relative Cost

The question that frequently follows "Is it available?" is "How much does it cost?" One of the best ways to answer that question is to compare the price of alternative refrigerants on a relative price basis.

Figure 1: CFC-11 1991 Price Basis Of Comparison

	1991	1993	1996
CFC-11	1.0	1.6	2.2
HCFC-123	1.4	1.2	0.9
HFC-134a	4.0	2.8	1.8

Figure 1 uses CFC-11 as the basis of comparison and projects relative cost of both CFC-11 as the alternative refrigerants over the next five years. Figure 1 allows for some interesting observations:

1. HCFC-123 is projected to be less expensive than CFC-11 by 1993.
2. HCFC-123 is also projected to remain less expensive than the other major alternative refrigerant, HFC-134a, for the foreseeable future. The prime reason for this cost difference is that production of HFC-134a requires a two-step chemical process. Step one produces a chemical like HCFC-123, then the process must be repeated to produce the final product. For this reason, HFC-134a will continue to cost between 50 and 100 percent more than HCFC-123 for at least the next five to seven years.

Safety

One of the questions facing HCFC-123 is that of safety. On June 24, 1991, the Program for Alternative Flourocarbon Toxicity (PAFT) testing announced preliminary results from a two-year inhalation toxicity test. These results indicated that, while the test animals actually lived longer than their control group counterparts, a higher incidence of benign tumors were found in the pancreas and testes of some of the male rats. It is important to review both of these test results to understand their safety implications.

Longer life: The PAFT studies showed that the survival rate of the test animals actually increased with exposure levels; not by a little, but by a significant margin. For example, the survival for the male rats in the highest exposure group (5000 ppm) was more than double that of the control group which was not exposed to any HCFC-123. In the case of the female test animals, the survival rate was even greater. While not totally understood at this point in the testing, a March 13 PAFT report cited slight weight loss, lower levels of cholesterol and lower levels of triglycerides as probable reasons for the increased survival rates. Further, of the tumors found:

- All were nonmalignant
- All occurred late in life
- None had life-shortening effect (in fact, just the opposite)
- Even the group not exposed to HCFC-123 developed the same kind of tumors, just not in the same numbers.

However, the fact remains that the study did indicate the presence of benign tumors. Because of this, Du Pont (the industry's prime supplier of HCFC-123) reduced HCFC-123's allowable exposure limit (AEL) from 100 parts per million (ppm) to 10 ppm as a precautionary measure.

The critical question was "Can a refrigerant with an AEL of 10 ppm safely be used in hermetic centrifugal chillers?"

In a word, **yes**. However this conclusion is the result of exhaustive testing done both before and after the June 24 announcement. Testing that included scientifically conducted measurements of equipment room concentrations.

The tests conducted prior to the June 24 announcement indicated the equipment room concentrations for hermetic centrifugal chillers were below one ppm, which compared to an AEL of 10 ppm, offering a 10 to one margin of safety. However, with the lowering of the AEL to 10 ppm, Trane and Du Pont jointly agreed to commission a study to even more rigorously measure the refrigerant concentrations in all existing HCFC-123 equipment rooms.

The results of these scientifically conducted tests confirmed the original findings which showed that the time weights average concentrations were below 1 ppm. In fact, as shown in Figure 2, as long as proper refrigerant handling procedures and ASHRAE Standards 15R guidelines (the revised safety code for mechanical refrigeration) were followed, the time-weight average concentrations were typically below .4 ppm, which was the minimum level of quantification of the instrumentation used to conduct the scientific measurements.

Figure 2: HCFC-123 Equipment Room Concentrations

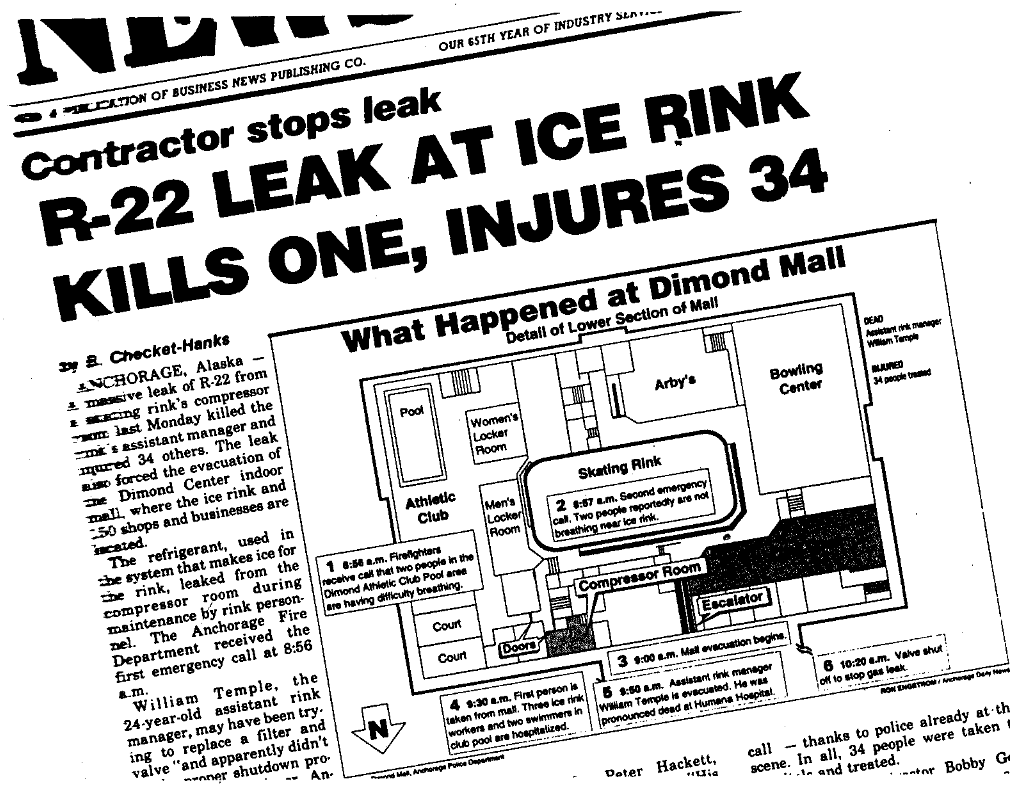
Location	Measured PPM (TWA) Normal Operation
Abilene, Texas	<0.38
Austin, Texas	<0.38
Blacksburg, South Carolina	<0.35
Carson, California	0.64
Charleston, South Carolina	<0.33
Indianapolis, Indiana	<0.40
Los Angeles, California	<0.39
Omaha, Nebraska	<0.40
Orlando, Florida	<0.50
Rootstown, Ohio	<0.39
St. Peters, Missouri	<0.39
Melbourne, Florida	<0.56

These tests showed that the concentrations were typically at least 25 times below the AEL of 10 ppm, providing even greater margins of safety than originally projected.

Separate tests were also conducted by the EPA on a variety of installations. The EPA tests produced similar undetected results. The EPA-sponsored report stated "The lack of detectable concentrations of HCFC-123 vapor appears to reflect the resistance of chillers and recycling equipment to developing leaks ... The results demonstrate that worker exposure to HCFC-123 can be maintained well below the recommended 10 ppm-8 hour TWA limit as long as appropriate chiller equipment and recommended recycling procedures are used."

To fully appreciate the margin of safety referenced in both studies, one needs to understand the definition of AEL. The AEL is that concentration that a typical operator can be exposed to eight hours a day, 40 hours a week for 50 plus years without experiencing any harmful effects. Because most operators do not spend a full 40 hours a week in the equipment room, the margins of safety are even further enhanced.

To put these findings into prospective, it's also important to understand that the greatest danger of all refrigerants is not their toxicological effects. Rather it is asphyxiation. All halogen refrigerants are heavier than air, they all displace oxygen and, in an enclosed space, one can drown in refrigerant just as one can drown in water. This fact was tragically underscored by an accident in Alaska. One person was killed by asphyxiation and several others injured when high-pressure HCFC-22 spewed from an ice-making machine not only into the equipment but also into the adjacent mall area.


OF BUSINESS NEWS PUBLISHING CO.

OUR 65TH YEAR OF INDUSTRY SERVICE

Contractor stops leak

R-22 LEAK AT ICE RINK KILLS ONE, INJURES 34

By B. Checket-Hanks

ANCHORAGE, Alaska — A massive leak of R-22 from a skating rink's compressor room last Monday killed the rink's assistant manager and injured 34 others. The leak also forced the evacuation of the Dimond Center indoor mall, where the ice rink and 150 shops and businesses are located.

The refrigerant, used in the system that makes ice for the rink, leaked from the compressor room during maintenance by rink personnel. The Anchorage Fire Department received the first emergency call at 8:56 a.m.

William Temple, the 24-year-old assistant rink manager, may have been trying to replace a filter and valve "and apparently didn't ... proper shutdown pro- ... An-

... Peter Hackett, ... call — thanks to police already at the scene. In all, 34 people were taken to ... and treated. ... Bobby Gor-

This is where low-pressure refrigerants offer a safety advantage. If a low pressure chiller should happen to develop a break or sight glass, for example, air will normally leak in. If a medium or high pressure machine should happen to break a sight glass, the refrigerant will rush out. Because of this, low-pressure machines have a much lower chance of a catastrophic loss of refrigerant to the equipment room that enhances its ability to be applied safely.

Bottom line: the issue of whether a centrifugal chiller can be safely applied with a refrigerant with an AEL of 10 ppm comes down to the proper design and operation of the equipment room. Clearly, as long as the equipment room is properly designed...which means adhering to ASHRAE Standard 15R guidelines...and the proper refrigerant practices are followed, there is conclusive proof that HCFC-123 with an AEL of 10 ppm can safely be applied in hermetic centrifugal chillers.

Microprocessor-Based Monitoring

One of the original questions relative to HCFC-123 when its AEL was lowered to 10 ppm was "Are there sensors competitively priced and readily available that can monitor in the 0-10 ppm range?" The answer is yes. In fact, advancements are being made that will allow the microprocessor-based sensor to be tied into the building automation system which is also typically microprocessor-based.

There are a number of reasons why the monitoring of refrigerants may become a standard practice for all refrigerants. For example, this level of control will not only sense the refrigerant concentrations and initiation of necessary alarms, but will also automatically dial out any alarms to a service company. It can provide an inexpensive means by which a trained expert can constantly overlook equipment room operation with the ability to respond quickly, if there is a problem. This concept is often an opportunity to improve the safety of all refrigerants.

Using this concept allows the refrigerant concentrations to be documented, providing help in a number of ways:

1. To help employees feel comfortable that they are working in a safe environment.
2. To document via printed reports that refrigerant concentrations were consistently maintained below the appropriate allowable exposure limits (AEL).
3. Pending EPA regulations for emission controls, recovery and recycling may include requirements for verification of operating procedures that control CFC and HCFC equipment room emissions. Automated reports can provide unquestionable documentation that even minute levels of refrigerant concentrations have been monitored and recorded.
4. This level of refrigerant monitoring provides an extra measure of safety for all refrigerants. Oxygen deprivation sensors are required by BSR/ASHRAE 15-1989R for "A1" refrigerants and are typically set to alarm when the percentage of oxygen is less than 19.5 or 195,000 parts per million. By monitoring refrigerant levels with highly accurate sensors, it is possible to provide an extra margin of safety for all refrigerants.
5. Survey after survey has shown that leaks are the number one cause of refrigerant loss to the atmosphere. Monitoring is an excellent way to uncover even the most minute refrigerant leaks so they can be detected early and repaired.

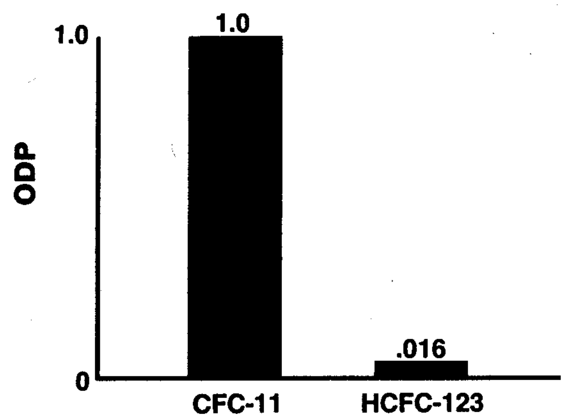
The Real Issues

Today, just as before the recent HCFC-123 announcements, the real issues are ozone depletion, global warming and energy efficiency. This is the main reason why HCFC-123 has received support from noted environmental authorities such as the U. S. Environmental Protection Agency (EPA). To better appreciate the environment balance offered by HCFC-123 each of these major environmental issues will be examined separately.

Ozone Depletion

At the 1990 International CFC and Halon Alternatives Conference, John Hoffman, director of the division of global change for the EPA, provided the information in Figure 3. Mr. Hoffman used this chart to underscore his basic premise, "As long as proper recycling and recovery techniques are used, HCFC-123's use in chillers would have little, if any, impact on the stratospheric ozone. From an ozone depletion standpoint, HCFC-123, which has an ozone depletion factor of only .016, is seen as an environmentally acceptable alternative."

Figure 3: Ozone Depletion Potential



Global Warming

There are two aspects of global warming: The direct effect and the indirect effect. Of the two, the indirect effect is more significant. However, current projections are that both will continue to play a role in the U. S. Global warming efforts. Because of that, this paper will look at HCFC-123 from both direct and indirect effect perspectives.

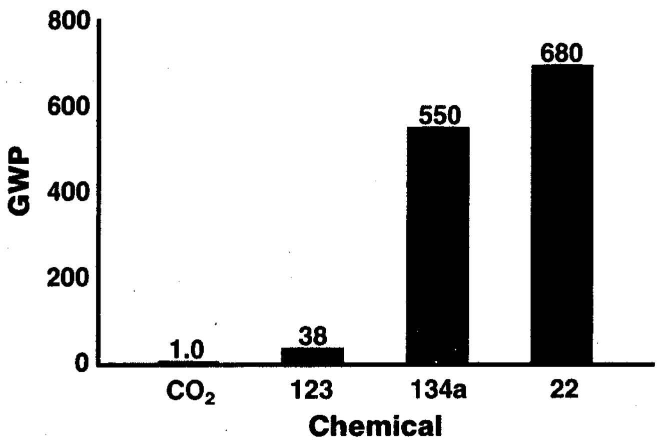
The **direct effect** of a chemical is best described as its ability to allow the solar energy to pass but trap the infrared rays of heat, which is precisely how the glass on a greenhouse works, hence the name the greenhouse effect. In the past, the greenhouse warming potential of the various chemicals was most frequently displayed using CFC-11 as the base, as shown in Figure 4. In this type of comparison, HCFC-22 looks favorable with a greenhouse warming potential of over 60 percent less than CFC-11. And HFC-134a looks even better with a greenhouse warming potential of over 70 percent less than CFC-11.

Figure 4

	Ozone Depletion Potential	Greenhouse Warming Potential
CFC-11	1.0	1.0
CFC-12	1.0	3.05
CFC/HFC-500	0.75	2.27
HCFC-22	0.05	0.37
HFC-134a	0.0	0.285
HCFC-123	0.016	0.019

However, at the 1991 ASHRAE convention, the most frequent basis of comparison was no longer CFC-11. Rather, it was the gas most frequently associated with global warming, CO_2. Looking at the data in Figure 5, one obtains an entirely different perspective, even though the ratios are the same as in the CFC-11 based analysis. Looking at this comparison, one can see why HCFC-123 is considered to be the most benign direct effect global warming alternative refrigerant.

Figure 5: Global Warming Potential



Energy Efficiency

Energy efficiency has always played a role...sometimes more, sometimes less...in the purchase of large water chillers. This is proper in that most chillers will typically consume enough power in less than two years to equal their first cost. However, in the near future energy efficiency is projected to play an even more important role because of the indirect effect of global warming.

The indirect effect simply acknowledges that, worldwide, approximately 60 plus percent of the electricity is produced by the burning of fossil fuel. This means that for every additional kwh consumed more CO_2 is exhausted up the power plant's smoke stack. As the concern over global warming grows, so will the need for even more efficient products and systems.

An increasingly important aspect in the search for improved chiller efficiencies will be efficiency of the refrigerants themselves. One way to compare this refrigerant efficiency difference is to analyze the theoretical hp/ton, Figure 6.

Figure 6

Refrigerant	Power (HP)	Relative Power
CFC-11	.606	100%
HCFC-123	.618	102%
HCFC-22	.668	110%
CFC-12	.682	112%
CFC/HFC-500	.684	113%
HFC-134a	.696	115%

Performance rated at 40 F evaporating, 100 F condensing.

There are several comments that can be made relative to these charts.

1. In North America alone there are over 80,000 centrifugal chillers. Of these 80,000 chillers, over 80 percent use CFC-11. Clearly one of the major reasons why is because CFC-11 was, and still is, the most efficient refrigerant.
2. On a theoretical basis, HCFC-123 is only two percent lower in efficiency than the industry leader CFC-11. And it is significantly better than other alternative refrigerants.

While these observations are accurate, there are two areas that must be understood if the reader is not to be mislead.

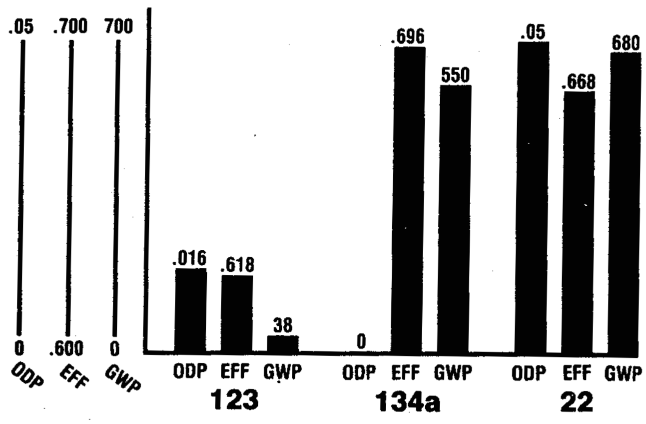
1. This comparison is made on a theoretical hp/ton basis. Is there a difference between theoretical and actual? Absolutely. For example, differences can exist in compressor efficiencies, motor efficiencies and approach temperatures, to name a few. However, as energy efficiency becomes more and more important, manufacturers will be driven to common compressor efficiencies, common motor efficiencies, common approach temperatures, etc. This will mean the theoretical hp/ton will play an important role in determining the efficiency of the chiller, hence the validity of using theoretical hp/ton for this comparison.
2. Today's HCFC-123 chillers are not yet meeting the efficiency goal of only two percent difference between a chillers performance on CFC-11 versus HCFC-123. The actual number is more like five percent. However, major strides are being made in the industry as a whole and within the next 18 months alone this two percent difference appears very attainable.

Without question, HCFC-123 holds outstanding promise from an efficiency standpoint which is the driving force behind the indirect effect of global warming.

The Environment Balance

Many have asked "Why HCFC-123?" When all three elements of the environmental balance...ozone depletion, global warming and energy efficiency...are considered, the answer is simply that it offers the most environmentally balanced alternative. To highlight the environmental balance offered by HCFC-123, Figure 7 presents all three major environmental issues for all of these alternative refrigerants.

Figure 7: Why HCFC-123?



Does this mean that HCFC-123 is the only alternative refrigerant of the future?

While HCFC-123 is the most balanced alternative refrigerant, we are not suggesting that it is the only alternative refrigerant of the future. We do suggest that today owners and system designers have good choices that include:

1. If preferred low pressure machines with CFC-11 yesterday, they have a good choice in HCFC-123.
2. If they preferred medium pressure machines with CFC-12 or 500 yesterday, they have a good choice in HFC-134a.
3. If they preferred high pressure machines with HCFC-22 yesterday, they have a good choice in continued use of HCFC-22.

In the rush to make refrigerant decisions, engineers and perspective buyers must not overlook the basics that have always played an important role in the selection of large water chillers:

- o Efficiency
- o Reliability
- o Proven Track Record
- o Trained Local Service Personnel
- o Readily Available Parts
- o Acceptable Sound Levels

A chiller represents a major purchase decision. Clearly, the refrigerant issue is important. And today's designers have a range of acceptable alternatives. It is imperative, however, that the refrigerant issue not cloud other issues that will remain long after the refrigerant question is resolved.

*