P 05493

Converting Chillers to CFC-Free Refrigerants

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By now, plant engineers know that chlorofluorocarbons (CFCs) are becoming dramatically more expensive, and that they will be phased out of production within two years. Some major refrigerant manufacturers plan to stop producing most CFCs by the end of this year.

For plants using CFCs as chiller system refrigerants — typically, R-11, R-12, and R-500 — the situation is critical. The reliability of process cooling systems cannot be jeopardized, and the prospect of doing without comfort cooling is equally untenable.

Throughout industry, chiller maintenance and service have already taken on a new level of importance. Periodic leak-checking, installation of high-efficiency purge units, and improved refrigerant handling procedures are standard. Some firms have undertaken aggressive conversion/replacement programs. But the pace of change is not nearly rapid enough to prevent serious, widespread CFC shortages. Even with active CFC-reclamation, the chemical industry predicts a shortfall of some 1 to 3 million pounds of R-11 by 1996.

For plants that can obtain R-11, the cost will be high. CFC prices have increased more than tenfold in the last four years. By 1996, a pound of R-11 could cost well over $20.

Although fewer installed chillers use R-12 and R-500, they, too, will be affected by rapidly diminishing supplies and sharply rising costs. The chemical industry predicts at least 1000 chillers will be left without a service supply of R-12 by 1996.

Plants already conserving refrigerant and following an approved chiller conversion/replacement plan should avoid the worst of the crisis. Those who choose to wait are likely to find their options limited (Fig. 1).

Failure to act now risks refrigerant shortages or even loss of cooling in the future

The manufacturing capacity of the HVAC/R industry today is between 4000 and 5000 units, far short of expected demand over the next several years. Even at an accelerated conversion rate of 9000 units per year, it would take all the qualified centrifugal chiller service technicians available today 7 to 8 yr to convert or replace existing CFC-11 chillers alone. If a majority of these chillers are not dealt with until the shortages occur, the potential for losing cooling capability becomes a real probability for many plants.

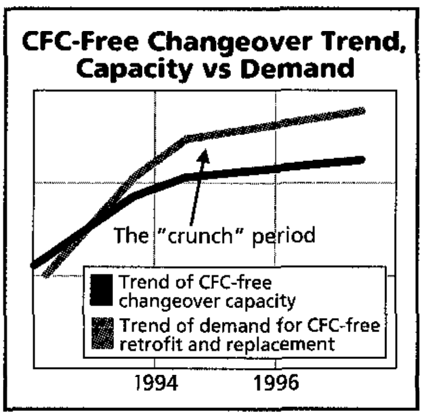

Fig. 1. Continuing to use CFC-based refrigerants may limit a plant's options in the future. If the retrofit demand strains manufacturing capacity, users may be put on allocation, creating a CFC crunch. Those using CFC-based equipment left without sufficient refrigerant face the loss of cooling and possible business interruptions.

There are solutions for making the transition away from CFCs. These include several chiller conversion and retrofit options that adapt existing chillers so that they use alternative refrigerants having low or no ozone depletion potential (ODP). In many cases, performance is maintained or even improved. In all cases, additional years of useful service are derived.

Conversion vs Replacement

Conversion is a viable option at least 80% of the time, especially with open-drive chillers. Several factors should be considered in every case.

Age. Age of the chiller system and its remaining useful life are important. Chillers under 10-yr-old are often good candidates for conversion, because mechanically they should have the longest remaining service life. Chillers more than 20-yr-old may be more difficult and expensive to convert. It may be wiser to replace them. The decision is more difficult for chillers between 10 and 20-yr-old. A more detailed analysis is generally required to find the best engineering and operating solution.

Condition and service needs. Condition of the chiller system is a major consideration. Equipment experiencing serious maintenance or service problems may be a good retrofit candidate. In any case, it is easier and

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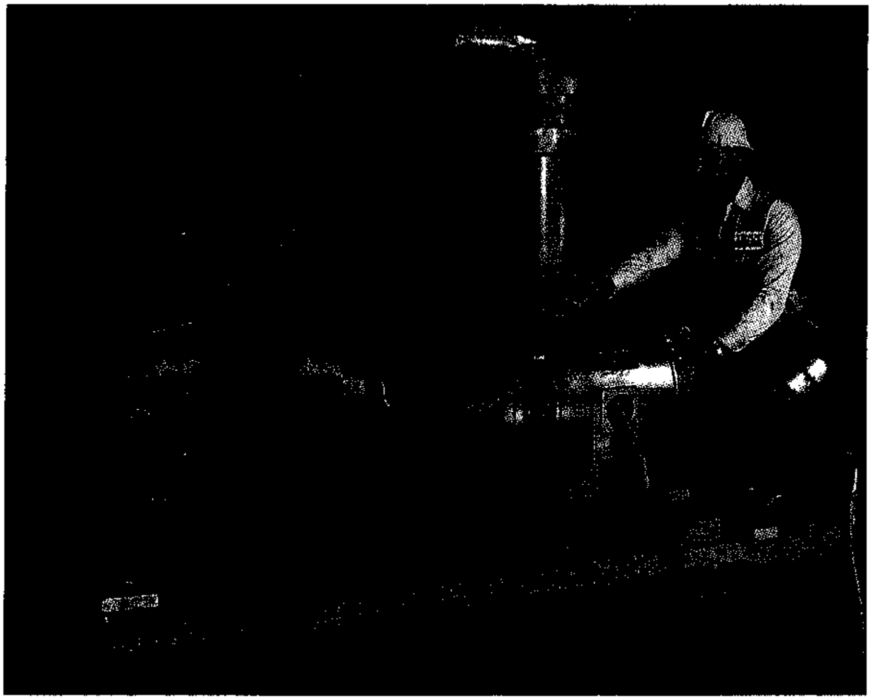

Fig. 2. A single-stage centrifugal driveline is delivered to an equipment room where space restrictions made installation of new replacement chillers with large heat-exchanger shells impractical. The compact unit fits through a 36-in. doorway.

less costly to tackle a refrigerant conversion during a maintenance shutdown or scheduled overhaul.

Location. Location of the equipment room and configuration of the chiller system also must be examined. In some cases, extensive demolition and reconstruction are required to remove the old units and bring in new ones. It may be advisable to retrofit existing chillers with new components — for example, a new driveline — and leave the large heat exchanger shells in place (Fig 2.).

Nature of application. Most process cooling systems are critical to plant operations. The risk or potential cost of an unscheduled shutdown may dwarf the actual conversion cost. Many plants are converting to alternative refrigerants rather than take this risk.

Performance. Refrigerant conversions can affect chiller efficiency and capacity. Each application is different. A number of conversion techniques were developed to fine-tune chiller performance after the retrofit. Generally, the more optimizing required, the more expensive the conversion. As a result, some plants choose replacement.

Cost. Cost versus benefit is always an important concern. Plant engineers should solicit proposals that offer multiple solutions, each with its own estimated cost and payback. Each proposal should state a specific cost and timetable so that the user can choose the solution that best matches plant needs and budget restrictions.

Technical support. Every conversion or replacement is unique. However, it should be based on technical information and support from the chiller manufacturer, service contractor, and inhouse service technicians. At a minimum, the conversion/replacement team should:

- Calculate and document chiller performance with the proposed new refrigerant
- Compare the results with the plant's cooling requirements
- Recommend further modifications to improve performance, if needed
- Perform eddy current tube testing of the chiller's evaporator and condenser tubes (unless this has been done and documented within 3 yr) and recommend repairs, if necessary
- Leak test the entire system and recommend repairs, if necessary
- Perform oil and refrigerant chemical analyses to ascertain signs of compressor wear or damage and recommend repairs, if necessary
- Ensure the converted system meets all applicable codes and complies with Clean Air Act requirements
- Ensure that a competitive warranty covering parts, labor, and refrigerant compatibility is provided and backed by the manufacturer on the team.

Converting R-11 Chillers to R-123

Approximately 85% of the installed CFC-based chillers are low-pressure centrifugal R-11 machines in the 100 to 1500-ton range. The accepted alternative is R-123, a hydrochlorofluorocarbon (HCFC) with a very low (0.02) ozone depletion potential.

Although R-123 has good performance characteristics, it is not a perfect drop-in replacement. Its different operating pressures and temperatures tend to degrade chiller efficiency and capacity 10 to 15%. The refrigerant's solvent properties render it incompatible with some of the older materials used for seals, O-rings, and gaskets. The product is also incompatible with hermetic motor windings, a factor that accounts for most of the added cost and complexity of converting a chiller that uses a hermetic motor. This cost is often twice that of its open-motor counterpart.

Open-motor chillers. Substituting R-123 in most open-motor chillers is a relatively simple *compatibility conversion.* Seals, O-rings, and gaskets are changed out and controls converted to adapt to the new refrigerant's operating pressures and temperatures. The major cost is for the labor required to

Several chiller conversion and retrofit options are available to adapt existing units to refrigerants having low or no ozone depletion potential

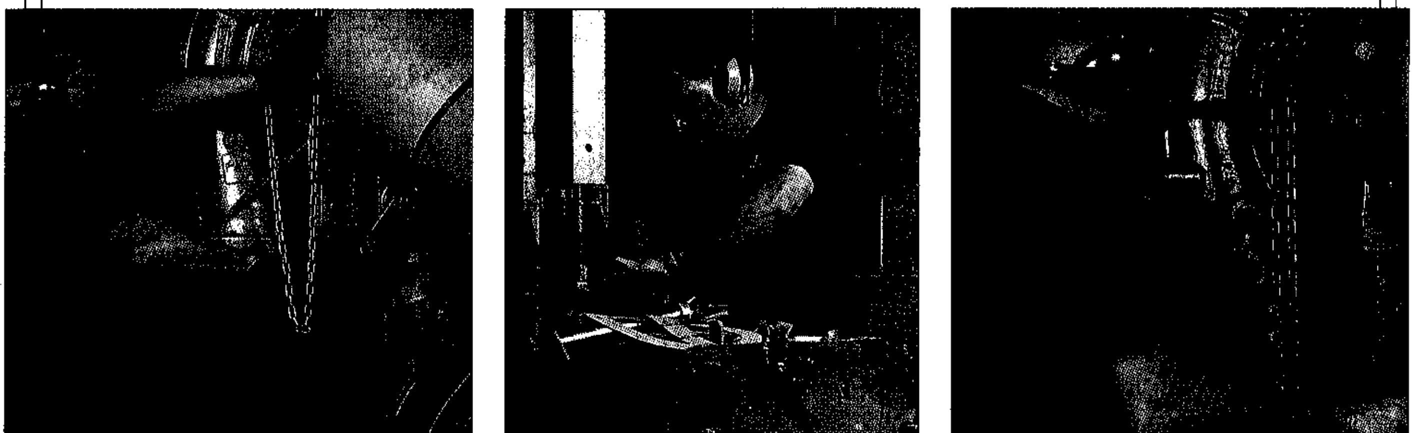

Fig. 3. A driveline retrofit on an R-11 centrifugal chiller is an extensive conversion that includes installation of an open motor, centrifugal compressor, and starter and control center compatible with R-123. Photos show, from left, positioning of suction piping between the heat exchanger and compressor; cleaning of the baffle on the condenser discharge opening; and making final alignment adjustments between the suction piping and the condenser.

open the compressor and work inside the system. Performance degrades as expected, but because many chillers were oversized initially, the performance penalty usually can be accommodated. On the average, compatibility conversion costs 20 to 30% that of a total chiller replacement.

An *optimized conversion* to regain capacity or boost efficiency requires one additional step: a gear change. The new gear is selected for the unit's compressor on the basis of its operation with R-123. The cost is 40 to 60% that of installing a new chiller.

The most extensive conversion is a *driveline retrofit* (Fig. 3). Developed in the 1970s as an energy-saver and method to extend chiller life, this technique involves replacing the chiller's existing starter, motor, compressor, and controls with those compatible with R-123. The new driveline also may be resized, normally to a lower tonnage for higher efficiency gains.

A driveline retrofit requires that the condition of the unit's existing heat exchanger shells be verified by eddy current tube testing. Faulty tubes must be repaired, replaced, or plugged. Avoiding the need to remove and replace the shell reduces the complexity and cost of this conversion to 60 to 80% of an outright replacement. An open-motor driveline retrofit can be performed on virtually any make or model R-11 chiller and the converted machine can be warranted as new.

Hermetic-motor chillers. A *compatibility conversion* with a hermetic-motor chiller is more complex than with an open-motor unit. In addition to changing out the seals, O-rings, and gaskets, and modifying the controls, the hermetic motor must be rewound or replaced with one compatible with R-123. This process takes longer and costs 50% or more of the cost of a total chiller replacement.

An *optimized conversion* regains capacity and requires, in addition to the compatibility conversion changes, either a gear change for gear-driven machines or an impeller change for direct-drive units. Fine tuning compressor performance to the new refrigerant and optimizing chiller operation in this way costs 75% or more of the cost of a new chiller.

A *driveline retrofit* on a hermetic-motor chiller is possible, although more restricted. The procedure is essentially the same as for an open-motor unit and requires sound shells with tubes in good condition. This retrofit can achieve excellent energy performance and may be the most practical solution, depending on the accessibility of the equipment room.

The cost of retrofitting a hermetic chiller with an open-motor driveline is about the same as for an open-motor chiller: 60 to 80% of replacing the system. New hermetic-motor drivelines for existing hermetic chillers are more expensive, often 90% of the cost of total replacement. The open-motor driveline also is inherently more efficient, helping to offset the efficiency loss of using R-123. Hermetic motors are 88 to 93% efficient, while open motors yield 93 to 96% efficiency.

A number of chiller manufacturers and service contractors offer some or all of these R-11 conversion options. In all cases, proper refrigerant monitoring and equipment-room ventilation systems must meet local codes when using R-123. These costs have been figured into the percentage costs listed (see table). Plant engineers are encouraged to follow ASHRAE monitoring and ventilation standards. However, local building codes always prevail.

Converting R-12/R-500 Units to R-134a

About 15% of installed chillers that are conversion candidates use R-12 and R-500 and range in capacity from 100 to 7000 tons. The accepted alternative refrigerant is R-134a, a hydrofluorocarbon (HFC) that contains no chlorine and has no ODP.

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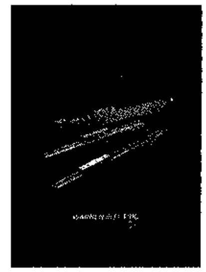

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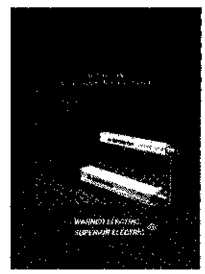

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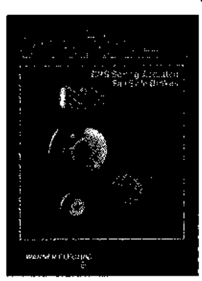

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Whenever a chiller conversion is considered, a chiller manufacturer with extensive retrofit experience should be involved early in the planning process

Average Cost of Conversion vs Replacement*

Chiller Type	Compatibility Conversion	Optimized Conversion	Open-Motor Driveline Retrofit	Hermetic Driveline Retrofit
Open-drive R-11	20% to 30%	40% to 60%	60% to 80%	Not applicable
Hermetic R-11	50% or more	75% or more	60% to 80%	90% or more
Single-stage R-12 or R-500	Not applicable	60%	80%	Not applicable
Multi-stage R-12 or R-500	Not applicable	50%	60% to 80%	Not applicable

* Replacement = 100%

High-pressure, R-134a centrifugal chiller conversions present a different set of challenges. Although there are few hardware problems, R-134a is not compatible with conventional mineral oil lubricants. The existing system refrigerant and lubricant must be completely evacuated and drained. The system must be relubricated with an ester-based synthetic oil and recharged and operated with R-12. This action flushes and absorbs any residual mineral oil.

Next, the system must be tested to ensure no more than 1 to 3% mineral oil remains before the system is charged with R-134a. If these conditions are not met, reflushing is necessary. Failure to evacuate the mineral oil thoroughly causes severe fouling of the external heat exchanger tube surfaces and dramatic performance degradation in a short time. Even more immediate is the performance penalty associated with the different operating characteristics of R-134a. Generally, there is no practical, simple conversion to R-134a unless the application can accommodate severe derating in operating range and increased horsepower and noise levels.

In most cases, the higher head pressure must be addressed, usually by increasing compressor speed 10 to 15%. An *optimized conversion* involving impeller and gear changes accomplishes this. The cost averages 60% that of a new replacement system.

An R-134a *driveline retrofit* further enhances the chiller's performance. Changes include a new, high-efficiency open motor, compressor designed for R-134a with gears and impellers selected for the application, and new starter, controls, and warranty. The procedure is similar to that for an R-123 conversion. It requires the condenser and evaporator shells and tubes to be in good working order. Although a driveline retrofit averages 70 to 80% of the cost of a new, single-stage R-134a system, the change is viable because it improves chiller performance to meet operating needs and simplifies installation.

Far fewer chillers use multistage compressors. Most range in capacity from 1000 to 7000 tons. However, their size, expected long life, and critical nature of their application make them prime retrofit candidates. There is no simple, drop-in R-134a conversion for these machines. Higher head pressure degrades performance so severely that nearly all conversions require extensive re-engineering.

An *optimized conversion* includes mineral oil flushing and a gearset and rotor changeout. Specifications and components are available only from the original compressor manufacturer. The investment averages half the cost of a new, R-134a multistage system.

The *driveline retrofit* option for multistage machines offers the same advantages as that for single-stage chillers. However, they are very complex activities and cost 60 to 80% that of a new replacement system.

Whenever a chiller conversion is considered, the plant engineer should involve a chiller manufacturer early in the planning process. The chille manufacturer should have extensiv retrofit experience, and does not nec essarily have to be the manufacturer c the unit in question.

Qualified service contractors o inhouse staff play a major role in exe cuting chiller conversions. If specifi cations and procedures are approve and supervised by a chiller manufac turer, skilled service technician should be able to handle most of th onsite work on single-stage units. Suc work also helps technicians acquir first-hand knowledge and documenta tion of the converted system that wi be useful in the future.

Plant engineers should be satisfie with the credentials, qualifications and references of any provider befor proceeding. Not only are plant opera tions at stake, but civil and crimina penalties are attached to mishandlin refrigerants. ❑

For more information . . .

"Managing Refrigerants in a CFC-Free Era," (PE, 9/3/92, p 53, File 2510) and "Maximizing Chiller Performance" (PE, 1/10/91, p 36, File 2510) discussed other aspects of the CFC phaseout problem.

The author will answer technical questions about this article. He may be reached at 717-771-6339.

. . . Jeanine Katzel, HVAC Editor, 708-390-2701