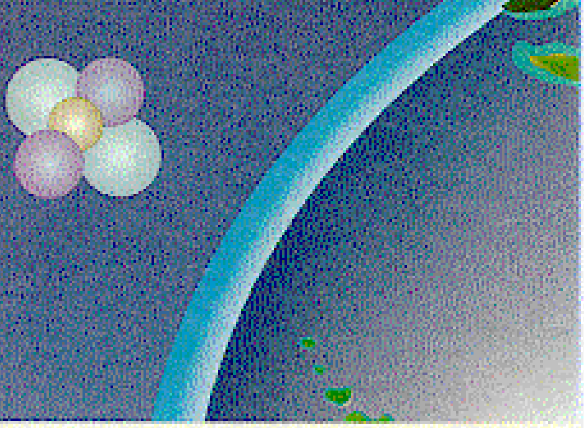
Consulting-Specifying Engineer

INTEGRATION: Reducing the Cost of CFC Chiller Replacement



With careful planning, engineers can help building owners find the "silver lining" in the ominous cloud of CFC ceased production

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As the Dec. 31, 1995, ban on manufacturing chlorofluorocarbons (CFCs) approaches, difficult choices will have to be made regarding the future of central-plant cooling equipment. Of the 80,000 chillers being used in the United States, nearly 10,000 of them will have been replaced with non-CFC equipment by the end of 1994, according to statistics compiled by the Air-Conditioning and Refrigeration Institute (ARI). At least 12,000 more are expected to be replaced by the end of 1996.

While, at first glance, replacement may appear to be an expensive and less than optimal choice, this large and complicated process possesses "hidden" opportunities that can make cooling plants more energy efficient, provide added capacity and reliability, improve plant operations and maintenance, and create greater comfort—all with a modest return on investment.

By presenting a well-thought-out, integrated modernization plan that offers attractive benefits and features, engineers can take some of the sting out of CFC retrofit. They may even be able to create funding for projects that would otherwise be delayed until the last moment.

Upgrade equipment

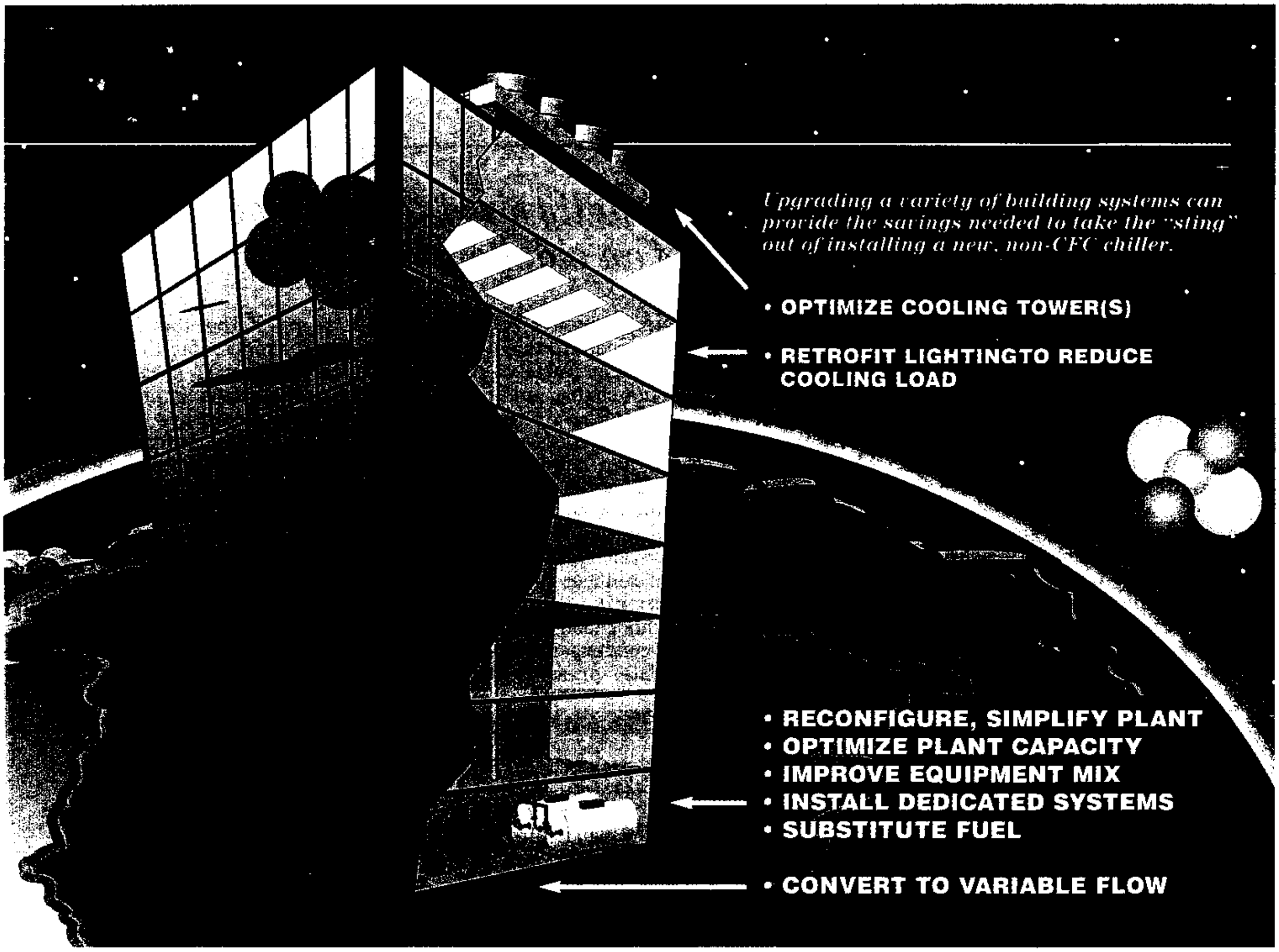
One of the benefits of using newly designed and optimally sized equipment is that, in most cases, it will use only about half the energy consumed by an older, less optimally configured system. Most modern chillers also offer integrated control systems for direct interface with building-automation systems. This interface can provide a more effective automated reset of chilled-water temperature for additional energy conservation.

Generally, if chillers are near the end of their life expectancy, so are cooling towers. The size of a replacement tower should be evaluated carefully for energy-saving opportunities. Traditional "rules of thumb" have resulted in many cooling towers being selected to provide 85°F condenser water to the equipment.

However, greater use of evaporative cooling has resulted in cooling-tower sizing being value engineered for the most cost-effective combination of approach and cost, especially in relatively benign climates such as Northern California. For example, while an 18°F approach temperature would be traditional in Northern California (85°F condenser water with a 67°F design wet bulb), 5°F to 8°F approaches are relatively easily achieved. With condenser water at 75°F instead of 85°F, a much lower chiller kilowatt (kw) per ton can be achieved, down to 0.5 or lower.

Given the fact that a cooling tower is, in essence, a big box full of corrugated plastic, the added cost to increase its size (rather than just increase the fan speed and motor size, which would be counter to energy efficiency) is relatively cheap compared to the reduction in chiller power consumption and cost of operation. The longer the annual operating hours and the hotter the climate, the faster a bigger tower will pay for itself.

On one hospital project, for ex-



ample, the added cost of a larger tower was approximately $10,000 (for equip-ment only), while the annual reduction in chiller operating cost was nearly $20,000.

Change plant capacity

Another benefit of modern chillers is their physical size. Many of today's chillers are much smaller than their predecessors of equal capacity. In addition, the newer chillers use less energy per ton of cooling.

The implication of both these factors is the ability to install greater cooling capacity in the same space without increasing the connected electrical load or electrical service equipment. This can be beneficial if the existing system is under capacity or if plans exist for increased demands on the cooling plant. Building additional capacity into the central-cooling plant may obviate the need for installing peripheral, ancillary cooling equipment as an afterthought to meet future needs.

But what if the chilled-water plant was adequately sized when it was originally built...or even oversized? By

Containment, Retrofit or Replacement?

Chiller replacement is not the only option when it comes to the chlorofluorocarbon (CFC) phase-out. In fact, in many instances, it may be the least attractive option available.

For some building owners, using CFCs after the production deadline may be a satisfactory option if a supply of refrigerant can be stockpiled and the equipment has only very limited life left.

Problems arise, however, when stockpiles run out, and they will eventually, perhaps sooner than many think. Purchasing CFCs also is expensive because of excise taxes.

In addition, the Environmental Protection Agency (EPA) requires extensive records for CFC equipment; systems containing more than 50 pounds of refrigerant are limited to 15 percent per year leakage, and this must be documented.

If equipment is relatively new and operating efficiently, retrofitting equipment to a non-CFC refrigerant may be the way to go. Some loss in capacity and a slight drop in efficiency may result from the refrigerant change, but this can be compensated to an extent by installing high-efficiency motors and new heat exchangers.

In some cases, equipment is too old to be cost-effectively converted, leaving replacement as a better alternative. However, replacing equipment tends to be expensive when done by itself. But combining other building-retrofit efforts that improve efficiency and operation with equipment replacement can offset costs and turn an otherwise disagreeable prospect into a positive change. □

A new central chiller and an optimally sized cooling tower will use only about half the energy of an older system

combining retrofit efforts in make-up air evaporative precooling, air-to-air heat recovery, pumping operations or lighting with the chilled-water-plant replacement, refrigeration equipment can be downsized, thereby decreasing the total cost of retrofit and potentially providing even more efficient plant operation.

For example, a significant reduction in peak cooling loads can be achieved by installing direct or indirect evaporative-cooling systems on the outside-air intakes of air-handling systems. Peak load of a 100 percent outside-air system in a hot, dry climate, for example, could be reduced by 35 to 40 percent in this way.

Similarly, installing water-to-air heat exchangers in exhaust- and outside-air ducts along with a circulation pump, piping and controls (a "run-around" system) can reduce peak cooling loads by 20 to 30 percent—and save energy during cold weather, too. Also, reducing the condenser-water flow in an existing piping system by 10 percent reduces the power required for pumping condenser water in the neighborhood of 30 percent—or more, if condenser selection is optimized for water-pressure drop.

While some of the above options are better suited to facilities with large outside-air loads, such as laboratories, manufacturing plants and hospitals (office buildings generally use a moderate amount of ventilation air), or to areas with extreme weather, retrofitting lighting systems is something from which all buildings can benefit. That is because every watt of lighting energy emitted contributes to the cooling load—sometimes as much as 40 to 60 percent.

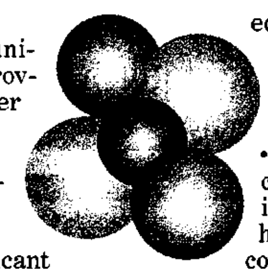
However, by having energy-efficient luminaires that supply adequate amounts of light and less heat, fewer watts need to be removed by the cooling system. Combined with the fact that new lighting technologies are relatively inexpensive to install as the systems are readily accessible, unlike mechanical systems, integrating a buildingwide lighting retrofit into a CFC abatement project can further improve the economic attractiveness of the overall building-retrofit program.

Improve equipment "mix"

In most cases, new-construction design is rightly focused on peak design conditions and operations. However, light-load conditions occur with much greater frequency. The result, at times, is a cooling-equipment mix where a very large machine is actually the smallest machine available. As a result, on light load days, the unit's auxiliaries (chilled-water pump, condenser-water pump, cooling tower) also may exceed the refrigeration machine itself in terms of total power draw, thereby causing considerable energy waste.

A poor mix of primary equipment, specifically chillers, may not only waste energy but also may provide less reliability and redundancy than needed. For example, a 500-ton plant with two 250-ton centrifugal chillers is vulnerable should one machine be lost. Increasing the total number to three machines of perhaps 125-, 225- and 225-tons would provide additional capacity, allow the facility to operate normally on all but the hottest days if the smallest chiller were lost and allow 70 percent operation on the

One Step Further: Improving *System* Efficiency



CFC replacement offers the opportunity to explore improving the efficiency of other heating, ventilating and air-conditioning components. For example, converting to a variable-flow, chilled-water system may offer significant energy savings—especially in facilities with widely varying cooling demands.

During periods when cooling demand is less than the system's total capacity, less chilled water is needed. Slowing the centrifugal pump's operating speed in response to this lessened demand provides dramatic energy savings.

While variable flow is common in new construction, few older systems are so configured. In order to implement a variable-flow scheme, a few things are needed:

- First, create a dual-loop system to allow constant flow through the chiller while varying flow through cooling coils in air-handling units. Alternatively, a single-loop system may be maintained if provisions for minimum flow through the lead chiller are provided, either by leaving some three-way control valves or by installing an automated bypass valve that is shut off once total system flow demand has exceeded minimum flow needs.
- Second, convert the control valves on the cooling devices (such as air-handling-unit cooling coils) to two-way control by closing the bypass balancing valve and installing a larger actuator, if required to give the valve sufficient close-off capability. (Beware, large valves frequently have close-off capabilities as low as 10-pounds-per-square-inch differential and will be pushed open by the head of the circulating pump). Alternatively, replace the valve or abandon the control valve and convert a butterfly shut-off valve to control use by installing an actuator and positioner.
- Third, install differential pressure controls by installing a sensor at the most "distant" control valve (multiple sensor locations may be required) and adjusting pump speed to maintain a constant differential pressure (or reset the set point based on the load or a pseudo-load indicator, such as outside air temperature). □

Combining retrofit efforts with chilled-water-plant replacement can decrease total costs and provide more efficient operation

hottest day if the largest chiller were lost to service. Depending upon the nature of the operation, having a "spare" chiller may be of great value and could potentially be incorporated into a CFC-retrofit project quite easily (albeit at increased cost).

Furthermore, depending upon the variety of loads being supported (perhaps a computer center as well as general office space), it may make sense to select one or more of the refrigeration machines so they are well suited for the critical load, particularly with regard to turn-down and cycle-time capabilities. For example, a 250-ton centrifugal chiller carrying a 25-ton (minimum) computer-room load in cold weather might cycle off and not be restartable for 30 minutes, which might allow the computer room to overheat. A smaller rotary-screw or reciprocating machine, on the other hand, could carry a smaller load continuously and be able to cycle off and on more quickly.

Reconfigure plants

Another issue to consider when performing a CFC retrofit is the ever-changing plant layout. As building additions and reconfigurations occur, the plant often evolves into a cramped, complex multiplicity of pumps, chillers, cooling towers and piping. Because central systems are complex, the size of an individual reconfiguration does not always justify the time expenditure to fully analyze its effect on the entire system.

This practice can result in short-sighted approaches to solving critical, immediate problems. For example, in one hospital, the need for air-conditioning a CAT-scan computer room in a former basement area of the building was met by installing a small fan-coil unit and interconnecting it to the central chilled-water piping.

Because of the room's location, it was not physically feasible to provide an outside-air economizer, and as a result, the central plant, consisting of one large chiller, was forced into 24-hour operation 365 days per year. While this solved an immediate problem, the wear and tear on the chiller resulted in its premature demise.

With a little extra effort, the engineers could have developed a better solution: in this case, installing a small, dedicated chiller with an adjacent dry cooler to provide a water-side economizer during cold weather (in this cold climate). Eventually, this path was chosen, and not only did the equipment allow the central plant to be shut down for a major overhaul, but the economizer worked successfully at ambient temperatures much higher than expected (up to 60°F).

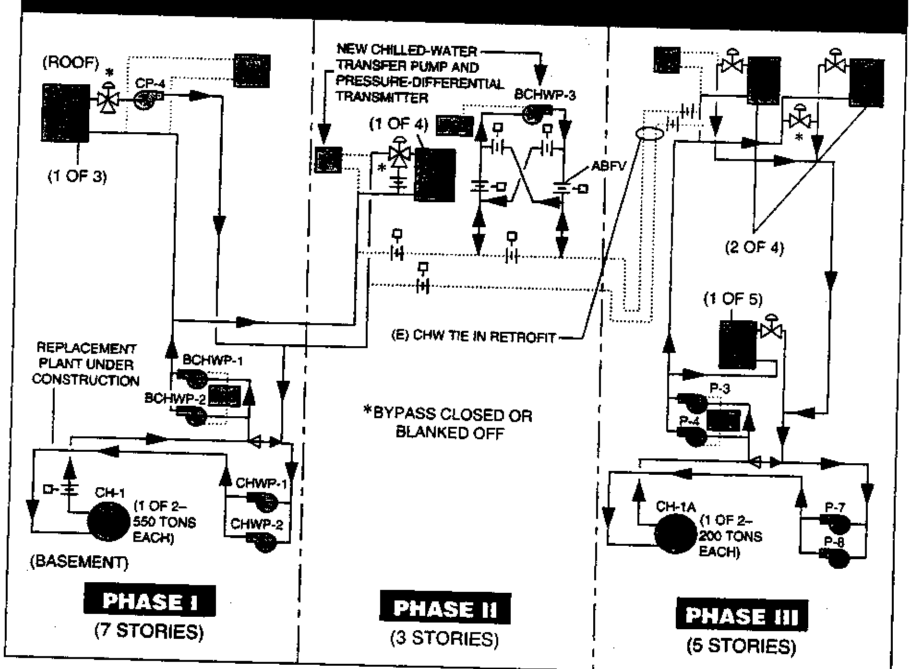
CFC retrofits offer the opportunity to correct these "quick fixes"; they provide the chance to step back and reevaluate how systems are designed. For example, sometimes entire plants are added on to a building—creating not only an operations and maintenance headache but a waste of energy, as two sets of plant auxiliaries are started up at a point where only a small total load exists. Increased equipment wear and tear also occurs.

These problems may be eliminated, however, by tying the plants together with an interconnecting chilled-water pipeline (see Figure) and operating them with a building-automation system as though they were one. (Note: A variable-flow conversion generally would need to be part of such a retrofit if the systems were not already configured as one. See sidebar, "One Step Further.")

With the largest portion of energy savings coming from single-auxiliary operation at light loads, the interconnecting pipeline need not be sized to handle the full capacity of either plant. Rather, it could handle the equivalent of one chiller's capacity should the pipeline need to be pressed into service if a chiller were lost during peak-load conditions.

In addition, depending upon plant-operation implications, it may make sense to interconnect small, dedicat-

FIGURE–CHILLED-WATER SYSTEM



Schematic diagram of a 370,000-square-foot hospital in Northern California shows the integration of two chilled-water plants by means of an interconnecting pipeline, the addition of a transfer pump to allow sharing of plant capacity between the buildings, even during peak-load conditions, and conversion to variable-flow.

A poor equipment mix wastes energy and provides less reliability

ed systems to central plants. This allows the central-cooling plant to supply its low-kw-per-ton cooling when it is in operation, as opposed to the likely high-cost cooling of the dedicated equipment (most likely air-cooled, reciprocating equipment). Many secondary pumps and chillers also can be eliminated in a newly designed, properly sized and efficiently piped system.

Fuel substitution

As a final consideration, engineers can specify equipment that does not use vapor compression, such as gas-fired and steam/hot-water-fired absorption units. While electric chillers have a coefficient of performance (COP) roughly six times that of gas-fired absorbers, in many markets the cost of electricity is 10 times that of natural gas on a per-Btu basis—meaning the cost of absorber operation will be 30 to 40 percent less.

And, given the likelihood that demand charges will continue to rise as free energy markets (brought about through natural-gas deregulation and upcoming retail wheeling of electricity in some areas) cause the real cost of electrical capacity to be passed on to the end user, nonelectric cooling plants may be an excellent long-term strategy.

Keep in mind, though, that absorption machines take up a lot of real estate and cannot be broken down into pieces that squeeze into a basement or penthouse equipment room. This may be offset, to some extent, by the fact that absorption units may eliminate the need for boilers, depending on the application, for domestic hot-water and space heating.

Absorption units are also two to three times the cost of equal-capacity electric machines (although utility rebates often are available to help offset the units' higher first costs), and the cooling towers required for absorption machines are also much larger than those required for an electric machine. (Remember, the absorber uses heat to cool.)

Conclusion

A great many possibilities exist for improving the efficiency and operation of a central-cooling plant while on the way to CFC abatement, and engineers can help their customers take advantage of these opportunities. All that is needed is a thoughtful, integrated approach and a rethinking of cooling operations to develop a blend of system upgrades and modifications that are mutually complementary and beneficial.

Some engineers have already taken advantage of this marketing approach and successfully incorporated into their projects a majority of the concepts described herein, indicating that the ominous cloud of ceased CFC production does indeed have a "silver lining." □

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- **Integrated IAQ-CFC Retrofit Saves Energy**, by Gershon. Meckler, P.E., March 1993, p. 42.

Energy Star: An Integrated Approach to Retrofit

The Environmental Protection Agency's (EPA's) Energy Star Buildings Program is designed to assist in coordinating a wide range of energy-efficiency measures with CFC-abatement regulations. It consists of five stages to reduce a building's net cooling requirements and the size and cost of replacement cooling equipment (see Table).

To encourage participation, EPA provides a variety of support and assistance, including:

- Public recognition of program participation.
- The "Building Retrofit Manual."
- Savings-analysis software.
- Financing data base.
- Case-study documentation of specific technologies.
- Technical specifications for energy-efficient technologies.
- Information and guidance on indoor-air-quality issues.
- Technical assistance in using the CFC phase-out to increase efficiency and reduce the cost of transition to alternative refrigerants.

Buildings participating in the program's first phase have the opportunity to become showcase buildings and receive additional recognition and support. □

TABLE: ENERGY STAR BUILDING PROGRAM

Stage	Description	Action
1	Green Lights	Install energy-efficient lighting technologies to save energy and reduce the building's cooling load.
2	Building Tune-Up	Check for optimal operation of existing building systems for further energy savings.
3	HVAC Load Reductions	Improve window and roof systems. Use Energy Star Computers when replacing personal computers.
4	Fan-System Upgrades	Upgrade variable-air-volume (VAV) systems with variable-frequency drives. Convert constant-volume systems to VAV. Reduce air-side system oversizing, and replace standard motors with high-efficiency motors.
5	HVAC Plant Improvements	Replace or upgrade chillers. Retrofit chillers and pumps with variable-frequency drives. Replace electric resistance heating.