Chiller Strategy to Cool Energy Costs
by Joseph J.Watson,P.E.

Replacing a chiller plant is often one of the largest ends- of-useful-life expenditures facing facility executives. Although there are many factors to consider while determining when to replace an aging chiller plant, using a life-cycle analysis as a decision-making tool allows facility executives to cover all bases.

A life-cycle analysis considers the four components of owning and operating costs, including annual utility costs, maintenance costs, replacement costs and remaining useful life. All costs are adjusted based on the time value of money to allow equivalent comparisons. With this method, all potential system types can be evaluated and compared to determine the most cost-effective alternative.

Despite the traditional emphasis on minimizing the installed cost of a plant, the most significant expenditure over the life of the plant is typically the annual operating costs.For example, consider a plant that has an installed cost of $500,000,an annual operating cost of $100,000 per year, and a maintenance cost of $20,000 per year. Assuming a useful life of 20 years, the present value of the installed cost is $500,000, the operating cost is 1.3 million and the maintenance cost is $250,000.Therefore, the installed cost accounts for only 25 percent of the total expenditures over the life of the system. This relationship should be kept in mind when evaluating alternative systems.

As that previous example points out, operating costs are the most significant expenditure over time. Higher first costs that provide improved efficiency can often be justified over the life of the system. But there are many pitfalls that can undermine the decision-making process.

Experience shows that deciding to install the most efficient equipment is always a good idea. But installing efficient equipment does not automatically assure that a plant will operate efficiently. Many plants with a low installed kilowatt per ton operate at a much lower efficiency than older or less efficient plants. The two main factors that significantly impact chiller plant operating costs are building load profile and chiller sequencing strategies. In both cases, plant efficiency is determined largely by the part-load efficiency of the chillers.

The first step in evaluating the chiller plant is to develop the plant load profile.The easiest way to accomplish this is by using the trending function of the plant ’s energy management system. Data collected from a chiller plant should include the entering and leaving water temperature for both the chiller and the condenser, chiller amps, and status information on chilled water pumps, condenser water pumps and cooling tower fan s. This information should be collected hourly and can be used to calculate a part-load performance curve for the chiller and the plant. As data is gathered and evaluated during the operating season, a very accurate plant load profile can be generated.

Larger plants with multiple chillers offer a better opportunity to operate the chillers closer to design capacity. However, it is not an easy task to properly sequence multiple chillers. Most of the owners of large chiller plants prefer to sequence chillers manually. Much of the reasoning for this decision is the comfort level from knowing one of the operators is verifying the operation of the chillers with “hands-on” control. Most competent operators are very good at determining when chillers should be brought online, based on load conditions. However, much of the low-end part-load operation in a large plant occurs after a high-load day, when the plant load drifts down from the peak. Often, multiple chillers may be left idling for several hours before being taken offline. The ability to aggressively take chillers offline will have a larger impact on plant efficiency than the decisions to bring the chillers on-line.

Both factors can have a larger impact on operating efficiency than the initial design efficiency of a machine. When considering a chiller plant upgrade, be sure that the plant has a direct digital control (DDC) system and a viable sequence of operation before spending additional dollars on a lower kilowatt per ton machine. In all cases, the control system should have the ability to monitor, control and verify plant operation. The feedback from the plant energy management system should be used to continuously fine tune the operation of the plant. Relying on operators for average plant load or chiller sequencing information might result in missed opportunities to significantly improve system operation.

Another factor to consider is the maintenance and repair cost for chillers. Scheduled maintenance costs for chillers of similar type and size are usually consistent. However, new machines will have lower unscheduled repair costs than older machines. The historical repair data for an existing machine can be summarized and included in the analysis. It is important to review manufacturer recommendations for the required frequency of component overhauls, especially when comparing different machine types, such as turbine-driven or centrifugal. An overhaul can be a significant expenditure and may be required frequently depending on hours of use. These expenditures should be identified and included as part of the life-cycle analysis. Getting a full maintenance service contract price during the budgeting process, including required overhauls, is a good way to get a realistic estimate of these costs on an annualized basis.

The most difficult task in a life-cycle analysis is determining system useful life. ASHRAE committees have conducted numerous studies and surveys performed to quantify this information, either through detailed life studies of individual components or by anecdotal evidence gathered through operator surveys. Both methods have severe drawbacks in attempting to use the conclusions to make assumptions about the useful life of any given system.

Many factors can come into play when determining when an existing system has reached the end of its useful life. Some relate to the component itself. Others relate to its specific application. For example, there are currently many chillers operating on CFC-based refrigerants. The manufacture of these refrigerants were legislated out of existence in the mid 1990s, so that replacement refrigerant would be available only from existing stock. Many plant operators chose to retrofit or replace their chillers prior to the phase-out date to assure uninterrupted operations. In hospitals and other critical applications, the reliability of the equipment is paramount, and decisions are routinely made to minimize the risk of potential failure. In these cases, immediate replacement was likely necessary. Other chiller operators made plans to replace or retrofit once CFC refrigerants became scarce. In discussions with plant operators in the mid 1990s,no one expected their chillers to be operating on CFC-based refrigerants in 2002.However,with an increased emphasis on leak detection and control, adequate supplies of refrigerant are still available today and probably will be for the foreseeable future.

So how does an operator address useful life in the analysis? Unfortunately, there is no universal truth applicable to all situations. However, there are factors that can minimize its impact. When performing a comparison between alternative systems, estimates of useful life must be made for each system type. Fortunately, the nature of the life-cycle analysis makes the difference between a system with a 20-year useful life and one with a 30-year useful life insignificant in terms of present value.

However, this is not necessarily true in determining whether to replace an existing plant. In the absence of factors that necessitate a system replacement, an existing chiller plant could continue to be operated indefinitely. Indeed, there are several chiller plants with equipment installed in the early 1960s that are continue functioning adequately for their specific application. The life- cycle analysis is the best tool to determine if the system should be replaced from a financial and point. Beyond that, it is the responsibility of the facility executive to decide what level of reliability and risk they are willing to accept in the operation of their plants.

Boosting Part-load Chiller Efficiency
Part-load operation can significantly affect the operating efficiency of a chiller. In this example, a machine with a design efficiency of .5 kw per ton can operate at 1.2 kw per ton or higher during periods of part-load operation. The goal in operating the plant is to operate the chillers as close to design capacity as can be achieved. In the case of a plant with a single chiller, or two chillers with full redundancy, the chiller part-load profile is the same as the plant part-load profile. If you find your load profile is the typical bell curve centered around 50%load,you may want to consider installing two smaller chillers to improve part-load performance. Another alternative may be to consider a chiller equipped with a variable speed drive, which is much more efficient under part-load operation.

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