HVAC: Natural Gas Chillers

Although gas-fired chillers cost more than comparable electric chillers, the additional cost can often be recovered through reductions in electrical demand and infrastructure costs. However, gas chillers aren't universally more cost-effective than electric chillers, so before you buy one, it's worth doing a thorough life-cycle cost analysis. Also, because gas chillers are expensive, smart buyers may benefit by improving the overall efficiency of their chilled water systems—including cooling towers, fans, and pumps—before selecting a chiller. If you eliminate inefficiencies in these auxiliary components, you're likely to pay less than you would for the extra chiller capacity that would otherwise be needed to compensate for the inefficiencies. The largest reduction in chiller size can be realized by looking at ways to reduce actual cooling loads.

What Are the Options?

Absorption chillers. Rather than using a mechanical compressor to drive a vapor compression cycle, absorption chillers use a thermochemical "compressor" (see **Figure 1**, next page). This thermochemical process takes advantage of the fact that some chemicals tend to dissolve into other chemicals, a property chemists call "affinity." An absorption cycle uses two fluids: a refrigerant and an absorbent. In contrast to the compression that takes place in a conventional chiller, the refrigerant in an absorption chiller dissolves into an absorbent solution for which it has a high affinity. (Two common refrigerant/absorbent combinations are water and lithium bromide and ammonia and water.) An electric pump moves the absorbent solution into a generator section, where heat is applied to drive the refrigerant vapor out of the solution and into the evaporator. Substituting thermal energy for mechanical compression means that absorption chillers use much less electricity than mechanical compressor chillers. Absorption chillers are cost-effective when the thermal energy they consume is less expensive than the electricity that is displaced.

Absorption chillers can be direct- or indirect-fired and single- or multiple-effect. Direct-fired chillers contain a burner that runs on natural gas or another fuel to produce the heat required for the absorption process. Indirect-fired chillers use steam or hot water produced externally by a boiler or cogeneration system. A system of piping and heat exchangers transfers the heat to the chiller.

Single-effect absorption chillers use thermal energy to drive a single refrigeration cycle. Multiple-effect absorption chillers use two or more refrigeration cycles: The first is driven by high-temperature thermal energy, and the second and subsequent stages are driven by lower-temperature energy rejected by the previous cycle's condenser. Multiple-effect chillers are more efficient than single-effect chillers, but they require a much hotter source of thermal energy. Single-effect chillers may be driven by hot water ranging from 160 to 200 degrees Fahrenheit, but double-effect chillers require either direct heat from a gas flame or high-pressure steam. Double-effect chillers are also much more expensive, usually at least double the initial cost. The most commonly used absorption chillers are of the single-effect, indirect-fired variety, primarily because of the lower first cost.

Engine-driven chillers. Engine-driven chillers use the same vapor compression cycle used in electric chillers, but they are driven by a reciprocating gas or diesel engine or gas turbine rather than an electric motor (**Figure 2**, next page). They are available with a variety of compressors: reciprocating (up to about 700 tons), screw (about 100 to 1,000 tons), or centrifugal (about 350 to 5,000 tons). The most common configuration in use today is a reciprocating engine powered by natural gas and driving a screw or centrifugal chiller. More information is available from the American Gas Cooling Center, which publishes an "Applications Engineering Manual for Engine-Driven Chillers." (The manual can be ordered from the American Gas Association by calling 201-986-1131.)

Figure 1: Simplified absorption cycle

Absorption cooling uses a thermochemical “compressor” and makes use of the property of certain materials to be chemically drawn to dissolve in one another. Two fluids are used: a refrigerant and an absorbent. The refrigerant/absorbent combinations are water and lithium bromide and water and ammonia.

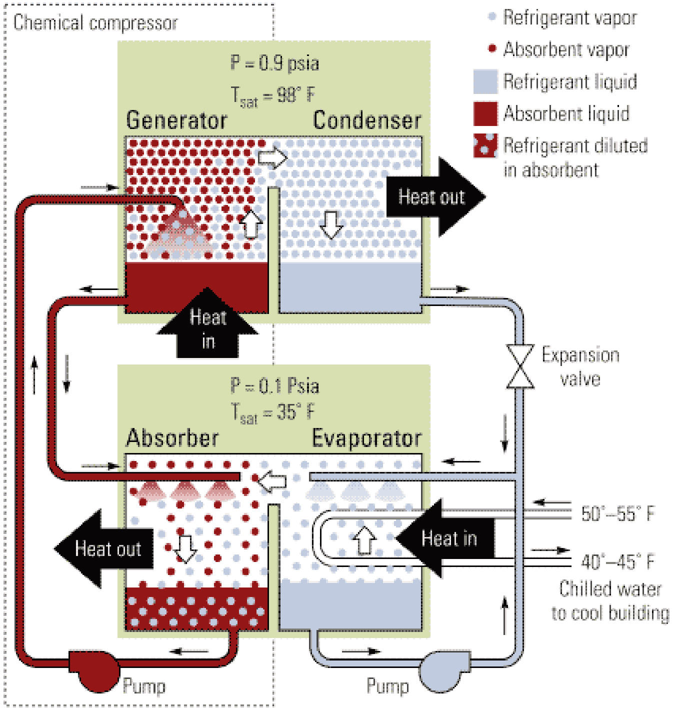

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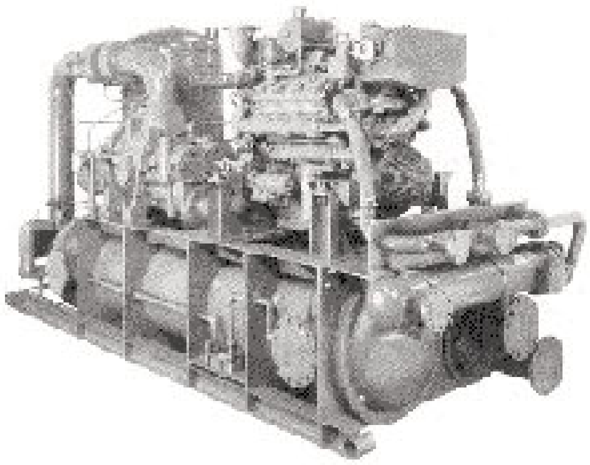
Figure 2: Engine-driven chiller

Engine-driven chillers use the same vapor-compression cycle as electric chillers, differing only in that a natural gas-fired engine replaces the electric motor.



Source: Tecogan

Hybrid systems. Combining electric and gas chillers in the same plant can help reduce first costs and operating costs. For the most part, chiller operation in hybrid systems is alternated so that, at any given moment, the chillers that are operating are powered by the less expensive energy source. For example, in an electric and natural gas hybrid chiller system, the electric chillers would only operate when inexpensive off-peak electric rates were available. When expensive on-peak electric rates applied, the gas-fired equipment would operate. Both electric and gas chillers might be operated simultaneously to meet peak cooling loads.

How to Make the Best Choice

The bottom line is that installing the highest-efficiency gas chiller available will not pay off if it's part of a system that is inefficient to begin with. If the overall system is inefficient, the chiller will be larger than necessary and will therefore cost more. First, optimize the entire chiller system for the best savings—and then consider a high-efficiency chiller.

Before Selecting a Chiller

Before specifying a chiller, take these two preliminary steps:

Reduce cooling loads. Load-reduction measures such as lighting retrofits not only save energy directly; they also indirectly reduce cooling loads, which makes it possible to purchase smaller chillers, cooling towers, and pumps. Improving the efficiency of lighting, office equipment, building shell, and windows can reduce cooling loads.

Optimize HVAC auxiliary systems. Pumps, fans, cooling towers, controls, and other HVAC system components may offer large savings opportunities--sometimes at little or no cost. For example, most fans are oversized and often operate outside of their highest efficiency range. Simply putting in the right size fan would save energy at no extra cost. For more information, please see the Purchasing Advisor on "Fans."

When Selecting a Chiller

Having optimized the entire chiller system, you are now ready to select a high-efficiency chiller.

First, you will need to determine the cost-effectiveness of gas cooling. How cost-effective gas cooling is in a particular application depends on the relative costs of gas and electricity, the relative efficiencies of the two types of equipment, the cooling loads, and the operating hours. Before you proceed with detailed calculations, use the calculation tool that follows to help you with preliminary screening.

Gas Cooling Screening Analysis

For a more detailed study than the calculation tool provides, do a thorough life-cycle economic analysis that accounts for the following factors:

Annual chiller energy performance. The performance of gas chillers usually is rated in terms of coefficient of performance, or COP: the cooling output (Btu) divided by the energy input (Btu). The higher the COP, the more efficient the unit. Because chiller efficiency varies depending on the load under which it operates, determining annual energy performance can be tricky. Either account for the most commonly experienced cooling loads and corresponding equipment efficiencies, or use building energy simulation software. Running multiple simulation scenarios can help sort out which combination of chiller technologies (absorption, engine-driven, or electric) and capacities—as well as which control strategies and configurations of towers, fans, and pumps—will minimize operating costs for a specific application.

Equipment cost. Installed cooling capacity is expensive, and gas cooling equipment is considerably more expensive than electric chillers. Absorption and engine-driven chillers can cost from $350 per ton for large units to about $800 per ton for small units, compared with $200 to $450 per ton for electric equipment. In addition, these systems will often require larger cooling towers and larger condenser water pumps, which further increase system costs.

Electric energy and demand savings. The lion's share of the savings associated with gas cooling equipment typically can be attributed to reduced electric demand charges. The electric energy savings and the gas energy charges often cancel each other out. Electric demand charges vary with time of day and season and from one utility to another, ranging from about $3 to $30 per kilowatt per month. When estimating demand charges, remember to account for any "ratchets" in the electricity pricing structure, which tend to boost those charges during months when demand draws are especially low. Because electrical demand and consumption costs can vary by season and also time of day, it is important to develop an operating strategy that runs different types of chillers (that is, gas or electric) during times of lowest energy cost. So-called hybrid plants can provide significant cost savings, but building operators must pay attention to comparative changes in gas and electrical costs.

Fuel costs. Until late 2000, natural gas was generally inexpensive but was still the largest single life-cycle cost of a gas chiller project. With higher gas prices, it becomes an even bigger component. The biggest challenge is predicting how gas and electricity costs will vary over the period covered by the life-cycle economic analysis.

Electric infrastructure savings. Adding electrical distribution infrastructure is expensive. The cost of a new substation alone can add from hundreds of thousands to millions of U.S. dollars to a project. Sometimes, by installing gas cooling plants, building owners and operators can avoid these costs.

Maintenance costs. Although it costs more to maintain engine-driven chillers than electric chillers (expect to pay an additional penny per ton-hour, less as capacity increases), maintenance can be a minimal expense for facilities with on-site maintenance personnel. Maintenance costs for absorption chillers range from about the same as for electric chillers to as much as one-third more.

Recovered heat savings. Thermal energy recovered from an engine-driven chiller can be used for space, water, or process heating. Absorption chillers don't offer this advantage. (However, an absorption chiller can be used to provide heating instead of cooling; it can do one or the other, but not both simultaneously. For this reason, absorption machines are sometimes called "chiller/heaters.")

Costs for emission abatement. Local regulations may require additional or modified air quality permits for gas-fired chillers. Absorption chillers can be installed in any location in the U.S. without additional costs for emissions control. In some areas, engine-driven chillers may require prohibitively expensive emissions controls.

Noise abatement costs. Engine-driven chillers typically have noise levels ranging from 93 to 98 decibels (at 3 feet), whereas absorption and electric units range from about 80 to 89 decibels. Manufacturers of engine-driven chillers usually offer, for an additional cost, sound-attenuation enclosures for the engine and compressor, which can reduce noise levels to around 86 to 89 decibels. For comparison, from 50 feet away, noise from a car engine averages about 70 decibels. A gas-powered lawn mower 50 feet away has a decibel level of about 90.

Size and weight. Although both engine-driven and absorption equipment take up more room than electric equipment, absorption equipment is bigger and substantially heavier. In some cases, building structural modifications may be required.

After Installing a Chiller

Consider maintenance contracts. Most chiller manufacturers offer maintenance contracts under which all maintenance and overhauls are performed by local, factory-trained mechanics. An advantage of this strategy is that trained mechanics who deal with several engine-driven or absorption chillers develop expertise that can improve preventive maintenance and prove useful in troubleshooting. (Be sure to include these costs in the life-cycle cost analysis.)

What's on the Horizon?

Packaged hybrid systems. Electric and gas-fired cooling technologies combined in a packaged, "single-skid" hybrid plant are coming to market. They offer significant advantages, particularly to owners of chiller plants under a few hundred tons, where typically only one chiller would be installed.

Solar-powered absorption chillers. Solar-driven air conditioning has been used in a few demonstration projects, such as the new Los Angeles Audubon Society Visitors Center, a 5,000 square foot off-the-grid facility in Los Angeles, California, and its use may increase in the future. The system uses solar collectors to heat water that is then pumped to a small single-effect absorption chiller. Installed capacity of the demonstration systems has been 9 to 14 tons.

Triple-effect absorption chiller. Still in development, this type of chiller will offer energy efficiencies as much as 30 to 50 percent higher than the efficiencies that double-effect units now offer. Because the third stage of a triple-effect chiller must withstand a high operating temperature (up to 420 degrees Fahrenheit) and corrosive conditions, more expensive materials may be necessary, thus increasing manufacturing costs. Also, being more complex, this absorption chiller will have higher maintenance costs. Nonetheless, the higher efficiency of these units may more than pay for the increased manufacturing and maintenance costs.