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Natural Gas Chillers

Though natural gas chillers have effectively served many end users over the past half century, all signs today are pointing to a drastic decline in the use of this technology. Manufacturers we spoke with reported that sales have dropped by up to 75 percent in the U.S. from approximately 2006 to 2010. Most—and for some manufacturers, all—new gas-fired chillers sold in the U.S. are being used to replace existing gas systems, not for new installations. According to one manufacturer, gas chiller sales for new installations are in decline worldwide. In addition, no gas-fired absorption chillers are made in the U.S. anymore. When existing gas chillers eventually reach their end of life, system owners will need to decide whether to replace them with another gas chiller, knowing that this technology is in decline, or to convert their facility to accept an electric chiller—a potentially expensive option.

Traditionally, gas-fired chillers were able to overcome their higher first cost compared to electric chillers because gas-fired systems produce lower electrical demand costs. However, the steady increase in efficiency of electric chillers has narrowed the operating cost differential with gas chillers. The high gas prices seen over the past seven years, peaking in 2008, undoubtedly also hampered consumers' uptake of gas chillers. But even with the dramatic decline in gas prices since the peak, gas-fired chillers have not seen a resurgence in interest.

It appears that new gas-fired chiller installations will be relegated to niche applications. One placement that still might prove cost-effective is where alternative energy sources are available, such as digester or landfill gas. If this alternative gas is clean and cheap enough, it could be used to offset the use of natural gas. However, the gas source would need to be located near a building with a significant cooling load—not a common occurrence. Another niche market is where waste heat is available, such as from an industrial process, that could be used with a hybrid direct/indirect-fired absorption chiller to offset the use of natural gas.

WHAT ARE THE OPTIONS?

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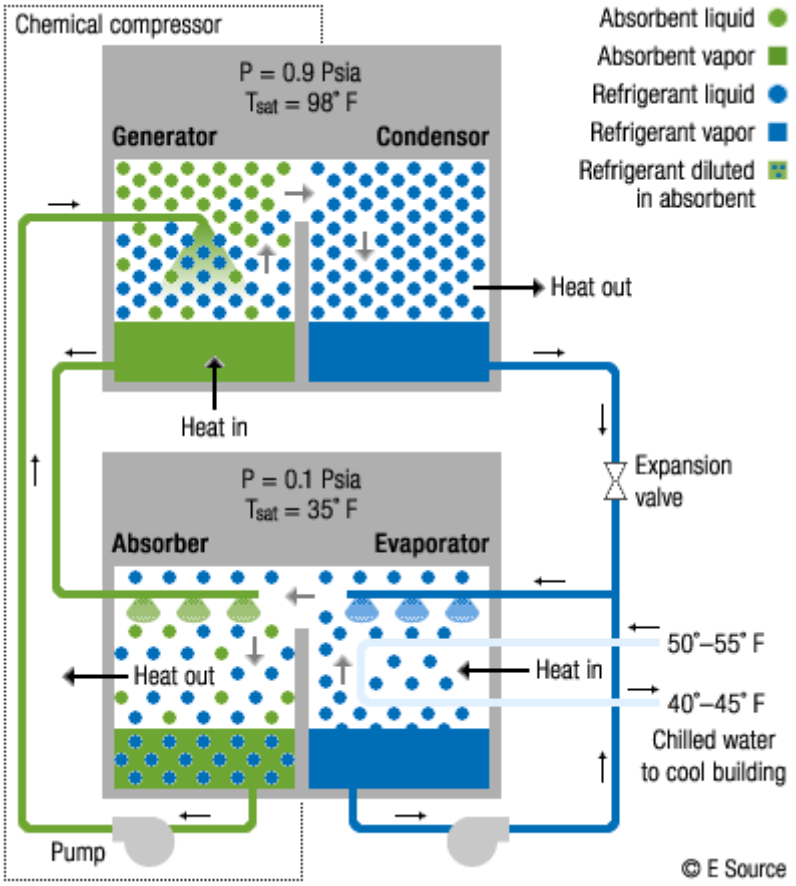
For those looking to replace an existing gas-fired chiller that has failed with another gas-

fired unit, the options are absorption, engine-driven, or hybrid chiller systems.

Absorption chillers. Rather than using a mechanical compressor to drive a vapor compression cycle, absorption chillers use a thermochemical “compressor” (**Figure 1**). 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.

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 changes phase and circulates through the entire system. Two common refrigerant/absorbent combinations are water and lithium bromide and water and ammonia.



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.

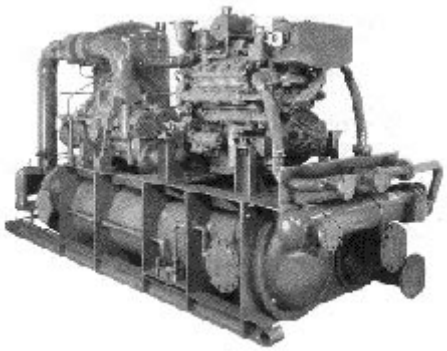
Single-effect absorption chillers use thermal energy to drive one refrigeration cycle. Multiple-effect absorption chillers use two or more refrigeration cycles: The first is driven by high-temperature thermal energy, and the second and subsequent stages are driven by lower-temperature energy rejected 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° 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 as electric chillers, but they are driven by a reciprocating gas or diesel engine or a gas turbine

rather than an electric motor (**Figure 2**). 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.

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

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To decide whether to replace an existing gas chiller with another one versus with an electric chiller, several costs must be considered. In addition to the first cost and operating expense of each type of chiller, the cost of upgrading a facility that used to house a gas chiller to one that can house an electric chiller must be factored in. Typically, the electric service within the building will need to be upgraded to support the higher electric load. In

addition, the electric distribution system that feeds the building may need to be upgraded (this latter cost may be borne, in part or as a whole, by the electric utility). How much it will cost to upgrade the building's electric service and the electric distribution system will vary greatly based on existing conditions and will require a site-specific survey to evaluate.

Before Selecting a Chiller

No matter what type of chiller you decide to use, take two preliminary steps before specifying one.

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. Measures that improve the efficiency of office equipment, building shell, and windows can also reduce cooling loads.

Conduct a preliminary analysis of gas versus electric chillers. 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 our calculator to help you with preliminary screening.

Gas Cooling Screening Analysis

In addition, factor in the cost of upgrading the facility for an electric chiller. Electric chillers are usually smaller and lighter than gas-fired equipment, and they have no emissions equipment, so the building typically will not need structural upgrades. However, you may have to upgrade the electrical service within the building, and in some cases, the distribution feeding the building as well.

Conduct a more thorough analysis. If a gas-fired chiller looks like it could be cost-effective at a quick glance, conduct a more in-depth life-cycle analysis of gas and electric chiller options. This will include optimizing the operation of the entire chiller plant, including the auxiliary systems. Pumps, fans, cooling towers, controls, and other HVAC system components may offer large savings opportunities—sometimes at little or no cost. To thoroughly analyze the system and the application typically requires the use of computer simulations.

When Selecting a Chiller

If you decide to go with a gas-fired chiller, take into account the following factors (for more details on electric chiller selection, see the guide on Centrifugal and Screw Chillers).

Annual chiller energy performance. The performance of gas chillers is usually rated in terms of coefficient of performance (COP)—the cooling output (in Btu) divided by the energy input (in 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. According to our survey of manufacturers, gas-fired double-effect absorption chiller COPs go up to about 1.35; ASHRAE (the American Society of Heating, Refrigerating, and Air-Conditioning Engineers) standard 90.1-2007, the Energy Standard for Buildings Except Low-Rise Residential Buildings, allows a minimum COP of 1.0 for chillers.

Equipment cost. Installed cooling capacity is expensive, and gas cooling equipment is considerably more expensive than electric chillers. According to our survey of manufacturers, absorption chillers can cost between $500 and $750 per ton, compared with $300 to $500 per ton for electric equipment. Gas engine-driven chillers can be as much as $1,000 per ton. 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 zero to $25 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 operational cost savings, but building operators must pay attention to comparative changes in gas and electrical costs.

Fuel costs. Even in 2000, when natural gas prices were at their lowest point of the past decade, natural gas 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. Natural gas costs peaked in 2008 and have fallen dramatically since then. Some current forecasts predict a slow and gradual increase in prices. The availability of alternative fuels, such as clean digester or landfill gas, or waste heat from an industrial process (for indirect-fired chillers), would decrease the reliance on and cost of using natural gas.

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. However, with the decline in gas chiller sales, the number of personnel available to maintain these systems is also declining. This could make it difficult to find experienced personnel in the future. And gas chiller systems are more dependent on proper maintenance than electric ones. According to the manufacturers, significantly larger performance penalties are often seen for small maintenance lapses with gas chillers than with electric chillers.

Recovered heat savings. Thermal energy recovered from an engine-driven chiller can be used for space, water, or process heating. The waste heat from absorption chillers is not as hot, which makes it more difficult to cost-effectively make use of. (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 emissions 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 and a gas-powered lawn mower has a decibel level of about 90.)

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?

this section

With the decline in sales in the U.S. market over the past several years, development of new technology for gas-fired chillers in the U.S. has virtually stopped. However, development may continue in other markets, such as Asia, which currently has 80 percent of the gas-fired chiller market.

WHO ARE THE MANUFACTURERS?

this section

Absorption

- Trane
- York
- Carrier

Engine-driven

- Tecogen
- York

Neither this list nor any mention of a specific vendor or product constitutes an endorsement or recommendation by E Source, nor does any content the Business Energy Advisor constitute an endorsement or recommendation, explicit or otherwise, of your service provider's various technology-related programs.

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