COOL YOUR JETS!

Chiller Technologies for Turbine Inlet Cooling (Part 2)

This column is the fourth in a series covering turbine inlet cooling (TIC), and the second part to April's column on chiller technologies for TIC, which covered the technology and economics of using only electric chillers. (To read April's "Cool Your Jets" column go to www.energy-tech.com and search under "Articles," then "Archives," or log on to www.turbineinletcooling.org/News/ETApr04.pdf). This column continues the discussion on chiller technologies and covers the technologies and economics of non-electric chillers. As stated in the previous columns, all TIC technologies have their advantages and limitations and the selection of an optimum technology for a specific power plant depends on a number of factors, including the plant's geographical location, CT characteristics, plant operating mode, market value of electric energy, and fuel cost. Discussions on these details are outside the current scope of this column.

Technologies

As shown in a process schematic in the April issue of the column, all TIC systems that use chillers draw the turbine inlet air across a cooling coil in which either chilled water or a refrigerant is circulated, and pressure drop across the cooling coil is generally 1 to 2 inches of water column. The chilled water could be supplied directly from a chiller or from a thermal energy storage (TES) tank that stores ice or chilled water. The two most common types of chiller technologies used for TIC are mechanical chillers and absorption chillers. The mechanical chillers in general and electric motor-driven mechanical chillers (hereafter referred to as "electric chillers") in particular were discussed in the April column. This column discusses non-electric chillers: absorption chillers, and mechanical chillers driven by engines (using natural gas or diesel) or turbines (driven by steam or combustion gases).

Absorption Chillers are different from mechanical chillers in that they do not need a mechanical compressor for compressing the refrigerant and that the refrigerant they use is either water or ammonia, instead of a hydrocarbon fluid as used in mechanical chillers. The primary source of energy for absorption chillers is thermal, instead of electrical or mechanical. The process schematic of an absorption chiller is shown in Figure 1. The source of thermal energy for absorption chillers could be hot water, steam, or a fuel, like natural gas. Compared to mechanical chillers that require 0.7 to 0.8 kW/RT, (One Refrigeration Ton, RT, chiller capacity is defined as heat removal rate capability of 12,000 Btu/h.), absorption chillers require very little electrical energy necessary for operating only a few pumps. Typically, an absorption chiller needs parasitic power of only about 0.02 kW/RT plus up to 0.26 kW/RT for condenser water pumps and cooling tower fans, and thus, a total power need of 0.28 kW/RT.

Many types of absorption chillers are commercially available. Absorption chillers could be single-effect or double-effect. The double-effect chillers are more energy efficient but require higher temperature heat and more capital cost. Absorption chillers could incorporate a mixture of lithium bromide with water or water with ammonia. Absorption chillers that use lithium bromide–water mixture are significantly more commonly used than those that use water and ammonia mixture chillers. The single-effect chiller is the most popular absorption chiller for TIC applications. A single-effect absorption chiller (using lithi-

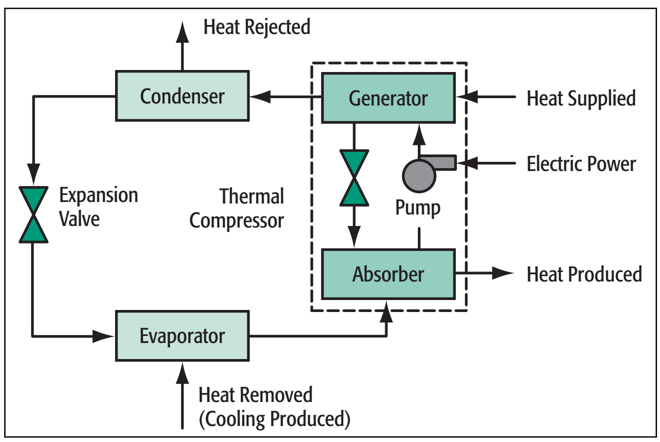

Figure 1. Process Schematic of a Single-Effect Absorption Chiller

um bromide and water mixture) can use hot water at least 190°F or 18 lbs/h of steam at 15-psig per RT. A double-effect absorption chiller (using lithium bromide and water) requires about 10 lbs/h of steam at about 115 psig per RT. These absorption chillers are generally used to cool the turbine inlet air to about 50°F. Absorption chillers using water and ammonia can cool the inlet air to 42°F, just as the mechanical chillers do. (For more information on absorption chillers, please go to www.gastechnology.org/gascooling/gti.) The use of absorption chillers is attractive in applications that have excess thermal energy, and the conversion of this energy to higher-value electric energy is a win-win proposition for the power plant owner.

Non-Electric Mechanical Chillers are similar to electric chillers except the compressor for the refrigerant in these chillers is driven by either an engine or a turbine.

If an engine operates a mechanical chiller, total electric power requirement for the chiller system is only about 0.18 kW/RT. Engines are generally used in applications where natural gas or diesel fuel is available at low cost and/or combustion turbines are operating mechanical equipment, i.e., gas compressors and pumps, rather than electric power generators.

If a steam turbine is used for operating a mechanical chiller, total electric power required by the chiller system is about 0.28 kW/RT. This parasitic power need is higher than that for the engine-driven chiller system because the steam turbine system requires more power for the cooling tower pumps. A steam turbine-driven chiller requires about 10 lbs per hour of steam (at 120 psig) per RT of cooling. Steam turbine-driven systems are economical when steam is easily and economically available and it is desirable to maximize the electric power output of the power plant instead of using a part of it for operating chillers. Generally, steam turbine driven chillers are economical for chiller capacities of at least 700 RT.

Advantages & Limitations

The primary advantages and limitations of using chiller technologies are outlined in April's column. The primary advantage of all non-electric chillers (absorption as well as engine- and turbine-driven mechanical chillers) over electric chillers is that they allow higher net power capacity enhancement when cooling turbine inlet air to the same temperature, because of their lower parasitic power needs.

The major disadvantage of all non-electric chillers is their higher capital costs compared to the same capacity electric chillers.

A limitation of absorption chillers using lithium bromide and water is that they cannot cool the inlet air to temperatures as low as possible as with mechanical chillers. Generally, these absorption chillers are used to cool the inlet air to about 50°F.

Economics

The economics of chiller technologies for TIC discussed here uses an example of a cogeneration power plant located in the Houston, Texas area, having a rated capacity of 316.8 MW (3 industrial frame CTs of 105.6 MW each). When the ambient temperature in Houston is 95°F, dry-bulb and coincident wet-bulb temperature is 80°F, the output of the cogeneration plant, without any cooling drops to about 273 MW. Compared to the rated capacity, the plant output drops by about 44 MW or a capacity loss of about 14 percent.

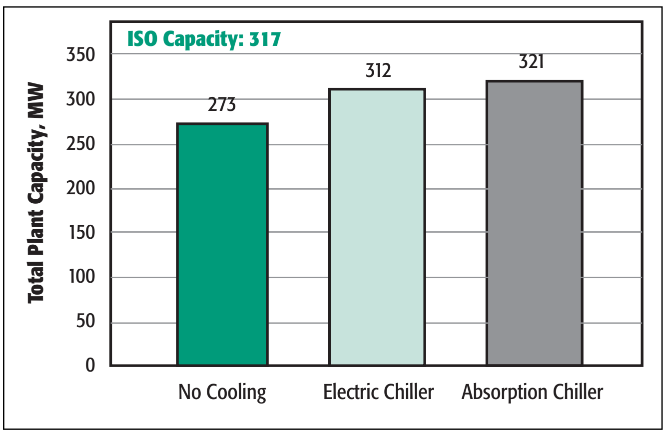

Figure 2. Effect of Chiller Technology on Net Power Output

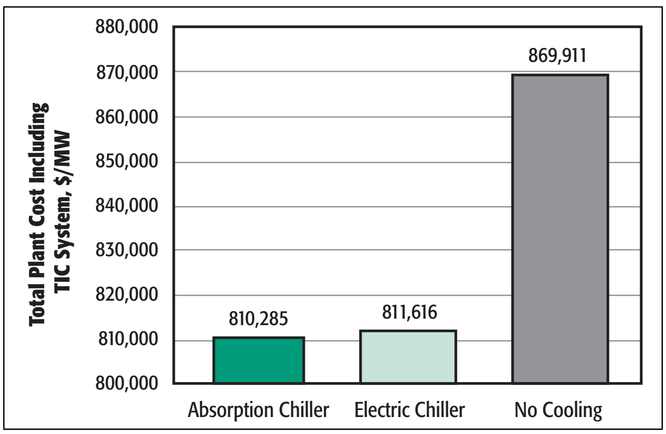

Figure 3. Effect of Chiller Technology on Total Plant Investment

Figure 2 shows the effect of chiller technology on net power output capacity when the inlet air is cooled from 95°F ambient dry-bulb temperature to 50°F. The results show that the single-effect absorption chiller provides the maximum net power capacity of 321 MW or a capacity enhancement of 48 MW above the 273 MW capacity of the uncooled system at 95°F ambient temperature. The electric chiller provides a total capacity of 312 MW or a capacity enhancement of 39 MW. The results in this figure are based on total parasitic loads of 0.81 kW/RT and 0.28 kW/RT for the electric and absorption chillers, respectively, and cooling coil pressure drop of 1.5 inches of water column.

Figure 3 shows the effect of cooling technology on total plant (power plant plus TIC system) cost per MW of the net capacity of the plant for similar conditions as those for Figure 2. The costs in Figure 3 are based on the following installed costs for the power plant and TIC systems: $750,000/MW for the cogeneration plant at the rated capacity, $834/RT for the complete TIC system (with cooling coil, chillers, pumps, demisters and cooling towers) with electric chillers, and $1,240/RT for the complete TIC system with the absorption chiller. On this basis, the total cost of the cogeneration plant without TIC is $237.6 million. When the ambient temperature rises to 95°F and its total capacity decreases to 273 MW, the effective capital cost of the cogeneration plant rises from $750,000/MW to about $870,000/MW for the same total investment of $237.6 million. The results in Figure 3 show that the total plant cost is the lowest for the plant with the TIC system using absorption chiller.

Figure 4 shows the effect of chiller technology on the total cost for the incremental power capacity enhancement above the capacity of the uncooled plant at 95°F for the same set of conditions discussed for Figures 2 and 3. It shows that both TIC systems provide incremental power at nearly half the cost of an uncooled system and that the TIC system using electric chillers provides the incremental capacity at the lowest cost of $398,000/MW.

The estimates in Figures 2 through 4 are only "snapshot" results when the ambient dry-bulb temperature is 95°F and the turbine inlet air is cooled to 50°F for the plant's location in Houston. Based on the information in these figures, it is premature to draw any conclusion about the optimum technology for this plant. Further analyses are necessary using hourly weather data for all 8,760 hours of the year for estimating the net annual production of electrical energy (MWh) and steam and their respective market values and annual operating and maintenance costs.

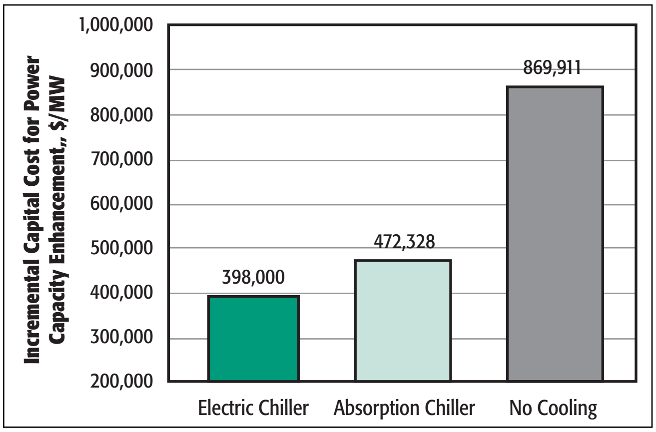

Figure 4. Effect of Chiller Technology on Capital Cost for Incremental Plant Capacity Enhancement

Users

Many CC plants across the U.S are using various chiller technologies that best suit their needs. A database of some of these installations is available in the Experience Database section of the Turbine Inlet Cooling Association website (www.turbineinletcooling.org).

Summary

In TIC systems, non-electric chillers produce higher power enhancement than the electric chillers. All chillers allow higher power enhancement than evaporative cooling systems and can produce capacity enhancement at less than one-half the capital cost per MW of the uncooled system. Subsequent columns will address the use of chillers coupled with thermal energy storage, as well as hybrid systems incorporating electric and non-electric chillers.

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