Use Low-Grade Waste Steam to Power Absorption Chillers

Absorption chillers use heat, instead of mechanical energy, to provide cooling. The mechanical vapor compressor is replaced by a thermal compressor (see figure) that consists of an absorber, a generator, a pump, and a throttling device. The refrigerant vapor from the evaporator is absorbed by a solution mixture in the absorber. This solution is then pumped to the generator where the refrigerant is revaporized using a waste steam heat source. The refrigerant-depleted solution is then returned to the absorber via a throttling device. The two most common refrigerant/absorbent mixtures used in absorption chillers are water/lithium bromide and ammonia/water.

Comparison of Mechanical and Thermal Vapor Compression Systems*

Compared to mechanical chillers, absorption chillers have a low coefficient of performance (COP = chiller load/heat input). Nonetheless, they can substantially reduce operating costs because they are energized by low-grade waste heat, while vapor compression chillers must be motor- or engine-driven.

Low-pressure, steam-driven absorption chillers are available in capacities ranging from 100 to 1,500 tons. Absorption chillers come in two commercially available designs: single-effect and double-effect. Single-effect machines provide a thermal COP of 0.7 and require about 18 pounds of 15-pounds-per-square-inch-gauge (psig) steam per ton-hour of cooling. Double-effect machines are about 40% more efficient, but require a higher grade of thermal input, using about 10 pounds of 100- to 150-psig steam per ton-hour.

*Suggested Actions
Determine the cost-effectiveness of displacing a portion of your cooling load with a waste-steam absorption chiller by taking the following steps:

- Conduct a plant survey to identify sources and availability of waste steam.
- Determine cooling load requirements and the cost of meeting those requirements with existing mechanical chillers or new installations.
- Obtain installed cost quotes for a waste-steam absorption chiller.
- Conduct a life-cycle cost analysis to determine if the waste-steam absorption chiller meets your company’s cost-effectiveness criteria.

*The evaporator and the condenser, required for both systems, are not shown in the figure.
Example

In a plant where low-pressure steam is currently being exhausted to the atmosphere, a mechanical chiller with a COP of 4.0 is used 4,000 hours per year (hr/yr) to produce an average of 300 tons of refrigeration. The cost of electricity at the plant is $0.06 per kilowatt-hour (kWh).

An absorption unit requiring 5,400 pounds per hour of 15-psig steam could replace the mechanical chiller, providing annual electrical cost savings of:

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\text{Annual Savings} = 300 \text{ tons} \times \left( \frac{12,000 \text{ Btu/ton}}{4.0} \right) \times 4,000 \text{ hr/yr} \times \frac{$0.06/\text{kWh}}{3,413 \text{ Btu}} = $63,287
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Resources

U.S. Department of Energy—DOE’s software, the Steam System Assessment Tool and Steam System Scoping Tool, can help you evaluate and identify steam system improvements. In addition, refer to Improving Steam System Performance: A Sourcebook for Industry for more information on steam system efficiency opportunities.

Visit the Advanced Manufacturing Office website at manufacturing.energy.gov to access these and many other industrial efficiency resources and information on training.