DATA CENTERS & AB/ADSORPTION CHILLERS

A few circumstances in a data center make it ripe for a CHP design to boost efficiency. Let's get into the options within both relevant chiller types, why payback may be shorter than expected, and the assorted potential benefits from lower costs to higher reliability. Some tips from an array of manufacturers' reps round out this useful investigation.

By Marcia Karr, P.E.

There are many who believe that combined heat and power (CHP) will be the norm in building design for the next generation of engineers. A discussion about CHP is not complete until one considers the cooling needs in a building, especially in data centers. To maximize the performance of a CHP system, we would use the waste heat of a prime mover all year:

- For year-round base loads, such as potable hot water and/or refrigeration
- In the winter for space heating
- In the summer for space cooling

Many buildings will benefit from engineers offering CHP with absorption chillers to their customers such as hotels and resorts, food processing, cold storage facilities, breweries, supermarkets, health care, etc. Data centers, however, offer a unique opportunity for absorption chillers. Since data centers have a good balance between electric and thermal loads all year, the operation/commissioning of the CHP plant can be optimized to meet the relatively flat annual load profile. Data centers do not have the seasonal variations that require equipment to operate at part load most of the time. Data centers require reliable and high-quality power. In addition, there are great strategies and technologies available to allow data centers to significantly reduce operating costs, even though data centers are an all-electric operation.

When maximizing the potential of the CHP plant by adding ab/ad sorption chillers in data centers, we:

- Reduce energy costs
- Stabilize risks associated with fluctuating energy costs
- Improve equipment reliability
- Reduce greenhouse gas emissions by up to 50% for the power generated
- Reduce grid congestion
- Reduce electrical demand charges
- Provide reliable power supply

Also, ab/ad sorption chillers use natural refrigerants (existing in nature) like R717 (NH3) and R744 (CO_2), water and air, which are promoted through the LEED certification program, ASHRAE, EPA, DOE, and GSA. (CHP can be shown to offer 5-9 LEED points, *http://www3.epa.gov/chp/documents/treatment_of_chp_in_leed_building_design.pdf.*)

There are numerous case studies where the above listed potential is achieved in data centers with the implementation of absorption chillers. One such study identified a data center located next to a power plant, so they got their waste heat from the power station to use in their absorption chillers!

Data centers are an all-electric operation where, according to 42U (a leader in data center design and management), about 33% of the energy is for chillers and 30% is for servers. The rest is for CRAC, PDU, and about 18% is for the UPS. With CHP, the UPS

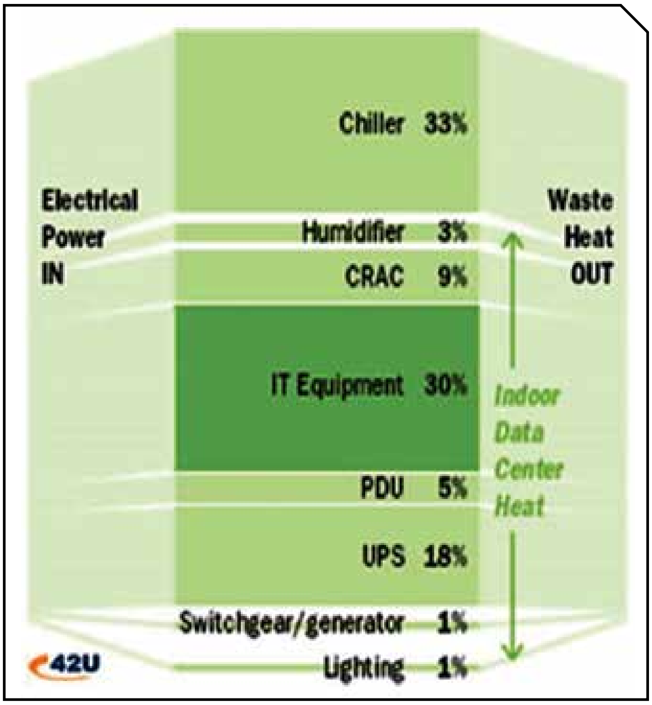

FIGURE 1. Where does the energy go in data centers? (Source: The Green Grid)

may be considered redundant and therefore not needed, saving 18% of the energy use in data centers off the bat (Figure 1).

PAYBACK

Let's consider an example data center that uses an average of 500,000 kWh per month and has a cooling load of 33% of that electric consumption. This condition would warrant a 400 kW reciprocating engine coupled with a 200-ton chiller. If we further use a COP of 3.0 for the existing chiller and a COP of the ab/ad sorption chiller of 0.8, we find we get a payback of about eight years. But a simple payback analysis is not complete unless we consider avoided costs, as it makes no sense to do a payback analysis against doing nothing. Therefore, if we consider converting to absorption chiller technology when we need to do a chiller replacement, and have the avoided costs of a new DX chiller, the payback drops to under five years. Furthermore, if we consider any incentives available from the list of possible incentives provided at *www.dsireusa.org*, the payback can drop to around three years, making this a very viable consideration. (This payback does not consider a data center set up to maximize free cooling using outside air in the winter season.)

From page 29 of the March 2009 *ICF Opportunities for Combined Heat and Power in Data Centers*, (*http://www1.eere.energy.gov/manufacturing/datacenters/pdfs/chp_data_centers.pdf*) we find the following Table 13, followed by some interesting project specifics. Without incentives factored in, the payback ranges from 6.1 years to 11.5 yrs for the 1,000-kW IT load. With incentives, the payback can be very attractive to the private sector needs.

The basic operation of absorption chillers is not mechanical like the standard refrigeration cycle, but rather a thermochemical process involving evaporation, absorption, pressurization, vaporization, condensation, throttling, and expansion. The basic cycle can be seen in Figure 3, where the "hot water in" is the cooling water for the engine.

The standard absorption chiller uses water as the refrigerant and an absorbent, like lithium bromide (LiBr) or ammonia, both natural refrigerants. An example of the absorption technology in which we are all familiar is the propane refrigerator in a recreational vehicle.

Absorption and adsorption chillers can be run off hot water or steam. In general, the efficiency of the chiller is directly related to the temperature of the heat source. The hotter the heat source, the higher the efficiency. But, not all chillers can provide all temperatures of refrigeration. For data centers, we only need "high" temperature refrigeration so absorption technologies are a viable technology, and the best absorption chiller technology will depend on other heat loads in the building. In general, absorption chillers are less noisy than mechanical chillers, so these are used where noise is a concern, such as hospitals and schools.

TWO BASIC TYPES OF ABSORPTION CHILLERS

Lithium bromide absorption chillers. Lithium bromide type absorption chillers are available in single- and double-effect type. This technology provides chilled water temperature at ~42°F. The single-effect COP is between 0.5 and 0.7 and can accept lower water temperatures (about 170°F) than the double effect. The double effect absorption chillers have a higher COP, 1.1 to 1.39, but

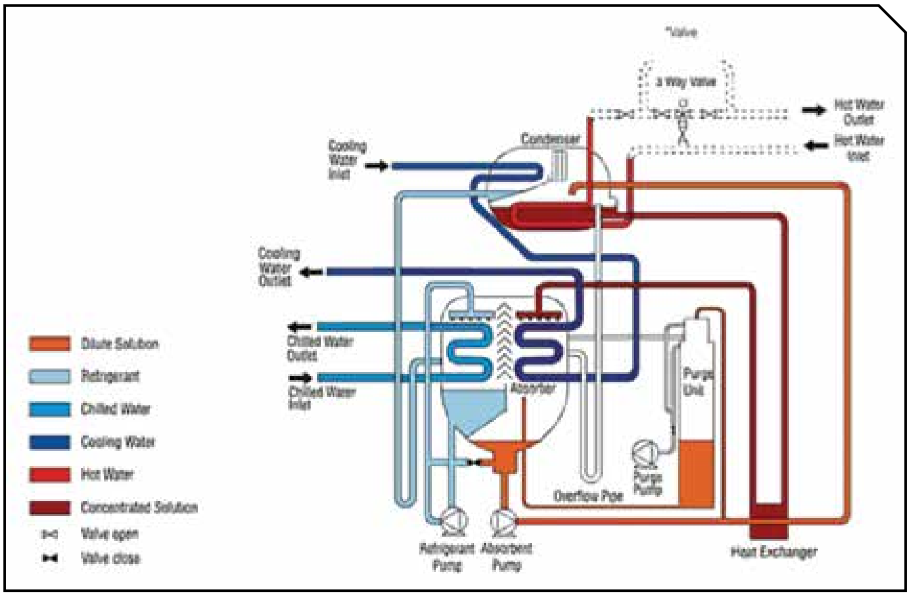

FIGURE 2. Cogenie & ProChill basic cycle diagram. (Source: Trane)

Data Center Applications	1,000 kW IT load			10,000 kW IT load
CHP System	Jenbacher Recip J320V085	UTC PureComfort Model 400M	UTC PureCell Model 400	Solar Mercury 50 GT
System Type	Recip. Engine	Micro-turbine x 2	Fuel Cell x 3	Gas Turbine x 2
Chiller Type	Single Effect	Double Effect	Single Effect	Double Effect
Capacity kW	1,060	752	1,200	8,850
Thermal, Btu/kWh	4,259	4,937	4,270	2,937
Cooling tons	266	362	150	2606
Natural Gas Use MMBtu/hr	10.25	9.19	11.37	88.22
Heat Rate, HHV	9,668	12,221	9,471	9,968
Electric Efficiency	35.3%	27.9%	36.0%	34.2%
CHP Efficiency	79.4%	68.3%	81.1%	63.7%
Virtual Electric Eff.	40.6%	33.8%	39.7%	40.3%
tons/kWh	0.25	0.48	0.13	0.29
Installed Capital Cost w/o chiller, $/kW	$2,100	$2,500	$4,750	$1,547
Absorption Chiller Installed Cost $/ton	$1,600	$2,000	$2,000	$828
Total Capital Cost, $/kW	$2,501	$3,463	$5,000	$1,791
Est. O&M cost $/kWh	$0.019	$0.021	$0.020	$0.008

TABLE 1. Example CHP systems cost and performance for 1,000 and 10,000 nominal IT load cases. (Source: ICF International, Inc.)

require a hotter water temperature to achieve these efficiencies, which may be too hot for proper operation of the prime mover.

A detailed load profile is needed for the most appropriate combination of equipment to be specified since the best sorption chiller is a function of the quality of waste heat available from the CHP system. Most of the waste heat off a genset is great for hot water needs as needed for single-effect absorption chillers. For some generators, only the stack offers a temperature hot enough to generate steam. And, steam is what is needed for the higher-efficiency chillers. The highest temperature of the jacket, lube system, and intercooler may need to be in the 170°F range to prevent damage to the engine. The percentage of waste heat available from the stack is only about a quarter of the total heat available off the genset. If the electric load in the facility is large enough, the available steam off the engine stack may be enough to warrant the double-effect chillers.

The LiBr chillers are production units and available from about 15 manufacturers globally. They are intended for HVAC chilled water duty, not for "medium" or "low" temperature refrigeration duty. LiBr absorption chillers are available in sizes ranging from 50- to 800-ton for single-effect hot water, and 100- to 1,000-ton capacity for exhaust gas or steam double-effect chillers.

Aqueous ammonia absorption chillers. The aqueous ammonia type requires hot fluid driven in the 250° to 350°F fluid temp range, a temperature that may be too hot for the prime mover cooling jacket water. These chillers do offer chilled fluid temp from the -50°F to 32°F range using glycol or other low-temp heat transfer fluid. COPs available from the aqueous ammonia chillers are from .40 to .7 currently, although some manufacturers, like Thermax, are working with higher-COP systems. There are about five manufacturers globally, and these chillers are custom built for the application. Aqueous ammonia absorption chillers are available in sizes ranging from 50- to 500-ton using high-pressure hot water or steam.

Then there is the adsorption chiller. This type of chiller has been manufactured and successfully installed by three or four global manufacturers. This chiller only needs hot water input of 140°F to 176°F (an ideal temperature for cooling an engine) and can provide 41°F chilled water outlet temperature, which is perfect for data center cooling. The adsorption chiller has COPs from .5 to .68 and can use the lower heat source temp than the absorption chillers. It is the best option when a low-heat source temperature is available, such as a reciprocating engine prime mover or free heat from solar hot water panels (Figure 4).

The refrigerant in the adsorption chiller is water, and the adsorbent is either a silica gel or a zeolite. Adsorption chillers are available in 20- to 25-ton capacity. The adsorption chiller uses a natural refrigerant, is very quiet, and does not require a certified operator. The storage tank is used like a battery, storing thermal energy for use when needed.

Finally, just to keep it interesting, there is a waste heat single-effect chiller-heater. This unit takes the waste heat off the genset to provide chilled water, using water as the refrigerant and LiBr as the absorbent just like the absorption chiller described above. This technology offers a chiller and boiler in one package and is appropriate for a site that has heating or potable hot water needs too.

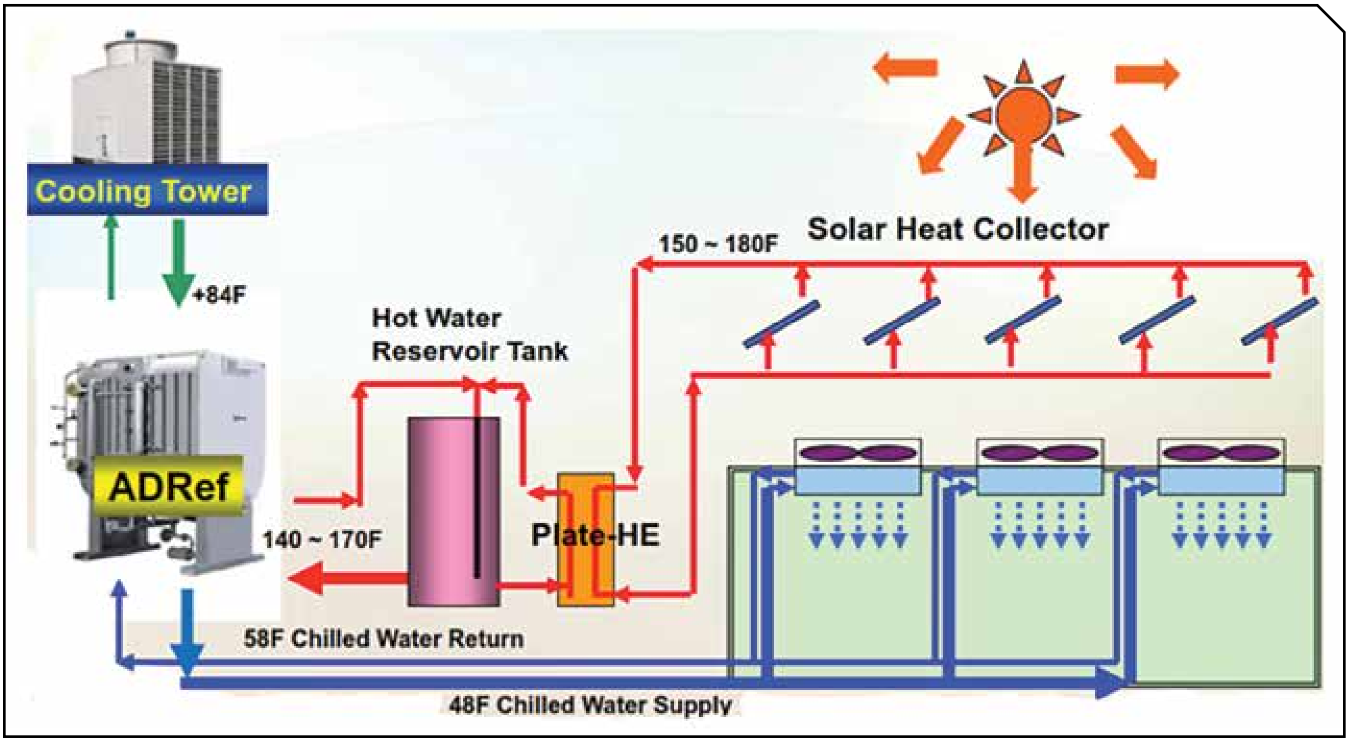

FIGURE 3. Low, temperature adsorption waste heat chiller. (Source: Mayekawa)

Beyond the standard waste heat chillers, we have a few hybrid type systems. For example, we can use CO_2 to improve the efficiency of data centers. Using CO_2 as the secondary fluid for data centers is a technology that saves trying to cool the whole data center room, focusing only on the servers. A CO_2 plate heat exchanger located under the server for cooling is significantly more efficient than cooling the whole data center. This approach cools only the server using pumped liquid CO_2, which is cooled by the screw package. It is much more efficient and much less pumping horsepower is required for CO_2 versus the typical chilled water setup (Figure 5).

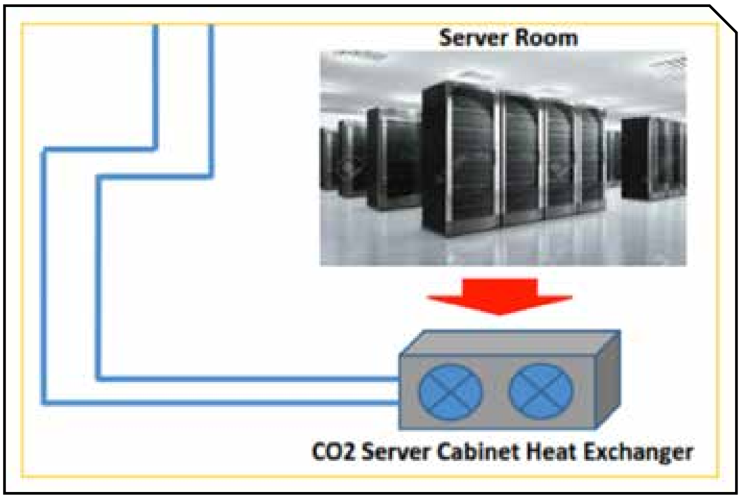

FIGURE 2. Data center chilled CO_2 distribution. (Source: Mayekawa)

COMMISSIONING

One of the biggest problems that rise in ab/ad sorption chiller installations stems from the commissioning process. Typically, each piece of equipment is commissioned as a standalone unit. However, ab/ad sorption chillers require interaction with many other pieces of equipment as part of a bigger system. There are emissions, generators, grid interconnection, waste heat recovery, desiccant air dryers, building systems integration, etc., all requiring a sophisticated control logic for optimal interdependent operation. Many features need to be controlled based on dynamic conditions within the facility.

Commissioning is particularly tricky when traditional chillers are installed for peak loads or for backup as flow rates are unique to each technology. This requires a detailed points list from the design engineer to make adjustments based on a variety of input conditions. Manufacturers of equipment in the sophisticated central plant will encourage 24-hr monitoring and preventative diagnostic services to address any issues promptly and efficiently.

What are manufacturer's representatives saying about lessons learned?

"The important factor in project longevity would be to keep up on the required maintenance specified by the equipment manufacturers and the design engineer, much like other thermal based equipment. These projects also have NG engines, so keeping up on the maintenance schedule of these components is very important. Most engine manufacturers, like CAT, MWM, and GE Jenbacher have factory maintenance groups that offer after sales maintenance programs and emergency service. Also, it is important to keep

up to date on natural gas costs, exploring different third-party gas service providers, and considering long-term cost contracts. Opportunities can come up with lower NG costs that can further improve system cost savings years after initial start-up."

—Troy Davis, energy manager, Mayekawa USA, MYCOM

"For a successful, long-lived CCHP installation, there needs to be an on-site champion who takes the complexity of CCHP system operations and maintenance seriously. This champion needs trained talent not unlike that required for boiler operator certification, who will stay the course of the 15-20 year life of the system."

—Nolan Hill, Highland West Energy

"By far, the most common mistake is the lack of a method to stop the heat medium flow when the unit is shut down because the chilled water loop is satisfied. At least 25% of the time, the site has no heat medium bypass valve and does not use the proper contacts to control the heat medium pump. The most dangerous oversite though is to not check rotation of the solution pump. Lack of heat medium flow control might cause trouble. Reversed solution pump rotation WILL cause service trouble."

—Chris McCord, training and technical services manager, Yazaki Energy

"It is important that there be 24-hr monitoring, yearly sorbent solution check, and preventive diagnostic services."

—Stefan Lidington, Norman S. Wright Northwest

For many applications, it will make sense to go with a packaged system, where the major components are already interconnected and skid mounted or containerized. Companies like Mayekawa, 2G Cenergy, and Broad offer a wide range of chiller styles and models and offer complete skid packages that include the prime mover, containers, cooling tower/radiator, pumps, electrical switchgear and panels, and more for a complete package designed to fit the loads of a specific site. For these packaged systems, the controls can be defined as integral for the most part. The control of the peripheral components outside of the box can be commissioned as usual. **ES**

REFERENCES

Information in this article was obtained by manufacturers of ab/ad sorption chillers and from:

- Energy Recovery Systems for the Efficient Cooling of Data Centers using Absorption Chillers and Renewable Energy resources, *http://www.wseas.us/e-library/conferences/2013/Valencia/ICCS/ICCS-12.pdf*
- Combined Heat and Power Partnership, *http://www3.epa.gov/chp/*
- Opportunities for Combined Heat and power in Data Centers, ICF International, https://datacenters.lbl.gov/sites/all/files/chp_data_centers.pdf
- The Green Grid, *http://www.thegreengrid.org/*

Marcia Karr, P.E., an energy engineer with the Washington State University Energy Program, has over 30 years of experience in commercial building design, construction, and maintenance. Her positions have included providing DOE hotline support, CHP assessments and peer review of assessments, building and energy code plan reviewer, union trades supervisor, design/build engineer, field construction engineer and project coordinator, and HVAC designer (commercial and institutional). Karr is a registered Professional Engineer in Washington and Oregon, has a B.S. in mechanical engineering, and is a licensed Commercial Buildings Energy Code (NREC) Plans Examiner.

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