New Series: Optimizing Central Plants

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Resort Saves Money Using Rejected Heat

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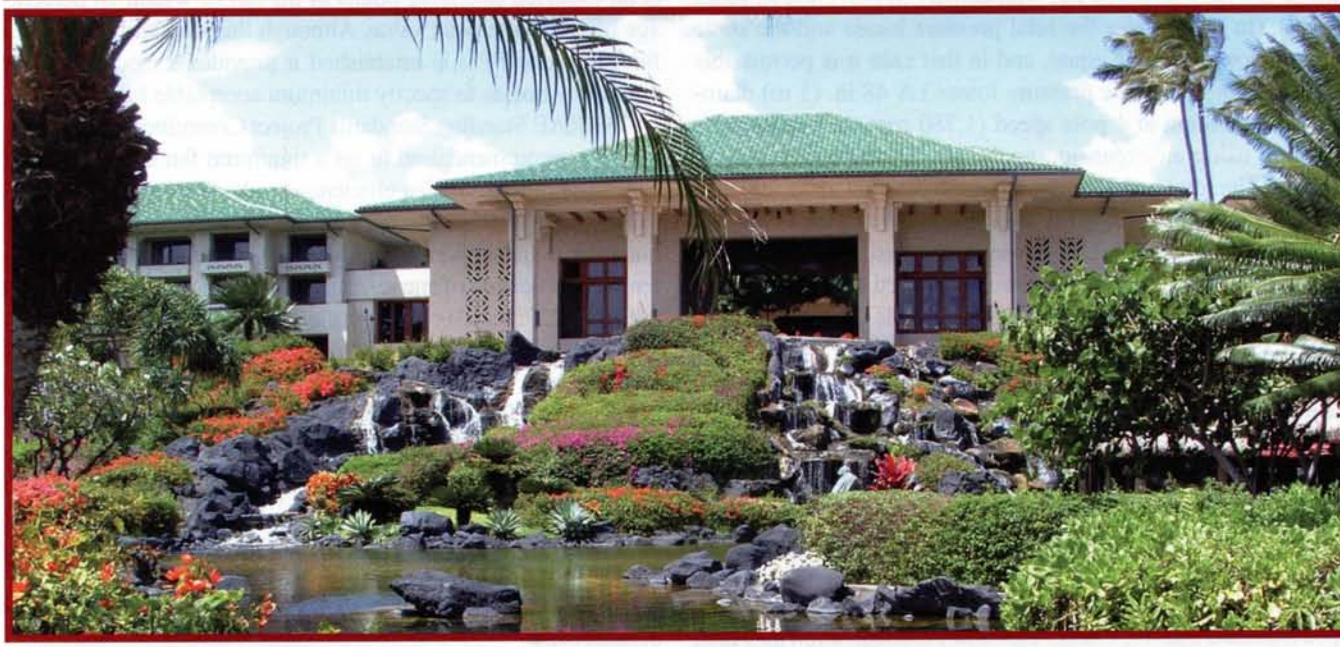

The hotel's grand lobby provides an expansive view of the Pacific Ocean and the manicured landscaping of the property.

RESORT CENTRAL PLANT

By Al Butkus, P.E., Member ASHRAE

Grand Hyatt Kaua'i Resort and Spa is a resort located on the south side of the island of Kauai on Poipu Beach. The 750,000 ft^2 resort includes 602 guestrooms, a full-service spa, 65,000 ft^2 of meeting space, three restaurants, and multiple pools, including a saltwater swimming lagoon. Ownership and management of the property wished to address operational issues related to central plant heat rejection and domestic hot water generation. They wished to do so as efficiently as possible while maintaining reliability and redundancy of systems.

Central Plant Heat Rejection System

Figure 1 depicts the original central plant heat rejection system. The primary source of rejected heat is that rejected by two, 600 ton centrifugal chillers (C-l and C-2). Each chiller has a design heat rejection of 8,379 MBH (1,800 gpm, 85°F to 94.3°F). The design cooling load for the building was estimated to be approximately 950 tons.

Heat from the chillers can be rejected to the fresh water swimming pool (HEX-1, 6,258 MBH design heat transfer), and to the saltwater lagoon (HEX-2 and HEX-3, 4,185 MBH design heat transfer). The saltwater lagoon is a swimmable water feature on the property. HEX-2 and HEX-3 can be used as supplemental heat rejection exchangers for the central plant's chillers.

Any excess heat is rejected to the ground water via HEX-4 or often referred to as the source well plate heat exchanger. This heat exchanger was rated at 13,200 MBH heat rejection. The source of the groundwater is a well that is a 16 in. casing. Saltwater is supplied via two fiberglass pumps (SW-1 and SW-2, rated at 2,000 gpm each).

The saltwater can be directed through heat exchangers HEX-2, HEX-3, or HEX-4 to reject heat from the condenser loop. After the water is heated, it passes through a water feature lagoon, referred to as the flow-through lagoon, which is not a swimmable water feature. Water from the lagoon drains into a surge tank

°C = °F – 32/1.8; L/s = gpm × 0.0631; kW = bhp × 9.81; L = gallon × 3.78

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and is pumped via a set of pumps (BAG-1 and BAG-2) that pump water through bag filters and back into the ground via injection wells.

On paper, the system looked great, but the following deficiencies were uncovered and/or developed over time.

• The source well temperature was assumed to be 78°F in design. It was actually rarely observed to be below 80°F.

• The source well water flow was designed at 3,000 gpm, but this was rarely, if ever, achieved. Actual flows ranged from 1,400 gpm to 2,700 gpm.

• The system used a significant amount of pumping energy: 160 bhp if one chiller was operating and 250 bhp if two chillers were operating.

• The bag filter system was maintenance-intensive as were the additional pumps and heat exchangers needed to operate the system.

More than enough heat was available to heat the pools in summer conditions; however, heat rejection was inadequate for the plant. Chiller leaving condenser water was observed to be as high as 103°F (versus 94.3°F design), increasing chiller energy consumption dramatically.

Many options were considered to address the issue, including:

• Install additional water features to increase pool heat rejection;

• Reduce building cooling loads, reducing heat rejection required;

• Use thermal storage to shift cooling load to other hours of the day;

• Install air-cooled chillers that would not require the use of the source well;

• Modify the source well to increase its capacity; and

• Install a new heat rejection system that uses cooling towers.

The first four options mentioned previously weren't considered feasible. Some reasons included:

• Additional water features to increase pool heat losses was not considered feasible due to the space required to do so.

• Reducing building cooling loads at peak times would be difficult at the level of reductions needed.

• The economics of thermal storage was likely to be a challenge. Space for chilled water storage would be difficult to find and the cost of an ice storage system was cost prohibitive, in our opinion.

• Air-cooled refrigeration would add to the facility's energy costs and was not in keeping with the project's goals.

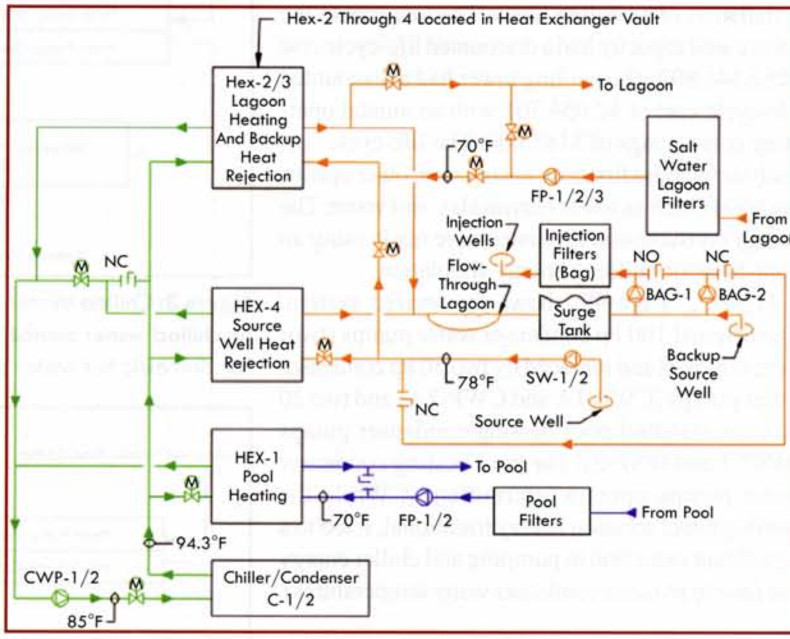

Figure 1: Original Plant Heat Rejection Diagram. The heat from the chillers was rejected to two water features: a pool and swimming lagoon, as well as to groundwater, via four plate heat exchangers.

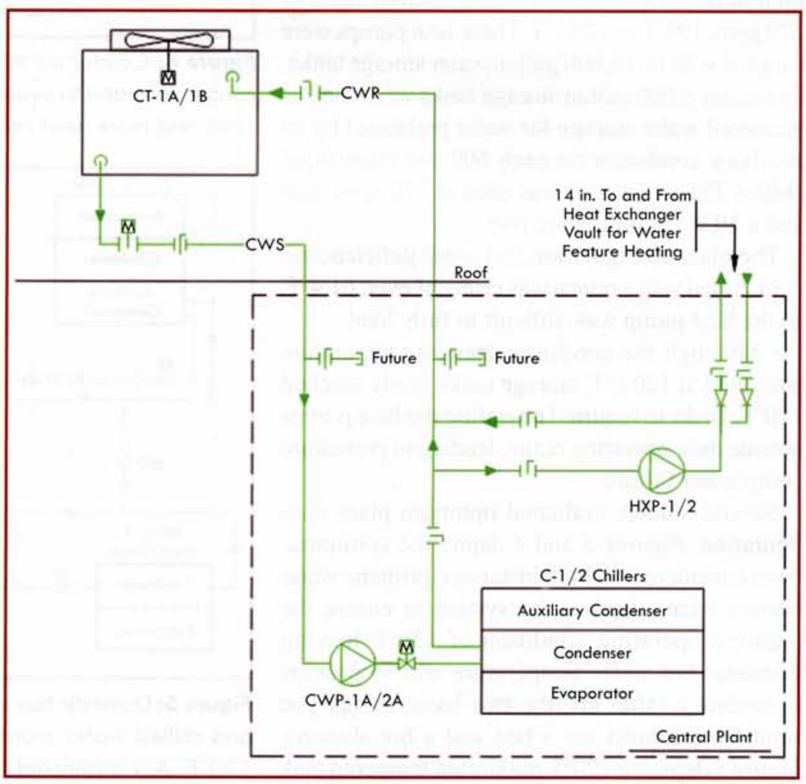

Figure 2: Revised Central Plant Heat Rejection Diagram. A traditional cooling tower replaced the groundwater heat rejection system, using far less energy. The configuration of heating for the water features remained the same using a much smaller pump (HXP 1/2).

A life-cycle cost analysis was performed on the two scenarios that were deemed feasible: modifying the source well to increase capacity and the installation of a cooling tower. The increase to the source well capacity had a discounted life-cycle cost of $2,546,802. The cooling tower had a discounted life-cycle cost of $2,054,701 with an annual operating cost savings of $185,000. The life-cycle cost analysis includes first cost, energy cost, other operating costs (such as tower chemicals), and water. The energy consumption estimates were made using an hour-by-hour building energy simulation.

Figure 2, Page 49, shows the revised system. The original 100 hp condenser water pumps (two) were removed and replaced by two 50 hp condenser water pumps (CWP-1A and CWP-2A) and two 20 hp (one standby) pool heating condenser pumps (HXP-1 and HXP-2). The pool heating condenser water pumps operate intermittently. While the cooling tower solution is very traditional, it led to a significant reduction in pumping and chiller energy use (due to reduced condenser water temperatures).

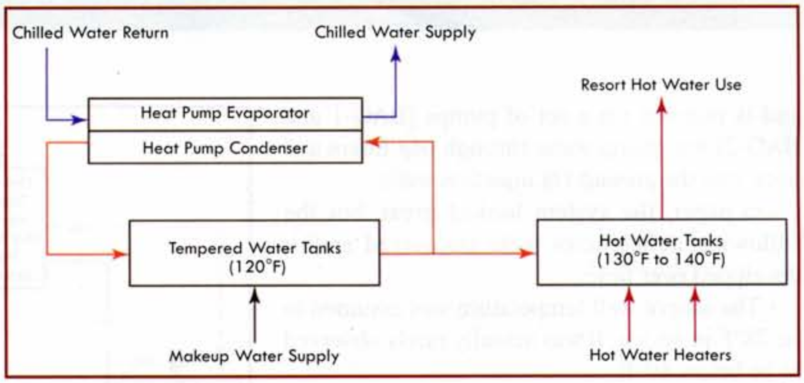

Figure 3: Chilled Water Source Heat Pump. Economic comparisons were made of chilled water source and condenser water source (Figure 4) heat pumps for domestic hot water production.

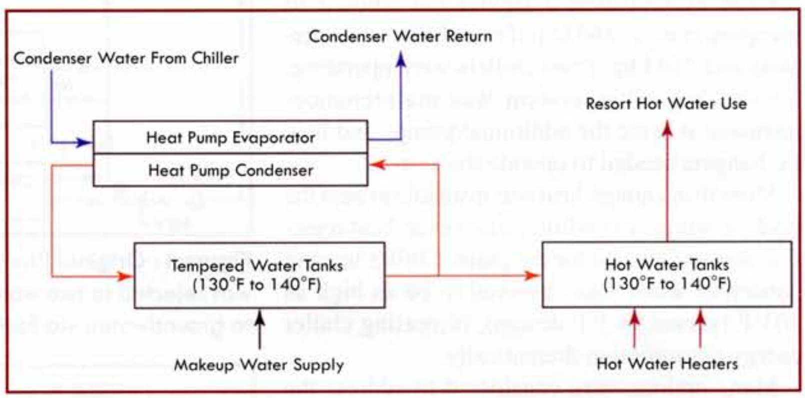

Figure 4: Condenser Water Source Heat Pump. Use of higher temperature condenser water in evaporator allowed for higher tempered water temperatures and more heat recovery energy.

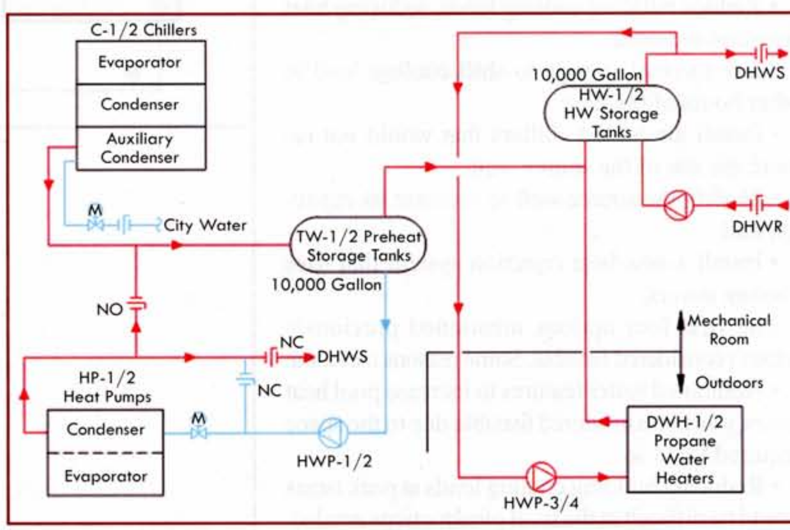

Figure 5: Domestic Hot Water Flow. Heat from auxiliary condensers in chillers and chilled water source heat pumps charge the preheat storage tanks to 120°F. Any additional heat needed for domestic hot water supply conditions is provided by propane water heaters.

Domestic Hot Water Production

The original plant consisted of two 85.1 ton water source heat pumps rated at 61.4°F to 48°F, 152 gpm in the evaporator and the condenser rated at 230 gpm, 109°F to 120.6°F. These heat pumps were coupled with two 5,000 gallon water storage tanks. Two other 5,000 gallon storage tanks were used as tempered water storage for water preheated by an auxiliary condenser on each 600 ton centrifugal chiller. This condenser was rated at 230 gpm each and a 10.9°F temperature rise.

The plant configuration had some deficiencies:

• Chilled water return was rarely, if ever, 61.4°F, so the heat pump was difficult to fully load.

• Although the condenser leaving temperature was rated at 120.6°F, storage tanks rarely reached 120°F. To do so required operating the heat pumps outside their operating range, leading to premature compressor failures.

Several studies evaluated optimum plant configuration. *Figures 3* and *4* depict the configurations considered. In both instances, propane water heaters were added to the system to ensure the required operating condition of 130°F leaving domestic hot water temperature and to provide redundancy (after all, the two basic things you want from a hotel are a bed and a hot shower). *Figure 3* depicts a 120°F maximum tempered tank storage configuration using chilled water as the source. The propane-fired heaters would provide an additional 10°F to 20°F boost to supply the proper operating temperature for the domestic water system. *Figure 4* depicts a 140°F maximum tempered tank configuration using condenser water as the source. As in the previous case, propane heaters

Option	Manufacturer	Capacity (Tons)	Equip. Cost (Each)	First Year Energy Costs	Energy LCC (Present Value)	Project First Costs (Present Value)	Total LCC (Present Value)	LCC (Percent of Min.)
Option 1 Replace Existing Heat Pumps with Chilled Water Source Heat Pumps (120°F)	Mfr A-1	70.6	$63,500	$209,096	$2,074,713	$354,000	$2,428,713	116%
	Mfr A-2	94.6	$57,000	$206,747	$2,099,937	$341,000	$2,440,937	117%
	Mfr A-3	106.0	$82,200	$216,050	$2,208,473	$391,400	$2,599,873	124%
	Mfr B-1	68.1	$49,000	$176,554	$1,768,232	$325,000	$2,093,232	100%
	Mfr B-2	88.2	$57,400	$177,799	$1,819,128	$341,800	$2,160,928	103%
	Mfr B-3	103.3	$63,900	$178,705	$1,857,088	$354,800	$2,211,888	106%
	Mfr C-1	83.0	$101,750	$165,266	$1,692,793	$430,500	$2,123,293	101%
	Mfr C-2	100.0	$107,250	$163,721	$1,711,759	$441,500	$2,153,259	103%
	Mfr C-3	150.0	$119,100	$160,838	$1,782,936	$465,200	$2,248,136	107%
Option 2 Replace Existing Heat Pumps with Condenser Water Source Heat Pumps (140°F)	Mfr D-1	68.3	$81,800	$189,159	$1,886,037	$467,600	$2,353,637	112%
	Mfr D-2	85.3	$103,000	$180,059	$1,835,085	$510,000	$2,345,085	112%
	Mfr D-3	99.5	$103,600	$181,563	$1,876,778	$511,200	$2,387,978	114%
	Mfr C-4	61.0	$105,000	$195,113	$1,926,140	$514,000	$2,440,140	117%
	Mfr C-5	61.0	$105,000	$202,821	$1,997,970	$514,000	$2,511,970	120%
	Mfr C-6	83.0	$105,000	$175,314	$1,786,538	$514,000	$2,300,538	110%
	Mfr C-7	83.0	$105,000	$170,653	$1,742,524	$514,000	$2,256,524	108%

Table 1: Summary of replacement option life-cycle costs.

	kWh 2007	kWh 2010	kW 2007	kW 2010	Gallons Water (In Thousands) 2007	Gallons Water (In Thousands) 2010	Gallons Propane 2007	Gallons Propane 2010
Total	16,090,204	12,666,639	29,878	23,184	157,949	125,112	316,987	208,300
Percent Change		–21.28%		–22.40%		–20.79%		–34.29%

Table 2: Energy use comparison 2010 vs. 2007.

exist; however, propane heater use is limited to extreme load conditions and to provide redundancy.

Table 1 summarizes a life-cycle cost analysis for each option and alternatives considered. You will note that the life-cycle costs are very close for Option 1, Alternates B-l, B-2, C-1 and C-2. After review by hotel operations and ownership, Option 1, Alternative C-l was selected.

The final plant configuration is depicted in *Figure 5*. Domestic water is preheated through the auxiliary condensers of the centrifugal chillers (C- 1/2), which then provides makeup water to the tempered water storage tanks (TW-1 and TW-2). Heat pumps 1 and 2 (HP-1 and HP-2) heat the tempered water storage tanks to a maximum of 120°F. Water then flows to the hot water storage tanks (HW-1 and HW-2), where the propane-fired heaters provide any additional heat necessary to maintain proper operating temperature.

Estimated Energy Savings

Both of the projects, the cooling tower and heat pump installations, were fully implemented by the end of 2008 and have been in operation for a little over two years (*Table 2*). Based on the electricity and propane costs noted for 2009, the hotel saved approximately $388,000 in electricity and $184,000 in propane (data not shown). For 2010, the hotel saved approximately $783,000 in electricity and $213,000 in propane for a combined savings of $1.58 million dollars in the first 24 months of operation. The project had a construction cost of approximately $1.8 million dollars, which leads to a simple payback of about three years (adjusted for two other projects that reduced energy consumption and demand). First, photovoltaic solar system reduced electric consumption approximately 410,000 kilowatt hours per year ($135,000, 2009 costs) or about one-third of the 2009 electric savings. Second, a guestroom thermostat upgrade project's energy savings have not been estimated with precision. Savings are not adjusted for weather or occupancy.

Acknowledgments

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Joe Lstiburek gets away with murder in his footnotes. Case in point: In Footnote 5 in his June 2011 article, he needlessly goes off on Chicago baseball teams. I'd like to remind Joe that the White Sox have been in the playoffs several times since the Blue Jays have, and won the World Series in 2005. Further, Chicago does have a hockey team.