BULLETIN

Mining gold... *and green*

Recovering energy from condenser water significantly reduces energy costs, earning points toward LEED certification

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Millions of Btus of heat are rejected through cooling towers of a water-cooled chiller system. That includes every Btu collected in a building, plus the heat generated from compressor motors, pumps and fans. For a hospital running a 400-ton chiller, this amounts to four million ton-hours per year or six million Btu of heat. As a result, condenser water is typically a building's largest waste heat source—yet it has the potential to significantly reduce energy costs and contribute to a greener environment. Reclaiming this heat and using it to heat the building or the domestic hot water turns an unused resource into a valuable one.

Recovering energy from condenser water is not a new idea. The technology has existed for decades. However, its application has not always been successful, due partly to lack of understanding and partly to lack of the proper tools. Today engineers have both, plus two more important incentives: ASHRAE 90.1-2001 (soon to be 2004), which requires energy recovery in certain applications; and the LEED™ (Leadership in Energy and Environmental Design) certification program, which is driving the movement on building sustainability.

Hospitals and hotels are prime candidates for a heat recovery system because they require simultaneous heating and cooling.

What makes a building suitable for condenser water heat recovery?

Heat recovery can occur only when there is a source (a cooling load in the building) and a simultaneous requirement (a heating load in the building). Hospitals, healthcare centers, hotels and other hospitality facilities are prime candidates for a heat recovery system because they meet these conditions. Other good applications include schools and industrial processes.

In addition to the type of building, the type of HVAC system will also dictate the viability of condenser heat recovery. Good heat recovery candidates include constant-volume with reheat, four-pipe fan coil, and multizone HVAC systems because each of those systems provides simultaneous heating and cooling. Variable-air-volume and unit ventilator systems are not as successful. The only way to know for sure if condenser energy recovery for heating is viable is to conduct an energy analysis with a software tool such as the McQuay Energy Analyzer™ program, which helps to evaluate and size systems.

How does energy recovery help increase LEED points?

Energy recovery systems can add points to the Energy and Atmosphere section of the LEED rating system. Energy performance above the minimum level of energy efficiency, as determined by ASHRAE 90.1-1999, can earn up to 10 additional points. Energy recovery systems reduce fossil fuel consumption and lower the cost of heating. To determine energy savings, follow the Energy Cost Budget method defined in Section 11 of ASHRAE Standard 90.1, and use computer software to quantify energy performance versus a baseline building.

What are the basic design requirements?

As previously discussed, the primary requirement for a condenser water energy recovery system is simultaneous heating and cooling in the building. Other considerations include ASHRAE Standard 90.1, the heat recovery design size, and the type of recovery system.

ASHRAE Standard 90.1

ASHRAE Standard 90.1 requires heat recovery in certain applications. This standard is updated frequently, so a thorough understanding is necessary prior to designing a system. Highlights of the standard include:

- Condenser heat recovery is required for domestic hot water systems if they operate 24 hours per day, and have a cooling load of at least 400 tons and a domestic hot water load of at least one million Btu/hr.
- Air or waterside economizers are not required if condenser heat recovery is used.
- Simultaneous heating and cooling is allowed if at least 75 percent of the reheat energy is provided by a site-recovered energy source.
- Airside energy recovery is not required if 60 percent or more of outdoor heat energy is provided from site-recovered energy.

Heat recovery design size

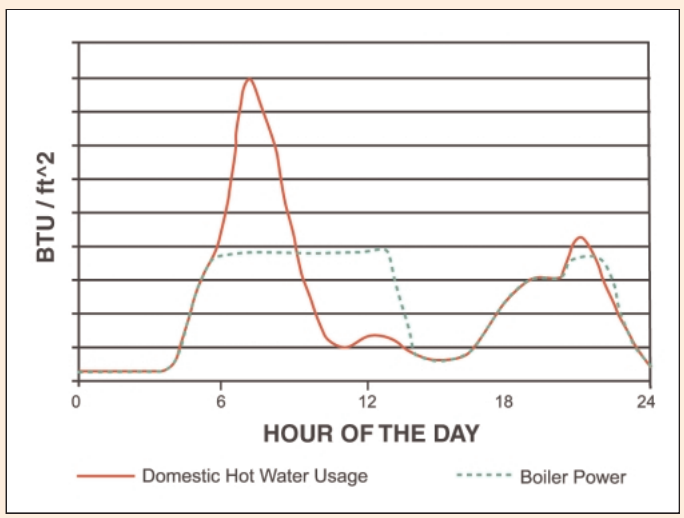
An important step in the design process is to estimate the source (chiller plant) load profile and the heat (service hot water or building heat) load profile. These profiles cannot be determined from the design heating or cooling load calculations normally performed in mechanical system design. Building heating applications require that the engineer find the point where the heat recovery source load matches the heating load, which will be at some part load condition.

Service hot water design considerations

Service hot water systems for large users usually consist of a large storage tank indirectly heated by a boiler. The boiler may be dedicated to heating service hot water or it may be the main heating plant for the facility. A typical hot water load profile for a hotel (Figure 1) shows both the service hot water flow rate and the boiler load throughout the day. The boiler is rarely sized to meet the instantaneous heating requirements at design load conditions. Instead, the boiler and storage tank are matched so that the combination of using stored hot water plus the instantaneous output from the boiler meets the peak load needs.

During periods of low load, the boiler is used to recharge the storage tank. The storage water temperature is usually 140˚F, and a tempering valve is used to lower the water temperature to the fixtures.

Figure 1. Typical hotel service for hot water load profile.



The temperature of the water from the condenser water energy recovery system will dictate how it can be used for service hot water heating. If the condenser energy recovery system can provide 140˚F or hotter water, it can be used to heat the water in the storage tank. If the condenser energy recovery system can only provide temperatures less than 140˚F, then it can only be used for preheat.

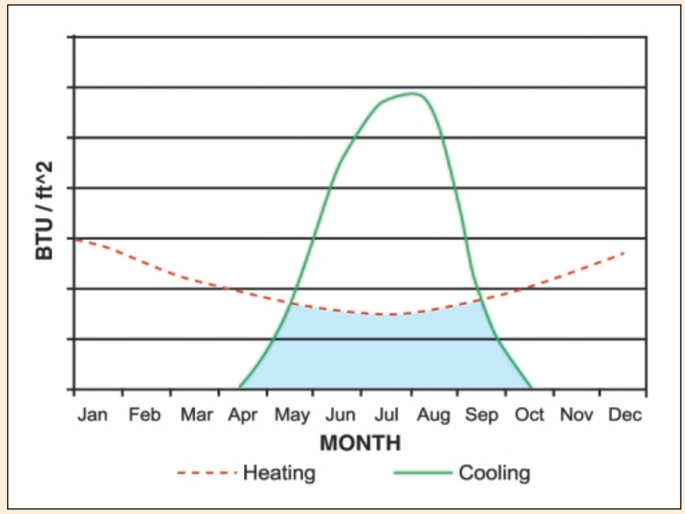


Figure 2. Typical reheat load profile.

Building heat design considerations

A typical annual heating and cooling load profile for a constant volume with reheat system (Figure 2) commonly used in healthcare facilities underlines the requirement of simultaneous heating and cooling. The ideal size for the energy recovery equipment is the point at which the instantaneous heat source meets the instantaneous heating requirement, which is where the two lines cross. Energy can be recovered in the area outlined under both curves.

The chart illustrates why the heat recovery system should not be sized to match the design output from the chiller plant or the design output of the boiler plant. When peak cooling load occurs, there is little heat required, and the heat recovery system would be oversized. When the facility is at design heating load, there is little or no energy source since the chillers may be off-line if there are airside economizers.

For a manual method of determining the appropriate heat recovery design size, consult the ASHRAE publication, Application Guide Chiller Heat Recovery. Alternatively, the McQuay Energy Analyzer program sizes condenser water recovery systems by performing an annual energy analysis and identifying the source-load balancing point. It also estimates energy and cost savings.

Energy recovery systems

Condenser water rejected to the cooling tower is usually 90˚ to 95˚F. To improve the value of the rejected heat, the water temperature must be increased.

There are two main methods to accomplish this: heat recovery chillers, either single condenser or split condenser, and McQuay Templifier™ water heaters. The two heat recovery chiller types can provide hot water to about 110˚F, while a Templifier unit can provide hot water at 140˚ to 160˚F.

Heat recovery chillers

Heat recovery chillers come in two forms: single condenser and split condenser. A single condenser heat recovery chiller is simply a chiller selected to operate with 105˚F to 110˚F leaving condenser water (Figure 3a).

The more common split condenser chiller has, in effect, two condensers with the water loops isolated from each other

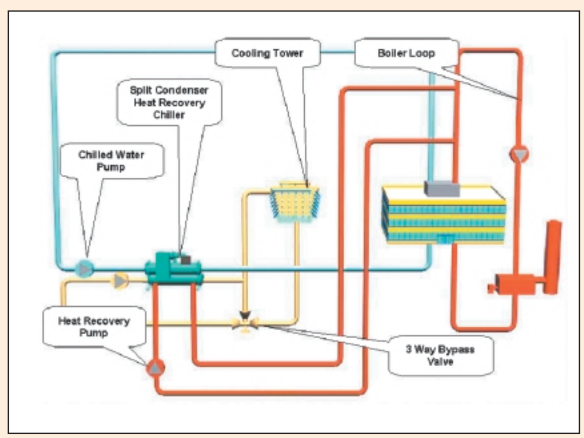


Figure 3a. Single condenser heat recovery chiller

The economics of heat recovery –

The following example evaluates condenser water heat recovery and compares Templifier units to heat recovery chillers:

Acute care hospital, Chicago –

- Three stories, 480,000 square feet
- 1800-ton chiller plant
- 22,000-MBH boiler plant
- Air system: constant volume with reheat supplying 409,330 cfm of air (192,000 is ventilation air).

The recovered energy will be used for building heat.

Option 1—base building
- Two 900-ton dual compressor centrifugal chillers

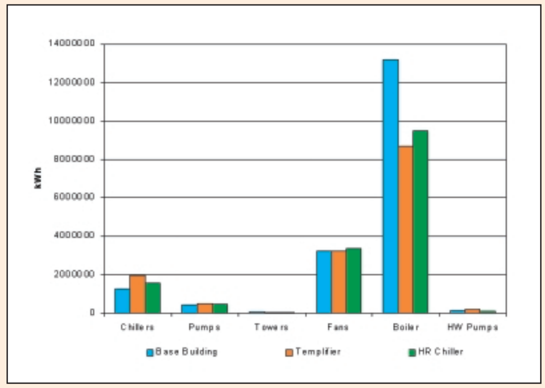
Option 2—Templifier water heaters
- 460-ton Templifier unit
- Two 900-ton dual compressor centrifugal chillers

Option 3—heat recovery chiller
- 400-ton split condenser heat recovery chiller with 0.73 kW/ton performance in heat recovery mode providing 105ºF hot water
- 1400-ton dual compressor centrifugal chiller

Design considerations

Option 2 requires a 460-ton centrifugal Templifier unit that produces 140ºF hot water with 70ºF source water. The larger source chiller allows for the use of 2200 US gpm of source water for the Templifier unit and lowering the temperature range to 5ºF. The COP is 4.4. However, the source chiller condenser pump had an additional 20 feet of head added to offset the two machines in series. A tertiary hot water pump was also added.

Option 3 requires a split condenser heat recovery chiller sized for the design heat recovery load. Using Energy Analyzer, the design heat recovery load was estimated at 5,324 MBH, so a 400-ton chiller was selected. If a 900-ton heat recovery chiller had been specified, it would have provided, at best, 50 percent load in heat recovery mode—and less than that most of the time. The balance of the chiller plant is handled by one 1400-ton dual compressor centrifugal chiller. The supply fan's static pressure was increased by 0.2 in. w.c. to offset the required deeper heating coils. A tertiary hot water pump was also added.



Results: reduced boiler load provides largest savings

Both condenser water energy recovery approaches increased the chiller work (see chart above for the results of the comparison). The Templifier unit was higher because it produced 140ºF hot water. The pump work for the energy recovery approaches was slightly higher due mostly to the tertiary pump. The Templifier unit has a slightly larger operating period than the heat recovery chiller (more run-hours). The fan work increased by four percent for the heat recovery chillers due to the deeper heating coils.

The reduced boiler work provided the largest savings. The heat recovery chiller reduced the boiler work by 28 percent while the Templifier unit reduced the work by 34 percent. The Templifier unit outperformed the heat recovery chiller because the Templifier unit can reclaim heat both from the building and the compressor work of the source chiller, as well as its own compressor work.

Overall, both systems saved more than six million kBtus per year. The Templifier unit saved $120,000 per year with a payback of less than two years and an internal rate of return of 80 percent. The heat recovery chiller provided $90,000 in savings.

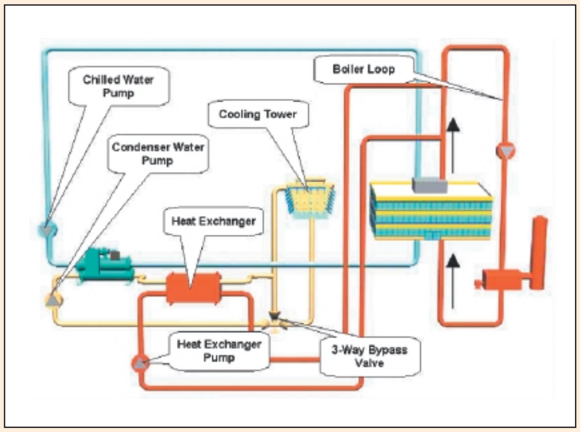


Figure 3b. Split condenser heat recovery chiller

(Figure 3b). One loop is used to reject heat to the cooling tower, while the other loop is used to collect heat for the building.

As the chillers produce hotter condenser water, they work harder and their performance (kW/ton) will drop 25 to 30 percent due to the increased lift on the compressor. The chiller will not be optimized when operating in non-energy recovery mode. Most heating systems are designed to operate at 180˚F supply water. During heat recovery mode, the heating system must be able to meet the requirements of the building with only 105˚ to 110˚ water. This may require changes to the heating system design that will increase capital and operating costs.

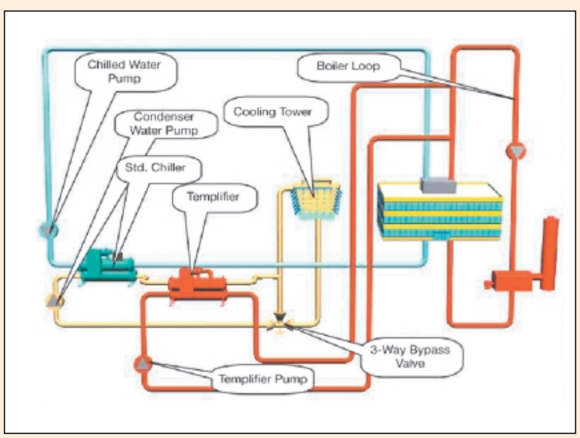


Figure 3c. Templifier application

Templifier water heater

Dedicating a unit for heat recovery changes the application and the economics. The McQuay Templifier water heater can recover low-grade heat and convert it into high-grade heat. It is used with either reciprocating or centrifugal compressor chillers. The Templifier unit takes heat out of the condenser loop and raises the temperature to 140˚F for centrifugal compressors and 160˚F for reciprocating compressors (Figure 3c). This heat, which would otherwise be rejected from the building, is recovered and used for either building heat or domestic hot water heating. The typical coefficient of performance (COP) is 3.5 to 5. A COP of 5 provides 5 parts heat for one part electricity.

Typically, the savings are calculated as a function of using electricity to run a dedicated heat recovery chiller versus gas to operate a boiler. Since a dedicated heat recovery chiller can easily be six times as efficient as a boiler, savings can be dramatic. However, other benefits can save an additional 15 to 20 percent. These include chiller efficiency improvements if colder cooling tower water is available, and cooling tower fan savings for less heat rejection.

Templifier units have a much smaller impact on the rest of the HVAC system design than heat recovery chillers. The higher water temperature possible from a Templifier unit usually means heating coils with additional rows are not required (heat recovery chillers may require heating coils with additional rows in order to operate with cooler than normal water during heat recovery mode for building heat applications). Supplying hot water at 140˚F during cool weather is usually satisfactory. During really cold weather, the Templifier unit is usually off-line due to a lack of source heat, and the boiler supply setpoint can be reset to design temperatures (180˚F).

Green... *and gold*

Heat recovery taps a readily available and inexpensive energy source. As today's buildings work to reduce costs and increase energy efficiency, the use of condenser water is a heating resource that's rarely exploited. In the right application, condenser water energy recovery is a gold mine—and a green one, too.