

HEAT RECOVERY FROM CHILLED WATER SYSTEMS

Applications for Heat Reclaim Chillers



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April 2008

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INTRODUCTION

Is it possible to save energy by using waste heat from a chilled water system?

The answer to this question is certainly yes – the process is known as Heat Recovery. This paper examines several heat recovery methods of capturing heat from the chilled water system. This heat, which is otherwise wasted to the environment, can be used for many purposes, including building heat, service water heating and process heat applications. To maximize the captured waste heat without decreasing the chiller plant efficiency, the system must accomplish the following:

- Capture sufficient heat for useful purposes
- Minimize chiller lift and maximize chiller efficiency
- Control the hot water temperature without sacrificing stable chiller plant operation

These accomplishments can lead to reduced energy consumption, lower greenhouse gas generation, and increased LEED® certification points, which are extremely desirable goals given today's focus on energy conservation and the development of high performance buildings.

WASTE HEAT SOURCES

Capturing Sufficient Heat for Useful Purposes

Air-conditioning systems transfer heat from one location to another through work that typically consumes electricity. Heat is drawn into the system to provide indoor cooling while heat leaves the system in the form of wasted heat at the condenser (Fig. 1.) The amount of wasted heat can be 25% more than the cooling that the process creates.

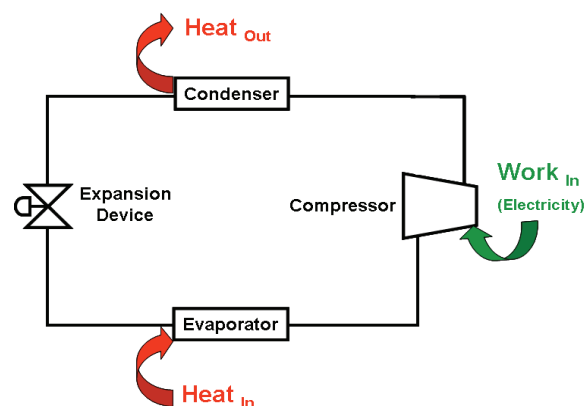


Fig. 1. Heat and Work Relationship in an Air-Conditioning System

The ability to capture and use this waste heat is known as heat recovery, since the waste heat is recovered and used for other purposes, including heating hot water. Although this process is not new, the benefits of heat recovery are even greater today. The use of heat recovery to generate hot water can reduce the total energy needs of a building and, if applied correctly, contribute to LEED® certification of the building.

To determine the potential to use this waste heat, the system efficiencies must be understood. A measure of an air conditioning system's efficiency is known as the Coefficient of Performance, or COP. The COP for a system that produces heat is the ratio of the output heat to the supplied work as shown in Equation 1.

In this equation, Q is the useful heat and W is the work consumed. The work comes from electricity consumed by the compressor.

$$\text{COP} = \frac{\text{Heat}_{\text{out}}}{\text{Work}_{\text{in}}}$$

Equation 1
Coefficient of Performance

From Fig. 1, consider how this system might be used for heat recovery. When capturing the “Heat Out” for a useful purpose, the COP equation would be represented by Equation 2.

$$\text{COP}_{\text{heating}} = \frac{\text{Heat}_{\text{out}}}{\text{Work}_{\text{in}}}$$

Equation 2
Coefficient of Performance for Heating

However, a heat recovery system not only produces heat, it also produces cooling. Instead of the traditional air conditioning system, consider a system that produces hot water and the additional benefit of chilled, cold water. So, the COP equation to measure efficiency of producing chilled water can be expressed as shown in Equation 3.

$$\text{COP}_{\text{cooling}} = \frac{\text{Heat}_{\text{in}}}{\text{Work}_{\text{in}}}$$

Equation 3
Coefficient of Performance for Cooling

But with heat recovery systems, the benefit of hot and cold water can be realized. So, the equation that quantifies the combined benefit of hot and cold water can be expressed as shown in Equation 4.

$$\text{COP}_{\text{total}} = \frac{\text{Heat}_{\text{out}}}{\text{Work}_{\text{in}}} + \frac{\text{Heat}_{\text{in}}}{\text{Work}_{\text{in}}}$$

Equation 4
Total COP for Heat Recovery + Chilled Water

This combined efficiency can contribute to reducing the whole building energy consumption while influencing the number of LEED-NC EAc1 points for LEED certification. Systems that generate sufficient useful heat for both heating and cooling purposes are entirely possible. In fact, heat recovery systems can generate hot and chilled water simultaneously for use within the building or for process applications.

HOT WATER SYSTEMS

How can the recovered heat be used?

Heat from hot water can be used for many purposes in the building or for process applications. In particular, hot water can be used for heating the building, heating service water or as part of a manufacturing or industrial process. There are many examples of each of these heating needs. However, before the appropriate system is considered for these needs, certain design criteria should be understood for each of these applications. Keep in mind that ASHRAE 90.1-2004 requirements for building heat and service hot water differ, so a thorough understanding of the standard is essential prior to designing the system.

Building Heating

Heating within the building can be achieved in many different ways, from radiant heating sources or reheat to hot water coils installed as part of an air-handling system, and many other means in between. Most importantly, the hot water temperature, flow (in gallons per minute or GPM) and capacity (expressed in Btu/hr) must be fully understood in light of the dynamic heat transfer effects that the building will experience throughout the year. Fluctuations in outdoor temperature; the ever changing loads from solar gains caused by the sun and internal heat sources such as lights, office equipment, and people; and the all important load from ventilation air must be understood and appropriately considered. Load estimating programs that evaluate the building's thermal performance throughout the entire year can help the system designer better understand the thermal dynamic forces influencing the heating needs. A program such as Carrier's Hourly Analysis Program (HAP) can help evaluate the heating load from an HVAC system perspective [1] (Fig. 2).

Understanding the appropriate hot water temperature needs for building heating purposes is important. Most reheat and building heat applications do not need 130 to 140 F to perform satisfactorily. As discussed later in this paper, operating the reclaim chiller at higher leaving condenser water temperature (LCWT) increases lift and reduces chiller plant efficiency. According to the 2004 ASHRAE Systems and Equipment Handbook, Applied Heat Pump and Heat Recovery Systems, p. 8.20

"For typical buildings, chillers normally provide hot water for space heating at 105° to 110°F (40.6 to 43.3°C)."

In many VAV (variable air volume) reheat applications, 105 F hot water can be used very

effectively by simply specifying a 2-row reheat coil instead of a 1-row coil. So, elevated hot water temperatures may not be necessary for building heating applications. Lower temperatures will maximize chiller plant efficiency while minimizing system energy consumption.

To further understand the building heating load requirements and the potential for a heat recovery system, the monthly or even hourly heating loads should be considered. Figure 3 shows a typical hot water boiler plant load for an office building in Chicago. This information is necessary to determine when heating and cooling loads occur. A program like HAP can help estimate the times when these loads occur.

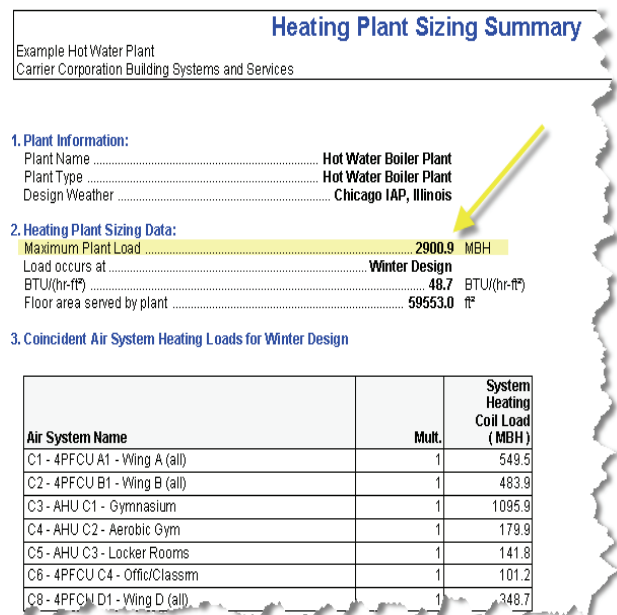


Fig. 2. Building Heating Plant Sizing Summary from Carrier HAP version 4.3

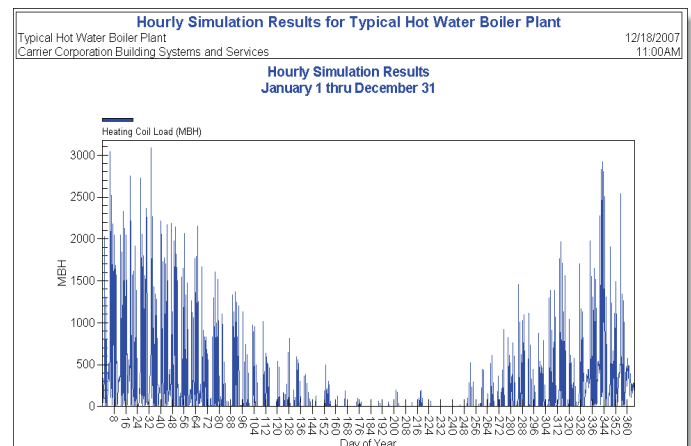


Fig. 3. Hourly Building Heating Plant Results from Carrier HAP version 4.34

However, the heating load is only half of the required heat that can be satisfied by a heat recovery system. The building cooling loads must also be evaluated. An example of typical cooling loads for the same building is shown in Fig. 4.

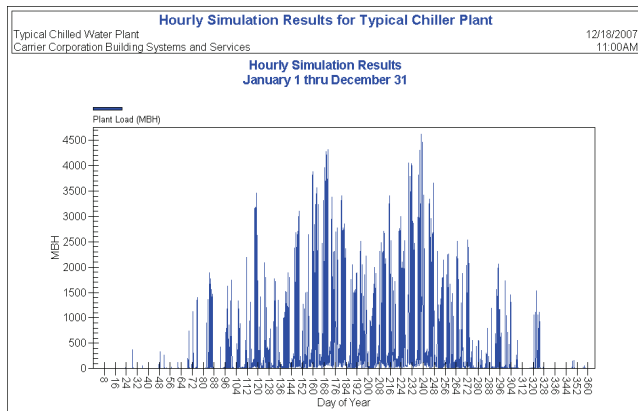


Fig.4. Typical Hourly Cooling Coil Loads

The designer's challenge is to determine when both heating and cooling loads exist and how best to capture the heat from a heat recovery system to maximize the benefit of such a system. For building heating applications, some of the best opportunities for heat recovery exist when the building operates 24 hours per day, with high internal cooling loads that may also require heating for perimeter zones. Casinos, hospitals, and full service hotels are some of the likely candidates.

Service Water Heating

Service water needs vary widely with the building type, occupancy and internal processes such as laundry, dish washing and food preparation. Many design references are available to help the mechanical engineer better understand the maximum demand for hot water. However, it is the design engineer's responsibility to recognize, understand and properly apply all appropriate codes and local regulations to the plumbing system design. Accurate sizing of the service water heater and the source for the heat is essential to ensure an adequate supply of hot water for all fixtures, all the time.

Nationally recognized and/or code approved demand flow rates (typically expressed in gallons per hour, GPH) and demand factors must be understood to properly size these systems. Hot water demand flow rates, based on the building or facility type and the calculated results, should include probable maximum demand in GPH, the required water heater output in Btu/hr, and any required storage tank capacity in gallons.

Some codes require the hot water supply to be sufficient to satisfy the continuous and peak hot water demands of the establishment. If ASHRAE 90.1-2004 criteria is used, tempering the service hot water from "street" temperatures to 85 F would be sufficient. However, most chiller-based heat recovery equipment can produce water temperatures of approximately 120 to 135 F, which is far in excess of the ASHRAE criteria and possibly more useful from a service water perspective. Regardless of temperature, the heat recovery system must accommodate the continuous and peak hot water demands while providing a controlled source of service hot water. Further information on this topic is discussed later in this white paper.

Potable water, or water intended to be consumed through drinking by humans, must be of sufficient quality to serve as drinking water whether it is used as such or not. As a result, this water must be protected from contamination from potentially harmful sources. Many codes require the separation of the potable hot water source from non-potable sources by means of a double-wall vented air gap in the heat exchanger as a minimum. This would minimize the risk of internal leakage and cross-contamination between the two fluids. Other means exists to meet the code intent. The design engineer must consider the code requirements before proceeding with the system design.

Process Hot Water

Process hot water can come from many different sources and be used for many applications. From a plastic injection molding machine pre-heater to a swimming pool heater, process heating requirements can vary with each application. The information commonly used to design the heat recovery system is very similar to the building heating and service hot water applications described above: the hot water flow, temperature and capacity must be understood to support the process heating needs.

As we have seen, there are many different potential uses for the hot water generated by a heat recovery system, each with its own unique requirements and design criteria. Next let's explore how to best capture the useful heat from a heat recovery system while minimizing wasted heat reducing energy consumption, and maximizing the chiller plant efficiency.

IS HEAT RECOVERY REQUIRED?

ASHRAE 90.1-2004 Energy Standard

The current ASHRAE 90.1-2004 Energy Standard Section § 6.5.6.2 Heat Recovery for Service Water Heating requires heat recovery from the condenser side of water-cooled systems for preheating service hot water in large 24-hour facilities [2]. There are a few exceptions identified in this standard; the design engineer is encouraged to closely examine this standard and other codes associated with the project to completely understand the content and intent.

Systems seeking to meet the intent of ASHRAE 90.1-2004 can do so with a plate frame heat exchanger located in the return condenser water as shown in Fig. 5. The ability to obtain 85 F pre-heated service water is entirely possible but it is a function the leaving condenser water temperature (LCWT) from the chiller plant. Keep in mind, the LCWT is a function of the outdoor ambient wet-bulb temperature, condenser flow rate and the chiller load. Since a minimum of 85 F service water during peak conditions is required to meet the intent of the standard, the system must produce LCWTs slightly

above 85F. However, *elevating the LCWT will increase the chiller lift, reduce the chiller efficiency and increase the chiller plant energy consumption.* This is not a favorable condition.

These conditions must be understood to determine the energy benefit for this application. One potential benefit of this design is that colder condenser water could be sent to the tower leading to lower tower energy consumption. In addition, the energy consumption for service hot water preheating is reduced. However, the trade off between these benefits must be weighed against elevated LCWT, higher lift, lower chiller plant efficiency and increased chiller plant energy consumption. With this in mind, projects seeking to maximize LEED-NC EAc1 certification points may choose to apply heat recovery using a method that minimizes building energy consumption. To do so, the designer must determine the best means to capture sufficient heat and convert it into useful purposes without decreasing the chiller plant efficiency.

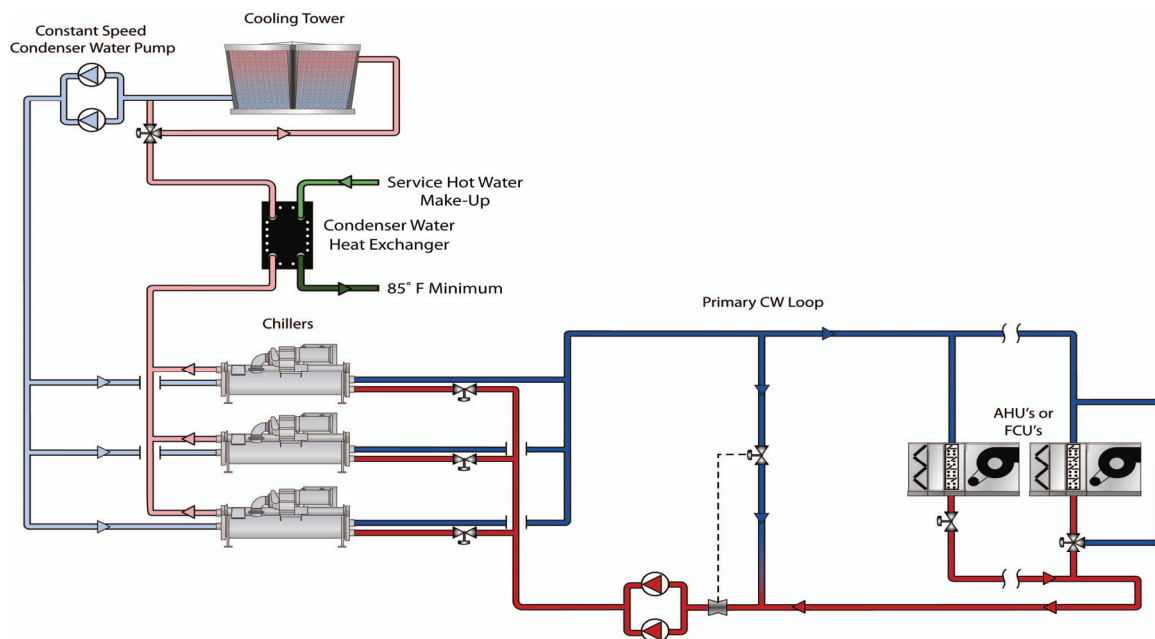


Fig. 5. Pre-Heat of Service Hot Water with Condenser Water Heat Exchanger

MINIMIZING CHILLER LIFT WILL MAXIMIZE CHILLER EFFICIENCY

How can chiller lift be minimized?

Heat recovery should be considered for applications seeking to reduce energy consumption. However, in doing so the design engineer must ensure that that overall chiller plant efficiency is not sacrificed. The quest to capture more heat can lead to the consideration of higher leaving condenser water temperatures. However, higher leaving condenser water temperatures will reduce the chiller efficiency.

This outcome can be understood by examination of a typical refrigeration pressure-enthalpy (P-h) diagram to uncover the answer.

In Fig. 6, the top line (A-D) is the condenser load also known as the total heat of rejection (THR). This is the amount of heat that could be recovered from the refrigerant. Elevating the leaving condenser water temperature will raise the refrigerant pressure as shown in Fig. 7.

The work required by the compressor is referred to as the *lift*. Lift, also known as head pressure in positive displacement compressors, can best be described as the amount of work necessary to increase the refrigerant from a lower pressure to one that is much higher. Increased pressure differential translates into a greater amount of work necessary to compress the

refrigerant. The work performed by the compressor is provided by the compressor motor, which uses electrical energy to drive the compressor shaft. As a result, higher lift increases electrical demand and energy consumption. It's that simple. *Increased lift on the chiller increases chiller power consumption* and should be avoided. Therefore, the system designer should make every attempt to reduce the lift to minimize energy consumption. Stated another way, *minimizing lift maximizes energy savings*.

As a result, applying heat recovery with elevated condenser water temperatures to the entire chiller plant must be avoided. Otherwise, overall chiller plant efficiency will decrease. Keep this important principle in mind when designing the heat recovery system. This point is illustrated by a comparison of the annual energy impact of two similar 500-ton chillers applied to a building in Chicago. Figure 8 compares two chillers with 3.0 gpm/ton condenser water flow: one operating with 95 F leaving condenser water and the other with 115 F leaving condenser water temperature. In this example, higher leaving condenser water temperatures increased the annual energy consumption by 34%. This certainly does not provide favorable results for projects seeking a high level of LEED certification.

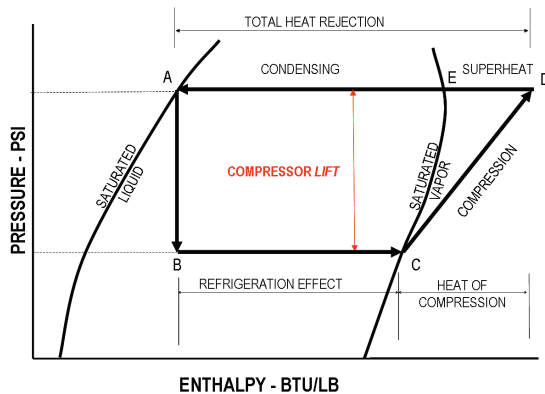


Fig. 6. Refrigeration P-h Diagram

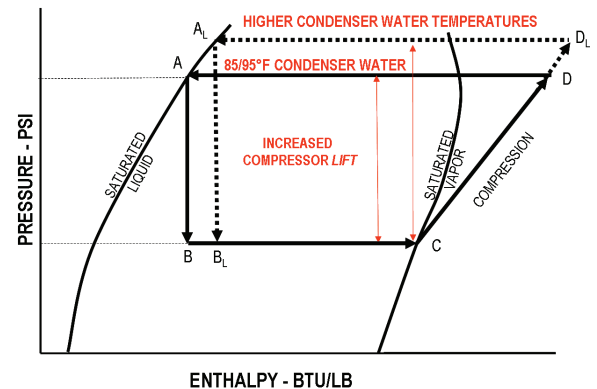


Fig. 7. Increased Leaving Condenser Water Temperature Increases Compressor Lift and Power Consumption

Electrical Energy Use by Month

Project: Heat Recovery Comparison 85/95°F vs 95/115°F
Prepared By: Building Systems and Services

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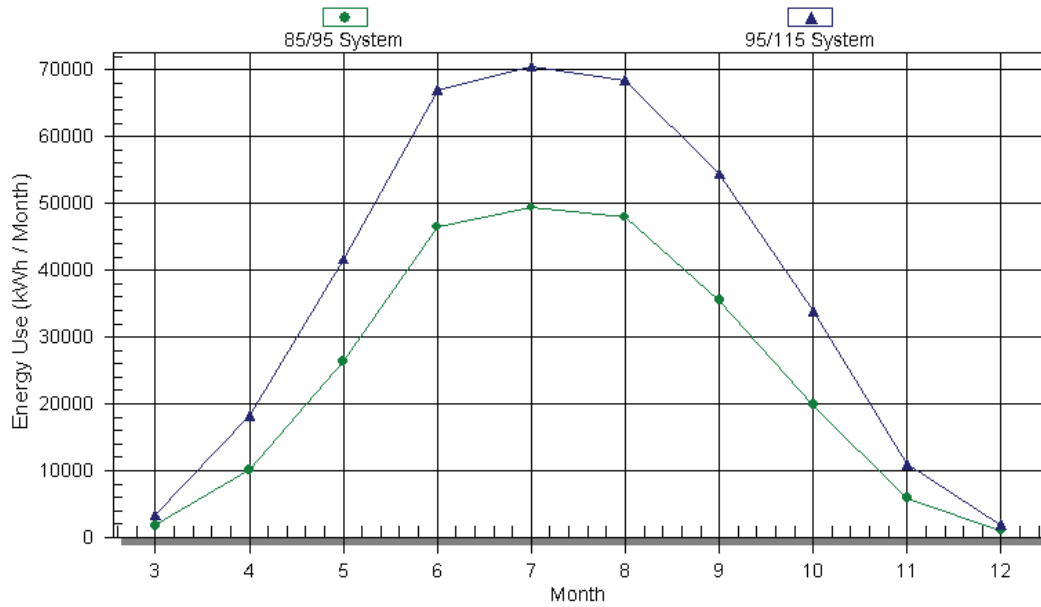


Fig. 8. Energy Comparison: 500 Ton Chiller Plant at 85/95 and 95/115°F Condenser Water Temperature

SAVING WASTED HEAT FOR USEFUL PURPOSES

How can a chiller minimize wasted heat?

To answer this question, consider the traditional chilled water HVAC system that transfers heat from indoors (at the air handler chilled water coil) to outdoors (at the cooling tower) as shown below. (See Fig. 9.)

Heat leaving the system at the cooling tower is “wasted” by being disposed to the outdoors. In fact, energy is actually consumed at the cooling tower and condenser water pumps in disposing this heat into the outdoor environment. What if this “wasted” heat could be minimized and then captured to heat the building or generate hot water? This is entirely possible and can save significant quantities of energy that would otherwise be wasted.

The first step is to minimize the amount of heat that must be pumped to the cooling tower. The easiest way to do this is to specify high-efficiency chillers with full and part load efficiencies surpassing ASHRAE 90.1-2004 minimum efficiency levels. More efficient chillers simply generate less wasted heat and convert more useful work into producing chilled water. Some variable speed screw chillers on the market today have industry leading full and part load efficiencies as low as 0.53 and 0.33 kW/ton, respectively, at ARI 550/590 conditions. When applied in a series counterflow plant, the full and part load efficiencies can be even better – 0.49 and 0.29 kW/ton! These chillers should be considered for projects seeking to minimize “wasted” heat and reduce energy consumption for LEED® certification of the building.

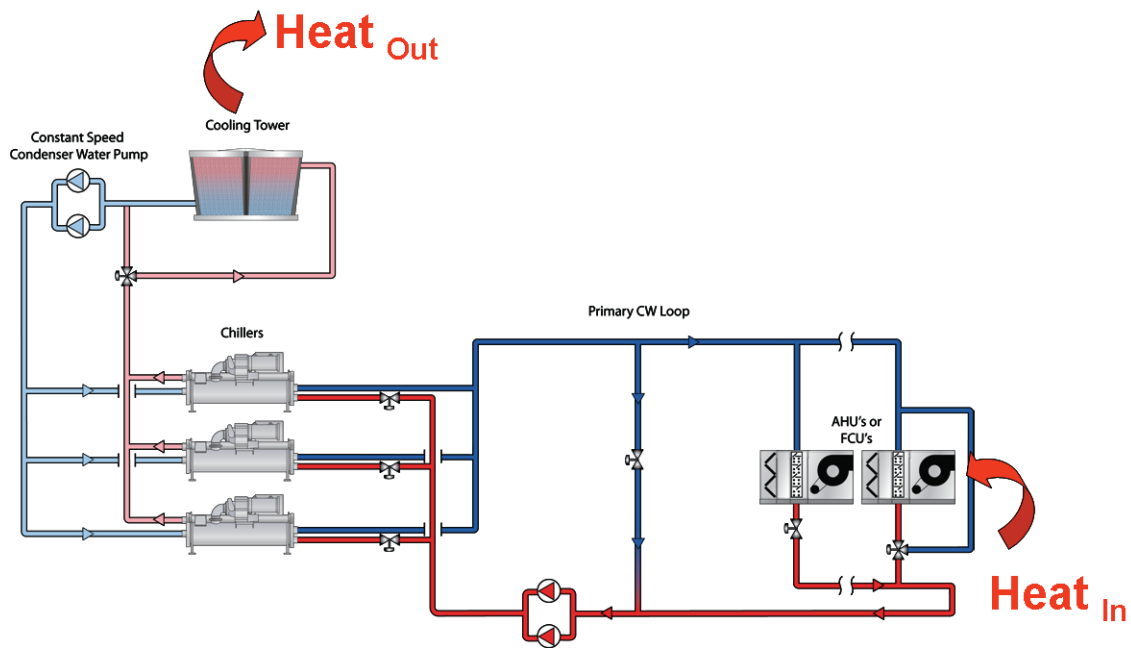
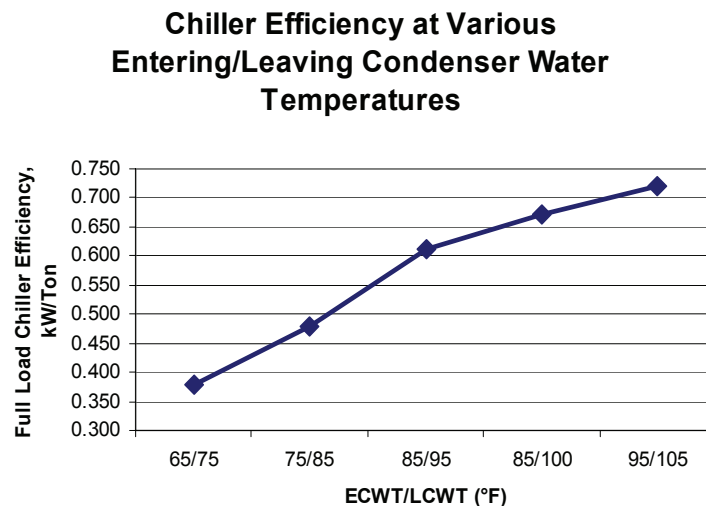


Fig. 9. Chilled Water HVAC System

Another way to minimize the “wasted” heat is to divert it to a device that can capture the heat and convert it into a useful heat source. This device is known as a heat reclaim chiller. All vapor compression chillers, even the heat reclaim chillers, must expel heat from their condenser to continue the refrigeration process. The condenser is the device that reduces the refrigerant pressure through transfer of heat from the refrigerant to the condenser water, hence raising the condenser water temperature. So, the condenser can generate sufficiently warm water for useful purposes. But, there is a challenge. As discussed earlier, raising the leaving condenser water temperature (LCWT) raises the chiller lift and reduces its efficiency, which is obviously an undesirable result. An example of sacrificed efficiency and the resulting increased energy consumption due to higher condenser temperature is illustrated in Fig. 10.

Some may suggest increasing the chiller plant LCWT to provide the necessary heat to produce hot water. This practice is *not* recommended. As discussed earlier, when lift increases, chiller plant efficiency decreases and increased energy consumption will result as illustrated in Fig. 10.

However, there is a solution. Heat can be captured and converted for useful purposes on a much more practical scale such that the entire chiller plant efficiency does not suffer.



*Fig. 10. Increased Chiller Energy Due to Higher
Condenser Water Temperature*

HEAT RECLAIM CHILLER FUNDAMENTALS

The Heat Reclaim Chiller

The heat reclaim chiller generates high pressure refrigerant within the condenser that can be used to produce higher temperature condenser water. The heat reclaim chiller is very similar to a conventional “cold water” chiller, but modified to optimize the heat recovery performance. These modifications include optimized compressor motors and supporting electrical systems, a heat recovery condenser bundle for each refrigerant circuit and a leaving condenser water temperature control system.

As previously described, the hot water requirements can vary considerably, given the unique heat, service water heating, and process hot water demand of each building. There are several types of heat reclaim machines available to meet these needs:

Single Bundle Heat Reclaim Chiller

This packaged chiller, shown in Fig. 11, is used where leaving water temperatures of up to 120 F are needed for non-potable water applications, such as building heating and process water systems. With a packaged chiller, the on-board control system maintains the “hot” water temperature leaving the condenser while simultaneously producing a source of chilled water.

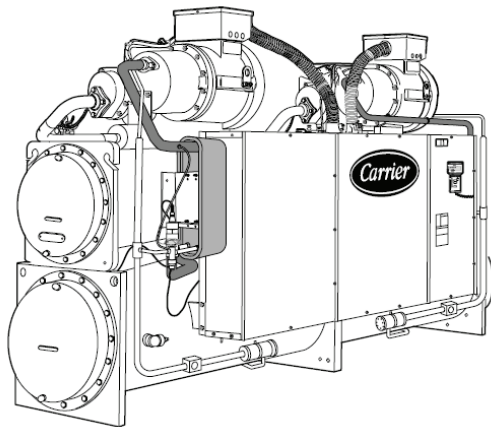


Fig. 11. Carrier's Heat Reclaim Chiller

Double Wall Vented Heat Reclaim Chiller

The double wall vented heat reclaim chiller can produce water temperatures up to 135 F. However, these chillers may be used for potable water applications due to the double wall vented heat exchanger design if permitted by the local building codes. The heat exchanger has an air gap to separate the potable water from the refrigerant thus minimizing the potential for potable water contamination.

The configuration shown in Fig. 12 uses a desuperheater to produce “hot” potable water. The desuperheater is located in the blue box adjacent to the compressor/cooler. It extracts the high pressure, high temperature heat from the refrigerant to “desuperheat” it to a lower pressure refrigerant. In doing so, hot water is produced. With desuperheating, the amount of heat is less than what could be extracted with a single bundle heat reclaim chiller. Since full condensing does not occur in the desuperheater, the refrigerant vapor must be piped to a separate refrigerant heat exchanger for the remaining condensing process to occur. This process can take place in a remote water-cooled or air-cooled condenser.

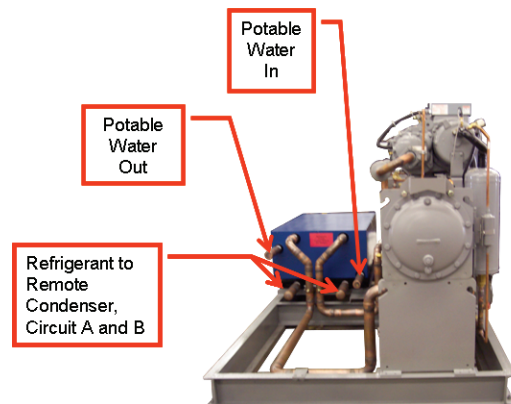


Fig. 12. Heat Reclaim Chiller with Double Wall Vented Desuperheater

Double Bundle Heat Reclaim Chiller with Full Condensing Heat Exchanger

The double bundle heat reclaim chiller with full condensing heat exchanger can produce water temperatures up to 135 F plus provide full refrigerant condensing through the second heat exchanger bundle. The additional heat exchanger (located below the blue box in Fig. 13) provides condensing of the refrigerant. These packaged chillers also have on-board controls to maintain the leaving “hot” water temperature. Head pressure control on the water-cooled condensers is required to ensure that the desired hot water temperature can be achieved. This can be a regulating valve or 3-way bypass valve controlled by a 4 to 20 mA signal from the chiller.

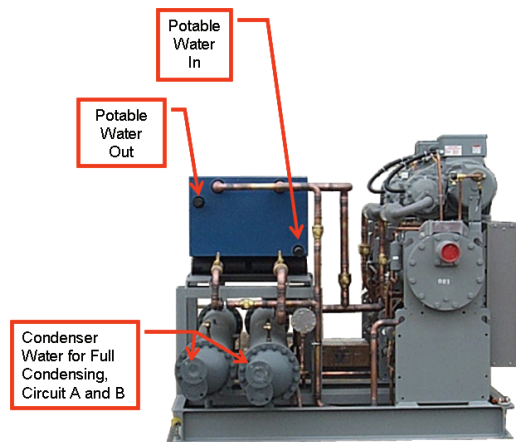


Fig. 13. Double Bundle Heat Reclaim Chiller - Double Wall Vented Desuperheater with Full Condensing Heat Exchanger

Hot Water Temperature Control

Some packaged chillers have capacity control capabilities that use the entering and leaving condenser water temperature to determine which stage of compressor capacity is necessary to maintain the hot water temperature set point. This method is very similar to the way in which conventional chillers control the leaving chilled water temperature. However, this control system uses condenser water temperature information to maintain the HEAT set point (Fig. 14). As the leaving condenser water temperature deviates from the HEAT set point, the chiller will adjust the compressor capacity to ensure the hot water temperature is maintained.

There is one exception to this. During the HEAT mode, the chilled water temperature is allowed to float and is no longer the primary input for capacity control. This could over cool the chilled water loop during light cooling load conditions. However, when the leaving chilled water temperature falls below the cooling set point, an additional software routine will limit the capacity of the heat reclaim chiller. This logic is known as “low source protection.” When the leaving chilled water temperature falls below the cooling set point, a stage of capacity is removed. This ensures the greatest amount of useful heat can be extracted from the heat reclaim chiller system without sacrificing the stability of the chilled water system.

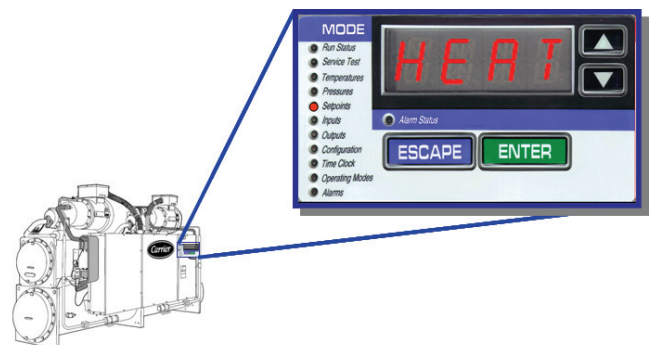


Fig. 14. Hot Water Temperature Control

CHILLER PLANT APPLICATIONS FOR HEAT RECOVERY

There are several means to configure and control a heat recovery system. Each of these chiller plant configurations will:

- Capture sufficient heat for useful purposes
- Minimize lift and maximize chiller efficiency
- Control the hot water temperature without sacrificing stable chiller plant operation

Primary/Secondary Chilled Water System with Heat Recovery Chiller

This is a conventional primary/secondary chilled water system with a small capacity heat recovery chiller installed in parallel with the chiller plant (Fig. 15). This configuration minimizes the chiller plant lift and maximizes energy efficiency while allowing direct control of both the hot and chilled water temperatures. The heat recovery chiller produces a base load of chilled water while generating hot water controlled to

the HEAT set point temperature. The heat reclaim chiller offsets the main chiller plant load by providing the base load of chilled water before it enters the primary chillers. Under base load operation, the heat reclaim chiller will provide chilled water to the secondary loop. The “low source protection” feature of the heat reclaim chiller ensures the chilled water temperature will not fall below the cooling set point temperature. This feature ensures stable chiller plant operation while providing a controlled source of hot water. If the chilled water temperature can not be satisfied by the heat reclaim chiller, the first chiller in the primary loop can be energized to provide the necessary chilled water temperature thus maintaining the secondary loop water conditions. This configuration provides a stable source of controlled hot water and a base load of chilled water without affecting the main chiller plant efficiency.

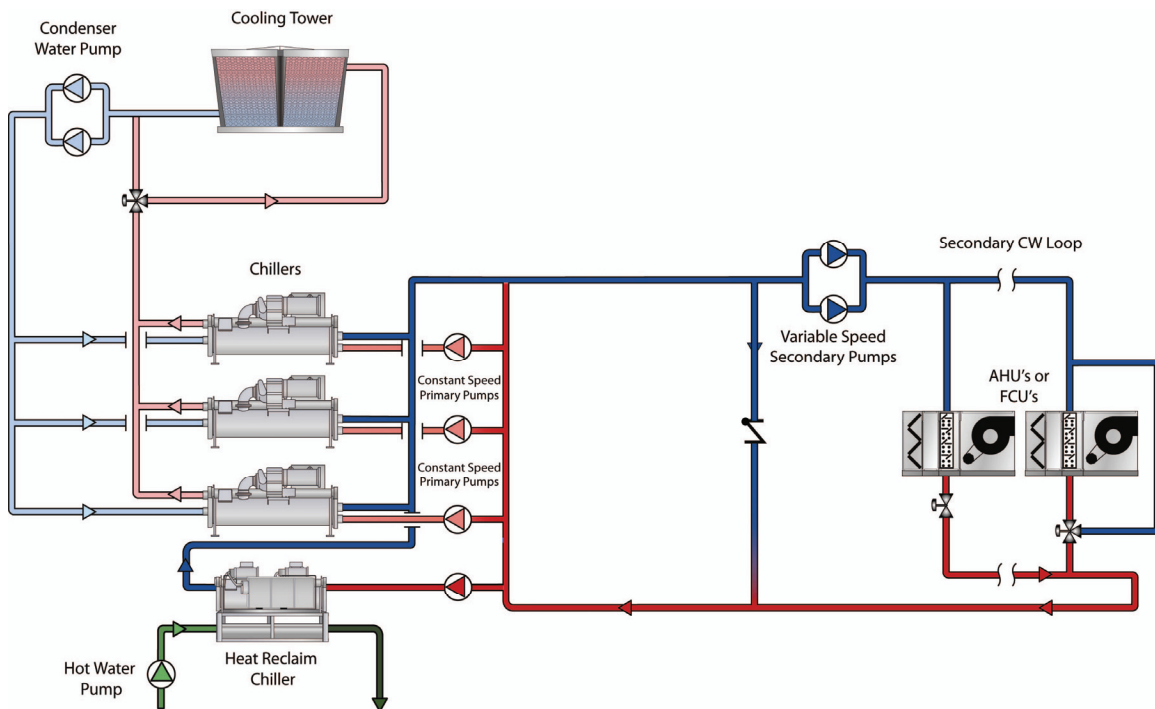


Fig. 15. Primary/Secondary Chilled Water System with Heat Recovery Chiller [3]

Variable Primary Flow Chilled Water System with Heat Recovery Chiller

A variable primary flow system, excluding the benefits available from heat reclaim, can offer energy savings beyond other chiller plant configurations. One such study found that “variable flow, primary-only systems reduced total annual plant energy by 3 to 8-percent, first cost by 4 to 8-percent, and life cycle cost by 3 to 5-percent relative to conventional constant primary flow/variable secondary flow systems.” [4] Several plant and load variables contribute to these savings, but overall these systems should be considered when low energy solutions are desired.

This system works much the same as the primary/secondary system previously described with the heat reclaim chiller providing a base load of chilled water for the primary chiller plant (Fig. 16). On a call for cooling to maintain the primary loop chilled water temperature, the heat reclaim chiller would be

energized as the first stage of cooling. The control valve located upstream of the heat reclaim chiller would open, flow would be proven at the chiller through its chilled water flow sensor, and the chiller would be energized to maintain the HEAT set point temperature. At the same time, the heat reclaim chiller’s “low source protection” feature will ensure that chilled water is provided at a temperature that is not less than the cooling set point temperature. Ideally, the heat reclaim chiller provides a base load of chilled water to the main chiller plant and it would control the hot water temperature based on its HEAT set point. This ensures a controlled source of hot water is provided when the heat reclaim chiller is operating and a base load of chilled water is provided to augment the main chiller plant.

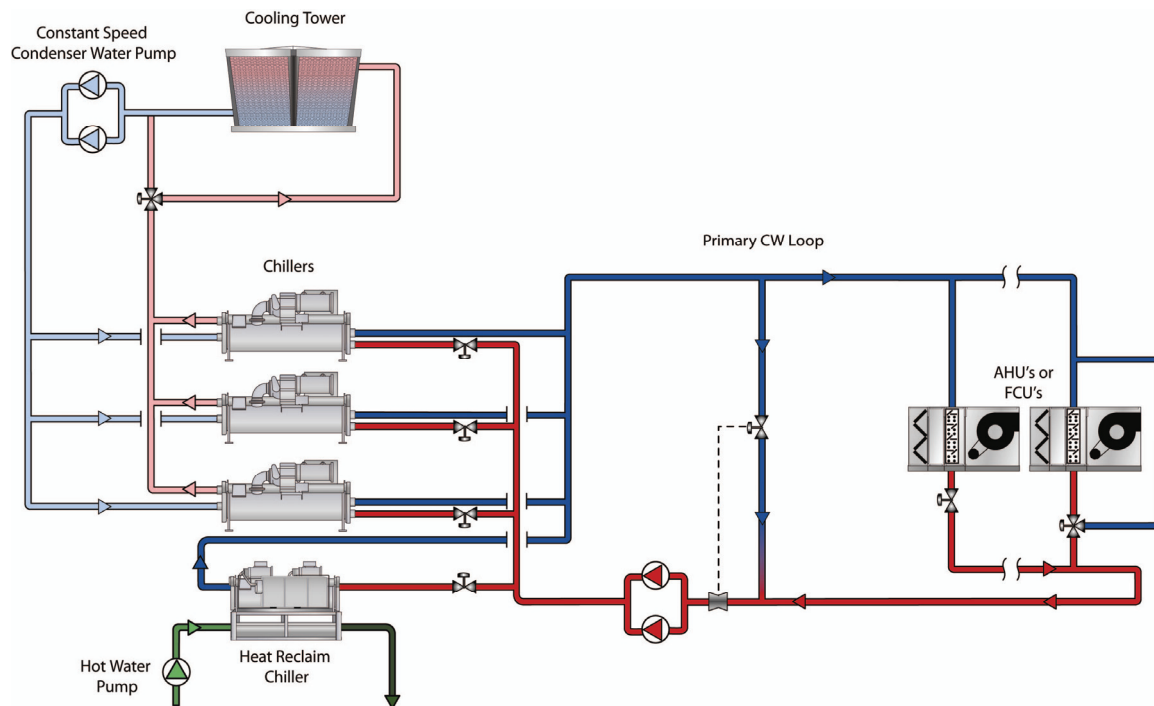


Fig. 16. Variable Primary Flow Chilled Water System with Heat Recovery Chiller

Series Counterflow Chilled Water System with Heat Recovery Chiller

The series counterflow application is yet another means to save even more energy (Fig. 17). Variable speed screw chillers offer precise capacity control under varying return water flow and temperature conditions while providing exceptional full and part load efficiency [5][6]. These chillers are ideal for this application since the instabilities associated with surge in centrifugal chillers are not present. Screw chillers with VFD (variable frequency drive) speed control respond exceptionally well to variations in load and head. However, other chiller types can also benefit from higher overall chiller plant efficiency offered by the series counterflow arrangement. This system takes advantage of the lower lift provided by smaller differences between the leaving chilled water temperature and the leaving condenser water temperature. The series counterflow plant benefits from significantly lower lift and improved overall

chiller plant efficiency. As with the previously described primary/secondary and primary variable flow applications, the first stage of cooling is provided by the heat reclaim chiller. On a call for cooling from the primary chilled water loop, the heat reclaim chiller provided the first stage of cooling while providing a controlled source of hot water based on its HEAT set point temperature. At the same time, the heat reclaim chiller's "low source protection" feature will ensure that chilled water is provided at a temperature that is not less than the cooling set point temperature. If additional cooling is needed to maintain the primary loop chilled water temperature, the series counterflow chiller plant would be energized. At the same time, the heat reclaim chiller would continue to control the hot water temperature based on its HEAT set point and provide a base load of chilled water.

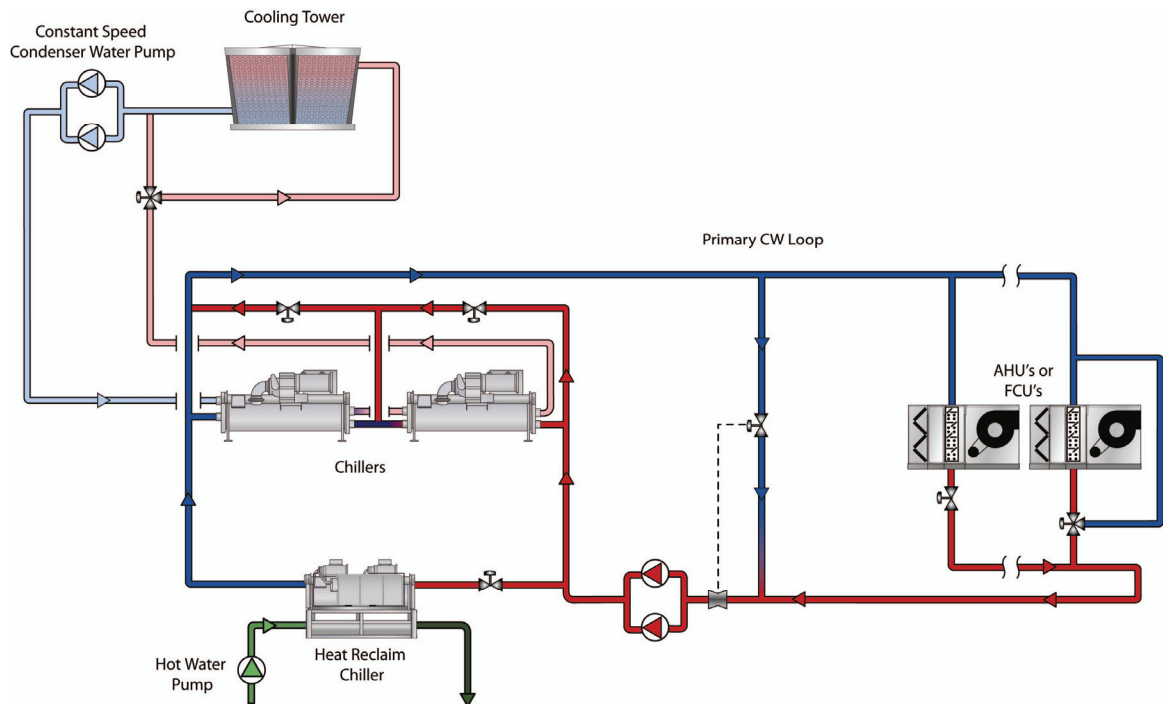


Fig. 17. Series Counter-Flow Chilled Water System with Heat Recovery Chiller

USING THE CAPTURED HEAT

Ensuring Hot Water is Available

The heat reclaim chiller can produce water temperatures up to 135 F when it is operating. When available, this can be sufficiently warm enough to satisfy many applications. However, some applications may need to ensure that a source of hot water warmer than 135 F is always available. When the building cooling load is satisfied, the heat reclaim chiller must shut off to ensure the chilled water loop is not over-cooled. At this point, hot water will not be generated by the heat reclaim chiller. To ensure that hot water is always available at the necessary temperature, a system similar to Fig. 18 should be considered. This system can capture heat from the heat reclaim chiller when it is available and provide hot water at a temperature needed for the specific application. The benefit of preheating the cold make-up water can be realized when the heat reclaim chiller is operating.

Many commercial potable water systems require hot water to be circulated throughout the building to ensure that hot water is immediately available when the hot water faucet is opened. To accomplish this, a circulating pump distributes hot water throughout the building. Figure 18 shows how to pipe the heat reclaim chiller into this type of circulated hot water system. This system can be used for potable water applications since a double wall heat exchanger is provided with the heat reclaim chiller. It is important to size the preheat storage tank to account for the recovery time of the heat reclaim chiller. The recovery time is a function of the storage tank volume, cold water make-up rate and temperature and the heating capacity of the heat reclaim chiller.

Notice the location of the tank piping connections. Thermal stratification or improper thermal mixing within these tanks can lead to poor hot water temperature control. The location of the piping connections must ensure thorough thermal mixing within the tanks. The heat reclaim supply should enter the water heater tank approximately 1/3 down from the top of the tank. The interconnecting pipe between the water heater tank and the preheat storage tank should connect as low as possible to the water heater tank and enter the top of the preheat storage tank. Flow in this pipe can go either way depending on the rate of hot water draw from the system and the heat reclaim water flow from the heat reclaim chiller. To ensure proper mixing, it is recommended that the heat reclaim water pump between the preheat storage tank and the heat reclaim chiller remain on at all times. The heat reclaim return piping should connect as low as possible to the preheat storage tank. This is suggested to ensure suitable mixing in the preheat storage tank.

A back-up water heater must also be provided to ensure a controlled source of hot water is available during times when the heat reclaim chiller is not operating. The back-up heater can be a conventional water heater, hot water boiler or steam converter. The mixing valve is necessary to ensure the proper temperature water is distributed to the circulated hot water system. This system ensures that the cold make-up water is preheated by the hot water generated by the heat reclaim chiller and the hot water temperature supplied to the heat load is controlled.

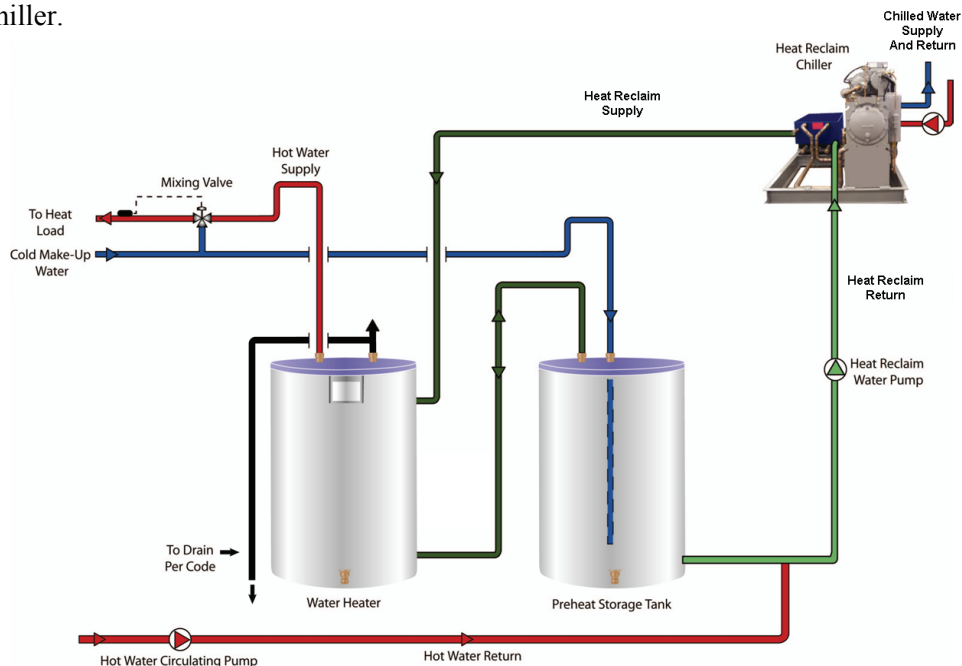


Fig. 18. Circulated Potable Water Heating System

CONCLUSIONS

Capturing useful heat is possible with appropriate equipment applied to meet the hot water and chilled water system needs.

There are several means to meet the intent of ASHRAE 90.1-2004 while maximizing LEED-NC certification points. Heat reclaim systems are certainly practical and available with today's technology. These systems also ensure:

- Sufficient heat is captured for useful purposes
- Lift is minimized and chiller efficiency is maximized
- A controlled source of hot water with stable chilled water system operation is provided

A properly designed heat recovery system must ensure:

1. Accurate determination of the peak hot water usage.
2. Reasonable recovery time for the heat reclaim chiller to make hot water. This is a function of the size of the storage tank, the cold water make-up rate and temperature and the heating capacity of the heat reclaim chiller.
3. Heat reclaim chiller properly sized for heating purposes. Do not oversize the chiller. An oversized heat reclaim chiller will short cycle under part load conditions and lead to poor hot water temperature control and reduced chiller life.
4. Properly sized hot water storage tank(s) to accommodate the necessary recovery time for hot water storage and ensure stable hot water temperature control. A minimum active loop volume of 6.0 to 10.0 gallons/ton of heating is required. The active loop volume should include the condenser or desuperheater volume, heat reclaim piping, water heater tank, and preheat storage tank.
5. Proper piping connection locations for the storage tanks. Multiple pipe connections may be necessary to overcome tank thermal gradients. The connection locations must promote thorough mixing in the tank to ensure the entire tank volume can contribute to the 6.0 to 10.0 gallons/ton minimum loop volume. Proper blending of the cold make-up water with the circulated hot water and the heat reclaim water is essential for stable hot water temperature control.

6. Integrated back-up heat provided for times when the heat reclaim chiller is not operating. This back-up can be a conventional water heater, hot water boiler or steam converter. Regardless of the source of back-up heat, it must be sized to accommodate the system heating load when the heat reclaim chiller can not provide sufficient heat to maintain the hot water storage tank temperature.
7. Storage tank arrangements for integrating recovered pre-heated water from main chiller heat rejection with the primary heated water from the heat reclaim chiller.

Experience has proven that the above recommendations are essential for proper heat reclaim chiller operation and stable hot water temperature control. These recommendations must be followed to avoid chiller short-cycling, unstable hot water temperature control, poor thermal mixing in the storage tanks, and improper integration of the back-up heating system.

It is important to understand how to design the heat reclaim system to meet the heating requirements of the building or process. Specifying the appropriate equipment to serve these needs is also important when a controlled source of hot water is desired. There are several chiller plant configurations that will accomplish this goal. Equipment must be specified that can provide a controlled source of recovered heat for hot water. On-board chiller controls can maintain the hot water set point temperatures without sacrificing efficiencies of the entire chilled water plant. The combination of captured heat with optimum chiller plant efficiency will minimize energy consumption and maximize LEED-NC certification points.

References:

1. The Benefits of System – Based Design, James Pegues, Sr. HVAC Systems Engineer, Carrier Software Systems, Carrier Corporation, Syracuse, New York, April, 2002
2. 90.1 User's Manual, ANSI/ASHRAE/IESNA Standard 90.1-2004, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA USA
3. Diagrams are for illustration purposes only. System design requirements remain the sole responsibility of the design engineer.
4. Variable Primary Flow Chilled Water Systems: Potential Benefits and Application Issues Final Report, Volume 1, March 2004, Bahnfleth, and Peyer, Air-Conditioning and Refrigeration Technology Institute, ARTI-21CR
5. Carrier's 23XRV variable speed screw chillers have exceptional plant efficiencies. When applied in a series counter-flow plant, efficiencies can reach 0.49 kW/ton for full load operation and part load IPLV of 0.29 kW/ton.
6. Consult chiller manufacturer's application data for minimum and maximum cooler flow requirements and flow variation rate limits.



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