Water-side Heat Recovery

by ***Ilse Dubois***
Senior Applications Engineer,
Trane,
Brussels, Belgium

As energy costs are rising, and environmental awareness is coming to the industry fore front, the interest in energy recovery is increasing as well. Heat recovery from the condenser of air-cooled or water-cooled chillers can provide significant savings, if the setting and the usage of the building is suitable for this application. Feasibility of water-side heat recovery can be decided by taking into account several factors such as number of hours of simultaneous cooling and heating needs, space availability for heat storage, etcetera…

To arrive at a decision on the appropriate water-side heat recovery usage, one should be well aware of all different heat recovery chiller configuration possibilities, system design configurations and controls to ensure efficient operation. Knowing these factors well will provide savings through water-side heat recovery, taking into account initial investment.

Which Energy is Recovered?

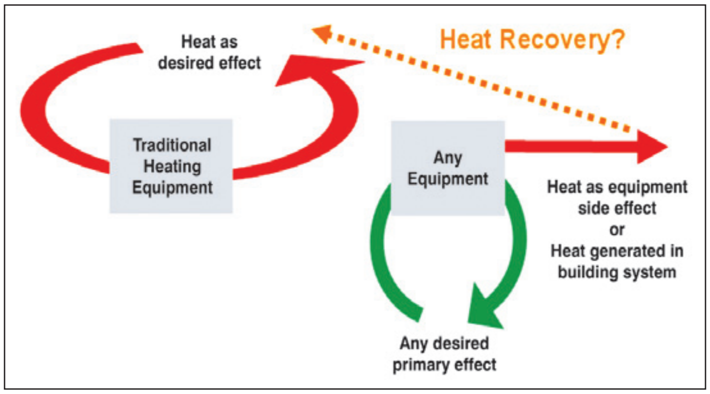

Figure 1: Heat recovery could help to divert waste heat to places where it is needed.

In any cooling system, heat is transferred from the load location whether the load is a result of space temperature conditioning, dehumidification, or a process. When air conditioning equipment is providing this cooling, several sub-processes are involved:

- Heat is removed from either the space or the process by the evaporator or the chilled-water coil.
- Heat is transferred to a condenser during the refrigeration process.
- Heat is transferred from the condenser to the outdoor air, directly through an air-cooled condenser, or via the cooling tower or dry cooler

About the Author

Ilse Dubois hold a Master of Science degree in electro mechanical engineering with specialization in industrial management from Spain. She can be contacted on infoindia@trane.com

connected to the water-cooled condenser.

Why Heat Recovery?

- **Energy costs:** *Figure 1* Recovering otherwise rejected and thus wasted heat, gives a double benefit; recovered heat reduces purchased heat (and cost) and also reduces the ancillary power necessary to reject the heat. The building annual operating costs to produce the necessary cooling and heating, will be reduced.
- **Energy codes:** Some national and/or international regulations require condenser heat recovery for service water (domestic hot water) pre-heating or heating. Applications that meet these criteria are hotels, dormitories, hospitals, etc.
- **Reduced environmental emissions:** Burning fossil fuels increases site emissions. If the job site has already reached the maximum emission levels allowed, recovering heat can satisfy future loads without consuming more fuel on site. Also, some places are considering emissions trading, where this may become extremely valuable.

Feasibility Analysis

Accurate feasibility analysis of heat-recovery systems is critical. Factors to take into accounts are :

- Calculate coincident cooling and heating loads.
- Account for various fuels (when using electric chillers and natural-gas boilers for instance)
- Model diverse utility rates: time-of-day usage and demand charges.
- Accurately model chiller heat-recovery conditions and energy usage.
- Model system configurations that are used in heat-recovery applications.
- Model reductions in substances such as CO_2, NOx, SO_2, when comparing heat-recovery alternative with other alternatives.

Heat Recovery Types: Full or Partial Heat Recovery?

On air-cooled chillers, a heat-recovery condenser may be added in parallel or in series with the air-cooled condenser, inside the packaged chiller itself. On water-cooled chillers, we may be looking at chillers with only one water-cooled condenser, where the heat recovery will be realized in the hydraulics system, or at chillers with an additional heat-recovery condenser in parallel (dual) or series (auxiliary) with the water-cooled condenser, inside the packaged chiller itself. Depending on the chiller configuration, full or partial heat recovery will be obtained. But what exactly does full or partial recovery mean? The total heat which any chiller must reject anyway, is the sum of its cooling capacity and the compressor's power input. This amount is the gross heat rejection. (*Figure 2*) Depending on the chiller configuration: air-cooled or water-cooled and series or parallel heat-recovery condenser versus standard condenser, this full gross heat rejection amount could be recovered or not. When the answer is no, this means physically, the heat-recovery condenser can only recover part of the otherwise rejected heat, due to its size, or due to its configuration. Is "full" better than "partial"? This is not really the question to ask. All depends on the building: what are the simultaneous cooling and heating needs? When cooling is provided, how much heating is needed? What use does it make to recover all rejected heat when providing cooling, if that heat is not needed in the building? Also when cooling is needed maximum, most likely, the instantaneous hot water need will not be maximum. In this case, to be able to maximise benefit from the rejected heat, it needs to be stored in hot water tanks. The availability of tanks, is an important factor in the ability to use the recovered heat at a different time of the day.

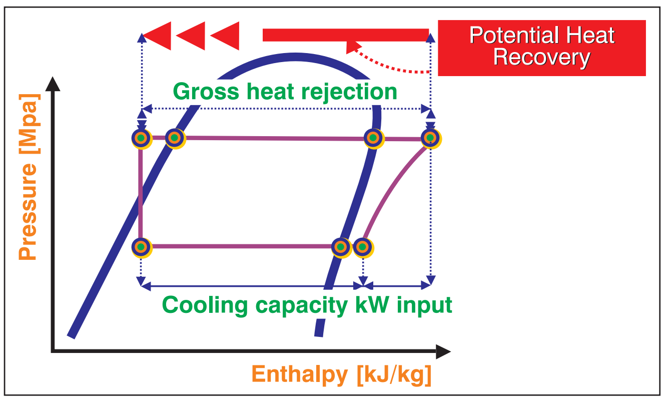

Figure 2: Total heat recovery possible = cooling capacity + kW input

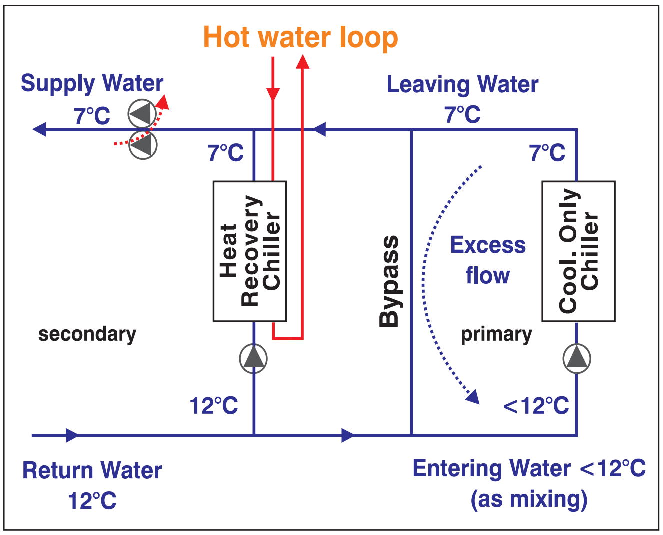

Figure 3: Decoupled preferential load design

continued on page 120

continued from page 118

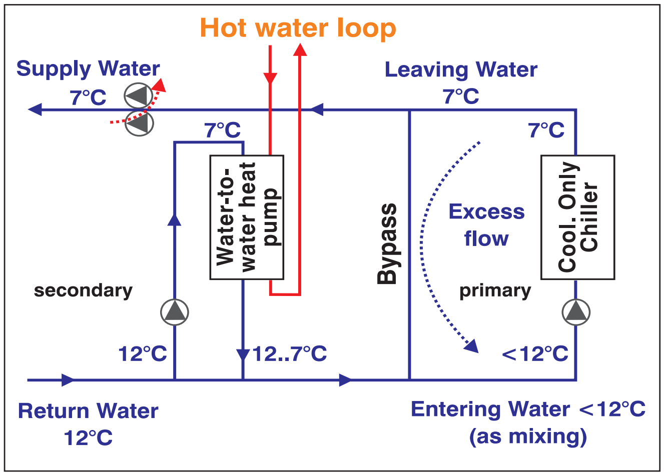

Figure 4: Side stream arrangement

Heat Recovery Types: Controlled or Uncontrolled Heat Recovery?

Another important aspect to distinguish among different heat recovery types is the controlled versus uncontrolled heat recovery. A chiller which provides the possibility to operate at "controlled" heat recovery conditions will fix the leaving hot water temperature of the heat recovery condenser, independent of the outside ambient conditions. The advantage is obvious; however, the disadvantage may be that the chiller consumes more energy in heat recovery mode, than it would be at normal ambient conditions, when providing cooling only. However, when the chiller is operating in a very hot climate and the demanded leaving hot water temperature is not extremely high, the chiller will actually operate at a more advantageous energy efficiency level than it would be in cooling only mode. In a hot climate, controlled heat recovery has both advantages: recovering heat, and running the chiller at a lower energy consumption ratio.

Fixing the leaving hot water temperature at a high level, compromises the chiller efficiency, but reduces the consumption of heating devices such as boilers. As the electricity meter is on the building, and not on individual equipment, a balance should be found between compromising chiller efficiency, versus saving boiler energy.

Uncontrolled heat recovery chillers are less sophisticated. Here the chiller is configured to obtain best, lowest energy consumption as would be in cooling only mode, taking advantage of ambient relief, when outside temperatures are lower, and hence the chiller runs at better energy efficiency ratios. The consequence of this, is that the leaving hot water temperature will be high when ambient is high, and will be lower, when ambient is lower. The leaving hot water temperature is not guaranteed, you get what you can, you recover what you can. However, due to the fact that the heat-recovery condenser adds to the total condenser capacity, these chiller types actually have slightly better chiller efficiencies. Typical applications are pre-heating of domestic hot water, so that boiler consumptions are reduced.

Chilled Water System Configuration: Preferential loading

When a chiller (air-cooled or water-cooled) is located on the load side of the bypass line in a primary-secondary system, it is loaded preferentially because it always receives the warmest return-water temperature (Fig.3). The chiller will always work at full load, unless system cooling demands are really low, all other chillers are shut down, and the preferential chiller also needs to run at part load. Therefore, because of the maximum loading situation, when operating, it rejects as much heat as possible - depending on the chiller heat recovery configuration capacity. A chiller piped in this location also adds to the chiller-plant flow rate and does not directly reduce the return-water temperature to other chillers. If the chiller supply-water temperature is maintained, the chiller may reject more heat than can be used by the heating load, in which case, the chiller provides more heat than the system needs. If it concerns an air-cooled chiller, then more heat will need to be rejected through the standard air-cooled condenser to guarantee that the refrigerant fully condensates. When it concerns a water-cooled chiller, then part of the heat will need to be removed through the cooling tower or dry cooler.

If the heat-recovery chiller can tolerate variable evaporator water flow, a variable-speed drive may be installed on its chilled-water pump, so that amount of cooling, hence amount of recovered heat, can be influenced. Another solution to the preferential loading potential problem of delivering too much heat capacity than needed by the system, is going to sidestream position.

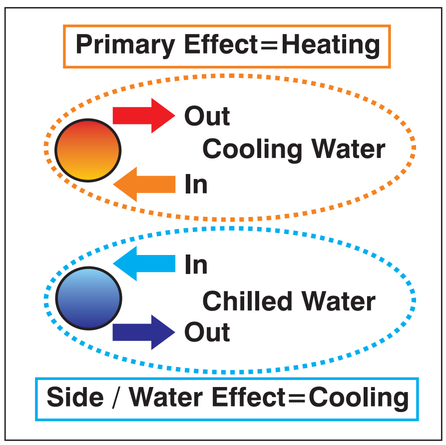

Figure 5: Heat pump configuration with 'cooling' recovery

continued on page 122

Chilled Water System Configuration: Side-stream

A chiller piped in a side-stream position (*Figure 4*) will be controlled on delivered heating capacity. It will at all moments produce exactly as much heating as needed by the system. As the control is on the heating capacity, the cooling capacity is a result through varying its leaving chilled-water setpoint. When operating, the sidestream chiller cools the return chilled-water temperature to the non-heat recovery chillers, which will then operate in part load. We speak about the concept "cooling recovery".

The non-heat-recovery chiller pumps must supply the entire flow demand of the cooling load. These chillers must be designed for total design cooling capacity. Cooling capacity of the side-stream chiller is an add-on, but you will not count on it to deliver required cooling capacity. When both heat-recovery and standard chillers are operating, the standard chillers experience a reduced DT and will not have to load to full capacity. This can result in an operating condition where more than one standard chiller is operating to satisfy flow requirements, even though one could meet the load.

An advantage of the side-stream configuration is that the side-stream chiller does not need to produce the design system supply-water temperature. It can produce the exact chilled water temperature necessary to meet the required heating load. This allows the chiller to operate more efficiently because the cooling is produced at a higher chilled-water temperature. Also, even if the side-stream chiller leaving water temperature is higher than the system supply temperature, it will be lower than the system return temperature, and hence the non-heat-recovery chillers will experience a pre-cooled entering water temperature.

Side-stream is an effective configuration to use for a heat-recovery chiller in a constant primary, variable secondary-flow system. Also, a water-cooled chiller, positioned in side-stream, will function as a water-to-water heat pump (*Figure 5*), where no cooling tower is needed. The heat pump is controlled on leaving condenser water temperature and will be fully loaded when the system demands full heat capacity. When less heat is needed, the heat pump will go in part load, and always delivers the amount of heat needed by the system, never more.

Summary

- Water-side heat recovery is a viable option to address the goals of reduced energy costs and environmental emissions. With increasing awareness on operating costs, and return on investment calculations, heat recovery is used more today than in the recent past, and is ideal for applications on (pre-) heating domestic hot water, process water, or even comfort heating. Typically hotels, hospitals, dormitories, take benefit of water-side heat recovery.
- The amount of heat that can be recovered changes with system configuration and equipment choice.
- Each of the heat recovery chiller configurations and system configurations has advantages and disadvantages. The system and chiller type that is right for your building depends on your specific project conditions.
- Where you place the chiller in the system hydraulics can give you some flexibility in how it is controlled.
- The electricity consumption meter is on the building, not on individual equipment. Energy costs of the total system should be investigated. Worse energy efficiency performance on one equipment, due to for example forced heat recovery, may still lead to lower global energy costs, due to for instance lower boiler consumptions. Find the right balance of all factors. ❖