Introduction of Heat Recovery Chiller Control and Water System Design

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Abstract: The styles, feature and main concerns of heat recovery water system are discussed, and the entering condenser water temperature control is recommended for higher chiller efficiency and reliable operation. Three optimized water system designs are introduced for more heat recovery or higher heating water temperature.

Keywords: heat recovery temperature control water system design

1 PREFACE

Use of the heat recovery of water cooled chillers can significantly reduce the energy operating costs of many buildings by using heat which normally would be rejected to the atmosphere by cooling towers. Typical uses for this heat are perimeter zone heating, reheat air conditioning systems and any hot water requirements. Any building with a simultaneous heating and cooling load is a potential candidate, such as hotels, office buildings, hospitals, schools, etc.

2 HEAT RECOVERY STYLES

There are two kinds of heat recovery methods, one is using a heat exchanger, another is using an additional condenser.

Figure 1 shows one method, which uses a heat exchanger outside of the water-cooled condenser. Instead of rejecting heat to the cooling tower, heat is recovered from the condenser water. Usually the heating water temperature is lower due to additional heating transfer by heat exchanger.

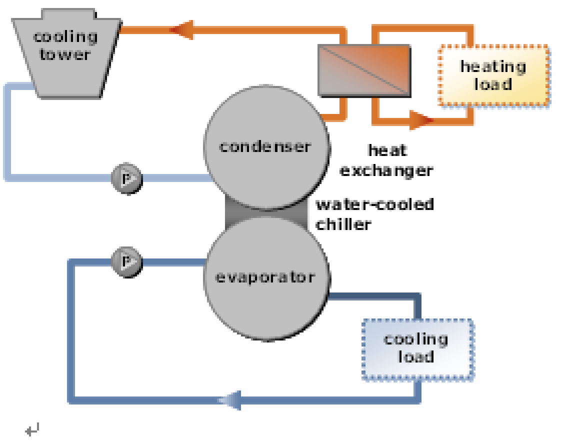

Fig.1 Heat recovery using a heat exchanger

In another mothod, this heat recovery can take place directly from hot refrigerant in the refrigeration circuit (refer to Figure 2) by using an additional condenser bundle, piped in parallel with the normal condenser. The heating circuit and cooling tower circuit are separate, preventing cross contamination. [1]

Usually the heating water temperature is higher due to direct heat transfer by condenser bundle.

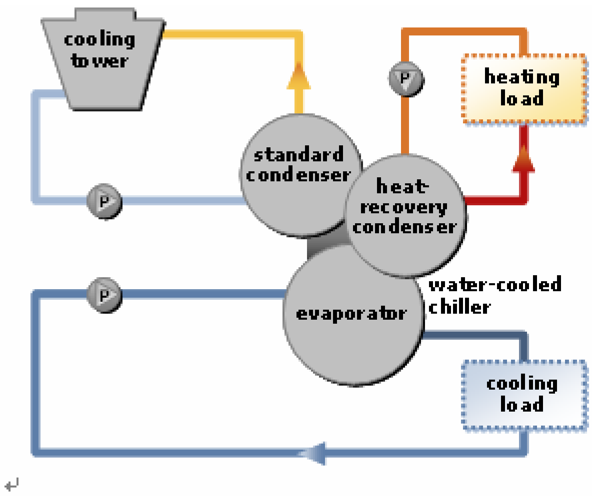

Fig. 2 Heat recovery using an additional condenser

3. FEATURES OF HEAT RECOVERY CHILLERS

Most heat recovery chillers are required to produce higher leaving condenser water temperature, and thus will not duplicate the energy efficiencies of cooling-only machine. Figure 3 illustrates the typical operating cycles of a cooling-only machine and a heat recovery machine.

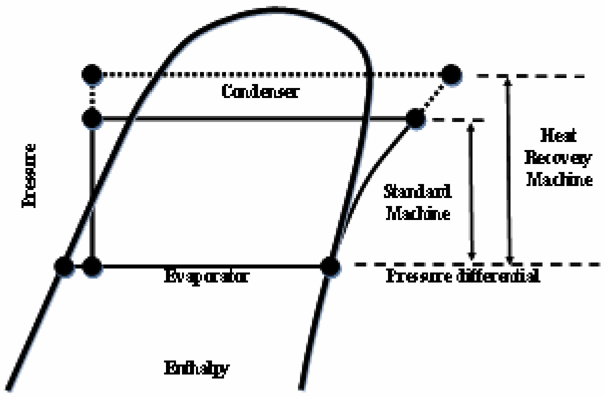

Fig. 3 Refrigerant pressure difference

The most noticeable differences are:

（1） The Pressure differential provided by the compressor is much greater for the heat recovery cycle.

（2） The amount of heat rejected from the heat recovery condenser is greater than that which would be rejected in cooling–only operation.

（3） The heat recovery machine has a lower energy efficiency during heat recovery operation, due to the increased pressure differential and reduced refrigeration effect, that means the compressor must pump more gas per ton of refrigeration.

4. MAIN CONCERNS OF HEAT RECOVERY

4.1 Maximum amount of heat recovery

The heat amount is the sum of cooling load and compressor power in theory. The maximum amount of heat recovery can be 100% of cooling capacity for some centrifugal chillers using an additional condenser. The heat amount will be reduced in response to reduced cooling capacity at part load operation.

4.2 The highest heating water temperature

As the heat recovery chiller removes heat in the evaporator from cooling load to the condenser, and then recovers heat rejection from the condenser to the cooling tower. It takes priority to make cooling, heat can not be recovered without cooling. The higher heating water temperature is, the lower efficiency and cooling capacity is, even the chiller operates unsteadily and break down. 43^{O}C to 48^{O}C of heating water is available for heat recovery centrifugal chillers, an auxiliary heat source is needed, if higher heating water temperature is required.

4.3 Heating Water Temperature and Control

It’s always desirable to use as low a heating water temperature as the application allows. In general, the heat recovery power consumption will increase 7 to 14 percent for every 5.6 ^{O}C increase in the design heating water temperature.

In most cases, the heating water temperature control should be designed to maintain the return heating water temperature. By allowing the supply heating water temperature to float, the mean water temperature in the system drops as the chiller load decreases and less heat is rejected to the condenser (refer to Figure 4). As the mean water temperature drops, so does the refrigerant condensing temperature and pressure difference which the compressor is required to produce at part load. This increases the unloading range of the compressor. [2]

When the supply heating water temperature to the building system is maintained and the return heating water temperature to the condenser is allowed to float, the mean heating water tempearture actually rises as the chiller load decreases and less heat is rejected to the condenser. As Figure 4 illustrates, when the compressor unloads, the pressure difference that it must oppose to prevent surging remains essentially the same, while the compressor’s capability decrease. Therefore, the unit’s capacity to unload without the use of hot gas bypass is reduced.

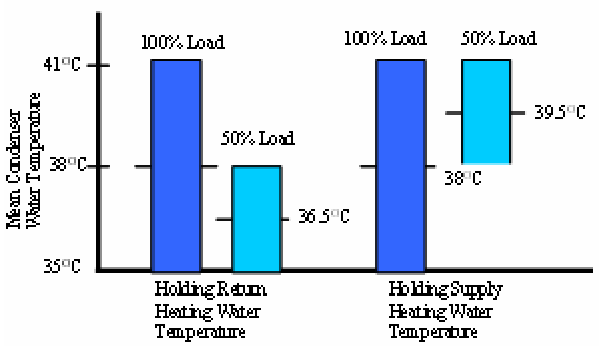

Fig. 4 Heating Water Temperature Control

5. HEAT RECOVERY OPERATION USING 2 CONDENSERS

5.1 Operation principle

Heat recovery is most commonly accomplished using 2 condensers and the fact that hot refrigerant vapor migrates to the area with the lowest temperature. Raising the refrigerant condensing temperature in the standard condenser prompts the refrigerant to flow instead to the second condenser, where it rejects its heat to the water flowing through the tubes. The condensing temperature in the standard condenser is controlled by varying the temperature, or the flow rate

of the cooling tower water.

5.2 Operation Control

Figure 5 shows a control configuration of a double-bundle chiller as it separates the heating loop from the cooling tower loop and requires only simple, understandable controls to maintain the entering condenser water temperature (T2).

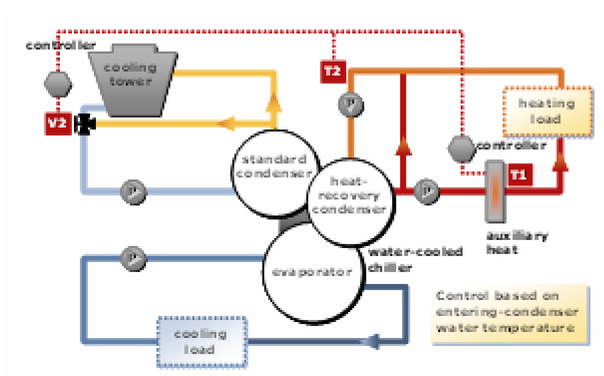

Fig.5 Control configuration of 2 condensers

If there is no heating load, the heat-recovery pump is off and all heat is rejected to the cooling tower.

When a heating load begins, the heat recovery condenser water pump operates, starting water flow to the heat recovery condenser.

As the heat-recovery condenser entering-water temperature (T2) rises and causes the condenser-water pump to start, the diverting valve (V2) to close, and cooling-tower fans to modulate. This rejects heat to the cooling tower and lowers the heat-recovery condenser entering water temperature.

Conversely, as the heat-recovery condenser entering-water temperature (T2) is reduced, the cooling-tower fans modulate and the diverting valve (V2) opens. All heat is therefore rejected to the heating loop. Eventually, the condenser-water pump is turned off.

6. OPTIMIZED SYSTEM DESIGN FOR MORE HEAT RECOVERY

6.1 Primary–Secondary

Many chilled-water systems are configured in the traditional primary–secondary arrangement (Figure 6). This may not be optimal for performing heat-recovery operation. The simple reason is that all operating chillers are loaded to equal percentages.

The amount of heat recovery available is limited by chiller loading. For the same building load, the load on each chiller can be significantly different and depends on the chilled-water system configuration.

6.2 Preferential Loading

When a chiller is located on the load side of the bypass line, it is loaded preferentially, because it always receives the warmest return-water temperature (Figure 7). Therefore, when operating, it rejects as much heat as possible. A chiller piped in this location also adds to the chiller-plant flow rate and does not reduce the return-water temperature to other chillers. If the system supply-water temperature is maintained, the chiller may reject more heat than can be used by the heating load.

If multiple heat-recovery chillers are used, one of the heat-recovery chillers can be left off until a second chiller is required to satisfy the cooling load. In this situation, when put into operation, the heat-recovery chiller will be fully loaded and able to provide the design supply-heating water temperature. This greatly simplifies system control and keeps a centrifugal chiller out of a region in which it may surge.

6.3 Sidestream

A chiller piped in a sidestream position, shown in Figure 8, can be loaded to any load condition by varying its chilled-water setpoint. The chillers piped in parallel have a flow rate greater than those in a traditional primary–secondary system, because the sidestream pump does not help satisfy system chilled water flow requirements. This is because the sidestream chiller precools the water and these chillers have an entering-water temperature lower than the temperature of the water from the cooling loads.

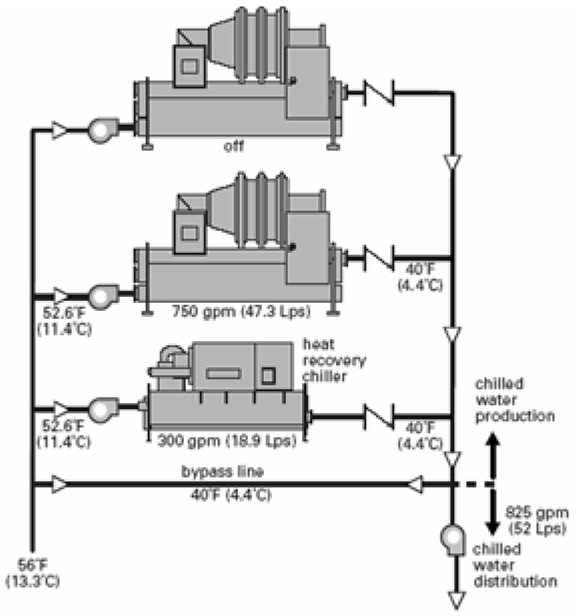

Fig. 6 Primary-Secondary

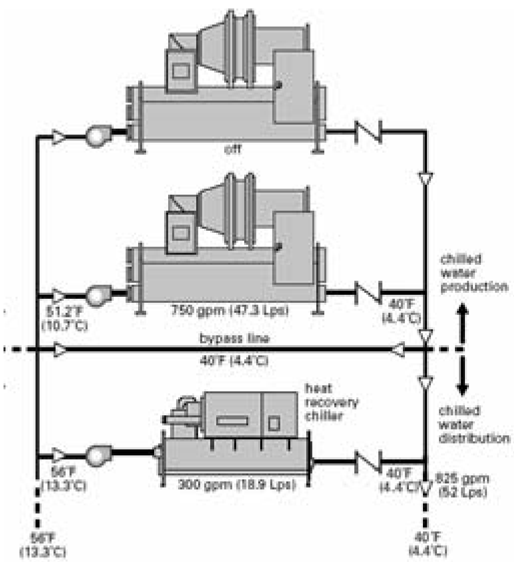

Fig. 7 Preferential Loading

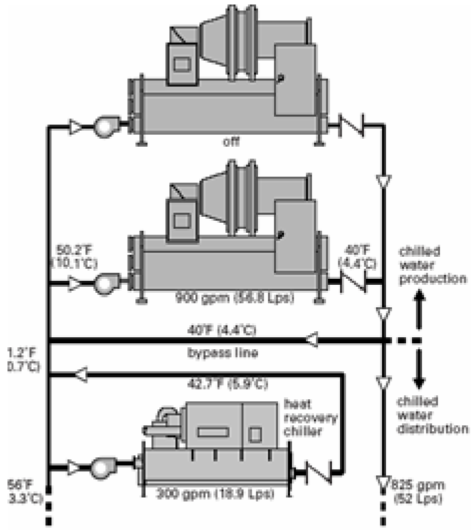

Fig. 8 Sidestream

An advantage of the sidestream location is that the sidestream chiller does not need to produce the design system supply-water temperature. It can produce whatever water temperature is necessary to exactly meet the required heating load. This allows the cooling to be produced at a higher chilled-water temperature, resulting in more-efficient operation.

Because the heat-recovery chiller is controlled to only provide the amount of heat required, there may be no need for this chiller to be connected to a cooling tower. This allows a single-condenser chiller to be used in this position without the need for a separate heat exchanger.

6.4 Comparison of the three system designs

Table 1 shows the comparison: the building cooling load is 1934 kW and heating load is 585 kW, using one 1758kW cooling-only chiller and one 703kW heat-recovery chiller, the design chilled water temperatures are 13.3^{O}C entering, 4.4 ^{O}C leaving. [1]

Tabel 1 Heat available/required comparison

	Primary Secondary	Preferential Loading	Side stream
Cooling only Cooling Load	1382 kW	1231 kW	1347 kW
Heat-recovery Cooling load	552 kW	703 kW	587 kW
Heat-recovery Supply temp.	4.4^{O}C	4.4^{O}C	5.9 ^{O}C
Available heat	555 kW	705 kW	585 kW
Auxiliary heat required	30 kW	-120 kW	0 kW

The negative auxiliary heat required shows that the heat-recovery chiller ran at a higher capacity than necessary to satisfy the heating load. This is not necessarily a disadvantage, when compared with the primary–secondary configuration, because this heat must be rejected whether it is from the cooling-only chiller or the heat-recovery chiller.

7. SYSTEM DESIGN FOR HIGHER WATER TEMPERATURE

Two chillers overlap in series, recovering cooling load heat rejection from the first stage chiller's condenser water on the way to the cooling tower, then delivering these heat to the heat load by the second stage chiller in series for higher heating water temperature up to 57 ^{O}C (Figure 9) . Also the compressor's power has been added to the chiller condenser. [3]

Heat removed from the cooling load has been delivered to the heating load through the following water circuit loop: cooling tower, the first stage chiller's condenser, the second stage chiller's evaporator, cooling tower. If the heating load can not match the cooling load, the cooling tower rejects any leftover heat to the atmosphere.

As the operation condition of the second stage chiller is different from that of traditional chillers, chillers need modified to oprate steadily.

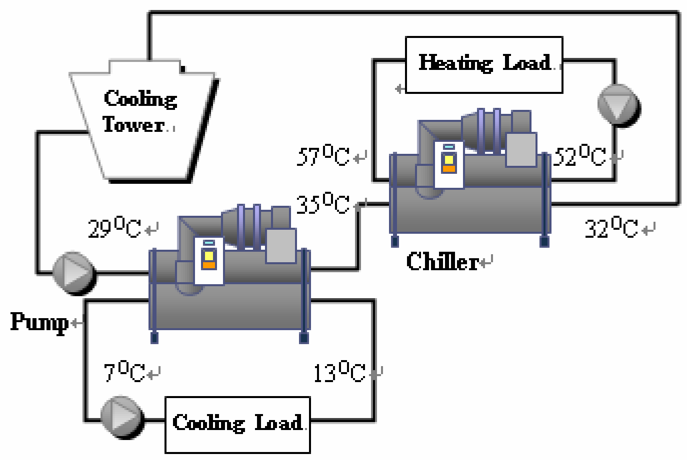

Fig. 9 Configuration for higher water temperature

8. CONCLUSION

Heat recovery using 2 condensers produces higher temperature water than that using a heat exchanger. Heat recovery chillers can provide more heat with less efficiency than that operate in cooling only mode. The 3 main concerns of heat recovery are maximum heat amount, the highest heating water temperature, and operation control method. Entering-condenser water temperature control is recommended for higher chiller efficiency and reliable operation. The three heat recovery system design are introduced: Preferential loading and Sidestream are for more heat recovery, two chillers overlap in series for higher water temperature.

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