Hydronic Heat Recovery In Health Care

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Swedish Issaquah, a 350,000 ft^2 (32 500 m^2) hospital located in Issaquah, Wash., uses a hydronic heat recovery system to achieve a 50% energy savings compared to an average hospital in the Pacific Northwest. After I wrote an article (June 2013 ASHRAE Journal) about the hospital last year, readers asked about using exhaust air for heat recovery in hospitals, and about comparing exhaust air for direct air-to-air heat recovery versus chilled water to recover heat from the exhaust air for use in a hydronic heat recovery system using a heat recovery chiller.

This article seeks to answer the questions I received, describe the advantages of hydronic heat recovery, and provide design considerations regarding hydronic heat recovery design. While this article is meant to address general concepts of heat recovery in health care, data from Swedish Issaquah will be used for examples to illustrate concepts.

For the purposes of this article, hydronic heat recovery refers to building level hydronic systems (chilled water and heating water systems). This should not be confused with the hydronics of a runaround loop air-to-air heat recovery system.

Heat demand in a hospital can be grouped into three general categories; central ventilation heating, envelope losses, and zone air tempering due to minimum airflow requirements. Air-handling unit heating coils serve central ventilation heating requirements, and zone level heating coils serve both the envelope losses and zone air tempering.

Many hospitals are served by 100% outdoor air supply systems with air-to-air heat recovery. Various types of heat exchanger options recover heat from outgoing exhaust air and transfer the heat to supply air, reducing demand on the AHU heating coils. However, these systems only recover heat when ventilation heating is required. For much of the year, more energy is available in the exhaust air than can be recovered by these methods. As was done for the Swedish project, Chilled water cooling coils can be placed in the exhaust air and used in conjunction with a heat recovery chiller to recover the additional heat and apply it to the heating water system,

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allowing the additional heat to be used at zone level heating coils.

The pie chart in *Figure 1* shows the portions of annual heating energy consumed at the AHU level and the zone level for Swedish Issaquah, which is served by recirculating VAV AHUs with hot water terminal heating. The data is taken from an energy model, but two years of trend data from the operational building match the modeled data quite well. As can be seen in the chart, the majority of heat demand in the building is served by the zone heating coils. The percentages shown in *Figure 1* will vary by system type, climate, and operation.

Energy modeling indicates that if the AHUs had been 100% outdoor air supply systems with 50% effective air-to-air heat recovery, the amount of heating energy at the AHU heating coils would have roughly doubled to about 4% for this building. To get an idea of how this might vary by type and climate, the weather file was changed to Chicago and the model was run with 100% outdoor air supply with 50% effective heat recovery, and with both VAV and constant volumes systems. The highest percentage of energy ventilation heating accounted for in any scenario was 8%, and the ratio of ventilation heating to terminal heating was similar in all scenarios.

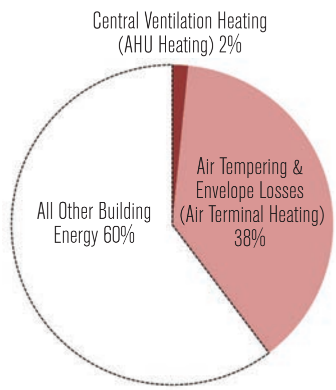

FIGURE 1: Building energy consumption.

Zone heat demand was much larger than the AHU heating coil demand, and the cause will be present in all hospitals. Minimum ventilation requirements of hospitals dictate higher airflows than necessary to meet space cooling loads for most spaces in a hospital. To not over-cool spaces, the air is tempered at zone heating coils. This air tempering happens 24/7 and is the single largest energy demand in most hospitals. To use recovered energy to serve this zone heating demand in a hot water reheat system, hydronic heat recovery is necessary.

Advantages of Hydronic Heat Recovery

Hydronic heat recovery recovers heat from internal loads through a heat recovery chiller and applies the recovered energy to the heating water system, allowing the heat to be used anywhere. *Figure 2* is a scatter plot showing the annual hourly heating water, chilled water, and domestic hot water (DHW) demand in the building. Orange is heating water, red is DHW, purple is chilled water, and blue is the amount of energy available in the chilled water system if chilled water coils are used to recover heat from exhaust and relief air.

The data in *Figure 2* indicates that there is enough heat from internal loads in the building to meet the heating demand for a majority of the year. This is likely to be true for many health-care projects, and for this reason a hydronic heat recovery system may be a beneficial solution.

Design Considerations

Some design issues to consider when designing a hydronic heat recovery system are sources of energy available, sizing of the heat recovery chiller and additional heating and cooling equipment, design and reset temperatures. Next are some examples of how these issues were addressed in the example hospital that have proven to work well in that application.

Basic Description

The hydronic heat recovery system at Swedish consists of a 300 ton (1055 kW) heat recovery chiller, three 520 ton (1830 kW) water-cooled chillers, six 3,000 MBH boilers, chilled water (CHW) coils in all major exhaust airstreams, and a control sequence that allows the AHU main CHW coils to recover heat that would normally be relieved in economizer mode. Refer to *Figure 3* for a schematic diagram of the system.

Sources of Energy

The heat recovery chiller is controlled by heating demand. It rejects all of its heat to the heating water loop, and gets the energy it needs from the chilled water (CHW) loop. The first source of energy in the CHW loop are the process loads. Examples of process CHW loads are fan coils units serving spaces such as electrical and IDF rooms, and water-cooled medical equipment such as CT Scan and MRI machines. These loads are available year-round and serve as a base load for the heat recovery chiller.

During times in which outdoor air temperatures are warm enough, the second source of energy comes from cooling at AHU cooling coils necessary to meet supply air set point temperatures. When AHU cooling is not available, the third source of energy are exhaust heat recovery coils. The exhaust heat recovery coils consist of normal CHW coils placed in exhaust airstreams. These coils cool the outgoing exhaust air to provide the load being called for by the heat recovery chiller. These coils are only used when heating demand exceeds genuine cooling demand in the building. When the heating demand exceeds the cooling load and all the exhaust heat recovery coils are full open, the last source of energy the system will search for is energy available from relief air of AHUs operating in economizer mode.

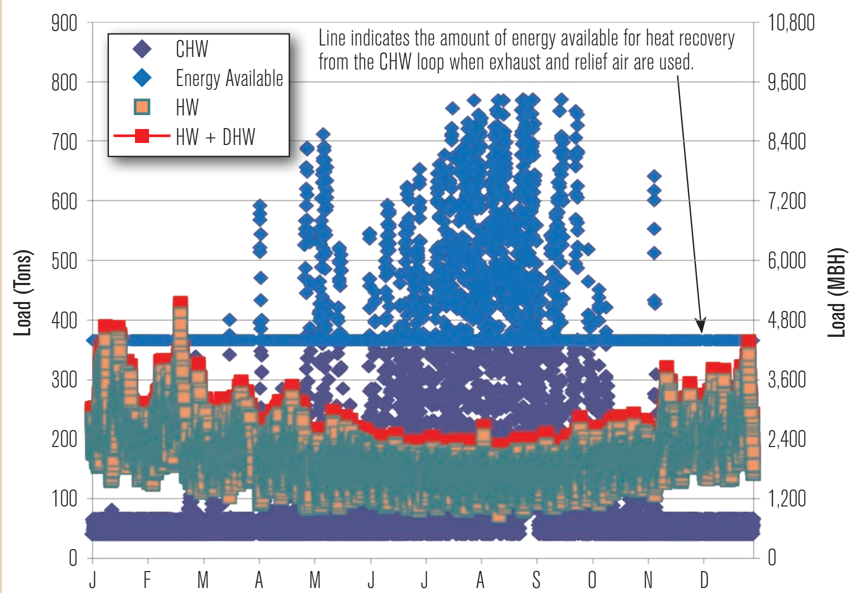

FIGURE 2: Building hydronic hourly loads.

If AHUs are operating in economizer mode, the DDC system will calculate the appropriate mixed air temperature required for the AHU cooling coil to meet the load being called for by the heating water system. Then, economizer operation will be over-ridden, the AHU will mix return air with outdoor air supply to achieve the calculated mixed air temperature, and the AHU cooling coil will be used to extract the amount of energy necessary for the heat recovery chiller to meet heating demand.

Equipment Sizing

The heat recovery chiller was not sized to meet design conditions. Instead, an energy model was used to produce the scatter plot shown in *Figure 2* and the heat recovery chiller was sized using a combination of average heating demand in the summer, spring, fall, and available energy in the CHW system during winter. The heat recovery chiller is controlled to meet heating demand. It does not have the ability to reject heat anywhere except the heating water system. When cooling demand exceeds heating demand in the building, three variable speed water-cooled chillers serve the additional cooling required. Because the water-cooled chillers have lower condenser temperatures, they have the ability to meet cooling demand much more efficiently. When winter heating demand exceeds the amount of energy available in the CHW loop, six condensing boilers supplement the heat recovery chiller to meet the load.

Temperatures

The heat recovery chiller operating efficiency is a function of the lift on the compressor. The lower the heating water temperature and higher the CHW temperature, the higher the heat recovery chiller operating efficiency. Design temperatures were chosen to balance operating efficiency of the heat recovery chiller with size and first cost of CHW and heating water coils. The heating water system was designed with a 120°F (49°C) supply and 100°F (38°C) return temperatures. With a supply temperature of 120°F (49°C), most air terminal reheat coils were two row coils and only a few required three row coils. The CHW system was designed using 42°F (6°C) supply temperature to meet humidity requirements. To keep the lift on the heat recovery chiller as low as possible without dramatically increasing the size of equipment, the heat recovery chiller was designed to supply 48°F (9°C) CHW. Fan coil units serving process cooling loads were designed using 48°F (9°C) CHW and a bypass valve was included so the main chillers could be bypassed when no ventilation cooling is required, and all process loads could be served by the heat recovery chiller directly.

Commissioning

A hydronic heat recovery system is highly interactive. AHUs, chillers, boilers, and other components that operate independently in a traditional system may impact the operation of each other in a hydronic heat recovery system.

For Swedish Issaquah, several iterations of control sequence adjustments were required during the year after startup commissioning was complete and the building was occupied for the system to achieve optimum results. It is recommended that a project pursuing a similar system consider planning for post occupancy commissioning to make any necessary adjustments for optimal operation.

Results

Trend data from 2013 shows that 93% of heating energy was served by the heat recovery chiller with an average heating only COP of 4.0. The energy use intensity (EUI) for the past two years has been 112 kBtu/ft^2·yr (353 kWh/m^2·yr), and the heat recovery system saves the hospital approximately $120,000/yr. While EUI reductions similar to that seen at Swedish Issaquah may likely be seen in any hospital project that has an opportunity to design a similar system, the economic benefits depend on the local price of natural gas, electric rates and demand charge structures. Careful analysis using local utility rates to determine project specific economic benefits is recommended.

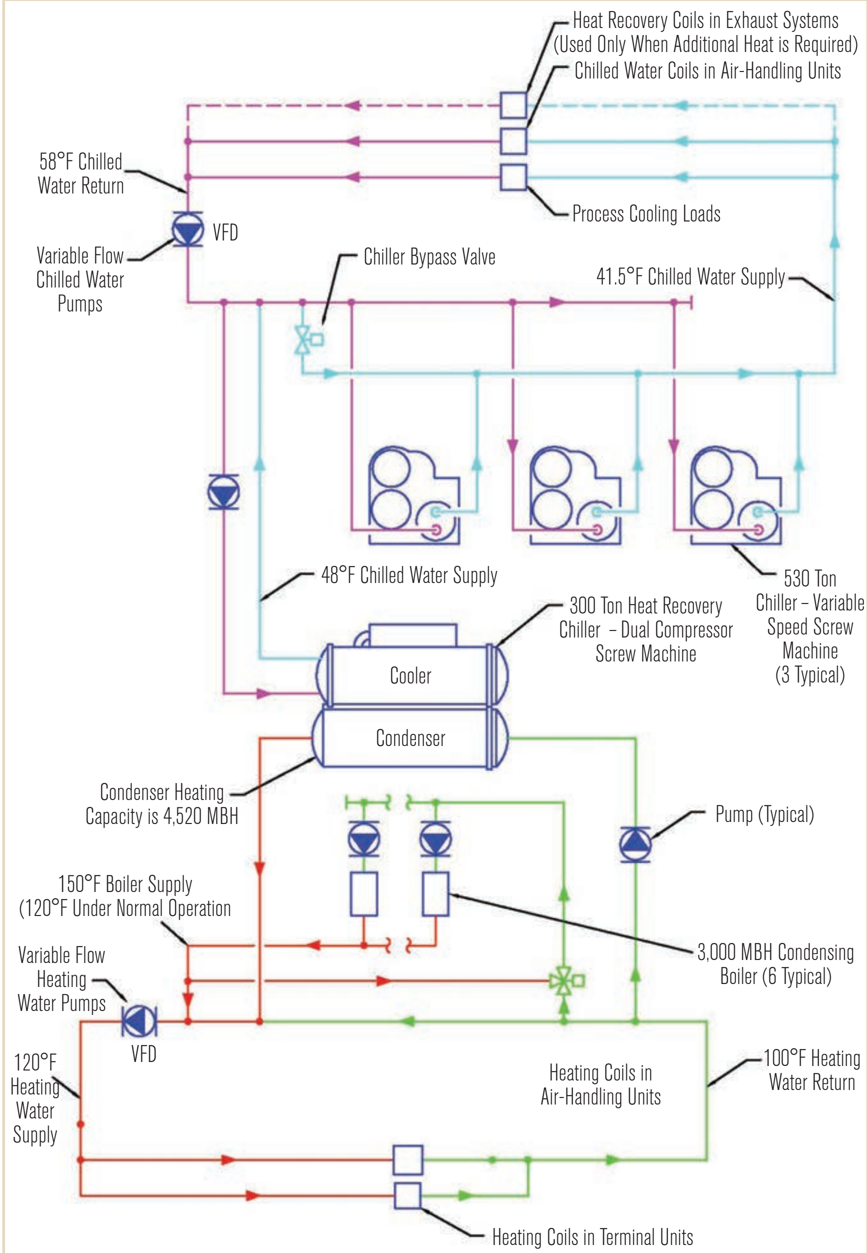

FIGURE 3: Heat recovery system.

Existing Buildings

Although this article is focused on new hospital projects, the general concepts may be applicable to differing degrees in existing hospitals. If the heating water supply temperature in an existing building can be reset low enough during summer months and moderate conditions for a heat recovery chiller to operate (typically 130°F and maybe higher), then a heat recovery chiller could potentially meet a significant portion of the heating demand. If the existing system is served by constant air volume AHUs, the amount of air tempering in the building would be significantly higher than the example used in this article. Therefore, the potential savings from a hydronic heat recovery system would also be significantly higher.

Conclusion

Substantial energy is available within a hospital for heat recovery. In many applications, it may be enough to meet a majority of building heating demand. A hydronic heat recovery system using a heat recovery chiller and exhaust recovery coils offer significant energy savings compared to traditional boiler heating systems, and in many areas of the country also offer substantial economic savings. ■