Chillers are considered primarily as a cold water provider. With today's technology, they are also capable of heat recovery. Given HVAC equipment’s substantial contribution to a building's total energy consumption, heat recovery (HR) offers an appealing way to reduce energy use. ASHRAE standard 90.1 may require HR in certain applications. Combining HR with the Daikin Trailblazer®, the industry's most efficient scroll chiller available on the market today, gives you unprecedented efficiency capability. This Daikin Blueprint explains how chillers can add HR with desuperheaters to reclaim normally rejected energy, and reduce hot water loads for process or comfort cooling applications.
CONTENTS

1 UNDERSTANDING HEAT RECOVERY
2 HEAT RECOVERY DESIGN
3 HEAT RECOVERY OPERATION
4 TYPICAL APPLICATIONS
5 ENERGY CONSIDERATIONS
6 SUMMARY
HR involves harvesting energy normally discarded during heating and cooling processes from air or water mediums. For air-side equipment (rooftop units, air handlers, etc.), the selected approach is either an enthalpy wheel (top diagram, below) mounted inside the cabinet, or an energy recovery ventilator (bottom diagram), external to the rooftop unit or air handler, with the ducting run. Figure 1 below shows each of these designs.

Figure 1: Heat Recovery Systems

**Enthalpy Wheel**

**Energy Recovery Ventilator**

Sources – Daikin Applied & Cold Climate Housing Research Center
In each approach, the engineering concept is to extract the otherwise wasted energy (enthalpy) of exhaust air and use it to preheat cold outdoor air. These approaches must be used, at a minimum, to comply with ASHRAE 62.1.

Unlike air systems with an enthalpy wheel directly inside the air handling unit, chiller heat recovery is more complex because it requires integration into the existing refrigeration circuits. This paper explains how chillers can reclaim normally rejected energy to help reduce hot water loads for process or comfort cooling applications. Since chillers are among the largest energy consuming devices in an HVAC system, many different avenues can be taken to reduce energy consumption, including: altering set points, maximizing control strategies, adding unit features such as variable frequency drives (VFDs), and HR.

The two main chiller designs used today are air-cooled and water-cooled. Air-cooled chillers reject building load heat to the atmosphere via condenser fans. In contrast, water-cooled chillers reject heat to another water loop (condenser loop), which subsequently rejects the heat to the atmosphere by means of a cooling tower.

There are pros and cons to each approach, but the selection often comes down to the size of a facility, available engineering and maintenance staff, and upfront costs. It is imperative to fully analyze the future facility operating profile and customer needs to take advantage of emerging technologies and efficiency improvements. For HR to be an appropriate application for a chiller, the building needs simultaneous heating or cooling demand. Since HR adds complexity to a project, the application should be analyzed in detail to ensure it is a good fit for the project in question. The following section explores applications that fit an HR profile.
Two HR heat exchangers (HX) are shown in Figure 2 below for different applications.

Figure 2: Vapor compression cycle with different HR options installed.

HX-1 is used with air-cooled chillers and is commonly called a desuperheater. During HR mode, hot refrigerant gas leaves the compressor and enters the HX where the energy contained in the refrigerant gas is transferred to the incoming hot water loop serving the building. As a result, the refrigerant is pre-cooled prior to entering the condenser coil section, reducing fan energy and further improving energy efficiency. There are limitations to how much energy can be extracted from the refrigerant; the gas must not pre-condense prior to entering the condenser coils, or it will result in operational issues and lower efficiency. A desuperheater allows production of higher temperature water without raising the saturated condensing temperature of the condenser loop. Because of this, even though a desuperheater offers less capacity than a full HR condenser barrel, it can offer the water at a higher temperature without impacting the chiller's cooling efficiency.

For water-cooled chillers, the design utilizes a special condenser barrel (HX-2) able to transfer heat to a separate water loop or reject heat to the normal condenser loop if HR is not needed.

Next, we'll focus specifically on desuperheaters in air-cooled chiller applications.
HR use in chillers requires additional design considerations, since greater infrastructure and controls are needed than with air-side recovery. Figure 3 below shows a standard piping layout for the hot water loop serving reheat VAV boxes, fan coil units, etc. The components shown are typical of most water loops and include: vibration eliminators, a strainer, and shut-off valves at the pump. Control of the HR loop is performed by the chiller controller to ensure the leaving water temperature does not encroach on the refrigerant temperature limits, inadvertently causing a pre-condensing event. As conditions change, the controller sends a signal (either a 0-10 DCV or 4-20 mA signal) to modulate the device selected by the engineer, which can be a three-way valve or VFD pump. Daikin’s ability to control the three-way valve or pump from the unit controller helps simplify installation and ensure proper operation. Without this ability, additional sensors and control strategies would have to be added thus increasing costs and the probability of operation outside proper safety range values. The controller uses algorithms that rely on refrigerant pressures, outside air temperature, and other inputs to send the appropriate output signal for HR loop control. The engineer can determine which device is best by evaluating factors including equipment served, piping design, and capital costs.

Figure 3: Heat Recovery Piping Schematic

1. A VFD controlled water pump or an electronic 3-way valve is required for temperature control.
2. Field installed 3-way valve or water pump VFD to be controlled by 0-10 DCV or 4-20 mA output from the chiller unit controller.
3. The temperature control sensor(s) for the heat recovery piping loop should equal 2 to 3 times the heat recovery loop GPM flow rate.
4. For potable water use, a secondary heat exchanger in a separate loop is required.
5. Water piping connections at the unit are 2" Victaulic.
Building designs where HR can be used effectively vary depending on geographical location, load profile, etc. When applied correctly, HR can be an attractive option for increasing system efficiency and reducing energy consumption. Currently, not all projects will be a good fit for HR applications for the aforementioned variables, which is why it is imperative to review the building design to determine the viability of integrating HR. However, as greater focus to environmental influences and tightened energy efficiencies is adopted, HR will become commonplace in building designs and retrofits. Below is a list of typical facilities where HR should be considered during the initial design stage of the project:

- **Hotels** – The hospitality industry is potentially the largest sector when it comes to using HR. The high demand for domestic hot water (DHW*), high utility rates (for remote locations), and other stints of simultaneous heating/cooling makes HR an effective option.

- **Schools** – Educational buildings vary widely in design due to the large variations in space types (classrooms, labs, gymnasiums, etc.) and can sometimes require large amounts of DHW, lending itself a candidate for HR.

- **Health Care Facilities** – The group can range from hospitals to medical office buildings, depending on the specific building tenants. These facilities use large quantities of energy for conditioning their space and in most cases require heating/cooling.

- **Office Buildings** (mostly larger facilities where heating and cooling are simultaneous) – The physical size and geographical location will likely be the largest factors in whether or not HR should be considered for office buildings. For smaller buildings, normally there is only cooling or heating at any one time rather than simultaneous, especially if these buildings are located in more extreme climates such as Florida.

* Note that for any use in domestic hot water systems a dual wall HX must be used to comply with building codes.
Energy savings play a large role when deciding whether or not to implement an HR application since HR requires additional capital investment. The typical relative increase in full load EER for various sized scroll compressor chillers when switching from a standard packaged unit to an HR unit is about 0.5 EER. This full load EER bump is due to the condenser fans running for fewer hours as the hot refrigerant vapor is pre-cooled by transferring heat to the hot water loop prior to entering the condenser coil.

When comparing part load operation, the efficiency boost with HR is expected. However, at low loads there are relatively low efficiency gains as the condenser fan operation time has already been reduced in order to maintain head pressure. This means in addition to full load EER being increased, a chiller with HR would have an IPLV equal to or greater than a normal chiller without HR.

Switching over to the hot water loop, the energy savings would be linked to the boiler(s) serving the reheat loop. A 100 ton air-cooled scroll chiller with HR can output ~417,600 BTU/hr into the hot water loop when fully loaded. Assuming the average boiler efficiency is 86%, the boilers would require some 485,600 BTU/hr of input energy in order to achieve the same value of output to the system. A system running natural gas at a cost of $1.34/therm (average price in Washington/Baltimore area for August 2017 according to U.S. Department of Labor Statistics) will produce a cost savings of $6.50 per hour on the boiler side while the chiller is running at full load. The chiller will see a reduction of 4.3 kW at full load, resulting in a cost savings of ~$0.50 per hour. This does not take into account any additional savings from demand billing.

These cost savings quickly add up depending on the size of the system and the amount of time these systems operate. This example analysis calculates a simple payback of less than two years.

Another area affected by installing an HR application is the hot water loop and associated pumps. By adding an additional heat exchanger and piping, there is an increased pressure drop that the pumping system needs to address.

For the chiller HR example above, there was an additional 3.2 ft pressure drop for the HR HX, which does not include any additional piping losses accounted for in an application. If the chiller is going into an existing building as a replacement job, any existing pumps need to be checked to see if they can handle the additional head requirements. The energy losses associated with the increased head will vary from pump to pump based upon the efficiency curve, so a proper analysis needs to be performed. In our simulation, an increase of 0.10 kW was revealed.
Determining equipment selection and the necessary options for a specific job can be a daunting task given the amount of items to consider in today’s marketplace. More emphasis is being placed on equipment and system efficiency than ever before, and adding HR to a project can provide potential energy savings for chillers and boilers. In some cases, HR can even help with downsizing heating equipment. One key step for HR application is to ensure that the building team (including design, operations, and owner) has evaluated adding the HR option to their chiller selection to determine the prospective energy and cost savings. The new discussion to have is, “Do you want hot water with your chiller?”

Daikin Applied’s diverse line of chiller products offer energy conscious solutions for a variety of designs and building uses, including heat recovery. Trailblazer air-cooled scroll chillers are available with optional desuperheater heat recovery technology, raising performance to new levels of efficiency and comfort. To learn more about the Trailblazer and other revolutionary Daikin chiller technologies, contact your local Daikin Applied Representative (http://www.daikinapplied.com/sales.php) or visit http://www.daikinapplied.com/chiller-trailblazer-air-cooled-scroll.php.