Central Cooling

In 2007 the air conditioning on UVM’s central campus got a lot cooler. With the installation of a steam-driven central chilling system at the Central Plant, the University improved control over the economics, energy-efficiency, and environmental footprint of campus cooling.

The mechanical system that chills water for central cooling is comprised of three main parts. The chillers remove heat from the water. The cooling towers reject waste heat to the outside air. The pumps “push” the chilled water around campus through the underground network of pipes. The chillers do the work of cooling the system’s water enough to air-condition campus buildings.

The First Steam-Driven Chillers in Vermont

Each of UVM’s two state-of-the-art steam-powered chillers has an air-conditioning capacity of 1,365 tons of cooling. One ton of cooling is the amount of power that would be required to melt one ton (2000 lbs) of ice (and thus produce one ton of chilled water) in a 24-hour period. Through the 2007 cooling season only one of the chillers was required to handle the campus demand. The second was installed as a stand-by backup chiller until the campus requires its capacity in the future. In the summer of 2007, the central chilled water loop fed the Davis Center, the Bailey-Howe Library, the Royall Tyler Theater, and Old Mill-Lafayette. In the future, as more buildings are connected to the underground chilled water pipe line the standby chiller will become more active as additional demand is added to the system.

The chillers are unique because they use steam energy instead of electricity to cool water. They are the first two of their kind in Vermont. Because the boilers in the Central Plant need to be on standby—even in summer—there is excess steam capacity available that the chillers can put to use. By using steam instead of electricity for cooling, the chillers avoid putting extra strain on the regional energy grid during peak electricity demand times (i.e. the summer months). To learn more about how steam is used to power the chillers, read Fact Sheet #5 in this series on Greener Cooling.

Each chiller has several components that allow it to do this job. These components work together to perform continuous rounds of a vapor-compression cycle, during which a chemical substance called a refrigerant is allowed to evaporate and condense so that it can take up and release energy from the water. Inside the chiller, pipes carry the water to be chilled through an evaporator where heat is transferred between the water and the refrigerant. This heat transfer process lowers the temperature of the water to about 42 degrees F, at which point it is cold enough to make the journey to the buildings. Aside from the evaporator, the other working components in each chiller include a refrigerant condenser, a compressor, a steam turbine, and a steam condenser. These components function to support the work of the evaporator, and interface with the other parts of the mechanical cooling system, like the cooling towers and pumps.
Just like the process that goes on inside your refrigerator, the water in the chilled water system is cooled by phase changes in a vapor compression cycle. This cycle depends on the physical properties of substances called refrigerants. There are a number of refrigerants available on the market, but they all have a few things in common: they are fluids that can absorb a lot of heat rapidly and easily at low temperatures. Refrigerants have relatively low boiling points and high specific heats, which means that they boil at low temperatures and absorb a lot of energy during the boiling process. Since they absorb heat, these fluids produce a “cooling” effect on other substances in their surroundings. This “cooling” effect is the key for making the cold water in UVM’s chilled water system.

When water is carried through the evaporator tank of one of UVM’s chillers, it is cooled as the surrounding refrigerant absorbs heat from the water. The refrigerant vapor, containing the thermal energy it absorbed from the building water, passes from the evaporator to the condenser tank of the chiller. The condenser, like the evaporator, facilitates heat exchange. However, the condenser allows heat to transfer away from the refrigerant instead of into the refrigerant the way the evaporator does. The water passing through the condenser is coming directly from the cooling towers and not from campus. This condenser water is cooler than the refrigerant when it enters the condenser, and the condenser forces heat to transfer from the refrigerant to the water. This forcing occurs because of high pressure inside the condenser that causes the refrigerant to condense and thus release some of the kinetic energy held in its molecules. The pressure elevation inside the condenser is maintained by a compressor, which continuously operates and moves the refrigerant through the condenser-evaporator-compressor loop.

The energy used to power the compressor is harnessed from steam generated in the Central Plant by a steam turbine. Each chiller has a steam turbine that converts the thermal energy held in the steam supply to mechanical power that can drive the compressor. To learn more about the energy used to drive the chilled water system, read Fact Sheet #5 in this series, on Greener Cooling.
Steam-Powered Coolness

The mechanical energy used to drive the refrigeration process in the chillers is produced using steam-driven turbines that are incorporated into each chiller. Steam, which is produced by the boilers in the Central Plant for the purpose of heating water used on campus, is channeled into a loop of steam-supply pipes in the chilling system. High-energy pressurized steam entering this loop from the boilers is “worked” as it rotates the blades of a turbine. The steam molecules collide with the surface of these blades and transfer their energy to spin the turbine. The exhaust, lower energy, lower pressurized steam is then passed through a steam-condenser on top of the Chiller. This allows the steam to transfer away a little more energy so that it can condense to liquid form and re-enter the plant feed water supply system for the boilers. The spinning turbine on each chiller powers a compressor which drives the vapor-compression cycle explained above.

The Cooling Towers

The condenser water (also called the tower water), which absorbs heat from the refrigerant and steam condenser, travels continuously through a short loop of piping between the cooling towers and the plant. The towers are rejecting the heat into the atmosphere that was transferred from the chiller’s condenser. That heat was picked up from the refrigerant in the evaporative process. The refrigerant gained heat from the return water circulated back from campus by the chilled water loop. Electrically driven pumps push the water from a large 30,000 gallon “sump-pit” through the towers and back through to the chillers in the central plant. At the cooling towers, this heat is rejected from the tower water into the atmosphere. On its way back to the chiller, the tower water passes through a secondary condenser, called a steam or surface condenser. Inside the surface condenser, the now cool tower water absorbs some heat from the steam that has already passed through the chiller’s steam turbine. This transfer of a little remaining heat away from the turbine’s exhaust steam allows this “worked” steam to condense into water and be returned to the boilers for reuse.

Electricity Usage and Reliability

Currently during the cooling process, electricity is being used to power the following: one condenser-water pump that supplies two cooling towers, one variable-speed-drive pump that moves chilled water around campus, and a small-sand filter that cleans the tower water to prevent corrosion in the pipes. In addition motorized valves, controls, sensors and power panels are all consuming small amounts of electricity in the plant. In total there are three chilled water pumps, two chillers, three condenser water pumps, and four cooling tower cells available in the system. All of the equipment including the boilers is used on a rotational basis. The redundancy built into the system allows for flexibility, back-up capacity, and regular, preventive maintenance. A diesel-powered generator is available to keep the system going in case of a power outage.