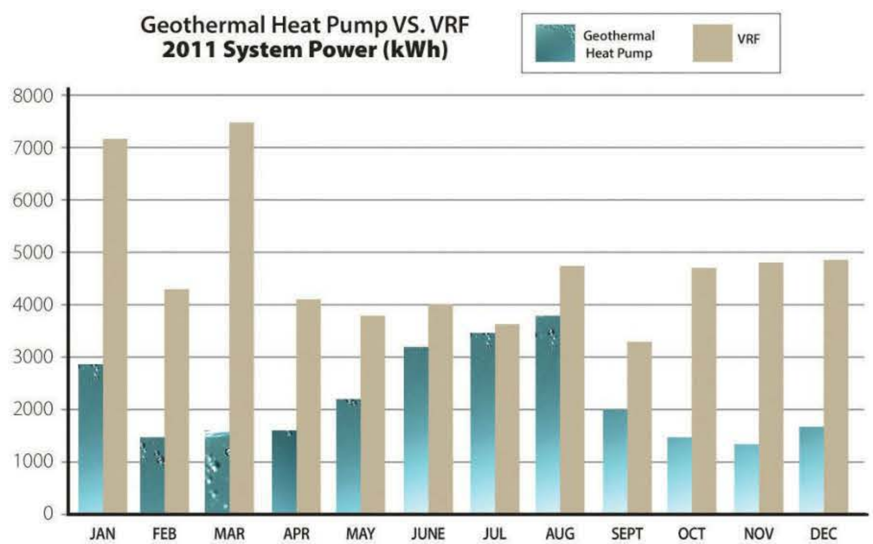
by Greg Cunniff, P.E.

Hydronic systems offer better efficiency

ASHRAE building in Atlanta offers real-world evidence.



The energy consumed at the ASHRAE headquarters in Atlanta shows the monthly efficiencies of two HVAC systems on different floors of the building.

Today's HVAC industry offers a number of choices when it comes to providing heating and cooling in a large building. The three basic methods to provide comfort and move Btu around a building are by using water, air or refrigerant.

This editorial is the first in a series of articles that will compare these types of comfort systems. In this month's column, we'll look at energy efficiency. (A longer version of this article can be found at www.pmengineer.com.)

The energy consumption of any HVAC system is comprised of two components: equipment that generates heating or cooling and equipment that distributes it. The energy needed to generate heating and cooling commands the majority of energy consumption in an HVAC system, but the energy required for distribution is significant. It can take 40% of total electrical cooling energy demand to move Btu in an air system, 30% in refrigeration systems and 20% in hydronic systems.

The challenge of comparing the energy efficiency of HVAC systems always has been to take both the distribution and generation components into account while using the same set of test criteria. New ratings for variable refrigerant flow equipment have been developed by the Air-Conditioning, Heating, and Refrigeration Institute in conjunction with the American National Standards Institute and ASHRAE — Standard 1230, Rating of VRF Equipment. Earlier standards have been available for chillers — Standard 550-590, Rating of Water Chilling Packages — and heat pumps — Standard 13256, Water Source Heat Pumps Rating for Performance.

These AHRI standards have attempted to simplify the effort required to compare equipment efficiencies by developing a single number that can be used to compare various manufacturers' equipment, especially part load performance. The part load number is a weighted seasonal average of efficiency for various climate (ambient) conditions and part loads. For chiller equipment, this number is an Integrated Part Load Value, or IPLV. For airside equipment, this is an Integrated Energy Efficiency Ratio, or IEER. However, AHRI has not published a single part load rating number for water-source heat pumps. The IEER and IPLV information is published in the AHRI Directory of Certified Performance and can be found at www.ahridirectory.org/ahriDirectory/pages/home.aspx.

Even with these rating standards, it is still difficult to compare the performance of these different HVAC systems because of the different distribution system energy that is included or not included.

Fortunately, a real-world comparison exists for comparing a water-based system with a refrigerant-based system. The headquarters building of the American Society of Heating, Refrigerating and Air-Conditioning Engineers in Atlanta is equipped with a geothermal heat pump system on one floor and variable refrigerant flow system on another.

Apples to apples

Several years ago, the ASHRAE building went through an HVAC retrofit to upgrade its heating and cooling. A geothermal ground-source heat pump system with constant-speed compressors was installed to serve the second floor; a VRF system with variable-speed compressors was installed to serve the ground floor. Both systems use no backup heat and rely solely on the electric energy to the compressors to both heat and cool the building, affording an apples-to-apples comparison.

Photo credit: Taco

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Data on the energy consumption of the two systems was collected between 2010 and 2012 using actual metered electrical energy consumption.

The data for the Atlanta building shows the VRF system consumes 60% to 85% more energy than the geothermal heat pump system. Data for 2012 indicates an energy consumption of 1.5 kWh/sq. ft. for the geothermal system and 2.5 kWh/sq. ft. for the VRF system. The constant-speed geothermal heat pump system is slightly more efficient than the variable-speed VRF system in cooling. However, in the heating cycle, the VRF system consumes more than double the electrical energy as the geothermal system.

Proponents of VRF systems claim the systems do not need backup heat, even in heating climates. However, the systems achieve this performance by speeding up the compressor, up to double the speed, to produce higher heating capacities at lower ambient temperatures. This occurs at the expense of efficiency. If a variable-speed compressor has a higher efficiency at reduced speed, it will have a lower efficiency at increased speed. This can be seen in the ASHRAE building's monthly breakdown for the heating months.

Further comparisons

For heating, AHRI Standard 210/240 developed an average or seasonal energy efficiency ratio called the Heating Season Performance Factor, or HSPF. It is, again, an attempt to rate compressorized equipment for various climate (ambient) conditions and part loads.

The biggest difference in energy consumption of the geothermal and VRF systems is heating, not cooling, and the difference in energy consumption for heating is more than AHRI's HSPF ratings would indicate.

Comparing energy consumption in heating for water, air and refrigerant systems is not as simple as comparing different HSPF ratings for compressorized equipment, as can be done for the ASHRAE building. Most heating generation equipment for water and air systems use natural gas-fired boilers. Comparisons should be done on the basis of the cost of producing a Btu of heat, taking into account the local climate (heating hours), local cost of electricity and natural gas.

Let's look at a VRF system with an HSPF of 8 using electricity at an average cost of $0.11 per kWh from the U.S. Energy Information Agency. The unit cost of delivered heat is $13.74 per million Btu. A 90% efficient boiler using natural gas at an average cost of $8.50 per mcf ($0.85 per therm) from the EIA, the unit cost of delivered heat is $9.44 per million Btu. This is a savings of 30% in heating costs.

The VRF manufacturers have recognized this difference in heating costs between air-source heat pumps and natural gas boilers in heating climates. The problem is the coefficient of performance of an air-source heat pump decreases with lower ambient temperatures. The heating COP of an air-source heat pump drops with decreasing heat sink or outside air temperatures. The COP of a VRF unit decreases even faster because the compressor is sped up to maintain heating capacity.

Hydronic systems provide the most efficient method of generating and distributing Btu in a building.

To get over this hurdle, VRF manufacturers have suggested that their outside condensing units be installed inside a building in a heated space using natural gas unit heaters as the backup heating source. As an example, if the space can be maintained at 40° F, then the COP of the condensing unit remains high. The cost of heating is lower because cheaper natural gas heat replaces the higher-cost electric heat from the VRF condensing unit's lower COP at lower ambient temperatures.

In this example, the outside air dampers are open in the summer for heat rejection to the outside air and closed in the winter for heat addition from the natural gas unit heater. This configuration negates the advantage claimed by VRF manufacturers that their equipment doesn't need inside mechanical rooms for their equipment since it is mounted outside.

Variable-speed technology

Most HVAC systems are designed to keep a building cool on the hottest days and warm on the coldest days. That being the case, an HVAC system needs to work at full capacity on only the hottest and coldest days of the year. For the rest of the year, the HVAC system should operate at a reduced capacity to save energy.

This is where a system equipped with variable-speed technology can be used to match system fluid flow to actual heating and cooling demands. Variable-speed systems of any kind pump less mass flow, resulting in less horsepower to move the fluid. In addition, at part load the heat exchanger is oversized for the lower mass flow rate since it was sized for full load. The system is, therefore, more efficient.

U.S. chiller and heat pump manufacturers now offer variable-speed compressors similar to VRF systems. All variable-speed equipment has similar performances. The differences are in the heat sink temperatures that the equipment rejects heat to. These are the earth, wet bulb air temperature and dry bulb air temperature. Geothermal open-loop (earth) is the most efficient, followed by geothermal closed-loop (earth), water-cooled chillers and heat pumps (wet bulb air temperature), air-cooled chillers, VRF and rooftop units and air-cooled condensing units (dry bulb air temperature).

The Energy Efficiency Ratio of a typical constant-speed chiller is approximately 12. However, using the AHRI part load rating conditions for chillers at lower ambient temperatures yields a substantial increase in integrated part load value for constant speed chillers to 16. A typical VRF unit has an EER of approximately 13 and an IEER of 19. Therefore, the increase in the IEER for VRF is due primarily to being able to rate part loads at lower ambient conditions, not variable-speed operation.

With the use of new variable-speed chillers and heat pumps, and variable-speed pumps, hydronic systems provide the most efficient method of generating and distributing Btu in a building. **pme**

About the author: Greg Cunniff, P.E., is the applications engineering manager for Taco. He can be reached at grecun@taco-hvac.com.