
White Paper
August 2014
Variable Refrigerant Flow (VRF) zoning and geothermal systems (or water-source) are two of the most energy-efficient options for heating and cooling available in the U.S. today. Fortunately, technology exists that combines the benefits of both systems. This white paper provides an overview of geothermal VRF zoning technology and its advantages compared to traditional geothermal systems, air-source VRF zoning systems and conventional HVAC systems. In addition, this paper covers considerations for specifying water-source VRF zoning systems and provides case studies of successful applications.

**VRF Zoning Technology Overview**

VRF zoning is a method of providing precise comfort control to buildings with multiple floors and areas by moving refrigerant through piping to the zone to be cooled or heated. Selected VRF zoning systems can simultaneously cool some zones while heating others. Regardless of time of day, sun or shade, season of the year or special requirements, VRF zoning systems provide personalized comfort to each zone or space.

**Geothermal Technology Overview**

Geothermal systems use the earth’s relatively constant underground temperature to balance the temperature of the exchange medium. Water in the heat exchanger circulates through a series of loops below the surface, absorbing or expelling heat to the below-ground heat sink depending on the time of year. This function ultimately reduces the load on the condenser during the cooling and heating cycles and results in significant energy savings.

**Combining Two Technologies: Geothermal VRF Zoning Systems**

Water-source VRF zoning systems combine the benefits of a geothermal system with the sophistication of VRF zoning systems. Together, the technologies take advantage of the INVERTER-driven compressor coupled with a closed geothermal loop instead of air as a heat exchange medium.

Water-source VRF zoning systems have a number of benefits, including many that users have come to expect from air-source VRF zoning systems.

1. **Flexible installation.** Installation is possible in tight spaces because the two-pipe design requires less space than ducted systems. The relatively small water-source VRF zoning compressor units can be installed in fairly small utility closets with minimal access on either side of the unit. Refrigerant, water and electrical connections are housed on the front of the unit for ease of access.

2. **Application variety.** Water-source VRF zoning outdoor units can be connected to an array of indoor unit styles to accommodate the specific needs of the space. All models feature quiet operation, easy maintenance and optimal comfort. The configuration of the below-ground loop systems can be customized to accommodate the building’s surroundings. For example, loops can be buried under a building or a parking lot by drilling either vertical bore holes or horizontal trenches.

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3. **Low maintenance.** Water-source VRF zoning systems offer easy maintenance. One unit can be serviced without taking the whole system offline. Indoor units feature washable filters that are easy to clean or replace. Condensers are housed in floor-level utility closets for convenient access and minimal disruption to occupied spaces.

4. **10-year payback period.** Installing a water-source VRF zoning system may have a higher first cost. Over time, the system efficiency and low maintenance expenses can offset the initial cost of the system in energy savings. The average payback period is 10 years.*

5. **Advanced controls.** VRF zoning systems offer several controller types. The central controller can monitor, schedule and control up to 50 indoor units. Multiple central controllers can be networked together with integrated centralized control software and systems can be tied to a BMS using LonWorks and BACnet protocols.

6. **Clean energy source.** Water-source VRF zoning systems use the clean and sustainable energy stored in the earth to heat and cool buildings. This is a more environmentally friendly and efficient source of energy compared to non-renewable fossil fuels.

7. **System efficiency.** VRF zoning technology includes the use of an INVERTER-driven compressor in the outdoor unit that varies the speed of the motor rotation, allowing it to precisely meet each zone’s load requirement while reducing power consumption. Also, geothermal VRF zoning systems are able to take advantage of stable ground temperatures for even greater efficiencies.

8. **Tax credits.** Water-source VRF zoning systems may qualify for up to a 10 percent commercial tax credit for the total installed cost of the geothermal system. Contact your local tax professional to determine eligibility.

**Water-source VRF Zoning System Advantages**

Water-source VRF zoning systems in combination with geothermal systems deliver distinct advantages over traditional geothermal systems without VRF zoning technology, air-source VRF zoning systems and traditional HVAC systems.

**Advantages of Water-source VRF Zoning Systems Over Stand-alone Traditional Geothermal Systems**

A significant advantage of water-source VRF zoning systems over traditional geothermal systems is the ability of the condenser units to connect to up to 50 indoor units. Traditional geothermal systems require multiple condensers in each zone and the units must be installed in the ceiling space. Fewer condenser units results in easier installation, less equipment and reduced maintenance. Water-source VRF zoning system condensers are serviceable from a utility closet at floor level, not the ceiling, for improved access and minimal disruption to occupied spaces.

* Source: U.S. Department of Energy
Another benefit of water-source VRF zoning technology over stand-alone geothermal systems is the potential for heat recovery. Some water-source VRF zoning systems allow for simultaneous cooling and heating. In these applications, the compressor operating power in a VRF zoning system will be reduced during heat recovery periods compared to that of an equivalently-zoned traditional geothermal system. Water-source VRF zoning technology often exceeds the efficiency of traditional geothermal systems due to the ability to recover energy more efficiently on the refrigeration side first, compared to multiple distributed traditional geothermal systems. [see below]

**Advantages of Water-source VRF Zoning Systems Over Air-source VRF Zoning Systems**

Water-source VRF zoning systems contain many of the same benefits associated with air-source VRF zoning systems. These systems also contain additional benefits not found in air-source systems that are primarily associated with their geothermal capabilities. The most significant advantage over air-source systems is the heating de-rates. In colder climates, the expected capacity of the air-source VRF zoning equipment can be reduced due to the temperature. Sometimes the equipment must be upsized to handle the peak heating demand, but with water-source VRF zoning systems this is not an issue. Coupling the VRF zoning units with a geothermal loop provides the benefit of higher efficiencies from milder loop temperatures. The power required by the outdoor units may be reduced by as much as 35 percent when compared to air cooled systems.

**Advantages of Water-source VRF Zoning Systems Over Other HVAC Systems**

There are many advantages of these systems when compared to unitary or boiler/chiller HVAC systems. The combination of geothermal and VRF zoning technology results in significant energy saving potential due to the milder loop temperatures requiring less work from the condensers. The water-source VRF zoning outdoor units are small, eliminating the need for large equipment rooms or above-ground space. The refrigerant, water and electrical connections are on the front of the unit so the condensers can be installed in relatively small utility closets with minimal access on either side of the units. These systems can be connected to an array of indoor unit styles allowing for a wide variety of applications and do not require ductwork. Also, VRF zoning systems offer the benefit of INVERTER-driven compressors, which vary the refrigerant flow to each unit to provide precise and efficient control.

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Considerations for Selecting a Water-source VRF Zoning System

Water-source VRF zoning systems are ideal for climates that experience significant temperature variations throughout the year, where having the heat exchange medium located in a temperature-stable underground environment will have the most impact. Because of the combined energy efficiency of ground source and VRF zoning technology, water-source VRF zoning systems can result in one of the most energy-efficient heating and cooling systems available. As with all VRF zoning systems, the indoor units require no ductwork, making them ideal for retrofitting older buildings and replacing old boiler/chiller systems. These systems are ideal for applications such as schools, offices, medical centers or any other building in which individual zone control is essential to occupant comfort.

There are some factors to consider when installing water-source systems. Geothermal systems require a series of wells or loops. Constructing a well field, and having the land to do so, may be cost prohibitive in some cases and impossible in areas such as large metropolitan cities where space is at a premium. Additionally, anytime digging into the earth is involved, care must be taken to not disturb any existing underground infrastructure. Lastly, installing a geothermal well field may be expensive up front; however, over time, these systems tend to payback in the form of energy savings.

CASE STUDY: Muscatine County Courthouse

Challenge. Muscatine County Courthouse, Muscatine, Iowa, is a 1907 Beaux Arts style building listed on the National Register of Historic Places. Courthouse officials needed a replacement for a failing 30-year-old cooling and heating system that was costly in both upkeep and energy usage. They wanted a replacement system that would be low maintenance and high efficiency.

Aesthetics and ease of installation were also an issue. The indoor units were loud and moldy. The large condenser unit sitting prominently on the roof of the historic building was an eyesore and needed to be replaced with a smaller unit that could be housed elsewhere. The building’s 24-inch-thick limestone walls made the possibility of retrofitting ductwork difficult. Court sessions needed to be conducted throughout the installation which ruled out any system that required extensive demolition and construction.

Solution. The Muscatine County Board of Supervisors had already invested in drilling a geothermal test well in anticipation of replacing the old HVAC system. The board selected a WR2-Series water-source VRF zoning system from Mitsubishi Electric US Cooling & Heating Division (Mitsubishi Electric) that would interface with the existing geothermal field. The specifying engineer and the board felt that the geothermal system was especially suited for Iowa where it’s not uncommon for winter temperatures to dip below minus 10 degrees Fahrenheit.
The ductless, two-pipe design of the Mitsubishi Electric system would save on labor and equipment cost because it required far less fittings on the refrigerant lines than a competitive three- or four-pipe system. The ductless design also meant that the installers did not have to drill through the thick limestone walls and disrupt court sessions. The compressor units could be easily transported down the stairs into the basement of the courthouse where they would be housed instead of the roof.

**Result.** The installation proceeded smoothly and not one day of work was disrupted by installation. “Judges were holding court [while we were making this transition], and we could not afford to have a lot of banging, pounding and installation of new equipment,” said Sherry Seright, county budget director. Courthouse employees were also pleased with the system. “It’s so quiet, people often ask if it is operating,” she added.

The system also provided the desired energy efficiency levels. Courthouse officials observed in the first summer of operation that the well field could handle the campus system heat transfer requirement with just 20 percent of the design flow.

Because of the installation’s success, the board decided that the water-source Mitsubishi Electric water-source VRF zoning systems would be the new standard for any future HVAC retrofits in Muscatine County. They currently have plans to design geothermal VRF zoning systems for two additional county-owned buildings.

**CASE STUDY: Miami University’s Elliot and Stoddard Halls**

**Challenge.** Miami University of Ohio (Miami) is the 10th oldest public university in the U.S. Its two oldest buildings, Elliott and Stoddard Halls, needed a new cooling and heating system to replace the ineffective and outdated existing coal-fired steam heat system.

Selecting a new HVAC system presented two distinct challenges. The first was the need to preserve the architectural integrity of the buildings. Both were listed on the National Register of Historic Places and neither had existing ductwork, making a central air solution impossible. The second challenge was meeting the school’s energy efficiency goals. The university developed a utility master plan that prioritized energy efficiency and mandated moving away from inefficient technologies like coal burning.

“Renovation of any historic building is a complex undertaking requiring a balance between the original architecture and modern building systems,” said Alec R. Carnes, PE, CEM, LEED AP BD+C and senior principal of mechanical engineering for Heapy Engineering, designers of the system.
Solution. The design team selected a Mitsubishi Electric geothermal VRF zoning system for the job. “Geothermal is very advantageous for our climate in Ohio, where heating and cooling loads are closely matched over the year,” said Doug Hammerle, PE, Miami’s director of energy systems. “This helps balance the well field temperature and maximize the efficiency of the system.”

Seventeen 600-foot-deep geothermal wells were placed under the sidewalks surrounding the halls. As modern footings were unknown 150 years ago, the hand-dug basements had no space for the Mitsubishi Electric WR2-Series heat pumps. An easy-to-access mechanical room was built into the attic of each hall for the three heat pumps and centralized controller.

Result. In 2011, Elliott and Stoddard switched from coal-fired steam heat to geothermal cooling and heating. Metered as one, the two halls showed an annual 61 percent decrease in energy consumption compared to 2010. The oldest buildings on campus became the most energy efficient.

The VRF zoning systems’ ductless design also preserved the original aesthetic of the buildings. The team selected floor-mounted indoor units that could be concealed in cabinets, lending the historic look of a radiator case. “These cabinets are beautiful,” Hammerle said. “None of this would have been possible without the two-pipe system design. The interior would have been severely cut up with a hydronic four-pipe system.”

The university was also pleased with the cost savings of the system. “This new system has already saved us a ton of money and enables me to have many more satisfied customers,” Hammerle continued. “The Mitsubishi Electric engineering has performed so well that I can say with certainty that VRF is my system of choice for all new outlying buildings on campus not tied into the central plant.”

CASE STUDY: Strawberry Mansion

Challenge. Built in 1789 as a summer home, Philadelphia’s Strawberry Mansion is now a museum, but the historic building needed renovations.

One of the most pressing needs of the rehabilitation process was a new cooling and heating system to replace the existing system that dated back to the 1930s. The museum had never been centrally air-conditioned and it needed reliable climate control for the museum’s collection of antiques. With 10,000 square-feet on four levels, 23 rooms and masonry-bearing walls, it was a challenge to find a central cooling and heating system that would have an unobtrusive impact on the home. In addition, the museum wanted to adhere to the Greenworks Philadelphia Plan, a six-year plan launched in 2009 with the goal of making Philadelphia the greenest city in America. There was a strong desire to find an innovative, green building solution to this challenge.
The mansion already had an existing 12-well geothermal field and the project team first considered a 4-pipe water based system. They soon found it was not practical to install. The 200-year-old stone walls could not accommodate many of the 24 inches wide by 8 inches deep chases required for the 4-pipe design. In many areas there was no space for ductwork or for pipe routes perpendicular to structural elements.

**Solution.** Mitsubishi Electric’s water-source VRF zoning system was able to meet the unique needs of Strawberry Mansion. The two-pipe system and compressor units could easily fit in the old chase walls and ceiling where there was no space for ducting. The flexibility of the refrigerant lines as opposed to ductwork and diversity of indoor unit styles were well-suited for the design restrictions posed by the historic structure.

The design team placed the two water-source heat pumps in the basement. They are specifically engineered for closed water loop systems that would efficiently interact with Strawberry Mansion’s existing 12-well geothermal field. Designed to fit in small spaces, these units take up little room and are flexible enough to cool or heat up to 50 individual zones maximizing energy, equipment and installation efficiency.

**Result.** The system met the energy efficiency expectations of the museum and also saved the owners $50,000 upfront, compared to the original 4-pipe proposal. “I love our new system!” exclaimed Beth Kowalchick, president of the all-volunteer 1926 Committee who presided over the restoration. “You have no idea what a remarkable difference it makes. Our collection has suffered from decades of no air conditioning or humidity control. After a few months, I could see a noticeable difference in the appearance of our textiles, prints, antique furniture and fine art.”

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