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WHITE PAPER
February 2016

Hydronic systems: Technologically advanced and highly efficient

In head-to-head comparisons, hydronics outperform VRF systems

Presented by: Xylem Applied Water Systems

Every minute of every day, valuable data is collected about energy consumption at the American Society of Heating, Refrigeration and Air Conditioning Engineers headquarters in Atlanta. This data is accessible to researchers around the world, enabling them to monitor performance of the building's resource-conserving systems and extract data for further study.

ASHRAE, the international oversight organization for the HVAC industry, completed a $6.2 million renovation of its 30,000-square-foot headquarters in 2008, creating a sustainability showcase to promote renewable energy, water efficiency, indoor and outdoor environmental quality and, above all, highlight the energy efficiency of advanced HVAC systems in a living lab environment.

The building features separate HVAC systems – a variable refrigerant flow (VRF) system on the first floor and a geothermal/hydronic pumping system on the second floor. The corresponding performance data has sparked debate within the industry about which technology –VRF or hydronic – is the most energy efficient.

VRF systems, used in Asia and Europe since the 1980s, were introduced in the United States in 2005. A VRF system uses a refrigerant as a heating/cooling medium that runs through pipes to individual air handling units. It currently represents about 5 percent of the $7 billion HVAC market in North America, and a growing number of U.S. manufacturers are offering VRF systems alongside traditional HVAC systems.

Hydronic systems provide water-based heating and cooling through pipes and other components such as pumps, drives, controls, heat exchangers and valves that deliver heated or cooled air via an air-handling unit through ductwork and air terminals.

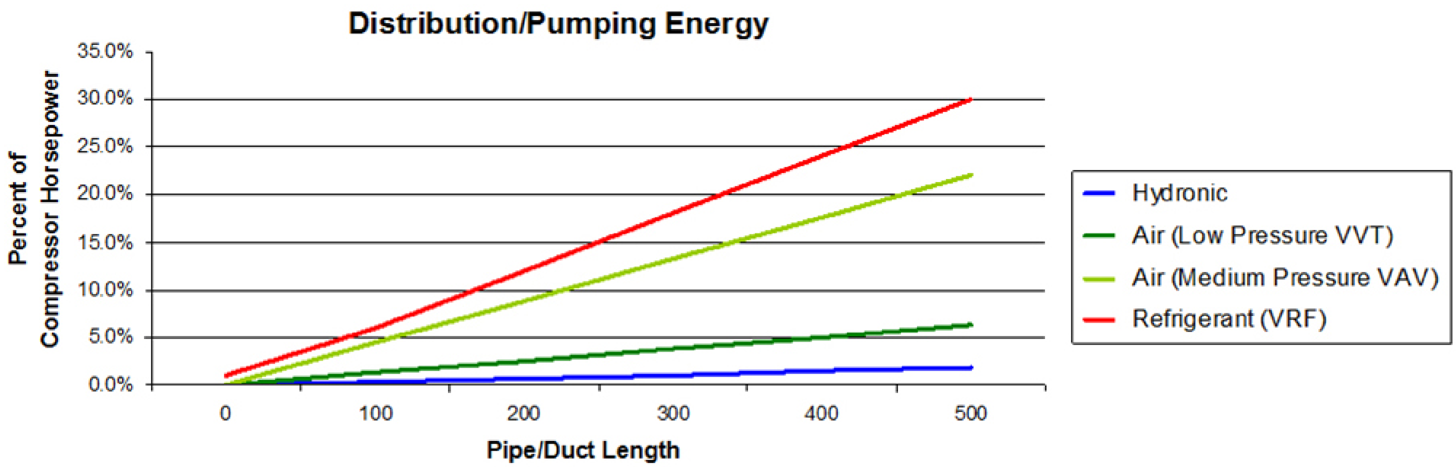
A 2014 report issued by the Hydronics Industry Alliance (HIA) evaluated the ASHRAE data for the two systems. HIA called into question VRF manufacturers' claims of superior energy efficiency to that of hydronic systems. "On an annualized basis, the VRF system had an energy consumption 57 percent higher than the geothermal/hydronic system in 2010, 84 percent higher in 2011 and 61 percent higher in 2012," according to the HIA report.

VRF manufacturer Daikin disputes the findings reported by HIA. ASHRAE isn't formally endorsing one technology over the other, though the data is available online for review by industry professionals.

While there is growing interest among consulting engineers, contractors and building owners to adopt new HVAC technologies such as VRF, a lack of performance data should temper acceptance of manufacturer efficiency claims. The concern over sparse data has been noted in a number of papers on VRF, including this 2012 report prepared by the Pacific Northwest National Laboratory for the U.S. General Services Administration: "Surprisingly, despite the long history with VRF technology in Europe, Japan and elsewhere, the U.S. research community has not found useful research on VRF from these places. While some general literature is available about these systems, there is a lack of critical evaluation of actual field energy performance."

In addition to strong mixed views on efficiency, a number of perceptions exist among industry professionals on the advantages and disadvantages of VRF systems, driven in large part by aggressive marketing and education campaigns by VRF manufacturers.

Key areas of differentiation between the two types of HVAC systems are outlined as follows, along with important considerations for those who influence system selections.



Source: Hydronics Industry Alliance

Evaluate the costs

Costs of VRF systems are generally reported to be between 5 and 20 percent higher than hydronic systems due to their complicated refrigerant management system and controls.* The expectations of greater energy efficiency over the life cycle of the system offset the higher upfront costs in the minds of many decision-makers.

Other factors that can significantly impact the bottom line must also be taken into account.

- **Life cycle costs –** VRF systems generally have a shorter life expectancy than hydronic systems. Hydronic systems have been known to last 20 to 25 years, while VRF systems could need replacing as soon as 10 or 15 years after installation. The compressor in a VRF system is forced to work harder during heating cycles, reducing the life of the bearings and the compressor.

- **Complexity –** VRF systems are proprietary and require specialized technicians for installation and maintenance, compared to hydronic water systems designed with universal components that can be installed and serviced by any HVAC service technician. This will also add to life cycle costs as building owners will be reliant on the VRF manufacturer for the life of the building. In hydronic systems, component manufacturers can be changed and new technologies installed.

The initial cost of a hydronic system is generally lower, and systems offer a much wider range of flexibility for components, operation and maintenance, both in terms of parts and service. Advanced systems include application of technologies such as integrated and single-pipe systems that dramatically reduce piping, and costs, and pumps equipped with variable speed drives that increase energy efficiency.

Components in a hydronic system are factory made and tested, reducing rate of failure after installation. Since VRF piping requires brazing and soldering on-site, the quality of the installation depends on the level of expertise of the installer. Installers also must be qualified to work with refrigerants under extremely high pressure and be knowledgeable about leak detection and ventilation requirements per ASHRAE Standard 15.

In addition, each VRF manufacturer has a different protocol, which further reduces the pool of qualified technicians for installation and maintenance. Improper installation and maintenance can cause premature failure of VRF systems.

Climate matters

Extreme temperatures can impact system performance of both hydronic and VRF systems, though hydronic systems are less affected by temperature changes. For VRF systems, efficiency is reduced as the ambient temperature goes up in the cooling mode, and down in the heating mode.

At lower temperatures, hydronic systems are more reliable than VRF systems. That's because a VRF system may require a supplementary heat source in cold climates, such as electric heat, which could negate the energy efficiency of the system. Without another heat source, the VRF compressor can be set to run at maximum capacity for the morning warm-up, but that takes more electricity, potentially negating any efficiency benefits, including reduced energy costs.

Some VRF manufacturers rate their systems to minus 4 degrees Fahrenheit, but in practical use that can cause complications, such as coil freezing. The cost-effectiveness of a VRF system is generally considered optimal in temperate climates where cooling is the predominant function.

A VRF system can provide simultaneous heating and cooling, and can recover heat from one zone and use it in another. This is effective in buildings with multiple temperature zones, such as a hotel. However, a VRF system does not have the capability of storing energy. Water in a hydronic system can draw the heat or chill out of a room and carry that energy back to the system for storage and later use, reducing energy consumption and costs.

Building factors

When specifying a system, it's important to consider not just building size, but also the size of the system itself. Hydronic systems are better suited to handle buildings requiring 50 to 100 tons of cooling capacity or more. Hydronic systems also have the capacity to pump water efficiently and effectively very long distances, such as across a sprawling campus or in high-rise buildings.

A VRF system is generally limited to buildings fewer than 10 stories because the length of piping runs must be limited in order to carry refrigerants and oil through the building in accordance with manufacturer guidelines. Long lengths of piping can jeopardize performance of the unit if oil or refrigerant accumulates in the piping or migrates back to the unit. A larger project could include multiple VRF systems, but that increases costs significantly.

Since VRF systems do not need a ducting system within a building to transfer air, they are being selected for some specific retrofit situations, particularly in older, smaller buildings with multiple temperature zones. Hydronic systems also have advantages when multiple temperature zones are required, particularly in large buildings that employ multiple terminal units that are linked to one set of central generating equipment with one piping distribution system. VRF retrofits can be more complicated than updating a hydronic system because all of the refrigerant piping must be removed and replaced floor by floor, which can quickly drive up costs for building owners and likely the tenants of those spaces.

Refrigerant safety

Refrigerants that contain chlorofluorocarbons and hydrochlorofluorocarbons, such as R-22, are being phased out internationally. This phase out is primarily due to concerns over damage to the ozone layer and contributions to global warming. Substitute refrigerant media such as R-410A are now widely in use.

R-410A, when used in a VRF system, is under significantly higher pressure than its predecessor, R-22, which requires greater care on the part of technicians. If the piping runs in a VRF system are too long and contain multiple connections, there is a higher risk of refrigerant leaks. Any such leaks can be hard to find and difficult to repair as they are not detectable by sight or smell. Refrigerants are heavier than air, and in the event of a leak can displace oxygen in a room, which puts people at risk of asphyxiation. If the VRF system serves a small office space within a larger facility, the life safety standards of ASHRAE Standard 15 should be reviewed to ensure compliance. Standard 15 establishes safety procedures for refrigeration systems; its companion, Standard 34, targets the refrigerants used in the systems.

Though Standard 15 requires monitoring of refrigerant concentration levels within a building's mechanical room, it does not require detection alarms in tenant spaces of a building — a clear danger to the occupants should a leak occur.

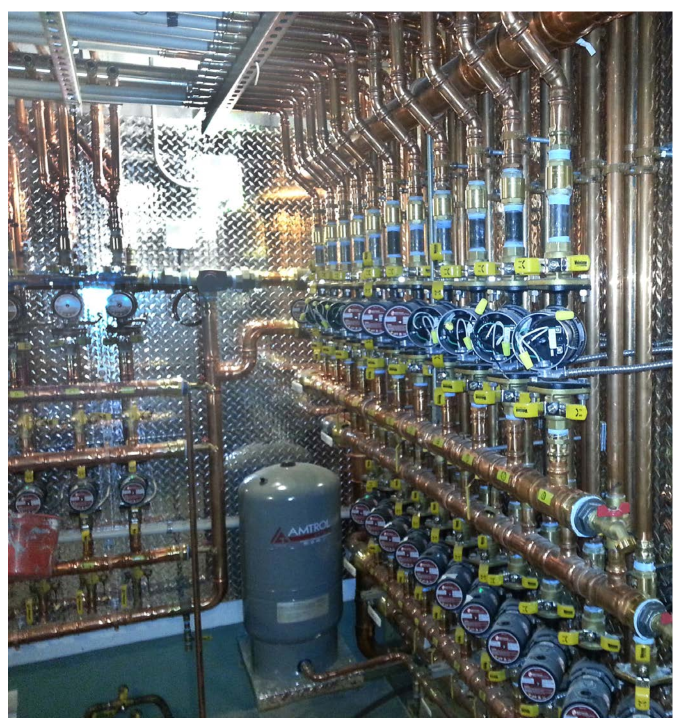
Conversely, the water running through a hydronic system and in its pipes over the life of the system is unquestionably safe.

System comparisons

Heating and cooling are among the largest costs for most buildings, compelling building owners to focus on finding new and effective approaches for new buildings and to improve performance of existing facilities. Increasingly stringent ASHRAE and MEI efficiency standards are driving the effort to develop more efficient system components – and smart and forward-thinking engineers, architects and contractors are embracing the changes.

In the absence of rigorous laboratory testing and field analysis, it is difficult to measure the cost-effectiveness and energy efficiency of one system over the other, though some organizations, like ASHRAE, are leading the way with side-by-side comparisons.

In India, fast-growing software firm Infosys conducted its own comparisons in its quest to do business in net-zero facilities. The company wanted to determine which system would be the best investment as it charts its plan for construction of future facilities to keep up with company growth.



In the city of Hyderabad, with an average temperature of 109 degrees, Infosys built a 250,000 square-foot complex made of two separate, same-sized buildings connected by a walkway. One building was cooled with hydronics, the other with VRF. All of the equipment in both buildings was metered. After one year, the radiant cooling system used 24 percent less energy than the VRF system.

Infosys also conducted an occupant comfort survey during the testing period, which revealed greater comfort on the radiant side of the complex. Sixty-three percent said they were satisfied or very satisfied with the comfort level of the building, compared to 45 percent on the VRF side.

Conclusion

Though hydronic systems as a room comfort technology have been in use in some form for centuries, it is also the HVAC technology of the future because it enables engineers, architects and building owners to adapt to changing demands. The concept of a net zero energy building, one that produces as much energy as it consumes during the course of a year, is being modeled in a few select projects, but it will soon by the norm as governments worldwide — from the U.S. to Europe to Japan — set into place net zero standards for new public buildings between 2020 and 2030. The most efficient systems will be in demand to help meet energy goals and keep building costs in line. Hydronic heating and cooling systems will continue to be the most efficient solutions over time in terms of cost, performance and efficiency.

*Roth, Kurt et al. 2002, "Energy Consumption Characteristics of Commercial Building HVAC Systems Volume III: Energy Savings Potential"

About the Author

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