WATER REMAINS THE "GOLD STANDARD"

Twelve comparisons between hydronics and VRF/VRV systems.

BY JOHN SIEGENTHALER

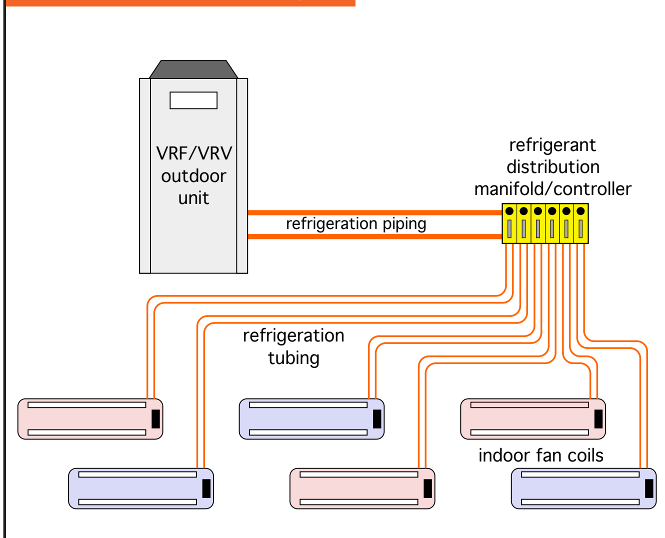
Hydronics technology has long been known for unsurpassed heating comfort.

It has also been used for cooling, primarily through chilled water distribution systems in commercial and institutional buildings. This well-established and highly successful track record is, in part, based on the thermal properties of water. It is also based on the versatility of hydronic systems in adapting to a wide range of applications. No other heat transport material provides the versatility, safety, reliability, energy efficiency, or environmental compatibility of water.

Over the last few years, a new method for moving thermal energy through buildings has appeared on the North American market. This approach uses refrigerant as the transport media throughout a building and is known as either a variable refrigerant flow (VRF/VRV) system, or a variable refrigerant volume (VRV) system.

VRF/VRV systems use multiple interior heating/cooling terminal units that have refrigerant passing through them, as illustrated in *Figure 1*. The refrigerant flow rate through each terminal unit varies depending upon the heating or cooling load that terminal unit is trying to satisfy.

Figure 1 VRF/VRV system diagram



THINKING IT THROUGH

HVAC system designers, architects, and building owners have many choices when it comes to heating and cooling buildings. The choice of system should consider up front cost, operating cost, long-term serviceability, expandability, reliability, safety, and environmental responsibility. With these criteria in mind, let's examine the benefits that modern hydronic systems offer relative to VRF/VRV systems.

BENEFIT #1: HYDRONIC SYSTEMS CAN BE USED WITH MANY ENERGY SOURCES.

Hydronic heating and cooling systems are easily adaptable to a wide variety of current and future energy sources. These devices include boilers fueled by natural gas, propane, or fuel oil, geothermal and air-to-water heat pumps, and renewable energy heat sources such as solar thermal collectors and biomass boilers. Other potential heat sources include waste heat recovery, off-peak thermal storage systems and combined heat and power (CHP) systems.

In some cases two or more of these heat sources can be combined in the same system. They can share the load based on the most favorable operating conditions for each source.

Likewise, many options exist as sources of chilled water for hydronic-based cooling systems. They include chillers and heat pumps operating on standard vapour compression refrigeration cycles, as well as gas-fired absorption chillers, and even water drawn from large/deep lakes.

VRF/VRV systems are solely sourced by electricity.

BENEFIT #2: HYDRONIC SYSTEMS ALLOW FOR SIMPLER FUTURE MODIFICATIONS.

When older commercial or institutional buildings are upgraded, their existing hydronic distribution system, or portions of that system, may be reusable in combination with a new central plant for producing heated and chilled water.

When VRF/VRV systems are used, the existing hydronic piping and all hydronic terminal units must either be decommissioned in place or removed from the building. All new copper piping and refrigerant-based terminal units must then be installed to each conditioned space. This can be highly disruptive to the normal use of the building.

BENEFIT #3: HYDRONIC SYSTEMS REDUCE RISKS ASSOCIATED WITH REFRIGERANT LEAKS.

It is possible for a leak to develop in either a hydronic heating / cooling system, or a VRF/VRV system. A leak in a hydronic system is generally easy to detect and the material leaking is just water or a mixture of water and antifreeze. Well-designed hydronic systems provide numerous isolation valves that allow the portion of the system where the leak is to be isolated from the remaining parts of the system. Hydronic systems that distribute heating or cooling energy produced by a refrigerant-based source can be designed so that the refrigerant-containing devices are confined to a mechanical room, or located outside the building.

A leak in a VRF/VRV system is a serious and potentially dangerous matter. VRF/VRV systems contain much more refrigerant compared to hydronic systems served by a typical heat pump or direct expansion chiller. Under certain conditions, a single leak can be responsible for a complete loss of refrigerant from the system. Large refrigerant leaks can require immediate evacuation of the building and intervention of Hazmat teams.

Refrigerants such as R-410a are heavier than air. If a leak develops in the interior portion of a VRF/VRV system the refrigerant could accumulate in the lower portions of rooms with highest concentrations near the floor. Such accumulation will displace air in the room. In spaces with minimal ventilation it is possible for refrigerant concentrations to reach values that could render occupants unconscious and ultimately lead to suffocation.

ANSI/ASHRAE standards 15 and 34 define specific refrigerant concentration limits based on pounds of refrigerant per thousand cubic feet of interior volume, beyond which acute toxicity is expected. Those designing VRF/VRV systems should verify that the amount of refrigerant that could be lost due a leak, and the smallest space into which this refrigerant could accumulate, are in compliance with this standard.

BENEFIT #4: HYDRONIC SYSTEMS USE LESS DISTRIBUTION ENERGY.

Although proponents of VRF/VRV systems point out that no circulators are needed to move refrigerant throughout a building, electrical energy is still required just to move refrigerant gas and liquid through piping. That energy is supplied as electrical input to the system's compressor(s). The electrical energy consumption for moving refrigerant through a VRF/VRV system, per unit of heat or cooling energy delivered, is significantly higher than that required for a well-designed hydronic system, as shown in *Figure 2*.

Figure 2 Energy required to move cooling effect

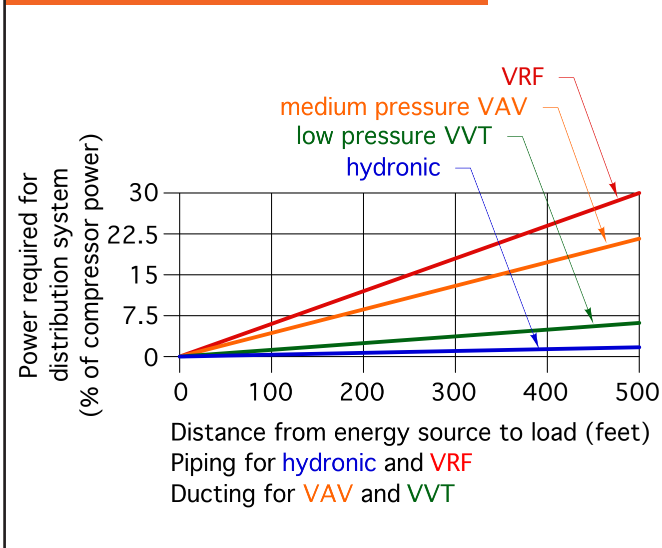


Figure 2 compares the energy required to move the cooling effect through a building. It assumes that the thermal energy is supplied by a vapour/compression source such as used in a VRF/VRV system. The vertical axis represents the percentage of the compressor power required to move (not create) the cooling effect generated by the refrigeration system. The horizontal axis represents the distance from the thermal energy source (e.g., boiler, outdoor unit, etc.) to the load.

The VRF/VRV system uses about six per cent per 100 feet of refrigerant line set, compared to the hydronic system, which uses about 0.3 per cent per 100 feet of distribution distance (e.g., 200 feet total piping circuit length).

BENEFIT #5: HYDRONIC DISTRIBUTION SYSTEMS ARE NOT DEPENDENT ON SPECIFIC REFRIGERANTS.

Hydronic systems are not subject to radical redesign or modification based on future changes in refrigerants.

Over the last two decades, highly successful refrigerants such as R-22 have be phased out of the North American market due to concerns over their global warming potential. Replacement refrigerants have been and continue to be developed. The properties of these replacement refrigerants have mandated changes in components such as refrigerant piping and the oils that are carried throughout the system with the refrigerant.

While it is impossible to know what refrigerants will remain acceptable over the next 10 to 20 years, efforts to determine optimal future refrigerants continue. This could lead to breakthroughs that allow refrigerants such as carbon dioxide or propane to emerge as the new standards. Eventually, legacy chillers, heat pumps, or VRF/VRV systems that rely on present day refrigerants could be rendered obsolete. The tubing that carries present day refrigerants throughout a building in a VRF/VRV system may not be suitable for future refrigerants or their associated oils. Upgrading a legacy VRF/VRV system could require replacement of piping, terminal units, or other hardware, as well as recycling of refrigerant and oils. Such changes would be very costly.

BENEFIT #6: HYDRONIC SYSTEMS ALLOW EASY INTEGRATION OF THERMAL STORAGE.

Many heating and cooling systems can benefit from thermal storage. The high heat capacity of water makes it an ideal thermal storage material for both heating and cooling systems. The heated or chilled water may be produced by heat pumps or chillers at times when off-peak electric utility rates are in effect, which significantly reduces the cost of delivered thermal energy.

Water-based thermal storage can also be used in systems that have renewable energy heat sources such as solar thermal collectors, air-to-water heat pumps, or biomass-fuel boilers. Combined heat and power (CHP) systems also benefit from water-based thermal storage.

Thermal storage is easy to implement when a hydronic heating source and distribution system are used. In many systems, the water that stores thermal energy in a tank can eventually pass through the distribution system without need of any heat exchangers. This eliminates the cost and complexity of the heat exchanger(s) and the thermal penalty imposed by their use.

The use of thermal storage for space heating and cooling with VRF/VRV systems is not practical. While it is possible to transfer heat from refrigerant to water using heat exchangers, it is not practical to recover that heat back into refrigerant for subsequent delivery to VRF/VRV terminal units.

BENEFIT #7: PIPING OPTIONS

Hydronic systems can use traditional piping materials such as copper tubing or steel piping. Modern hydronic systems can also use polymer-based piping materials such as PEX, PEX-AL-PEX, PERT and polypropylene. These piping products are less expensive and generally easier to install than the all copper piping systems required with VRF/VRV systems.

VRF/VRV systems use copper tubing. *Figure 3* shows some of this tubing being installed in the hallway of a commercial building. A multi-storey building with such a system could contain several thousand feet of copper tubing, with hundreds of brazed or mechanical joints. Hydronic systems can use larger piping for mains and thus reduce the linear footage of piping and joints that need to be installed.

Figure 3

BENEFIT #8: HYDRONIC SYSTEMS ALLOW FOR RADIANT HEATING AND COOLING

Hydronic radiant panel heating has long been recognized for providing unsurpassed thermal comfort. Warm water from a variety of heat sources can be supplied to these panels. They create interior surface temperatures and air temperature profiles that are ideal for human comfort. They operate silently, with minimal air movement and deliver heat to spaces using a fraction of the distribution energy required for forced air systems or VRF/VRV systems.

VRF/VRV systems are limited to air as the final means of conveying heat or cooling effect from refrigerant into heated spaces. As such, they are not well suited to interior spaces with tall ceilings, or applications where internally generated dust would quickly clog air filters.

BENEFIT #9: HYDRONIC SYSTEMS PROVIDE LOAD VERSATILITY

In addition to space heating and cooling, hydronic systems can be configured to provide high capacity domestic water heating, snowmelting, and pool heating. These ancillary loads can be prioritized to reduce the total thermal capacity needed.

VRF/VRV systems are not currently used for such ancillary loads.

Figure 4 Ultrasonic-based heat meters

BENEFIT #10: HYDRONIC SYSTEMS PROVIDE LONGER LIFE EXPECTANCY

A well-designed and properly maintained hydronic heating or cooling system is a long term investment. Although the life of the original heat source or chiller is typically 15 to 25 years, the distribution system (the piping, valves, heat emitters and terminal units for cooling) can usually provide many decades of service. Many hydronic systems that were installed over 50 years ago remain in operation today.

The 2015 ASHRAE Applications Handbook lists the medium service life of air-to-air heat pumps and similar refrigeration-based HVAC equipment using fixed-speed compressors and outdoor condenser units at 15 years. There is no listing specifically for VRF/VRV equipment because of its relatively new use in the North American market. Anticipated life expectancies should be similar to air source heat pumps with outdoor condenser units.

BENEFIT 11: HYDRONIC DISTRIBUTION SYSTEM COMPONENTS ARE WIDELY AVAILABLE

The piping, valves, circulators and terminal units required in most hydronic systems can be sourced from many companies with distribution networks across North America. This provides options when the system is initially designed, as well as when maintenance or replacement parts are needed in the future.

Most VRF/VRV systems are manufactured in Asia and many use proprietary components. The availability of these specialized components may be more limited, especially in emergencies where they are needed quickly.

Most manufacturers of VRF/VRV systems require installation and maintenance by factory-trained technicians. These technicians often use specialized diagnostic equipment for troubleshooting. The rapid evolution of electronic controllers and firmware used in VRF/VRV systems underscores the need for readily available, trained technicians who can keep these systems operating and do so at competitive rates.

BENEFIT #12: HYDRONIC SYSTEMS ALLOW FOR HEAT METERING

In hydronic systems, an accurate measurement of flow rate and temperature drop (from supply to return) allows for a simple calculation of the rate of heat transfer. The total thermal energy that passes a specific point in the system can also be determined by integrating these measurements over time.

Several companies now offer "heat metering" hardware that can be installed easily in a range of hydronic heating and cooling systems. *Figure 4* shows two examples of ultrasonic-based heat meters that can be used in applications such as apartments, condominiums and leased commercial space.

Heat metered systems allow owners of multi-tenant buildings to know what each tenant's thermal energy use was and to invoice them accordingly. Such systems can centralize heat production and chilled water production, which provides many technical and economic benefits.

THE FINAL ANALYSIS

Water remains the gold standard when it comes to moving thermal energy through buildings. Hydronic systems can provide decades of reliable, safe, and efficient delivery of heating or cooling from a wide variety of sources. They can expand as building configurations change and be retrofitted with different heating and cooling sources as energy markets change, or the original heating/cooling sources reach the end of their service life.

Be sure to consider the points discussed above when evaluating options for heating and cooling systems.

John Siegenthaler, P.E., is a mechanical engineering graduate of Rensselaer Polytechnic Institute and a licensed professional engineer. He has over 34 years experience in designing modern hydronic heating systems. Siegenthaler's latest book, Heating with Renewable Energy, was released recently (see www.hydronicpros.com for more information).