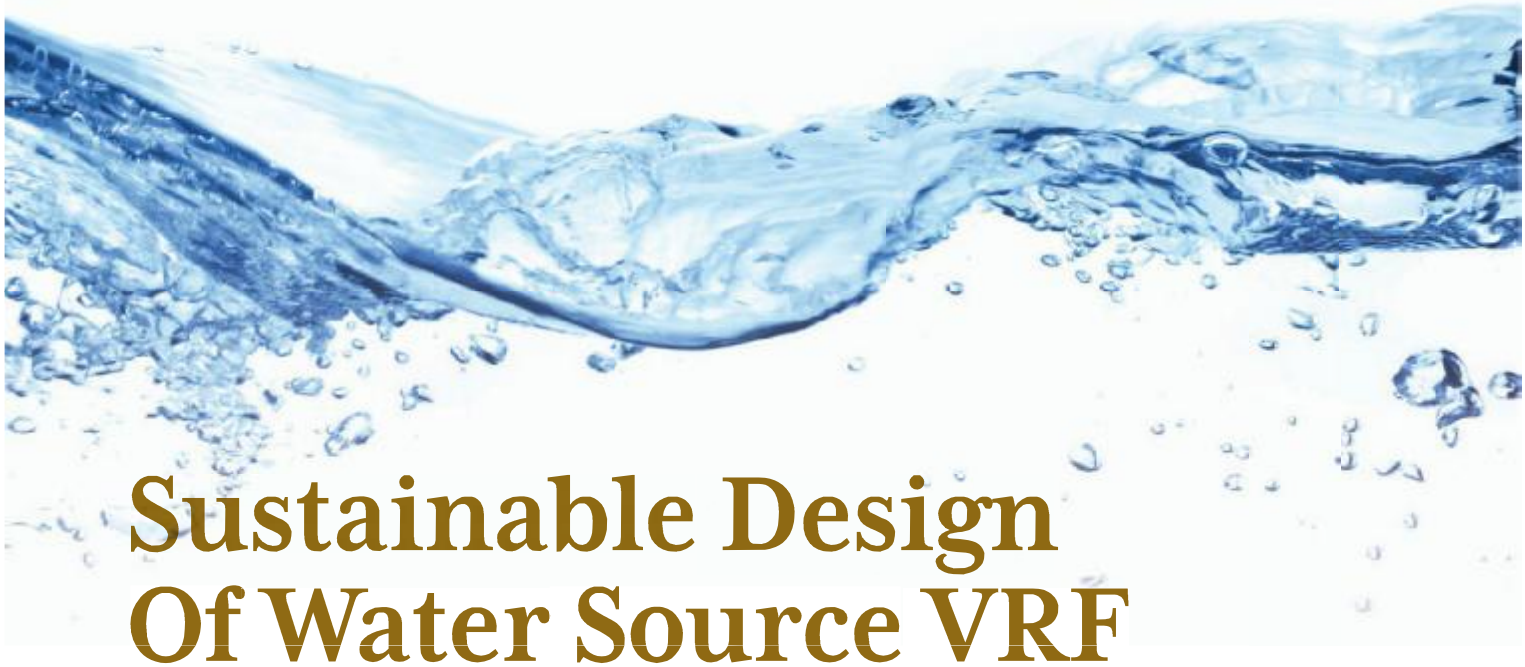

Sustainable Design Of Water Source VRF

BY RAMEZ AFIFY, P.E., MEMBER ASHRAE

A water source variable refrigerant flow (VRF) system is comprised of single or multiple indoor water source units typically connected to several air handling sections via refrigerant pipes. When properly designed and installed, the system provides effective thermal zoning and capacity modulations at operating efficiency that far exceeds conventional water source heat pump systems. However, there are several factors that reduce the overall efficiency of the system and/or cause premature failure. This article discusses opportunities and precautions to maximize the potential of water source VRF systems.

Overview

There are many similarities between water source and air-cooled VRF systems. The air-handling sections can be ceiling mounted, wall mounted, concealed or exposed, ducted or ductless. Each air-handling section can be controlled by a thermostat that is capable of fully modulating its electronic expansion valve to maintain space temperature setpoint. Refrigerant pipes from each air-handling section are routed back to its water source section. Water source VRF can be selected to provide simultaneous heating and cooling (where some air-handling sections would provide cooling while others provide heating), or it can be selected so that all air-handling sections provide either cooling or heating. The physical size of the water source sections is small enough to fit within closets with approximate dimensions of 3 ft long × 2 ft wide × 5 ft high (1 m long × 0.6 m wide × 1.5 m high), depending on unit capacity and equipment manufacturer. Water source sections can be stacked to enable fitting multiple units within small closets.

A central controller can be provided as a convenient way of controlling the entire system from one central location. The system also can be tied in to building management systems.

Design Considerations

Several design considerations and precautions must be considered while applying the water source VRF.

ABOUT THE AUTHOR Ramez Afify, P.E., is a principal at E4P Consulting Engineering in New York, N.Y. He is a member of TC 6.1, Hydronic and Steam Equipment and Systems. He is also an ASHRAE-certified High-Performance Building Design Professional.

Best Performance Zone

VRF manufacturers are constantly expanding the envelope of permissible operation. However, there are penalties including reduction in cooling and heating capacities and increasing required power input. This reduces the efficiency of the system. The following parameters provide an example of a window of efficient operation:

- Cooling Water Temperature: 85°F (29°C) or lower
- Heating Water Temperature: 68°F (20°C) or higher
- Distance between water source unit and furthest fan coil section: 150 ft to 180 ft (46 m to 55 m) of equivalent length or less. Consider providing multiple water source units to avoid inefficient operation/capacity reduction, but beware of reducing overall system efficiency as a result of longer water pipes and more pumping power.

Complying with Standard 15

Consider a non-compliant layout: one fully enclosed office size of 10 ft wide × 10 ft long × 10 ft high (3 m wide × 3 m long × 3 m high) served by a 12 ton (42 kW) water source VRF with refrigerant charge of 30 lbs (14 kg), including field pipes. The following are possible revisions to comply with ASHRAE Standard 15:

- Locate the VRF air-handling section within an open space that meets the concentration level and use unducted return.
- Take out the critical air-handling section off the 12 ton (42 kW) system and make it part of a neighboring water source VRF system with refrigerant charge below RCL.
- Provide permanent openings between the enclosed space and a larger open space. Permanent openings can be achieved by omitting the door, providing door louver, providing transfer ducts, or similar strategies.
- Omit hung ceiling within the room if possible, which may increase the room volume to achieve compliance with the standard.
- Modify the design of refrigerant pipes to reduce the system refrigerant charge.

Condenser water temperature. This is critical for the overall system efficiency. As the inlet condenser water temperature increases during cooling, the output cooling capacity decreases and the input power increases, resulting in an overall reduction of system efficiency. For example, a water source VRF system supplied by water from a dry cooler at 110°F (43°C) entering water temperature would require about more than 20% input power

to produce less than 90% of the rated cooling capacity. Sidebar "Best Performance Zone" provides the range of water temperatures that maximize the efficiency of the system.

Water quality. A closed loop source must be used to serve water source VRF unit to prevent corrosion and premature failure. When the system is connected to an open loop cooling tower, a secondary heat exchanger (frame and plate heat exchanger is commonly used) must be used. The water introduced to the water source VRF units must be chemically treated. The water pH level should be maintained between 7.0 and 8.0.

Condenser water circulation. The condenser water pump should continuously circulate water across the water source unit. When multiple water source units are implemented, piping them in reverse return fashion ensures uniform water distribution across all units.

Length of refrigerant pipes. Although variable refrigerant flow systems allow for long runs of refrigerant pipes (more than 500 ft [152 m] of equivalent refrigerant pipes lengths, depending on manufacturer), there are losses in heating and cooling capacities associated with long runs (Close to one-fifth of the cooling capacity is lost at 500 ft [152 m] of equivalent pipes' length). In large floors, it may be beneficial to provide multiple water source units at strategic locations to minimize the lengths of refrigerant pipes while observing the impact on water piping and pumping power. The designer should establish the permissible acceptable de-rating and limit the refrigerant pipes lengths accordingly (see sidebar "Best Performance Zone").

Volume of refrigerant. Based on Addendum l to Standard 34-2010,[1] a water source VRF using R-410A refrigerant cannot have refrigeration concentration exceeding 26 lbs (11.79) of refrigerant per 1,000 ft^3 (28 m^3) of room volume (only 13 lbs [6 kg] per 1,000 ft^3 [28 m^3] of room volume for institutional occupancy). Examples on calculating maximum refrigeration charges are provided by Stephen Duda, P.E.[2,3] The sidebar "Complying with ASHRAE Standard 15" indicates options that can be implemented when the calculations indicate non-compliance with ASHRAE Standard 34.

Outside air. Similar to air-cooled VRF,[4] water source VRF system cannot handle high volumes or 100% outside air. Most manufacturers now offer system integrated energy recovery units (ERV) that can efficiently address high ventilation rates. A dedicated outdoor air-conditioning system (DOAS) unit can also be provided to serve the system where 100% outdoor air is required. Refer to Chapter 18 of the 2012 ASHRAE Handbook[5] for more information on ventilation air strategies.

Opportunities & Applications

One of the most attractive applications for water source VRF is retrofit projects where an existing condenser water system serves conventional water source heat pump units. Replacing the conventional heat pump system with water source VRF allows for improving controls because of the capacity modulation feature. Also, it reduces noise by replacing the compressor within the heat pump with a much quieter fan coil section, and it reduces the required ceiling plenum height. The height of the air-handling section of VRF can be close to one-half the height of conventional heat pump units.

Conclusion

Water source VRF can be effective and efficient and manufacturers are constantly expanding the permissible operating limits. Designing and operating the system within the extreme conditions, however, deteriorate the overall efficiency of the system. The designer and the operator do need to self-impose tighter envelope of parameters to maximize system efficiency.

References

1. ASHRAE Standard 34-2010, *Designation and Safety Classification of Refrigerants.*

2. Duda, S. 2011. "Application of ASHRAE Standard 15-2010 with respect to multi-evaporator split air-conditioning systems." *ASHRAE Transactions* 117(2).

3. Duda, S. 2012. "Applying VRF? Don't overlook standard 15." *ASHRAE Journal* 54(7).

4. Afify, R. 2008. "Designing VRF systems." *ASHRAE Journal* 50(6):52.

5. *2012 ASHRAE Handbook—HVAC Systems and Equipment,* Chapter 18. ■