PROJECT OVERVIEW

Variable Refrigerant Flow Overview

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This Variable Refrigerant Flow (VRF) Overview discusses both the energy-efficiency considerations and the non-energy drivers for VRF systems, as well as information that was required for utility energy-efficiency incentives. Several case studies are included to demonstrate how these heating, ventilating and air conditioning (HVAC) systems benefited various buildings.

Background

Variable Refrigerant Flow (VRF) heating and cooling systems promise energy efficiency, flexibility and improved comfort in small to mid-sized commercial buildings. Traditional heat pumps have been evolving in Asia over the last thirty years, and VRF systems are now the preferred HVAC system for small and medium commercial buildings in both Asia and Europe.

It is estimated that VRF systems condition over 50 percent of Japanese commercial buildings less than 70,000 square feet, and 15 percent of larger buildings. VRF systems were introduced in the U.S. around 2002, and have been installed in many types of commercial buildings,
including offices, hotels, luxury apartments, low-income multi-family buildings and universities.

While VRF systems have the potential to save energy, very few have received utility energy-efficiency incentives in the Pacific Northwest, because of the difficulty quantifying and verifying VRF system energy savings.

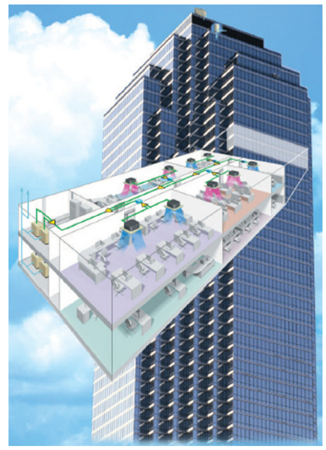

Photo courtesy of Daikin

What is VRF?

VRF systems (also known as Variable Refrigerant Volume or VRV) are very similar to traditional heat pump systems, but they use inverter drives to vary their capacity, similar to mini-split (ductless) heat pumps. Some larger VRF systems with heat recovery capability can transfer heat between areas, rather than rejecting heat, efficiently providing simultaneous heating and cooling. VRF systems cost more, are typically larger and include more indoor units than mini-split (ductless) heat pumps, as illustrated in the following table:

	Mini-Split Heat Pump	VRF Heat Pump System	VRF w/ Recovery Capability
Relative Cost	Low	Medium	High
Maximum Single Unit Size (tons)	5	30	24
# of Indoor Zones Per Outdoor Condensing Unit	Up to 8	Up to 50	Up to 50

Traditional ducted HVAC systems provide heating and cooling by moving air; both mini-split (ductless) heat pumps and VRF systems provide heating and cooling by moving refrigerant, which is more efficient and eliminates duct losses. Additional energy savings can be achieved by separating the heating and cooling system from the code-required ventilation system; this separation also allows for smaller ductwork and potentially lower installation costs.

Both mini-split (ductless) heat pumps and VRF systems have a lot of moving parts. They modulate compressors, fans and expansion valves. This results in improved space temperature control, low ambient performance, equipment efficiencies, and part-load system efficiencies. Energy savings due to the optimized efficiencies, duct losses, ventilation system and heat recovery are difficult to estimate, verify or guarantee. While VRF system manufacturers typically claim their systems will save between 30 and 50 percent over a baseline system, field tests have not been performed to verify these claims. In 2011, Bonneville Power Administration will be among the first to perform rigorous field tests, as part of EPRI's Energy Efficiency Demonstration project.

VRF systems with heat recovery capability

VRF systems with heat recovery capability cost more, but can minimize energy use by efficiently providing simultaneous heating and cooling. Instead of rejecting heat these systems can transfer heat from an area that needs cooling, such as a conference room, to another area, such as a perimeter office, as shown in the following diagram.

The amount of savings and heat recovery depends on the building loads and system design. To maximize heat recovery, Washington State Energy Code requires systems to serve "at least 20 percent internal zones and 20 percent perimeter zones." Where "internal zones" are defined as interior areas that don't have an exterior wall within 12 feet, "perimeter zones" are defined as having an exterior wall within 12 feet, and percentages are determined based on the conditioned floor area served.

VRF system non-energy benefits

In addition to potential energy savings, VRF system non-energy benefits can include:

- Better temperature control in smaller zones;
- Lower building costs or more rentable space, due to smaller mechanical space requirements –smaller interior mechanical rooms and less space required for ductwork between floors, as well as smaller exterior equipment space requirements;
- Easier retrofits where clearance for installing ductwork is an issue or where existing ductwork can be used for code-required ventilation system, and
- Lighter equipment weight, potentially reducing structural requirements.

Economizers and VRF systems

Building codes require outside air to be provided for ventilation purposes and require air-side economizers on most HVAC systems to offset mechanical cooling needs and save energy. Several studies have shown that economizers seldom save as much energy as they should. In addition, adding economizers to VRF systems, or dedicated ventilation systems may not be cost effective.

Energy modeling performed for the Washington State Energy Code estimated that because a VRF system with heat recovery capability uses about the same amount of energy as a non-VRF system with economizers, there is an exception to the economizer requirement for VRF systems with heat recovery capability. Oregon Energy Code also has an exception to the economizer requirement for VRF systems with heat recovery capability. Idaho and Montana use a version of the International Energy Conservation Code that does not currently have an economizer exception for VRF systems with heat recovery capability.

Energy Savings

VRF system energy savings depend on many variables including the baseline HVAC system, the VRF system design and operation,
the climate, and the building type, design and use. VRF system energy use should be estimated using energy simulation models, and energy savings estimated by comparing the VRF system energy use to that of an identical building with a baseline HVAC system. VRF system energy use should be verified with post installation model calibration, per IPMVP option D Whole Building Calibration. Estimating and verifying VRF system energy savings are required to receive most utility energy-efficiency incentives.

VRF system documentation

The following documentation is are necessary forVRF system energy savings.

Prior to purchasing the VRF system:

- A description of the baseline HVAC system
- Documentation of the expected energy savings
- Documentation of the incremental cost between the VRF system and the baseline HVAC system
- An approved plan to verify the energy savings

After VRF system installation:

- Documentation of verified energy savings
- Documentation of VRF system incremental cost and when it was installed.

These items, as well as lessons learned and insights from the building owner, architect, mechanical engineer, contractor and the serving utility are included in the Pacific Northwest VRF system case studies.

VRF system resources

- Cendón, S. (2009, April 10). New and cool: variable refrigerant flow systems. AIArchitect, 16, Retrieved from 0H0HHU http://info.aia.org/aiarchitect/thisweek09/0410/0410p_vrf.cfmU
- Consortium for Energy Efficiency. (2010, January). Information for CEE program administrators on the new part load efficiency metric for unitary commercial HVAC equipment. Retrieved from 1H1HHU http://www.cee1.org/com/hecac/Prog_Guidance_IEER.pdfU
- Energy Star® Program requirements for light commercial HVAC: partner commitments, version 2.0. (n.d.). Retrieved from 2H2HHU http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/lhvac/spec_v2_final.pdfU
- Goetzler, W. (2007, April). Variable refrigerant flow systems. ASHRAE Journal, Retrieved from 3H3HHU http://www.ashrae.org/docLib/20090204_goetzler.pdfU