VARIABLE REFRIGERANT FLOW FOR **HEATING & COOLING** SYSTEMS

INTRODUCTION

Variable Refrigerant Flow (VRF) for heating and air-conditioning (HVAC) in buildings was invented in Japan by the Daikin company in 1982. Today this innovative and advanced HVAC technology is used in 50% of midsize Japanese office buildings and 33% of large commercial Japanese buildings. European acceptance of VRF technology has also created strong demand which is driven by favorable VRF application scenarios, such as higher retrofit opportunities in older buildings that lacked any air conditioning where duct installation would prove difficult or costly.

In contrast to much of the developed world, U.S. market penetration of VRFs has been surprisingly limited given the indications that VRFs offer significant performance advantages over conventional HVAC systems. VRF systems can provide higher energy efficiency, lower noise levels, customized comfort and high reliability compared to baseline.

HOW DOES A VRF SYSTEM WORK?

VRF systems are differentiated from conventional HVAC systems in that the volume of refrigerant flowing to the each of the air handlers can be modulated, enabling the use of many evaporators of differing capacities, individualized comfort settings by zone, and sometimes heat recovery from one zone to another. VRF systems, unlike unitary systems, feature a variable speed motor to drive the compressor which allows the system to operate efficiently under partial-load conditions. VRFs come in two basic designs; two pipes and four pipes. Two pipe systems require all the zones to be either cooling or heating at the same time, while four pipe designs have the flexibility to simultaneously cool some zones while heating other zones.

It is the ability of VRF system to operate more efficiently under average conditions which results in substantial energy savings. The efficiency of VRF systems are based on partial loads, whereas conventional HVAC systems are based on peak design loads. Partial loads are design loads calculated for the average outdoor temperatures in the summer and winter, whereas the peak design loads are calculated at the highest summer outside temperature and at the lowest outside winter temperatures to ensure that the HVAC system works at the extreme temperatures. The VRF systems use integrated controls, variable speed drives, refrigerant piping, and one compressor for multiple indoor comfort zones, modulating the heating and cooling loads for the indoor comfort temperatures.

WHAT IS HAMPERING MARKET PENETRATION OF VRF SYSTEMS IN THE U.S.?

Until recently, it was not possible to evaluate VRF systems using standard energy modeling software. Historically there was insufficient support infrastructure from Japanese manufacturers and a shortage of performance documentation. These factors combined to hamper U.S. market acceptance for decades. VRF systems were viewed as unproven technology by consumers and HVAC design firms.

There are recent signs that these U.S. market barriers for VRF systems are disappearing. For example, in the 2016 Energy code, the energy calculations will be integrated in certified software modeling programs that will indicate not only the VRF system energy calculations, but also the energy savings over a baseline conventional HVAC system. This feature will allow energy consultants to model and show proposed energy savings to clients in an effort to more accurately predict VRF system cost and energy efficiency. Available manufacturer data and case study literature is becoming more available, although much of the literature is from outside the U.S. As the result, non-residential installations of VRFs in North America were about 40,000 per year in 2015 and this usage is expected to double in ten years.

HOW MUCH DO VRF SYSTEMS COST AND HOW MUCH CAN THEY SAVE?

Available studies indicate that VRFs are from 15% to 35% more energy efficient than conventional HVAC systems. Initial costs for VRF systems are 5% to 20% higher than chilled water systems and cost 30% to 50% more than equivalent capacity single package units with a SEER of 13 or 14. However, installed costs for a VRF system are highly dependent on the building application, construction type and whether the building is new or retrofit. Therefore, to fully understand the pros and cons of installing VRFs, rigorous analysis and/or advanced energy modeling is essential during the preliminary design of a project.

WHAT ARE VRF APPLICATIONS FOR SCHOOLS?

VRF systems are ideal for schools located in mild climates because the system rarely has to work at peak design loads based on peak temperatures. (As previously noted, VRFs are more efficient under partial-loads based on average outdoor temperatures.) The VRF pipes are also smaller in diameter than conventional systems, thus reducing the HVAC plenum space and allowing for higher ceilings. Another advantage is that the low noise level of VRFs is known to be particularly conducive to learning environments. For example, interior units measure about 24 dBA and exterior units measure about 56 dBA.

A recent review of High Performance School (K–12) Incentive Grant projects in California reveals that about 5% of grant applicants have installed VRF systems. A common scenario that favored VRF systems over conventional systems in school projects is a mechanical retrofit; however, the building's air distribution system will require replacement.

PROS AND CONS OF VRF SYSTEMS

The Pros

- Good partial-load performance
- Sophisticated control, flexibility for zone control, better comfort
- No duct leakage
- Easily adapted to demand response strategies and feature sophisticated controls to enable units to respond to signals from energy management systems. Operate at relatively low-noise levels

The Cons

- Higher initial cost compared to baseline
- Where applicable, the cost to install a separate ventilation system to satisfy local code requirements for delivery of outside air may offset some of the retrofit advantages of VRF systems
- Offer no economizer cycle benefit (free cooling)
- More rigid regulation of refrigerants is a future challenge for VRF systems because refrigerant piping is run like a spider's web throughout the building instead of being confined to a smaller area, as in conventional systems. VRF systems are inherently complex, which may increase the risk of refrigerant leaks and other refrigerant-related safety issues

SUMMARY

The installation of VRF systems will become more common in U.S. commercial and institutional sectors (schools and community colleges) now that market barriers are disappearing. While VRFs can provide significant benefits such as energy efficiency, energy cost savings, noise reduction, and individualized comfort, their advantages are application dependent and site-specific. Therefore, rigorous evaluation of applicability is recommended when considering VRF systems.

DSA DIVISION OF THE STATE ARCHITECT
DEPARTMENT OF GENERAL SERVICES

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