Variable Refrigerant Flow Systems

An Online Continuing Education Course for Engineers

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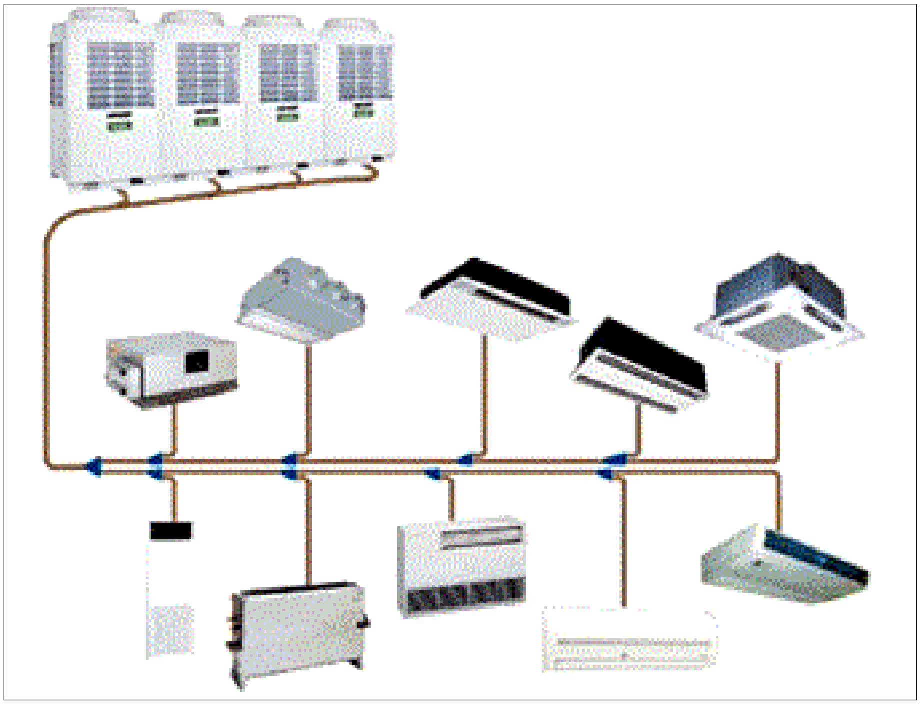

Photo Credit: Toshiba Industries and shows its VRF R410A system.

Introduction

Commercial buildings account for approximately 40% of the energy consumption in the United States. About a third of commercial building energy usage is for heating, cooling and ventilation. See the chart in Figure 1.

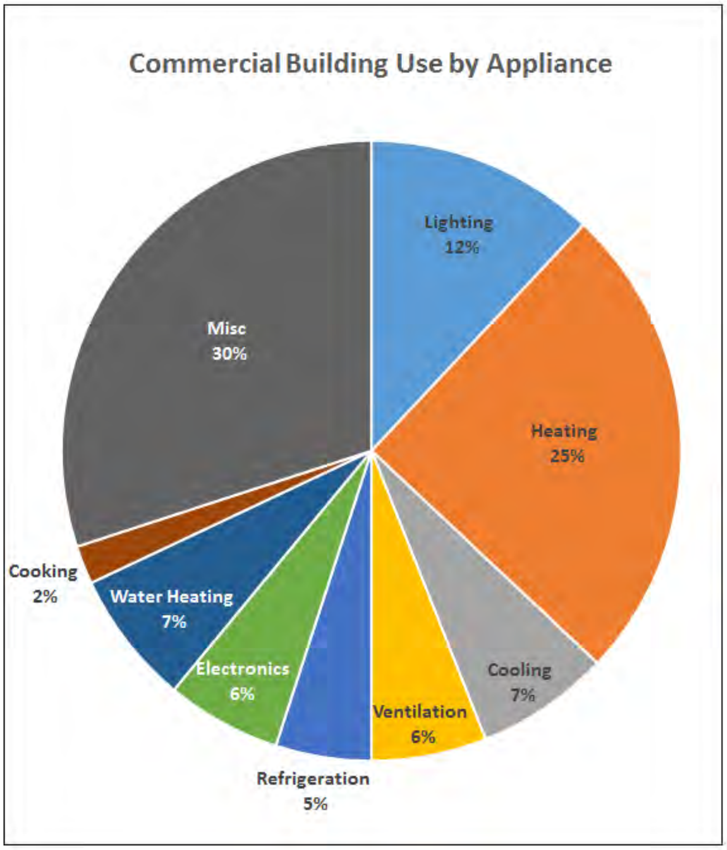

Figure 1

One HVAC technology that is in common usage outside of the United States and beginning to enter the U.S. market is variable refrigerant flow (VRF) multi-split systems. These systems are also referred to as variable refrigerant volume (VRV) systems. VRFs are packaged outdoor compressor units connected through refrigerant lines to multiple refrigerant fan coil units in the building.

Variable refrigerant flow (VRF) heating, ventilation, and air conditioning (HVAC) systems are one possible tool to improve energy efficiency. They are the primary HVAC system choice in Europe, Japan, China, and other parts of the world. VRF is particularly appropriate to existing buildings that use excessive energy or need HVAC repair and upgrade for other reasons.

VRF has about 24% of the global commercial air conditioning market, and over 35% market share in China, India, the European Union, and Eastern Europe. The VRF share of the U.S. market is still only about 3%, but multiple manufacturers sell these systems in the U.S. and sales are growing. These manufacturers provide the products through an integrated supply system, including installation and design training, and sometimes provide part or all of the design, as well as quality control.

The U.S. market has been slower to accept VRF technology for several reasons. In Europe, many buildings did not have air conditioning, and adding ductwork was expensive or nearly impossible given space constraints. Europe has tended to provide cooling with chilled water fan coils rather than ducted systems. The United States has a long history with ducted HVAC systems using both *direct expansion* (DX) systems and chilled water systems..

VRF systems use refrigerant lines to distribute the refrigerant throughout the building, and since VRF systems use more refrigerant than direct expansion systems this raises concerns about leaks and compliance with ASHRAE Standard 15 Safety Standard for Refrigeration Systems which regulates refrigerant safety and environmental and sustainability impacts.

VRF systems combine many of the features of other HVAC systems, which offer energy efficiency with a limited number of components relative to systems with central plants. VRF systems have limited space requirements, particularly for the distribution system inside the building. VRF HVAC systems include two major components, a compressor unit and multiple indoor fan coil units. The compressor unit cools and heats refrigerant connected through piping to condition the building.

The compressor units are typically air cooled. Sometimes water-cooled units are used and are connected to a cooling tower and boiler. These systems are capable of simultaneously cooling some zones and heating others and can recover heat from spaces being cooled for use in spaces being heated and vice versa. The compressor unit uses variable refrigerant flow and is controlled by a variable-speed drive, which operate more efficiently than conventional compressors. However, the complexity of the variable refrigerant flow compressor and controls results in significantly more expensive compressor units than comparable conventional systems.

VRF systems include sophisticated controls integrated with the units that may not require a separate building automation system, when such a system is part of the project requirements. VRF systems include self-diagnostics and monitoring points, as well as the ability to communicate with a wide variety of other building systems with non-proprietary building automation communication protocols.

VRF is well suited to retrofit applications in older buildings because it can be added on to or replace existing equipment in limited space, where there is currently limited or no ductwork. VRF may be the least expensive option in some of these cases, or may offer a reasonable payback relative to other options.

Even though VRF HVAC systems are a mature technology, they are relatively new to the U.S. market and important questions about the actual energy savings remain unanswered. Some studies show that VRF systems can achieve 30% and higher HVAC energy cost savings relative to older conventional systems, or older inefficient systems and a range of building types.

Costs and energy savings vary a great deal particularly for retrofit projects. It is not possible to define a single payback for the many applications of the systems, but there are opportunities to achieve reasonable paybacks on investments in VRF systems. Packaged rooftop units, *constant-air volume* (CAV) and *variable-air volume* (VAV) with hot water or electric reheat systems may have simple paybacks of 15 years or less. Facilities managers should look for opportunities in buildings whose energy usage is above-average for other, similarly situated facilities. Chilled water VAV systems have similar potential simple paybacks; however, there is not enough information to clearly distinguish the incremental cost and potential energy cost savings for air-cooled and water-cooled chillers, or air-cooled and water-cooled VRF systems.

Constant-air volume (CAV) is a type of HVAC system that delivers supply air at a constant flow rate, but in which the supply temperature will vary to meet variable thermal loads.

Variable Air Volume (**VAV**) is a type of HVAC system that varies the airflow at a constant temperature. The advantages of VAV systems over constant-volume systems include more precise temperature control, reduced compressor wear, lower energy consumption by system fans, less fan noise, and additional passive dehumidification.

The best opportunities for VRF systems include buildings with these target characteristics:

- Inefficient HVAC systems and high energy costs,
- Lack of cooling or inadequate cooling capacity,
- Older buildings with limited room to install or change systems,
- New building projects that can take advantage of opportunities to reduce floor-to-floor height, or increase usable floor space by removing mechanical equipment from inside the main building areas,
- VAV systems with electric reheat or heat pumps with electric back-up heat,
- Significant heating requirements,
- Inefficient fan systems,
- Leaky or poorly designed or installed ductwork, and

- Facilities already identified for HVAC upgrades, replacements, or energy improvements.

One significant barrier to the technology is the uncertainty in estimating savings. There is not a complete, independently developed energy simulation protocol, nor is there commonly available real energy savings results isolated to VRF savings.

This course reviews the basic operation of HVAC systems and then explains how Variable Refrigerant Flow systems work. A case study, presented by the US General Services Administration is reviewed and the various application factors concerning VRF systems are discussed.