



■ 2018 WHITE PAPER

GETTING STARTED WITH VRF

The Basics of Variable Refrigerant Flow Technology





This white paper describes the requirements, advantages and opportunities associated with specifying and applying Variable Refrigerant Flow (VRF) systems and addresses common misconceptions professionals may encounter in the field.

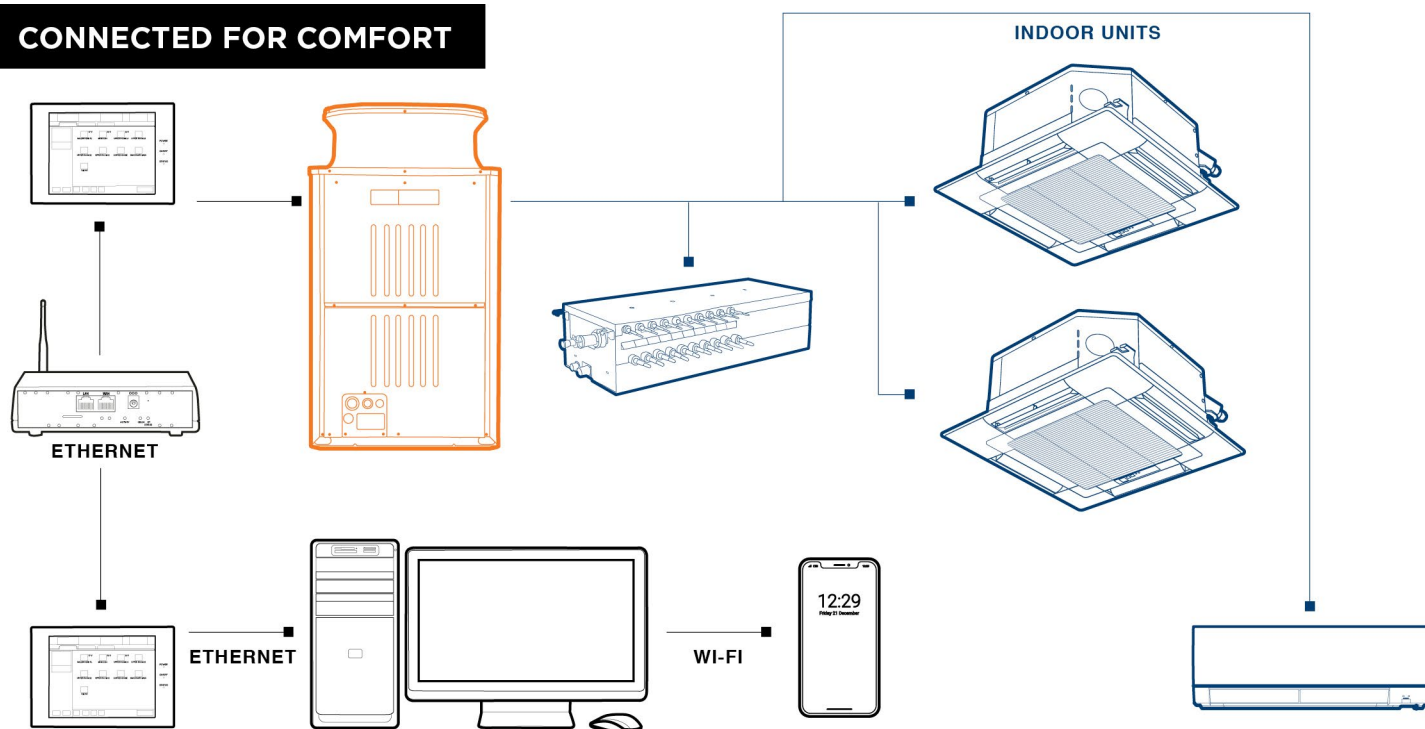
Popular in Asia and Europe since the 1980s, VRF was introduced to the U.S. market for commercial applications in 2003. According to a report published by Prescient and Strategic Intelligence, the fastest growth in the global VRF market **between 2018 and 2023** will occur in North America. With that projected growth, there is a surging opportunity for qualified HVAC professionals to specify, install, and service VRF systems.

WHY VRF?

VRF is an HVAC technology designed to provide energy-efficient comfort control for a building's occupants according to the conditioning needs of a building's zones. Supported by integrated controls and sensors, VRF accomplishes cooling and heating through the transfer of conditioned refrigerant between each zone's indoor unit(s) and an outdoor unit. As the name Variable Refrigerant Flow indicates, VRF systems are able to **modulate the flow of refrigerant** so that the system only uses the precise amount of energy needed to meet each zone's conditioning requirements.

The powerful global movement toward a more sustainable, but technologically advanced built environment is a key driver for VRF system adoption. As architects design high-performance buildings to satisfy the requirements associated with LEED®, Green Globes®, Passive House, Zero-Net Energy (ZNE), deep-energy retrofits and ambitious sustainability goals set by governments and private entities, the need for VRF technology as an energy-efficient HVAC system has become more widely recognized.

CONNECTED FOR COMFORT



STRATEGIC ELECTRIFICATION

The 2018 report published by the [U.N. Intergovernmental Panel on Climate Change](#) (IPCC) indicates that a complete modernization of the built environment is needed to keep planetary climate change from exceeding 1.5° Celsius above pre-industrial levels. In the climate models where climate change does not reach 1.5°C, or only modestly overshoots that point, humanity, by 2030, successfully reduces global net anthropogenic carbon dioxide emissions by approximately 45 percent from 2010 levels and achieves net zero carbon dioxide emissions by 2050.

To achieve a decarbonized built environment, Strategic Electrification is essential. **Strategic Electrification** — also known as Beneficial Electrification — is the modernization of technologies, transportation systems and the built environment so that they are powered by electricity drawn from renewable energy sources that do not generate CO2 emissions — [sunlight](#), as an example. Along with greener electrical grids and innovative batteries to store excess power, highly-efficient, electric-powered mechanical systems such as VRF are critical to Strategic Electrification. VRF systems are engineered to use only the precise amount of energy needed to heat or cool a commercial

space. As manufacturers innovate, the Minimum Circuit Ampacity (MCA) and Maximum Overcurrent Protection (MOP) ratings of VRF systems continue to fall. This efficient use of electricity makes VRF an ideal mechanical system for applications that use solar, wind or hydroelectric as a power source. Optimal use of renewable energy sources requires high efficiency, in part due to the current limitations of technologies related to collection and storage of energy. With minimal electrical waste, the precision of VRF systems promotes a more sustainable, decarbonized built environment that still retains modernity and comfort.

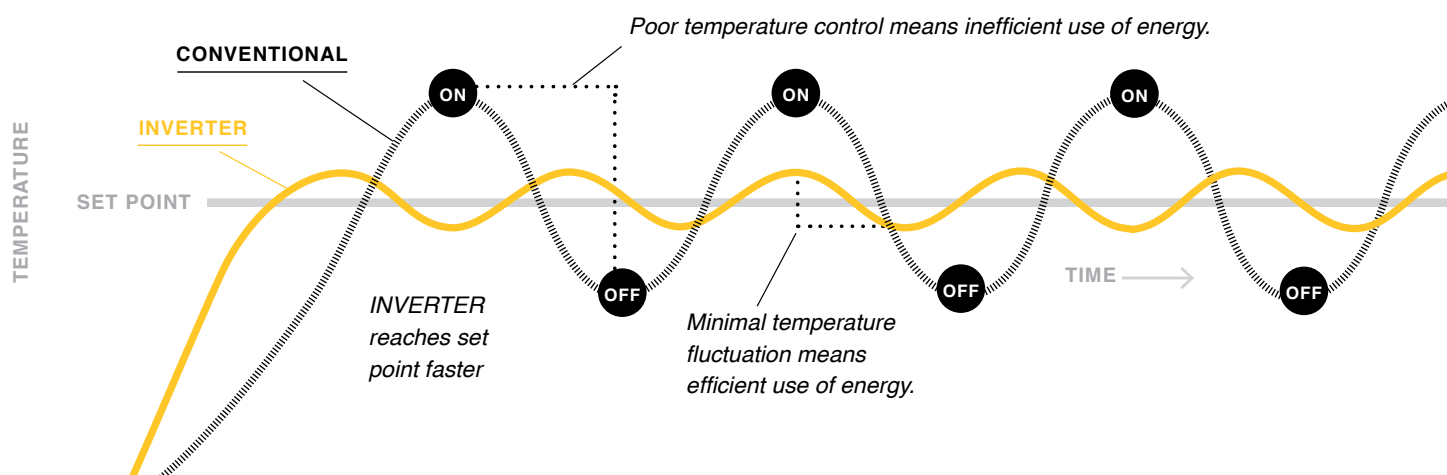
SMART COMFORT

The appeal of VRF systems goes beyond sustainability. Through zoning and advanced controls, VRF can address the expectations formed by widely-available smart technologies that provide individuals with near-instant access to information, commerce and entertainment. While occupants are looking for personalized local comfort control, building owners and facility managers are demanding better-centralized control of equipment through more sophisticated controllers and building management systems (BMS). VRF offers sophisticated controls and [can integrate with a BMS](#) through standard protocols like BACnet® for efficient management, reporting and tighter control of usage and utility costs.

In addition to providing personalized, energy-efficient, thermal comfort, VRF systems provide a more comfortable auditory environment by **keeping operational noise to a minimum**. VRF indoor units run at whisper-quiet sound levels between 19 and 34 decibels while VRF outdoor units operate at levels as low as 58 decibels, which is not louder than a typical conversation. The low level of operational noise coupled with how VRF units are relatively compact compared with traditional HVAC units give architects, engineers, HVAC contractors and building owners a range of options that maximizes usable space.

THE INVERTER ADVANTAGE

As the mechanism that controls the capacity within the system, the compressor has been referred to as the heart of HVAC systems. The compressor serves the same mechanical function in both traditional HVAC systems and VRF systems but has distinct electrical characteristics in each requiring different approaches for service and diagnosis. In traditional HVAC systems the compressor runs at the same speed regardless of the load, **while in VRF systems the compressor is equipped with an inverter that enables the compressor to vary its speed and capacity to match the cooling or heating load of a space at a particular point in time.** The metaphor of the heart is more apt for the inverter-driven compressor of VRF systems. Just as a human heart beats faster during exercise and slower during sleep, the inverter-driven compressor enables VRF systems to automatically **adjust conditioning in response to user commands and environmental conditions.**



GETTING STARTED

When designing HVAC systems, the HVAC contractor or mechanical engineer will perform a room-by-room load calculation according to Air Conditioning Contractors of America (ACCA) guidelines published in Manual J®. Then, following the guidelines published in ACCA Manual S®, the project team will determine the appropriate tonnage or system size to specify. Both sets of calculations use American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) **design temperatures that account for the coolest and the hottest days the site is expected to experience in a year.** If the HVAC system is undersized, it will fail to provide enough heat on cold days, but an oversized HVAC system creates temperature swings and wastes energy by short cycling: constantly turning on and off.

While sizing and load calculations must account for extreme temperatures, design temperature days only occur a few times per year. HVAC systems typically operate in part-load conditions. With tonnage specified for the design temperature days, traditional HVAC systems are effectively oversized. If two tons

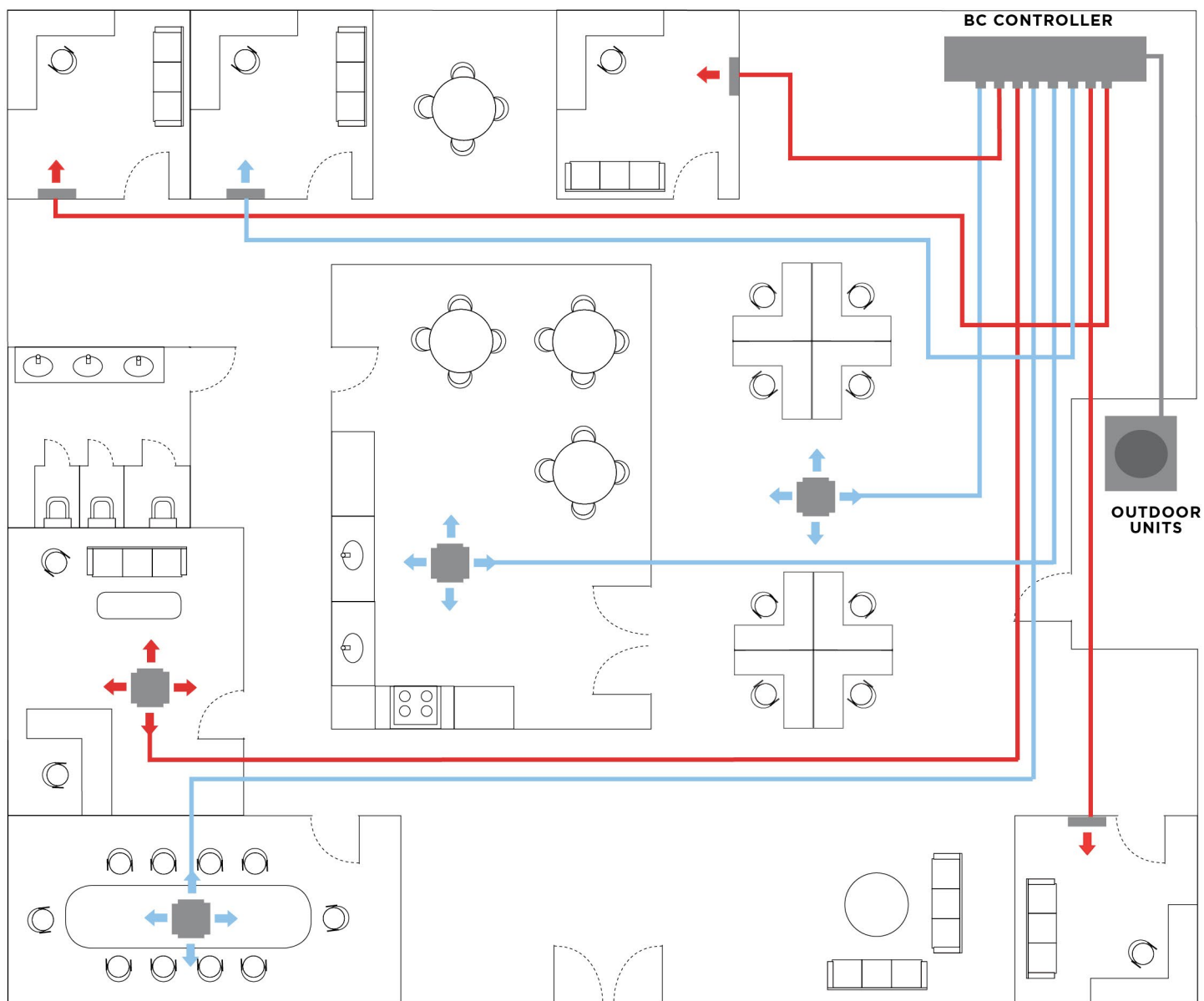
were specified for a temperature of 86 degrees and 50 percent humidity, there is an excess of tonnage if the HVAC system's compressor runs at the same speed during more common temperatures; say 70 degrees for this example. Perhaps the actual load on most days only requires half of a ton. During the "shoulder season" between design day extremes, the fixed speed compressors of traditional HVAC systems are unable to transition between maximum capacity and low-capacity output leading to a low turndown ratio.

Fixed-speed compressors in conventional HVAC systems are either running at full power or turned off, **but the inverter-driven compressor of a VRF system continually adjusts the flow of refrigerant to precisely meet the actual load of each zone.** In this way, VRF's variable capacity effectively eliminates the issue of oversizing as well as the energy-intensive process of turning a compressor on and off to meet loads, which are subject to change throughout a day and vary according to how occupants use spaces. This increases energy efficiency by up to 25 percent over conventional HVAC systems.

FALSE MYTH

Sizing guidelines don't apply to VRF systems

The ability of VRF systems to successfully manage part load conditions and vary capacity to meet conditioning requirements should not be taken as license to forgo load calculations and ACCA sizing guidelines. A VRF system is still an HVAC system, and optimal performance requires precise load calculations that account for all variables including ventilation, geospatial orientation and how occupants will use each zone.



SIMPLIFIED ZONING

Unitary HVAC systems package cooling, heating and fan components together within a single unit that serves multiple rooms, or zones. To condition interior spaces, HVAC contractors must install ductwork that runs from the main unit and splits off into different rooms. **Zoning is possible with unitary systems but requires dampers and space-intensive ductwork.**

If a commercial building uses a chiller, the HVAC contractor will install pipes in the range of four to eight inches in width to allow heat transfer between the rooftop water tower and the interior spaces.

In contrast, a VRF system consists of an outdoor unit and a network of indoor units connected via refrigerant lines and governed by a network of controls and sensors. The outdoor unit contains the condenser coil, heat exchanger, and fan(s). **The indoor units contain fan(s), a filter, a heat exchanger and environmental sensors. Each outdoor unit may be connected to multiple indoor units and individual outdoor units may be combined to increase tonnage.** Rather than running extensive ductwork, the HVAC contractor installs refrigerant pipes and wires from the outdoor unit to each zone's indoor unit. Giving each zone its own indoor unit simplifies zoning and saves space with the largest refrigerant pipe having a width of an inch and three eighths.



INSTALLATION IS DIFFERENT

Zoning and installation are simplified **due to the significant reduction in ductwork with VRF systems**. That said, HVAC contractors who are experienced with traditional systems should not assume installing a VRF system is the same as installing more familiar HVAC systems.

FALSE MYTH

Installing VRF systems is just like installing all traditional systems

VRF systems are electronics-based allowing continuous communication between components. While wires in conventional systems transmit electricity, VRF systems use wires designed to carry information as well as voltage. For example, while older systems used thermostats that were little more than a series of switches, **a VRF system uses a controller that transmits system performance data**. This is a key difference. Installing the familiar wiring of a traditional system will distort and disrupt necessary communication within the VRF system. HVAC contractors must concern themselves with maintaining the integrity of signals rather than just the flow of power.

When installing a conventional system, HVAC contractors consider the maximum length of refrigerant piping and follow manufacturer guidelines concerning how much refrigerant to add based on environmental factors including temperature readings, outdoor conditions and room temperatures.

With a VRF system, pipe sizing is important, but the length of pipe is the key factor used to determine the specific amount of refrigerant needed when the system is charged. HVAC contractors will want to follow VRF manufacturer guidelines and refrigerant density considerations informed by ASHRAE Standards 15 and 34.

To communicate and function properly, the indoor units, outdoor units and controllers must be addressed according to VRF manufacturer specifications. Addresses are assigned to each unit of equipment via a set of dials or rotary switches. In addition to providing necessary training on how to address systems, VRF manufacturers may provide software that automatically selects address numbers to help HVAC contractors avoid errors.

IAQ AND VRF

VRF systems provide zone filtration and allow for the integration of ventilation air. To ensure compliance with the ventilation requirements of **ASHRAE Standard 62.1** and the International Mechanical Code, HVAC contractors can apply an Energy Recovery Ventilator (ERV) or a Dedicated Outdoor Air System (DOAS) with VRF. **Specialized mechanical systems** engineered for use with VRF systems are energy-efficient with all the benefits of variable capacity and can deliver ventilation rates of 30 percent or more above ASHRAE 62.1-2007 requirements.

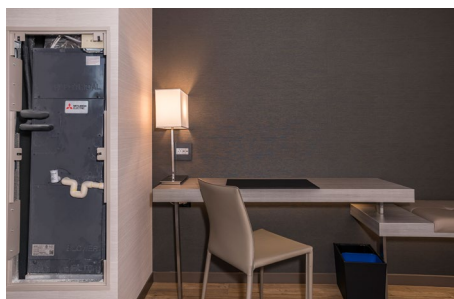
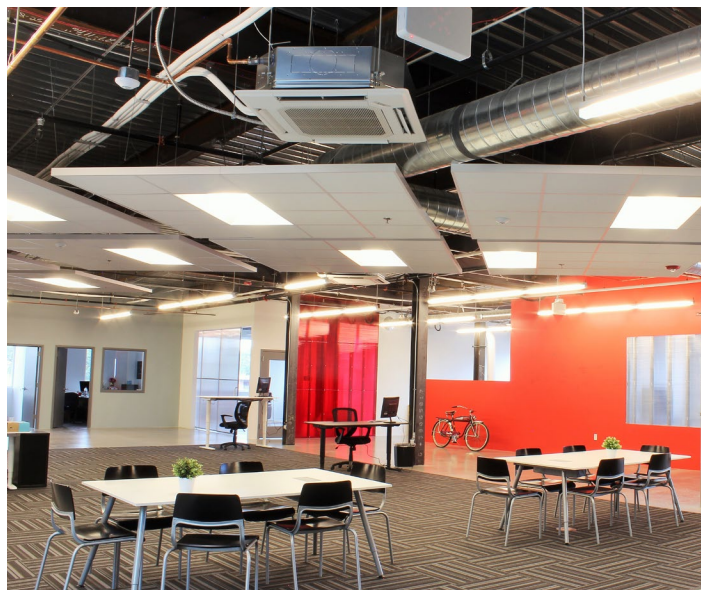
VARIETY AND VRF

HVAC contractors may encounter the misconception that VRF indoor units are only available as wall-mounted, ductless models.

FALSE MYTH

VRF indoor units are always wall-mounted

In fact, depending upon the application and aesthetic considerations, a zone may be served **by a wall-mounted unit, a low-wall unit, a ceiling-recessed cassette or a ceiling-suspended unit, among other styles.** Ductless systems were once primarily considered for renovations, but the diverse options available today make ductless systems appropriate for new construction and a wide range of applications.



FALSE MYTH

VRF applications are always ductless

HVAC contractors may encounter the misconception that VRF applications are always ductless. This is false. **HVAC contractors can install multi-position air handlers and fully-concealed, horizontal-ducted units that connect to VRF outdoor units via refrigerant lines.** Whether ductless or ducted, VRF systems provide the advantages of variable capacity and simplified zoning. Also, for some projects, a hybrid application is the best choice.

HEAT PUMP OPERATION

During cooling, the outdoor unit will pump liquid refrigerant to a zone's indoor unit. **The refrigerant will absorb heat from the zone as the liquid is vaporized by the indoor unit's heat exchanger which functions as an evaporator during cooling.** Now carrying unwanted heat, the refrigerant gas will return to the outdoor unit so the refrigeration cycle can begin again.

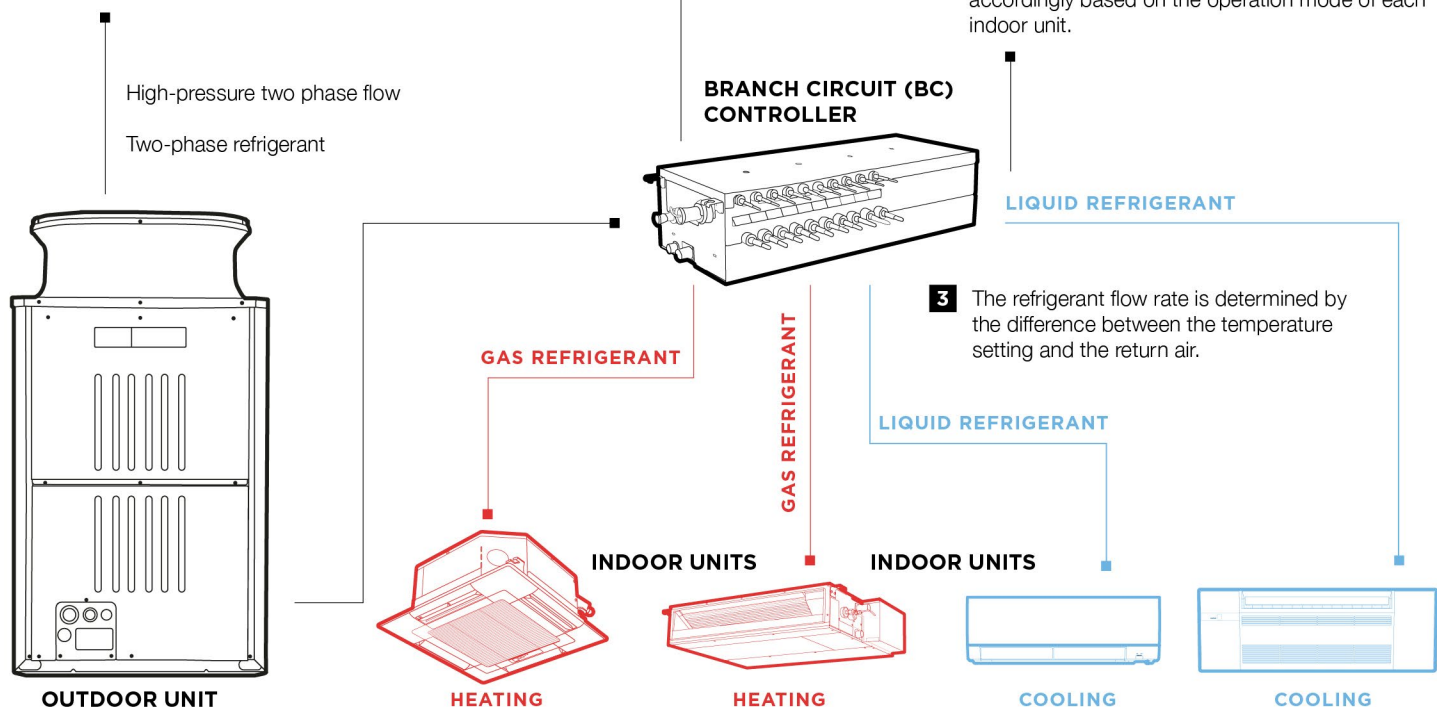
The outdoor unit's compressor converts low-pressure refrigerant gas from the indoor unit into a high-pressure gas. As the refrigerant gas is compressed, its temperature rises. **The hot, high-pressure gas then passes through a heat exchanger which will function as a condenser and extract heat. Now condensed into a lower-temperature liquid, the refrigerant flows to the indoor unit's expansion devices which reduces the liquid's pressure.** With lower pressure, the boiling point and temperature of the refrigerant will decrease and enable it to once again absorb heat.

During heating, the process is reversed. The refrigerant absorbs ambient heat as it is vaporized by the outdoor unit's heat exchanger and the compressor pumps hot, high-pressure refrigerant gas to the indoor units. In heating mode, the indoor unit's heat exchanger functions as a condenser which liquifies the refrigerant and releases heat into the zone. The liquid refrigerant then passes through expansion devices and flows back to the outdoor unit where it can again be used to absorb ambient heat.



VRF WITH HEAT RECOVERY

- 1 Compressor frequency and heat exchanger mode are determined according to whether the pressure is high or low to control the refrigerant flow rate.



HEAT RECOVERY?

Standard VRF heat-pump systems are either in cooling mode or heating mode. Throughout the building, indoor units are either receiving refrigerant gas for heating or liquid refrigerant for cooling. **These VRF systems are appropriate for large, single-zone applications such as auditoriums, theaters, gyms, dance clubs and restaurants.** Standard heat-pump VRF systems are also used in warm climates where cooling is required all year.

When applied with heat recovery, VRF heat-pump systems have the ability to provide simultaneous cooling and heating. In VRF applications with heat recovery, sophisticated controls and a heat-recovery module will direct refrigerant gas to indoor units in heating mode and liquid refrigerant to indoor units in cooling mode. Heat-recovery VRF systems can transfer refrigerant to indoor units directly from the outdoor unit, but can also transfer refrigerant between indoor units that are in opposite modes. With this capability, heat-recovery VRF

systems are able to repurpose heat that would otherwise be rejected at the outdoor unit's condenser and leverage load diversity to increase total applied capacity by up to 150 percent over the rated capacity of the outdoor unit. Also, some VRF systems are equipped with a branch circuit controller engineered to provide simultaneous cooling and heating with just two refrigerant pipes. This design reduces installation costs.

FALSE MYTH

HVAC contractors can save clients money with heat pump VRF systems in diverse applications that require heat recovery

While both types of VRF systems are equipped with sensors, controls and an inverter-driven compressor to meet the load of a zone in a particular moment, comfort issues will arise if the HVAC contractor and project team specify heat-pump VRF systems for buildings where some zones may require heating at the same time others require cooling. **Multi-family buildings, office buildings and hotels are examples of applications that require VRF systems with heat recovery.** Selecting the correct VRF system and educating clients about the difference between heat-recovery and heat-pump systems are key to each project's success. Yes, heat-pump VRF systems have a lower upfront cost, but selecting the appropriate system is less expensive than a callback that might ultimately result in replacing the system.

THE BASICS STILL MATTER

While more sophisticated than traditional HVAC systems, a VRF system is still an air conditioning system based on a refrigeration cycle. To reduce the risk of callbacks when installing and servicing VRF systems, HVAC contractors must continue to adhere to certain HVAC best practices.

FALSE MYTH

Triple evacuation is optional for VRF systems

Since a refrigeration system should not contain moisture inside its pipes before startup, HVAC contractors should not neglect to perform triple evacuation to a minimum of 500 microns when installing a VRF system.

Many of the maintenance requirements for a VRF system are the same in principle as for traditional HVAC systems. **With the addition of diagnostic software provided by VRF manufacturers, HVAC contractors will use familiar servicing equipment to clean coils, clean drains and ensure quality airflow.**

VRF indoor units are equipped with easily accessible, washable filters that can last for up to 10 years.

ONGOING EDUCATION

Electricity is electricity. Thermodynamics is thermodynamics. Refrigeration is refrigeration. VRF technology does not magically change any of these foundational elements of air-conditioning systems. To successfully install and service VRF systems, **HVAC contractors must draw upon the science they have already learned and supplement that science with new knowledge for electronics-driven systems.** The situation is analogous to how in the automobile industry mechanics cannot fully service a modern vehicle — even one with a traditional combustion engine — without training that would be wholly unrecognizable to mechanics from the 1950s. VRF is a highly-computerized HVAC system and HVAC contractors require specialized training to stay current as the technology evolves and changes.

Training equips HVAC contractors so that they can properly educate end users about how VRF systems are operated. Providing accurate information and guidance to end users helps avoid service calls that result from misunderstandings.



TRAINING PROVIDED BY MANUFACTURERS

Just as HVAC contractors recognize they can not install and service sophisticated VRF systems without VRF-specific training, VRF manufacturers recognize that they cannot succeed without a well-trained network of design, installation and service professionals.

Mitsubishi Electric Trane HVAC US (METUS) offers industry-leading courses accredited by the [International Association for Continuing Education and Training](#) (IACET) at state-of-the-art training centers across the United States. By enrolling in training classes provided directly by METUS, **HVAC contractors benefit from in-depth discussions of the techniques associated with installing commercial CITY MULTI® VRF systems and have opportunities to learn through practice with VRF equipment.** Instruction covers subject areas including best practices, limitations and manufacturer's requirements that pertain to design, wiring, addressing, refrigerant piping, installation, maintenance, controls and software unique to VRF systems.

Paul Chaves, Technical Training Manager at METUS, said "The number one reason contractors should attend our classes is to prevent callbacks. If something goes wrong, they have to go back and fix the problem, and they can't charge the end customer for that. They carry the cost in time and labor, and that eats up the profit margin on the job. **The first step in limiting callbacks with VRF systems is attending the manufacturer's training. METUS offers different levels of training, from basic classes to advanced classes, and if contractors take them, and follow the procedures discussed in class, they can walk away from a job knowing they've minimized the risk of a callback due to workmanship.** The contractors will know the proper way to install VRF, which eliminates most problems before they start, and even if there is an issue the equipment will be under extended warranty so the problem can be addressed with no cost for parts to the contractor."

As the portfolio leader responsible for ductless solutions for Trane Commercial HVAC, Matt Barga has firsthand experience with the training provided by established CITY MULTI experts and a clear vision for how the expanded capabilities of METUS, a joint venture between Ingersoll Rand and Mitsubishi Electric US, Inc., significantly increases the opportunities for HVAC contractors to obtain the training they need.

Barga said, "Before the joint venture, the Mitsubishi Electric team did a great job building and capturing a substantial share of the VRF market. We've been working with them very closely to develop the right level of capability inside our channel. **Our Trane commercial sales team has received extensive training on CITY MULTI inclusive of product overviews and software and application guidance.** We've taken our post-sales technical support team, which is distributed in our channel, through some of that same training plus additional application, installation and maintenance training on VRF. Over the first 12 to 18 months of the joint venture, we're installing 30 training centers within our offices and are now training our technical team to train contractors who will in turn train customers on our products and applications. By making sure every part of the value chain has adequate understanding of our offerings, we're demonstrating METUS's commitment to no problem jobs."

"No-problem jobs" are the function of proper design and execution and also provide the additional benefit of an extended warranty. Barga continued, "We want to train contractors so they know how to apply the product and design the HVAC system so that it leverages the strengths of the CITY MULTI VRF system and avoids potential application pitfalls. Some of the training is about making sure the contractor and the customer end up with the right design. **The second piece is about execution: correct installation of the equipment and interconnecting piping as designed.** Also, we know that in the field contractors can encounter things that were unforeseen during design, such as an obstruction. We provide training on how to go back and update the design so that the as-built report matches what is installed in the field, which is one of the requirements for getting the extended warranty. When a VRF system is installed by a manufacturer-trained contractor, the contractor has the right skills to troubleshoot any minor issues and the building owner becomes eligible for a 10-year extended warranty."





TRAINING PROVIDED BY DISTRIBUTORS

In addition to attending training offered by VRF manufacturers, HVAC contractors can increase their expertise and marketability by attending training classes provided by established distributors of VRF technology.

With over 60 years as an HVAC solutions wholesaler in the Mid-Atlantic region, **Aireco, Inc., based in Laurel, Maryland, was the first distributor to carry CITY MULTI VRF technology from METUS in Washington, D.C., Maryland and Virginia.** For over five years, Aireco's Advanced Products Group (APG) has offered year-round, comprehensive and hands-on training for METUS VRF equipment.

Tim Kemp, technical service advisor, has worked with Aireco for over 30 years and is one of the lead instructors in the APG-provided classes. Drawing upon years of direct experience, Kemp introduces VRF concepts and theories along with in-depth functional studies of the technology. To reinforce the concepts and ensure the confidence of students turned practitioners, APG classes include practical troubleshooting exercises with VRF systems. Kemp said, "By completing these classes and getting familiar with how a VRF system operates, students have completed the first step. They know how the

system is supposed to work and so they can figure out if something has gone off the rails. That makes it a little less intimidating when they go to install or service CITY MULTI systems. We like to mix as much hands-on instruction as we can with the lecture side of things, so students get a better understanding. Also, for the CITY MULTI class, we spend time on system design."

According to Kemp, one of the most popular class topics is simultaneous cooling and heating. "One of the biggest mysteries to most students is how one system can heat and cool at the same time, which is one of the biggest advantages of CITY MULTI heat-recovery VRF. We review the refrigerant circuit, and we have an animated flow diagram that explains how the system works."

Among the biggest advantages of attending training at APG's state-of-the art training facilities in Savage, Maryland or Newport News, Virginia is local support from startup and commissioning to ongoing operations and maintenance. Kemp said, "I give everybody in the class my card. They have my email and phone number. If they get in a pinch, they can call me or if necessary, I can swing by the job."

CONCLUSION

As the VRF market continues to expand and VRF technologies continue to evolve, the demand for HVAC contractors with expertise in these systems will only grow. By taking advantage of training provided by VRF manufacturers and distributors, HVAC contractors can distinguish themselves and elevate their businesses above contractors who attempt VRF projects without the requisite training. **Given the opportunities, HVAC contractors have every reason to resist the fear of unfamiliar or highly-sophisticated technologies like VRF and understand that the resources they need to succeed are readily available.** To learn more and schedule VRF training, HVAC contractors may visit mitsubishipro.com/training.