What is VRF? Why Choose VRF?

Introduction:

A VRF system is one outdoor unit (can be up to three units combined into a larger capacity module) connected to multiple types of indoor units through a single refrigerant piping network. Each indoor unit, or zone, is controlled by its user or by a central controller which can operate several zones. The system constantly varies the amount of refrigerant flowing to each indoor unit to match the internal load requirement, by allowing the compressors to work only at the needed capacity to meet that load. This consumes less energy than on/off systems; even if VRF run time is longer. When correctly designed, a VRF system is usually operating at a capacity less than 100%.

Definition:

A VRF system is a sophisticated heat pump system. At the very basic level, a VRF system, heat pump or heat recovery, is a heat pump. A VRF system has a single outdoor unit connected to multiple types of indoor units through a single refrigerant piping network. In North America all VRF systems currently use R410a as the refrigerant. ASHRAE, American Society of Heating, Refrigeration and Air Conditioning Engineers, and AHRI, Air Conditioning, Heating and Refrigeration Institute, have set the definition for VRF. The main criteria are that the system has a common refrigeration network and three steps of control.

ASHRAE defines VRF as,

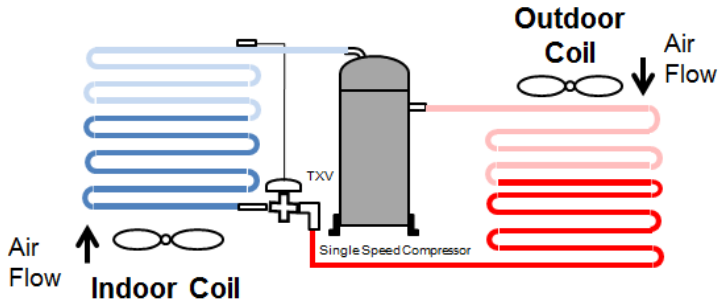
> Variable Refrigerant Flow (VRF) System: An engineered direct expansion (DX) multi-split system incorporating at least one variable capacity compressor distributing refrigerant through a piping network to multiple indoor fan coil units each capable of individual zone temperature control, through integral zone temperature control devices and common communications network. Variable refrigerant flow utilizes three or more steps of control on common, inter-connecting piping.[i]

AHRI defines VRF as,

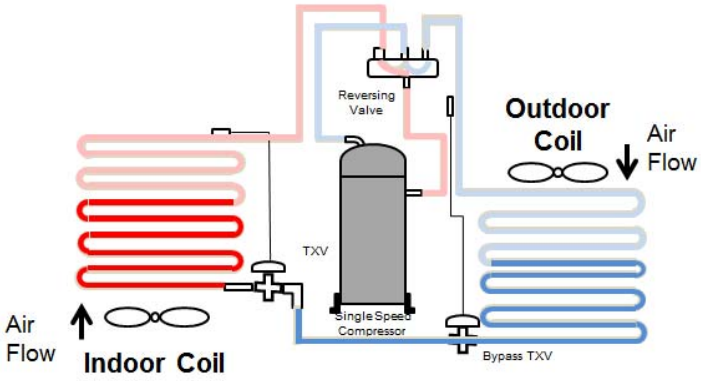
> *VRF Multi-Split System*. A split system air-conditioner or heat pump incorporating a single refrigerant circuit, with one (1) or more outdoor units, at least one (1) variable speed compressor or an alternative compressor combination for varying the capacity of the system by three (3) or more steps, multiple indoor fan coil units (each of which is individually metered), and individually controlled by an integral control device and common communications network. The system is capable of operating either as an air-conditioner or a heat pump.
>
> *VRF Heat Recovery Multi-Split System*. A split system air-conditioner or heat pump incorporating a single refrigerant circuit, with one (1) or more outdoor units, at least one (1) variable-speed compressor, or an alternate compressor combination for varying the capacity of the system by three (3) or more steps, multiple indoor fan coil units, each of which is individually metered and individually controlled by a integral control device and common communications network. This system is capable of operating as an air-conditioner or as a heat pump. The system is also capable of providing simultaneous heating and cooling operation, where recovered energy from the indoor units operating in one (1) mode can be transferred to one (1) or more other indoor units operating in the other mode.[ii]

Evolution:

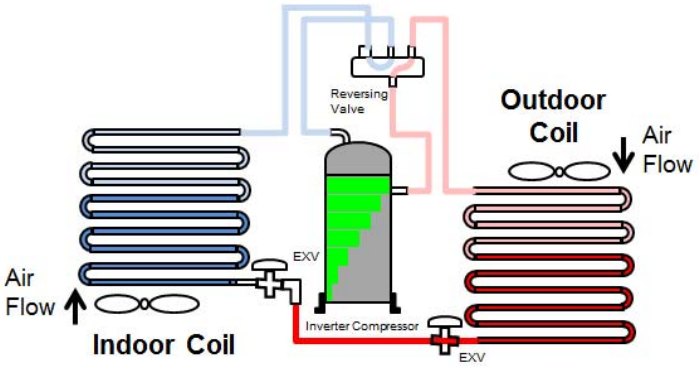
VRF systems operate like heat pumps and follow the same refrigeration cycle as any other comfort cooling equipment. The evolution of VRF systems can be traced back to single-speed air conditioning units. They had a single-speed compressor, a condenser, a metering device and an evaporator. The system could only cool, not heat.



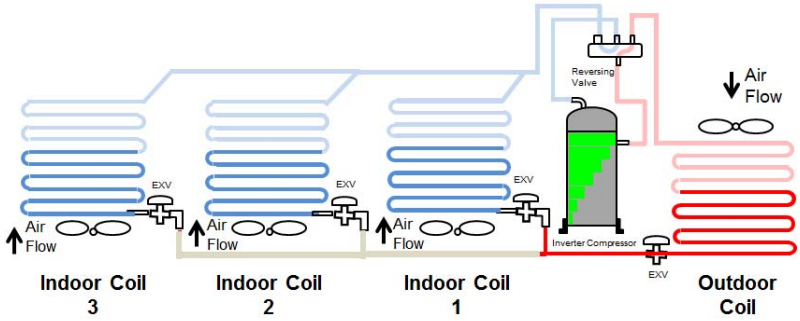
The single-speed air conditioner was followed by the heat pump system; a reversing valve and a metering device at both the indoor and outdoor coils were added which were the main components that enabled the system to have the ability to produce heating and cooling without the requirement of a supplementary heating component.



Next was the introduction of the inverter compressor to vary the speed and electric expansion valves that allowed for capacity modulation. This provided more precise control and capacity.



In order to have zoning capabilities, additional indoor coils were added to the system. This allowed for individual temperature control of each zone. With an inverter compressor, the system operates at a capacity meeting the internal load, increasing the overall efficiency. The efficiency is gained by reducing the capacity at part-load conditions; most systems operate 60% to 80% of the time at part load. As additional zones call for cooling, the compressor speeds up to provide the needed capacity. As a zone is satisfied or the cooling load decreases, the compressor slows down and reduces capacity to only what is needed. This makes the system highly efficient because it is only providing the capacity needed and not wasting energy.



Key Components:

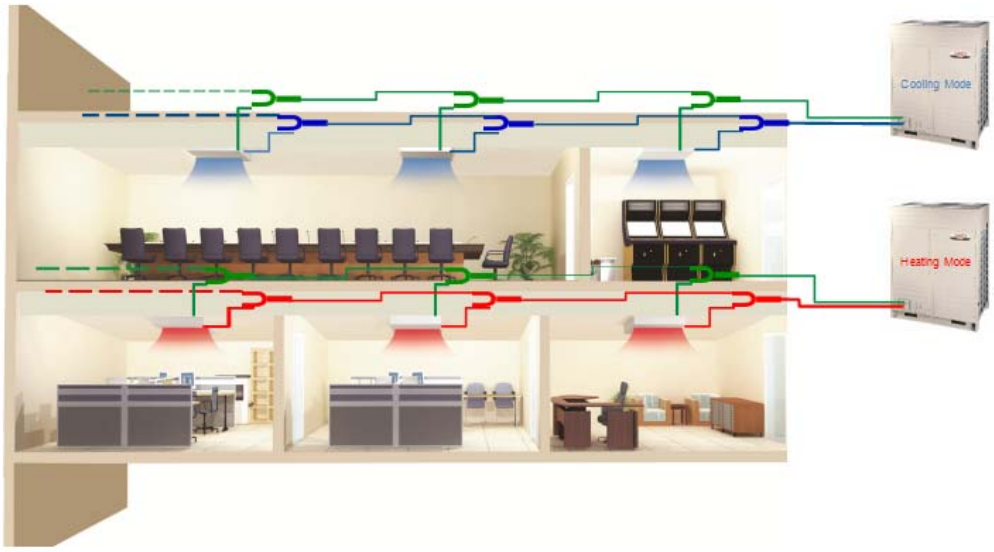
There are two key components to a VRF system; a variable speed, inverter driven, digitally commutated compressor, and the electronic expansion valve, or EXV.

VRF systems use inverter technology with electronic expansion valves to control the refrigerant flow for varying capacity. The inverter is an electronic component that varies the speed of the compressor. By varying the compressor speed, the refrigerant mass flow rate increases or decreases to match the required internal load. This allows the VRF system to only produce the necessary required capacity at any one time. Most VRF manufacturers have moved to all inverter-driven compressors at the outdoor unit.

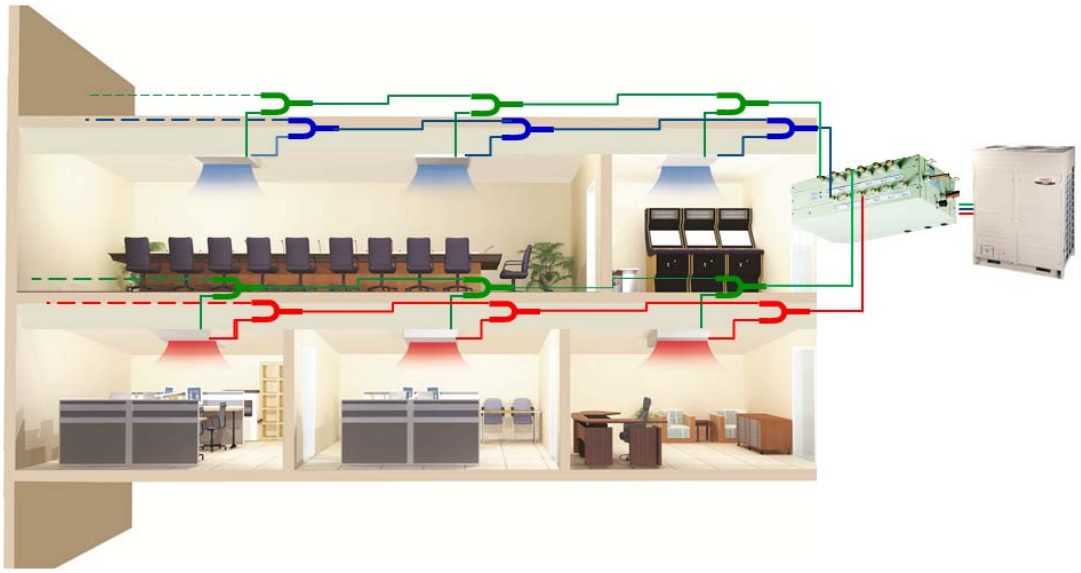
The electronic expansion valve, EXV, opens and closes in increments allowing the precise amount of refrigerant to flow through the evaporator coil. The EXV also opens to a preset position during heating operation to allow refrigerant flow through the condenser, thus eliminating a by-pass check valve. Each indoor unit has an EXV. The EXV has a variable “pulse rate”; it modulates the refrigerant flow at the indoor unit. It allows the indoor unit the required amount of refrigerant to meet the zone demand.

System Types:

VRF systems are offered in heat pump and heat recovery systems. A VRF heat pump system can heat OR cool the space; it cannot do both at the same time. A VRF heat recovery system allows for simultaneous heating and cooling of individual spaces. The heat recovery VRF system moves recovered heat from one area to another. This is a total comfort controlled system allowing cooling in one area and heating in a different area at the same time. The ability to use the waste heat created when cooling a space to heat a different space is the true value of the heat recovery system. Most heat recovery systems are known as a 3-pipe system - Liquid pipe, high pressure gas-discharge pipe, and low pressure gas-suction pipe.



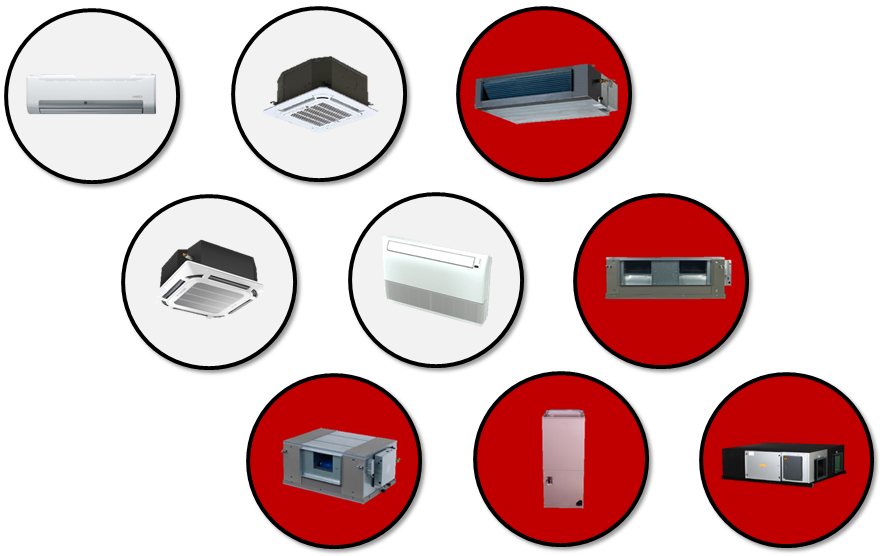
Two Heat Pump Systems



One Heat Recovery System

Indoor Units:

Indoor units are offered in a variety of types and capacities to meet a variety of applications. Typical VRF indoor unit styles include non-ducted wall and ceiling mounted units. Typical ducted styles are medium and high static horizontal and vertical air handlers.

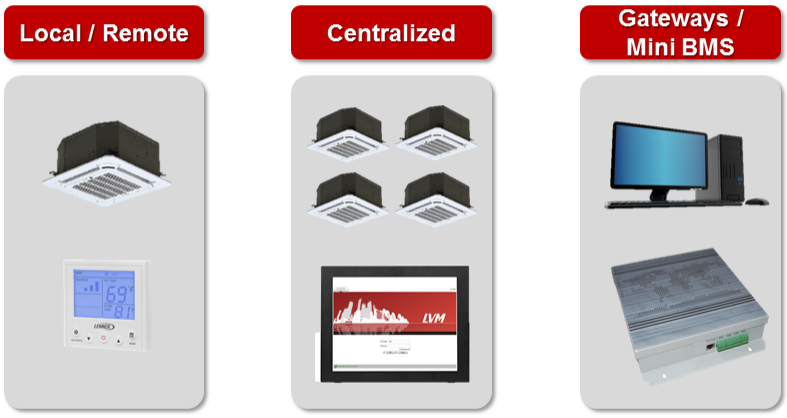


Mode Selector Box:

A mode selector box, also known as a heat recovery box, is used on VRF heat recovery systems to allow simultaneous heating and cooling. It sets the mode of the indoor units “down-stream” of the MS box.

Controls:

VRF controls give feedback to the VRF system as to the space load requirement. This is typically a daisy-chained communications system that can allow for individual zone mode control (heating or cooling) and temperature control. Through the use of gateways or interfaces, the VRF control system can be connected to BACnet or LonWorks building management control systems.



Accessories:

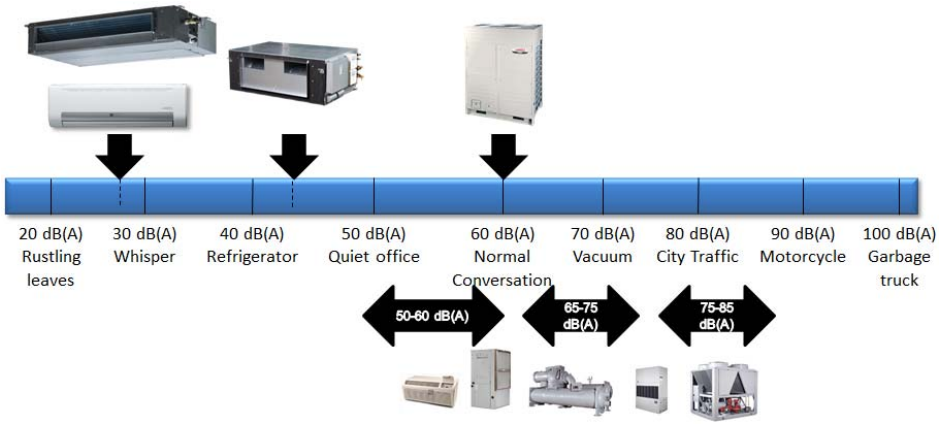
Accessories can range from condensate lift pumps, control for auxiliary heat options, refrigerant piping branch connectors, and remote room sensors.

Advantages:

VRF systems have many advantages over conventional on-off systems.

Quiet performance:

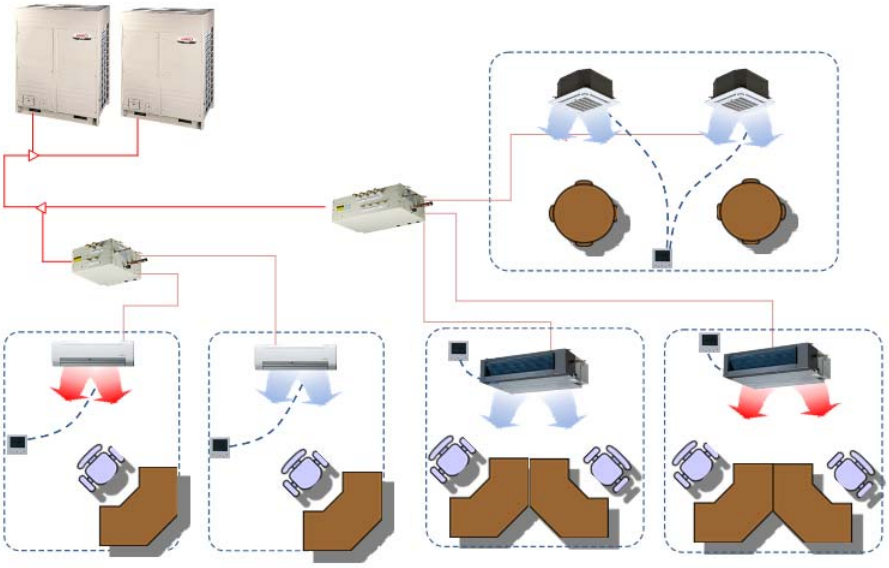
VRF Outdoor Unit sound ratings are comparable to indoor units of other HVAC systems. VRF Indoor Unit sound ratings are often compared to whispering. Many indoor units are so quiet that it is hard to tell they are operating until you see the louvers move.

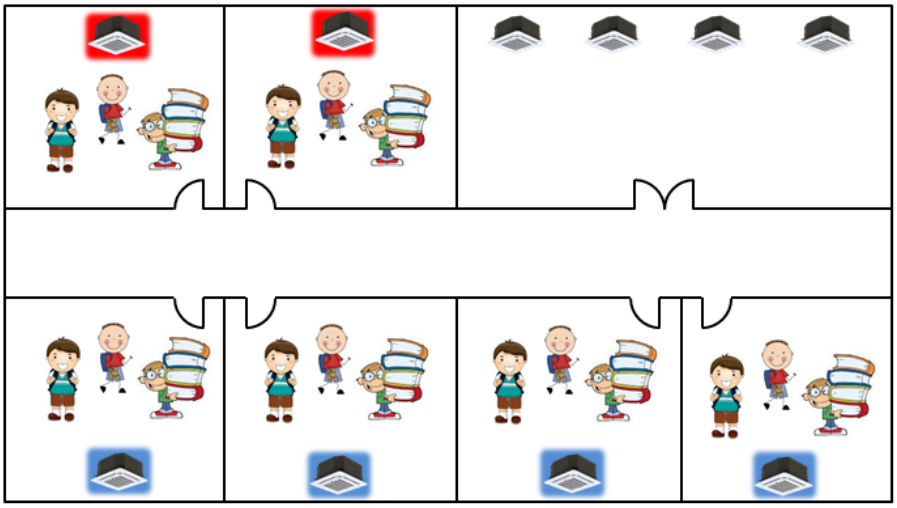


Superior Zoning:

Superior individual zone control is possible with VRF heat recovery systems. Individual users can control the temperature in their own environment by providing cooling or heating when and where it is required. Each indoor unit controls its own environment by sensing the temperature of the return air and controlling the in-built electronic expansion valve accordingly. This provides a high level of comfort for the user. This is an excellent solution for buildings with varying loads and different zones. It is ideal for hotels, schools, and office

buildings where individual users want to have control over temperatures in their areas.

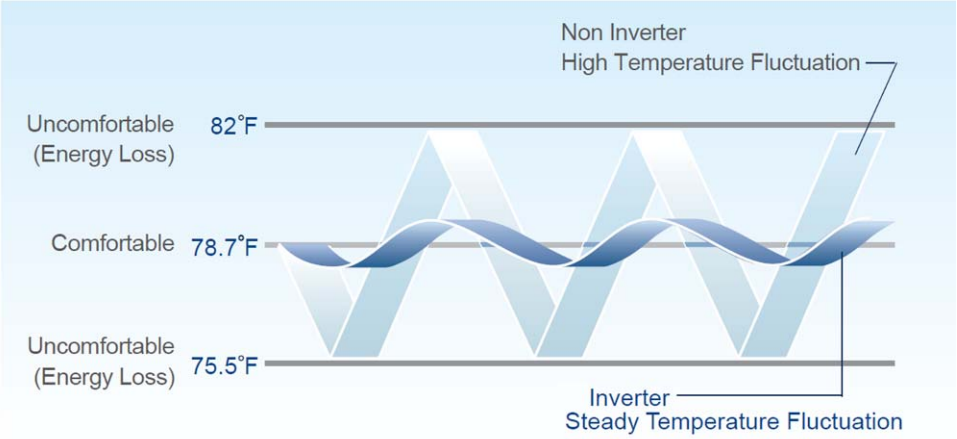




Even Zone Temperatures:

Low temperature fluctuation equals even temperatures in each zone. The compressor capacity meets internal load demand capacity for an even space temperature. This is improved comfort over a conventional on/off system. With the compressor capacity matching the internal load, the system operates using less energy and cycles on and off less eliminating cycle losses. By meeting the

actual heating or cooling demand, there is less temperature fluctuation in each individual zone.



Adaptable to Application:

VRF systems are modular, or scalable, in system capacity. Multiple modules can be added to meet design load capacities.

Modular versatility, varying capacities of outdoor units, and multiple types of indoor coils, both ducted and non-ducted, makes the VRF system a solution to meet a wide variety of applications. Multiple types of fan coils and sizes provide design flexibility for different applications. Outdoor units can be installed on a roof, at ground level or in an equipment room with proper intake and exhaust.

When space above the ceiling is at a premium, non-ducted indoor units make an excellent choice. No invasive ductwork means that VRF systems are ideally suited for many different types of structures including historical buildings. Refrigerant lines require much less space than sheet metal ducts.

Initial Vs. Lifecycle Costs:

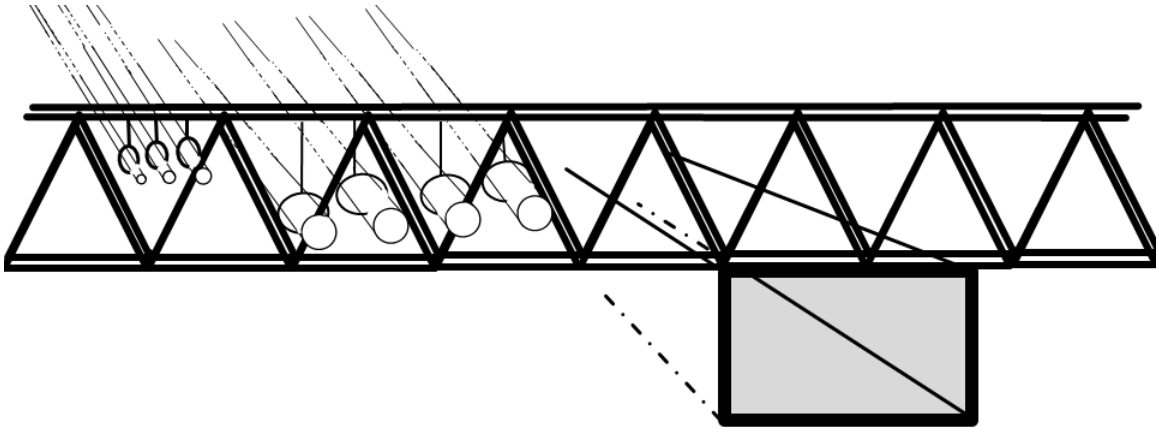
The initial costs of a VRF system vs. a four-pipe heating and cooling systems system are similar. It is the maintenance costs down the road that really hit the pocket book.

Quarterly maintenance of a VRF system consists of cleaning indoor unit filters, keeping the indoor and outdoor heat exchangers clean and checking condensate pumps and drains for leakage and blockages. Four-pipe heating and cooling systems on the other hand, require water treatment, cooling tower maintenance, water circulating pumps maintenance, central heating plant maintenance plus numerous amount of motorized valves and control items which require regular servicing plus keeping the indoor heat exchangers clean and checking condensate drains and pumps if used.

Less Intrusive:

Small refrigerant piping makes VRF systems less intrusive to the structure. Refrigerant pipe is significantly smaller than water pipe or duct. On a twenty-ton heating and cooling system the cross sectional area of water piping is ten times larger than refrigerant piping. On a comparable ducted system, the cross sectional area of the duct is two hundred and eighty four times larger than

refrigerant piping.



Not all VRF systems are ductless, but in a ducted VRF system, the individual zones are smaller which require smaller ducts. The smaller duct is easier to install where space is limited. As a general rule of thumb, in a ten-story building you can gain one entire floor by using refrigerant piping rather than ducts.

VRF systems require less space to move the same amount of capacity. Refrigerant piping takes up one hundred times less space than a ducted system.

Energy Efficiency:

A VRF system only uses the energy required to meet load requirements. VRF systems are extremely efficient by only using the energy required to meet the internal load, especially at part load operations. Depending on the application, most VRF systems operate at part load 60% to 80% of the time.

In a VRF heat recovery system, the waste heat generated by the indoor units that are cooling parts of the building is used to provide heating capacity to other indoor units that are providing heat to different parts of the building, further increasing the efficiency of the system.

Efficiency is measured in four metrics: IEER, Integrated Energy Efficiency Ratio; EER, Energy Efficiency Ratio; SCHE, Simultaneous Cooling and Heating Efficiency; and COP, Coefficient of Performance. Using these metrics, in general, VRF systems are highly efficient.

Other Advantages:

VRF systems in general are quite reliable. In fact, when correctly installed, the system seldom breaks down. VRF Systems transfer heat with refrigerant not water so cooling towers and circulating pumps are not required.

The VRF outdoor unit, or condenser, can be installed in many locations to suit the application. Outdoor units can be installed on ground level, on the roof, or pretty much anywhere in between. VRF systems do not require an equipment room and not having an equipment room provides more usable space. However, if an equipment room is required for the application, VRF outdoor units can be installed indoors.

The soft start of the inverter compressor eliminates lock rotor amps. Lower minimum circuit ampacity (MCA) allows for smaller wire size which can be a substantial savings on large jobs with multiple systems. For retro-fits, this can mean that the existing electrical supply is sufficient for the VRF system. Four-pipe system retro-fits may exceed the existing electrical supply.

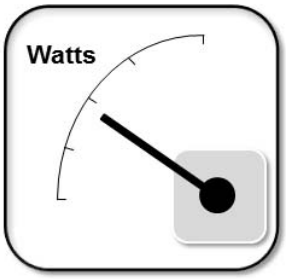
And lastly, VRF outdoor units can fit in a standard elevator which saves time and money. Traditional HVAC installations in hard to access locals like downtown Dallas require cranes and other heavy equipment and even for streets to be closed for several hours. A VRF outdoor unit weighs up to 600 pounds, it will take several people to move it in a freight elevator and proper safety precautions must be observed. However, if the alternative is to shut down a major through fair, a freight elevator is may be the best option.

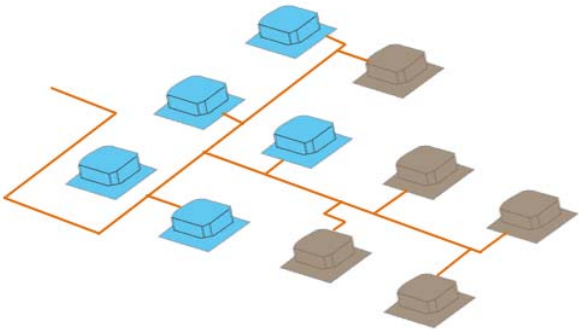
Design Conditions:

Many elements go into the design of a VRF system: the space layout - how is the space going to be used, types of indoor and outdoor units to be used, heating and cooling load considerations and how the refrigerant piping and condensate piping will be laid out. Individual comfort, zone limitations and reliability are also considerations.

How the building is used has a lot to do with whether or not a VRF system is the right fit. Buildings with many small zones are well served by a VRF system.

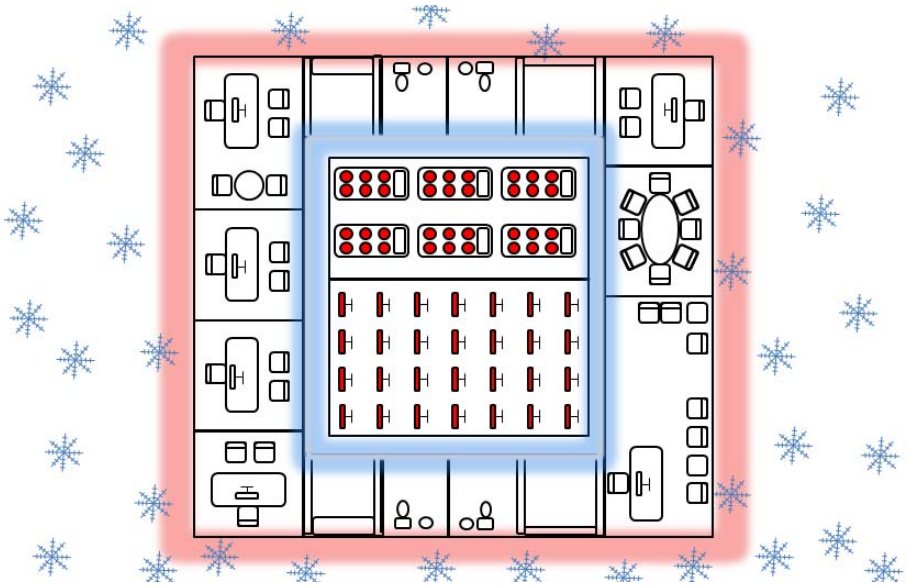
Part load conditions are where VRF systems really shine. Because the compressor only provides the capacity needed to satisfy demand, the system only uses the energy needed. When the load is low, the energy use is also low. As more indoor units call for cooling, the compressor ramps up to supply the demand.





The loads on a building can vary significantly. For example, in winter most of a building has a heating load. However, some areas like the cafeteria and kitchen areas almost always have a cooling load due to the heat generated while preparing and serving foods - the ovens, the refrigerators and refrigerated display cases - all that equipment generates a lot of heat, even in the winter. A mechanical room can also have a cooling load most of the time due to the equipment operating inside it. A VRF system can supply simultaneous heating

and cooling - serving the heating needs of the building's office space while meeting the cooling demands of the kitchen and mechanical rooms.



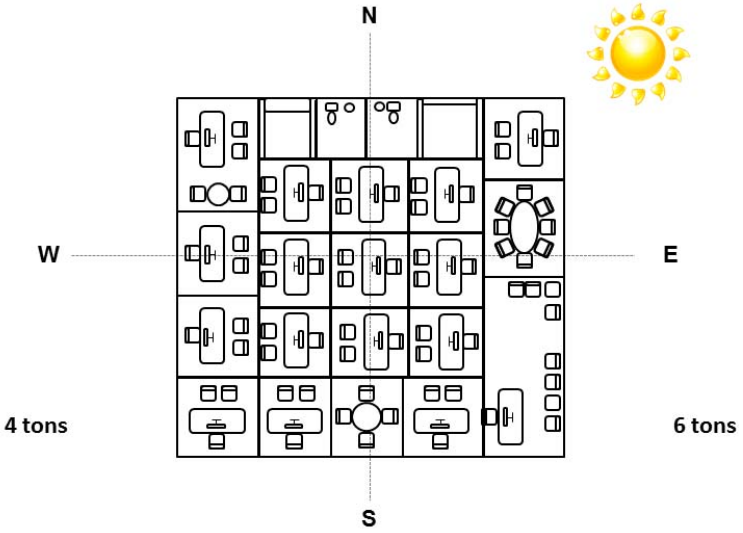
What kind of Indoor Units will work best for the building and for the occupants is another design consideration. Is there room for ducts in the building? Will occupants share a common space like a waiting room? Do occupants need their own control of the temperature? Are wall mounted or ceiling cassette units a better choice?

When designing the refrigerant piping network you must consider how you will lay out the piping. What obstacles such as structural beams exist within the building? How are you going to work around them? Every bend or elbow in the system piping has an equivalent length factor that has to be factored into the piping length parameters. Excessive bends and elbows can affect system performance. Care is required when determining how to route around.

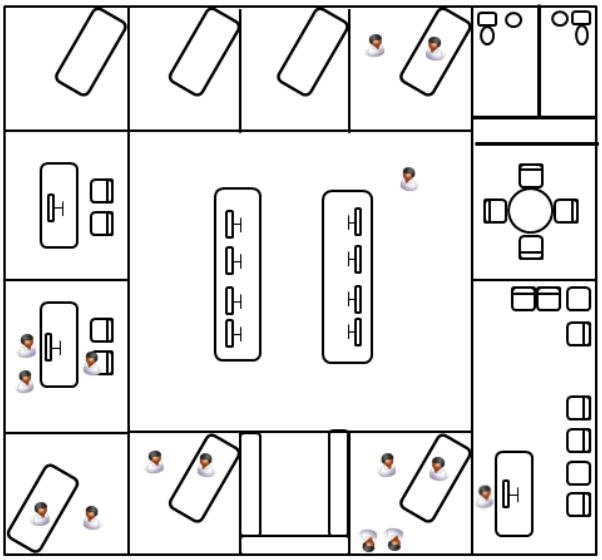
Design Diversity:

Diversity allows for a larger total indoor unit capacity than the total capacity of the outdoor unit. Typically 130% diversity can be applied to a building. That means that indoor units can have a connectable capacity of 130% above the outdoor capacity. That does not mean that the outdoor unit will operate at 130%, 100% is all of the capacity the outdoor unit can ever provide. True diversity means that not all of the indoor units will operate in any one particular mode at any one time, the internal load shifts during the day, so that outdoor unit capacity can be shifted as needed suit each indoor unit’s requirements.

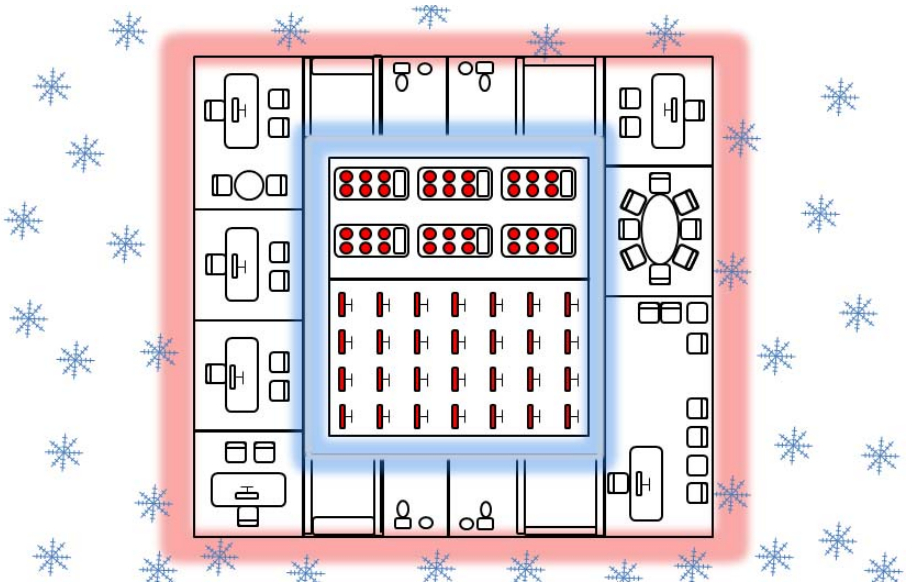
As the solar loads on the building move throughout the day, a VRF system can shift to meet that load by providing the capacity needed by each zone.



As the occupant loads change throughout the day, a VRF heat recovery system can shift the capacity to meet the load.



How is the building laid out? Is there a core to the building that needs different cooling than the exterior of the



building?

Local and Industry Standards:

Can VRF systems meet ASHRAE standards? Yes they can! Local, state, and industry standards are a factor with any HVAC system, VRF systems are no different. In fact, ASHRAE standards apply to the building as a whole, not just the HVAC system. VRF heat recovery and heat pump systems can be designed to adhere to local, state, and industry codes and standards.

ASHRAE Standard 15 Establishes safeguards for life, limb, health, and property and prescribes safety requirements for the design, construction, test, and inspection of refrigeration systems.

ASHRAE Standard 34 classifies refrigerants based on toxicity and flammability, and establishes acceptable levels of refrigerant concentration within a space. This is the standard that causes so much confusion. VRF systems and the buildings that house them can be designed to ensure the safety of the occupants and comply with this standard.[iii]

ASHRAE Standard 62 Provides guidance on the fresh air ventilation requirements of an occupied building.[iv]

Conclusion:

VRF technology combines multiple indoor fan-coil units with a single outdoor condensing unit circulating refrigerant as the cooling and heating medium. The Lennox VRF system adjusts capacity by continually altering the compressor speed according to the demand of each indoor unit, decreasing energy usage and lowering utility bills. Each indoor unit operates to an individual temperature set point, and indoor units connected to a single heat recovery system can operate in either heating or cooling mode simultaneously as needed. This zoning flexibility is ideal for providing optimum comfort in a wide variety of commercial spaces, such as offices, hotels, healthcare units, multi-family structures, retail spaces, education facilities and restaurants, among others. The innovative technology, unique design and unobtrusive installation of the system within the building walls allow engineers, contractors and owners flexibility in design, while maximizing energy savings.

A VRF System can be the right solution for many heating and cooling applications. Let the experts at Lennox VRF work with you to find the right VRF solution for your building. With a full line of heat recovery, heat pump, ducted, and non-ducted indoor units, as well as centralized and local controllers, the Lennox VRF system could be the right system for you.

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[i] *ANSI/ASHRAE/IES Addenda ce and cp to ANSI/ASHRAE/IESNA Standard 90.1-2007.American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. www.ashrae.org.www.ashrae.org/File%20Library/docLib/StdsAddenda/90_1_2007_ce_cp.pdf.*

[ii] *Operations Manual Variable Refrigerant Flow Multi-Split Air-Conditioners and Heat Pumps Certification Program. Air Conditioning, Heating, & Refrigeration Institute. http://www.ahrinet.org/App_Content/ahri/files/Certification/OM%20pdfs/VRF_OM.pdf*

[iii] Safety Standard for Refrigeration Systems and Designation and Classification of Refrigerants. ASHRAE. *https://www.ashrae.org/resources--publications/bookstore/standards-15--34.*

[iv] *Ventilation for Acceptable Indoor Air Quality. ASHRAE. https://www.ashrae.org/resources--publications/bookstore/standards-62-1--62-2.*