

Variable Refrigerant Flow (VRF) Systems

Flexible Solutions for Comfort



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Syracuse, New York**

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TABLE OF CONTENTS

INTRODUCTION	2	DESIGN CONSIDERATIONS	7-10
VRF TECHNOLOGY	2	Space Layout	7
ADVANTAGES OF A VRF SYSTEM.....	3-4	Type of System – Heat Recovery or Heat Pump?	8
Control Means Comfort.....	3	Size of Units	10
Design Flexibility	4	Piping Configuration	10
Cost Effective Installation	4	CONCLUSION	10
Energy Savings.....	4		
COMPARISON OF VRF SYSTEMS	5-6		
Single Variable Speed Compressor	5		
Variable Speed Compressor Plus Fixed-Speed Compressor.....	5		
Multiple Variable Speed Compressors	5		
Twin Rotary Compressor vs Scroll Compressor	6		

INTRODUCTION

Variable refrigerant flow (VRF) systems vary the flow of refrigerant to indoor units based on demand. This ability to control the amount of refrigerant that is provided to fan coil units located throughout a building makes the VRF technology ideal for applications with varying loads or where zoning is required.

VRF systems are available either as heat pump systems or as heat recovery systems for those applications where simultaneous heating and cooling is required.

In addition to providing superior comfort, VRF systems offer design flexibility, energy savings, and cost effective installation.

This paper will outline the benefits of a typical VRF system, describe the advantages offered by the most advanced outdoor units available, and provide general guidelines for selecting a heat pump system versus a heat recovery system.

VRF TECHNOLOGY

In a VRF system, multiple indoor fan coil units may be connected to one outdoor unit. The outdoor unit has one or more compressors that are inverter driven, so their speed can be varied by changing the frequency of the power supply to the compressor. As the compressor speed changes, so does the amount of refrigerant delivered by the compressor.

Each indoor fan coil unit has its own metering device that is controlled by the indoor unit itself, or by the outdoor unit. As each indoor unit sends a demand to the outdoor unit, the outdoor unit delivers the amount of refrigerant needed to meet the individual requirements of each indoor unit (Fig. 1).

These features make the VRF system ideally suited for all applications that have part load requirements based on usage or building orientation, as well as applications that require zoning.

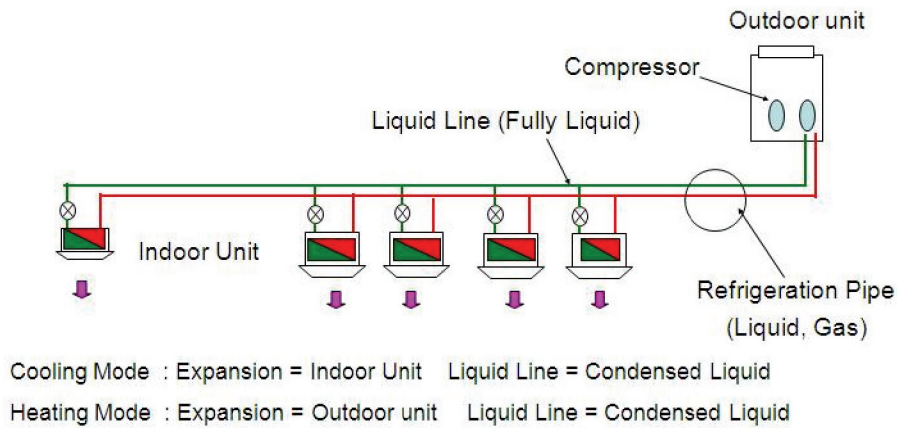


Figure 1 – Typical VRF Heat Pump System

ADVANTAGES OF A VRF SYSTEM

Control Means Comfort

The key to providing comfort is to supply heating or cooling when and where it is required without swings in room temperature.

In conventional systems, the compressor is either on or off, so even spaces that have individual controls experience fluctuations in room temperature as the compressor stops and then starts again to maintain the thermostat setting (Fig. 2).

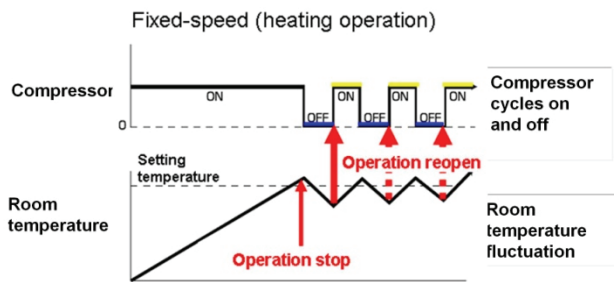


Figure 2 – Traditional Fixed-Speed Compressor Operation

In a VRF system, since the speed of the compressor can be varied, the compressor does not cycle on and off, but operates continuously for longer periods (Fig. 3). The required refrigerant flow is supplied to the indoor fan coil and once the set point is reached, the refrigerant flow is adjusted to maintain the room temperature smoothly without fluctuation.

In addition to having distinct set points, the indoor unit fan speeds and louver positions can be changed to provide additional comfort in the space.

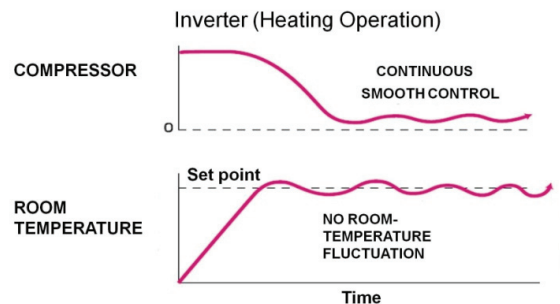


Figure 3 – VRF System Inverter-Driven Compressor Operation

Design Flexibility

One of the major advantages of a VRF system is the flexibility provided by the diversity of the product offering. Multiple types and sizes of fan coils are available to fit any application.

Figure 4 shows a sample zoning layout for a VRF system, combining outdoor units, 4-way cassette type fan coils, and hi-wall type fan coils to create comfortable conditions for varying uses of 15 different spaces within the same building.

When selecting a VRF system, keep in mind that not all systems have the same piping capabilities. Systems that offer expanded piping capabilities will maximize the application flexibility provided by the VRF technology. Important considerations when reviewing piping capabilities are: 1) the maximum elevation difference allowed between the highest and lowest indoor units on a single system and 2) the distance allowed from the outdoor unit to the farthest fan coil on the system.

Cost Effective Installation

Depending on the application, the installation of a VRF system can be a cost effective alternative to traditional systems that require ductwork or large pipe sizes, and pumps and boilers in the case of chilled water systems.

Outdoor units are light in weight and have a small footprint. This means that they will fit in a service elevator, so no crane is required for lifting to a rooftop installation. In some cases, savings on the total construction cost can be achieved since the lightweight unit means that additional support structure in the roof is not required.

Energy Savings

All VRF systems provide energy savings by varying compressor speed and matching the output of the system as closely as possible to the load. In addition, VRF systems do not experience the same energy losses as systems that move conditioned air through ductwork.

However, differences in design in the available outdoor units will influence the efficiency level that is achieved.

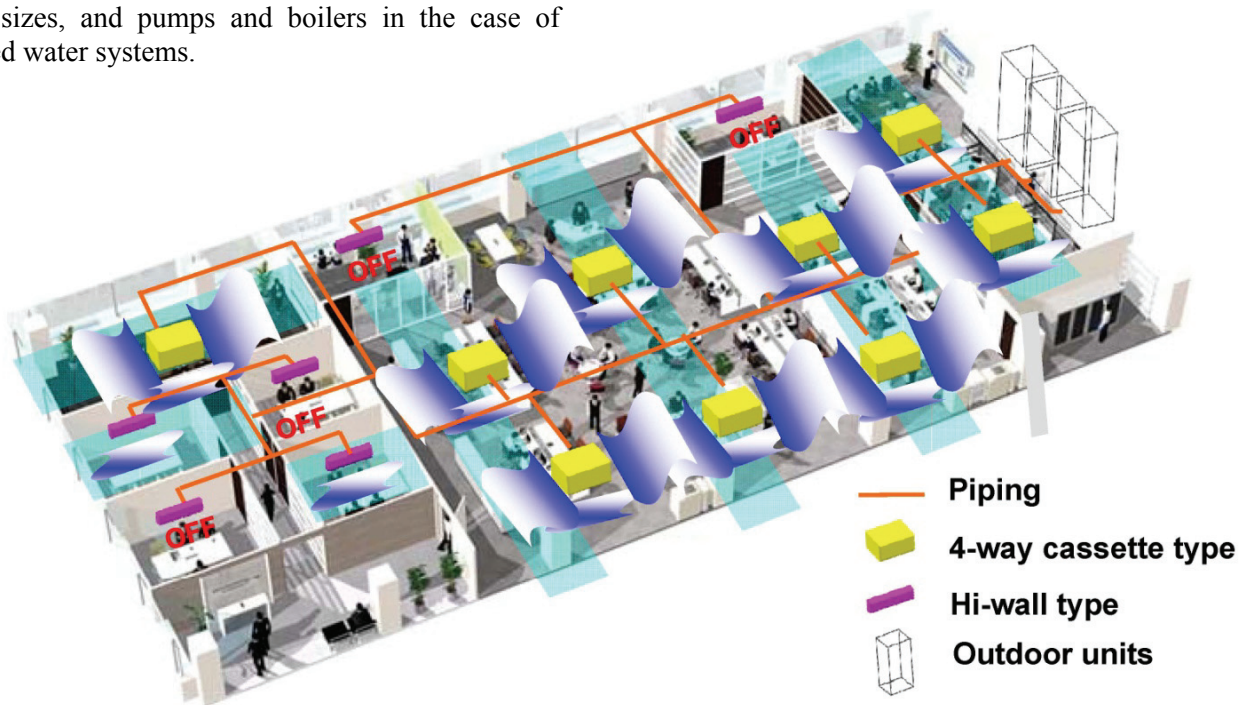


Figure 4 – Zoning Layout for VRF System (Cooling Operation Shown)

COMPARISON OF VRF SYSTEMS

The VRF systems available on the market today differ according to the number and type of compressor.

The 3 types of units that will be compared here are:

- Single Variable Speed Compressor
- Variable Speed Compressor Plus Fixed-Speed Compressor
- Multiple Variable Speed Compressors

Single Variable Speed Compressor

In this system with a single, large-capacity scroll compressor, the same compressor starts and runs when there is demand and no redundancy is available if the compressor fails.

Variable Speed Compressor Plus Fixed-Speed Compressor

In this two-compressor system, the inverter-driven compressor always starts and ramps up until it reaches its maximum capacity at which time the fixed-speed compressor starts and the inverter-driven compressor ramps down. This system provides back-up capability.

Multiple Variable Speed Compressors

Outdoor units with multiple inverter-driven twin rotary scroll compressors, as shown in Fig. 5, offer the most complete set of advantages achievable with a VRF system.

The system with 3 inverter-driven compressors also provides greater back-up capability. If one of the compressors fails, the system will continue to operate at 67% of its original capacity, and comfort will be maintained in the conditioned space until the faulty compressor can be replaced.

The starting sequence of the compressors is rotated, equalizing their operating time and thereby minimizing excess operation of an individual compressor.

Multiple inverter-driven compressors allow the unit to provide better part load performance without the need to use hot gas bypass. Under low-load conditions, the system has the advantage of running only as many compressors at whatever speed is required to achieve the capacity necessary to satisfy the load and maintain comfort within the conditioned space.



Figure 5 – Cut-Away View of VRF Outdoor Unit with Multiple Inverter-Driven Compressors

Figure 6 compares the operating status of outdoor units as changes occur in the air-conditioning loads. With multiple inverter-driven compressors, a better match can be made between the load in the space and the output of the compressor; the system does not waste energy generating extra capacity and at the same time provides greater comfort by eliminating room temperature fluctuations.

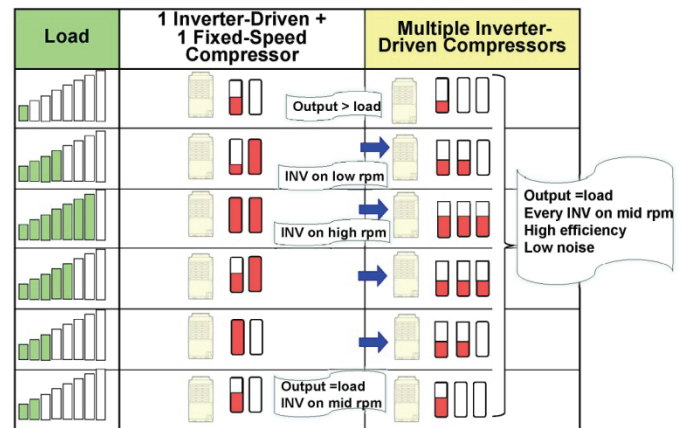


Figure 6 – Compressor Operation at Part Load

Twin Rotary Compressor vs Scroll Compressor

As noted above, the two types of compressors used in VRF outdoor units (Fig. 7) provide different levels of efficiency.

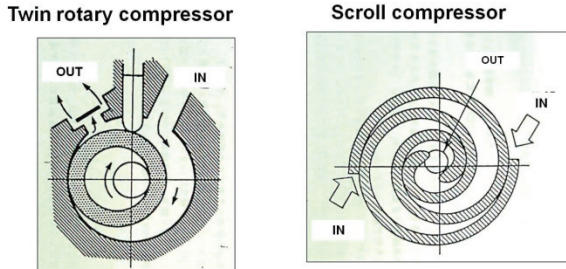


Figure 7 – Comparing Rotary and Scroll Compressors

Figure 8 compares the efficiency of a twin rotary compressor with the efficiency of a scroll compressor. The dotted line represents the scroll compressor, which has a poor efficiency at low and

high speeds. In contrast is the solid line representing the twin rotary compressor, which has excellent efficiency at all speeds.

The design features of a typical rotary compressor create an advantage over the typical scroll compressor by requiring less oil to be pumped from the compressor to the refrigerant system. Reducing the amount of oil moving through the refrigerant system contributes to the efficiency of the twin rotary compressor system. Most of the oil circulated by the rotary compressor can be further isolated to the system's outdoor unit. This means that once a zone has been satisfied, the metering device can be closed completely—not left partially open to facilitate oil return, as required by scroll compressor systems. Closing the metering device prevents refrigerant from circulating through the unit and avoids overcooling or overheating of the space. The result is greater comfort as well as higher efficiency.

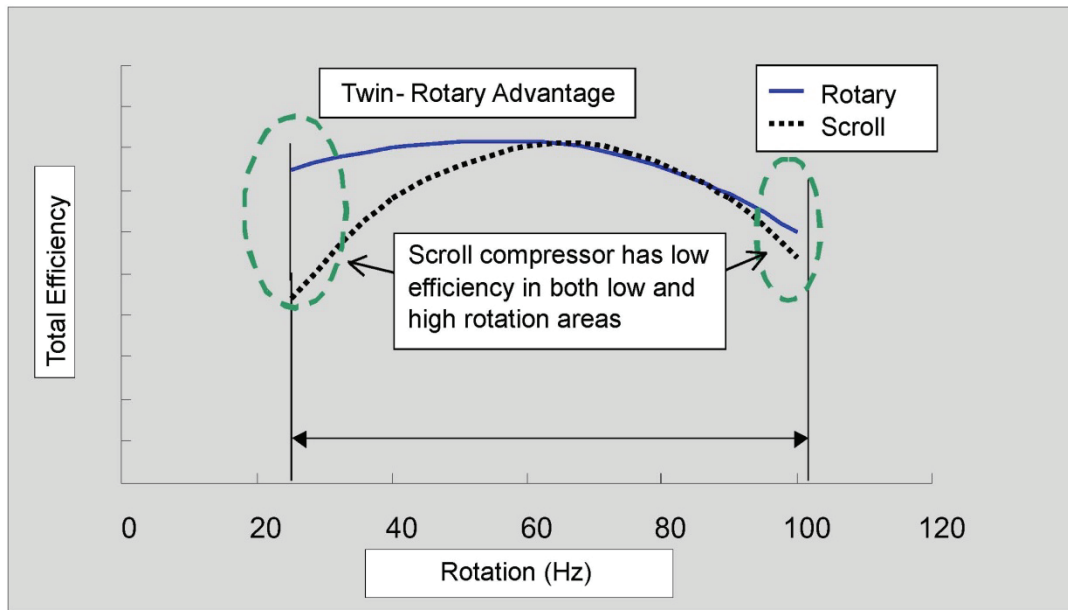


Figure 8 – Compressor Efficiency: Rotary vs. Scroll

DESIGN CONSIDERATIONS

Space Layout

The design of a VRF system begins with understanding the space layout. The orientation of the building and the seasons during which peak loads occur must be considered. The type of load (heating or cooling) and the distribution of loads into zones will depend on the intended use of the space. In turn, these factors will determine whether a heat pump system or heat recovery system will be the most efficient choice.

Figure 9 shows a typical space layout, with zones specified as requiring heating or cooling and the load reflected in the size and type of the indoor units shown.

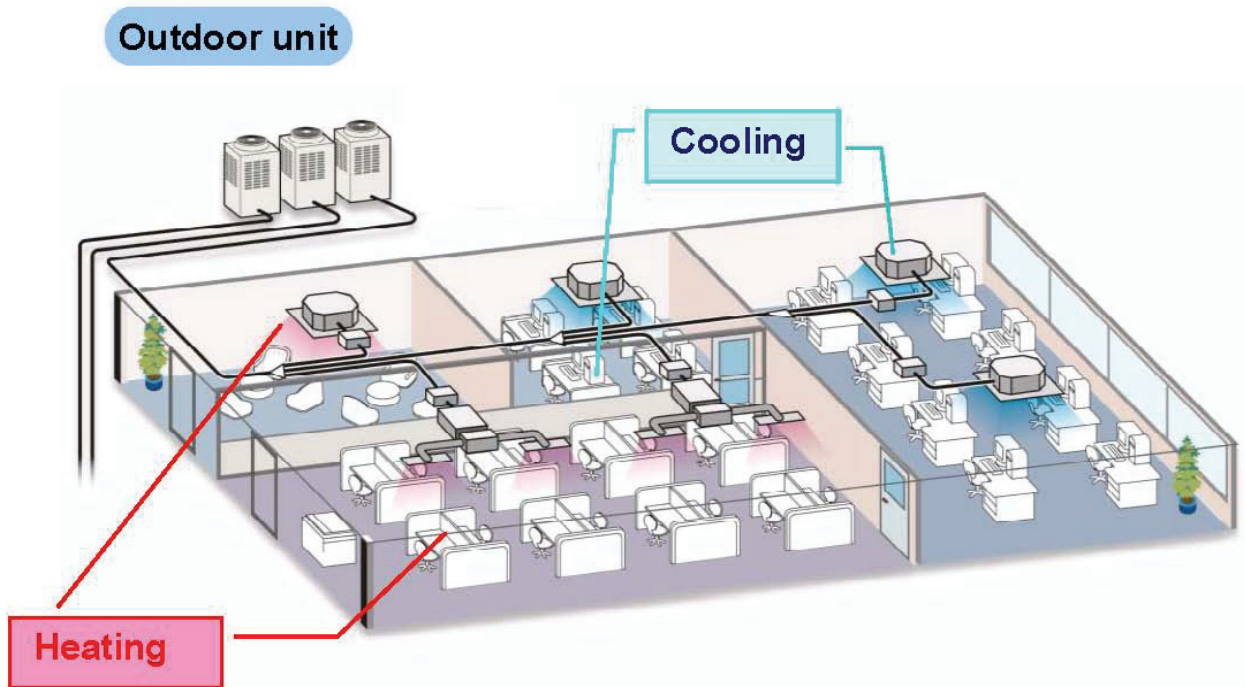


Figure 9 – Typical VRF System Space Layout

Type of System — Heat Recovery or Heat Pump?

Heat pump and heat recovery systems both provide heating and cooling.

A heat pump system provides either heating or cooling as required.

A heat recovery system is ideal when simultaneous heating and cooling is required. The greatest efficiency will be realized when the heating and cooling loads are equal, by maximizing the amount of energy that can be transferred from one zone to another using the refrigerant, as shown in Fig. 10.

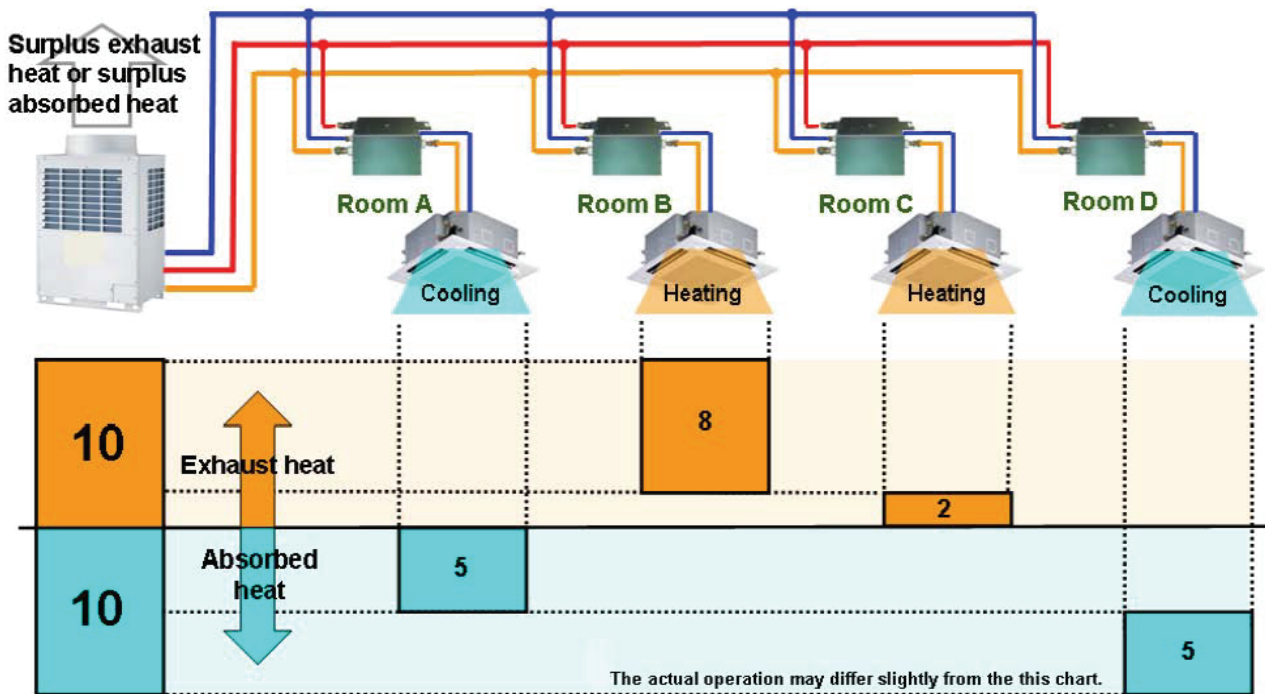


Figure 10 – Typical VRF Heat Recovery System with Simultaneous Heating and Cooling Operation

Figure 11 shows a building layout with 6 zones.

One way to meet the design requirements of this building would be to install 3 heat pump systems as shown below:

System 1 – Zones A, C, and D, which have similar profiles for heating and cooling requirements

System 2 – Zones E and F, which have similar profiles for heating and cooling requirements

System 3 – Zone B, which requires cooling only

Alternatively, one larger heat recovery system could be installed.

To determine the best design choice, an efficiency analysis and cost comparison of the two options should be completed. In addition, the consequence of a greater amount of refrigerant circulating through the larger system should be considered, since the amount of refrigerant in the system has implications when it comes to meeting the requirements of ASHRAE 15.

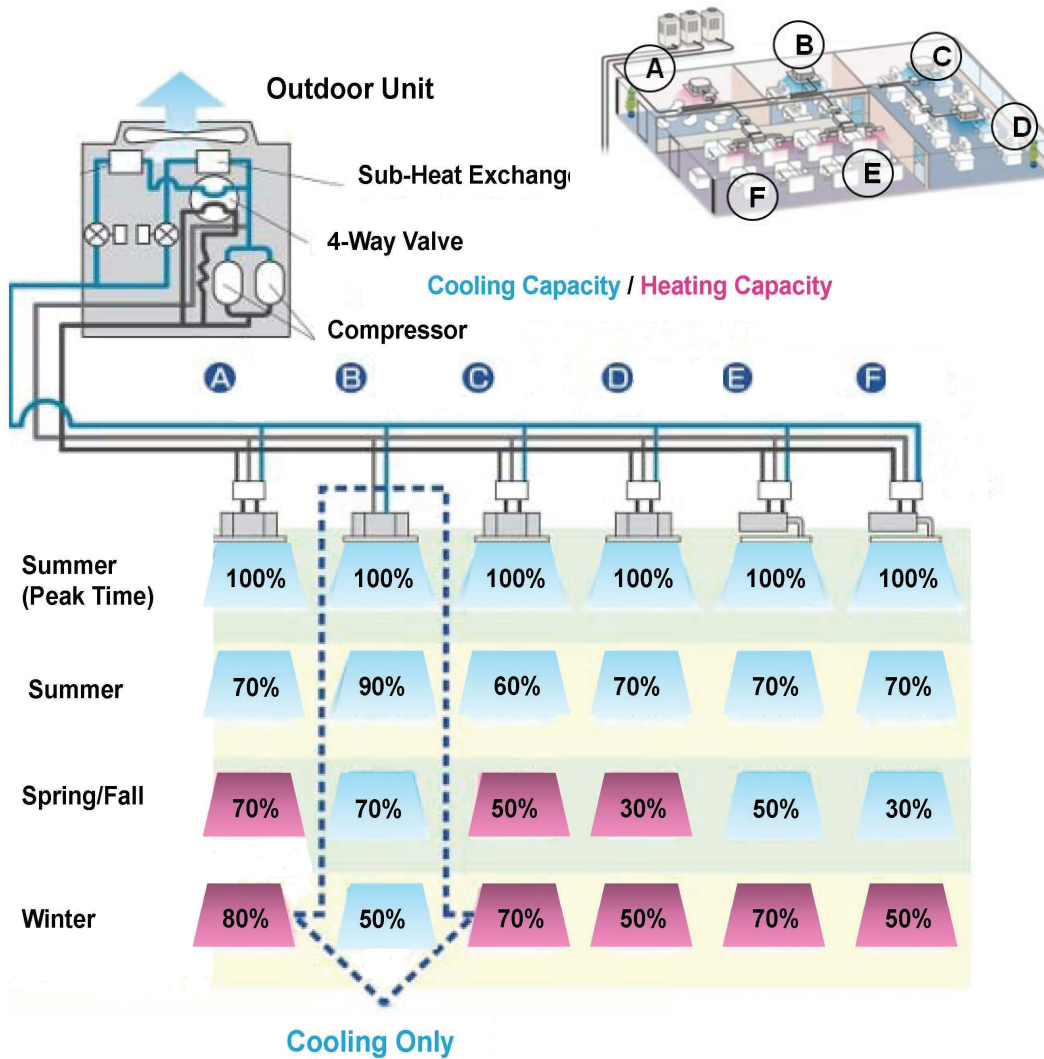


Figure 11 – Space Layout with Cooling and Heating Load Capacity by Zone

Size of Units

The size of the units selected must be considered for impact on the design of the system; smaller units will provide flexibility of zoning and require less piping and less refrigerant per system.

Piping Configuration

Flexibility of the piping options available should be considered. A system that provides more options for combining Y-shape joints and headers could minimize the amount of piping and refrigerant used, thus reducing the total cost of the job.

CONCLUSION

A VRF system offers flexible installation and energy-saving cooling and heating comfort and should be considered as an alternative to traditional systems for those applications where zoning or part load operation is required.



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