PART 1: INTRODUCTION

1.1 PURPOSE

A. System Description

1. This section pertains to the material and installation requirements for direct expansion, air- and water-source heat pump systems utilizing variable refrigerant flow (VRF) as a means of refrigerant control and distribution. Various manufacturers use the terminology of variable refrigerant volume to describe their system. Use of the term VRF in this standard shall refer to all variable flow refrigerant designs interchangeably.
2. This section covers applications in buildings that are used for new construction, renovations (whole or partial) and supplemental uses such as IT/data rooms. Designer shall review all potential applications for VRF systems with Yale Engineering.
3. This section covers air- and water-source heat pump systems. Water source VRF may be part of a geothermal (ground source) system for that application. Use of campus chilled water, or steam, as a heat source, or sink, shall not be considered for the design without prior written approval of Yale Utilities.
4. To implement refrigerant-based systems as a heating alternative to both fossil fuel and electric resistance heating. The engineer of record (EOR) shall avoid planning and specifying electric resistance heat as a means of convenience.

PART 2: GENERAL DESIGN REQUIREMENTS

2.1 GENERAL

A. System Architecture

1. Variable refrigerant flow (VRF) systems shall be a variable capacity, direct expansion (DX) field selectable heat pump, or heat recovery engineered system, unified within a single cabinet. The outdoor condensing unit shall consist of one or more frames connected though a common two (2)- pipe heat pump, or three (3)-pipe heat recovery refrigerant piping network, and control communication wiring. Each system shall have single or multiple inverter compressor(s).
   a) Basic heat pump systems where the entire system is indexed to either heating or cooling operation are generally limited to process cooling applications or single zone occupied areas.
   b) Heat recovery systems are generally applied to occupied areas where zone conditions vary. Additionally, heat recovery systems shall be capable of simultaneous heating and cooling of individual zones.
2. Each system shall be connected to multiple indoor terminal units (ducted or mixed combinations) through a common refrigerant piping network with integrated system controls and communication network. Each indoor unit shall be capable of being controlled individually for small zones or as a group for larger zones.

B. DESIGN

1. The design engineer shall consider/include the following items for the design.
2. Branch controller locations need to be placed in areas where acoustic disturbance is not a potential issue for concern.
3. Include smart changeover (optimized) functionality for cooling/heating switchover type systems.
4. When configuring a system design layout, group like spaces together that operate on similar schedules and combine them with a single outdoor unit. Also consider maximizing the heat recovery capability of the system, for VRF heat recovery applications, grouping zones that are likely to be in different modes at the same time to maximize the heat recovery potential of the system and, thus, achieving energy savings.
5. Consider resiliency when laying out the VRF system and how zones are grouped together onto branch boxes and outdoor units. Consider how the failure of any single outdoor unit or branch box will impact the use of the building.
6. VRF systems that are dependent on an uninterruptible power source to protect equipment from memory loss during a power failure shall not be considered for design installation. Systems shall automatically resume operation upon restoration of power at previous modes and setpoints.
7. Space thermostats for VRF system control needs are to be sourced by the same VRF manufacturer for proper functionality. Central VRF controllers need to have full BACnet capability to communicate with campus through the building management system. Consider including an independent building automation system temperature sensor within each zone that is served by a VRF unit for redundant temperature monitoring, or to control other heating or cooling systems, within the zone such as perimeter radiation.
8. Designers comply with the latest ASHRAE 15 and ASHRAE 34 requirements when laying out system pipe routing and consider open/closed plenum spaces to meet standard requirements for refrigerant concentrations in the event of a leak. Designers shall submit refrigerant volume calculations to Yale Engineering for each system that demonstrate compliance with ASHRAE 15 and ASHRAE 34.
9. All air-source VRF systems shall include a low ambient kit that includes wind baffles, where required, to meet the design ambient condition of 0°F or below.
10. Where used as the primary heating source, VRF systems shall provide full design heating capacity at 0°F outdoor ambient without the use of supplementary electric resistance heating. Designers shall base compressor unit selection(s) on the greatest load, cooling versus heating. Consider the application of augmented heating output type units for these installations.
11. Designers shall evaluate each system for a defrost cycle and determine the impact the operation and frequency of this cycle will have on maintaining space temperature while the compressor is in the defrost mode.
12. Designers shall include the ventilation air conditions (or supply from a ventilation unit if one will be utilized) and flow rates in their load calculations for sizing and selecting the indoor units.

Selections and capacities shall be determined by actual entering air conditions rather than by nominal entering air conditions of 80°Fdb/67°Fwb.

a) Energy recovery ventilators (ERV) are preferred overheat recovery ventilators for exchange of sensible and latent heat energy.

b) Higher outdoor air flow rates can be connected to indoor units if pretreated with a ventilation unit such as an ERV or a dedicated outdoor air supply (DOAS) ventilation system. However, designers must follow the VRF manufacturer guidelines for recommended mixed air temperatures entering the indoor unit coil and not exceed them in heating or cooling mode. In particular, VRF indoor units do not handle high incoming air humidity well in cooling mode.

c) Designers can consider supplying outdoor air from a ventilation unit at neutral conditions directly to room(s) in lieu of ducting air to the indoor units. This should also be considered for high occupancy spaces.

13. Designers shall coordinate the proposed location of outdoor units with the project architect or Yale project manager for approved locations. Outdoor units may be located on grade, rooftop, indoor, or sidewall depending on the building and application. All proposed locations shall conform to the manufacturer's requirements for clearance on all four sides and overhead. Stacking units, or the creation of "farms," are acceptable within the manufacturer's limitations.

14. The mounting height for VRF outdoor units with probable exposures shall accommodate snow/ice build-up concerns. Rooftop and on-grade installations shall include an engineered structural steel stand a minimum of 12-inches-high. Use of the manufacturer's engineered products are preferred.

15. Locating on the sidewalls shall be limited to renovation or supplemental applications only with approval from the project architect or Yale project manager. Designers shall consider provisions for service access for high sidewall installations.

16. Mounting of outdoor units indoors must be in conformance with manufacturer's requirements for ducted discharge and air intake configurations and static pressure limits. Provisions for gravity drainage of defrost water shall be included in enclosure.

17. Water source systems shall review the requirement for a propylene glycol solution of adequate concentration to prevent freezing.

18. VRF components shall be provided with a 10-year material warranty for compressors and mechanical parts.

19. Minimum energy efficiency (SEER and COP) shall be as mandated by the current energy code requirements unless the project has higher goals for sustainable design achievement.

20. Designers shall work with the manufacturer, or its representative, to create the system architecture and generate a system flow diagram that incorporates the unit piping sizes and distribution lengths. This diagram shall be included as part of the construction documents bid package. Designers shall select major component sizes and configurations that are available across all approved VRF manufacturers so that if an alternate approved VRF manufacturer is submitted, changes to the overall system configuration will be minimal.

C. CONSTRUCTION

1. The contractor/design engineer shall consider/include the following items for construction.
2. Contractors must have a minimum of 10 documented and successful installations of VRF systems with any of the acceptable manufacturers listed in the next section, and system sizes similar to the current project installation scale.
3. Contractors must be certified to install VRF systems and must be certified with the specific manufacturer that is being installed as part of a project. Documentation of experience and certification is provided as part of the submittal process.
4. A manufacturer representative shall attend a preconstruction meeting and shall also verify that the training certifications provided by the contractor are in order. Construction managers shall submit list of contractors who have been trained and certified within a designated geographical range to service and replace systems installed.
5. Contractors shall provide a basis of design bid as specified and with specified products. If the contractor wishes to propose alternate products to the basis of designed products, they shall provide a separate and complete bid detailing the proposed alternate products. The alternate shall clearly identify the impact to the scope of work for each trade. Any product proposed as an alternate shall have been offered, as a VRF product, in the United States for a minimum of five (5) years.
6. Refrigerant piping used to connect VRF system components shall be type L-ACR hard temper copper, ASTM B-280, B-819. Piping shall be shipped to jobsite with nitrogen charge and capped ends until ready for installation. Use with long radius wrought copper refrigeration fittings with brazed connections. Annealed copper tubing (soft temper) may be substituted in retrofit applications that are approved in advance by Yale Engineering.
7. Refrigerant piping shall be insulated with preformed flexible elastomeric, type E-1, in accordance with Yale's design standard, 23 07 00 HVAC Insulation. Exposed (outdoor) insulation shall be covered with a type B PVC jacket.
8. Upon job completion, contractors will provide the owner with a copy of an approved submittal, including mobile service and diagnostic software (VRF system service diagnostics), project mechanical and control drawings, all as-built piping drawings with device controls addressing map and guide, operations and maintenance instructions, troubleshooting guides, startup and system configuration reports, the final total refrigerant charge of each system, and any service and engineering manuals in PDF format. Additionally, contractors will provide any specialized repair tools needed for system maintenance.

PART 3: MINIMUM PRODUCT REQUIREMENTS

A. All equipment and components shall be new, and the manufacturer's current model.

B. All parts and components shall be readily available in the United States of America.

C. Acceptable Manufacturers:
   1. Mitsubishi Electric
   2. Daikin

D. VRF, Condensing Unit, Heat Pump Sections (Outdoor Section)

   1. The outdoor section shall be factory packaged with compressor(s), reversing valve(s), air- or water-source heat exchange components, refrigerant charging provisions, and controls. All components shall be factory mounted on a structural steel frame.

   2. Large capacity units shall be modular in design to allow multiple units to be connected in parallel to satisfy the design load.

   3. Outdoor style units shall utilize air coils for heat transfer with fans configured for a draw-through operation. Coils shall be constructed of all aluminum or composite aluminum fin and copper tube. Air coils shall be coated with a hard anodized protection from corrosion for coastal installations. Where outdoor units are installed on grade, provide coil protection grilles.

   4. Fan(s) for outdoor units shall be a shaped propellor type designed for reduced noise. Fan speed shall be variable through an onboard controller for capacity control and reduced energy consumption.

   5. Indoor style units shall utilize a brazed plate heat exchanger for heat transfer.

E. Indoor Terminal Units

   1. Indoor unit types shall be coordinated with the building architecture for the specific application. Unit types, including wall or ceiling hung, ceiling cassette, console, concealed ducted, and floor standing ducted may be used in any combination the manufacturer allows.

   2. Indoor units generally follow the configuration of fan coil units and include a refrigerant coil, blower, condensate drain pan, and controls.

   3. Units designed for installation in the space served include means for air distribution with supply and intake grilles. Casings for these units are constructed of high-impact plastic on a steel frame.

   4. Units designed for concealed and ducted applications shall have galvanized steel casings with coated insulation lining.

   5. Concealed units installed above a ceiling shall have a supplemental drip pan installed below the unit with leak detection monitored by the building automation system.

   6. Ducted units shall have the external static pressure calculated to operate within the unit's fan capacity. The fan motor size and speed shall be selected as applicable.

   7. Gravity condensate drainage is the preferred system and shall be designed wherever possible. The use of integral condensate lift pumps can be considered to facilitate condensate drainage where gravity drainage is impractical due to unit locations. Where unavailable due to unit style, external condensate pumps are an option. Condensate pumps may be used to lift condensate to overhead gravity system(s) or discharge directly to drain. Condensate shall be discharged indirectly to the storm waste connection(s) in the plumbing system.

   8. Some terminal units (i.e., cassette types) shall be able to accept a ventilation air connection. Only

terminal units designed for ventilation air shall be connected. Concealed units can be equipped with intake plenums for ventilation air connections.

F. Branch Control and Distribution Boxes

1. Various manufacturers utilize refrigerant distribution and control boxes to meter refrigerant to the indoor units from the outdoor units. This is especially true for heat recovery type installations. These boxes shall be located in mechanical rooms or in readily accessible locations for service access. Selection of the boxes shall be part of the manufacturer's engineering process and project support. Capacity and quantity of ports shall be coordinated with the load. Its branch controller shall have labels indicating which terminal devices are connected to it.

2. All branch controllers shall have isolation vales for each refrigerant circuit, both on the suction and liquid lines.

G. Controls

1. Control packages shall be scaled in size with the project. Small systems used for supplemental applications are required to be connected via a MSTP device, such as a Procon card, and have the ability for a BACnet MSTP. For larger system installations, units may connect to and be integrated with the building automation system (BAS) via BACnet IP (JCI Metasys, ALC, Tridium or Siemens as applicable).

2. The VRF manufacturer shall prepare a customer interface wiring diagram with all the required conductor numbers, insulation types, and wire gauges as part of their engineering support for the project. This drawing shall be included in the construction documents bid package.

3. The VRF system controller and space thermostats within each space shall include the following features and interface with the building BAS.

   a) Acceptance of indoor unit on/off command from the BAS, and ability to lock out these functions from the user at the thermostat.

   b) Acceptance of occupied/unoccupied command from the BAS, and ability to lock out these functions from the user at the thermostat.

   c) Acceptance of operating mode (heating, cooling, dehumidify) command from the BMS and ability to lock out these functions from the user at the thermostat.

   d) Dual setpoints (heating and cooling) in occupied, unoccupied, and standby. Standby setpoints will be in use when the BMS is commanded by the VRF and occupancy sensor in the space reads unoccupied.

   e) Push button temporary override. A button on the thermostat when the space BAS is scheduled to be unoccupied. This will provide occupied setpoints for up to 120 minutes.

   f) Limit of 2°F plus or minus adjustment from the setpoint. Gives users the ability to change occupied heating setpoints from 68°F to between 66°F and 70°F and cooling setpoints from 75°F to between 73°F and 77°F.

   g) Have all points available for BACnet view on the BAS and occupied/unoccupied setpoints as well as occupied command set to read and write.

4. Submit proposed VRF thermostat types for each space type within the building to Yale Engineering for review.

H. Commissioning of BAS Control Points

1. The section outlines requirements for commissioning the HVAC system and its subsystems and equipment.
2. The engineer of record shall:
    a) Review control designs for compliance with owner's project requirements and basis of design, controllability with respect to actual equipment installed.
    b) The design documents shall include a detailed piping and instrumentation diagram drawing with a control point list, and sequence of operation for each system and subsystem.
    c) The control point list shall clearly provide direction to the equipment vendor and mechanical and control contractor, which points shall be uploaded to the BMS.
3. The design documents shall clearly state that all other points not part of item two, shall be excluded from the BMS.

Date	Description of Change	Pages / Sections Modified	Department
03/2023	Entire document, and final committee comments	-	Yale Engineering and Operations