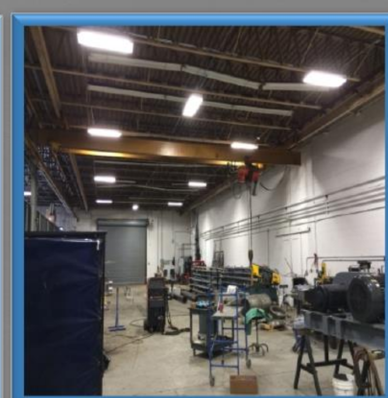
Senior Thesis Final Report

123 Alpha Drive

Pittsburgh, Pennsylvania



The Pennsylvania State University

Architectural Engineering

Mechanical Option

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Acknowledgements

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Executive Summary

The analyses presented and evaluated in this report are a result of information that have been collected over the fall and spring semesters. After a careful investigation of 123 Alpha Drive's building characteristics and components, modifications in the mechanical, acoustical, and electrical systems were proposed. The analyses were conducted in order to educate the author of this report about architectural engineering design principles and strategies.

The mechanical depth portion of the report consists of the installation of a variable refrigerant flow (VRF) system along with a dedicated outdoor air system (DOAS) in place of the existing roof-top units in the office and lab spaces of the building.

The variable refrigerant flow system analysis indicated a large savings in annual HVAC costs of up to $9000, and reduces the amount of energy consumed in comparison to the original HVAC design by over 15%. Carbon emissions from a variable refrigerant flow system were also found to be significantly reduced. When comparing first costs and annual HVAC costs, it was found that the proposed VRF system, accompanied by a dedicated outside air system, was economically unfeasible, as the payback period for the system was nearly 16 years.

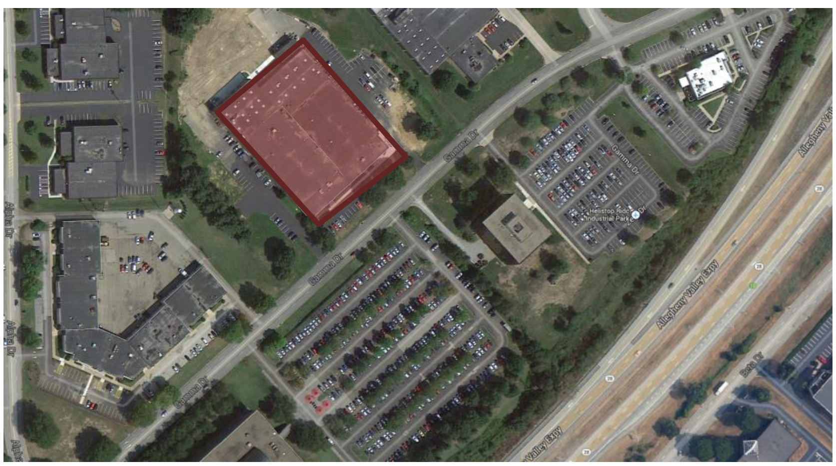
The proposed HVAC system does possess much more precise control than the original system, however. A building management system control was added to the variable refrigerant flow system, which allows for control of up to 256 indoor units and 16 outdoor condensing units. The building management system can also dictate the controls of the energy recovery ventilators, and can also set restrictions on occupant control of their individual indoor terminal unit. Wired remote controllers were also added in an effort to provide occupants with the opportunity to maximize their comfort. Simultaneous heating and cooling of each individual indoor unit was also made available.

The acoustical evaluation of the Noise Criterion ratings of the original HVAC system and the proposed VRF system indicated that the existing HVAC system did not meet the recommended rating for almost all categories of office and conference room noise criteria. Upon further software-based analysis, it was found the cassette style indoor terminal units produced a Noise Criteria rating far below the recommended values, further improving its aim to provide maximal comfort.

The electrical analysis focused on the replacement of mechanical panels based on the proposed variable refrigerant flow and dedicated outdoor air systems. A new 225A 460V 3 phase panel was installed in place of a motor control center of equal rating, limiting the amount of change in feeder size and wiring. Two 100A 208V 1 phase panels were added to accommodate for the VRF system indoor terminal units and the energy recovery ventilators. Attempts to place all indoor units on the same 225A were unsuccessful, as there were too many mechanical units compared to single pole switches.

Building Overview

123 Alpha Drive is a 74,000 square foot, office and warehouse building located on the campus of the Regional Industrial Development Corporation (RIDC) in Pittsburgh, PA. 123 Alpha Drive is a one story structure designed in order to manage various warehouse shipments and offer sufficient office space. Obtained by THAR Geothermal Incorporation in early 2011, the now serves as THAR's corporate headquarters and storage facility. The building is large enough to achieve adequate, storage and office space, while providing additional space purpose requirements such as laboratory areas and conference rooms. The façade of the structure is composed of primarily concrete masonry and brick sections, occasionally separated by large, retractable warehouse doors and typical 3'x5' rectangular window. The building was designed to achieve a high thermal mass within the walls of the building in order to compensate for the poor thermal resistivity properties of the large warehouse doors.



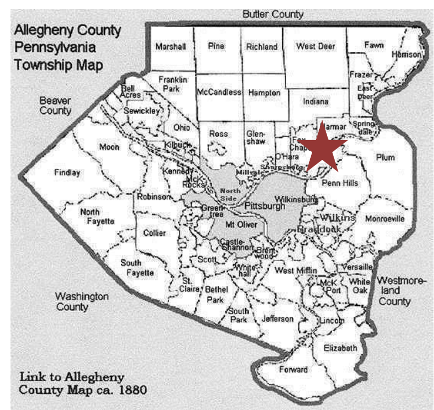


Figure 1: 123 Alpha Drive Location in RIDC Park and Allegheny County

Construction

123 Alpha Drive was renovated to provide THAR with a corporate headquarters in early 2012, and took nearly 10 months to complete. Few structural changes were made to the structure, but significant improvements and redesigns of the electrical, lighting, and mechanical systems were produced. In compliance with sprinkler and fire protection codes, a new life safety system was also installed. Areas of the building affected by the renovation include the office, café, conference room, dry lab, and warehouse storage rooms.

Electrical

123 Alpha Drive receives its electricity from Duquense Light. The electrical system was redesigned to accommodate for the lighting, power, and mechanical changes to the building during renovation. The building runs off an existing 120/208V Y 3 phase secondary system, as well as an existing 240V Delta 3 phase secondary system. A 208V existing utility transformer, and an existing 240V utility transformer share a concrete pad on the north side of the building. Two existing to remain switchgears are also part of the electrical distribution system. The renovation of 123 Alpha Drive includes a new 1200A 240V power panel and a 600A 460V power panel, with the appropriate 240V/460V transformer between the two. Two motor control centers (400A and 225A) are also to be added to the 460V line.

Lighting

The lighting within the building runs on 120V. The variety of fixtures includes several fluorescent downlight, fluorescent pendant, fluorescent lay-in troffer, and LED lamps. Occupancy sensors have been included in each corridor, office, and restroom in the building. Proper emergency lighting was installed in the large warehouse areas, office corridors, and dry labs. Emergency exit signs are located throughout

Structural

123 Alpha Drive has a roof live load of 23 psf. Wind loads were determined by assuming a basic wind speed of 90 mph and an occupancy category of II, resulting in an importance factor of 1.0. The building falls under Exposure Category B due to its office and retail workers. Seismic activity in the area is almost negligible, and thus falls into the Seismic Design Category A and Occupancy Category I . The calculated snow load for the Pittsburgh area is a ground snow load of 25 psf and a roof snow load of 23 psf because of the structure's flat roof.

Fire Protection

The majority of the building is equipped with a water suppression system, although two large warehouse spaces used for fluid technology research and development are equipped with a foam system.

Telecommunications

Data and phone jacks were installed in the office, conference room, café, and dry lab areas of the building when it was renovated.

Existing Mechanical System Overview

Ventilation

123 Alpha Drive is ventilated using six small rooftop units (RTUs) for the office, dry lab, and café areas and electric resistance heating for the warehouse spaces. Figure 2, below, indicates the appropriate AHU zoning for the building. Four of the six rooftop units are existing to remain, but the newly installed RTU's have been selected in order to incorporate an outside air carbon dioxide preconditioned heating and cooling cycle, a technique utilized in the airline business. The liquid CO2 preconditioning coil will be located in the outside air stream of the two units. The goal of this preconditioning is to achieve a lower 'delta T' at the final cooling and heating coils, saving considerable energy throughout the unit's lifetime. Equipped with a full economizer each, the RTUs will provide efficient ventilation in the building, along with a considerable reduction in energy consumption. The units utilize gas heating and electric cooling. The following figure shows which air handling units and rooftop units service different areas of the building.

Lab and Contaminant Exhaust

Various warehouse and dry lab spaces within the building require lab air and contaminant exhaust. Ten small down-blast, roof-mounted exhaust fans with motorized dampers were installed to handle the exhaust air requirements. The air will be replenished by a 4-ton, existing to remain, make-up rooftop unit.

Radiant Floor Slab Cooling and Heating

In addition to the rooftop units supplying fresh air to the office and lab spaces, a geothermal hydronic radiant floor cooling and heating system has been implemented through "wet installation", in which the tubing is attached in between the finished floor and subfloor. Utilizing an efficient fluid such as liquid carbon dioxide, the radiant floor slabs achieve a more efficient heating and cooling process than a ducted system, as no duct losses exist in a radiant system. A condenser and heat pump is used as to heat or cool the liquid within the tubes. Condensation is a considerable concern with radiant floor cooling, and will be explored throughout the course of this study. The radiant floor system is expected to support 50% of the load in the areas in which it conditions. Figure 3, found on page 10, indicates the spaces of the building in which the radiant floor system is utilized.

Figure 2: Rooftop Unit Zoning Map

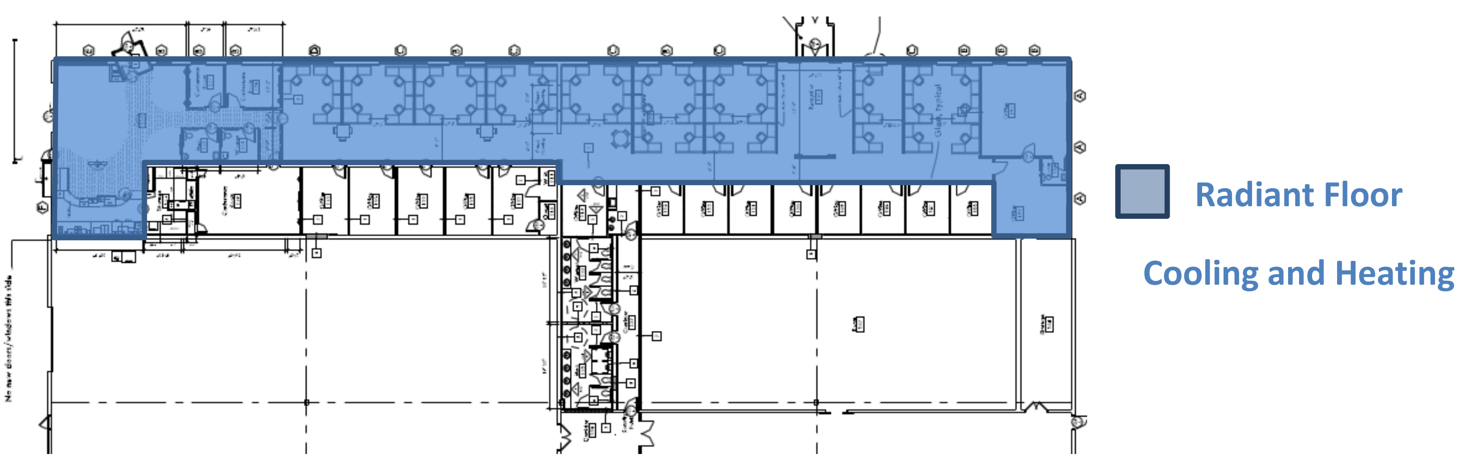


Figure 3: Radiant Floor Zoning Map

Outdoor and Indoor Design Conditions

123 Alpha Drive is located 9 miles east of Pittsburgh, Pennsylvania. Carrier HAP contains hundreds of locations that can be used to model buildings across the nation and in Canada. Conveniently, a design template for Pittsburgh is available in version 4.7 of Carrier HAP. The measurements were recorded at the Pittsburgh International Airport, which is located several miles southwest of Pittsburgh. There is a possibility that the design conditions at 123 Alpha Drive may not be perfectly modeled by the Pittsburgh IAP, but if such differences existed, they would be minimal. Figures 4 and 5, below, show the weather conditions information provided in Carrier HAP. Similar weather information can be found in the 2009 ASHRAE Handbook of Fundamentals.

Table 1: Outdoor Air Design Conditions

	Summer Design Cooling	Winter Design Heating
OA Dry Bulb (°F)	89 °F	2.0 °F
OA Wet Bulb (°F)	72 °F	.3 °F

Table 2: Indoor Air Design Conditions

	Offices & Lab	Warehouse & Packaging	Storage & Maintenance
Cooling Set Point	70 °F	85 °F	95 °F
Heating Set Point	55 °F	55 °F	60 °F
Relative Humidity	45%	-	-

Design Ventilation Requirements

Rooftop units 1 through 6 were analyzed to estimate the minimum outside air requirements for all applicable spaces. The warehouse air handling units did not contain enough information in the drawing set provided in order to produce an accurate minimum outside air requirement for their respective spaces. The air handling units supply warehouse spaces that were not included within the scope of the renovation project during THAR Geothermal's acquisition of the building.

Equation 6-1 in Section 6.2.2.1 of ASHRAE Standard 62.1 was utilized in order to calculate the breathing zone outdoor airflow value (V_{bz}).

$$Vbz = (Rp \times Pz) + (Ra \times Az)$$

For which: Az = zone floor area: the net occupiable floor area of the ventilation zone in ft2
Pz = zone population: the number of people in the ventilation zone during typical usage. (determined by counting seats from furniture plans)
Rp = outdoor airflow rate required per person as determined from Table 6-1
Ra = outdoor airflow rate required per unit area as determined from Table 6-1

The outdoor air that must be provided to ventilate the zone in question is known as the zone outdoor airflow (Voz).

$$Voz = Vbz/Ez$$

Ez = zone distribution effectiveness, which can be determined via table 6-2. Ez varies from values of 0.8,1, and 1.2 depending on the method of air distribution into the zone.

The primary outdoor air fraction (Zpz), is the minimum percentage of ventilation air compared to the required supply air. Zpz is calculated from equation 6.5.

$$Zpz = Voz/Vpz$$

Vpz is the zone primary airflow.

Table 3 below, has been constructed as a summary of all six rooftop units that were chosen to be analyzed under this method. The minimum outside air and design airflow (CFM) were obtained from the project documentation. These values were compared to the outside air CFM calculation based on the formulas provided from Section 6 of ASHRAE 62.1. In in-depth, detailed calculation analysis can be viewed in Appendix A at the end of this report.

Table 3: Minimum Ventilation Rates

Minimum Ventilation Rates				
Unit	Design CFM	Minimum OA CFM	ASHRAE 62.1 Min. OA CFM	Compliant?
ETR RTU-1	1600	1200	592	Yes
ETR RTU-2	3000	600	510	Yes
ETR RTU-3	3000	600	414	Yes
ETR RTU-4	3000	770	420	Yes
RTU-5	2000	600	495	Yes
RTU-6	1800	680	463.17	Yes

Existing Building Envelope

The existing building envelope was found to be compliant with AHSRAE Standard 90.1 upon investigation by the prescriptive building method described in Section 5.5. The insulation values for the building envelope of the building are compared with the requirements of the specific zone in which the building is located. Table 4 indicates the compliance determination for the walls, roof, and glazing sections of the enclosure.

Table 4: Building Material R-Values and U-Values

Building Envelope For Nonresidential Zone							
Element	R-Value	Insulation Min. R-Value	U-Value	Max U-Value	SHGC	Max SHGC	Compliant?
Walls, Above Grade Mass	15.4	11.4	0.06	0.09	N/A	N/A	Yes
Roofing	27.8	20	0.04	0.048	N/A	N/A	Yes
Glazing, Nonmetal Framing	N/A	N/A	0.26	0.35	0.32	0.4	Yes
Glazing, Metal Framing	N/A	N/A	0.34	0.8	0.32	0.4	Yes

Existing System Design Load Estimation

The 123 Alpha Drive energy model and building load simulation was produced with the assistance of Carrier HAP 4.7. Carrier HAP is used by smaller MEP consulting firms in the country, and although it does not contain the most sophisticated and/or complex analysis procedure, it provides a good baseline for the design of simple building with common heating and cooling applications. Hap 4.7 produced heating and cooling loads, ventilation loads, and an annual energy cost simulation for the entirety of the building. Areas such as restrooms and stairways were accounted for in order to develop an accurate ventilation rate and load. Different spaces within the building required different load considerations. The various spaces throughout the building included office space, warehouse space, dry and wet storage rooms, break rooms, corridors, and conference rooms. A breakdown of the locations of these space types is available in Figure 4 below.

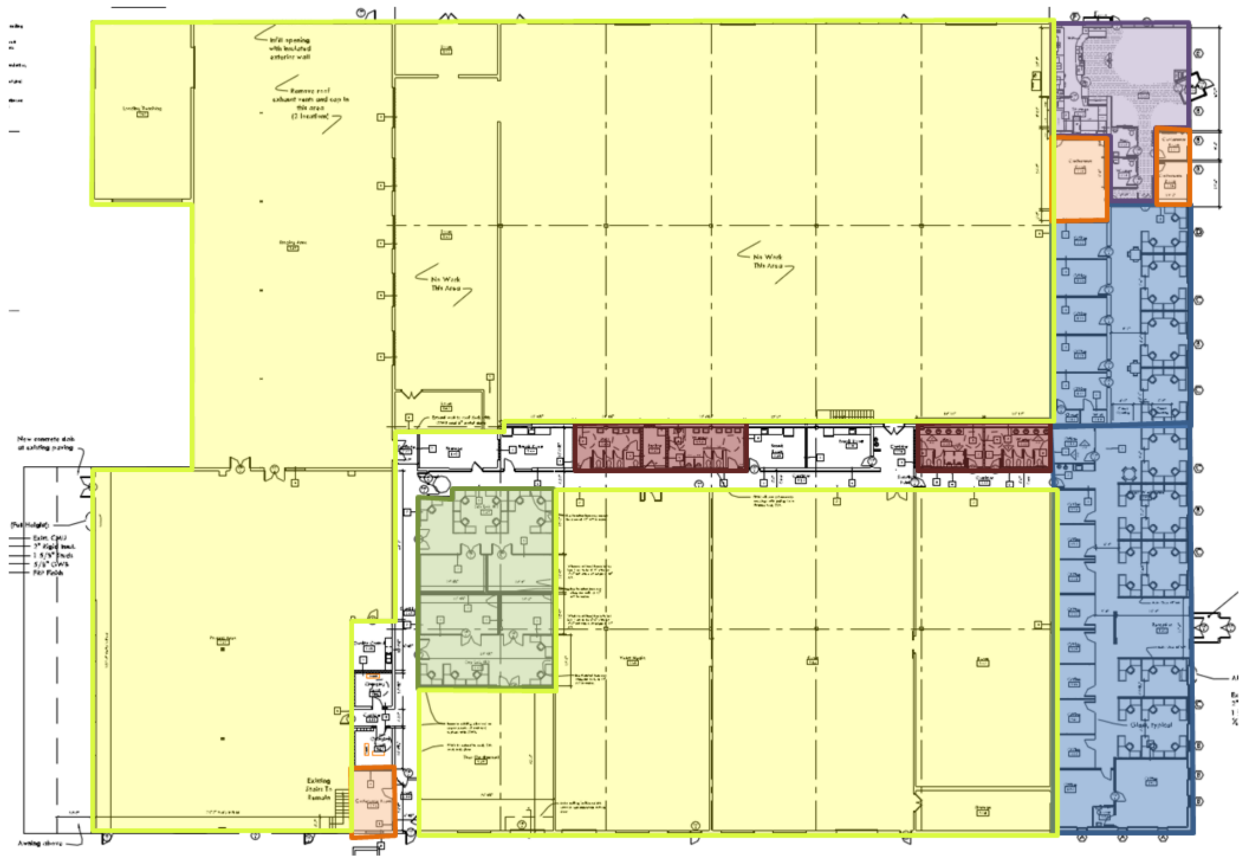


Figure 4: Space Type Layout

KEY

- Office Space
- Warehouse
- Dry Lab
- Restrooms
- Conference Rooms
- Café Space

Internal Loads

The internal loads for the building were dependent on the type of space in question. For office space and conference rooms, the lighting power density and electrical equipment load was 2.0 W/sq. ft. and 1.0 W/sq. ft., respectively. Warehouse areas were modeled to have a lighting power density of 2.5 W/sq.ft. and an electrical equipment load of 2.5 W/sq. ft. Corridor and restroom spaces were modeled as 1.0 W/sq. ft. for both internal loads. Areas such as office spaces, conference rooms, and lab spaces were designated as spaces containing people undergoing "office work", which determined their sensible people loads. People in warehouse areas were designated as "medium work" individuals, which created a larger sensible people load.

System Load Analysis Results

The six rooftop units were simulated individually to determine the amount of cooling, heating, and ventilation required for each space throughout different months of the year. Each system was modeled as a single zone, constant air volume (CAV) packaged rooftop unit. Occupied T-stat setpoints were considered at 74°F for cooling and 70°F for heating. The demand safety factors for latent and sensible cooling were set at 10%, while heating was set at 25%. All rooftop units were equipped with a preheat coil, and RTU-5 and RTU-6 were also considered to contain an economizer. Table 5, below, shows the cooling, heating, and ventilation rates per square foot of office area.

Table 5: Block Load Calculations

	Cooling (ft^2/ton)	Heating (Btu/h*ft^2)	Supply Air (cfm/ft^2)	Ventilation Air (cfm/ft^2)
RTU-1	561.7	7.8	0.85	0.15
RTU-2	569.7	9.3	0.86	0.21
RTU-3	355.0	14.5	1.46	0.13
RTU-4	405.2	10.5	1.28	0.12
RTU-5	287.5	17.5	1.66	0.22
RTU-6	427.1	14.4	1.09	0.41

The variation in supply air (cfm/ft^2) is best explained by the different load needs for each space. Although the six rooftop units do not possess a relatively similar supply air rate, this can be understood by the various types of spaces and occupants for each space assigned to its respective rooftop unit. For instance, areas near the dry lab portion of the building are more likely to require a larger supply air per square foot, as the demand for fresh and new air is much more justifiable than in a region of internal offices, such as RTU-2. Although a good rule of thumb for cooling square feet per ton is roughly 400 ft^2/ton, the variability of each space played a major role in its deviance from that figure. Ventilation rates were also quite varied, as rooftop units such as RTU-5 and RTU-6 were forced to expel much larger quantities of air from the dry labs and bathrooms.

Existing System Energy Consumption and Operating Costs

Using the 'Building Simulation' component of Carrier Hap 4.7, a relatively accurate energy consumption and cost analysis was able to be conducted. The building simulation was able to calculate the monthly energy consumption and cost data for HVAC components such as air system fans, heating, and cooling demands, as well as non-HVAC building components such as lighting and electrical equipment. Local utility rates for electricity and natural gas were found through the assistance of the Duquesne Light and Columbia Gas Utility Rate Catalog. Table 6, below, lists the customer demand charge and utility rate for both electricity and natural gas in the Western Pennsylvania area. Table 7 lists the annual energy consumption for HVAC, lighting, and electrical equipment. Figure 5 is a graphical representation of this information.

Table 6: Local Utility Rates

	Customer Demand Charge ($)	Utility Rate
Electricity	$430 per month	$.1709 per kWh
Natural Gas	$130 per month	$20.78 per therm

Table 7: Energy Consumption Breakdown

	Energy (kWh)	Total Energy (%)
HVAC	595,045	18.3%
Electrical Equipment	1,162,376	35.7%
Lighting	1,494,636	46.0%

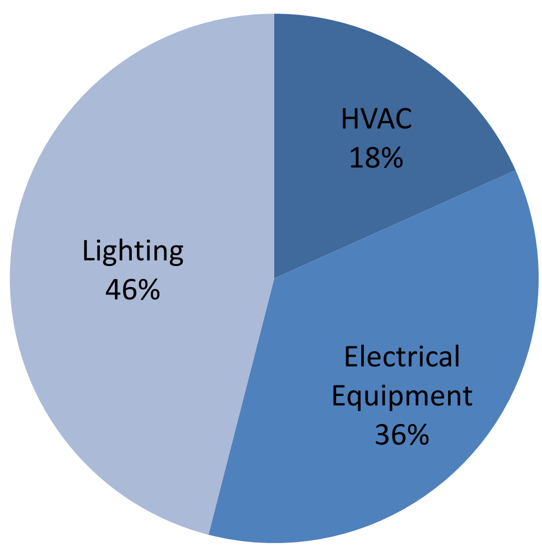


Figure 5: Energy Consumption Pie Chart

The energy consumption of 123 Alpha Drive can also be broken down by consumption per month, as shown in Figure 6 below. July was found to be responsible for the peak energy consumption, as the cooling load for the building was at its maximum.

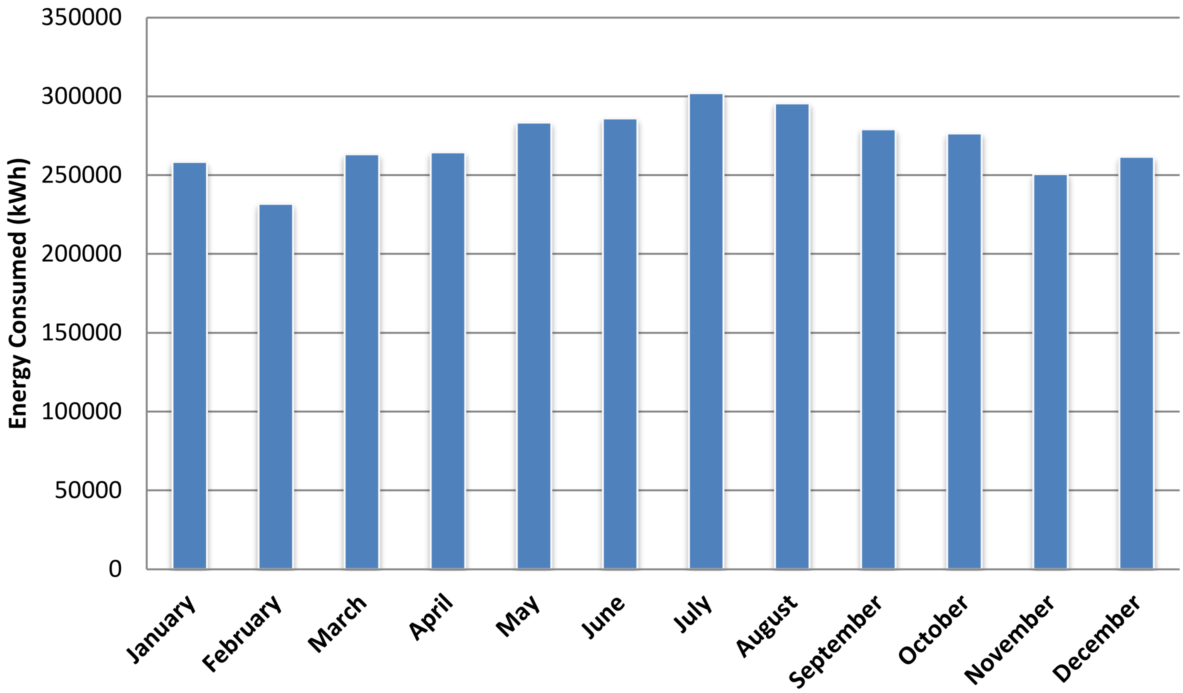


Figure 6: Monthly Electrical Energy Consumption

Monthly energy consumption is indirectly related to monthly energy cost, which can also be modeled using the Building Simulation tool in Carrier HAP 4.7. The electrical cost can be further broken down by use, such as HVAC, lighting, and electrical equipment. According to the building simulation report, the cost to provide HVAC electricity to 123 Alpha Drive was **\$0.96/ft^2** and the total electrical cost was found to be **\$4.89/ft^2**. Figure 7, below compares monthly electrical cost by use.

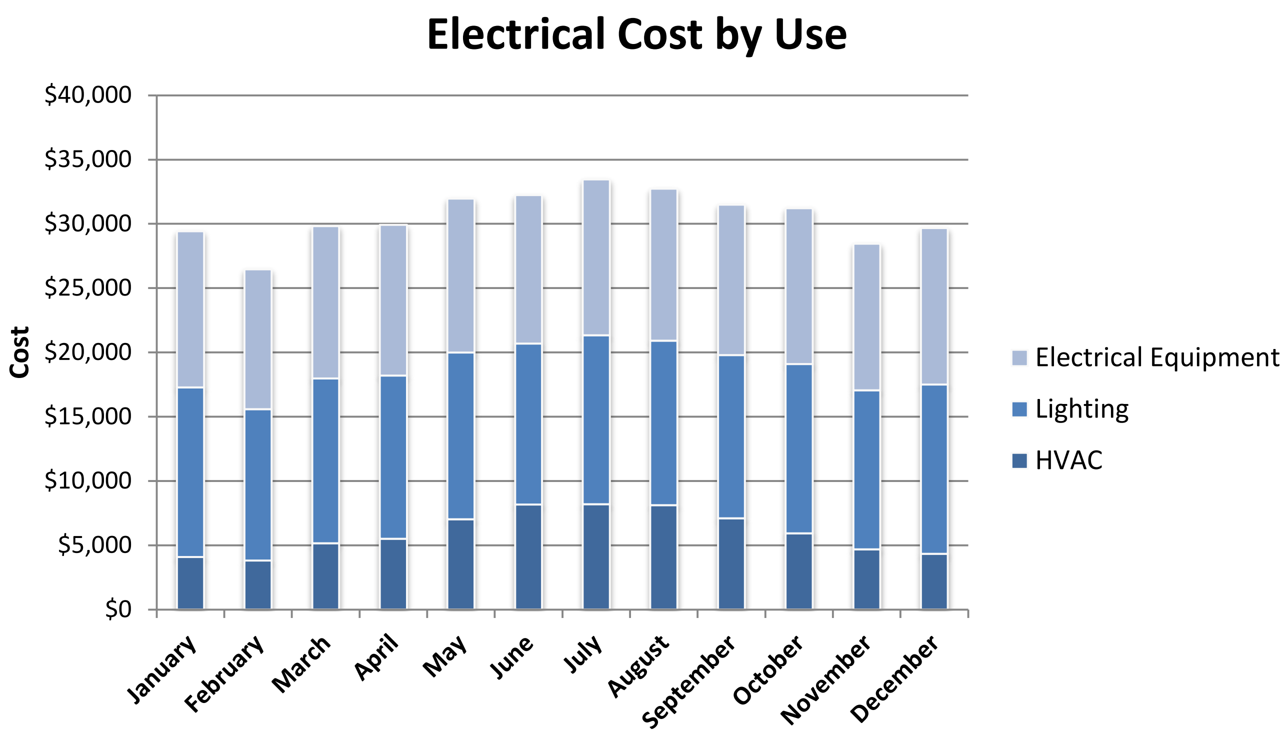


Figure 7: Monthly Electricity Cost by Use

Carbon Dioxide Emissions Analysis

The use of electricity and natural gas as energy sources results in a relatively significant amount of carbon dioxide pollutants produced and released into the surrounding atmosphere. Using carbon dioxide emissions factors for electricity and natural provided by the Environmental Protection Agency's 'Emission Factors for Greenhouse Inventories", found in Appendix __, an educated approximation of the annual carbon dioxide emissions was produced below.

Table 8: Annual CO2e Emissions

Component	Entire Building
CO2 Equivalent (lbs)	5,048,814

Building Energy and Cost Analysis Results

From the building load simulations and system design reports, it can be concluded that the majority of the annual energy consumption and electric costs are a consequence of the high electrical equipment and lighting loads for many of the spaces in 123 Alpha Drive. The warehouse and process areas of the building are the key contributor to high lighting and electrical equipment loads. With warehouse space occupying nearly 70% of the building's square area, it is not surprising that the percentage of energy consumption and cost is heavily based in these two categories. The total annual operating cost for 123 Alpha Drive was estimated to be **$366,742**, 80% of which was non-HVAC energy consumption. The building was determined to have an operating cost of $\$4.93/ft^2$, and an HVAC operating cost of $\$0.96/ft^2$.

Mechanical Depth Investigation

Introduction

In an effort to make 123 Alpha Drive more an energy efficient, adaptable, and comfortable HVAC environment to work in, a mechanical redesign of certain spaces has been proposed. This redesign aims to improve the office, conference room, dry lab, and café spaces in the building. The warehouse and processing areas of the building possess too little information available in terms of mechanical equipment and load requirements, so the following spaces will be investigated in this mechanical depth:

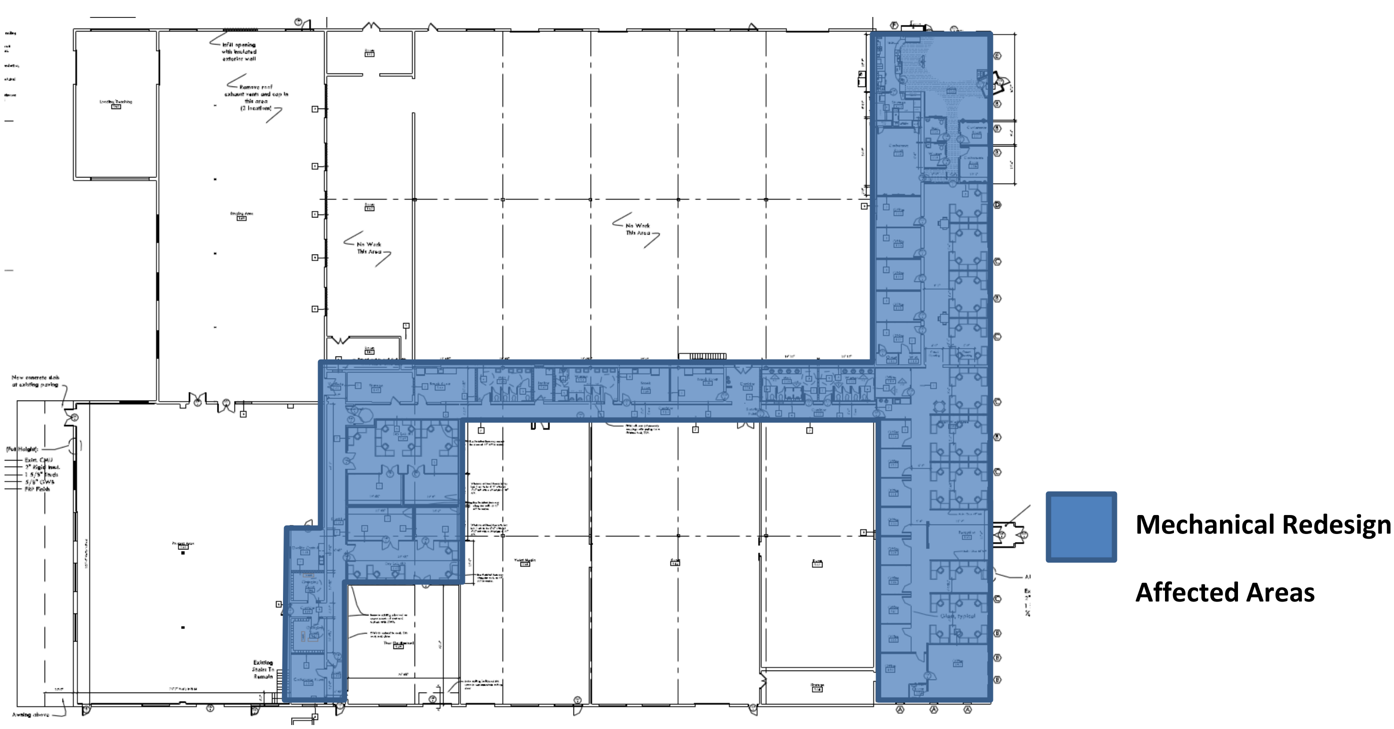


Figure 8: Proposed Mechanical Redesign Affected Areas

The affected HVAC systems for the proposed redesign include the 6 original rooftop units and the 7 ton radiant floor cooling and heating system located along the northeast portion of the building. Both mechanical systems will be substituted in favor of a variable refrigerant flow (VRF) system. The variable refrigerant flow system is expected to produce lower annual energy costs, emit less carbon dioxide pollutant into the surrounding area, and provide the highest level of variability and control for occupants in the system' spaces. The VRF systems installed are also expected to significantly reduce the amount of HVAC noise contribution to the office and lab spaces, as investigated later in the acoustical breadth section. As a standalone system, variable refrigerant flow fan coils do not possess the capability of ventilation and fresh air, so each VRF system will be accompanied by an energy recovery unit with an enthalpy wheel included. A detailed investigation into the control scheme for the VRF units will also be provided.

The first costs for the proposed variable refrigerant flow systems and energy recovery units are expected to be significantly higher than that of the original system, so a cost analysis will be done in order to determine a payback period and if the system is economically feasible.

Variable Refrigerant Flow Systems – Mechanical Depth

Background

The office and lab areas of 123 Alpha Drive are prone to a wide variety of conditioning and load needs for each specific space. The installation of six single zone constant air volume rooftop units (RTUs) to service these areas is not a poor choice in any regards, but there are opportunities to improve the reliability of comfort for building occupants and save on annual HVAC costs by replacing the existing RTUs with a variable refrigerant flow (VRF) system. Due to the size of the redesign area, it is likely that multiple VRF systems will be installed

Variable refrigerant flow systems are comprised of several different components, which in conjunction are able to utilize refrigerant flow in order to individually heat or cool spaces. VRF systems are effective in controlling the flow of the working fluid for each individual terminal unit so that each conditioning zone is ventilated properly with as little energy as possible. The working fluid for these systems involves a refrigerant and antifreeze mixture that transports heating or cooling throughout the system. The refrigerant and antifreeze selected for this investigation will be introduced later in the depth.

Components

Condensing Unit

Most VRF systems consist of a condensing unit, or string of condensing units in which refrigerant is converted from a gaseous state to a liquid state by the process of heat transfer and condensing. The cooling required to incite a phase change is accomplished by a built-in heat exchanger, which draws heat from the fluid and converts the refrigerant vapor to liquid form. A compressor installed within the condensing unit increases the pressure acting on the fluid, allowing it to move through the unit and into the outlet tubing.

Refrigeration Tubing

Upon leaving the condenser, the fluid must travel to the terminal fan coil units. In most HVAC applications, this involves a considerable amount of tubing to be installed in order to transport the working fluid to its destination. Contrary to traditional constant flow systems, three tubes are used to optimize the VRF process. These three tube lines work in conjunction with each other in order to complete the system loop and to deliver the correct amount and composition of fluid to each component of the system.

Line One: The liquid line, which draws the refrigerant from the condensing unit to the fan coil units, takes advantage of the compressor's pressure increase in order to deliver the fluid in an efficient and speedy manner.

Line Two: The suction line sends the refrigerant liquid that has already aided in conditioning the space back to the condensing unit so that it can be used again.

Line Three: The discharge gas line, which transports dry vapor produced at the terminal units back to the compressor and condensing unit.

Mode Change Units (MCU)

The variability that defines a VRF system is controlled by a mode control unit (MCU) for each zone that is being conditioned. The MCU ties into the main tubing circuit and creates a branch tubing line to the terminal unit it is servicing. Mode control units have the ability to service multiple terminal units, and the proposed VRF system allows for each line to be simultaneously cooled or heated. Several ON/OFF solenoid valves trigger heating and cooling in the connected fan coil units according to their demand operation mode. By adjusting the flow at which the fluid leaves the MCU, the terminal unit will produce the required airflow into the space being conditioned without using any excess thermal energy. The MCU allows for the exact amount of fluid pressure and speed to reach the indoor fan coil units, in order to provide the most energy efficient conditioning process possible.

Indoor Fan Coil Units

In the last step of the variable refrigeration flow process, the working fluid reaches the indoor fan coil units in the ceiling of the spaces which require conditioning. These fan coil units (FCU) draw heat from or add heat to the working fluid and transfer it to the fan portion of the unit, which blows the conditioned air into the space. After the working fluid passes through the fan coil unit, it enters the suction line en route to the outdoor condensing unit for the entire process to be repeated. These indoor fan coil units can either be cassette style units in which air is provided directly from the unit to the space or can be ducted units, typically differentiated by the amount of static pressure available.

Restrictions

Like all mechanical systems, the variable refrigerant flow system has certain restrictions that must be considered during design, zone determination, and unit selection. The following are major design considerations that will affect the VRF systems recommended for 123 Alpha Drive.

Condensing Unit Elevation

If the condensing units chosen for a VRF system are specified to be outdoor units, it is advantageous and common to locate them on the roof of the building. Since head losses can negatively affect the performance and efficiency of the HVAC system, vertical distance from the condensing unit to the heat pumps needs to be considered in design. Since 123 Alpha Drive is a one story building, the highest elevation distance possible for a Samsung DVM S VRF system can be ignored for this application. The largest elevation difference, however, is shown to be 360 vertical feet in the DVM S catalog, shown below.

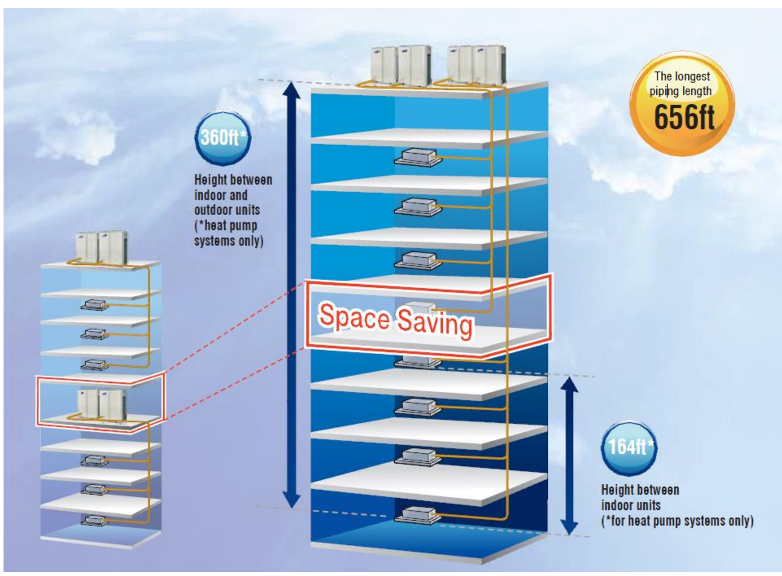


Figure 9: Vertical and Length Piping Restrictions

Length of Piping

As Figure 9 shows above, the DVM S VRF system from Samsung allows for up to nearly 650 feet of piping from the condensing unit to the farthest heat pump. 123 Alpha Drive is a building with a large building footprint, and its one story configuration makes the allowable length of piping a significant factor in the design of the VRF systems. When designing VRF systems for the office and lab spaces, the length of piping will have to be considered and checked for the longest pipe length of each system.

Ventilation and Fresh Air

Unfortunately, a VRF system does not have the ability to provide fresh air to the spaces it is conditioning and also cannot expel return or exhaust air. As a result, most VRF systems require a Dedicated Outdoor Air System (DOAS), typically in the form of an energy recovery unit. Such a system will accompany each VRF system installed in this redesign to ensure proper ventilation, contaminant removal, and fresh air.

Refrigerant Type

For some VRF systems, like the Samsung DVM S series, the available refrigerants and antifreeze solutions are quite limited. For this mechanical investigation, the only available refrigerant accepted by the DVM S series VRF system is R-410A.

Static Pressure

One of the more challenges characteristics about the indoor units of the VRF system is the lack of external static pressure, which allows for longer duct lengths and terminal unit placement farther away from the diffuser or grille. In order to combat this issue, the two piping lines from the mode change unit can extend over 400 feet to the terminal unit. This allows for each unit to be placed near or at the area it is servicing. In addition, various indoor unit models provide ductless cassette style discharge directly into the space, eliminating the issue of little external static pressure. If ducted units must be used, the DVM S Series catalog offer slim duct, medium static pressure, and high static pressure duct units.

Sizing

In order to design the most energy efficient and cost effective variable refrigerant systems, a detailed sizing exercise must be conducted for the condensing units and the terminal unit heat pumps. The first step taken in this process is the subdividing of spaces in the redesign area in order to determine how many VRF systems will exist for the building. Horizontal piping length (maximum of ~650 ft) and zone demand loads were referenced to create 3 separate zones in which three VRF systems could service the office and laboratory spaces. Figure 10, below, splits the building redesign zone into 3 system areas based on piping length restrictions with a safety factor of 25%, meaning a maximum piping length of 490 feet will be enforced for each system. If all condensing units are installed near the middle of each zone, the longest piping lengths for each system will be compliant with the maximum piping length allowed.

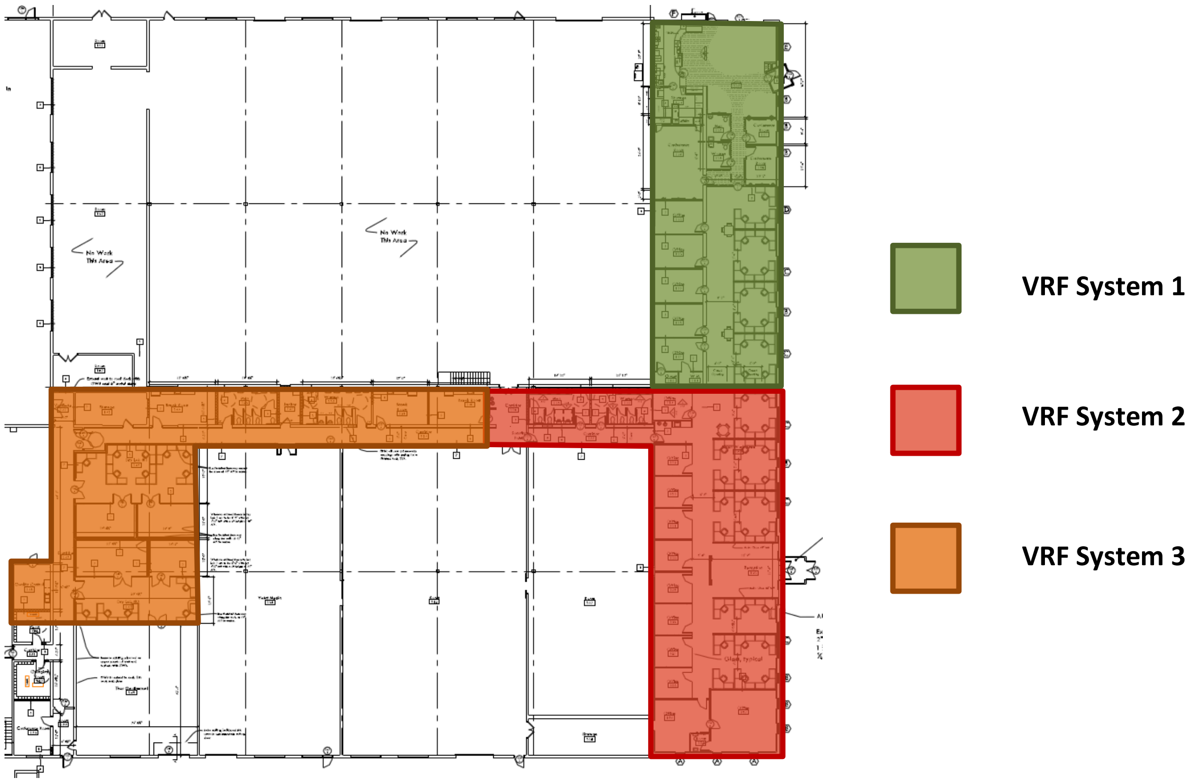


Figure 10: VRF System Area Layout

The next step in sizing the 3 variable refrigerant flow systems involves calculating the necessary tonnage for each condensing unit. For the Samsung DVM S series, the number of condensing units required per system increases depending on the require tonnage. Table 9, below, indicates the necessary number of condensing units per ton required for each VRF system.

Table 9: Condensing Unit Quantity for VRF Systems

Number of Condensing Units Needed	One	Two	Three
Size (tons)	6-12	14-24	26-36

By finding the approximate tonnage per VRF system outlined in Figure 10, the number of condensing units required for each VRF system can be determined, as well as the required tonnage for each individual heat pump servicing its respective zone. Tables 10, 11, and 12 represent the individual tonnages for each zone and the total tonnage required for the variable refrigerant system. This information will be able to be used to select the proper mechanical equipment for each VRF system. Tonnages are found by dividing the maximum cooling load by 12,000 BTUs. These values can be referencing in the zone summary reports provided in Appendix B.

Table 10: VRF System 1 Approximate Tonnage

VRF System 1		
Zone Space	**Required Cooling Load (tons)**	**Nearest Heat Pump Size (tons)**
Storage 124	0.21	0.75
Café 122	0.33	0.75
Office 121	0.24	0.75
Office 120	0.24	0.75
Office 119	0.24	0.75
Office 118	0.24	0.75
Office 117	0.28	0.75
Conference Room 127	0.32	0.75
Conference Room 128	0.375	0.75
Conference Room129	0.66	0.75
Open Work Area	3.46	4
	Total	**11.5**

Table 11: VRF System 2 Approximate Tonnage

VRF System 2		
Zone Space	**Required Cooling Load (tons)**	**Nearest Heat Pump Size (tons)**
Office 102	0.97	1
Office 105	0.45	0.75
Office 106	0.175	0.75
Office 107	0.175	0.75
Office 108	0.175	0.75
Office 109	0.175	0.75
Office 111	0.175	0.75
Office 112	0.175	0.75
Office 113	0.175	0.75
Office 114	0.183	0.75
Office 119	0.24	0.75
Open Work 101	2.86	3
Corridor 131	0.22	0.75
Women 132	0.3	0.75
Men 133	0.3	0.75
	Total	**13.75**
	Safety Factor	1.25
	CU Tonnage	**17.19**

Table 12: VRF System 3 Approximate Tonnage

VRF System 3		
Zone Space	**Required Cooling Load (tons)**	**Nearest Heat Pump Size (tons)**
Dry Lab Storage 1	0.275	0.75
Dry Lab Storage 2	0.275	0.75
Dry Lab Storage 3	0.275	0.75
Dry Lab Storage 4	0.275	0.75
Dry Lab 147	1.06	1.5
Dry Lab 145	0.85	1.5
Corridor 151	0.7	1
Storage 141	0.28	0.75
Break Room 144	0.28	0.75
Conference Room 153	0.43	0.75
Quality Control 146	0.25	0.75
	Total	**10**
	Safety Factor	1.25
	CU Tonnage	**12.5**

Safety Factors of 25% were applied to the approximate condensing unit tonnages in order to ensure that the VRF system is always capable of meeting its load. The smallest possible VRF terminal unit heat pump is roughly .75 ton, which explains the rightmost column in the three tables above. This is advantageous, however, as these heat pumps will almost surely operate at a partial load at all times of the year, resulting in reduced energy costs and consumption. With this data we can determine the number of condensing units required for each VRF system.

Variable Refrigerant System 1: 1 Required Outdoor Condensing Unit (12 combined tons)

Variable Refrigerant System 2: 2 Required Outdoor Condensing Units (18 combined tons)

Variable Refrigerant System 3: 2 Required Outdoor Condensing Units (14 combined tons)

DOAS System Sizing

Each variable refrigerant flow (VRF) system will require fresh air to be supplied and stale air to be expelled from the zones. To accomplish this, a dedicated outdoor air system (DOAS) will be installed in conjunction with each VRF system. The DOAS system will utilize a total energy wheel in order to gather the energy contained in the exhausted air and use it to precondition the outdoor ventilation air in the system. The total energy wheel will also serve to de-humidify and humidify incoming ventilation air depending on the required needs of the building and time of the year. The controls for the energy recovery ventilation aspect of the system will be explained in more detail later in the depth. By using the zone summary reports obtained through Carrier HAP 4.7 (Available in Appendix B), it can be determined that each DOAS system should provide close to 1200 cfm of supply air to each VRF system area. This will ensure proper ventilation and humidification of the air in these spaces. 10% of the original required ventilation was factored into this calculation in order to include parasitic energy for drive losses for supply and exhaust air. Table 13, below shows the sizing information for a DOAS system.

Table 13: Dedicated Outside Air System Sizing

	Airflow (cfm)	Ext. Static Pressure (in wg.)	Motor Brake Horsepower	Fan Speed (RPM)
Supply Air	1,250	1.50	1.00	1723
Exhaust Air	1,175	.75	.64	1413

Layout

The last design consideration to be made before selecting particular mechanical equipment for the VRF system and DOAS systems is the layout of each system. In an attempt to save on mechanical first costs and to promote an intelligent system design, each system will feature four to six terminal unit heat pumps to each mode change unit (MCU). This will reduce main line piping length from the condensing units to the mode change unit and if each MCU is located correctly next to the four to six nearby heat pumps it will be servicing. In addition, spaces that are large and require significant conditioning like the open office areas will be installed with multiple smaller heat pumps spread across its area in order to achieve an even airflow across the space and maximize comfort. A potential layout scheme can be viewed in Appendix B of this report.

Equipment Selection

For variable refrigerant flow systems to work properly, it is essential that the condensing units, mode change units, and terminal fan coil or heat pump units are able to work and communicate together. For this reason, the mechanical equipment selected for the three variable refrigerant flow systems will be from Samsung's DVM S Series. The DVM series allows for excellent control options throughout each stage of the VRF process, and offers a wide variety of terminal units to best suit each situation. DVM S Series systems also allow for simultaneous individual heating and cooling of each terminal unit, even if two terminal units share a mode change unit. The efficiencies of these systems, which will be introduced later in the report, are quite favorable.
The overall variability and adaptability of the DVM Series systems makes it an ideal choice for 123 Alpha Drive. A proper selection of the series' available units are very crucial to the success and effectiveness of each system, however. Below are the selected condensing and terminal units for each VRF system.

Outdoor Condensing Units

Using the approximated tonnage requirements from the sizing portion of this report, the following selections were made for the three VRF systems.

Table 14: Condensing Unit Selection

	Number of Condensing Units	Model Name	Combined CU Model Names		Airflow (cfm)	Nominal Capacity	
						Cooling (BTU/h)	Heating (BTU/h)
						TC	TC
CU-1	1	AM144FXVAJR/AA	-	-	9535	144000	162000
CU-2	2	AM192FXVAJR/AA	AM072FXVAJR/AA	AM120FXVAJR/AA	16421	192000	216000
CU-3	2	AM192FXVAJR/AA	AM072FXVAJR/AA	AM120FXVAJR/AA	16241	192000	216000

For the combined condensing units, Figure 11 below indicates how the two condensing units may be linked.

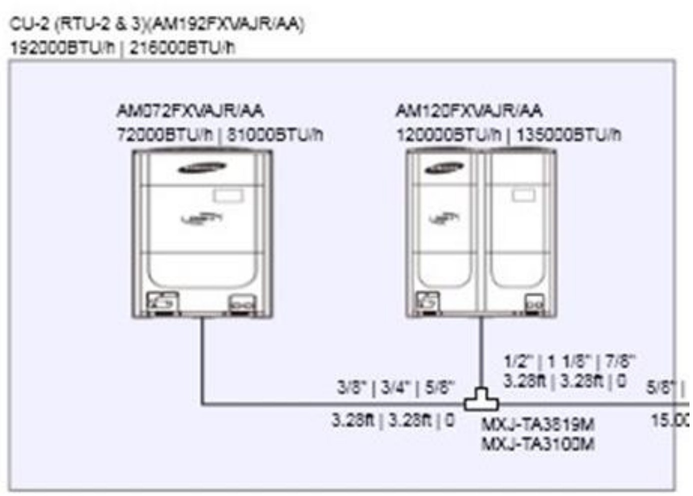


Figure 11: Combined Condensing Unit Diagram

Mode Control Units (MCUs)

The mode control units available through the DVM S Series catalog allow for four to six terminal units to be linked to a single MCU. Simultaneous heating and cooling is available with these units, as well as the ability to completely shut off any individual heat pump while the others remain active. Figure 12, below, illustrates a typical mode control unit for the DVM S Series. The mode control units for the DVM S Series are significantly smaller in volume and weigh up to 70% less than competitors' mode control units, allowing them to be placed in tighter spaces and making design layout easier. Figure 13, below, shows the reduction in volume and weight for a typical mode control unit.

Figure 13: Typical DVM S Mode Control Unit

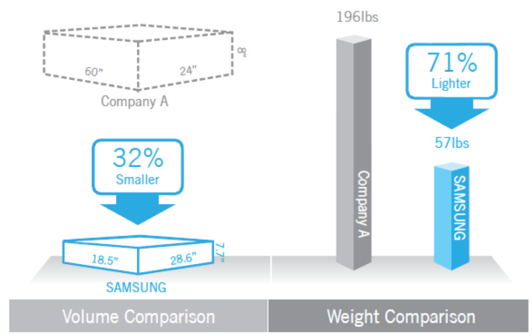


Figure 14: DVM S MCU Size Reductions

Indoor Fan Coil Terminal Units

The last selection components for the variable refrigerant flow system include its terminal units, which can vary from .75 tons to 4 tons depending on the space load. Samsung's DVM S Series offers many different variations of fan coil units to best serve the prescribed design requirements. Since a majority of the terminal units will be placed directly above the spaces they are conditioning, the option to use ductless cassette style units was made. For the individual office spaces, 1 way cassette fan coil units were installed, but for larger areas requiring a better distribution of air across its area, 4 way cassettes were selected. 1 way cassette units should be placed along the walls of the room it is conditioning, while 4 way cassette units are best suited for a central ceiling placement. Figure 15, below, shows a typical placement of each cassette option.

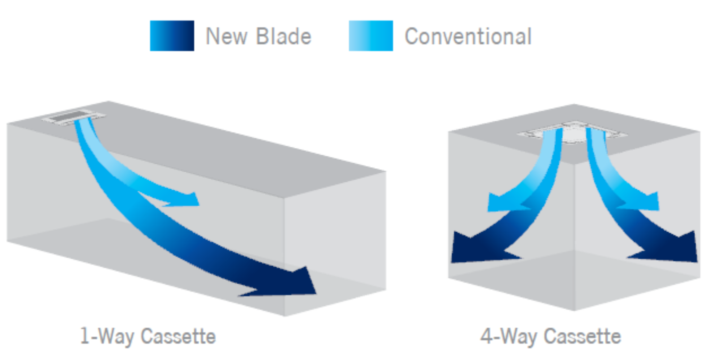


Figure 15: 1-Way vs. 4-Way Cassette Placement

Figure 16: 1 Way Cassette Indoor Unit

Figure 17: 4 Way Cassette Unit

For VRF system 3, areas such as the quality control room and break rooms were outfitted with a High Static Pressure (HSP) Duct Unit, which allows for ducted supply to reach areas that would normally be inaccessible due to piping length restrictions. The HSP duct fan coil unit was selected over the medium and slim duct units in order to deliver up to .99” of external static pressure to the system, which should allow for the HSP ducts to service multiple spaces without significant performance. Tables 15, 16, and 17 list the unit selection for VRF systems 1, 2, and 3 respectively.

Figure 18: High Static Pressure Duct Unit

Table 15: Variable Refrigerant Flow System 1 Terminal Unit Selection

Variable Refrigerant Flow System 1						
Unit	Model Name	Unit Type	Airflow (cfm)	Nominal Capacity		
				Cooling (BTU/h)		Heating (BTU/h)
				TC	Sensible Cooling	TC
Unit 1	AM007FN1DCH/AA	1-Way Cassette	212	7500	5100	8500
Unit 2	AM007FN1DCH/AA	1-Way Cassette	212	7500	5100	8500
Unit 3	AM007FN1DCH/AA	1-Way Cassette	212	7500	5100	8500
Unit 4	AM007FN1DCH/AA	1-Way Cassette	212	7500	5100	8500
Unit 5	AM007FN1DCH/AA	1-Way Cassette	212	7500	5100	8500
Unit 6	AM007FN1DCH/AA	1-Way Cassette	212	7500	5100	8500
Unit 7	AM007FN1DCH/AA	1-Way Cassette	212	7500	5100	8500
Unit 8	AM007FN1DCH/AA	1-Way Cassette	212	7500	5100	8500
Unit 9	AM007FN1DCH/AA	1-Way Cassette	212	7500	5100	8500
Unit 10	AM012FNNDCH/AA	Mini 4-Way Cassette	335	12000	9300	13500
Unit 11	AM012FNNDCH/AA	Mini 4-Way Cassette	335	12000	9300	13500
Unit 12	AM012FNNDCH/AA	Mini 4-Way Cassette	335	12000	9300	13500
Unit 13	AM012FNNDCH/AA	Mini 4-Way Cassette	335	12000	9300	13500
Unit 14	AM012FN4DCH/AA	4-Way Cassette	494	12000	9300	13500
Unit 15	AM024FN4DCH/AA	Mini 4-Way Cassette	565	24000	17100	27000

Table 16: Variable Refrigerant Flow System 2 Terminal Unit Selection

Variable Refrigerant Flow System 2						
Unit	Model Name	Unit Type	Airflow (cfm)	Nominal Capacity		
				Cooling (BTU/h)		Heating (BTU/h)
				TC	Sensible Cooling	TC
Unit 1	AM007FN1DCH/AA	1-Way Cassette	212	7500	5100	8500
Unit 2	AM007FN1DCH/AA	1-Way Cassette	212	7500	5100	8500
Unit 3	AM007FN1DCH/AA	1-Way Cassette	212	7500	5100	8500
Unit 4	AM007FN1DCH/AA	1-Way Cassette	212	7500	5100	8500
Unit 5	AM007FN1DCH/AA	1-Way Cassette	212	7500	5100	8500
Unit 6	AM007FN1DCH/AA	1-Way Cassette	212	7500	5100	8500
Unit 7	AM007FN1DCH/AA	1-Way Cassette	212	7500	5100	8500
Unit 8	AM009FNNDCH/AA	Mini 4-Way Cassette	300	9500	6800	10500
Unit 9	AM009FNNDCH/AA	Mini 4-Way Cassette	300	9500	6800	10500
Unit 10	AM009FNNDCH/AA	Mini 4-Way Cassette	300	9500	6800	10500
Unit 11	AM009FNNDCH/AA	Mini 4-Way Cassette	300	9500	6800	10500
Unit 12	AM012FNNDCH/AA	Mini 4-Way Cassette	335	12000	9300	13500
Unit 13	AM012FNNDCH/AA	Mini 4-Way Cassette	335	12000	9300	13500
Unit 14	AM012FNNDCH/AA	Mini 4-Way Cassette	335	12000	9300	13500
Unit 15	AM012FNNDCH/AA	Mini 4-Way Cassette	335	12000	9300	13500
Unit 16	AM012FNNDCH/AA	Mini 4-Way Cassette	335	12000	9300	13500
Unit 17	AM012FNNDCH/AA	Mini 4-Way Cassette	335	12000	9300	13500
Unit 18	AM012FNNDCH/AA	Mini 4-Way Cassette	335	12000	9300	13500
Unit 19	AM018FNNDCH/AA	Mini 4-Way Cassette	388	18000	13600	20000

Table 17: Variable Refrigerant Flow System 3 Terminal Unit Selection

Variable Refrigerant Flow System 3						
Unit	Model Name	Unit Type	Airflow (cfm)	Nominal Capacity		
				Cooling (BTU/h)		Heating (BTU/h)
				TC	Sensible Cooling	TC
Unit 1	AM007FN1DCH/AA	1-Way Cassette	212	7500	5100	8500
Unit 2	AM007FN1DCH/AA	1-Way Cassette	212	7500	5100	8500
Unit 3	AM007FN1DCH/AA	1-Way Cassette	212	7500	5100	8500
Unit 4	AM007FN1DCH/AA	1-Way Cassette	212	7500	5100	8500
Unit 5	AM009FN4DCH/AA	4-Way Cassette	495	9000	6700	10000
Unit 6	AM009FN4DCH/AA	4-Way Cassette	495	9000	6700	10000
Unit 7	AM030FN4DCH/AA	4-Way Cassette	688	30000	23000	34000
Unit 8	AM048FNHDCH/AA	HSP Duct	1183	48000	37000	54000
Unit 9	AM076FNHDCH/AA	HSP Duct	1836	78800	59200	85200

Dedicated Outside Air System (DOAS)

Considering the sizing determination made in the previous sections, a dedicated outside air system must be selected for each variable refrigerant flow system. Semco, a company that produces DOAS systems, will be used in the mechanical unit selection. The DOAS systems will act as an exhaust air system and a fresh air preconditioner. The DOAS system will incorporate a 3 angstrom total energy wheel that exercise energy recovery in both the winter and summer months, transforming the DOAS system into an energy recovery ventilator (ERV). A stop/jog economizer will also accompany the total energy wheel. Humidification and dehumidification applications are also present in the total energy wheel, which will aid is achieving maximum comfort in the office and lab space areas. Proper control of the DOAS system, more specifically the total energy wheel, will be visited in the next section. The Semco FV-2000 Fresh Air Preconditioner will be used for each of the VRF systems. Its unit information can be found below in Table 18.

Table 18: Dedicated Outside Air System Selection

VRF System	ERV Unit		Airflow (cfm)	External Static Pressure (in wg.)	Motor Brake Horsepower	Fan Speed (RPM)
1	FV-2000	Supply Air	1,250	1.5	1	1723
		Exhuast Air	1,175	0.75	0.64	1413
2	FV-2000	Supply Air	1,250	1.5	1	1723
		Exhuast Air	1,175	0.75	0.64	1413
3	FV-2000	Supply Air	1,250	1.5	1	1723
		Exhuast Air	1,175	0.75	0.64	1413

Controls

For a HVAC system as complex as a variable refrigerant flow system, the controls required to operate it at its full and desired potential must be understood and selected carefully. Fortunately, the Samsung DVM S series VRF system offers a wide variety of occupant, owner, and building control options. DVM S series systems offer individual control in the form of wired and wireless remote controllers, central control in the form of wired remote controllers, multiple building management systems controllers, and a heat pump mode selector switches.

Since the three variable refrigerant systems are conditioning the office and lab spaces of the building, individual control is a key characteristic to achieving occupant comfort. Individual wired remote controllers for each fan coil unit will be provided for each office and conference room, and will be tied into a central control unit that serves as a basic zone control system, can produce schedules, and can set upper and lower thermostat restrictions to prevent occupants from individually setting their desired temperature too high. The energy recovery ventilator controllers will be tied into the VRF system and will be monitored by the building management system. A more detailed explanation of the control design for these systems is provided below.

BACnet Gateway Central Building Management System

The BACnet Gateway is a standalone web server device that can connect up to 256 indoor units and 16 outdoor units via the internet. The product unit MIM-B17, a 12V 3A, 100-240 VAC DC adapter, offers an interface to control temperature settings, fan speed, temperature limitations, current control for outdoor units, and zone scheduling. The device is also equipped with 10 digital inputs, two of which are used for emergency shutdown. The BACnet gateway will serve to control all five condensing units and all indoor units as well. Zone management for open office areas and corridors will be monitored and executed from the MIM-B16 system. This system also provides the ability for weekly and/or daily schedule control Table 19 indicates the possible control and monitoring capabilities of the BACnet system.

Table 19: Control and Object Type for BAC-net System

BACnet MIM-B16	
Control	**Object Type**
On/Off	BV
Operation Mode	MV
Temperature Setting	AV
Fan Speed/Direction	MV
ERV Operation Mode	MV
ERV Fan Speed	MV
Fire Alarm Reset	BO
User Control Restriction	MV
Operation Mode Lock	MV
Set Temperature Limit	BV
Emergency Stop	BO
Output Contact Control	BI

Wired Remote Controller

The wired remote controllers for each indoor unit will be utilized by the building space occupants in order to control their individual indoor unit. The MWR-WE10N unit is a 12V DC device that communicates via a 2-wire PLC setup. The controller can control up to 16 indoor units and an energy recovery ventilator, although only 5 indoor units will be programmed to a controller at maximum. The device allows building occupants to control the conditioning of their office or space in terms of ON/OFF control, temperature setting, fan speed, and ERV operation. Table 20 indicates the possible control capabilities of the BACnet system.

Table 20: Control and Object Type for Wired Remote Controller

MWR-WE10N	
Control	**Object Type**
ON/OFF	BV
Operation Mode	MV
Temperature Setting	AV
Occupany Detection	BI
ERV Operation On/Off	MV
ERV Fan Speed	MV
Filter Alert and Reset	BO
Energy Saving Control	MV

Energy Recovery Ventilator

The BACnet Gateway and Wired Remote Controller have to ability to control the ERV associated with each VRF system. In the interest of controlling the ERV in the most efficient and effective manner, the building owner or maintenance staff should have control of the ERV system. In this case, the ERV controls will be monitored by the BACnet Gateway Building Management System.

Energy, Cost & Emissions Comparison

With the three variable refrigerant flow systems sized, selected, and each accompanied by a dedicated outside air system, a proper energy consumption and annual cost analysis can be conducted. Using the 'Building Simulation' component of Carrier Hap 4.7, a relatively accurate energy consumption and cost analysis was able to be produced. The building simulation was able to calculate the monthly energy consumption and cost data for HVAC components Local utility rates for electricity and natural gas were found through the assistance of the Duquesne Light and Columbia Gas Utility Rate Catalog. Table 21 lists the annual energy consumption for HVAC, lighting, and electrical equipment. Figure 19 is a graphical representation of this information.

Table 21: VRF System Annual Energy Consumption

	Energy (kWh)	Total Energy (%)
HVAC	72,316	9.2%
Electrical Equipment	321,943	40.8%
Lighting	394,259	50%

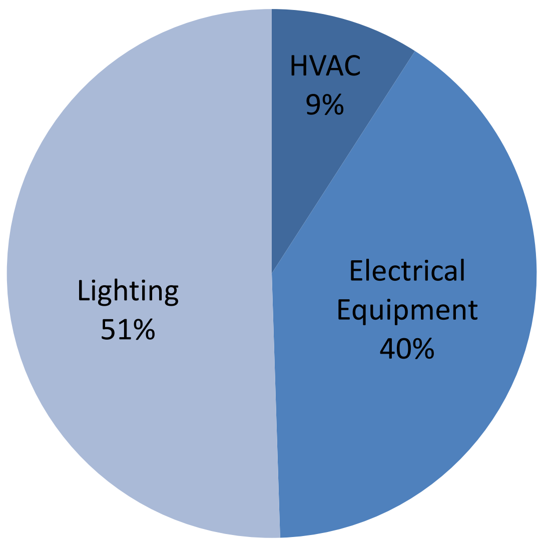


Figure 19: Annual Energy Consumption Percentage

The energy consumption of the variable refrigerant flow systems can also be broken down by consumption per month, as shown in Figure 20 below. July was found to be responsible for the peak energy consumption, as the cooling load for the building was at its maximum. Note that the data presented includes only the VRF and ERV systems of the building.

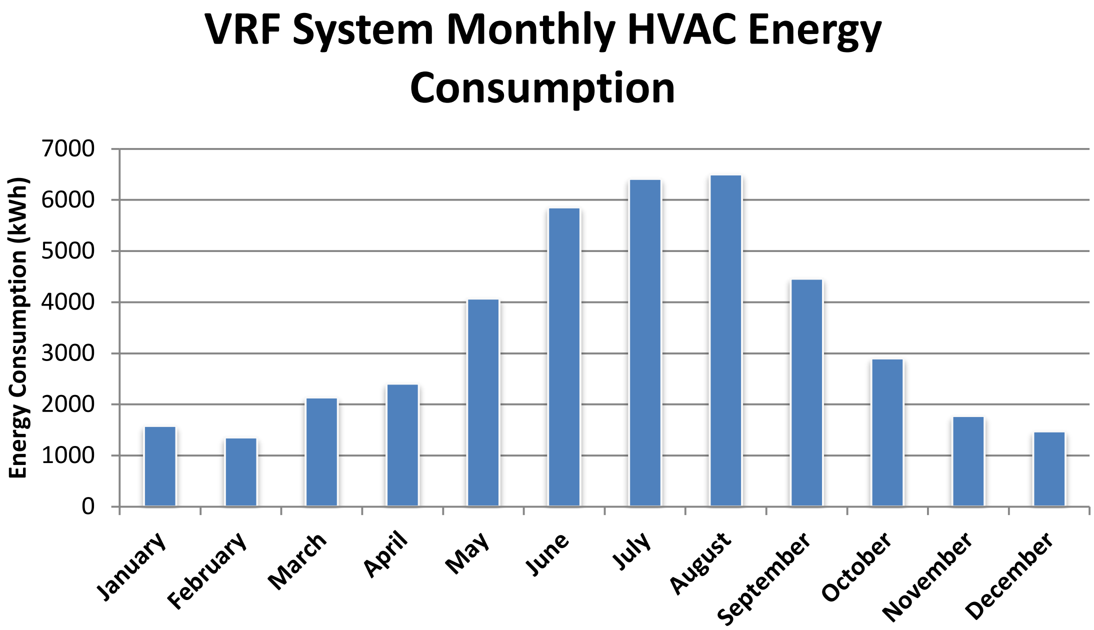


Figure 20: Monthly HVAC Energy Consumption (kWh)

Monthly energy consumption is indirectly related to monthly energy cost, which can also be modeled using the Building Simulation tool in Carrier HAP 4.7. The electrical cost can be further broken down by use, such as HVAC, lighting, and electrical equipment. According to the building simulation report, the cost to provide HVAC electricity to the affected VRF system zones was **$0.71/ft^2** and the total electrical cost was found to be **$3.87/ft^2**. Figure 21, below compares monthly electrical cost by use.

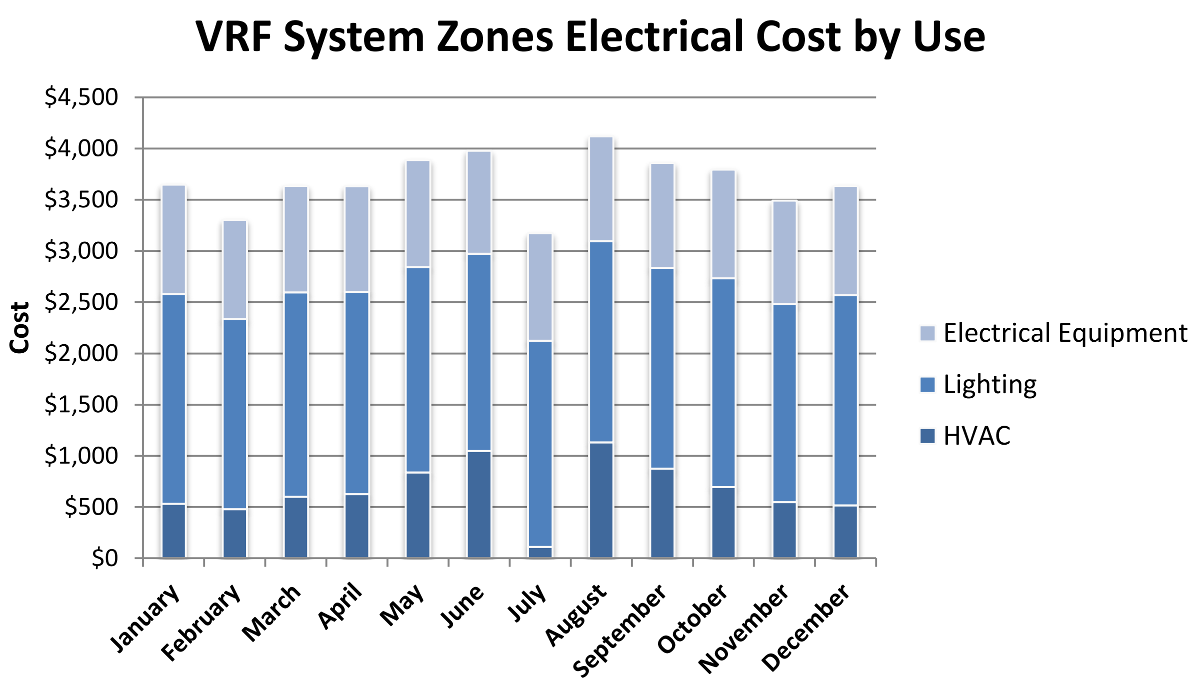


Figure 21: VRF Systems Zone Monthly Electrical Cost by Use

Cost and Energy Comparison

With the combined VRF and ERV systems simulated to find annual energy consumption and costs, a comparison between the VRF systems and the original system of the six single zone constant air volume rooftop units and the radiant floor cooling and heating system was made possible. Since the VRF systems and original rooftop units both service the same areas of the building, a building simulation was able to be conducted for only the affected and conditioned areas of the building. As a result, the following information has relatively lower costs and energy consumptions than the existing mechanical system energy analysis illustrated in pages 14-18, as that information included the entire building in the simulation report. The purpose of this comparison, however, is to compare energy costs and use for the office and lab spaces that were conditioned by the original rooftop units and the newly proposed VRF systems to determine if there is an economical benefit in favor of the VRF systems.

A comparison of monthly HVAC energy cost was done to analyze the difference in electricity and fuel costs for the original and VRF system. Table 22 shows the monthly and annual HVAC energy cost comparison between both designs. Figure 22 compares the two systems' monthly HVAC electric cost through the use of a visual medium. It was determined that the variable refrigerant flow system saves nearly $7,415 per year in comparison to the original rooftop unit and hydronic piping design, a savings of roughly 45%.

Table 22: Monthly HVAC Energy Cost Comparison

	HVAC Cost ($)		
Month	Original	VRF System	
January	$914	$531	
February	$871	$478	
March	$1,112	$600	
April	$1,183	$625	
May	$1,563	$837	
June	$1,902	$1,046	
July	$2,016	$1,117	
August	$2,026	$1,130	
September	$1,617	$875	
October	$1,279	$694	
November	$1,005	$549	
December	$928	$518	Difference
Total	**$16,416**	**$9,001**	**$ 7,415**

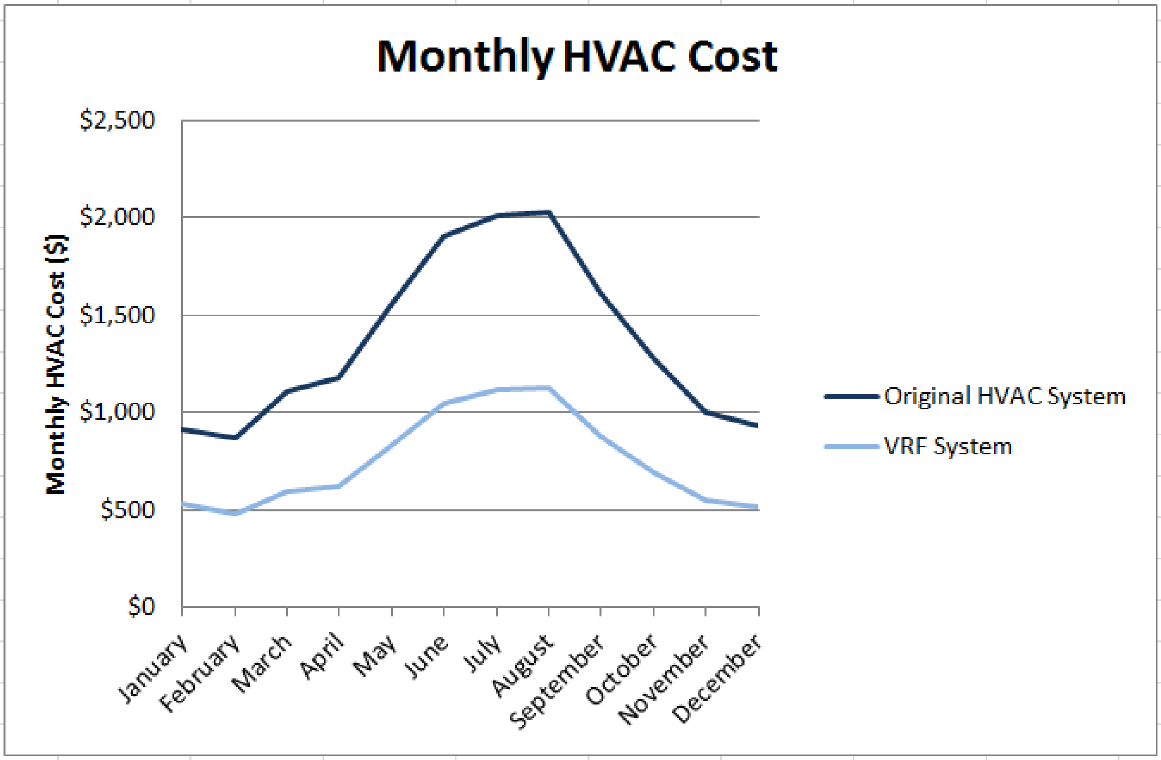


Figure 22: Monthly HVAC Cost Comparison

Energy consumption is another way to compare these two systems. A monthly energy use (kWh) comparison was conducted and the variable refrigerant flow system design was found to use 12,382 kWh less of energy in comparison to the original system. This reduction in energy usage is roughly a 15% reduction. Table 23 lists the monthly and annual energy usage for each HVAC system, while Figure 23 illustrates the difference in graphical form.

Table 23: Monthly HVAC Energy Consumption Comparison

	Energy (kWh)		
Month	Original	VRF System	
January	2630	4244	
February	2493	3759	
March	4922	4801	
April	5673	4988	
May	8943	6737	
June	11782	8439	
July	12802	9078	
August	12865	9170	
September	9381	7041	
October	6501	5568	
November	4016	4353	
December	3140	4138	Difference
Total	85148	72316	**12832**

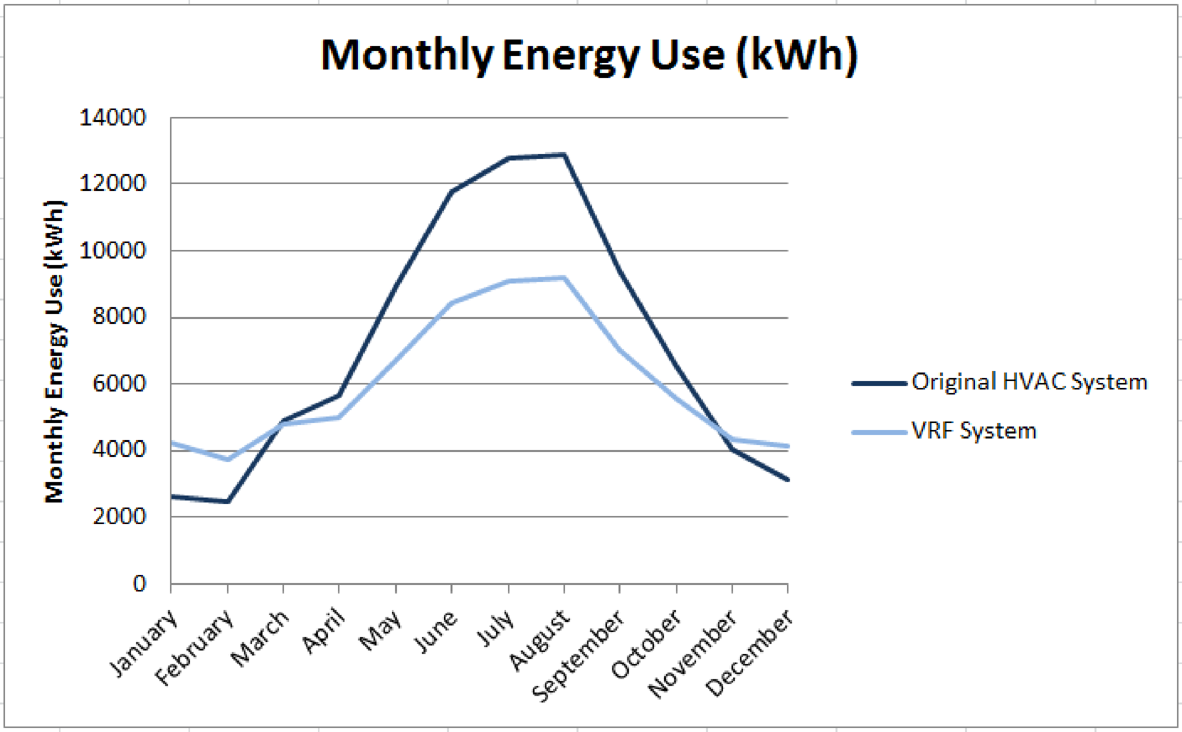


Figure 23: Monthly HVAC Energy Consumption Comparison

Clearly, the variable refrigerant flow system is significantly more cost effective on an annual cost basis, and does provide a slight reduction in energy usage in comparison to the original HVAC system. VRF systems, however, are known to have considerably pricier first costs in terms of equipment and installation, and so a comparison of firsts costs had to be conducted.

Using RSMeans, the HVAC first costs of the original HVAC system (6 rooftop units and a 7-ton CO_2 radiant floor cooling and heating system) and the first costs of the proposed system (variable refrigerant flow with assisting dedicated outdoor air system) were able to be calculated. The extent of these calculations from ductwork, fittings, controls, HVAC equipment, and refrigerants can be found in Appendix B of this report.

Upon finalizing the first costs of each system, a comparison was done between the two systems' material cost, labor costs, and total costs. A shown in Table 24, below, the materials and total first costs of the VRF system are significantly higher than that of the original HVAC system. The difference between materials cost was $178,038 in favor of the original HVAC system. The VRF system material costs were over double the cost of the RTU and radiant floor system material costs. In terms of labor costs, however, the variable refrigerant flow system was $59,042 cheaper than the original HVAC labor cost, a 74% difference.

In terms of total first costs, the original HVAC design was nearly 50% cheaper, and the difference between the two first costs was $118,996.

Table 24: Mechanical First Costs Comparison

	First Costs		
	Materials	Labor	Total
Original HVAC System	$149,663.88	$79,733.00	$229,396.88
VRF System	$327,702.26	$20,690.81	$348,393.07
Difference	-$178,038.38	$59,042.19	**-$118,996.19**
Percent Difference	118.96%	-74.05%	**51.87%**

With the first costs and the annual operating costs of each HVAC system determined, a payback period scenario could be explored. As the variable refrigerant flow system costs significantly more money upfront, a calculation was made to see how many years it would take to produce less combined first cost and annual HVAC energy costs than the original HVAC system. The following calculation was done to determine the payback period of the proposed VRF system.

FC_O= First Cost of Original HVAC System
AEC_O= Annual Energy Cost of Original HVAC System
FC_{VRF}= First Cost of Original VRF System
AEC_{VRF}= Annual Energy Cost of VRF HVAC System
X= Payback Period in years

$$FC_O + (AEC_O * X) = FC_{VRF} + (AEC_{VRF} * X)$$
$$\$229{,}396 + (\$16{,}416*X) = \$348{,}393.07 + (9001 * X)$$
$$\$118996 = \$7415 * X$$

X= 16.04 years

The projected payback period for the variable refrigerant flow system was found to be **16.04 years.**

Emissions

A carbon dioxide emissions estimate was made by retrieving each HVAC system's building simulation information. Table 25 shows the difference in annual carbon dioxide emissions, which was found to be a nearly 13% reduction in carbon emissions. The variable refrigerant flow system seems to have less of a harmful impact on the environment than the original HVAC system.

Table 25: Annual C02e Emissions Comparison

Pollutant	Regional Grid Emission Factors 2007 (lb/kWh)	Calculated Emissions (lb/year)		Emissions Reduction %
		Original	VRF	
C02e	1.55	701,073	611,089	**12.84%**

Acoustical Breadth

Background

With the implementation of the variable refrigerant flow (VRF) systems in the office and dry lab spaces of the building, the potential for a change in the acoustical quality of the indoor environment is quite likely. In areas such as the open plan office space that occupies the southwestern portion of the building, sound has the ability to travel long distances, which can become a problem if background noise levels such as HVAC noise are noticeable and distracting. For smaller, individual offices, even minor noise contributions from mechanical equipment can be annoying and detrimental to a productive work environment. One of the more common ways to gauge the acoustical effect that ventilation systems have on a room or space is by finding the Noise Criterion Rating of the HVAC system. Table 26, below, indicates the recommended Noise Criteria (NC) Ratings for various space types that are applicable to the existing rooftop unit systems and the proposed variable refrigerant flow system. These NC ratings were outlined in Chapter 48 of the 2009 ASHRAE Handbook.

Table 26: Recommended NC Ratings

	Recommended NC Rating	Equivalent Sound Level dBA
Open-Plan Offices	35-40	45-50
Private Offices	30-35	40-45
Conference Rooms	25-30	35-40

Under these guidelines, the existing mechanical system and the proposed VRF system can be compared to the recommended Noise Criterion Ratings to determine if they provide a suitable work environment for the given space. In order to determine the NC Rating for both systems, the acoustical software program Dynasonics AIM was used to simulate the HVAC noise contribution in a particular space. In an effort to represent a typical office setting, the open plan office area was selected as the environment in which the NC rating would be measured. Figure 24, shown below, indicates the boundaries of the space being investigated.

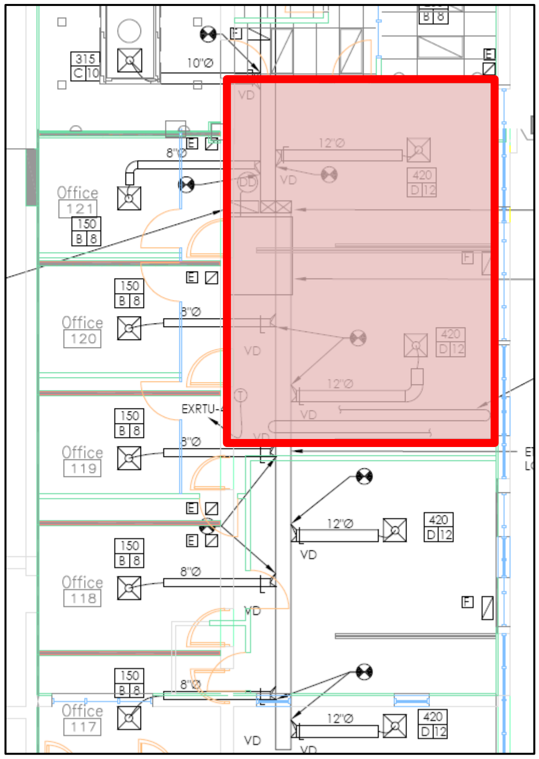


Figure 24: Office NC Rating Test Environment

Existing Mechanical System

Existing rooftop unit number 4 (RTU-4) services the area outlined in Figure 24 above, and will be used in the Dynasonics AIM simulation. RTU-4, a 5 ton constant air volume unit from Carrier, produces various sound power levels over a range of frequencies from 63 to 4000 HZ. The sound power levels were measured and obtained throughout experiment by Carrier, and are provided in the mechanical unit cut sheet. This cut sheet is available in Appendix C of this report. The measured sound power levels, referenced from 10^{-12} W, are displayed in the figure below.

Table 27: RTU-4 Sound Power Levels (re: 10^-12 W)

	Sound Power Level, dB (re 10^-12 W)						
Octave Band Frequency, HZ	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**
Discharge	**85.8**	**84.3**	**80.5**	**78.7**	**76.4**	**72.7**	**68.3**

To find the NC rating for the room in question, the initial sound power level of the rooftop unit must be adjusted according to the length, size, and transitions of ductwork en route to the diffuser. The highest possible NC rating in a room typically occurs at the first diffuser encountered along the supply path of the system. A complete path from the rooftop unit to the first diffuser was created in Dynasonics AIM, which holds values for different duct lengths, sizes, and transitions. The path being investigated is represented in Table 28 below. The values in red indicate a reduction in sound pressure level, which produces a more favorable NC rating. Since the dimensions of the room play a role in the NC and RC rating for the HVAC system, a Room Correction factor was applied at the end of the supply path. Factors such as end reflection losses and spacing/quantity of diffusers were also considered.

Table 28: Supply Path Sound Pressure Level Reductions

		Sound Pressure Level (re: 20 µPA)						
Path Component	**Properties**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**
50TCD06 (RTU-4)	RTU-4	86	84	81	79	76	73	68
Rectangular Duct	16”x16”x8’ (0”)	-3	-2	-1	0	0	0	0
Rectangular Elbow Turning Vanes	16”16” (1”)	0	-1	-4	-7	-7	-7	-7
Rectangular Duct	16”x14”X27’ (1”)	-1	-1	-2	-4	-8	-8	-5
Takeoff (Branch Power Split)	16”x16” / 12”	-5	-5	-5	-5	-5	-5	-5
Circular Duct	12” X 13.15’ (1”)	-3	-6	-11	-19	-29	-25	-19
End Reflection Loss	12” (Flush)	-12	-7	-3	-1	0	0	0
Room Correction (Classic Diffuse)	32’x25’x8’	-3	-3	-3	-3	-4	-4	-3

NOTE: Any duct properties with a (1”) after the duct size and length is considered to have 1” of fiberglass duct lining, significantly reducing sound pressure level through the duct.

Dynasonics AIM completes a Noise Criteria and Room Criteria Rating graph as each duct fitting and duct length is created. Once the supply path is completed, and all end loss reflection and room correction factors are applied, a final NC rating is produced based on the resulting sound pressure levels across the frequency range of 63 – 4000Hz. Dynasonics AIM designates an acceptable NC rating for office spaces to be NC-40, which is represented by the red line in Figure 25 below. The actual NC rating of the room is designated by the blue line.

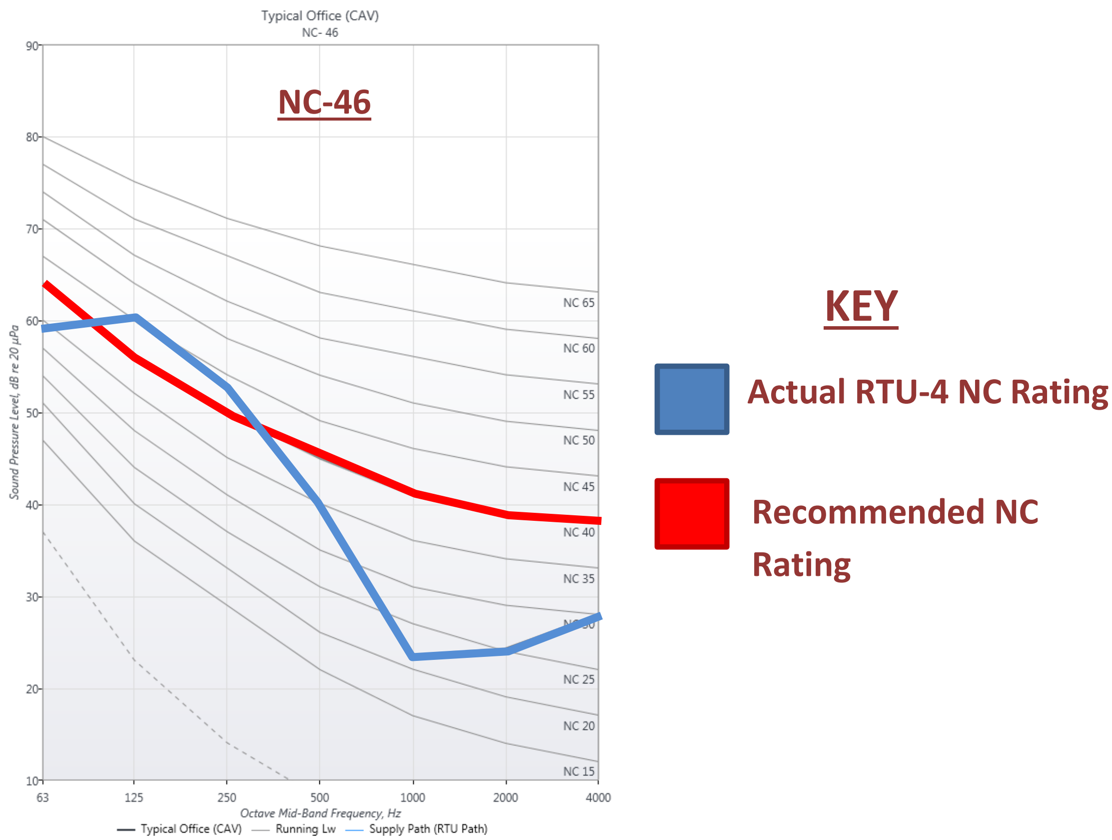


Figure 25: NC Rating for CAV RTU-4

The NC rating for the system is determined by finding the point at which the highest NC curve is contacted by a point on the HVAC system line. In this case, the HVAC system reaches NC rating curve 46, and is thus given an NC rating of NC-46. The associated dB(A) value for the system is 48 dB(A), which is also fairly unfavorable. Even though the majority of the HVAC system line is below the NC-40 curve in red, it is still in violation of the target NC rating of 40. With a significant amount of duct lining, elbows, and takeoffs to reduce the sound pressure level emitted by the rooftop unit, it would be difficult and costly to reduce the NC rating to a suitable level. One such solution, though costly, would be to place a duct silencer at the outlet of the rooftop unit in order to reduce the SPL before it reaches the majority of the supply path.

By referencing Table 26 on page 40, it is clear that the rooftop unit fails to achieve the recommended NC rating and dB(A) values provided in Chapter 48 of the 2009 ASHRAE Handbook. Only one of the 6 recommended limits was observed in the consideration of acoustical noise and distraction. For spaces such as the conference rooms and private offices, the measured NC rating of 46 does not even come close to the recommended values, and would surely affect the productivity of the occupants. Upon discovering the inadequacy of the rooftop units in place in regards to acoustical design, an investigation into the newly proposed variable refrigerant flow system was conducted to see if it met the NC rating and dB(A) values suggested in the ASHRAE Handbook.

Table 29: CAV RTU-4 NC Rating Comparison to Recommended Values

	Measured NC Rating	Recommended NC Rating	Measured dB(A) value	Equivalent Sound Level dBA
Open-Plan Offices	46	35-40	48	45-50
Private Offices	46	30-35	48	40-45
Conference Rooms	46	25-30	48	35-40

Variable Refrigerant Flow System

The proposed variable refrigerant flow (VRF) system consists of eight different kinds of fan coil units (FCUs) which provide conditioned air to the office and dry lab spaces in the building. In the effort to reduce the size of this report and time to complete this investigation, the fan coil unit with the loudest sound power levels ranging from 63 Hz to 4000 Hz was selected as the 'worst case scenario' for the Dynasonic AIM simulation. Samsumg's DMV S Series unit AM024FN4DCH/AA was found to have the highest SPL values of any of the other FCU's selected, and as acted as the terminal unit for the simulation. As all of these fan coil units were cassette discharges, meaning that no ductwork, fittings, or end loss reflections are present, only the sound power levels of the fan coil unit and the room correction factor would play a role in the determination of the NC Rating. For the sake of consistency, the same room dimensions and conditions were adopted for the VRF noise simulation. Table 30 illustrates the supply path reductions for the proposed HVAC system.

Table 30: Supply Path Sound Pressure Level Reductions for VRF System

		Sound Pressure Level (re: 20 µPA)						
Path Component	Properties	63	125	250	500	1000	2000	4000
AM024FN4DCH/AA	4 Way Cassette Fan Coil Unit	40.1	37.2	36.4	33.0	29.7	27.3	22.6
Room Correction Factor	32'x25'x8'	-3	-3	-3	-3	-4	-4	-3

Upon completing the supply path reductions and calculations, the NC curve graph indicated a strong improvement in NC Rating and dB(A) level, as shown by Figure 26 below. The NC Rating was found to be NC-25 for the fan coil unit, well below the recommended maximum NC Rating of NC-40 for office spaces. The dB(A) value produced was 32 dB(A), which was found to be within or below all recommended levels for open offices, private offices, and conference rooms, as shown by Table 31 below. It can be said that the entire selection of fan coil units will provide a much more comfortable acoustical environment for occupants than the rooftop units, as NC Ratings of the FCUs are well below the recommended NC ratings from the 2009 ASHRAE Handbook.

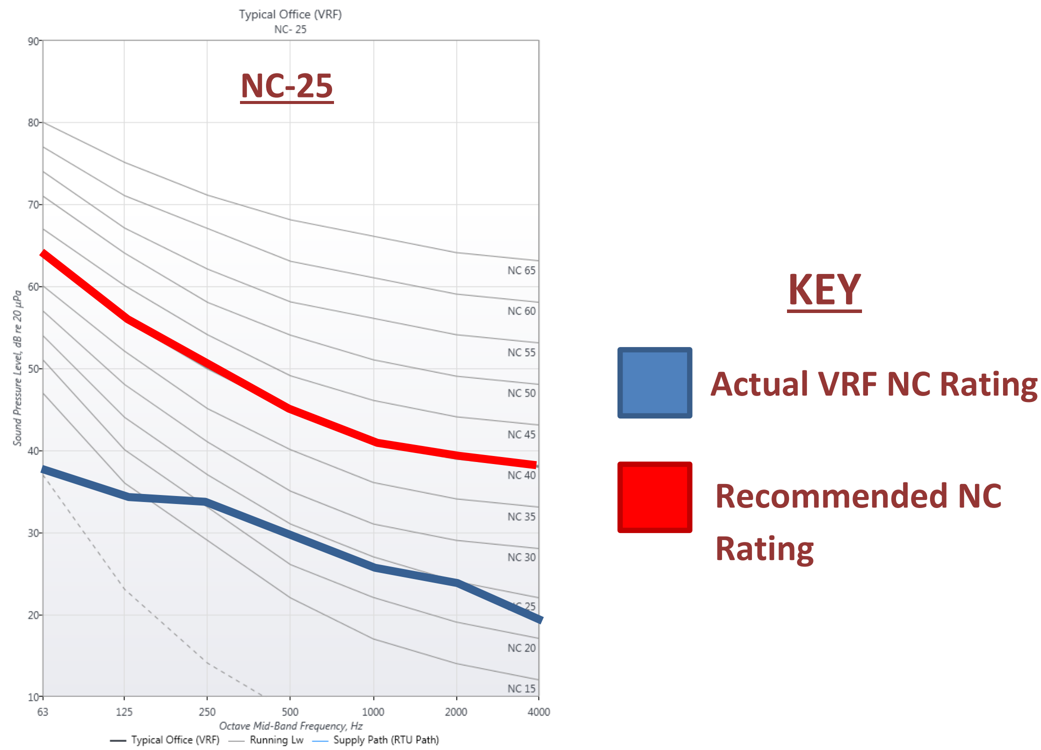


Figure 26: NC Rating for VRF System

Table 31: VRF System NC Rating Comparison to Recommended Values

	Measured NC Rating	Recommended NC Rating	Measured dB(A) value	Equivalent Sound Level dBA
Open-Plan Offices	**25**	**35-40**	**28**	**45-50**
Private Offices	**25**	**30-35**	**28**	**40-45**
Conference Rooms	**25**	**25-30**	**28**	**35-40**

Electrical Breadth

Background

The implementation of a new variable refrigerant flow system design for 123 Alpha Drive doesn't only affect HVAC performance. The affect that changing an HVAC system can have on the electrical system is potentially immense, as mechanical panels, transformers and electrical loads are subject to change. 123 Alpha Drive currently utilizes a 208V/120 distribution line and a three phase 240V Delta secondary system. Two existing to remain switchgears are also part of the electrical distribution system. The renovation of 123 Alpha Drive included a 1200A 240V power panel and a 600A 460V power panel, with the appropriate 240V/460V transformer between the two. Two existing motor control centers (400A and 225A) are tied into the 460V line, and provide electrical service to the mechanical equipment involved in the depth investigation. The six rooftop units and radiant floor cooling and heating system are controlled by these motor control centers.

With the installation of a variable refrigerant flow system and dedicated outdoor air system, there are several different pieces of mechanical equipment that will change the electrical load demand for the HVAC systems described in the depth section of this report. The following mechanical equipment units have been split into 208V single phase and 460V 3 phase:

208V 1 Ø :

Variable Refrigerant Flow Indoor Terminal Units :

- AM007FN1DCH/AA
- AM012FNNDCH/AA
- AM012FN4DCH/AA
- AM024FN4DCH/AA
- AM009FNNDCH/AA
- AM018FNNDCH/AA
- AM030FN4DCH/AA
- AM076FNHDCH/AA
- AM048FNHDCH/AA

Energy Recovery Ventilators (DOAS Sytem) :

- FV-2000

460V 3 Ø :

Outdoor Condensing Units

- AM144FXVAJR/AA
- AM192FXVAJR/AA

Solution

With this information, and electrical data gathered from cut sheets available in Appendix B, a compilation of electrical loads was calculated. By grouping all terminal units for each VRF system and calculating electrical load per VRF system, it was easier to determine how large and how many new panels would be needed for the 208V mechanical panel. The electrical loads for the energy recovery ventilators is also 208V single phase, so all electrical loads for the DOAS systems will go on a new 208V/120 panel. The selected ERVs will be provided with a 30 A disconnect and a 30A fuse breaker for overcurrent protection. For the outdoor condensing units, a motor control center will be removed, and a new 460V panel will be provided and sized.

Table 32 provides electrical load information for the 3 outdoor condensing units that make up the variable refrigerant flow system, which are 460V 3 phase. Information involving maximum operating current and wiring is also included in the table.

Table 32: Condensing Unit Electrical Data

Mechanical Unit	Quantity	Voltage	Phase	Wiring	FLA	MOCP	Power (W)	Individual Load (VA)	Total Load (kVA)
AM144FXVAJR/AA	1	460	3 Ø	AWG 10	26.4	40	16.9	21034.03	21.03
AM192FXVAJR/AA	2	460	3 Ø	AWG8	38.1	60	20.4	30355.92	60.71

By combining the total electrical load required by these three condensing units, it is found that the total 460V 3 phase load for the newly proposed VRF flow system is 142.45 kVA, which is shown below in Table 33.

Table 33: 460V 3 Phase Loads

460V Loads		
System	**Total Load (kVA)**	Number of units
CU-1	21.03	1
CU-2	60.71	1
Cu-3	60.71	1
Total	**142.45**	

In order to size a new mechanical panel for the three condensing units, the maximum amperage must be determined. By dividing the total required electrical load by the voltage (460V) and the square root of 3 (for 3 phase calculations), it is found that the maximum amperage for the VRF system would be 178.8 A. In order to accommodate such a figure, a 225 Amp MLO mechanical panel would take the place of the current 225 A motor control center which served the six rooftop units for the original HVAC design. No wiring would have to be adjusted, as both the MCC and new mechanical panel carry the same rating.

For the 208V single phase mechanical equipment, a table similar to Table 32 was constructed, as seen below. Since the majority of the indoor terminal units have such a small electrical load, overcurrent protection will be provided in the form of temperature sensors over fuses or circuit breakers.

Table 34: 208V 1 Phase HVAC Electrical Data

Mechanical Unit	Quantity	Voltage	Phase	Wiring	FLA	MOCP	Power (W)	Individual Load (VA)	Total Load (kVA)
AM007FN1DCH/AA	20	208	1 Ø	AWG 14	2.4		40	499.2	9.98
AM012FNNDCH/AA	11	208	1 Ø	AWG 14	2.4		28	499.2	5.49
AM012FN4DCH/AA	1	208	1 Ø	AWG 14	2.4		32	499.2	0.50
AM024FN4DCH/AA	1	208	1 Ø	AWG 14	2.4		40	499.2	0.50
AM009FNNDCH/AA	6	208	1 Ø	AWG 14	2.4		32	499.2	3.00
AM018FNNDCH/AA	1	208	1 Ø	AWG 14	2.4		36	499.2	0.50
AM030FN4DCH/AA	1	208	1 Ø	AWG 14	2.4		65	499.2	0.50
AM076FNHDCH/AA	1	208	1 Ø	AWG14	5.4		530	1123.2	1.12
AM048FNHDCH/AA	1	208	1 Ø	AWG14	4.0		330	832	0.83
ERV-1 FV-2000	1	208	1 Ø	AWG10	19.7	33.5		4097.6	4.10
ERV-2 FV-2000	1	208	1 Ø	AWG10	19.7	33.5		4097.6	4.10
ERV-3 FV-2000	1	208	1 Ø	AWG10	19.7	33.5		4097.6	4.10

By combining the total electrical load required by each variable refrigerant flow system, it is found that the total 208V 1 phase load for the newly proposed VRF flow system is 34.71 kVA, which is shown below in Table 35.

Table 35: 208V 1 Phase Electrical Data

208V Loads		
System	**Total Load (kVA)**	**Number of Units**
VRF - 1	7.488	15
VRF- 2	9.485	19
VRF -3	5.450	9
ERV	12.29	3
Total	**34.715**	

In order to size a new mechanical panel for the three sets of VRF system terminal units and the energy recovery ventilators, the maximum amperage must be determined. By dividing the total required electrical load by the voltage (208V) it is found that the maximum amperage for the VRF system would be 166.9 A. Although a 225 Amp MLO mechanical panel would be suitable for the 208V single phase loads, there are over 42 mechanical units which need powering, and so two panels must be added. By installing two 100A MLO mechanical power panels to the existing 208V system, the VRF systems and DOAS systems can be split among the two. VRF systems 1 and 2 will be serviced by the first 100A panel (combined maximum amperage of 81.6 A), while VRF system 3 and the three ERV units will be placed on the second 100A panel (85.3 A). By tying these two panels into the existing 208V line, there would be no issues regarding overloading, as at least three of the existing panels would not be needed because of the change in HVAC design.

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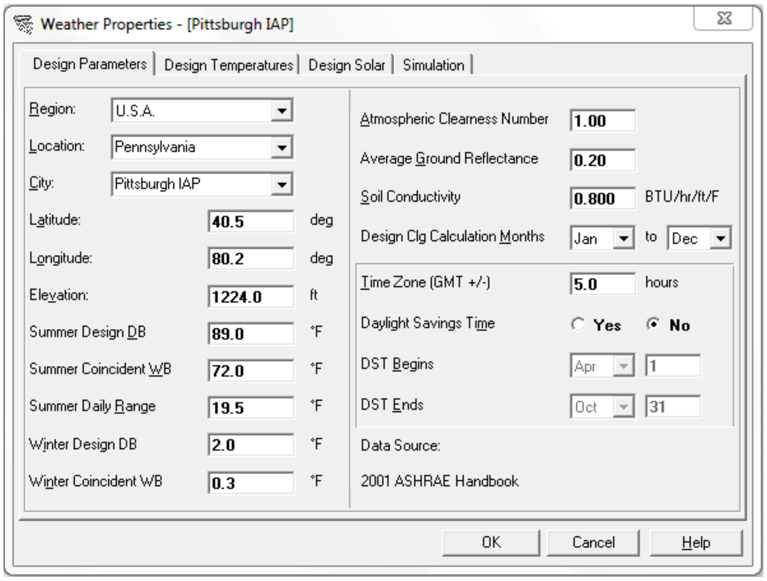
Appendix A – Building Load Analysis Documents



Component	Entire Building ($)
Air System Fans	9,467
Cooling	56,509
Heating	6,076
Pumps	0
Heat Rejection Fans	0
HVAC Sub-Total	**72,051**
Lights	153,254
Electric Equipment	141,438
Misc. Electric	0
Misc. Fuel Use	0
Non-HVAC Sub-Total	**294,693**
Grand Total	**366,744**

1

Component	Entire Building (%)
Air System Fans	2.6
Cooling	15.4
Heating	1.7
Pumps	0.0
Heat Rejection Fans	0.0
HVAC Sub-Total	**19.6**
Lights	41.8
Electric Equipment	38.6
Misc. Electric	0.0
Misc. Fuel Use	0.0
Non-HVAC Sub-Total	**80.4**
Grand Total	**100.0**

Component	Entire Building ($/ft²)
Air System Fans	0.126
Cooling	0.754
Heating	0.081
Pumps	0.000
Heat Rejection Fans	0.000
HVAC Sub-Total	**0.961**
Lights	2.044
Electric Equipment	1.886
Misc. Electric	0.000
Misc. Fuel Use	0.000
Non-HVAC Sub-Total	**3.930**
Grand Total	**4.891**
Gross Floor Area (ft²)	74980.0
Conditioned Floor Area (ft²)	74980.0

Air System Sizing Summary for RTU-1

Project Name: THAR Energy Thesis — 01/03/2014
Prepared by: Iams Consulting LLC — 01:38PM

Air System Information

Air System Name	RTU-1		Number of zones	1	
Equipment Class	PKG ROOF		Floor Area	3456.0	ft²
Air System Type	SZCAV		Location	Pittsburgh IAP, Pennsylvania	

Sizing Calculation Information

Zone and Space Sizing Method:

Zone CFM	Sum of space airflow rates	Calculation Months	Jan to Dec
Space CFM	Individual peak space loads	Sizing Data	Calculated

Central Cooling Coil Sizing Data

Total coil load	6.2	Tons	Load occurs at	Jul 1500	
Total coil load	73.8	MBH	OA DB / WB	89.0 / 72.0	°F
Sensible coil load	59.9	MBH	Entering DB / WB	74.9 / 62.9	°F
Coil CFM at Jul 1500	2931	CFM	Leaving DB / WB	55.1 / 54.0	°F
Max block CFM	2931	CFM	Coil ADP	52.9	°F
Sum of peak zone CFM	2931	CFM	Bypass Factor	0.100	
Sensible heat ratio	0.812		Resulting RH	48	%
ft²/Ton	561.7		Design supply temp.	55.0	°F
BTU/(hr-ft²)	21.4		Zone T-stat Check	1 of 1	OK
Water flow @ 10.0 °F rise	N/A		Max zone temperature deviation	0.0	°F

Central Heating Coil Sizing Data

Max coil load	27.1	MBH	Load occurs at	Des Htg	
Coil CFM at Des Htg	2931	CFM	BTU/(hr-ft²)	7.8	
Max coil CFM	2931	CFM	Ent. DB / Lvg DB	65.5 / 74.5	°F
Water flow @ 20.0 °F drop	N/A				

Precool Coil Sizing Data

Total coil load	0.5	Tons	Load occurs at	Jul 1500	
Total coil load	6.0	MBH	OA DB / WB	89.0 / 72.0	°F
Sensible coil load	6.0	MBH	Entering DB / WB	89.0 / 72.0	°F
Coil CFM at Jul 1500	530	CFM	Leaving DB / WB	78.0 / 68.9	°F
Max coil CFM	530	CFM	Bypass Factor	0.100	
Sensible heat ratio	1.000				
Water flow @ 10.0 °F rise	N/A				

Preheat Coil Sizing Data

Max coil load	23.5	MBH	Load occurs at	Des Htg	
Coil CFM at Des Htg	530	CFM	Ent. DB / Lvg DB	2.0 / 45.0	°F
Max coil CFM	530	CFM			
Water flow @ 20.0 °F drop	N/A				

Supply Fan Sizing Data

Actual max CFM	2931	CFM	Fan motor BHP	0.40	BHP
Standard CFM	2803	CFM	Fan motor kW	0.32	kW
Actual max CFM/ft²	0.85	CFM/ft²	Fan static	0.50	in wg

Outdoor Ventilation Air Data

Design airflow CFM	530	CFM	CFM/person	37.84	CFM/person
CFM/ft²	0.15	CFM/ft²			

Air System Sizing Summary for RTU-2

Project Name: THAR Energy Thesis 01/03/2014
Prepared by: Iams Consulting LLC 01:44PM

Air System Information

Air System Name RTU-2
Equipment Class PKG ROOF
Air System Type SZCAV

Number of zones 1
Floor Area 2912.0 ft²
Location Pittsburgh IAP, Pennsylvania

Sizing Calculation Information

Zone and Space Sizing Method:

Zone CFM Sum of space airflow rates
Space CFM Individual peak space loads

Calculation Months Jan to Dec
Sizing Data Calculated

Central Cooling Coil Sizing Data

Total coil load	5.1	Tons
Total coil load	61.3	MBH
Sensible coil load	48.1	MBH
Coil CFM at Jul 1500	2507	CFM
Max block CFM	2507	CFM
Sum of peak zone CFM	2507	CFM
Sensible heat ratio	0.784	
ft²/Ton	569.7	
BTU/(hr-ft²)	21.1	
Water flow @ 10.0 °F rise	N/A	

Load occurs at	Jul 1500	
OA DB / WB	89.0 / 72.0	°F
Entering DB / WB	75.1 / 63.9	°F
Leaving DB / WB	56.5 / 55.5	°F
Coil ADP	54.5	°F
Bypass Factor	0.100	
Resulting RH	51	%
Design supply temp.	55.0	°F
Zone T-stat Check	1 of 1	OK
Max zone temperature deviation	0.0	°F

Central Heating Coil Sizing Data

Max coil load	27.1	MBH
Coil CFM at Des Htg	2507	CFM
Max coil CFM	2507	CFM
Water flow @ 20.0 °F drop	N/A	

Load occurs at	Des Htg	
BTU/(hr-ft²)	9.3	
Ent. DB / Lvg DB	64.0 / 74.5	°F

Precool Coil Sizing Data

Total coil load	0.6	Tons
Total coil load	6.9	MBH
Sensible coil load	6.9	MBH
Coil CFM at Jul 1500	603	CFM
Max coil CFM	603	CFM
Sensible heat ratio	1.000	
Water flow @ 10.0 °F rise	N/A	

Load occurs at	Jul 1500	
OA DB / WB	89.0 / 72.0	°F
Entering DB / WB	89.0 / 72.0	°F
Leaving DB / WB	78.0 / 68.9	°F
Bypass Factor	0.100	

Preheat Coil Sizing Data

Max coil load	26.8	MBH
Coil CFM at Des Htg	603	CFM
Max coil CFM	603	CFM
Water flow @ 20.0 °F drop	N/A	

Load occurs at	Des Htg	
Ent. DB / Lvg DB	2.0 / 45.0	°F

Supply Fan Sizing Data

Actual max CFM	2507	CFM
Standard CFM	2398	CFM
Actual max CFM/ft²	0.86	CFM/ft²

Fan motor BHP	0.34	BHP
Fan motor kW	0.27	kW
Fan static	0.50	in wg

Outdoor Ventilation Air Data

Design airflow CFM	603	CFM
CFM/ft²	0.21	CFM/ft²

CFM/person	54.81	CFM/person

Air System Sizing Summary for RTU-3

Project Name: THAR Energy Thesis — 01/03/2014
Prepared by: Iams Consulting LLC — 01:47PM

Air System Information

Air System Name	RTU-3		Number of zones	1	
Equipment Class	PKG ROOF		Floor Area	2563.0	ft²
Air System Type	SZCAV		Location	Pittsburgh IAP, Pennsylvania	

Sizing Calculation Information

Zone and Space Sizing Method:

Zone CFM	Sum of space airflow rates	Calculation Months	Jan to Dec
Space CFM	Individual peak space loads	Sizing Data	Calculated

Central Cooling Coil Sizing Data

Total coil load	7.2	Tons	Load occurs at	Aug 1200	
Total coil load	86.6	MBH	OA DB / WB	84.5 / 70.7	°F
Sensible coil load	73.1	MBH	Entering DB / WB	74.8 / 62.9	°F
Coil CFM at Aug 1200	3732	CFM	Leaving DB / WB	55.8 / 54.7	°F
Max block CFM	3732	CFM	Coil ADP	53.7	°F
Sum of peak zone CFM	3732	CFM	Bypass Factor	0.100	
Sensible heat ratio	0.844		Resulting RH	50	%
ft²/Ton	355.0		Design supply temp.	55.0	°F
BTU/(hr-ft²)	33.8		Zone T-stat Check	1 of 1	OK
Water flow @ 10.0 °F rise	N/A		Max zone temperature deviation	0.0	°F

Central Heating Coil Sizing Data

Max coil load	37.1	MBH	Load occurs at	Des Htg	
Coil CFM at Des Htg	3732	CFM	BTU/(hr-ft²)	14.5	
Max coil CFM	3732	CFM	Ent. DB / Lvg DB	67.9 / 77.5	°F
Water flow @ 20.0 °F drop	N/A				

Precool Coil Sizing Data

Total coil load	0.3	Tons	Load occurs at	Jul 1500	
Total coil load	3.7	MBH	OA DB / WB	89.0 / 72.0	°F
Sensible coil load	3.7	MBH	Entering DB / WB	89.0 / 72.0	°F
Coil CFM at Jul 1500	324	CFM	Leaving DB / WB	78.0 / 68.9	°F
Max coil CFM	324	CFM	Bypass Factor	0.100	
Sensible heat ratio	1.000				
Water flow @ 10.0 °F rise	N/A				

Preheat Coil Sizing Data

Max coil load	15.0	MBH	Load occurs at	Jan 0800	
Coil CFM at Jan 0800	921	CFM	Ent. DB / Lvg DB	29.2 / 45.0	°F
Max coil CFM	324	CFM			
Water flow @ 20.0 °F drop	N/A				

Supply Fan Sizing Data

Actual max CFM	3732	CFM	Fan motor BHP	0.51	BHP
Standard CFM	3569	CFM	Fan motor kW	0.41	kW
Actual max CFM/ft²	1.46	CFM/ft²	Fan static	0.50	in wg

Outdoor Ventilation Air Data

Design airflow CFM	324	CFM	CFM/person	9.52	CFM/person
CFM/ft²	0.13	CFM/ft²			

Air System Sizing Summary for RTU-4

Project Name: THAR Energy Thesis — 01/03/2014
Prepared by: Iams Consulting LLC — 01:48PM

Air System Information

Air System Name	RTU-4		Number of zones	1	
Equipment Class	PKG ROOF		Floor Area	2282.0	ft²
Air System Type	SZCAV		Location	Pittsburgh IAP, Pennsylvania	

Sizing Calculation Information

Zone and Space Sizing Method:

Zone CFM	Sum of space airflow rates	Calculation Months	Jan to Dec
Space CFM	Individual peak space loads	Sizing Data	Calculated

Central Cooling Coil Sizing Data

Total coil load	5.6	Tons	Load occurs at	Aug 1200	
Total coil load	67.6	MBH	OA DB / WB	84.5 / 70.7	°F
Sensible coil load	56.9	MBH	Entering DB / WB	74.8 / 63.0	°F
Coil CFM at Aug 1200	2926	CFM	Leaving DB / WB	56.0 / 54.9	°F
Max block CFM	2926	CFM	Coil ADP	53.9	°F
Sum of peak zone CFM	2926	CFM	Bypass Factor	0.100	
Sensible heat ratio	0.842		Resulting RH	50	%
ft²/Ton	405.2		Design supply temp.	55.0	°F
BTU/(hr-ft²)	29.6		Zone T-stat Check	1 of 1	OK
Water flow @ 10.0 °F rise	N/A		Max zone temperature deviation	0.0	°F

Central Heating Coil Sizing Data

Max coil load	23.9	MBH	Load occurs at	Des Htg	
Coil CFM at Des Htg	2926	CFM	BTU/(hr-ft²)	10.5	
Max coil CFM	2926	CFM	Ent. DB / Lvg DB	67.7 / 75.6	°F
Water flow @ 20.0 °F drop	N/A				

Precool Coil Sizing Data

Total coil load	0.3	Tons	Load occurs at	Jul 1500	
Total coil load	3.0	MBH	OA DB / WB	89.0 / 72.0	°F
Sensible coil load	3.0	MBH	Entering DB / WB	89.0 / 72.0	°F
Coil CFM at Jul 1500	267	CFM	Leaving DB / WB	78.0 / 68.9	°F
Max coil CFM	267	CFM	Bypass Factor	0.100	
Sensible heat ratio	1.000				
Water flow @ 10.0 °F rise	N/A				

Preheat Coil Sizing Data

Max coil load	12.9	MBH	Load occurs at	Jan 0300	
Coil CFM at Jan 0300	689	CFM	Ent. DB / Lvg DB	26.9 / 45.0	°F
Max coil CFM	267	CFM			
Water flow @ 20.0 °F drop	N/A				

Supply Fan Sizing Data

Actual max CFM	2926	CFM	Fan motor BHP	0.40	BHP
Standard CFM	2799	CFM	Fan motor kW	0.32	kW
Actual max CFM/ft²	1.28	CFM/ft²	Fan static	0.50	in wg

Outdoor Ventilation Air Data

Design airflow CFM	267	CFM	CFM/person	10.27	CFM/person
CFM/ft²	0.12	CFM/ft²			

Air System Sizing Summary for RTU-5

Project Name: THAR Energy Thesis — 01/03/2014
Prepared by: Iams Consulting LLC — 01:54PM

Air System Information

Air System Name	RTU-5	Number of zones	1	
Equipment Class	PKG ROOF	Floor Area	1943.0	ft²
Air System Type	SZCAV	Location	Pittsburgh IAP, Pennsylvania	

Sizing Calculation Information

Zone and Space Sizing Method:

Zone CFM	Sum of space airflow rates	Calculation Months	Jan to Dec
Space CFM	Individual peak space loads	Sizing Data	Calculated

Central Cooling Coil Sizing Data

Total coil load	6.8	Tons	Load occurs at	Aug 1200	
Total coil load	81.1	MBH	OA DB / WB	84.5 / 70.7	°F
Sensible coil load	63.0	MBH	Entering DB / WB	75.1 / 63.9	°F
Coil CFM at Aug 1200	3235	CFM	Leaving DB / WB	56.2 / 55.2	°F
Max block CFM	3235	CFM	Coil ADP	54.1	°F
Sum of peak zone CFM	3235	CFM	Bypass Factor	0.100	
Sensible heat ratio	0.777		Resulting RH	52	%
ft²/Ton	287.5		Design supply temp.	55.0	°F
BTU/(hr-ft²)	41.7		Zone T-stat Check	0 of 1	OK
Water flow @ 10.0 °F rise	N/A		Max zone temperature deviation	0.1	°F

Central Heating Coil Sizing Data

Max coil load	34.0	MBH	Load occurs at	Des Htg	
Coil CFM at Des Htg	3235	CFM	BTU/(hr-ft²)	17.5	
Max coil CFM	3235	CFM	Ent. DB / Lvg DB	66.8 / 77.0	°F
Water flow @ 20.0 °F drop	N/A				

Precool Coil Sizing Data

Total coil load	0.4	Tons	Load occurs at	Jul 1500	
Total coil load	4.9	MBH	OA DB / WB	89.0 / 72.0	°F
Sensible coil load	4.9	MBH	Entering DB / WB	89.0 / 72.0	°F
Coil CFM at Jul 1500	430	CFM	Leaving DB / WB	78.0 / 68.9	°F
Max coil CFM	430	CFM	Bypass Factor	0.100	
Sensible heat ratio	1.000				
Water flow @ 10.0 °F rise	N/A				

Preheat Coil Sizing Data

Max coil load	19.1	MBH	Load occurs at	Des Htg	
Coil CFM at Des Htg	430	CFM	Ent. DB / Lvg DB	2.0 / 45.0	°F
Max coil CFM	430	CFM			
Water flow @ 20.0 °F drop	N/A				

Supply Fan Sizing Data

Actual max CFM	3235	CFM	Fan motor BHP	0.44	BHP
Standard CFM	3094	CFM	Fan motor kW	0.35	kW
Actual max CFM/ft²	1.66	CFM/ft²	Fan static	0.50	in wg

Outdoor Ventilation Air Data

Design airflow CFM	430	CFM	CFM/person	8.60	CFM/person
CFM/ft²	0.22	CFM/ft²			

Air System Sizing Summary for RTU-6

Project Name: THAR Energy Thesis — 01/03/2014
Prepared by: Iams Consulting LLC — 01:55PM

Air System Information

Air System Name	RTU-6		Number of zones	1	
Equipment Class	PKG ROOF		Floor Area	2379.0	ft²
Air System Type	SZCAV		Location	Pittsburgh IAP, Pennsylvania	

Sizing Calculation Information

Zone and Space Sizing Method:

Zone CFM	Sum of space airflow rates	Calculation Months	Jan to Dec
Space CFM	Individual peak space loads	Sizing Data	Calculated

Central Cooling Coil Sizing Data

Total coil load	5.6	Tons	Load occurs at	Jul 1200	
Total coil load	66.8	MBH	OA DB / WB	84.5 / 70.7	°F
Sensible coil load	47.4	MBH	Entering DB / WB	75.5 / 65.6	°F
Coil CFM at Jul 1200	2605	CFM	Leaving DB / WB	57.9 / 57.0	°F
Max block CFM	2605	CFM	Coil ADP	56.0	°F
Sum of peak zone CFM	2605	CFM	Bypass Factor	0.100	
Sensible heat ratio	0.709		Resulting RH	55	%
ft²/Ton	427.1		Design supply temp.	55.0	°F
BTU/(hr-ft²)	28.1		Zone T-stat Check	1 of 1	OK
Water flow @ 10.0 °F rise	N/A		Max zone temperature deviation	0.0	°F

Central Heating Coil Sizing Data

Max coil load	34.3	MBH	Load occurs at	Des Htg	
Coil CFM at Des Htg	2605	CFM	BTU/(hr-ft²)	14.4	
Max coil CFM	2605	CFM	Ent. DB / Lvg DB	60.9 / 73.6	°F
Water flow @ 20.0 °F drop	N/A				

Precool Coil Sizing Data

Total coil load	0.9	Tons	Load occurs at	Jul 1500	
Total coil load	11.0	MBH	OA DB / WB	89.0 / 72.0	°F
Sensible coil load	11.0	MBH	Entering DB / WB	89.0 / 72.0	°F
Coil CFM at Jul 1500	968	CFM	Leaving DB / WB	78.0 / 68.9	°F
Max coil CFM	968	CFM	Bypass Factor	0.100	
Sensible heat ratio	1.000				
Water flow @ 10.0 °F rise	N/A				

Preheat Coil Sizing Data

Max coil load	43.0	MBH	Load occurs at	Des Htg	
Coil CFM at Des Htg	968	CFM	Ent. DB / Lvg DB	2.0 / 45.0	°F
Max coil CFM	968	CFM			
Water flow @ 20.0 °F drop	N/A				

Supply Fan Sizing Data

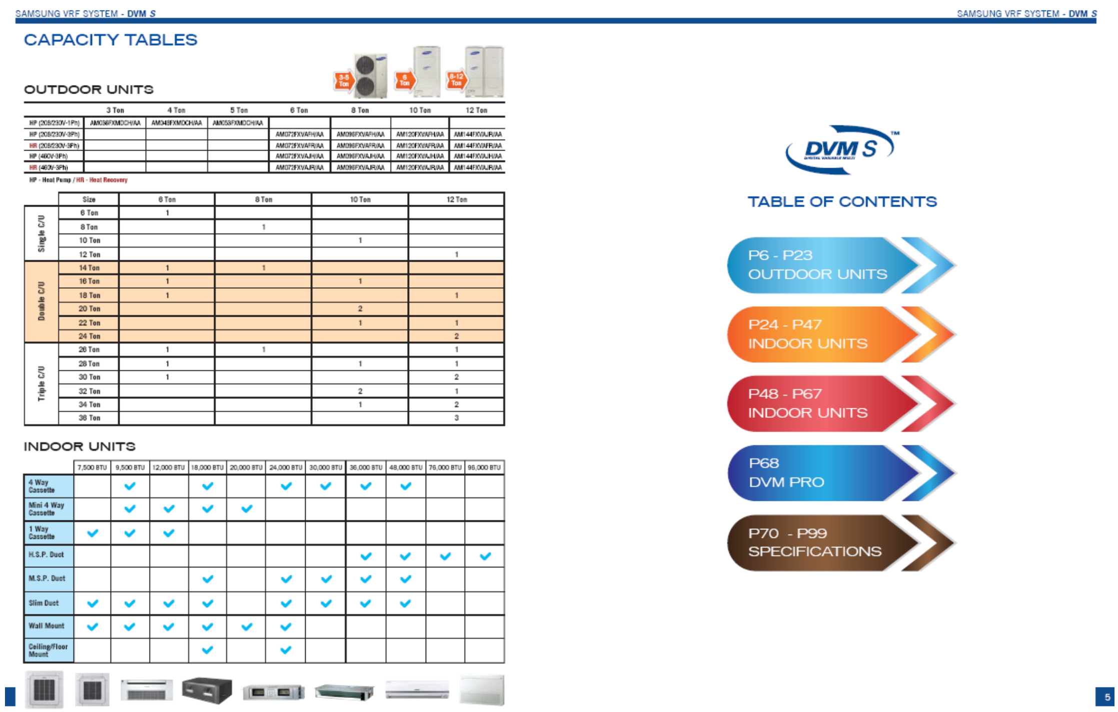
Actual max CFM	2605	CFM	Fan motor BHP	0.36	BHP
Standard CFM	2492	CFM	Fan motor kW	0.28	kW
Actual max CFM/ft²	1.09	CFM/ft²	Fan static	0.50	in wg

Outdoor Ventilation Air Data

Design airflow CFM	968	CFM	CFM/person	35.84	CFM/person
CFM/ft²	0.41	CFM/ft²			

Appendix B – Mechanical Depth Documents

DVM S Series Catalog Documents



SAMSUNG VRF SYSTEM - DVM S

CAPACITY TABLES

OUTDOOR UNITS

	3 Ton	4 Ton	5 Ton	6 Ton	8 Ton	10 Ton	12 Ton
HP (208/230V-1Ph)	AM036FXMDCH/AA	AM048FXMDCH/AA	AM053FXMDCH/AA				
HP (208/230V-3Ph)				AM072FXVAFH/AA	AM096FXVAFH/AA	AM120FXVAFH/AA	AM144FXVAJR/AA
HR (208/230V-3Ph)				AM072FXVAFR/AA	AM096FXVAFR/AA	AM120FXVAFR/AA	AM144FXVAFR/AA
HP (460V-3Ph)				AM072FXVAJH/AA	AM096FXVAJH/AA	AM120FXVAJH/AA	AM144FXVAJH/AA
HR (460V-3Ph)				AM072FXVAJR/AA	AM096FXVAJR/AA	AM120FXVAJR/AA	AM144FXVAJR/AA

HP - Heat Pump / HR - Heat Recovery

	Size	6 Ton	8 Ton	10 Ton	12 Ton
Single C/U	6 Ton	1			
	8 Ton		1		
	10 Ton			1	
	12 Ton				1
Double C/U	14 Ton	1	1		
	16 Ton	1		1	
	18 Ton	1			1
	20 Ton			2	
	22 Ton			1	1
	24 Ton				2
Triple C/U	26 Ton	1	1		1
	28 Ton	1		1	1
	30 Ton	1			2
	32 Ton			2	1
	34 Ton			1	2
	36 Ton				3

INDOOR UNITS

	7,500 BTU	9,500 BTU	12,000 BTU	18,000 BTU	20,000 BTU	24,000 BTU	30,000 BTU	36,000 BTU	48,000 BTU	76,000 BTU	96,000 BTU
4 Way Cassette		✔		✔		✔	✔	✔	✔		
Mini 4 Way Cassette		✔	✔	✔	✔						
1 Way Cassette	✔	✔	✔								
H.S.P. Duct								✔	✔	✔	✔
M.S.P. Duct				✔		✔	✔	✔	✔		
Slim Duct	✔	✔	✔	✔		✔	✔	✔	✔		
Wall Mount	✔	✔	✔	✔	✔	✔					
Ceiling/Floor Mount				✔		✔					

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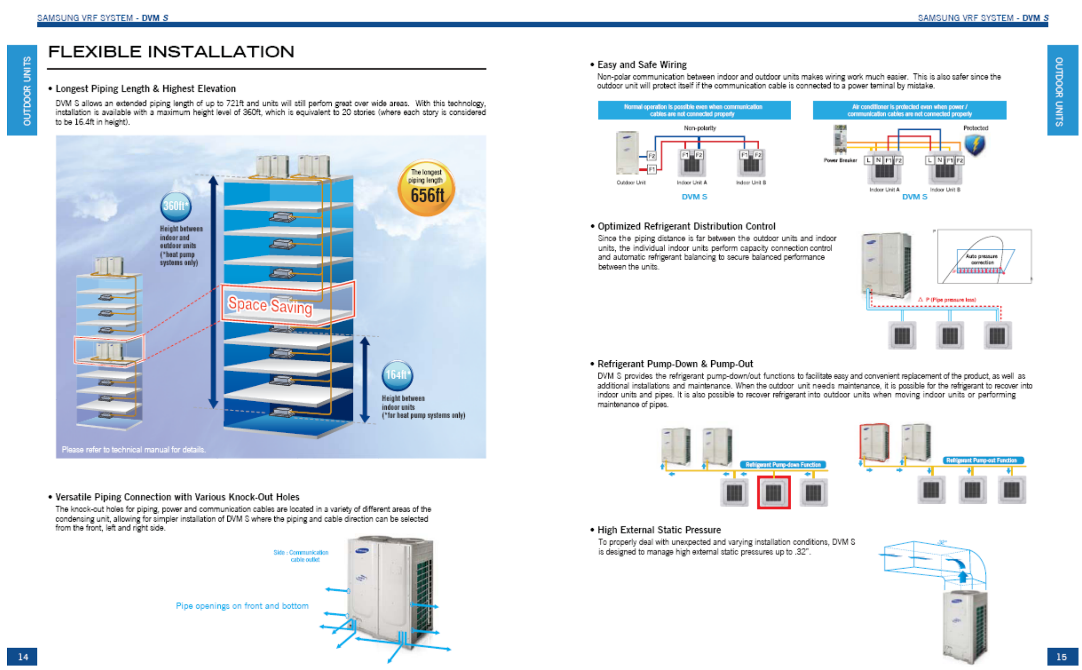

SAMSUNG VRF SYSTEM - DVM S

OUTDOOR UNITS

FLEXIBLE INSTALLATION

• Longest Piping Length & Highest Elevation

DVM S allows an extended piping length of up to 721ft and units will still perfom great over wide areas. With this technology, installation is available with a maximum height level of 360ft, which is equivalent to 20 stories (where each story is considered to be 16.4ft in height).

• Versatile Piping Connection with Various Knock-Out Holes

The knock-out holes for piping, power and communication cables are located in a variety of different areas of the condensing unit, allowing for simpler installation of DVM S where the piping and cable direction can be selected from the front, left and right side.

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• Easy and Safe Wiring

Non-polar communication between indoor and outdoor units makes wiring work much easier. This is also safer since the outdoor unit will protect itself if the communication cable is connected to a power teminal by mistake.

• Optimized Refrigerant Distribution Control

Since the piping distance is far between the outdoor units and indoor units, the individual indoor units perform capacity connection control and automatic refrigerant balancing to secure balanced performance between the units.

• Refrigerant Pump-Down & Pump-Out

DVM S provides the refrigerant pump-down/out functions to facilitate easy and convenient replacement of the product, as well as additional installations and maintenance. When the outdoor unit needs maintenance, it is possible for the refrigerant to recover into indoor units and pipes. It is also possible to recover refrigerant into outdoor units when moving indoor units or performing maintenance of pipes.

• High External Static Pressure

To properly deal with unexpected and varying installation conditions, DVM S is designed to manage high external static pressures up to .32".

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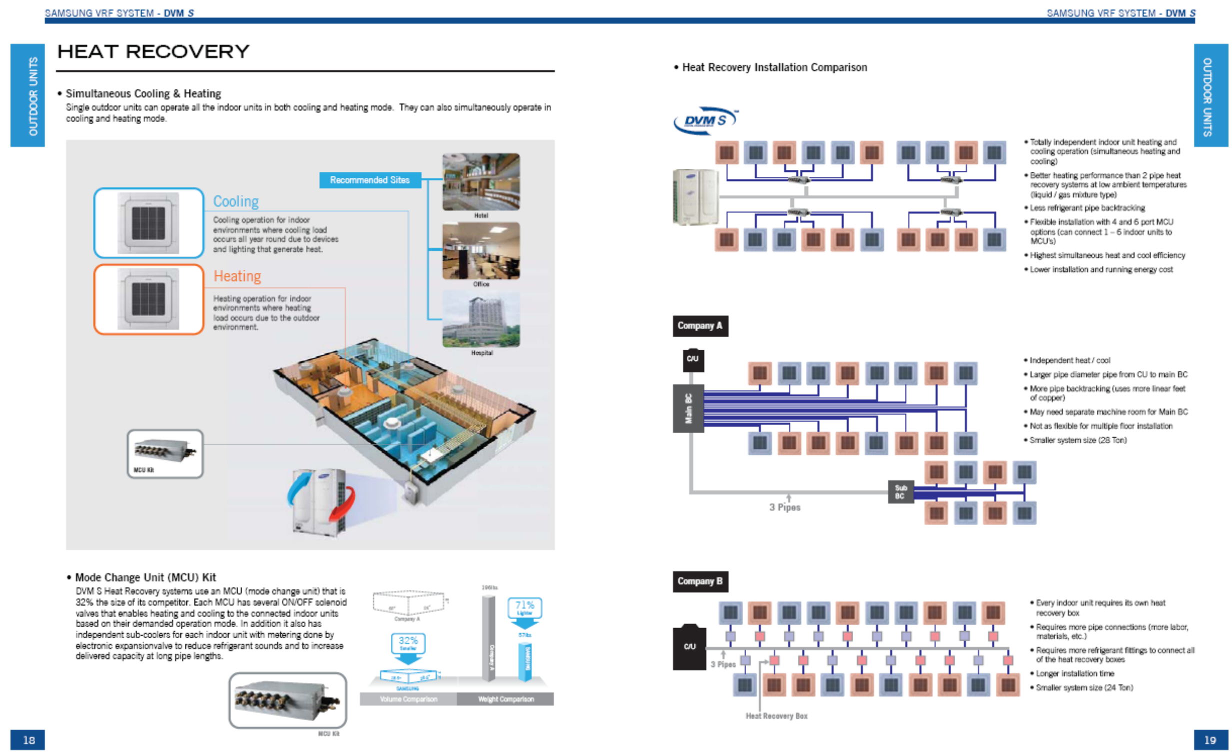

SAMSUNG VRF SYSTEM - DVM S

OUTDOOR UNITS

HEAT RECOVERY

• **Simultaneous Cooling & Heating**
Single outdoor units can operate all the indoor units in both cooling and heating mode. They can also simultaneously operate in cooling and heating mode.

• **Mode Change Unit (MCU) Kit**
DVM S Heat Recovery systems use an MCU (mode change unit) that is 32% the size of its competitor. Each MCU has several ON/OFF solenoid valves that enables heating and cooling to the connected indoor units based on their demanded operation mode. In addition it also has independent sub-coolers for each indoor unit with metering done by electronic expansionvalve to reduce refrigerant sounds and to increase delivered capacity at long pipe lengths.

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SAMSUNG VRF SYSTEM - DVM S

OUTDOOR UNITS

• **Heat Recovery Installation Comparison**

• Totally independent indoor unit heating and cooling operation (simultaneous heating and cooling)
• Better heating performance than 2 pipe heat recovery systems at low ambient temperatures (liquid / gas mixture type)
• Less refrigerant pipe backtracking
• Flexible installation with 4 and 6 port MCU options (can connect 1 – 6 indoor units to MCU's)
• Highest simultaneous heat and cool efficiency
• Lower installation and running energy cost

Company A

• Independent heat / cool
• Larger pipe diameter pipe from CU to main BC
• More pipe backtracking (uses more linear feet of copper)
• May need separate machine room for Main BC
• Not as flexible for multiple floor installation
• Smaller system size (28 Ton)

Company B

• Every indoor unit requires its own heat recovery box
• Requires more pipe connections (more labor, materials, etc.)
• Requires more refrigerant fittings to connect all of the heat recovery boxes
• Longer installation time
• Smaller system size (24 Ton)

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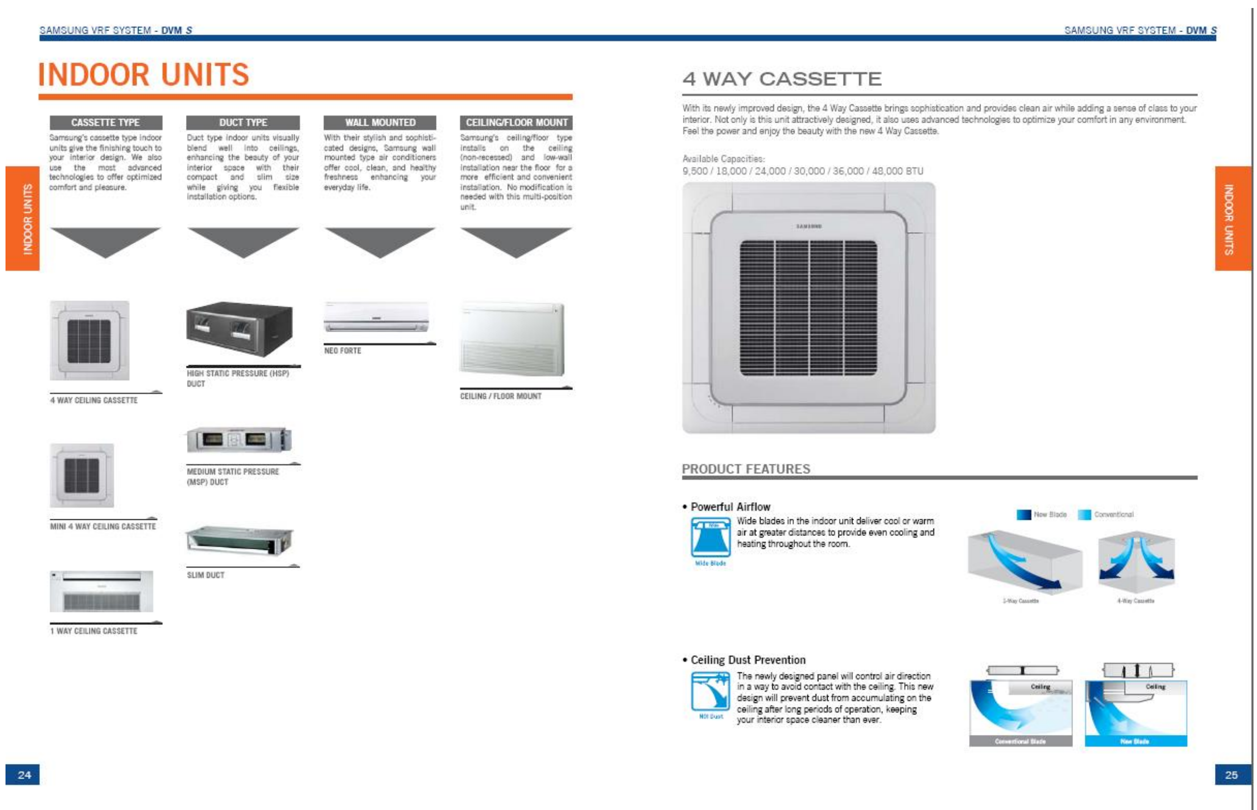

SAMSUNG VRF SYSTEM - DVM S

INDOOR UNITS

INDOOR UNITS

CASSETTE TYPE
Samsung's cassette type indoor units give the finishing touch to your interior design. We also use the most advanced technologies to offer optimized comfort and pleasure.

DUCT TYPE
Duct type indoor units visually blend well into ceilings, enhancing the beauty of your interior space with their compact and slim size while giving you flexible installation options.

WALL MOUNTED
With their stylish and sophisticated designs, Samsung wall mounted type air conditioners offer cool, clean, and healthy freshness enhancing your everyday life.

CEILING/FLOOR MOUNT
Samsung's ceiling/floor type installs on the ceiling (non-recessed) and low-wall installation near the floor for a more efficient and convenient installation. No modification is needed with this multi-position unit.

4 WAY CEILING CASSETTE

MINI 4 WAY CEILING CASSETTE

1 WAY CEILING CASSETTE

HIGH STATIC PRESSURE (HSP) DUCT

MEDIUM STATIC PRESSURE (MSP) DUCT

SLIM DUCT

NEO FORTE

CEILING / FLOOR MOUNT

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SAMSUNG VRF SYSTEM - DVM S

INDOOR UNITS

4 WAY CASSETTE

With its newly improved design, the 4 Way Cassette brings sophistication and provides clean air while adding a sense of class to your interior. Not only is this unit attractively designed, it also uses advanced technologies to optimize your comfort in any environment. Feel the power and enjoy the beauty with the new 4 Way Cassette.

Available Capacities:
9,500 / 18,000 / 24,000 / 30,000 / 36,000 / 48,000 BTU

PRODUCT FEATURES

• **Powerful Airflow**
Wide blades in the indoor unit deliver cool or warm air at greater distances to provide even cooling and heating throughout the room.

• **Ceiling Dust Prevention**
The newly designed panel will control air direction in a way to avoid contact with the ceiling. This new design will prevent dust from accumulating on the ceiling after long periods of operation, keeping your interior space cleaner than ever.

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INDOOR UNITS

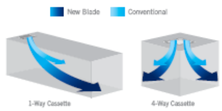
1 WAY CASSETTE

Available Capacities:
7,500 / 9,500 / 12,000 BTU

PRODUCT FEATURES

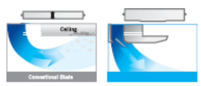
• Powerful Airflow

Wide blades in the indoor unit deliver cool or warm air at greater distances to provide even cooling and heating throughout the room.



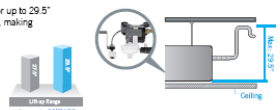
• Ceiling Dust Prevention

The newly designed panel will control air direction in a way to avoid contact with the ceiling. This new design will prevent dust from accumulating on the ceiling after long periods of operation, keeping your interior space cleaner than ever.



• High-Lift Up Drain Pump

The lift-up drain pump lifts condensed water up to 29.5" compared to our competitor's limit of 27.5", making installation more flexible and convenient.



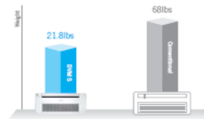
1 WAY CASSETTE . . .

• Stylish and Aesthetic Panel

Samsung's Slim 1Way Cassette provides a simple and refined design. The clean lines and simple display design make this a modern classic, which looks great with any interior.

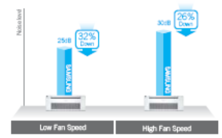
• Lighter Indoor Unit

Samsung is the first to apply ABS cabinets to its indoor units to provide the lightest units on the market. This slim and lightweight design makes installation and maintenance simple.



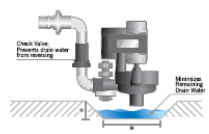
• Quiet Operation

Samsung new blade design drastically reduces noise levels so you can relax in peace and quiet.



• No Overflowing Drain Water

The check valve on the drain pump prevents drained water from flowing backward into the drain pan. This minimizes the the drain pan's water level so that you will never have to worry about water stagnation or overflowing drain water that could drip into your interior.



INDOOR UNITS

SAMSUNG VRF SYSTEM - DVM S

INDOOR UNITS

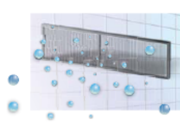
HSP DUCT

Available Capacities:
36,000 / 48,000 / 76,000 / 96,000 BTU

PRODUCT FEATURES

• Pre Filter

The HSP Duct's Pre Filter traps dusts particles from the air.

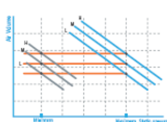


• Easy Filter Cleaning

After 1,000 hours of operation, the filter clean indicator will notify you that the filter should be cleaned. 1,000 hours is the default set time, which can be adjusted to 2,000 hours on the internal PCB.

• Smart Pressure Control

The Smart Pressure Control System adjusts fan speed according to the external static pressure so the air conditioner always provides you with consistent cooling and heating power, regardless of the surrounding environment.

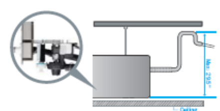


HSP DUCT . . .

• High Lift-Up Drain Pump* (Optional)

The lift-up drain pump lifts condensed water up to 29.5", compared to our competitor's limit of 27.5", making installation more flexible and convenient.

* The lift-up range of the drain pump for the 6 & 8 Ton HSP is limited to 18.5".

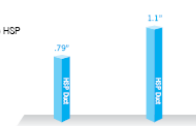


• Wired Remote Control

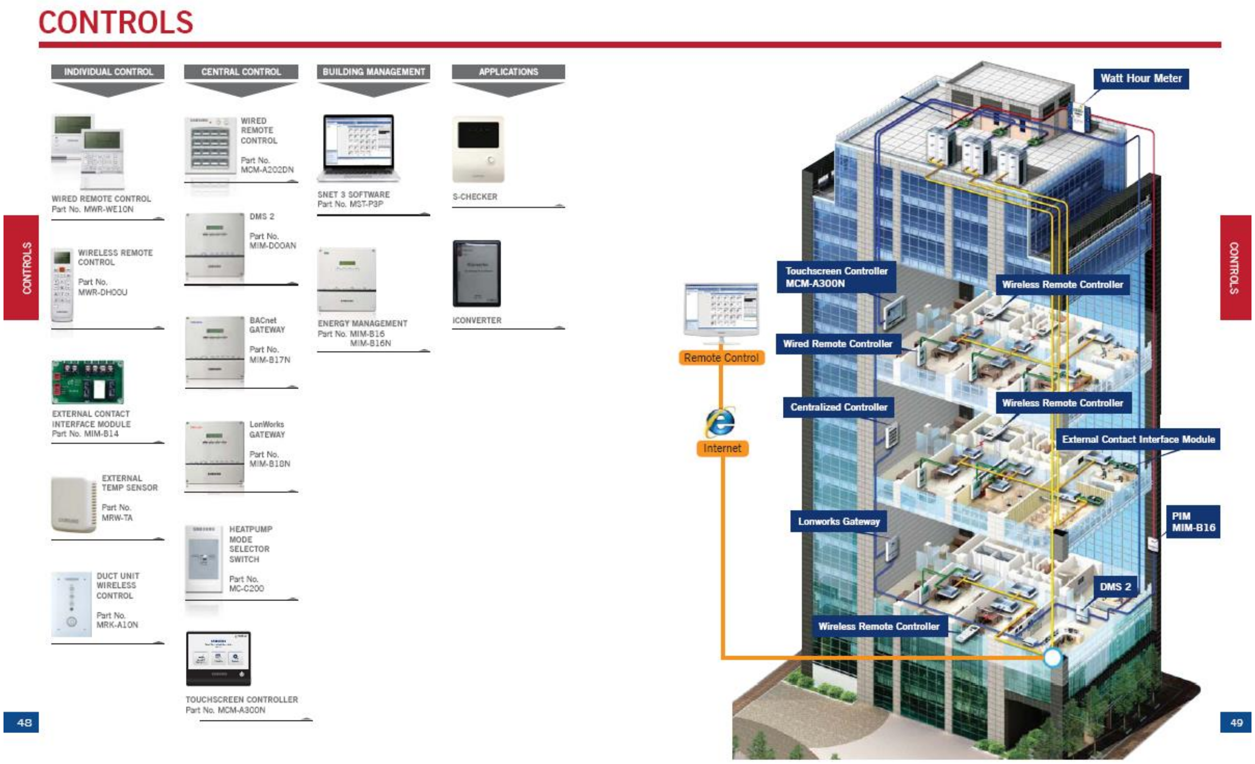
The HSP Ducted unit is controlled via a wired remote controller.

• High External Static Pressure

To properly deal with unexpected and various installation conditions, the HSP Duct is designed to manage high external static pressures up to .99".



INDOOR UNITS



INDIVIDUAL CONTROL

WIRED REMOTE CONTROL

Samsung's MWR-WE10N wired controller allows connection of up to 16 Samsung indoor units. Features include: built-in room sensor, air handler operation on/off, air handler operation mode, set temperature, air flow direction, fan speed, discharge air temperature setting (with supported indoor unit models), quiet and sleep modes, error display, filter replacement alarm display and reset, weekly operating schedule, different button permission levels, partial button lock option, backlight, temperature limit setting option, service mode support, independent louver control for DVM S series 4-way cassette models (AMO**FN4DCH), adjustable heating temperature compensation values, and child lock.

MWR-WE10N

- On/Off, Operation Mode, Fan Speed, Airflow, Temp Setting
- Individual and group control (maximum to 16 indoor units)
- Error display
- Filter replacement alarm reset
- Sleep & Silent mode
- Built-in room temperature sensor
- Child lock
- Automatic stop mode
- Wireless remote control restriction
- Clear & bright screen with LCD backlight
- Unified controller
- Different permission levels
- Weekly schedule setting
- Exception date setting
- Individual blade control (supports specific indoor unit models)
- Summer time

WIRELESS REMOTE CONTROL

MR-DH00U

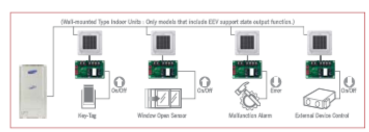
- On/Off, Operation Mode, Fan Speed, Airflow, Temperature Setting
- Filter replacement alarm reset
- Simple schedule control
- Wide display
- Soft touch button
- Individual blade control (supports specific indoor unit models)
- Multi-channel wireless remote control (maximum of 4 channels)

GUESTROOM MANAGEMENT MODULE

Direct indoor unit ON/OFF control (a single evaporator) by external contact, 0 volts signal. Also provides operation and error output terminals to control other devises/indicator lights with a dry-contact. E.G.: hotel key card switch, door/window switch, PIR sensor with timed relay, other occupancy sensors, enabling/disabling other ventilation.

MIM-B14 (External Contact Interface Module)

- Direct indoor unit control by external contact signal
- Window-synchronized indoor unit control
- Emergency control with simple contact input
- Indoor unit operation / error state output through relay contacts

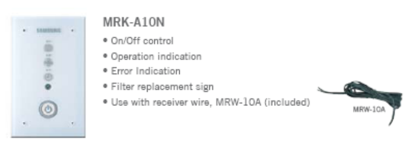


EXTERNAL TEMPERATURE SENSOR

MRW-TA

- External sensor to measure exact user environment temperature
- Wire length : 39ft.

DUCT UNIT WIRELESS CONTROL



MRK-A10N

- On/Off control
- Operation indication
- Error Indication
- Filter replacement sign
- Use with receiver wire, MRW-10A (included)

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CENTRAL CONTROL

CONTROLS

DMS 2 CONTINUED . . .

Power Distribution System

- Power distribution to a maximum of 256 indoor units
- Data query for watt-hour, usage time and usage ratio
- Files are saved in Microsoft® Excel® format
- 1-year power distribution data is saved in storage
- Current actual power consumption monitoring
- Current-type electricity meter support (CT ratio input)

Smart Central Management

- Control & monitoring zone edition
- Wireless/wired remote control restriction
- Temperature limit setting
- Operation mode restriction

A Zone: Cooling only / No remote controller / Minimum cooling temperature setting is 68°F

B Zone: Cooling only / Remote controller use

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BACnet GATEWAY

Standalone web server device that can connect to and control up to 256 indoor units via Internet Explorer. The MIM-B17 provides a simple, easy to use interface for control of the following: indoor unit operation mode, temperature setting, airflow direction, fan speed, temperature and mode limitations and restrictions, maximum current control of outdoor unit(s) to limit current (50% - 100% of design current) adjustable at outdoor unit or MIM-B17, heating and cooling output calibration of indoor units, and other various control points. To fit the needs of the commercial building, multiple user login accounts can be created with various levels of control for manager specified indoor units. The MIM-B17 shall also offer 10 Digital Input (2 reserved for system shutdown with emergency signal) and 8 Digital Output terminals (2 reserved) to control and monitor other devices on the project. The MIM-B17 will also interface with BACnet systems to allow full integration with building management systems.

MIM-B17N (DMS-Bnet)

- Interface for BACnet management system
- Maximum 256 indoor units plus ERVs support with a maximum of 80 interface modules
- Combinational use of BACnet and S-NET 3/ S-NET Mini
- Includes DMS 2 functions

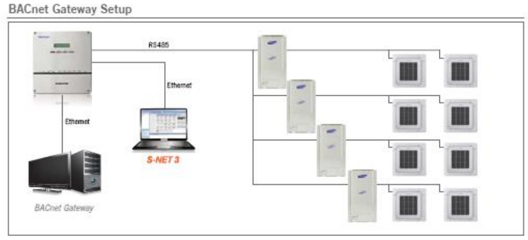
CONTROL

- On/Off control
- Operation mode
- Temperature setting
- Fan speed/direction
- ERV operation mode
- ERV fan speed
- Filter alarm reset
- User control restriction
- Operation mode lock
- Set temperature limit
- Emergency stop
- Output contact control

MONITORING

- On/Off control
- Operation mode
- Set/Room temperature
- Fan speed/direction
- ERV operation mode
- ERV fan speed
- Filter alarm
- User control restriction
- Thermo On/Off
- Power distribution
- Operation mode lock
- Set temperature limit
- In/Out contact state
- Emergency stop
- Error code

BACnet Gateway Setup



CONTROLS

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Dedicated Outside Air System Cut Sheets

FV Output Section:

Project Name	ALSM Altoona
Project Location	Altoona, PA
Mechanical Contractor	0
SEMCO Representative	0

Unit Designation	ERV-1	Date	12-Nov-13

Unit Size and Options Selected

Qty.(1) FV-2000 - Fresh Air Preconditioner

- **SEMCO 3 angstrom total energy wheel**
- Antimicrobial/anti-corrosion wheel face coating
- Wheel cassette slides in and out for service
- Outdoor Unit
- Outdoor air standard mesh filter
- Return air standard mesh filter
- Outdoor Damper - actuator and control
- V Configuration
- Standard paint finish
- Standard roof curb for FV unit
- 208V/1Ph
- Constant speed wheel - stop/jog economizer
- Hinged access door for filter, wheel and fan inspection
- Galvanized sheet metal liner (dual wall)
- 20 gauge galvanized steel enclosure
- DWDI fans
- 24 volt remote start/stop terminals provided
- Rotation detector with alarm relay
- AQFlow Airflow Measurement Station
- Disconnect - (non-fused)
- 5 year limited warranty

Fan and Electrical Data

Fan Data	Airflow (scfm)	External Static Pressure (inwg)	Motor Brake Horsepower*	Fan Speed (RPM)
Supply Air	1,250	1.50	1.00	1723
Exhaust Air	1,175	0.75	0.64	1413

* includes 10% added parasitic energy for drive losses for supply and exhaust

Electrical Data	Installed Horsepower	Voltage/Phase	Unit Full Load Amps	Min Circuit Amps	MOCP*
Supply Air	1.50	208V/1Ph	19.7	22.5	33.5
Exhaust Air	0.75				

* maximum overload circuit protection

Electrical Data	Recommended Fuse/Breaker	Recommended Disconnect*
Single Point Connection	30.0	30.00

* see list of selected options above to determine if disconnect is provided by SEMCO

Recovery Wheel Performance Data: Cooling Season

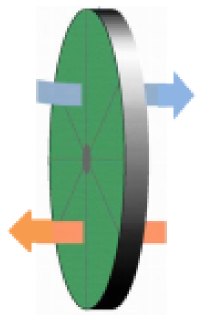
ERV-1

Outdoor Airstream

Dry bulb (°F)	95.0
Wet bulb (°F)	75.0
Grains	99.0
Enthalpy (BTU/Lb)	38.4

Exhaust Airstream

Dry bulb (°F)	90.8
Wet bulb (°F)	72.5
Grains	91.2
Enthalpy (BTU/Lb)	36.1



Supply Airstream

Dry bulb (oF)	80.2
Wet bulb (°F)	65.7
Grains	71.9
Enthalpy (BTU/Lb)	30.5
Airflow (scfm)	1,250

Return Airstream

Dry bulb (°F)	75.0
Wet bulb (°F)	62.0
Grains	62.4
Enthalpy (BTU/Lb)	27.8
Relative Humidity	48%
Airflow (scfm)	1,175

Unit Effectiveness	0.79
Supply Sensible Efficiency	0.74
Supply Latent Efficiency	0.74

Supply Air Pressure Loss	0.36
Exhaust Air Pressure Loss	0.33

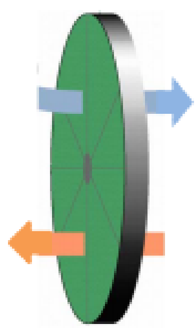
Recovery Wheel Performance Data: Heating Season

Outdoor Airstream

Dry bulb (°F)	0.0
Wet bulb (°F)	-1.0
Grains	3.7
Enthalpy (BTU/Lb)	0.6

Exhaust Airstream

Dry bulb (°F)	15.3
Wet bulb (°F)	14.0
Grains	9.2
Enthalpy (BTU/Lb)	5.1



Supply Airstream

Dry bulb (oF)	53.3
Wet bulb (°F)	43.5
Grains	26.5
Enthalpy (BTU/Lb)	16.9
Airflow (scfm)	1,250

Return Airstream

Dry bulb (°F)	72.0
Wet bulb (°F)	53.0
Grains	29.7
Enthalpy (BTU/Lb)	21.9
Relative Humidity	26%
Airflow (scfm)	1,175

Unit Effectiveness	0.79
Supply Sensible Efficiency	0.74
Supply Latent Efficiency	0.74

Supply Air Pressure Loss	0.32
Exhaust Air Pressure Loss	0.30

SPECIFICATIONS - OUTDOOR UNITS

DVM S HEAT RECOVERY (460V)

Model Name				AM072FXVAJR/AA	AM096FXVAJR/AA	AM120FXVAJR/AA	AM144FXVAJR/AA
Power Supply			Ø, V, Hz	3, 460, 60	3, 460, 60	3, 460, 60	3, 460, 60
Mode			-	HEAT RECOVERY	HEAT RECOVERY	HEAT RECOVERY	HEAT RECOVERY
Performance	Ton		TON	6.00	8.00	10.00	12.00
	Capacity (Nominal)	Cooling 1)	Btu/h	72,000	96,000	120,000	144,000
		Heating 1)	Btu/h	81,000	108,000	135,000	162,000
	Capacity (Rated)	Cooling	Btu/h	69,000	92,000	114,000	138,000
		Heating	Btu/h	77,000	103,000	129,000	154,000
Power	MCA		A	16.4	19	21.7	26.4
	MOP		A	20	25	30	40
Compressor	Type		-	SSC Scroll x 1	SSC Scroll x 1	SSC Scroll x 1	SSC Scroll x 2
	Output		kW x n	(4.96)	(6.13)	(6.13)	(4.96x2)
	Model Name		-	DS-GB052FAVASG x 1	DS-GB066FAVASG x 1	DS-GB066FAVASG x 1	DS-GB052FAVASG x 2
	Oil	Type	-	PVE	PVE	PVE	PVE
		Initial Charge	cc	1100	1100	1100	2200
			fl. oz.	77.77	77.77	77.77	155.54
Fan	Type		-	Propeller	Propeller	Propeller	Propeller
	Output x n		W	400 x 1	620 x 2	620 x 2	620 x 2
	Air Flow Rate		CFM	7,239.78	9,182.16	9,182.16	9,535.32
	External Static Pressure	Max.	mmAq	8.00	8.00	8.00	8.00
			In Wg	0.31	0.31	0.31	0.31
Piping Connections	Liquid Pipe		Ø, mm	9.52	9.52	12.70	12.70
			Ø, inch	3/8	3/8	1/2	1/2
	Gas Pipe		Ø, mm	19.05	22.22	28.58	28.58
			Ø, inch	3/4	7/8	1 1/8	1 1/8
	High Pressure Gas Pipe (for HR)		Ø, mm	15.88	19.05	22.22	22.22
			Ø, inch	5/8	3/4	7/8	7/8
	Installation Limitation	Max. Length	m	200(220)	200(220)	200(220)	200(220)
			ft	656(722)	656(722)	656(722)	656(722)
		Max. Height	m	110(40)	110(40)	110(40)	110(40)
			ft	361(131)	361(131)	361(131)	361(131)
Refrigerant	Type		-	R410A	R410A	R410A	R410A
	Factory Charging		kg	5.50	7.40	7.40	8.70
			lbs	12.13	16.31	16.31	19.18
Sound 2)	Sound Pressure		dB(A)	60.0	61.0	61.0	62.0
	Sound Power			81	81	81	83
External Dimension	Net Weight		kg	190.0	278.0	284.0	299.0
			lbs	418.88	612.89	626.11	659.18
	Shipping Weight		kg	206.0	300.0	303.0	318.0
			lbs	454.15	661.39	668.00	701.07
	Net Dimensions (WxHxD)		mm	880 x 1,695 x 765	1,295 x 1,695 x 765	1,295 x 1,695 x 765	1,295 x 1,695 x 765
			inch	34.65 x 66.73 x 30.12	50.98 x 66.73 x 30.12	50.98 x 66.73 x 30.12	50.98 x 66.73 x 30.12
	Shipping Dimensions (WxHxD)		mm	948 x 1,912 x 832	1,363 x 1,912 x 832	1,363 x 1,912 x 832	1,363 x 1,912 x 832
			inch	37.32 x 75.28 x 32.76	53.66 x 75.28 x 32.76	53.66 x 75.28 x 32.76	53.66 x 75.28 x 32.76
Operating Temp. Range	Cooling		°F	23.0 ~ 120.0	23.0 ~ 120.0	23.0 ~ 120.0	23.0 ~ 120.0
	Heating		°F	-4.0 ~ 75.0	-4.0 ~ 75.0	-4.0 ~ 75.0	-4.0 ~ 75.0

1) Nominal Capacity is based on (Equivalent refrigerant piping : 25ft , Level differences : 0ft);
- Cooling : Indoor temperature : 80°F DB, 67°F WB / Outdoor temperature : 95°F DB, 75°F WB
- Heating : Indoor temperature : 70°F DB, 60°F WB / Outdoor temperature : 47°F DB, 43°F WB

2) Sound pressure was acquired in a dead room. Thus actual noise level may be different depending on the installation conditions.

3) Specifications are subject to change without prior notice for product improvement.

DVM S HEAT RECOVERY (460V)

Model Name				AM168FXVAJR/AA	AM192FXVAJR/AA	AM216FXVAJR/AA	AM240FXVAJR/AA
Power Supply			Ø, V, Hz	3, 460, 60	3, 460, 60	3, 460, 60	3, 460, 60
Mode			-	HEAT RECOVERY	HEAT RECOVERY	HEAT RECOVERY	HEAT RECOVERY
Performance	Ton		TON	14.00	16.00	18.00	20.00
	Capacity (Nominal)	Cooling[1]	Btu/h	168,000	192,000	216,000	240,000
		Heating[1]	Btu/h	189,000	216,000	243,000	270,000
	Capacity (Rated)	Cooling	Btu/h	161,000	183,000	207,000	228,000
		Heating	Btu/h	180,000	206,000	231,000	258,000
Power	MCA		A	35.4	38.1	42.8	43.4
	MOP		A	60	50	60	60
Compressor	Type		-	SSC Scroll x 2	SSC Scroll x 2	SSC Scroll x 3	SSC Scroll x 2
	Output		kW x n	(4.96) + (6.13)	(4.96) + (6.13)	(4.96) + (4.96x2)	(6.13)x2
	Model Name		-	DS-GB052FAVASG x 1 + DS-GB066FAVASG x 1	DS-GB052FAVASG x 1 + DS-GB066FAVASG x 1	DS-GB052FAVASG x 3	DS-GB066FAVASG x 2
	Oil	Type	-	PVE	PVE	PVE	PVE
		Initial Charge	cc	2200	2200	3300	2200
			fl. oz.	155.54	155.54	233.32	155.54
Fan	Type		-	Propeller	Propeller	Propeller	Propeller
	Output x n		W	400 x 1 + 620 x 2	400 x 1 + 620 x 2	400 x 1 + 620 x 2	(620 x 2) x 2
	Air Flow Rate		CFM	7,239.78 + 9,182.16	7,239.78 + 9,182.16	7,239.78 + 9,535.32	9,182.16 x 2
	External Static Pressure	Max.	mmAq	8.00	8.00	8.00	8.00
			In Wg	0.31	0.31	0.31	0.31
Piping Connections	Liquid Pipe		Ø, mm	15.88	15.88	15.88	15.88
			Ø, inch	5/8	5/8	5/8	5/8
	Gas Pipe		Ø, mm	28.58	28.58	28.58	28.58
			Ø, inch	1 1/8	1 1/8	1 1/8	1 1/8
	High Pressure Gas Pipe (for HR)		Ø, mm	22.22	28.58	28.58	28.58
			Ø, inch	7/8	1 1/8	1 1/8	1 1/8
	Installation Limitation	Max. Length	m	200(220)	200(220)	200(220)	200(220)
			ft	656(722)	656(722)	656(722)	656(722)
		Max. Height	m	110(40)	110(40)	110(40)	110(40)
			ft	361(131)	361(131)	361(131)	361(131)
Refrigerant	Type		-	R410A	R410A	R410A	R410A
	Factory Charging		kg	12.90	12.90	14.20	14.80
			lbs	28.44	28.44	31.31	32.63
Sound[2]	Sound Pressure		dB(A)	-	-	-	-
	Sound Power			-	-	-	-
External Dimension	Net Weight		kg	190.0 + 278.0	190.0 + 284.0	190.0 + 299.0	284.0 x 2
			lbs	418.88 + 612.89	418.88 + 626.11	418.88 + 659.18	626.11 x 2
	Shipping Weight		kg	206.0 + 300.0	206.0 + 303.0	206.0 + 318.0	303.0 x 2
			lbs	454.15 + 661.39	454.15 + 668.00	454.15 + 701.07	668.00 x 2
	Net Dimensions (WxHxD)		mm	880 x 1,695 x 765 + 1,295 x 1,695 x 765	880 x 1,695 x 765 + 1,295 x 1,695 x 765	880 x 1,695 x 765 + 1,295 x 1,695 x 765	(1,295 x 1,695 x 765) x 2
			inch	34.65 x 66.73 x 30.12 + 50.98 x 66.73 x 30.12	34.65 x 66.73 x 30.12 + 50.98 x 66.73 x 30.12	34.65 x 66.73 x 30.12 + 50.98 x 66.73 x 30.12	(50.98 x 66.73 x 30.12) x 2
	Shipping Dimensions (WxHxD)		mm	948 x 1,912 x 832 + 1,363 x 1,912 x 832	948 x 1,912 x 832 + 1,363 x 1,912 x 832	948 x 1,912 x 832 + 1,363 x 1,912 x 832	(1,363 x 1,912 x 832) x 2
			inch	37.32 x 75.28 x 32.76 + 53.66 x 75.28 x 32.76	37.32 x 75.28 x 32.76 + 53.66 x 75.28 x 32.76	37.32 x 75.28 x 32.76 + 53.66 x 75.28 x 32.76	(53.66 x 75.28 x 32.76) x 2
Operating Temp. Range	Cooling		°F	23.0 ~ 120.0	23.0 ~ 120.0	23.0 ~ 120.0	23.0 ~ 120.0
	Heating		°F	-4.0 ~ 75.0	-4.0 ~ 75.0	-4.0 ~ 75.0	-4.0 ~ 75.0

1) Nominal Capacity is based on (Equivalent refrigerant piping : 25ft , Level differences : 0ft);
- Cooling : Indoor temperature : 80°F DB, 67°F WB / Outdoor temperature : 95°F DB, 75°F WB
- Heating : Indoor temperature : 70°F DB, 60°F WB / Outdoor temperature : 47°F DB, 43°F WB

2) Sound pressure was acquired in a dead room. Thus actual noise level may be different depending on the installation conditions.

3) Specifications are subject to change without prior notice for product improvement.

SPECIFICATIONS - INDOOR UNITS

4 WAY CASSETTE

Model				AM009FN4DCH/AA	AM018FN4DCH/AA	AM024FN4DCH/AA
Power Supply			Ø, V, Hz	1,208-230,60	1,208-230,60	1,208-230,60
Mode			-	HP/HR	HP/HR	HP/HR
Performance	Capacity (Nominal)	Cooling 1)	Btu/h	9,000	18,000	24,000
			US RT	0.75	1.50	2.00
		Heating 1)	Btu/h	10,000	20,000	27,000
			US RT	0.83	1.67	2.25
Power	Power Input (Nominal)	Cooling 1)	W	32.00	32.00	40.00
		Heating 1)		32.00	32.00	40.00
	Current Input (Nominal)	Cooling 1)	A	0.25	0.25	0.30
		Heating 1)		0.25	0.25	0.30
Fan	Motor	Type	-	Turbo Fan	Turbo Fan	Turbo Fan
		Output x n	W	65 x 1	65 x 1	65 x 1
	Air Flow Rate	H/M/L (UL)	CFM	547.40/494.42/423.79	547.40/494.42/423.79	618.03/565.06/494.42
	External Pressure	Min / Std / Max	Pa	-	-	-
Piping Connections	Liquid Pipe		Ø, mm	6.35	6.35	6.35
			Ø, inch	1/4	1/4	1/4
	Gas Pipe		Ø, mm	12.70	12.70	12.70
			Ø, inch	1/2	1/2	1/2
	Drain Pipe		Ø, mm	VP25 (OD 32,ID 25)	VP25 (OD 32,ID 25)	VP25 (OD 32,ID 25)
Refrigerant	Type		-	R410A	R410A	R410A
	Control Method		-	EEV INCLUDED	EEV INCLUDED	EEV INCLUDED
Sound	Sound Pressure 2)	High / Mid / Low	dBA	34.0/33.0/31.0	34.0/33.0/31.0	36.0/35.0/34.0
Dimensions	Net Weight		kg	15.00	15.00	15.00
			lbs	33.07	33.07	33.07
	Shipping Weight		kg	18.50	18.50	18.50
			lbs	40.79	40.79	40.79
	Net Dimensions (WxHxD)		mm	840 x 204 x 840	840 x 204 x 840	840 x 204 x 840
			inch	33.07 x 8.03 x 33.07	33.07 x 8.03 x 33.07	33.07 x 8.03 x 33.07
	Shipping Dimensions (WxHxD)		mm	898 x 275 x 898	898 x 275 x 898	898 x 275 x 898
			inch	35.35 x 10.83 x 35.35	35.35 x 10.83 x 35.35	35.35 x 10.83 x 35.35
Panel Size	Panel model		model name	PC4NUSKFN	PC4NUSKFN	PC4NUSKFN
	Panel Net Weight		kg	5.80	5.80	5.80
			lbs	12.79	12.79	12.79
	Shipping Weight		kg	8.40	8.40	8.40
			lbs	18.52	18.52	18.52
	Net Dimensions (WxHxD)		mm	950 x 45 x 950	950 x 45 x 950	950 x 45 x 950
			inch	37.40 x 1.77 x 37.40	37.40 x 1.77 x 37.40	37.40 x 1.77 x 37.40
	Shipping Dimensions (WxHxD)		mm	1005 x 100 x 1005	1005 x 100 x 1005	1005 x 100 x 1005
			inch	39.57 x 3.94 x 39.57	39.57 x 3.94 x 39.57	39.57 x 3.94 x 39.57
Additional Accessories	Drain pump	Drain pump	model name	Built-in	Built-in	Built-in
		Max. lifting Height / Displacement	mm/liter/h	750 / 24	750 / 24	750 / 24
	Air Filter		-	Long life filter	Long life filter	Long life filter

1) Nominal Capacity is based on (Equivalent refrigerant piping : 25ft , Level differences : 0ft);
- Cooling : Indoor temperature : 80°F DB, 67°F WB / Outdoor temperature : 95°F DB, 75°F WB
- Heating : Indoor temperature : 70°F DB, 60°F WB / Outdoor temperature : 47°F DB, 43°F WB

2) Sound pressure was acquired in a dead room. Thus actual noise level may be different depending on the installation conditions.

3) Specifications are subject to change without prior notice for product improvement.

4 WAY CASSETTE

Model				AM030FN4DCH/AA	AM036FN4DCH/AA	AM048FN4DCH/AA
Power Supply			Ø, V, Hz	1,208-230,60	1,208-230,60	1,208-230,60
Mode			-	HP/HR	HP/HR	HP/HR
Performance	Capacity (Nominal)	Cooling 1)	Btu/h	30,000	36,000	48,000
			US RT	2.50	3.00	4.00
		Heating 1)	Btu/h	34,000	40,000	54,000
			US RT	2.83	3.33	4.50
Power	Power Input (Nominal)	Cooling 1)	W	65.00	75.00	95.00
		Heating 1)		65.00	75.00	95.00
	Current Input (Nominal)	Cooling 1)	A	0.50	0.56	0.75
		Heating 1)		0.50	0.56	0.75
Fan	Motor	Type	-	Turbo Fan	Turbo Fan	Turbo Fan
		Output x n	W	97 x 1	97 x 1	97 x 1
	Air Flow Rate	H/M/L (UL)	CFM	776.95/688.66/600.37	847.58/776.95/706.32	1,024.16/953.53/847.58
	External Pressure	Min / Std / Max	Pa	-	-	-
Piping Connections	Liquid Pipe		Ø, mm	9.52	9.52	9.52
			Ø, inch	3/8	3/8	3/8
	Gas Pipe		Ø, mm	15.88	15.88	15.88
			Ø, inch	5/8	5/8	5/8
	Drain Pipe		Ø, mm	VP25 (OD 32,ID 25)	VP25 (OD 32,ID 25)	VP25 (OD 32,ID 25)
Refrigerant	Type		-	R410A	R410A	R410A
	Control Method		-	EEV INCLUDED	EEV INCLUDED	EEV INCLUDED
Sound	Sound Pressure 2)	High / Mid / Low	dBA	39.0/34.0/30.0	40.0/37.0/33.0	44.0/42.0/39.0
Dimensions	Net Weight		kg	18.50	18.50	18.50
			lbs	40.79	40.79	40.79
	Shipping Weight		kg	23.00	23.00	23.00
			lbs	50.71	50.71	50.71
	Net Dimensions (WxHxD)		mm	840 x 288 x 840	840 x 288 x 840	840 x 288 x 840
			inch	33.07 x 11.34 x 33.07	33.07 x 11.34 x 33.07	33.07 x 11.34 x 33.07
	Shipping Dimensions (WxHxD)		mm	898 x 357 x 898	898 x 357 x 898	898 x 357 x 898
			inch	35.35 x 14.06 x 35.35	35.35 x 14.06 x 35.35	35.35 x 14.06 x 35.35
Panel Size	Panel model		model name	PC4NUSKFN	PC4NUSKFN	PC4NUSKFN
	Panel Net Weight		kg	5.80	5.80	5.80
			lbs	12.79	12.79	12.79
	Shipping Weight		kg	8.40	8.40	8.40
			lbs	18.52	18.52	18.52
	Net Dimensions (WxHxD)		mm	950 x 45 x 950	950 x 45 x 950	950 x 45 x 950
			inch	37.40 x 1.77 x 37.40	37.40 x 1.77 x 37.40	37.40 x 1.77 x 37.40
	Shipping Dimensions (WxHxD)		mm	1005 x 100 x 1005	1005 x 100 x 1005	1005 x 100 x 1005
			inch	39.57 x 3.94 x 39.57	39.57 x 3.94 x 39.57	39.57 x 3.94 x 39.57
Additional Accessories	Drain pump	Drain pump	model name	Built-in	Built-in	Built-in
		Max. lifting Height / Displacement	mm/liter/h	750 / 24	750 / 24	750 / 24
	Air Filter		-	Long life filter	Long life filter	Long life filter

1) Nominal Capacity is based on (Equivalent refrigerant piping : 25ft , Level differences : 0ft);
- Cooling : Indoor temperature : 80°F DB, 67°F WB / Outdoor temperature : 95°F DB, 75°F WB
- Heating : Indoor temperature : 70°F DB, 60°F WB / Outdoor temperature : 47°F DB, 43°F WB

2) Sound pressure was acquired in a dead room. Thus actual noise level may be different depending on the installation conditions.

3) Specifications are subject to change without prior notice for product improvement.

MINI 4 WAY CASSETTE

Model				AM009FNNDCH/AA	AM012FNNDCH/AA
Power Supply			Ø, V, Hz	1,208-230,60	1,208-230,60
Mode			-	HP/HR	HP/HR
Performance	Capacity (Nominal)	Cooling 1)	Btu/h	9,500	12,000
			US RT	0.79	1.00
		Heating 1)	Btu/h	10,500	13,500
			US RT	0.88	1.12
Power	Power Input (Nominal)	Cooling 1)	W	24.00	28.00
		Heating 1)		24.00	28.00
	Current Input (Nominal)	Cooling 1)	A	0.17	0.19
		Heating 1)		0.17	0.19
Fan	Motor	Type	-	Turbo Fan	Turbo Fan
		Output x n	W	65 x 1	65 x 1
	Air Flow Rate	H/M/L (UL)	CFM	353.16/300.19/264.87	370.82/335.50/282.53
	External Pressure	Min / Std / Max	Pa	-	-
Piping Connections	Liquid Pipe		Ø, mm	6.35	6.35
			Ø, inch	1/4	1/4
	Gas Pipe		Ø, mm	12.70	12.70
			Ø, inch	1/2	1/2
	Drain Pipe		Ø, mm	VP25 (OD 32,ID 25)	VP25 (OD 32,ID 25)
Refrigerant	Type		-	R410A	R410A
	Control Method		-	EEV INCLUDED	EEV INCLUDED
Sound	Sound Pressure 2)	High / Mid / Low	dBA	34.0/30.0/26.0	36.0/34.0/31.0
Dimensions	Net Weight		kg	12.00	12.00
			lbs	26.46	26.46
	Shipping Weight		kg	14.00	14.00
			lbs	30.86	30.86
	Net Dimensions (WxHxD)		mm	575 x 250 x 575	575 x 250 x 575
			inch	22.64 x 9.84 x 22.64	22.64 x 9.84 x 22.64
	Shipping Dimensions (WxHxD)		mm	623 x 298 x 653	623 x 298 x 653
			inch	24.53 x 11.73 x 25.71	24.53 x 11.73 x 25.71
Panel Size	Panel model		model name	PC4SUSMEN	PC4SUSMEN
	Panel Net Weight		kg	2.70	2.70
			lbs	5.95	5.95
	Shipping Weight		kg	4.20	4.20
			lbs	9.26	9.26
	Net Dimensions (WxHxD)		mm	670 x 45 x 670	670 x 45 x 670
			inch	26.38 x 1.77 x 26.38	26.38 x 1.77 x 26.38
	Shipping Dimensions (WxHxD)		mm	714 x 106 x 724	714 x 106 x 724
			inch	28.11 x 4.17 x 28.50	28.11 x 4.17 x 28.50
Additional Accessories	Drain pump	Drain pump	model name	Built-in	Built-in
		Max. lifting Height / Displacement	mm/liter/h	750 / 24	750 / 24
	Air Filter		-	Long life filter	Long life filter

1) Nominal Capacity are based on (Equivalent refrigerant piping : 25ft , Level differences : 0ft);
- Cooling : Indoor temperature : 80°F DB, 67°F WB / Outdoor temperature : 95°F DB, 75°F WB
- Heating : Indoor temperature : 70°F DB, 60°F WB / Outdoor temperature : 47°F DB, 43°F WB

2) Sound pressure was acquired in a dead room. Thus actual noise level may be different depending on the installation conditions.

3) Specifications are subject to change without prior notice for product improvement.

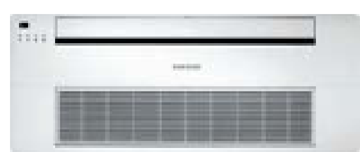
1 WAY CASSETTE

Model				AM007FN1DCH/AA	AM009FN1DCH/AA	AM012FN1DCH/AA
Power Supply			Ø, V, Hz	1,208-230,60	1,208-230,60	1,208-230,60
Mode			-	HP/HR	HP/HR	HP/HR
Performance	Capacity (Nominal)	Cooling 1)	Btu/h	7,500	9,500	12,000
			US RT	0.63	0.79	1.00
		Heating 1)	Btu/h	8,500	10,500	13,500
			US RT	0.71	0.88	1.12
Power	Power Input (Nominal)	Cooling 1)	W	40.00	45.00	50.00
		Heating 1)		40.00	45.00	50.00
	Current Input (Nominal)	Cooling 1)	A	0.23	0.25	0.28
		Heating 1)		0.23	0.25	0.28
Fan	Motor	Type	-	Crossflow Fan	Crossflow Fan	Crossflow Fan
		Output x n	W	20 x 1	20 x 1	20 x 1
	Air Flow Rate	H/M/L (UL)	CFM	247.21/211.90/176.58	247.21/211.90/176.58	282.53/247.21/211.90
	External Pressure	Min / Std / Max	Pa	-	-	-
Piping Connections	Liquid Pipe		Ø, mm	6.35	6.35	6.35
			Ø, inch	1/4	1/4	1/4
	Gas Pipe		Ø, mm	12.70	12.70	12.70
			Ø, inch	1/2	1/2	1/2
	Drain Pipe		Ø, mm	VP20 (OD 26,ID 20)	VP20 (OD 26,ID 20)	VP20 (OD 26,ID 20)
Refrigerant	Type		-	R410A	R410A	R410A
	Control Method		-	EEV INCLUDED	EEV INCLUDED	EEV INCLUDED
Sound	Sound Pressure 2)	High / Mid / Low	dBA	27.0/25.0/23.0	29.0/27.0/24.0	35.0/31.0/27.0
Dimensions	Net Weight		kg	10.50	10.50	10.50
			lbs	23.15	23.15	23.15
	Shipping Weight		kg	13.00	13.00	13.00
			lbs	28.66	28.66	28.66
	Net Dimensions (WxHxD)		mm	970 x 135 x 410	970 x 135 x 410	970 x 135 x 410
			inch	38.19 x 5.31 x 16.14	38.19 x 5.31 x 16.14	38.19 x 5.31 x 16.14
	Shipping Dimensions (WxHxD)		mm	1164 x 212 x 478	1164 x 212 x 478	1164 x 212 x 478
			inch	45.83 x 8.35 x 18.82	45.83 x 8.35 x 18.82	45.83 x 8.35 x 18.82
Panel Size	Panel model		model name	PC1NUSMAN PC1NUPMAN	PC1NUSMAN PC1NUPMAN	PC1NUSMAN PC1NUPMAN
	Panel Net Weight		kg	3.00	3.00	3.00
			lbs	6.61	6.61	6.61
	Shipping Weight		kg	5.00	5.00	5.00
			lbs	11.02	11.02	11.02
	Net Dimensions (WxHxD)		mm	1180 x 25 x 460	1180 x 25 x 460	1180 x 25 x 460
			inch	46.46 x 0.98 x 18.11	46.46 x 0.98 x 18.11	46.46 x 0.98 x 18.11
	Shipping Dimensions (WxHxD)		mm	1259 x 144 x 539	1259 x 144 x 539	1259 x 144 x 539
			inch	49.57 x 5.67 x 21.22	49.57 x 5.67 x 21.22	49.57 x 5.67 x 21.22
Additional Accessories	Drain pump	Drain pump	model name	Built-in	Built-in	Built-in
		Max. lifting Height / Displacement	mm/liter/h	750 / 24	750 / 24	750 / 24
	Air Filter		-	Long life filter	Long life filter	Long life filter

1) Nominal Capacity are based on (Equivalent refrigerant piping : 25ft , Level differences : 0ft);
- Cooling : Indoor temperature : 80°F DB, 67°F WB / Outdoor temperature : 95°F DB, 75°F WB
- Heating : Indoor temperature : 70°F DB, 60°F WB / Outdoor temperature : 47°F DB, 43°F WB

2) Sound pressure was acquired in a dead room. Thus actual noise level may be different depending on the installation conditions.

3) Specifications are subject to change without prior notice for product improvement.



HSP DUCT

Model				AM036FNHDCH/AA	AM048FNHDCH/AA	AM076FNHDCH/AA	AM096FNHDCH/AA
Power Supply			Ø, V, Hz	1,208-230,60	1,208-230,60	1,208-230,60	1,208-230,60
Mode			-	HP/HR	HP/HR	HP/HR	HP/HR
Performance	Capacity (Nominal)	Cooling 1)	Btu/h	36,000	48,000	76,800	96,000
			US RT	3.00	4.00	6.40	8.00
		Heating 1)	Btu/h	40,000	54,000	85,200	108,000
			US RT	3.33	4.50	7.10	9.00
Power	Power Input (Nominal)	Cooling 1)	W	210.00	330.00	530.00	790.00
		Heating 1)		210.00	330.00	530.00	790.00
	Current Input (Nominal)	Cooling 1)	A	1.47	2.38	3.80	5.90
		Heating 1)		1.47	2.38	3.80	5.90
Fan	Motor	Type	-	Sirocco Fan	Sirocco Fan	Sirocco Fan	Sirocco Fan
		Output x n	W	183 x 2	183 x 2	400 x 1	400 x 1
	Air Flow Rate	H/M/L (UL)	CFM	988.85/882.90/776.95	1,377.32/1,183.09/988.85	2,048.33/1,836.43/1,659.85	2,542.75/2,295.54/2,048.33
	External Pressure	Min / Std / Max	Pa	49.03/98.07/196.13	49.03/98.07/196.13	49.03/147.10/245.17	49.03/147.10/274.59
			in. Wg	0.20/0.39/0.79	0.20/0.39/0.79	0.20/0.59/0.98	0.20/0.59/1.10
Piping Connections	Liquid Pipe		Ø, mm	9.52	9.52	9.52	9.52
			Ø, inch	3/8	3/8	3/8	3/8
	Gas Pipe		Ø, mm	15.88	15.88	19.05	22.22
			Ø, inch	5/8	5/8	3/4	7/8
	Drain Pipe		Ø, mm	VP25 (OD 32,ID 25)	VP25 (OD 32,ID 25)	VP25 (OD 32,ID 25)	VP25 (OD 32,ID 25)
Refrigerant	Type		-	R410A	R410A	R410A	R410A
	Control Method		-	EEV INCLUDED	EEV INCLUDED	EEV INCLUDED	EEV INCLUDED
Sound	Sound Pressure 2)	High / Mid / Low	dBA	40.0/39.0/37.0	44.0/42.0/40.0	45.0/43.0/41.0	48.0/46.0/43.0
Dimensions	Net Weight		kg	62.00	62.00	89.00	89.00
			lbs	136.69	136.69	196.21	196.21
	Shipping Weight		kg	70.00	70.00	99.00	99.00
			lbs	154.32	154.32	218.26	218.26
	Net Dimensions (WxHxD)		mm	1200 x 360 x 650	1200 x 360 x 650	1240 x 470 x 1040	1240 x 470 x 1040
			inch	47.24 x 14.17 x 25.59	47.24 x 14.17 x 25.59	48.82 x 18.50 x 40.94	48.82 x 18.50 x 40.94
	Shipping Dimensions (WxHxD)		mm	1480 x 420 x 790	1480 x 420 x 790	1507 x 558 x 1155	1507 x 558 x 1155
			inch	58.27 x 16.54 x 31.10	58.27 x 16.54 x 31.10	59.33 x 21.97 x 45.47	59.33 x 21.97 x 45.47
Panel Size	Panel model		model name	-	-	-	-
	Panel Net Weight		kg	-	-	-	-
			lbs	-	-	-	-
	Shipping Weight		kg	-	-	-	-
			lbs	-	-	-	-
	Net Dimensions (WxHxD)		mm	-	-	-	-
			inch	-	-	-	-
	Shipping Dimensions (WxHxD)		mm	-	-	-	-
			inch	-	-	-	-
Additional Accessories	Drain pump	Drain pump	model name	MDP-M075SGU2D	MDP-M075SGU2D	MDP-N047SNC1D	MDP-N047SNC1D
		Max. lifting Height / Displacement	mm/liter/h	750 / 24	750 / 24	750 / 24	750 / 24
	Air Filter		-	Long life filter	Long life filter	Long life filter	Long life filter

1) Nominal Capacity is based on (Equivalent refrigerant piping : 25ft , Level differences : 0ft);
- Cooling : Indoor temperature : 80°F DB, 67°F WB / Outdoor temperature : 95°F DB, 75°F WB
- Heating : Indoor temperature : 70°F DB, 60°F WB / Outdoor temperature : 47°F DB, 43°F WB

2) Sound pressure was acquired in a dead room. Thus actual noise level may be different depending on the installation conditions.

3) Specifications are subject to change without prior notice for product improvement.

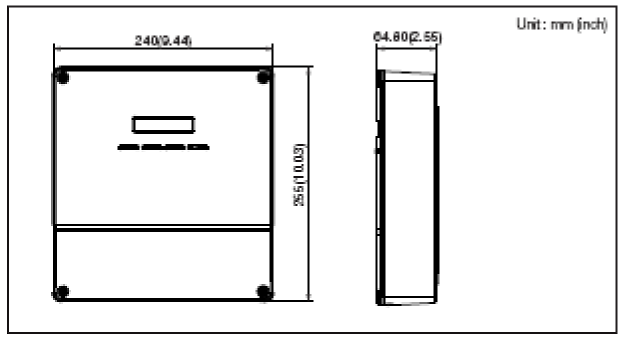
Control Systems

VI Building management system

2. DMS B-net (BACnet GW)

❑ *MIM-B17N*

1) Features



• For BACnet protocol system Support DMS2 control function at the same time.

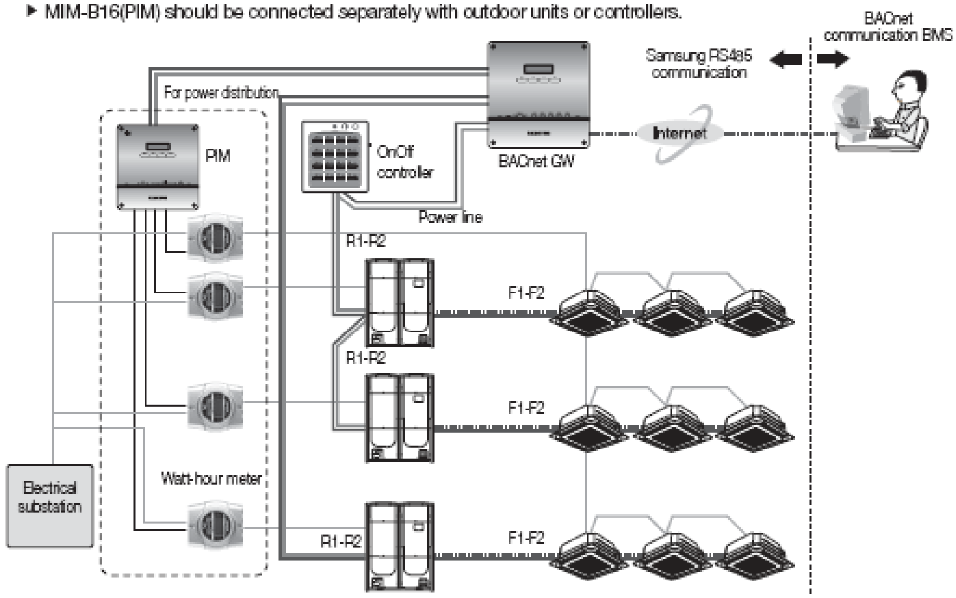
2) Product specification

Power supply	Source	DC Adaptor
	Input	100~240VAC (±10%), 50/60Hz
	Output	12V 3A
Operating temperature range		-10°C ~ 50°C (14°F~122°F)
Operating humidity range		10%RH ~ 90%RH
Communication connection		Lower layer : RS485 x 5 Upper layer : Ethernet 100Base-T x 1(BACnet IP)
External connection port	Digital Output	10
	Digital Input	10
Maximum length of connection	RS485	1000m (3280ft)
	Digital Output	100m (328ft)
	Digital Input	100m (328ft)
	Ethernet	100m (328 0ft) : When there is no repeater
Max. connectable number of device	Control layer	(see table below)

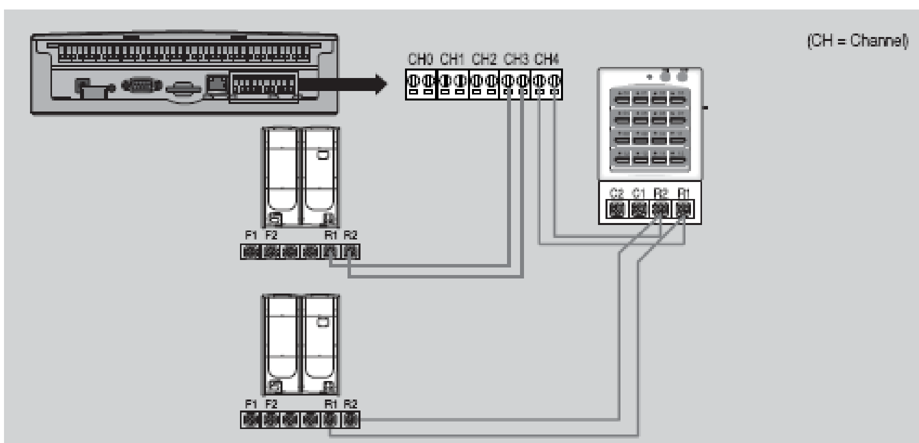
Device	Numbers per each channel	Total number for 5 channels
Indoor units (including ERV, MCU)	128	256
Outdoor unit (including compatible interface module MIM-N01)	16	80
On/Off controller	Total 15	Total 75
Touch centralized controller		
PIM interface module (MIM-B16)	8	8

4) Connection diagram

▶ MIM-B16(PIM) should be connected separately with outdoor units or controllers.



5) Wiring



(1) Connecting outdoor unit directly

- Maximum 16 outdoor units can be connected to each channel
- Total 80 outdoor units can be connected

(2) Connecting OnOff controller/Touch centralized controller

- Maximum 15 OnOff controller/Touch centralized controller can be connected to each channel

☑ *Note*

- BACnet GW can connect outdoor unit and OnOff controller/Touch centralized controller at the same time.
- Outdoor unit and OnOff controller/Touch centralized controller can be connected to 1 communication channel at the same time.

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BUILDING MANAGEMENT SYSTEM

7) Object list

(1) Indoor unit

Single indoor unit has following point list.

Instance Number	Object	Object Type	Object Name	Unit	Status value			
				Inactive	Active			
				Text-1	Text-2	Text-3	Text-4	Text-5
1	Indoor temperature	AI	AC_RoomTemp_xx_xxxxxx	°C(°F)				
2	Set temperature	AV	AC_Temp_Set_xx_xxxxxx	°C(°F)				
3	Setting lower temperature limit	AV	AC_Cool_LimitTemp_xx_xxxxxx	°C(°F)				
4	Setting upper temperature limit	AV	AC_Heat_LimitTemp_xx_xxxxxx	°C(°F)				
5	The power value of an indoor unit after the basic date	AI	AC_Baseline_kWh_xx_xxxxxx	kWh				
6	The number of hours usage of an indoor unit after the basic date	AI	AC_Baseline_Minute_xx_xxxxxx	Minute				
7	Power value within period	AI	AC_Period_kWh_xx_xxxxxx	kWh				
8	The number of hours usage of an indoor unit within period	AI	AC_Period_Minute_xx_xxxxxx	Minute				
9	Power On/Off	BV	AC_Power_xx_xxxxxx	Off	On			
10	Applying lower temperature limit setting	BV	AC_Cool_Limit_set_xx_xxxxxx	False	True			
11	Applying upper temperature limit setting	BV	AC_Heat_Limit_set_xx_xxxxxx	False	True			
12	Filter sign status	BI	AC_FilterSign_xx_xxxxxx	False	True			
13	Filter sign reset	BO	AC_FilterSign_Reset_xx_xxxxxx	False	True			
14	Operation mode status	MV	AC_Operation_Mode_xx_xxxxxx	Auto	Cool	Heat	Fan	Dry
15	Fan speed status	MV	AC_FanSpeed_xx_xxxxxx	Auto	Low	Mid	High	
16	Air flow direction status	MV	AC_FanFlow_xx_xxxxxx	None	Vertical	Horizon	All	
17	Operation mode limit status	MV	AC_Mode_Limit_xx_xxxxxx	No Limit	Cool Only	Heat Only		
18	Remote controller limit status	MV	AC_Remocon_Limit_xx_xxxxxx	Enable RC	Disable RC	Conditional RC		
19	Integrated error code of both indoor unit and outdoor unit	AI	AC_Error_Code_xx_xxxxxx	Refer to Samsung integrated error code list				
20(*)	SPI setting	BV	AC_SPI_xx_xxxxxx	False	True			
21(*)	HumanSensor setting	BV	AC_MDS_xx_xxxxxx	False	True			
22(*)	AC Indoor Notify	NC	AC_Notify_xx_xxxxxx	When the error occurred, send event to list of destination in the recipient_list. (Max : 8)				

※ Temperature setting range can be different depending on the model and the common range is as follows :

Auto : 18~30℃(64~86℉)
Cool : 18~30℃(64~86℉)
Heat : 16~30℃(60~86℉)
Fan : Temperature cannot be adjusted
Dry : 18~30℃(64~86℉)

(*) Mark is optionally supported.

BUILDING MANAGEMENT SYSTEM

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(3) ERV

Single ERV unit has following point list.

Instance Number	Object	Object Type	Object Name	Unit	Status value			
				Inactive	Active			
				Text-1	Text-2	Text-3	Text-4	Text-5
1	Power On/Off operation	BV	ERV_Power_xx_xxxxxx	Off	On			
2	Filter sign status	BI	ERV_FilterSign_xx_xxxxxx	False	True			
3	Filter sign reset	BO	ERV_FilterSign_Reset_xx_xxxxxx	False	True			
4	Operation mode status	MV	ERV_Operation_Mode_xx_xxxxxx	Auto	HeatEx	Bypass	Sleep	
5	Fan speed status	MV	ERV_FanSpeed_xx_xxxxxx	Low	High	Turbo		
6	Remote controller limit status	MV	ERV_Remocon_Limit_xx_xxxxxx	Enable RC	Disable RC	Conditional RC		
7	Integrated error code of ERV unit	AI	ERV_Error_Code_xx_xxxxxx	Refer to list of error code				
8	ERV Notify	NC	ERV_Notify_xx_xxxxxx	When the error occurred, send event to list of destination in the recipient_list. (Max : 8)				

2. DMS B-net (BACnet GW)

❑ *MIM-B17N*

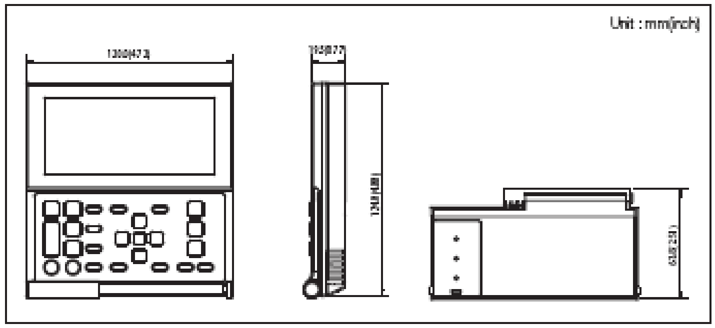
9) Standard object type

Object Type	Support	Description
Analog Input	■	[Indoor temperature], [The power value after the basic date], [The number of hours usage of an indoor unit after the basic date], [Power value within period], [The number of hours usage of an indoor unit within period], [Indoor unit error code], [AHU error code], [ERV error code], [AHU error code], [ERV error code], [Centralized controller error code], [Interface module error code], [SIM interface module error code], [DMS status], [DMS error], [Discharge current temperature], [Outside temperature]
Analog Output	☐	
Analog Value	■	[Set temperature], [Setting lower temperature limit], [Setting upper temperature limit], [Discharge cooling set temperature], [Discharge heating set temperature], [Cool capacity compensation], [Heat capacity compensation]
Averaging	☐	
Binary Input	■	[DI], [Filter sign status], [Compressor status]
Binary Output	■	[DO], [Filter sign reset], [All Device off]
Binary Value	■	[Power Onoff control], [Setting the fucntion of limiting lower temperature] [Setting the function of limiting upper temperatue], [SPI setting], [HumanSensor setting], [Humidification setting], [Outdoor air intake setting], [Ourdoor cooling setting]
Calendar	☐	
Command	☐	
Device	■	[DMS], [A/C Indoor Unit], [ERV], [AHU], [SIM], [Centralized controller], [Interface module], [DDC]
Event Enrollment	☐	
File	☐	
Group	☐	
Life Safety Point	☐	
Life Safety Zone	☐	
Loop	☐	
Multi-state Input	■	[Current humidity status]
Multi-state Output	☐	
Multi-state Value	■	[Operation mode control], [Fan speed control], [Air flow direction control], [Setting Cool only/ Heat only/ No Limit], [Control Enable RC/ Disable RC /Level1], [Set humidity status]
Notification Class	■	[AC Indoor Notify], [ERV Notify], [AHU Notify], [Centralized Controller Notify], [Interface Module Notify], [SIM Notify], [Gateway Notify]

3. Wired remote controller

1 *MWR-WE10N*

1) Features



(1) Air conditioner / ERV control (ERV cannot be connected to MWR-WE10N until end of 2013)
- AC operation ON/OFF control
- AC operation mode, setting temperature, fan speed, air flow direction setting
- AC individual blade control and occupancy detection
  (Function is available when indoor units support any of above functions)
- ERV operation ON/OFF control
- ERV operation mode, fan speed setting
- AC/ERV error monitoring
- Filter cleaning alert and reset alert time
- Individual/group control, indoor unit/ERV interlocking control
- Energy saving control
- Control maximum 16 "Indoor unit + ERV" in group with single wired remote controller

(2) Energy saving operation
- Upper/Lower temperature limit setting
- Automatic operation stop: Automatically stops the operation, when it is not used for certain period of time set by user

(3) Weekly operation schedule setting
- Weekly operating schedule (A/C only, ERV only, A/C+ERV)
- Able to set desired AC operation mode, setting temperature and fan speed to operate based on weekly reservation
- Able to apply schedule exception day for fluid management

(4) User convenience function
- Child lock
- Different button permission levels
  (Opertion mode, temperature setting, ON/OFF, fan speed)
- Real-time clock: Displays current time, day (Summer time support)
- Built-in room temperature sensor
- Service mode support
  - Indoor unit cycle data monitoring
  - Indoor unit option code setting and monitoring
  - Indoor unit address and option setting and monitoring

2) Product specification

Power Supply	DC12V
Power Consumption	2W
Operating Temperature range	0°C~40°C (32°F~104°F)
Operating Humidity range	30%RH~90%RH
Communication	2-wire PLC

Compatible product

Indoor unit	AM****N******Model

Zone Sizing Summary for VRF System 1

Project Name: THAR Geo Thesis
Prepared by: PSUAE

04/08/2014
05:01AM

Air System Information

Air System Name .... **VRF System 1**
Equipment Class .... **TERM**
Air System Type .... **VRF**

Number of zones **11**
Floor Area .... **4478.0** ft²
Location .... **Pittsburgh IAP, Pennsylvania**

Sizing Calculation Information

Zone and Space Sizing Method:
Zone CFM .... **Sum of space airflow rates**
Space CFM .... **Individual peak space loads**

Calculation Months .... **Jan to Dec**
Sizing Data .... **Calculated**

Zone Sizing Data

Zone Name	Maximum Cooling Sensible (MBH)	Design Air Flow (CFM)	Minimum Air Flow (CFM)	Time of Peak Load	Maximum Heating Load (MBH)	Zone Floor Area (ft²)	Zone CFM/ft²
Zone 1	2.9	147	147	Jul 1300	0.6	185.0	0.79
Zone 2	2.5	126	126	Jul 1300	0.5	175.0	0.72
Zone 3	41.5	2112	2112	Sep 1100	15.6	1596.0	1.32
Zone 4	2.9	147	147	Jul 1300	0.6	185.0	0.79
Zone 5	2.9	147	147	Jul 1300	0.6	185.0	0.79
Zone 6	2.9	147	147	Jul 1300	0.6	185.0	0.79
Zone 7	3.3	168	168	Jul 1300	0.7	215.0	0.78
Zone 8	4.5	231	231	Aug 1100	1.9	150.0	1.54
Zone 9	7.9	404	404	Jul 1300	1.3	409.0	0.99
Zone 10	3.8	195	195	Sep 1100	1.4	100.0	1.95
Zone 11	27.0	1375	1375	Aug 1100	12.7	1093.0	1.26

Zone Sizing Summary for VRF System 2

Project Name: THAR Geo Thesis
Prepared by: PSUAE

04/08/2014
05:03AM

Air System Information

Air System Name .... **VRF System 2**
Equipment Class .... **TERM**
Air System Type .... **VRF**

Number of zones **15**
Floor Area .... **4152.0** ft²
Location .... **Pittsburgh IAP, Pennsylvania**

Sizing Calculation Information

Zone and Space Sizing Method:
Zone CFM .... **Sum of space airflow rates**
Space CFM .... **Individual peak space loads**

Calculation Months .... **Jan to Dec**
Sizing Data .... **Calculated**

Zone Sizing Data

Zone Name	Maximum Cooling Sensible (MBH)	Design Air Flow (CFM)	Minimum Air Flow (CFM)	Time of Peak Load	Maximum Heating Load (MBH)	Zone Floor Area (ft²)	Zone CFM/ft²
Zone 1	2.6	133	133	Jul 1300	0.8	252.0	0.53
Zone 2	3.6	200	184	Jul 1300	0.8	256.0	0.78
Zone 3	3.6	200	184	Jul 1300	0.8	256.0	0.78
Zone 4	2.2	114	114	Jul 1300	0.4	140.0	0.82
Zone 5	34.3	1748	1748	Aug 1100	12.4	1411.0	1.24
Zone 6	2.1	108	108	Jul 1300	0.4	130.0	0.83
Zone 7	2.1	108	108	Jul 1300	0.4	130.0	0.83
Zone 8	2.1	108	108	Jul 1300	0.4	130.0	0.83
Zone 9	2.9	147	147	Jul 1300	0.6	185.0	0.79
Zone 10	2.1	108	108	Jul 1300	0.4	130.0	0.83
Zone 11	2.1	108	108	Jul 1300	0.4	130.0	0.83
Zone 12	2.1	108	108	Jul 1300	0.4	130.0	0.83
Zone 13	2.1	108	108	Jul 1300	0.4	130.0	0.83
Zone 14	5.4	275	275	Aug 1500	2.3	275.0	1.00
Zone 15	11.6	589	589	Aug 1500	6.4	467.0	1.26

Zone Sizing Summary for VRF System 3

Project Name: THAR Geo Thesis 04/08/2014
Prepared by: PSUAE 05:04AM

Air System Information

Air System Name .... VRF System 3
Equipment Class .... TERM
Air System Type .... VRF
Number of zones 11
Floor Area .... 4058.0 ft²
Location .... Pittsburgh IAP, Pennsylvania

Sizing Calculation Information

Zone and Space Sizing Method:
Zone CFM .... Sum of space airflow rates
Space CFM .... Individual peak space loads
Calculation Months .... Jan to Dec
Sizing Data .... Calculated

Zone Sizing Data

Zone Name	Maximum Cooling Sensible (MBH)	Design Air Flow (CFM)	Minimum Air Flow (CFM)	Time of Peak Load	Maximum Heating Load (MBH)	Zone Floor Area (ft²)	Zone CFM/ft²
Zone 1	10.2	519	519	Jul 1300	1.9	626.0	0.83
Zone 2	3.3	169	169	Jul 1300	0.7	235.0	0.72
Zone 3	3.3	169	169	Jul 1300	0.7	235.0	0.72
Zone 4	3.3	169	169	Jul 1300	0.7	235.0	0.72
Zone 5	3.3	169	169	Jul 1300	0.7	235.0	0.72
Zone 6	8.4	430	430	Jul 1300	2.5	814.0	0.53
Zone 7	3.4	174	174	Jul 1300	0.5	259.0	0.67
Zone 8	3.4	173	173	Jul 1300	0.7	240.0	0.72
Zone 9	5.2	266	266	Jul 1300	1.9	241.0	1.10
Zone 10	3.0	153	153	Jul 1300	0.6	194.0	0.79
Zone 11	12.7	645	645	Jul 1300	2.3	744.0	0.87

Variable Refrigerant Flow System Carrier HAP Building Simulation

Table 1. Annual Costs

Component	VRF Building Simulation ($)
Air System Fans	3,922
Cooling	4,860
Heating	218
Pumps	0
Heat Rejection Fans	0
HVAC Sub-Total	**9,000**
Lights	23,758
Electric Equipment	12,400
Misc. Electric	4,007
Misc. Fuel Use	0
Non-HVAC Sub-Total	**40,164**
Grand Total	**49,165**

Table 2. Annual Cost per Unit Floor Area

Component	VRF Building Simulation ($/ft²)
Air System Fans	0.309
Cooling	0.383
Heating	0.017
Pumps	0.000
Heat Rejection Fans	0.000
HVAC Sub-Total	**0.709**
Lights	1.872
Electric Equipment	0.977
Misc. Electric	0.316
Misc. Fuel Use	0.000
Non-HVAC Sub-Total	**3.166**
Grand Total	**3.875**
Gross Floor Area (ft²)	12688.0
Conditioned Floor Area (ft²)	12688.0

Note: Values in this table are calculated using the Gross Floor Area.

Table 3. Component Cost as a Percentage of Total Cost

Component	VRF Building Simulation (%)
Air System Fans	8.0
Cooling	9.9
Heating	0.4
Pumps	0.0
Heat Rejection Fans	0.0
HVAC Sub-Total	**18.3**
Lights	48.3
Electric Equipment	25.2
Misc. Electric	8.1
Misc. Fuel Use	0.0
Non-HVAC Sub-Total	**81.7**
Grand Total	**100.0**

Original HVAC Carrier HAP Reports

Table 1. Annual Costs

Component	CAV RTU Building Simulation ($)
Air System Fans	1,872
Cooling	8,534
Heating	6,009
Pumps	0
Heat Rejection Fans	0
HVAC Sub-Total	**16,416**
Lights	29,095
Electric Equipment	15,509
Misc. Electric	0
Misc. Fuel Use	0
Non-HVAC Sub-Total	**44,604**
Grand Total	**61,020**

Table 2. Annual Cost per Unit Floor Area

Component	CAV RTU Building Simulation ($/ft²)
Air System Fans	0.116
Cooling	0.530
Heating	0.373
Pumps	0.000
Heat Rejection Fans	0.000
HVAC Sub-Total	**1.020**
Lights	1.807
Electric Equipment	0.963
Misc. Electric	0.000
Misc. Fuel Use	0.000
Non-HVAC Sub-Total	**2.770**
Grand Total	**3.790**
Gross Floor Area (ft²)	16101.0
Conditioned Floor Area (ft²)	16101.0

Table 3. Component Cost as a Percentage of Total Cost

Component	CAV RTU Building Simulation (%)
Air System Fans	3.1
Cooling	14.0
Heating	9.8
Pumps	0.0
Heat Rejection Fans	0.0
HVAC Sub-Total	**26.9**
Lights	47.7
Electric Equipment	25.4
Misc. Electric	0.0
Misc. Fuel Use	0.0
Non-HVAC Sub-Total	**73.1**
Grand Total	**100.0**

Entire Building RS Means Estimate

RSMeans

THAR Processing
123 Alpha Drive
Pittsburgh, PA, 15215
Date: 07-Apr-14

Cost Estimate Report
RSMeans Online

Mechanical First Cost Old Sytem
Year 2012 Quarter 4
Unit Detail Report

Prepared By:
Alexander Radkoff
Pennsylvania State University

LineNumber	Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 23 Heating, Ventilating, and Air Conditioning (HVAC)					
232123134100	Pump, circulating, cast iron, close coupled, end suction, bronze impeller, flanged joints, 3 H.P., to 90 GPM, 2" size	1.00	Ea.	$3,311.69	$3,311.69
232323204450	Refrigeration specialties, refrigerant, R-410A, 25 lb. disposable cylinder	100.00	Lb.	$15.98	$1,598.00
233313135990	Duct accessories, multi-blade dampers, opposed blade, 8" x 6"	16.00	Ea.	$51.61	$825.76
233313135994	Duct accessories, multi-blade dampers, opposed blade, 8" x 8"	22.00	Ea.	$54.68	$1,202.96
233313135996	Duct accessories, multi-blade dampers, opposed blade, 10" x 10"	9.00	Ea.	$60.92	$548.28
233313136000	Duct accessories, multi-blade dampers, opposed blade, 12" x 12"	10.00	Ea.	$64.06	$640.60
233323139432	Duct accessories, turning vane components, double thick, factory fabricated vane, 14" high set	360.00	L.F.	$6.32	$2,275.20
233346101980	Ductwork, flexible coated fiberglass fabric on corrosion resistant metal helix, insulated, P.E. jacket, 1" thick, 8" diameter, pressure to 12"(WG) UL-181	154.00	L.F.	$9.94	$1,530.76
233346102020	Ductwork, flexible coated fiberglass fabric on corrosion resistant metal helix, insulated, P.E. jacket, 1" thick, 10" diameter, pressure to 12"(WG) UL-181	64.00	L.F.	$12.58	$805.12
233346102040	Ductwork, flexible coated fiberglass fabric on corrosion resistant metal helix, insulated, P.E. jacket, 1" thick, 12" diameter, pressure to 12"(WG) UL-181	70.00	L.F.	$16.50	$1,155.00
233353103344	Insulation, ductwork, board type, fiberglass liner, FSK, 1-1/2 lb. density, 1" thick	5,200.00	S.F.	$8.13	$42,276.00
233414102520	Fans, ceiling fan, right angle, extra quiet, 0.10" S.P., 95 CFM	1.00	Ea.	$378.55	$378.55
233414102540	Fans, ceiling fan, right angle, extra quiet, 0.10" S.P., 210 CFM	1.00	Ea.	$439.17	$439.17
233414102560	Fans, ceiling fan, right angle, extra quiet, 0.10" S.P., 385 CFM	6.00	Ea.	$537.47	$3,224.82
233414102580	Fans, ceiling fan, right angle, extra quiet, 0.10" S.P., 885 CFM	2.00	Ea.	$993.15	$1,986.30
233713101000	Diffuser, aluminum, ceiling, rectangular, 1 to 4 way blow, 6" x 6", includes opposed blade damper	16.00	Ea.	$98.35	$1,573.60

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LineNumber				Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
233713101010				Diffuser, aluminum, ceiling, rectangular, 1 to 4 way blow, 8" x 8", includes opposed blade damper	22.00	Ea.	$109.79	$2,415.38
233713101016				Diffuser, aluminum, ceiling, rectangular, 1 to 4 way blow, 10" x 10", includes opposed blade damper	9.00	Ea.	$134.92	$1,214.28
233713101060				Diffuser, aluminum, ceiling, rectangular, 1 to 4 way blow, 12" x 12", includes opposed blade damper	10.00	Ea.	$150.85	$1,508.50
233713301100				Grille, steel, air return, 12" x 12"	24.00	Ea.	$59.91	$1,437.84
233713301120				Grille, steel, air return, 24" x 12"	15.00	Ea.	$75.96	$1,139.40
233713601040				Register, air supply, ceiling/wall, anodized aluminum, adjustable curved face bars, one or two way deflection, 8" x 8", includes opposed blade damper	4.00	Ea.	$76.74	$306.96
233713601060				Register, air supply, ceiling/wall, anodized aluminum, adjustable curved face bars, one or two way deflection, 10" x 6", includes opposed blade damper	10.00	Ea.	$78.68	$786.80
233713601080				Register, air supply, ceiling/wall, anodized aluminum, adjustable curved face bars, one or two way deflection, 10" x 10", includes opposed blade damper	26.00	Ea.	$95.91	$2,493.66
235513161060				Duct furnace, gas fired, stainless steel heat exchanger, electric ignition, outdoor installation, 120 MBH output, includes burner, controls and power venter	2.00	Ea.	$4,229.40	$8,458.80
235513161080				Duct furnace, gas fired, stainless steel heat exchanger, electric ignition, outdoor installation, 157 MBH output, includes burner, controls and power venter	1.00	Ea.	$4,878.87	$4,878.87
235513161120				Duct furnace, gas fired, stainless steel heat exchanger, electric ignition, outdoor installation, 225 MBH output, includes burner, controls and power venter	3.00	Ea.	$6,280.31	$18,840.93
235719133100				Heat Exchanger, plate type, 400 GPM	1.00	Ea.	$39,505.70	$39,505.70
236333103440				Condenser, ratings are for evaporative, copper coil, pump, fan motor, 30Deg F T.D., 10 ton, R-22	1.00	Ea.	$12,343.95	$12,343.95
237313101000				Air handling unit, built-up, horizontal/vertical, constant volume, single zone, 40,000 CFM, with cooling/heating coil section, filters, mixing box	10.00	Ea.	$67,643.73	$676,437.30
237313101000		%		Metal ductwork, fabricated rectangular, for 30% fittings, add	1.00	Lb.	$703.37	$7,033.65

LineNumber				Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
237413103100				Air handling unit, packaged weatherproof, with cooling/heating coil section, filters, mixing box, constant volume, single zone, 2000 CFM, cooling coils may be chilled water or DX, heating coils may be hot water, steam or electric	6.00	Ea.	$13,532.33	$81,193.98
237413103100				Metal ductwork, fabricated rectangular, for 30% fittings, add	1.00	Lb.	$210.17	$1,261.02
238316100120				Radiant floor heating, tubing, PEX (cross-linked polyethylene), oxygen barrier type for systems with ferrous metals, 1/2"	4,250.00	L.F.	$2.68	$11,390.00
238316101150				Radiant floor heating, manifold, brass, valved, 4 circuit, 1"	1.00	Ea.	$445.51	$445.51
238316101154				Radiant floor heating, manifold, brass, valved, 5 circuit, 1"	1.00	Ea.	$517.64	$517.64
238316101158				Radiant floor heating, manifold, brass, valved, 6 circuit, 1"	1.00	Ea.	$558.36	$558.36
238316103110				Radiant floor heating, thermostatic zone valve actuator with end switch	1.00	Ea.	$72.45	$72.45
238333103330				Electric heating, wall heaters with fan, commercial, 4000 watt	2.00	Ea.	$609.25	$1,218.50
Division 23 Heating, Ventilating, and Air Conditioning (HVAC) Subtotal								$939,231.29

Subtotal		$939,231.29
General Contractor's Markup on Subs	0.00%	$0.00
Subtotal		$939,231.29
General Conditions	0.00%	$0.00
Subtotal		$939,231.29
General Contractor's Overhead and Profit	0.00%	$0.00
Grand Total		$939,231.29

VRF Building RS Means Estimate

RSMeans

THAR Processing
123 Alpha Drive
Pittsburgh, PA, 15215
Date: 08-Apr-14

Cost Estimate Report
RSMeans Online

HVAC New System Cost Estimate
Year 2014 Quarter 1
Unit Detail Report

Prepared By:
Alexander Radkoff
Pennsylvania State University

LineNumber	Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 22 Plumbing					
221113235880	Pipe, copper, refrigeration tubing, dryseal, 60' coils, 3/8" OD, excludes couplings and hangers	40.00	Coil	$76.21	$3,048.40
221113235890	Pipe, copper, refrigeration tubing, dryseal, 60' coils, 1/2" OD, excludes couplings and hangers	40.00	Coil	$105.37	$4,214.80
221113235900	Pipe, copper, refrigeration tubing, dryseal, 60' coils, 5/8" OD, excludes couplings and hangers	40.00	Coil	$141.17	$5,646.80
221113235910	Pipe, copper, refrigeration tubing, dryseal, 60' coils, 3/4" OD, excludes couplings and hangers	40.00	Coil	$168.80	$6,752.00
Division 22 Plumbing Subtotal					**$19,662.00**
Division 23 Heating, Ventilating, and Air Conditioning (HVAC)					
232120780100	Strainer, Y type, iron body, screwed, 250 lb., 1/2" pipe size	12.00	Ea.	$40.79	$489.48
232313108618	Refrigeration specialties, valve, solenoid, flange/solder, 3/4"	12.00	Ea.	$351.43	$4,217.16
232323101200	Anti-freeze, ethylene glycol, inhibited, concentrated, in large quantities, 55 gallon drums	1,000.00	Gal.	$10.84	$10,840.00
232323204450	Refrigeration specialties, refrigerant, R-410A, 25 lb. disposable cylinder	150.00	Lb.	$25.06	$3,759.00
237213104020	Heat recovery package, air to air, enthalpy recovery wheel, 2000 max CFM	3.00	Ea.	$9,939.35	$29,818.05
238129101160	Heat pump, gas driven, split, outdoor unit, multi-zone, (VFR) type, 15 ton cooling, for up to 33 zones, excludes interconnecting refrigerant tubing and multi-zone controls	3.00	Ea.	$49,375.85	$148,127.55
238129101170	Heat pump, gas driven, split, outdoor unit, multi-zone, (VFR) type, 15 ton cooling, isolation rails, excludes interconnecting refrigerant tubing and multi-zone controls	3.00	Pair	$1,348.94	$4,046.82
238219404130	Fan coil AHU, variable refrigerant volume (VFR) type, indoor type, duct free, ceiling mounted cassette, .75 ton cooling, outside air connection possible, excludes interconnecting refrigerant tubing and multi-zone controls	24.00	Ea.	$3,156.47	$75,755.28

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LineNumber				Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
238219404140				Fan coil AHU, variable refrigerant volume (VFR) type, indoor type, duct free, ceiling mounted cassette, 1 ton cooling, outside air connection possible, excludes interconnecting refrigerant tubing and multi-zone controls	12.00	Ea.	$3,387.20	$40,646.40
238219404150				Fan coil AHU, variable refrigerant volume (VFR) type, indoor type, duct free, ceiling mounted cassette, 1.5 ton cooling, outside air connection possible, excludes interconnecting refrigerant tubing and multi-zone controls	1.00	Ea.	$3,490.62	$3,490.62
238219404160				Fan coil AHU, variable refrigerant volume (VFR) type, indoor type, duct free, ceiling mounted cassette, 2 ton cooling, outside air connection possible, excludes interconnecting refrigerant tubing and multi-zone controls	1.00	Ea.	$3,723.67	$3,723.67
238219404170				Fan coil AHU, variable refrigerant volume (VFR) type, indoor type, duct free, ceiling mounted cassette, 2.5 ton cooling, outside air connection possible, excludes interconnecting refrigerant tubing and multi-zone controls	1.00	Ea.	$3,816.84	$3,816.84
Division 23 Heating, Ventilating, and Air Conditioning (HVAC) Subtotal								$328,730.87

Subtotal		$348,392.87
General Contractor's Markup on Subs	0.00%	$0.00
Subtotal		$348,392.87
General Conditions	0.00%	$0.00
Subtotal		$348,392.87
General Contractor's Overhead and Profit	0.00%	$0.00
Grand Total		$348,392.87

CAV RTU & Radiant Floor System RS Means Estimate

RSMeans

THAR Processing
123 Alpha Drive
Pittsburgh, PA, 15215
Date: 08-Apr-14

Cost Estimate Report
RSMeansOnline

Mechanical First Cost Old System - Depth
Year 2012 Quarter 4
Unit Detail Report

Prepared By:
Alexander Radkoff
Pennsylvania State University

LineNumber	Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Division 23 Heating, Ventilating, and Air Conditioning (HVAC)					
232123134100	Pump, circulating, cast iron, close coupled, end suction, bronze impeller, flanged joints, 3 H.P., to 90 GPM, 2" size	1.00	Ea.	$3,311.69	$3,311.69
232323204450	Refrigeration specialties, refrigerant, R-410A, 25 lb. disposable cylinder	250.00	Lb.	$15.98	$3,995.00
233313135990	Duct accessories, multi-blade dampers, opposed blade, 8" x 6"	16.00	Ea.	$51.61	$825.76
233313135994	Duct accessories, multi-blade dampers, opposed blade, 8" x 8"	22.00	Ea.	$54.68	$1,202.96
233313135996	Duct accessories, multi-blade dampers, opposed blade, 10" x 10"	9.00	Ea.	$60.92	$548.28
233313136000	Duct accessories, multi-blade dampers, opposed blade, 12" x 12"	10.00	Ea.	$64.06	$640.60
233323139432	Duct accessories, turning vane components, double thick, factory fabricated vane, 14" high set	360.00	L.F.	$6.32	$2,275.20
233346101980	Ductwork, flexible coated fiberglass fabric on corrosion resistant metal helix, insulated, P.E. jacket, 1" thick, 8" diameter, pressure to 12"(WG) UL-181	154.00	L.F.	$9.94	$1,530.76
233346102020	Ductwork, flexible coated fiberglass fabric on corrosion resistant metal helix, insulated, P.E. jacket, 1" thick, 10" diameter, pressure to 12"(WG) UL-181	64.00	L.F.	$12.58	$805.12
233346102040	Ductwork, flexible coated fiberglass fabric on corrosion resistant metal helix, insulated, P.E. jacket, 1" thick, 12" diameter, pressure to 12"(WG) UL-181	70.00	L.F.	$16.50	$1,155.00
233353103344	Insulation, ductwork, board type, fiberglass liner, FSK, 1-1/2 lb. density, 1" thick	5,200.00	S.F.	$8.13	$42,276.00
233713101000	Diffuser, aluminum, ceiling, rectangular, 1 to 4 way blow, 6" x 6", includes opposed blade damper	16.00	Ea.	$98.35	$1,573.60
233713101010	Diffuser, aluminum, ceiling, rectangular, 1 to 4 way blow, 8" x 8", includes opposed blade damper	22.00	Ea.	$109.79	$2,415.38
233713101016	Diffuser, aluminum, ceiling, rectangular, 1 to 4 way blow, 10" x 10", includes opposed blade damper	9.00	Ea.	$134.92	$1,214.28
233713101060	Diffuser, aluminum, ceiling, rectangular, 1 to 4 way blow, 12" x 12", includes opposed blade damper	10.00	Ea.	$150.85	$1,508.50
233713301100	Grille, steel, air return, 12" x 12"	24.00	Ea.	$59.91	$1,437.84

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LineNumber				Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
233713301120				Grille, steel, air return, 24" x 12"	15.00	Ea.	$75.96	$1,139.40
233713601040				Register, air supply, ceiling/wall, anodized aluminum, adjustable curved face bars, one or two way deflection, 8" x 8", includes opposed blade damper	4.00	Ea.	$76.74	$306.96
233713601060				Register, air supply, ceiling/wall, anodized aluminum, adjustable curved face bars, one or two way deflection, 10" x 6", includes opposed blade damper	10.00	Ea.	$78.68	$786.80
233713601080				Register, air supply, ceiling/wall, anodized aluminum, adjustable curved face bars, one or two way deflection, 10" x 10", includes opposed blade damper	26.00	Ea.	$95.91	$2,493.66
235719133100				Heat Exchanger, plate type, 400 GPM	1.00	Ea.	$39,505.70	$39,505.70
236333103440				Condenser, ratings are for evaporative, copper coil, pump, fan motor, 30Deg.F T.D., 10 ton, R-22	1.00	Ea.	$12,343.95	$12,343.95
237413103100				Air handling unit, packaged weatherproof, with cooling/heating coil section, filters, mixing box, constant volume, single zone, 2000 CFM, cooling coils may be chilled water or DX, heating coils may be hot water, steam or electric	6.00	Ea.	$13,532.33	$81,193.98
238316100120				Radiant floor heating, tubing, PEX (cross-linked polyethylene), oxygen barrier type for systems with ferrous metals, 1/2"	8,700.00	L.F.	$2.68	$23,316.00
238316101150				Radiant floor heating, manifold, brass, valved, 4 circuit, 1"	1.00	Ea.	$445.51	$445.51
238316101154				Radiant floor heating, manifold, brass, valved, 5 circuit, 1"	1.00	Ea.	$517.64	$517.64
238316101158				Radiant floor heating, manifold, brass, valved, 6 circuit, 1"	1.00	Ea.	$558.36	$558.36
238316103110				Radiant floor heating, thermostatic zone valve actuator with end switch	1.00	Ea.	$72.45	$72.45
Division 23 Heating, Ventilating, and Air Conditioning (HVAC) Subtotal								$229,396.38

LineNumber				Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Subtotal								$229,396.38
General Contractor's Markup on Subs						0.00%		$0.00
Subtotal								$229,396.38
General Conditions						0.00%		$0.00
Subtotal								$229,396.38
General Contractor's Overhead and Profit						0.00%		$0.00
Grand Total								$229,396.38

Appendix C – Acoustical Depth Documents

Carrier 50TCD06 RTU-4 Sound Performance Table

Table 4 – SOUND PERFORMANCE TABLE

UNIT	COOLING STAGES	OUTDOOR SOUND (dB)								
		A–WEIGHTED	63	125	250	500	1000	2000	4000	8000
A04	1	80	90.6	80.9	80.2	76	74.6	71.3	68.5	63.9
A05	1	81	90.9	84.6	79.5	77.9	76.5	71.1	66.9	62.5
A06	1	78	84.0	82.2	76.3	74.8	72.5	68.8	65.6	61.8
A07	1	78	88.8	81.8	76.9	74.4	73.3	69.8	66.3	62.7
A08	1	82	90.1	82.6	81.0	79.4	77.0	73.0	70.4	66.7
D08	2	82	85.8	84.3	80.5	78.7	76.4	72.7	68.3	65.1
A09	1	83	91.2	86.4	81.9	81.0	78.3	73.9	71.4	67.3
D09	2	82	88.6	85.0	81.6	79.5	77.4	74.1	71.0	66.3
A12	1	82	88.6	85.0	81.6	79.5	77.4	74.1	71.0	66.3
D12	2	82	89.0	83.1	80.5	78.5	75.5	71.6	69.6	69.3
D14	2	87	87.0	85.2	84.6	84.9	82.2	78.4	75.3	72.9
D16	2	87	87.0	85.2	84.6	84.9	82.2	78.4	75.3	72.9