ASHRAE Design Competition

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Christopher Erickson
Design Manager
Email: Erickson@knights.ucf.edu

Ian Faulkner
Operations Manager
Email: Ianff@knights.ucf.edu

Danny Marshall, LEED Green Associate
Project Manager
Email: DannyMarshall@knights.ucf.edu

Richard Suarez
Process Manager
Email: Richard.Suarez1@knights.ucf.edu

Kristian Szymanski
Communications Manager
Email: KristianSzymanski@knights.ucf.edu

Ju Young Yu
Research Manager
Email: JuYoungYu@knights.ucf.edu

***Local AHSRAE Chapter and Mentors*:**

ASHRAE Central Florida Chapter
Nathaniel Boyd: Nathaniel.boyd@cityoforlando.net
Kyle Inge: Kinge@peifla.com
Dr. Vazquez: Vazquez@ucf.edu

Section 1: Abstract

This design competition submission is from the University of Central Florida in Orlando, Florida. The objective is to design a high efficiency HVAC system with long life cycle, and excellent indoor air quality while maintaining cost effectiveness. The two story research and development office is located in New York, New York By employing Variable Refrigerant Flow (VRF) systems with simultaneous heating and cooling and dedicated outdoor air systems (DOAS) with energy recovery, the objectives can be completed. Other equipment used include air valves for the lab areas, High Efficiency Particulate Absorption (HEPA) filters, and exhaust fans to eliminate contamination.

The final loads for the building were calculated using Trane Trace. The total heating load for the building with the exception of the lab areas is 653,323 Btu/h and 1,250,896 Btu/h for the research and development and clean room areas, totaling 1,904,220 Btu/h. The cooling load for the building with the exception of the lab areas was calculated to be 52.2 tons, and 59.9 tons for the lab areas, totaling a cooling load of 112.1 tons on the building. To accommodate this load, 69 VRF units of various capacities ranging from ½ ton to 3.5 tons, three condensers, two DOAS units, and three exhaust fans with 4400, 7230 and 900 CFM for general, laboratory, and emergency exhaust, respectively. Controls are also incorporated into the system to promote building effectiveness and efficiency by modulating the equipment depending on several conditions, such as temperature, humidity, C02, and others. The equipment and controls will fulfill ASHRAE standards, which set standards for ventilation, energy and sustainability. The total pricing of the equipment is $570,203.83. This system will meet the requirements of a building life of 40 years and a 23% return on investment.

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Section 2: Introduction

This report will review the design choices and problem solutions to designing the HVAC system for the two story research and development office located in New York, NY. It is intended to inform the reader about the design decisions and detailed plans for the buildings various systems and procedures. A review of additional analysis including cos, compliance to ASHRAE standards, and energy savings will also be conducted in addition to a detailed description of the mechanical systems.

The customer has required that the entire building use a variable refrigerant flow system with the exception of the clean room in which a dedicated outdoor air system (DOAS) will be used. VRF systems are a newer technology that provides a high efficiency solution but with a small increase in initial cost. Due to budget requirements, the VRF system layout must be optimized so that copper piping is shortened and the space is conditioned appropriately. Along with budget considerations, the HVAC system must also meet at a minimum, several ASHRAE standards such as 55.1, 62.1, 90.1, and 189.1. ASHRAE standard 55.1 sets the standard for thermal comfort of occupants in the building. ASHRAE standard 62.1 gives ventilation requirements for the building, which details the minimum amount of outside air that the building must receive. ASHRAE standard 90.1 is the building performance standard which defines the minimum building envelope, lighting, and system performance of the final design. ASHRAE 189.1 is the design of high performance, green buildings, providing a total building sustainability package for those who strive to design, build and operate green buildings.

These standards are what drive the design so that the building is energy efficient, environmentally friendly, and comfortable for the occupants in the building. These requirements must be met in the proposed HVAC design. By utilizing a variety of software programs such as Trane Trace 700, Virtual Environment Pro, and Autodesk Revit, these designs will be vetted to meet these requirements while following the owner's project requirements.

This paper overviews various sections, including an overview of load calculations, design conditions, and design considerations. The designs include a multi system approach to satisfying these requirements: dedicated outdoor air systems to satisfy ventilation requirements, variable refrigerant flow system to provide for cooling/heating needs of zones, and exhaust fans to control building pressure and evacuate contaminated air. Thereafter, a section will be devoted to the chosen system, which will ensure clarity and highlight the details on why the proposed system has been selected. In addition, an analysis on detailed design decisions will also be presented that will add value to the project and differentiate from other competing teams. These details include sections on clean room air filtration and VRF unit selection. Additionally, the operation and maintenance section will cover the sequence of operations, which include the controls, heat recovery operations, fan filter units and exhaust fans, while maintenance will detail the needs for filtration service and general maintenance of coils. Finally the detail design section is an overview of the final decisions made by the team in satisfying building owner requirements. Schematics for VRF unit and ductwork will be presented along with detailed calculations and load results from Trane Trace software. In addition, a preliminary building information model (BIM) will be presented along with an example model of the 3D Revit model.

Section 3: Load Calculations

The entire building has several load factors such as lighting, occupancy, solar loads, equipment, and miscellaneous loads such as computers, printers, etc. Using Trane Trace, templates were created for the following space types: office, research and development, clean room, corridor, restroom, storage, library, and many more. Inside the templates, the room conditions are put into the program for occupancy, lighting, and envelope. Using these templates increases the speed of determining the loads as laid out below. The total loads for the clean room were calculated assuming 250 outside air changes, this load would be considerably reduced if the outside air change rate was not so demanding.

Table 1: VRF Area and Lab Area Loads

Area SQ. FT.	Cooling Tons	Heating BTU/HR	Area SQ. FT.	Cooling Tons	Heating BTU/HR
30,334	**52.2**	**653,323**	**3,227**	**59.9**	**1,250,896**

Table 2: Total Exhaust and VRF Airflow

Outside Air CFM	Exhaust Air CFM	VRF Airflow Capacity
11,630	**11,630**	**27,075**

Table 3: VRF Condenser Capacity

Condensing Units	VRF Condenser Capacity BTU/HR
(2) 20 Ton **(1) 10 Ton**	**600,000**

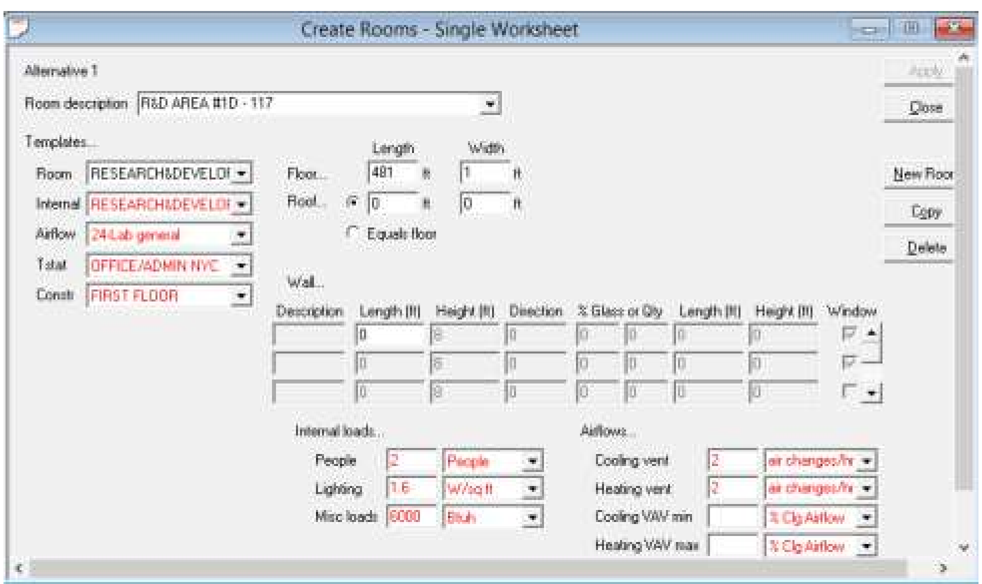


Figure 1: Trane Trace 700 Room Template

Table 4: Space Type & Miscellaneous Room Loads

Space Type	Misc. Loads
Break and Vending Areas	Refrigerator Microwave/Coffee Vending Mach
Computer Room	4 typical racks of blade servers 2 typical racks of networking equipment
Conference	CPU/Monitor LCD TV 2 Projectors
R&D Space	Research Equipment: 10 W/sqft Lighting 1.5 W/sqft
Office, Individual	CPU/Monitor
Office, Executive	CPU/Monitor LCD TV
Open Office	CPU/Monitor per workstation/person One High volume copy machine

The table above shows miscellaneous loads in the different room types throughout the building. These additional loads were put into Trane Trace to determine the overall load on the building. Each space in Trace was manipulated to perfectly describe each room's loads so that system selection could be finished as accurately as possible. After completing the Trane Trace load calculations, the total building airflows were examined for final unit selection. The clean room requires the greatest volume of air, although its room volume is the smallest based on space type. This is because the clean room is required to have 250 air changes per hour for proper laminar airflow in the room, filtration, and positive pressurization. Figure 2 below shows the total airflow percentage based on space type.

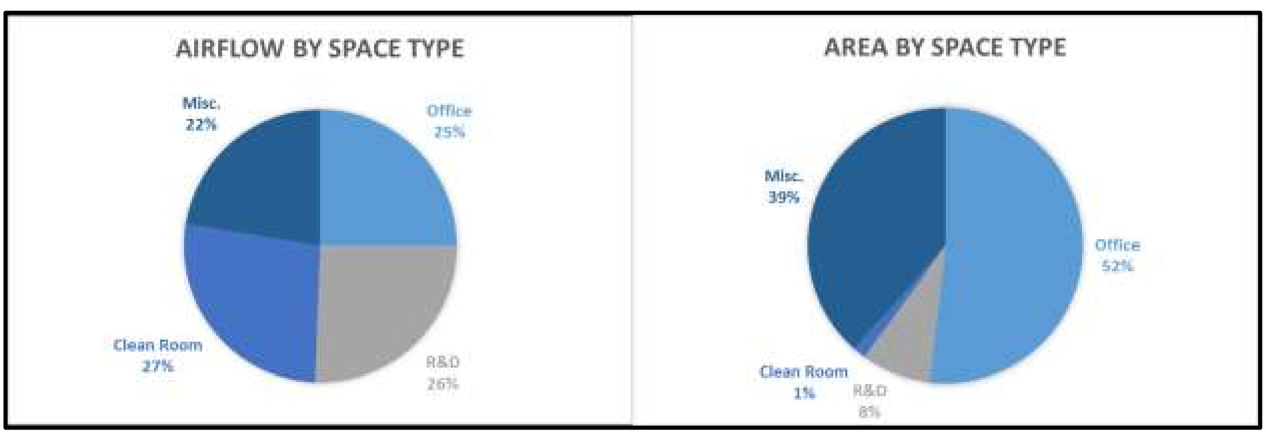


Figure 2: Airflow & Area by Space Type

Section 4: Design Conditions

The Research and Manufacturing center has several space types, which have different indoor air quality and climate control needs. Each of these space types requires a different amount of fresh outside air to comply with ASHRAE standard 62.1-2013. To ensure the thermal comfort for occupants in the building, the guidelines and requirements set by ASHRAE standard 55-2013 must be followed accordingly. Outperforming these guidelines create a wonderful workspace environment that occupants of the building will enjoy for many years. The design requirements and owners directed goals for the different areas are shown below in Table 5.

Table 5: Design Conditions and Owner Directives

	Office/Admin	*R&D*	*Clean Room*
Occupancy	10 hours/day	18 hours/day	18 hours/day
Summer DB	75°F	68°F	75°F
Humidity	50% RH	30-50% RH	40-50% RH
Winter DB	70°F	68°F	68°F
Acoustics	NC 35	NC 45	NC 40
IAQ	Complies with ASHRAE standards 55-2013 & 62.1-2013		
Maintenance	Ease of access for all equipment & low cost		
Energy Use	Energy conservation per ASHRAE standard 189.1		
Life Cycle	Provide the best life cycle cost for New York		

Energy efficiency must also be a main focal point for the building, as maintaining sustainability is a large factor in the design of the building. The system must be designed to operate under peak performance when required, and, through the use of controls and sequence of operations, provide energy efficiency by scaling down performance according to the conditions of each room. This ensures that sustainability is prevalent throughout the system and the building itself. For sustainability requirements, ASHRAE standard 189.1 must be used for guidance, which provides a "total building sustainability package". In order to fulfill proper energy standards, the building's envelope must be in accordance with ASHRAE standard 90.1-2013. The proposed system must exhibit cost-effectiveness, proper lighting, energy efficiency in the system and equipment, the use of energy recovery, and a sequence of operations to control the equipment per building requirements.

The facilities HVAC system has been designed based on owner directives and conditions displayed above. The building is in climate zone 4A in New York, New York and specific guidelines and requirements are to be followed for insulation, glazing, roof, and walls based on this climate zone, as stated in ASHRAE standard 90.1-2013 Appendix B. The outdoor conditions used for the design are acquired from the LaGuardia Airport weather file in Trane Trace and Virtual Environment Pro 2013. The graphics below in Figure 3 show the important weather data in New York, New York, with the graphic on the far right showing hot and cold stress on the building throughout the year. It is important to note that the building is primarily exposed to cool conditions, showing that the building requires more heating than cooling throughout the year.

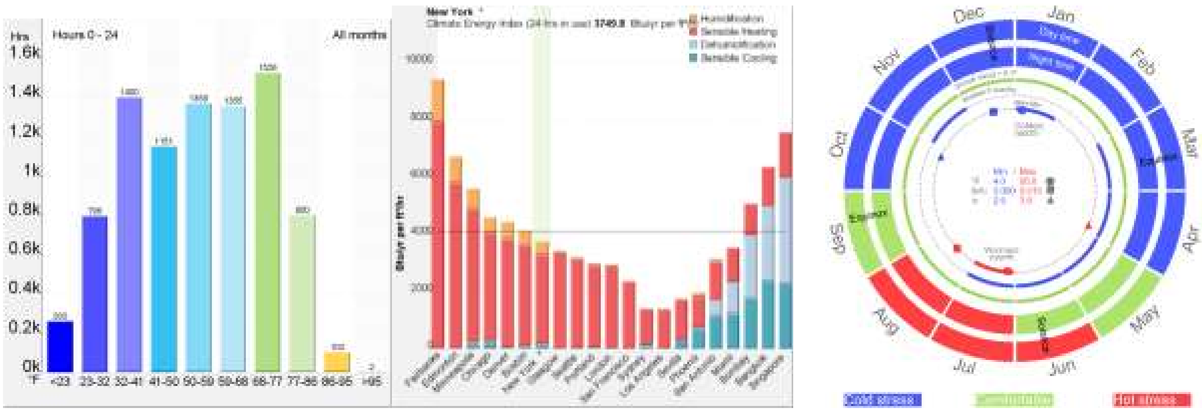


Figure 3: New York Climate Conditions

The building owner requests that variable refrigerant flow units must be used in the main building space with the exception of the clean room and lab areas. Because of the abundance of refrigerant being delivered to all evaporators in the building, as well as additional refrigerant piping throughout the building, the total refrigerant charge is higher than traditional HVAC applications. This creates a great importance for ASHRAE Standard 15-2013, and Standard 34-2013, which are two refrigeration safety standards. A system of controls has been implemented to handle any refrigerant leaks that may derive due to fracture in the refrigerant lines. Using efficient equipment, an enhanced building envelope, and proper maintenance and operations scheduling, the building will perform at levels much greater than the building owner requires.

Solar Simulation and Climate

Using Virtual Environment Professional, an advanced simulation program, the team was able to model the building using the weather data file for LaGuardia Airport. VE Pro software helps to speed up the understanding of the buildings outside environment, even if the building is thousands of miles away and shows realistic shading on the building early in the design phase. The figure below shows the shading on the building with windows and a completed building envelop. These simulations were used for solar load analysis before the final building loads were completed.

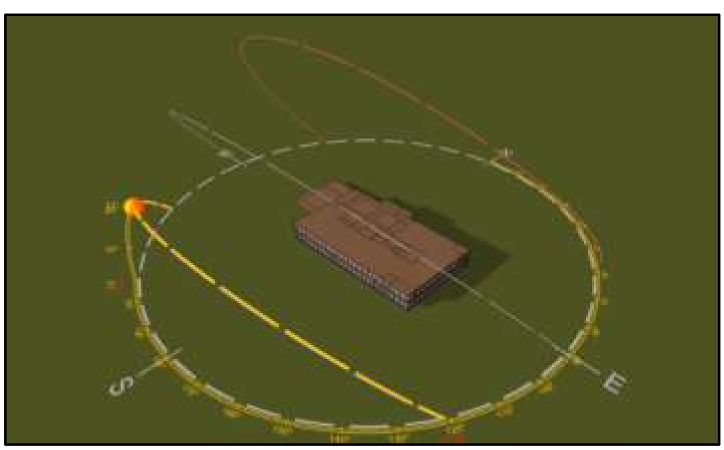


Figure 4: Solar Shading during Winter Solstice

Using the SunCast program inside Virtual Environment Professional, solar intensities of the building were simulated at different times of the year for an accurate display of solar loads on any portion of the building. It can be noted from the picture below that the highest solar intensity is on the roof with approximately 300,000 Btu/hr and the least amount of solar intensity is shown on the north walls of the building with approximately 50,000 Btu/hr.

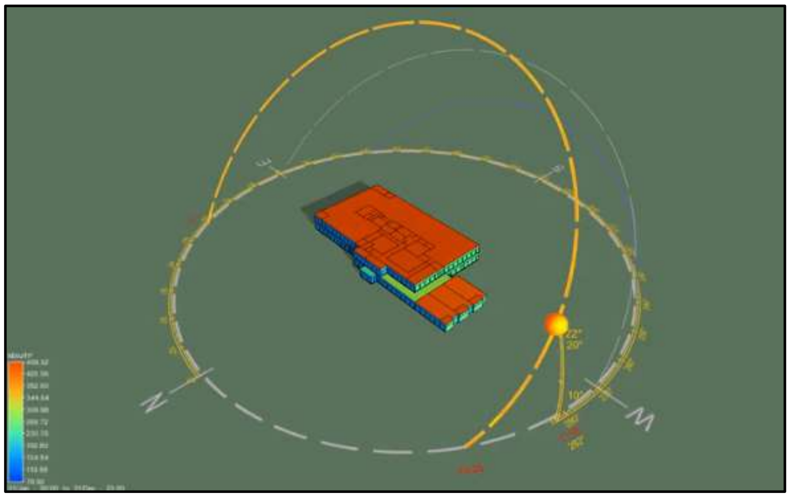


Figure 5: Solar Intensity during Summer Solstice

Duct Design

The extensive duct design is based on zoning, architectural coordination, and airflow per space. Many VRF units in the building are ceiling cassette styles that lie in the ceiling of each space. For all other VRF units, the supply duct was coordinated with other disciplines, mainly structural and architectural. All supply ducts from the VRF units are sized at 0.08 inches water column static pressure and varied based on cubic feet per minute requirements per room. The return ductwork for all VRF units is sized at 0.06 inches water column static pressure and CFM requirements for the space. The general exhaust ductwork is routed to spaces requiring fresh outside air so that pressurization can be adjusted when outside air is dumped into the space. The outside air ductwork from the DOAS and exhaust ductwork is sized at 0.08 In. W.C. and varied with airflow requirements as well for all general building areas, excluding the clean room and lab areas. All outside air ductwork and exhaust is routed to ceiling diffusers and grilles with the exception of the emergency exhaust fan. The emergency exhaust fan ductwork is routed to a low wall sidewall grille. The reason behind this is because possible refrigerant leaking in the building is heavier than air and will sink to the bottom of the space. Having low wall exhaust in these areas increases ventilation efficiency and speed of the affected areas. Volume dampers will be installed at all diffuser and grille locations to adjust airflow in the future. These dampers will be installed closest to the ductwork tap so that noise from the interrupted airflow is as far away as possible from the space. Additionally, multiple elbows will be put in the return and exhaust ductwork near large duct mains with high amounts of air passing through. These techniques will reduce overall noise levels inside the building and create a better working environment for employees.

The research and development areas are special cases due to the varying amount of outside air required based on exhaust rates for each room and sash height of each piece of equipment in the space. The research and development areas use complex air valves and controls to vary the amount of air at each room exhaust grilles, supply diffusers, and outside air diffusers. In order to increase ventilation in these spaces, the ductwork is sized using the air velocity instead of pressure. This allows for much for air to be moved through the ductwork while still using somewhat small duct sizes to clear structural beams and other obstacles in the plenum space. The clean room requires 250 air changes per hour for proper ventilation. Along with this amount of air, the space must be ventilated with laminar airflow. In order to have laminar airflow in the clean room, ductwork is routed to fan filter units mounted in the ceiling. These fan filter units redistribute the air so that proper laminar flow is achieved throughout the clean room. In order to achieve this flow, approximately 60% of the ceiling is covered in these fan filter units, while the additional area in the ceiling is used for lighting in the space.

Cold Process Water

Required by the owner, 60 degree water must be available at the research and development rooms for process cooling of special equipment used in the room. To efficiently serve the area with this process cold water, the domestic water in New York will be routed to the Lab DOAS on the roof, where the water will pass through the DOAS to temper the water to exactly 60 degrees. In many cases, the heat given off to the process cold water from the DOAS will increase the cooling capacity of the DOAS. In short, the heat absorbed from the process cold water is taken from the outside air being supplied to the building. This will save money on treating the process water for the research and development rooms and increase the efficiency of the DOAS when cooling is needed. This system does not use a domestic hot water heater with an electric heater coil as this would be inefficient.

Section 5: Design Considerations

DOAS

As part of the ASHRAE Design Calculations requirements, variable refrigerant flow technology had to be the main source of air supply throughout the spaces of the building. These systems are commonly used because of their efficiency, flexibility and the number of units to choose from. For this project ducted and non-ducted units were used. Since no fresh, outside air can be brought into the building using the VRF systems; outside air has to be delivered to the space by other means. The dedicated outdoor air system (DOAS) comes into play by providing outside air to achieve compliance with ASHRAE standard 62.1, while the VRF units manage the space cooling and heating. The DOAS units selected contain energy recovery which allows sensible and latent loads to be exchanged between entering outside air and the exhaust air. Using energy recovery, the DOAS units could be selected at nearly 6 tons below the true building load.

Figure 6: Examples of Ducted and Non-Ducted Units Side by Side

Design considerations were made to select units that would best maximize available efficiency. Ducted units were chosen for larger office spaces where the ability to route airflow would provide for maximum thermal management and comfort.

VRF Unit Placement

An additional design consideration involved the strategic placement of units throughout the building. Effort was made to ensure unit placement would allow for easier routing of refrigerant lines throughout the building to minimize installation difficulty and the possibility of unforeseen issues. In addition, alternative routes for ductwork were also considered for ducted units. The choice was made to use the shortest ductwork for each space to reduce the construction costs that will be calculated in the future. Care was taken to ensure that this design would not create undue hot or cold spots in the building by balancing the thermal distribution of diffusers in large open areas.

Another placement consideration was that of diffuser orientation and size. Most diffusers are of the simple 4X4 cassette variety wherein air is distributed out of angled slats that extend from the roof. However, alternative designs such as linear diffusers were taken into account in the selection of the VRF units. The advantage of this design is the possibility of providing additional thermal barrier along window surfaces from thermal incursion from outside conditions. In addition, the linear diffusers are smaller and compact units that allow for easy installation.

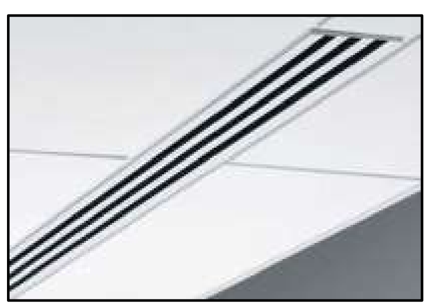


Figure 7: Linear Diffuser

Satisfaction for all of these air control/flow devices would be determined based on whether they would be adequate at lowering zone space to design specifications. Certain units were oversized to provide for the possibility of undue load requirements on the system.

Airflow Characteristics

Each VRF unit was analyzed for best flow characteristics and placed in the appropriate spaces. For instance, in a large bathroom with a small width, a two cassette was selected to provide for the highest rates of air velocity facilitating ventilation flow. A four-way cassette was not proficient in this space, as two of the four vents would have been directly facing walls. Similarly, in a large rectangular space such as an office room, a four cassette was used to provide the most airflow in all directions. Ducted units do not have these same considerations, as airflow is managed thorough ductwork routed throughout the space and delivered through diffusers.

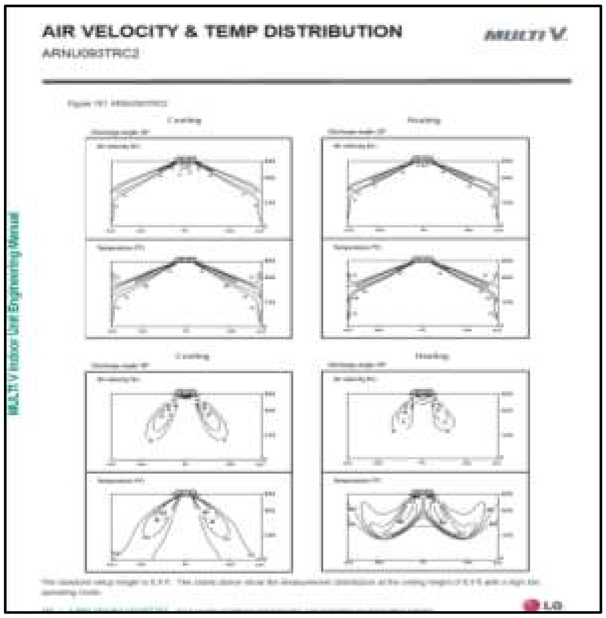


Figure 8: Airflow characteristics of a four way non-ducted cassette VRF unit

Heat Recovery Units

Heat recovery units were chosen to be implemented into the overall variable refrigerant flow design due to their ability to split refrigerant based on individual room loads. This will allow the system to realize the large energy efficiencies VRF systems are capable of achieving over other traditional HVAC system designs. Limitations of heat recovery (HR) units were kept in mind when selecting HR placement, including maintaining maximum and minimum distance between units (131 ft. and 2 ft. respectively) and maximum height restrictions when connected to the condenser and maximum capacity (160kBtu).

Figure 9: Heat Recovery Unit

ASHRAE Standards

Standard 15

ASHRAE Standard 15 discusses safety levels of the amount of refrigerant used per condenser. One of the major concerns is the refrigerant leakage from a pipe, seal, or system. Equation 1 shows the safety level of the amount of refrigerant allowed when a leakage does occur. The refrigerant for the HVAC system is R410A which has a refrigeration concentration limit (RCL) value of $10\frac{\text{lb}}{\text{Mcf}}$. Any room that has a higher value than the RCL value are to have exhaust ducts installed. These exhaust ducts are routed to an emergency exhaust fan and the fan only runs when refrigeration pressure is lost at any of the condensers. This pressure is measured using refrigeration pressure sensors at each condensing unit.

Equation 1: $\frac{Refrigerant\ quantity\ (lbs)}{Room\ Size\ (Mcf)}$

Table 6: RCL value

Refrigerant number	Safety group	RCL lb/Mcf*	Highly toxic or toxic under code classification
R-22	A1	5.5	neither
R-134a	A1	13	neither
R-407C	A1	15	neither
R-410A	A1	10	neither

*These values are included in the 2006 International Mechanical Code

The first floor consists of two condensers. The main condenser has a total refrigerant amount of 41.79lbs of refrigerant while the smaller condenser that handles the R&D room and the clean room has 18.34 lbs. The condenser on the second floor had a refrigerant amount of 43.45lbs. The rooms which require low wall exhaust ducts are in the center section of the building on each floor, and are labeled in the mechanical working plans.

Standard 55

ASHRAE Standard 55 determines the thermal comfort parameters for indoor conditions. Temperature is one of main factors to increase work capability and comfort levels while indoors. Equations 2 and 3 show the minimum and maximum temperature regions from ASHRAE Standard 55. Average clothing for New York is 0.5 during the summer and 1.1 during the winter. These clothing levels were obtained from ASHRAE Standard 55. In office conditions, the average metabolic rate is 1.2.

Equation 2:

$$T_{min,Icl} = \frac{(Icl - 0.5 * clo) * T_{min}, 1.0clo\ + (1.0clo - I_{cl}) * T_{min},\ 0.5clo}{0.5clo}$$

Equation 3:

$$T_{max,Icl} = \frac{(Icl - 0.5 * clo) * T_{max}, 1.0clo\ + (1.0clo - I_{cl}) * T_{max},\ 0.5clo}{0.5clo}$$

During the summer, results show that 80% of people are satisfied within the temperature regions between 76.1 and 81.5 degrees Fahrenheit. For winter, the same equation was used and 80% of people are satisfied for temperatures between 69.08 and 76.64 degrees Fahrenheit. One of the advantages of using a VRF system is its flexibility of controlling the indoor temperature. In order to satisfy the remaining percentage, the VRF system can be used to extent by changing the temperatures to meet ones need within certain zones.

Standard 62.1

In order to maintain indoor air quality at a certain safety level, ASHRAE Standard 62.1 was used to find the minimum amount of outdoor air needed. The amount of outdoor air needed was calculated through the spreadsheet. A series of equations are listed below to find the outside air rate needed for the general areas in the building.

Table 7: CFM required in building

QUANTITY	CLASSIFICATION
P_{MAX}=292 PEOPLE	Zone population
A_Z=29254SQFT	Zone floor area
R_P=5 CFM/PERSON	OA flow rate per person
R_A=0.06 - 0.12 CFM/SQFT	OA flow rate per unit area
$V_{BZ}= R_P* P_Z+ R_A*A_Z$=3501CFM	Breathing Zone OA flow
E_Z=0.8	Zone air distribution effectiveness
$V_{OZ}=V_{BZ}/E_Z$=4376CFM	Zone OA flow

Standard 90.1 - ANSI/ASHRAE/IESNA Standard 90.1 Appendix G Baseline System

The performance of the proposed design for the building must exceed standard 90.1-2013. The performance calculation for the proposed building performance and baseline building performance were calculated using the same simulation program, weather data, and energy rates. The data for the proposed building and the baseline building is compared to find the percentage improvement. The baseline building will use a Variable Air Volume system while the proposed building will use the VRF system. Equation 4 is used to calculate the percentage improvement of the building. The method to calculate each building performance is by using the energy cost budget method. The specified design increase of the baseline building is 26%.

Equation 4: $100 * \frac{(Baseline\ Building\ Performance - Proposed\ Building\ Performance)}{Baseline\ Building\ Performance}$

Standard 90.1 sets minimum building requirements, which were then increased to outperform the baseline building. New York is in ASHRAE climate zone 4A as determined by ASHRAE standard 90.1-2013. The building is categorized as a nonresidential building less than five floors. The manufacturing facility will have a roof insulation value of R-38 and wall insulation value of R-15. Window glazing was determined to be the best upgrade options because of the amount of glazing on the building. The new windows selected are Viracon windows with a solar heat gain coefficient of 0.31 and visual light transmittance of 60%. The baseline building envelope can be seen below.

Table 8: Building Envelope Requirement for New York

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Roofs						
Insulation Entirely Above Deck	U-0.048	R-20.0 c.i.	U-0.048	R-20.0 c.i.	U-0.173	R-5.0 c.i.
Metal Building	U-0.055	R-13.0 + R-13.0	U-0.055	R-13.0 + R-13.0	U-0.097	R-10.0
Attic and Other	U-0.027	R-38.0	U-0.027	R-38.0	U-0.053	R-19.0
Walls, Above-Grade						
Mass	U-0.104	R-9.5 c.i.	U-0.090	R-11.4 c.i.	U-0.580	NR
Metal Building	U-0.084	R-19.0	U-0.084	R-19.0	U-0.113	R-13.0
Steel-Framed	U-0.064	R-13.0 + R-7.5 c.i.	U-0.064	R-13.0 + R-7.5 c.i.	U-0.124	R-13.0
Wood-Framed and Other	U-0.089	R-13.0	U-0.064	R-13.0 + R-3.8 c.i.	U-0.089	R-13.0

Cistern Incorporation

To efficiently conserve water, a cistern water collection system has been incorporated into the design. These systems route rainwater from the roof and condensate produced from the HVAC equipment to a water storage tank. The purpose of having these systems is to recycle the water and have it function as a supplement to the building's water supply. Once the water is collected from various areas, the water leaving the system can be used for various grey water applications, which include relatively clean waste water from baths, sinks and washing machines. This water is filtered and treated along with periodic sanitization of the cistern itself. The use of a cistern in this project will allow the water stored in the condensate drains from the mechanical equipment, such as the indoor VRF and roof top DOAS units, to be routed to the cistern reservoir where the collected water can be utilized for flushing toilets on both floors, as well as supplying for use of other gray water systems.

Window Upgrades

Considering windows comprise a large part of the architectural features of the chosen building, the team has performed a window selection that should allow for excellent visual light transmittance (VLT) without the negative effects of undue glare inside of the space. Specifically, the team has selected the Viracon® VUE15-50 window for all outside facing windows. The VUE15-50 features a VLT of 51% to allow for adequate light into the workspace. This should provide for sufficient sun exposure to the workspace for maximum productivity and employee comfort.

The window will also feature a 13.2 mm argon gas filled space to provide for superior thermal insulation. With this added insulation, a solar energy reflectance of 35% can be reached. Meanwhile, the insulated space is supported by two 6 mm glass plies on either side. In addition, the window also contains a low emissive coating that allows for the reflection of heat while allowing light to easily pass through the glass. During the winter, heat is retained within the space due to the low-E coating, as well as a reduction in heating loads. These added features should provide for improved thermal management throughout the day when compared to standard non-insulating glass windows.

Figure 10: Outside Revit Rendering

Filters

As with any HVAC system, filters are required to manage the indoor air quality of the building and prevent any excess debris or pollutants to enter or leave the building. The MERV scale is the Minimum Efficiency Reporting Value (MERV) of filters to rate their effectiveness. The dedicated outdoor air system (DOAS) contains a pre-filter which is rated at MERV 8, as the pre-filtered air is not directly entering the building. The final filter for the DOAS is increased to MERV 12, as this air will now enter the building and must contain an acceptable indoor air quality to satisfy ASHRAE 62.1. The general exhaust DOAS filter is rated at MERV 8, as the exhaust air from the general area will not contain many pollutants/contaminants that are classified in the MERV 8 category. The laboratory area is slightly stricter on filters, as particulates entering and leaving the system is critical. The DOAS pre-filter remains at MERV 8, while the final filter is increased to MERV 13. The supply air to the clean room must contain high efficiency particulate air (HEPA) filters to minimize the amount of particulates entering the system, resulting in HEPA filters with a designation of MERV 13. The exhaust air from the laboratory area, including the clean room and research and development rooms, is to be MERV 13. This is increased from the general area designation of MERV 8, as the possibility of producing contaminants classified under the MERV 13 designation is much greater. Finally, there must be filters for the VRF units in order to properly supply acceptable conditioned air to these spaces. Each VRF will utilize MERV 12 filters, as this will deliver acceptable air quality to the office space occupants, as well as the conference room and other general areas that are conditioned by the VRFs.

Section 6: Chosen System

VRF System

Once all load calculations were finished for various zones and rooms, a selection of exact VRF units to be placed in each zone was then completed. Taking into consideration the design concerns outlined prior in this report various units were placed throughout the building. For this project the team chose LG as the manufacture of the VRF system. The team has some familiarity with the LG hardware thanks to local sponsors and ASHRAE mentor members providing real world instruction on how these units work. After unit placement was completed for non-ducted units, an analysis of ductwork routing for ducted units was then undertaken. As mentioned prior, efforts were made to reduce overall ducting size and complexity to control cost and ease of installation. Once all units were placed, refrigerant lines were then routed to each unit through a heat recovery unit that was in turn connected to the main condensers. These lines were routed through an access shaft located next to the women's restroom. This work lead to a schematic presented below of VRF placement, ductwork, refrigerant piping and heat recovery unit locations.

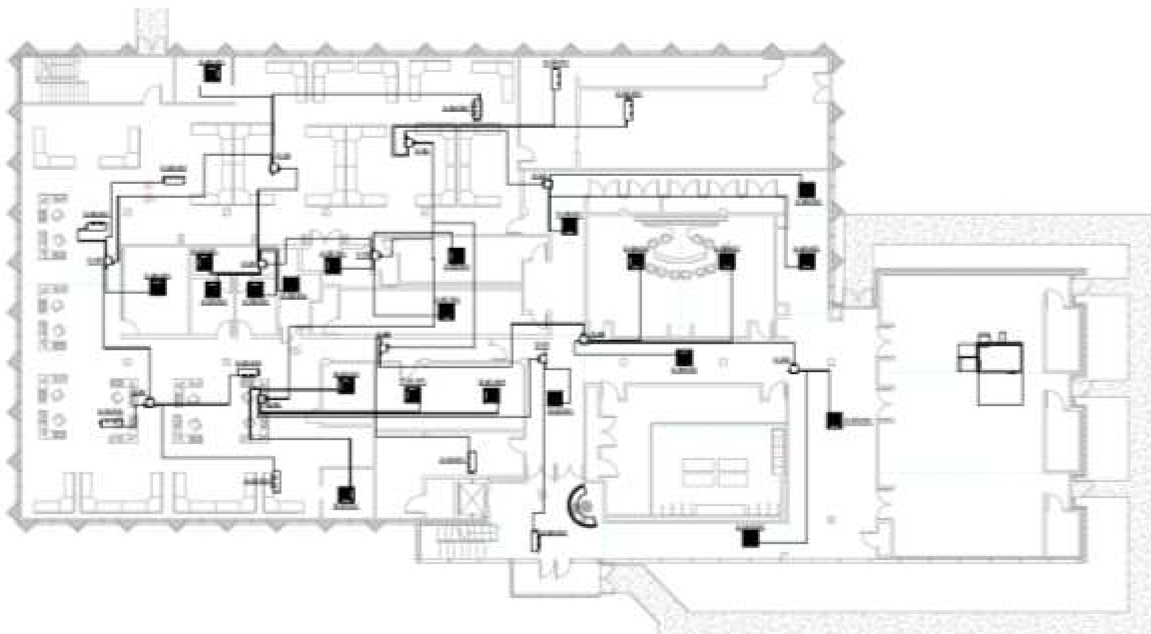


Figure 11: Example of Revit Piping Diagram for VRF System-1st Floor

Each VRF unit was also paired with a condenser and each system assigned to an individual condensing unit. After the condensing unit reached 20 tons, a new condenser was added to handle additional load. These calculations lead to a total of three condensers, placed on the roof, being used for the VRF condensing system. The following schematic shows the breakdown of VRF units associated with a specific color to represent various condensers.

Once all system placements had been completed, the team then used LG's proprietary software to determine whether the total system design would be consistent with the limitations of refrigerant placement and heat recovery unit specifications. Once the system had checked to be within limits, a model selection sheet of each condensing unit was then produced to show all connections. An example of the second condensing unit and evaporator tree is displayed in the figure below.

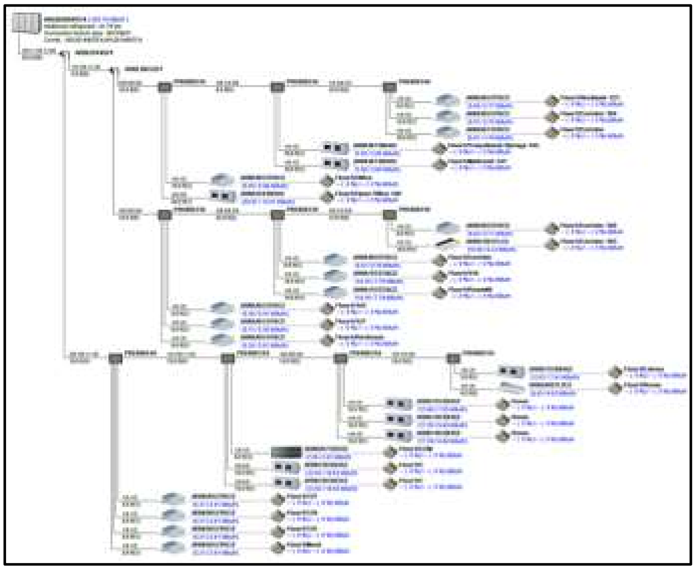


Figure 12: Model Selection Tree of Second Condensing Unit

Dedicated Outdoor Air System (DOAS)

The owner's project requirements for the competition calls for a conservative, energy efficient building that provides the best life cycle cost for the climate of New York City and the proposed budget. To achieve this, a variety of air handlers and VRF units are to be used to promote efficiency and maintain the owner's requirements for the interior conditions of the office and administration areas, research and development areas, and the clean room. A DOAS will be used in this system to provide preconditioned air that will reduce the cooling and heating loads of the VRF units and provide the necessary conditioned air to the research and development areas, as well as the clean room. The DOAS will be primarily used to comply with ASHRAE 62.1, *Ventilation for Acceptable Indoor Air Quality*, which specifies minimum ventilation rates and other measures to provide acceptable indoor air quality, which is determined by the control and removal of contaminant sources. The DOAS is needed to satisfy ASHRAE 62.1 because the VRF units do not provide outdoor air. They merely condition the air that is supplied to them, which will be supplied from the DOAS into each room. In theory, the design should replicate the diagram shown in Figure 13.

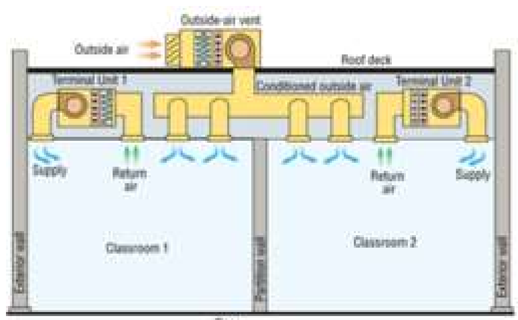


Figure 13: DOAS System Configuration

In order to correctly size the DOAS for the general areas and the research and development areas, correct load calculations are necessary. These load calculations are derived through Trane Trace 700 as described earlier. The loads in Trane Trace totaled to 647,828 Btu/hr for the general areas, resulting in a DOAS unit of 4400 CFM. The selected unit for the general area was a Greenheck RVE-50-46P-30H with a supply air rate of 4400 CFM. The selected unit has several features, including galvanized steel housing and double wall, internally mounted control center, dampers, filters and much more. The most important accessory is the energy recovery cassette with a desiccant wheel, as this feature allows for significant load reduction in the system. For cooling, the load is reduced my nearly 68,000 BTU/hr, while a reduction of nearly 64,000 BTU/hr occurs for the heating load. The energy recovery processes for this DOAS during the summer and winter are shown on the psychometric charts below in Figure 14.

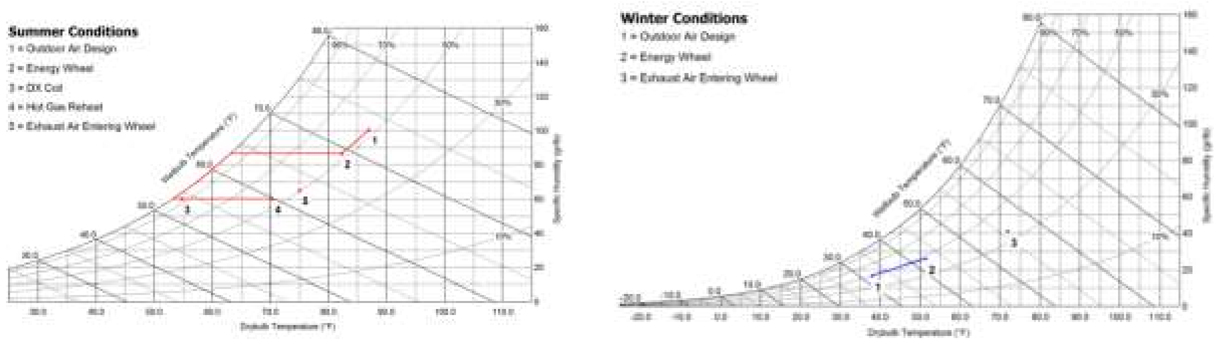


Figure 14: Psychometric Charts for Summer & Winter Conditions

The psychometric charts accurately depict why the energy recovery is valuable to the DOAS. Rather than practical theory, these charts show how the energy wheel saves energy in the system by allowing the incoming air to either be essentially preheated or precooled from the exhaust air. In order to fully understand the energy recovery, knowledge of the desiccant wheel is crucial.

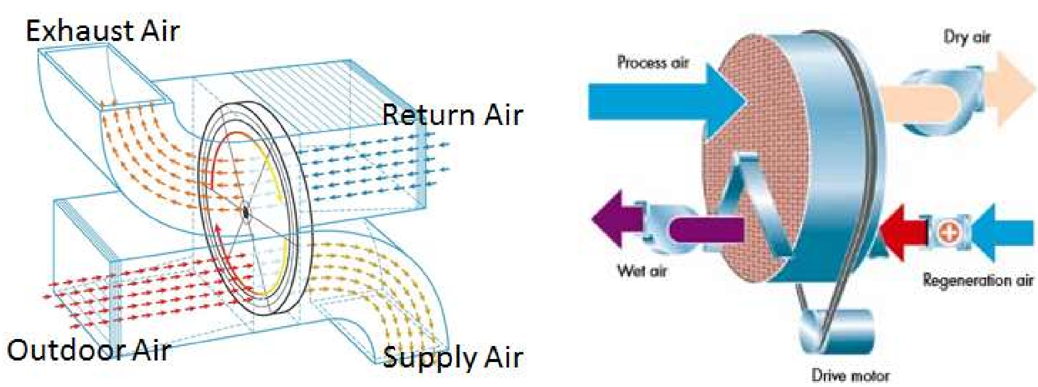


Figure 15: Energy Recovery Schematics

The pictures shown in Figure 15 show how the energy recovery works. In the summer conditions, the return air is cycled through the wheel, resulting in the sensible load being reduced from the outdoor air by the outdoor air receiving pre-cooling simply by running through the desiccant wheel which has been precooled from the return air. In addition, the latent load is amended by the humidity in the air sticking to the desiccant wheel, and disposed of by the exhaust air after a rotation. In the left picture of Figure 15 the colors of the arrows designate the temperature of the air, signifying that the return air does not leave at its cooled temperature, while the supply air enters at a precooled temperature. Although the DOAS must still precool this air before being distributed to the rooms for the VRF systems to further condition, this heat exchange process drastically reduces the amount of cooling.

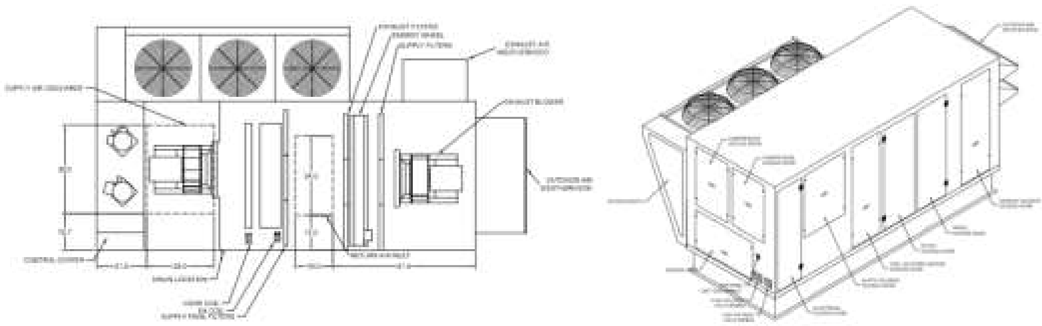


Figure 16: DOAS Schematics

Meanwhile, the schematics for the DOAS are shown in Figure 16. These diagrams show where each component of the DOAS is located.

For the lab areas, a separate DOAS was required in order to account for the high loads demanded by the clean room and research and development spaces. The loads calculated in Trane Trace 700 were found to be 719,982 Btu/hr for these research and development spaces, resulting in a supply of 7325 CFM. The selected DOAS unit for these spaces was the AAON RN-050, with a supply air capacity of 7325 CFM. The schematics are very similar to the schematics in the general area DOAS, as depicted in Figure 16. The air flow rate of 7325 CFM derives from the loads required by the research and development rooms, as well as the clean room requiring a constant rate of 25% outside air.

For each DOAS unit, including the supply and exhaust fans, there are to be variable frequency drives (VFD) implemented in each system. The DOAS can be employed to create a cycle in which the system can optimize delivery of preconditioned air while use is minimized during unoccupied hours, or 14 hours/day for the office and administration areas and 6 hours for the R&D and clean room areas. Although the R&D and clean rooms only have 6 hours of vacancy, the office and administration areas have a 58% per day vacancy period, which can lead to excessive energy costs if the system were run at a constant rate. To control this rate, variable frequency drives will be placed on the supply and exhaust fans to modulate the frequency and voltage of the fans to ramp up or reduce fan speeds.

Energy consumption can be reduced between 10 to 50 percent by eliminating oversizing of units and minimizing peak demands. Carbon dioxide (CO_2) and humidity sensors are crucial tools to maintaining compliance with ASHRAE 62.1. These sensors are to determine when the DOAS is to engage due to an increase in CO_2 or humidity, which is directly related to an increase in occupancy. These sensors will ensure an acceptable indoor air quality for the building, as the increased ventilation from the DOAS will eliminate the increase in CO_2 and humidity. After the contaminants are cleared and the readings on the sensors return to normal, the DOAS will be able to ramp down to its nominal state.

The considerations for the research and development rooms differ from the general area, resulting in the higher airflow requirement. Each research and development room contains a main duct, which is composed of four supply terminals and a minimum of one exhaust terminal. In peak conditions, the four supply terminals and exhaust terminals in each room are to run at maximum air flow. In each supply duct and exhaust duct, a Vor-Tek Blade Control valve is installed. These valves allow the air distribution to be adjusted according to the demands of the research and development rooms. In addition to the supply and exhaust ducts, there is a Vor-Tek Blade Control valve on the combined fume hood exhaust duct, meaning that if a research and development room has 3 fume hoods, only one valve will be required for these three fume hoods. In total, there are 12 control valves for the four research and development areas, as seen in the research and development configuration in Figure 17.

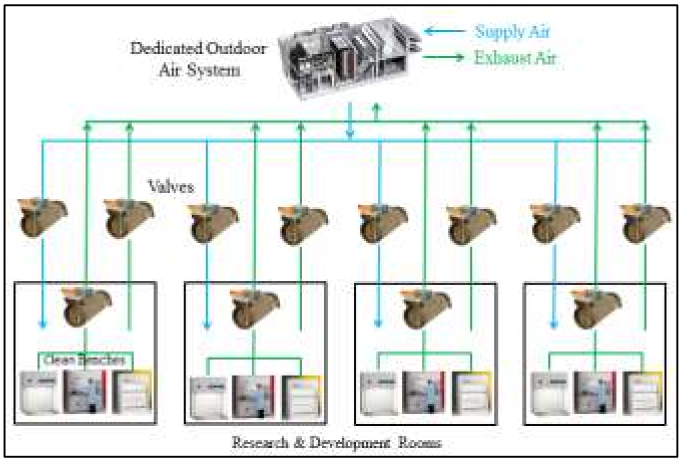


Figure 17: Research and Development Valve Configuration

These valves allow the airflow to be modulated according to the demands, and in peak conditions will be fully open in order to keep negative pressure within each room. The negative pressure is absolutely necessary to avoid any cross contamination from the research and development areas to surrounding spaces. When the research and development areas return to normal conditions, the air valves will adjust and close according to the pressurization of the rooms, maintaining the same negative pressure. This occurs in every research and development room.

Exhaust Fans

In order to account for pressurization needs and fresh air requirements, exhaust air demands must be fulfilled. To fulfill these demands, exhaust fans must be selected in order to maintain building pressure and take in to account the increase in supply air when the occupancy is raised. In the general area, a Greenheck G-203-B direct drive centrifugal roof exhaust fan is to be installed in the system. The rated airflow rate is 4400 CFM, matching the airflow volume from the general area dedicated outdoor air system.

The Greenheck G-203-B is to also contain a VFD in order to mimic the frequencies that are output by the DOAS. The operating power of this fan is rated at 1.53 hp. This unit is interlocked with the general area DOAS.

For the lab exhaust, the rated CFM was found to be 7325 CFM. The resulting selection is the Greenheck Vektor-H-22-20, which consists of a premium efficient motor that is purposefully designed to manage the fume exhaust. The motor also has a VFD to match the supply rate of the DOAS. The schematic of the system along with a diagram that shows the process of how laboratory air is properly exhausted is shown in. This exhaust fan is interlocked with the laboratory DOAS and contains a motor rated at 7.5 hp.

As with any building, emergency measures must be accounted for. A separate fan that is interlocked with the general area DOAS is required in order to account for any emergency situation that calls for an increase in exhaust, such as a refrigerant leak, significant increase in CO_2, or other contaminant emergencies. The selected unit is the Greenheck CUE-141-C, where the CUE stands for centrifugal upblast exhaust, and is shown in Figure 18.

Figure 18: Emergency Upblast Exhaust Fan

The Greenheck CUE-141-C is rated at 900 CFM and an operating power of 1/8 hp. This fan is noticeably smaller than the fans selected for the general and laboratory areas, as it is only meant to engage when an emergency is present.

Fan Filter Unit Selection

A Fan Filter Unit is a mechanical piece of equipment that is used to supply purified air to a cleanroom application. The goal of these units is to filter out harmful airborne particles before they can enter the lab environment and cause potential problems with the ongoing processes being conducted. In the case of the senior design project, the factors that were addressed were the amount of particles that needed to be filtered; the square footage of the FFU's to meet the supply air requirement and whether to use ducted or non-ducted units.

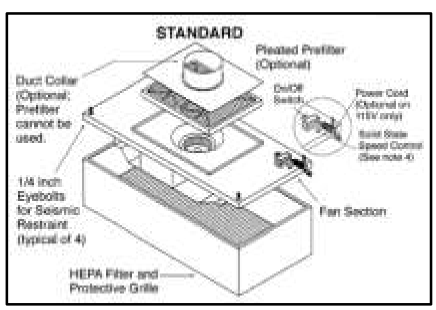


Figure 19: Ducted Fan Filter Unit

Shown in insert figure above is a ducted Fan Filter Unit (FFU) manufactured by Price. This mechanical piece of equipment is used to meet the requirement for air cleanliness for cleanroom applications. Included within this FFU are a fan/motor assembly and a high efficiency HEPA filter. The outdoor air provided by the dedicated outdoor air system (DOAS) will be ducted to the attachment shown at the top of the figure. For the units that will be drawing in recirculated air from the cleanroom, this ducted attachment will not be needed. Rather, the air in the return plenum just enters through the HEPA filter in the FFU and enters the cleanroom.

As seen in the floor plan there is a 500 sq. ft. cleanroom that is contained within a research and development room. This cleanroom is class 100, which limits only 100 particles sized 0.5 microns and larger per cubic ft. As far as airflow is concerned, unidirectional airflow is best suited for class 100 clean rooms. Unidirectional airflow is best shown in insert figure below, where the filtered/clean air enters the cleanroom only by means of the FFU's and exits through a floor plenum while maintaining laminar airflow. Knowing the cleanroom is class 100, along with assigning laminar airflow to the environment, allows CFM calculations to be made for this particular room's air requirement.

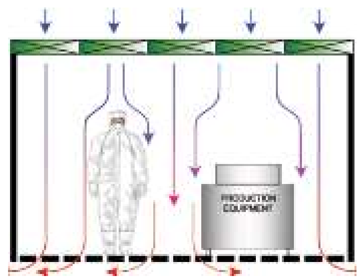


Figure 20: Linear diffusion in clean room

Based on research and professional expertise, the air change requirement for this particular room was set to be 50 air changes per hour. From this, the required outdoor air supply from the lab DOAS was set to 4175 CFM which is 25% of the 16,675 CFM requirement to meet the air changes. The other 75% is obtained from the recirculated air in the cleanroom plenum. As described above, this amount of air has to be brought in by means of the FFU's only. The number of FFU's selected to supply the required air to the cleanroom was found to be 40 units which encompass about 64% of the total ceiling coverage of the 500 sq. ft cleanroom. The other percentage is utilized for completely sealed fluorescent lighting to prevent air infiltration from the plenum. As stated before, 25% of the clean room airflow is sent to the clean room via the lab DOAS, and the other supply air is split amongst the four research and development rooms which do not utilize these fan filter units.

The fan filter unit that was implemented into this particular cleanroom is a Flanders Pureflo-FPM. This device is a lightweight low profile unit that consists of a fan/motor assembly and a Minipleat HEPA filter pack that provides unidirectional airflow to the space. This unit is 24 in. x 48 in. with a module efficiency of 99.99% for 0.3 micron particles for the class 100 cleanroom application. This device produces air at a velocity of 90 fpm which is recommended for unidirectional airflow while meeting the noise criteria specified in the OPR. These units each have the ability to provide 720 cfm to the cleanroom at the specified velocity.

Budget

All of the main VRF systems, DOAS units, sensors, ductwork, piping, etc. was priced using RS Means. RS Means is an industry pricing tool that takes into consideration standard purchase, installation, maintenance, labor, and all other costs that are inferred due to the designed system. RS Means serves as the best job estimating tool for multidisciplinary bidding services. These prices could then be used to calculate a life cycle cost of the system. Seen in Table 9 below is the full price break down of each section of the VRF HVAC package developed for this project.

Table 9: System cost for equipment and installation

QUANTITY	DESCRIPTION	COST
1	Variable refrigerant flow system	$186,483.39
1	Lab DOAS unit	$49,770.68
1	General DOAS unit	$32,509.55
1	General exhaust fan	$3,523.23
1	Lab exhaust fan	$7,599.28
1	Emergency exhaust fan	$1,958.17
1000	EMT, electrical conduit	$5,100.00
1	Variable frequency drive	$3,897.15
1200	Electrical wire	$156,792.00
5	Circuit breakers	$17,128.40
57	Controls, sensors, interface	$27,508.61
1	Rectangular ductwork	$30,720.33
1	Round ductwork	$5,120.85
1	Ductwork insulation	$6,092.19
64	Fan Filter Units, Flanders Pureflo	$36,000.00
	TOTAL	**$570,203.83**

Additionally, the VRF system used was compared with a base line system of a variable air volume system. In the table below the monthly and total cost for a year to operate the building are shown for the two systems.

Table 10: Monthly Electrical Prices

Electrical Price Per Month		
Month	**Constant Volume System**	**Variable Refrigerant Flow System**
Jan	$19,100.00	$16,310.00
Feb	$16,030.00	$14,285.00
Mar	$13,600.00	$12,520.00
Apr	$10,170.00	$9,750.00
May	$6,850.00	$6,130.00
Jun	$5,710.00	$4,895.00
Jul	$6,080.00	$4,720.00
Aug	$5,845.00	$4,355.00
Sep	$5,915.00	$4,450.00
Oct	$7,380.00	$6,440.00
Nov	$11,960.00	$10,665.00
Dec	$16,410.00	$14,760.00
Total Annual	**$125,050.00**	**$109,280.00**

By using the VRF system the building saves 14.5% annually over the standard DX pricing in electrical costs.

Life Cost Analysis

The life cycle cost analysis was completed based on the owners required 40 year life cycle. Using the system costs and the electrical consumption this life cycle cost estimation could then be made. When comparing the VRF system to the baseline DX system as seen in **Error! Reference source not found.** the VRF system reached mutual savings in 7 years. At the 20 year period; which is around a typical time for major maintenance and repairs of the system, the VRF system had brought the owner 18% in savings. At the end of the life cycle analysis the VRF system will save the owner 23% in annual savings.

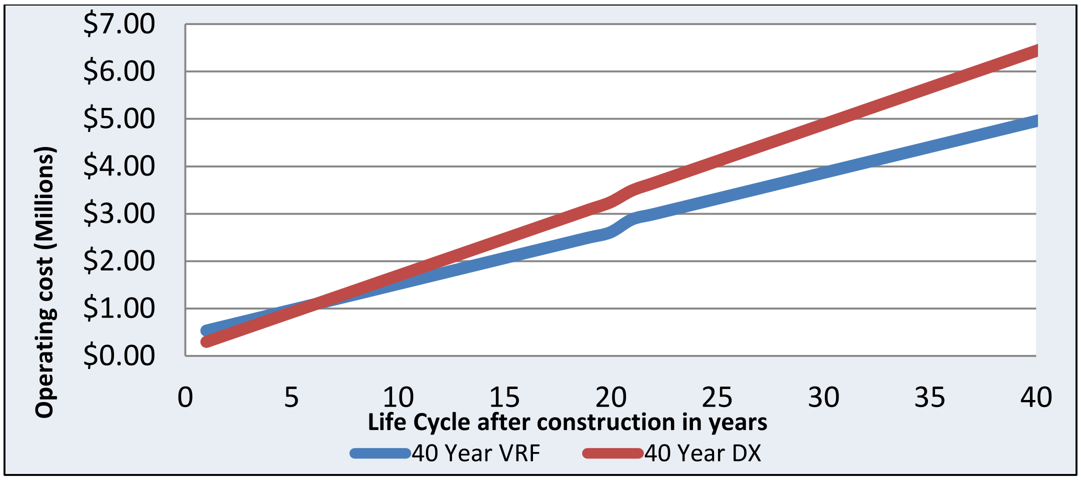


Figure 21: 40 year life cycle budget

Section 7: Operations and Maintenance

Sequence of Operations

With rising costs of electricity and the desire to have more control on the air handling needs of a building, by implementing VRF systems, owners can lower costs and manage data better than they ever have. Due to the complexity of the VRF system, controls and sequence of operations for the building are very unique. Building systems are monitored through the Building Automation System, which will communicate using BACnet/IP. BACnet is a communications protocol developed by ASHRAE and is detailed in ASHRAE standard 135.

In the office building each VRF unit has a built in thermostat on the return air side which allows control of air temperature to each space to be meticulously monitored. Additionally the system controls the supply air with two thermistors measuring the super heat or sub cool across the coil. On the thermistors the higher the difference of temperature between the two thermistors the greater the load in the space which determines the desired air temperature for the unit to supply the space.

Figure 22: Typical GUI for BACnet building monitoring system

Using a remote interface control system throughout the building will allow modest adjustments to the building settings when certain pre-set ranges are not able to keep up with the demand of the current space. These interfaces are web linked to the BACnet control system and can adjust everything from lighting to current temperature within the building manager's predefined scope. Additionally these interface points are integrated with the occupancy sensors to be a hands free point of contact throughout the building to turn off systems when not in use.

With ASHRAE standard 62.1 being the driving factor for clean air the design of the system was based on proper ventilation for each space. To solve this CO2 sensors have been placed throughout the building in key locations that develop large amounts of CO2 based on the amount of people in that space. Using 12 sensors on the first floor, and 8 on the second these sensors are spaced out in open office spaces, conference rooms, corridors, and the research and development rooms. The intent for this design is to quickly ventilate the space in the event that refrigeration leaks or C02 in the space rises quickly.

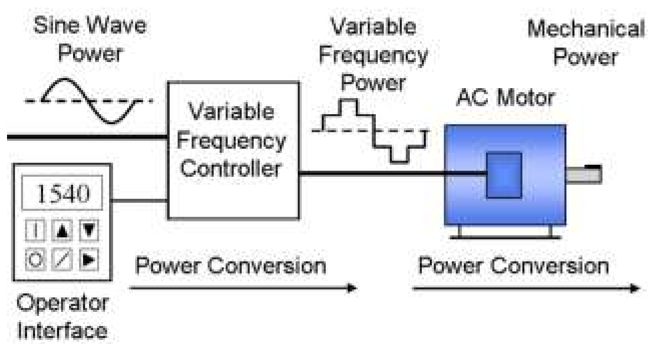


Figure 23: Typical VFD Control System

While the VRF system is capable of keeping the air cooled or heated to the desired rating, the DOAS system keeps the buildings air from becoming too stale by bringing in fresh air. To allow the DAOS to adjust the amount of fresh air coming into the spaces, a VFD is used. For our building needs, one VFD is used per DOAS unit. Current control settings are set so that if the building goes over 0.2 in. WC positive pressure, the exhaust fan kicks on. If the total building pressure drops down to 0.1 in. WC positive pressure, the DOAS kicks on. The purpose behind keeping the building positive pressurized is so that the moist contaminated outside air cannot get inside the building and cause problems with indoor air quality and other envelope factors such as mold. To control these settings in our building, pressure sensors have been selected that will allow the DOAS and exhaust system to ramp-up or slow down depending on the building pressure and current needs. Additionally bathroom air needs to be contained or negative pressurized so it does not leak into office spaces. To solve these issues pressure sensors will be located in each restroom, one in each research and development room, one for the clean room, and 8 sensors throughout the rest of the building at key locations like entry ways. These pressure sensors will communicate with the BACnet system and regulate the fans based on these sensor readings.

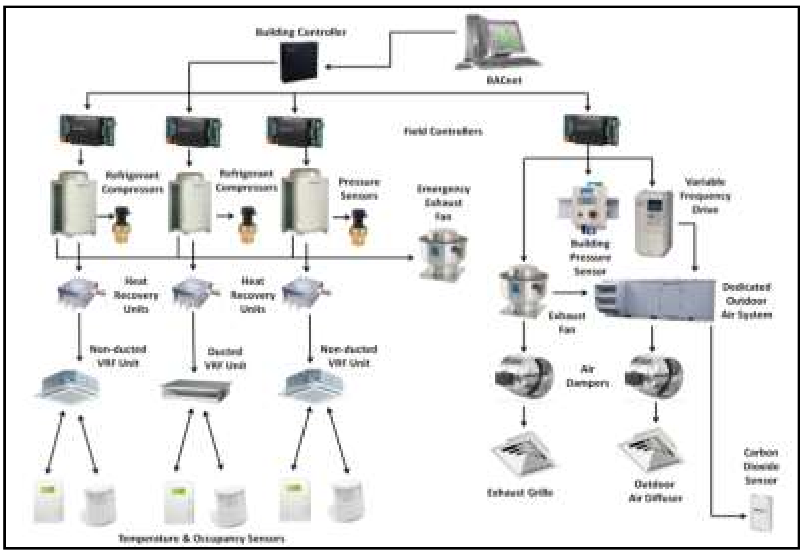


Figure 24: Controls Flow Chart

With refrigerant leakage being a large safety factor for individuals in the building, the VRF system needs to be controlled with pressure sensors and safety shutoff valves along the piping lengths. These sensors are rated with regards to ASHRAE standard 15 based on the R-410a refrigerant rating. The valves and sensors will allow the system to switch into a safe mode depending on the system needs.

Maintenance

The majority of the maintenance involves different types of filters for different units of the system. Starting with the DOAS system, the system has a DOAS pre-filter and a DOAS final filter that have to be changed monthly. The individual evaporators have a VRF filter that will have to be changed every three months depending on the condition of the filter. For the clean room and R&D rooms, HEPA filters are used for higher effectiveness in filtering particles. These filters must be changed each month and can be tracked by pressure sensors in the ductwork. The maintenance schedule for changing filters must be planned in order to keep the cleanroom at its regulated PPM.

Other parts of the system that require maintenance is the cooling coil located in each evaporator unit and the exhaust fans. For the system to remain effective, the coils must stay clean. To keep the coils clean, UV-C band lighting will be installed across the evaporator coils. The bulbs in these UV lights will need to be changed every 12 months for adequate coil cleaning additionally, belt fans must be checked by maintenance workers every three months and changed accordingly, typically every six months.

Section 8: Conclusion

The overall objective of this senior design project was to design an HVAC system by selecting mechanical equipment based on design calculations for all spaces contained within the building while meeting all requirements provided by ASHRAE outlined in the owner's project requirements (OPR). This project was spanned over the length of two semesters. The goal in the first semester was to obtain rough load calculations and know what equipment was going to be used with the exception of exact sizing. In the second semester, loads were perfected, a detailed Revit model was produced, final equipment selections and an overall price for the project was obtained. Load calculations were performed in Trane Trace 700 for all spaces based on room type and size. The resulting total building load was 1,364 MBH.

From the OPR, VRF's needed to be used throughout the building so appropriate equipment was selected to satisfy these requirements. A 20 ton DOAS unit, three condensing units and several heat recovery units were used to supply required air to all types of VRF units contained within the building. A separate 50 ton DOAS unit was used for lab areas due to high air change requirement of the clean room and high exhaust rate in the four research and development areas. For each DOAS unit, an exhaust fan was used, and one additional exhaust fan was selected for emergencies only, in the case of a refrigeration leak. Other areas where a lot of emphasis was placed were the controls and the sequence of operations of the systems in place. The total cost associated with the selected systems came out to be $570,203.83. In completing this project, this design encompasses efficiency, health and safety, comfort, functionality, longevity, flexibility and maintainability with a low life cycle cost.

Appendix

Table 11: Trane Trace Load Calculation Sample

System	Zone Room		Floor Area ft²	People #	Coil Cooling Sensible Btu/h	Coil Cooling Total Btu/h	Space Design Max SA cfm	Air Changes ach/hr	VAV Minimum SA cfm	VAV Minimum %	Main Coil Heating Sensible Btu/h	Heating Fan Max SA cfm	Percent OA Clg	Percent OA Htg
Alternative 1														
	COMPUTER SERVER ROOM - 130	Rm Peak	396	0.0	74,996	78,132	3,299	62.48	330	10	-8,164	2,969	3.2	3.2
	CONFERENCE ROOM - 138	Rm Peak	242	6.0	3,891	5,833	194	6.00	19	10	-4,510	174	33.3	33.3
	CORRIDOR - 105	Rm Peak	448	0.0	18,461	18,461	815	13.64	82	10	-13,153	734	0.0	0.0
	CORRIDOR - 106	Rm Peak	798	0.0	3,914	3,914	213	2.00	21	10	-3,873	192	0.0	0.0
	CORRIDOR - 107/103	Rm Peak	739	0.0	3,290	3,290	197	2.00	20	10	-1,639	177	0.0	0.0
	CORRIDOR - 122	Rm Peak	430	0.0	3,188	3,188	128	2.23	13	10	-2,032	115	0.0	0.0
	ELECTRICAL - 142	Rm Peak	105	0.0	902	1,112	56	4.00	6	10	-1,950	50	50.0	50.0
	ELEV MACH RM - 146	Rm Peak	49	2.0	6,938	7,708	393	60.11	39	10	-1,006	353	3.3	3.3
	HR OFFICE - 135	Rm Peak	100	1.0	1,238	1,646	80	6.00	8	10	-1,864	72	33.3	33.3
	HR OFFICE - 136	Rm Peak	105	1.0	1,287	1,704	84	6.00	8	10	-1,957	76	33.3	33.3
	HUMAN RESOURCES FILING - 137	Rm Peak	100	1.0	1,238	1,646	80	6.00	8	10	-1,864	72	33.3	33.3
	JAN/MECH - 131/132	Rm Peak	104	0.0	893	1,102	56	4.00	6	10	-1,931	50	50.0	50.0
	LIBRARY - 104	Rm Peak	364	5.0	6,658	9,624	291	6.00	29	10	-7,876	262	33.3	33.3
	LOBBY - 101	Rm Peak	522	17.4	13,480	16,960	584	8.39	58	10	-6,930	526	0.0	0.0
	MAILROOM - 147	Rm Peak	907	0.0	5,758	5,758	242	2.00	24	10	-6,445	218	0.0	0.0
	MEETING ROOM #3A - 119	Rm Peak	444	5.0	8,989	12,439	474	8.00	47	10	-29,990	426	100.0	100.0
	MEETING ROOM #3B - 120	Rm Peak	444	5.0	8,989	12,439	474	8.00	47	10	-29,990	426	100.0	100.0
	MENS RESTROOM - 127	Rm Peak	303	0.0	2,373	2,380	242	6.00	24	10	-5,647	218	33.3	33.3
	OFFICE - 133D	Rm Peak	108	1.0	2,402	3,234	135	9.36	13	10	-3,157	121	21.4	21.4
	OFFICE - 140B	Rm Peak	107	1.0	1,926	2,587	86	6.00	9	10	-3,152	77	33.3	33.3
	OPEN OFFICE - 133A	Rm Peak	897	6.0	10,358	13,281	718	6.00	72	10	-16,718	646	33.3	33.3
	OPEN OFFICE - 133B	Rm Peak	846	1.0	12,798	17,978	677	6.00	68	10	-18,748	609	33.3	33.3
	OPEN OFFICE - 133C	Rm Peak	846	1.0	13,186	18,232	677	6.00	68	10	-18,631	609	33.3	33.3
	OPEN OFFICE - 140A	Rm Peak	1,192	7.9	17,309	22,590	954	6.00	95	10	-28,860	858	33.3	33.3
	OPEN OFFICE - 140B	Rm Peak	1,545	10.3	17,840	22,875	1,236	6.00	124	10	-28,796	1,112	33.3	33.3
	OPEN OFFICE - 140C	Rm Peak	1,327	8.8	25,373	33,526	1,062	6.00	106	10	-31,243	955	33.3	33.3
	STORAGE - 139	Rm Peak	130	0.0	534	534	35	2.00	3	10	-288	31	0.0	0.0
	TRADITIONAL STORAGE - 145	Rm Peak	500	0.0	5,004	5,004	203	3.05	20	10	-6,713	183	0.0	0.0
	VESTIBULE - 100	Rm Peak	127	0.0	7,160	7,160	318	18.78	32	10	-6,733	286	0.0	0.0
	VESTIBULE - 121	Rm Peak	367	0.0	1,634	1,634	98	2.00	10	10	-814	88	0.0	0.0
	WARMING KITCHEN - 108	Rm Peak	262	2.0	5,083	6,588	524	15.00	52	10	-9,331	472	20.0	20.0
	WOMENS RESTROOM - 125	Rm Peak	415	0.0	3,260	3,273	332	6.00	33	10	-7,736	299	33.3	33.3
System 1		**Sys Peak**	**15,269**	**82.5**	**293,278**	**346,792**	**14,953**				**-311,740**	**13,458**	**23.4**	**23.4**
System 1		**Sys Block**	**15,269**	**82.5**	**279,673**	**333,807**	**14,953**				**-311,740**	**13,458**	**23.4**	**23.4**

Figure 25: Revit Clean Room Rendering

CONDENSING UNIT SCHEDULE																				
PLAN MARK	BASIS OF DESIGN			COOLING DATA						HEATING DATA			ELECTRICAL DATA							WEIGHT
							AMBIENT TEMP						CONDENSOR						UNIT	
	MFGR	MODEL	TYPE	TOTAL BTU/HR	REFRIG. TYPE	NO. CIRCUITS	DB °F	WB °F	EER	TOTAL BTU/HR	AMBIENT DB	HEATING COP	COMPRESSOR QTY	COMPRESSOR RLA	FAN QTY	FAN FLA	MCA	MOP	VOLTS	PHASE	
CU-1	LG	ARUB288BTE4	VAR. REF.	288,000	R-410A	2	80	67	13.3	324,000	47	3.9	4	24.8	4	5.2	48.8	60	208	3	1256
CU-2	LG	ARUB288BTE4	VAR. REF.	288,000	R-410A	2	80	67	13.3	324,000	47	3.9	4	24.8	4	5.2	48.8	60	208	3	1256
CU-3	LG	ARUB144BTE4	VAR. REF.	144,000	R-410A	2	80	67	13.2	162,000	47	3.9	2	12.4	2	2.6	48.8	60	208	3	628

INTERLOCK SCHEDULE	
AIR HANDLING UNIT	EXHAUST FAN
DOAS-1	EF-1

NOTES:

1. PROVIDE FIRE ALARM RELAYS FOR AUTOMATIC SHUT DOWN.
2. PROVIDE CONTROL RELAYS FOR MANUAL SHUT DOWN OF EXHAUST FANS AT THE AHU STARTER. EXHAUST FANS SHALL SHUT DOWN UPON MANUAL DEACTIVATION OF AIR HANDLER.
3. AHU AND INTERLOCKED EXHAUST FANS SHALL AUTOMATICALLY RESTART UPON FIRE ALARM RESET OR MANUAL REACTIVATION.

SEQUENCE OF OPERATIONS

DEDICATED OUTDOOR AIR SYSTEM

START/STOP:

WHEN THE DOAS IS INDEXED TO OPERATE BY OPERATOR COMMAND, EXHAUST FANS SHALL START. DOASS SHALL BE SEQUENCED TO OPERATE BASED UPON OCCUPANCY SCHEDULE OF FACILITY. AFTER ADJUSTABLE TIME DELAY, THE DOAS SUPPLY FAN SHALL START THROUGH THE VFD. ALL SAFETIES AND INTERLOCKS SHALL OPERATE THROUGH THE VFD IN BYPASS OR AUTOMATIC MODE. SEE INTERLOCK SCHEDULE FOR DOAS AND EXHAUST FAN INTERLOCKS. BAS SHALL MONITOR FAN STATUS, RETURN AIR TEMPERATURE, RELATIVE HUMIDITY, FILTER ALARMS AND ALL OTHER SENSORS.

DOAS SHALL INCREASE/DECREASE IN SPEED BASED ON BUILDING PRESSURE AND OCCUPANCY. DOAS VFD SHALL AUTOMATICALLY DECREASE IN SPEED TO MAINTAIN ADJUSTED STATIC PRESSURE SETPOINT.

UPON DOAS SHUTDOWN, OA DAMPER SHALL AUTOMATICALLY CLOSE.

SAFETIES

BUILDING FIRE ALARM:

WHEN BUILDING FIRE ALARM IS ACTIVATED, THE FOLLOWING SHALL OCCUR: DOAS UNIT SHALL DE-ENERGIZE AND THE ASSOCIATED EXHAUST FANS SHALL STOP. UPON ACTIVATION OF SMOKE DUCT DETECTORS THE AIR HANDLING UNIT AND ASSOCIATED EXHAUST FANS SHALL DE-ENERGIZE.

HIGH STATIC SHUTDOWN:

A HIGH LIMIT STATIC PRESSURE SENSOR BETWEEN THE SUPPLY FAN DISHARGE AND THE FIRST DAMPER DOWNSTREAM OF THE SUPPLY FAN SHALL PREVENT OVER PRESSURIZATION OF THE SUPPLY DUCTWORK. IF THE DISCHARGE STATIC PRESSURE RISES ABOVE THE SETPOINT AS MEASURED BY THE HIGH STATIC LIMIT THE DOAS SHALL BE DE-ENERGIZED BY THE BAS SYSTEM AND AN ALARM INITIATED. DOAS SHALL NOT BE ALLOWED TO RUN UNTIL AN OPERATOR MANUALLY RESETS THE SENSOR AT THE UNIT.

VRF (FCU) SCHEDULE																			
MARK	BASIS OF DESIGN			SA CFM	ESP (IN-WG)	COOLING CAPACITY						HEATING CAPACITY			ELECTRICAL DATA				LEVEL
	MFGR	MODEL	TYPE			TOTAL BTU /HR	SENS. BTU/HR	EAT DB °F	EAT WB °F	LAT DB °F	LAT WB °F	TOTAL BTU/HR	EAT DB °F	LAT DB °F	VOLTS	PHASE	MOP	AMPS	
01-HR1-VRF1	LG	ARNU363BGA2	DUCTED	975	0.4	36,200	26,800	80	67	55	85	40,600	55	85	208	1	15	2.3	LEVEL 1
01-HR1-VRF2	LG	ARNU363BGA2	DUCTED	900	0.4	36,200	26,800	80	67	55	85	40,600	55	85	208	1	15	2.3	LEVEL 1
01-HR1-VRF3	LG	ARNU363BGA2	DUCTED	875	0.4	36,200	26,800	80	67	55	85	40,600	55	85	208	1	15	2.3	LEVEL 1
01-HR2-VRF1	LG	ARNU243BHA2	DUCTED	650	0.3	24,200	17,700	80	67	55	85	27,300	55	85	208	1	15	0.9	LEVEL 1
01-HR2-VRF2	LG	ARNU363BGA2	DUCTED	900	0.4	36,200	26,800	80	67	55	85	40,600	55	85	208	1	15	2.3	LEVEL 1
01-HR2-VRF3	LG	ARNU053TRC2	CASSETTE	200	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 1
01-HR3-VRF1	LG	ARNU053TRC2	CASSETTE	100	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 1
01-HR3-VRF2	LG	ARNU053TRC2	CASSETTE	100	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 1
01-HR3-VRF3	LG	ARNU053TRC2	CASSETTE	100	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 1
01-HR3-VRF4	LG	ARNU053TRC2	CASSETTE	100	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 1
01-HR4-VRF1	LG	ARNU053TRC2	CASSETTE	100	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 1
01-HR4-VRF2	LG	ARNU363BGA2	DUCTED	825	0.4	36,200	26,800	80	67	55	85	40,600	55	85	208	1	15	2.3	LEVEL 1
01-HR5-VRF1	LG	ARNU073BHA2	DUCTED	300	0.3	7,500	5,500	80	67	55	85	8,500	55	85	208	1	15	0.9	LEVEL 1
01-HR5-VRF2	LG	ARNU243BHA2	DUCTED	450	0.3	24,200	17,700	80	67	55	85	27,300	55	85	208	1	15	0.9	LEVEL 1
01-HR6-VRF1	LG	ARNU053TRC2	CASSETTE	100	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 1
01-HR6-VRF2	LG	ARNU053TRC2	CASSETTE	150	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 1
01-HR6-VRF3	LG	ARNU053TRC2	CASSETTE	100	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 1
01-HR7-VRF1	LG	ARNU053TRC2	CASSETTE	150	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 1
01-HR7-VRF2	LG	ARNU123TRC2	CASSETTE	250	0	12,300	8,900	80	67	55	85	13,600	55	85	208	1	15	0.2	LEVEL 1
01-HR7-VRF3	LG	ARNU123TRC2	CASSETTE	350	0	12,300	8,900	80	67	55	85	13,600	55	85	208	1	15	0.2	LEVEL 1
01-HR8-VRF1	LG	ARNU073BHA2	DUCTED	300	0.3	7,500	5,500	80	67	55	85	8,500	55	85	208	1	15	0.9	LEVEL 1
01-HR9-VRF1	LG	ARNU243TRC2	CASSETTE	475	0	22,700	16,500	80	67	55	85	24,300	55	85	208	1	15	0.9	LEVEL 1
01-HR9-VRF2	LG	ARNU243TRC2	CASSETTE	475	0	22,700	16,500	80	67	55	85	24,300	55	85	208	1	15	0.9	LEVEL 1
01-HR9-VRF3	LG	ARNU053TRC2	CASSETTE	200	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 1
01-HR10-VRF1	LG	ARNU053TRC2	CASSETTE	150	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 1
01-HR10-VRF2	LG	ARNU243TRC2	CASSETTE	825	0	22,700	16,500	80	67	55	85	24,300	55	85	208	1	15	0.9	LEVEL 1
02-HR1-VRF1	LG	ARNU053TRC2	CASSETTE	150	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 1
02-HR1-VRF2	LG	ARNU053TRC2	CASSETTE	100	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 1
02-HR1-VRF3	LG	ARNU363TNC2	CASSETTE	1,650	0	36,500	32,100	80	67	55	85	38,600	55	85	208	1	15	2.3	LEVEL 1
02-HR1-VRF4	LG	ARNU363TNC2	CASSETTE	1,650	0	36,500	32,100	80	67	55	85	38,600	55	85	208	1	15	2.3	LEVEL 1
02-HR2-VRF1	LG	ARNU053TRC2	CASSETTE	200	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 1
02-HR2-VRF2	LG	ARNU073BHA2	DUCTED	375	0.3	7,500	5,500	80	67	55	85	8,500	55	85	208	1	15	0.9	LEVEL 1
02-HR3-VRF1	LG	ARNU123TRC2	CASSETTE	300	0	12,300	8,900	80	67	55	85	13,600	55	85	208	1	15	0.2	LEVEL 2
02-HR3-VRF2	LG	ARNU053TRC2	CASSETTE	100	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 2
02-HR3-VRF3	LG	ARNU053TRC2	CASSETTE	100	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 2
02-HR4-VRF1	LG	ARNU363BGA2	DUCTED	725	0.4	36,200	26,800	80	67	55	85	40,600	55	85	208	1	15	2.3	LEVEL 2
02-HR4-VRF2	LG	ARNU053TRC2	CASSETTE	100	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 2
02-HR4-VRF3	LG	ARNU053TRC2	CASSETTE	150	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 2
02-HR4-VRF4	LG	ARNU243BHA2	DUCTED	600	0.3	24,200	17,700	80	67	55	85	27,300	55	85	208	1	15	0.9	LEVEL 2
02-HR5-VRF1	LG	ARNU053TRC2	CASSETTE	100	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 2
02-HR5-VRF2	LG	ARNU123TRC2	CASSETTE	275	0	12,300	8,900	80	67	55	85	13,600	55	85	208	1	15	0.2	LEVEL 2
02-HR5-VRF3	LG	ARNU053TRC2	CASSETTE	100	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 2
02-HR5-VRF4	LG	ARNU123TRC2	CASSETTE	275	0	12,300	8,900	80	67	55	85	13,600	55	85	208	1	15	0.2	LEVEL 2
02-HR6-VRF1	LG	ARNU053TRC2	CASSETTE	100	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 2
02-HR6-VRF2	LG	ARNU053TRC2	CASSETTE	100	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 2
02-HR6-VRF3	LG	ARNU053TRC2	CASSETTE	100	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 2
02-HR6-VRF4	LG	ARNU123TRC2	CASSETTE	425	0	12,300	8,900	80	67	55	85	13,600	55	85	208	1	15	0.2	LEVEL 2
02-HR7-VRF1	LG	ARNU053TRC2	CASSETTE	100	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 2
02-HR7-VRF2	LG	ARNU053TRC2	CASSETTE	150	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 2
02-HR7-VRF3	LG	ARNU243TRC2	CASSETTE	600	0	22,700	16,500	80	67	55	85	24,300	55	85	208	1	15	0.9	LEVEL 2
02-HR7-VRF4	LG	ARNU053TRC2	CASSETTE	125	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 2
02-HR8-VRF1	LG	ARNU053TRC2	CASSETTE	100	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 2
02-HR8-VRF2	LG	ARNU243TRC2	CASSETTE	475	0	22,700	16,500	80	67	55	85	24,300	55	85	208	1	15	0.9	LEVEL 2
02-HR8-VRF3	LG	ARNU053TRC2	CASSETTE	100	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 2
02-HR8-VRF4	LG	ARNU243TRC2	CASSETTE	600	0	22,700	16,500	80	67	55	85	24,300	55	85	208	1	15	0.9	LEVEL 2
02-HR9-VRF1	LG	ARNU053TRC2	CASSETTE	100	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 2
02-HR9-VRF2	LG	ARNU073BHA2	DUCTED	300	0.3	7,500	5,500	80	67	55	85	8,500	55	85	208	1	15	0.9	LEVEL 2
02-HR9-VRF3	LG	ARNU053TRC2	CASSETTE	150	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 2
03-HR1-VRF1	LG	ARNU123TRC2	CASSETTE	225	0	12,300	8,900	80	67	55	85	13,600	55	85	208	1	15	0.2	LEVEL 2
03-HR1-VRF2	LG	ARNU363BGA2	DUCTED	825	0.4	36,200	26,800	80	67	55	85	40,600	55	85	208	1	15	2.3	LEVEL 2
03-HR1-VRF3	LG	ARNU053TRC2	CASSETTE	150	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 2
03-HR2-VRF1	LG	ARNU243BHA2	DUCTED	650	0.3	24,200	17,700	80	67	55	85	27,300	55	85	208	1	15	0.9	LEVEL 2
03-HR2-VRF2	LG	ARNU363BGA2	DUCTED	975	0.4	36,200	26,800	80	67	55	85	40,600	55	85	208	1	15	2.3	LEVEL 2
03-HR2-VRF3	LG	ARNU053TRC2	CASSETTE	100	0	5,500	3,900	80	67	55	85	6,100	55	85	208	1	15	0.2	LEVEL 2
03-HR3-VRF1	LG	ARNU243BHA2	DUCTED	650	0.3	24,200	17,700	80	67	55	85	27,300	55	85	208	1	15	0.9	LEVEL 2
03-HR3-VRF2	LG	ARNU243BHA2	DUCTED	675	0.3	24,200	17,700	80	67	55	85	27,300	55	85	208	1	15	0.9	LEVEL 2
03-HR3-VRF3	LG	ARNU363BGA2	DUCTED	1,000	0.4	36,200	26,800	80	67	55	85	40,600	55	85	208	1	15	2.3	LEVEL 2
03-HR4-VRF1	LG	ARNU363BGA2	DUCTED	750	0.4	36,200	26,800	80	67	55	85	40,600	55	85	208	1	15	2.3	LEVEL 2
03-HR4-VRF2	LG	ARNU243BHA2	DUCTED	500	0.3	24,200	17,700	80	67	55	85	27,300	55	85	208	1	15	0.9	LEVEL 2

AIR DISTRIBUTION SCHEDULE				
MARK	CFM	NECK SIZE	FACE SIZE LENGTH	DESCRIPTION
A	000-110	6Ø	24x24	SUPPLY DIFFUSER
	111-240	8Ø	24x24	BASIS OF DESIGN: TITUS OMNI
	241-420	10Ø	24x24	COLOR: WHITE
	421-620	12Ø	24x24	MATERIAL: ALUMINUM
	621-750	14Ø	24x24	OPPOSED BLADE DAMPERS: NO
	751-980	16Ø	24x24	
B	000-110	6x6	24x24	SUPPLY DIFFUSER
	111-220	8x8	24x24	BASIS OF DESIGN: TITUS OMNI
	221-350	10x10	24x24	COLOR: WHITE
	351-530	12x12	24x24	MATERIAL: ALUMINUM
	531-730	14x14	24x24	OPPOSED BLADE DAMPERS: NO
	731-970	16x16	24x24	1/2"x1/2"x1/2" GRID
	971-1240	18x18	24x24	
	1241-1540	20x20	24x24	
	1541-1880	22x22	24x24	

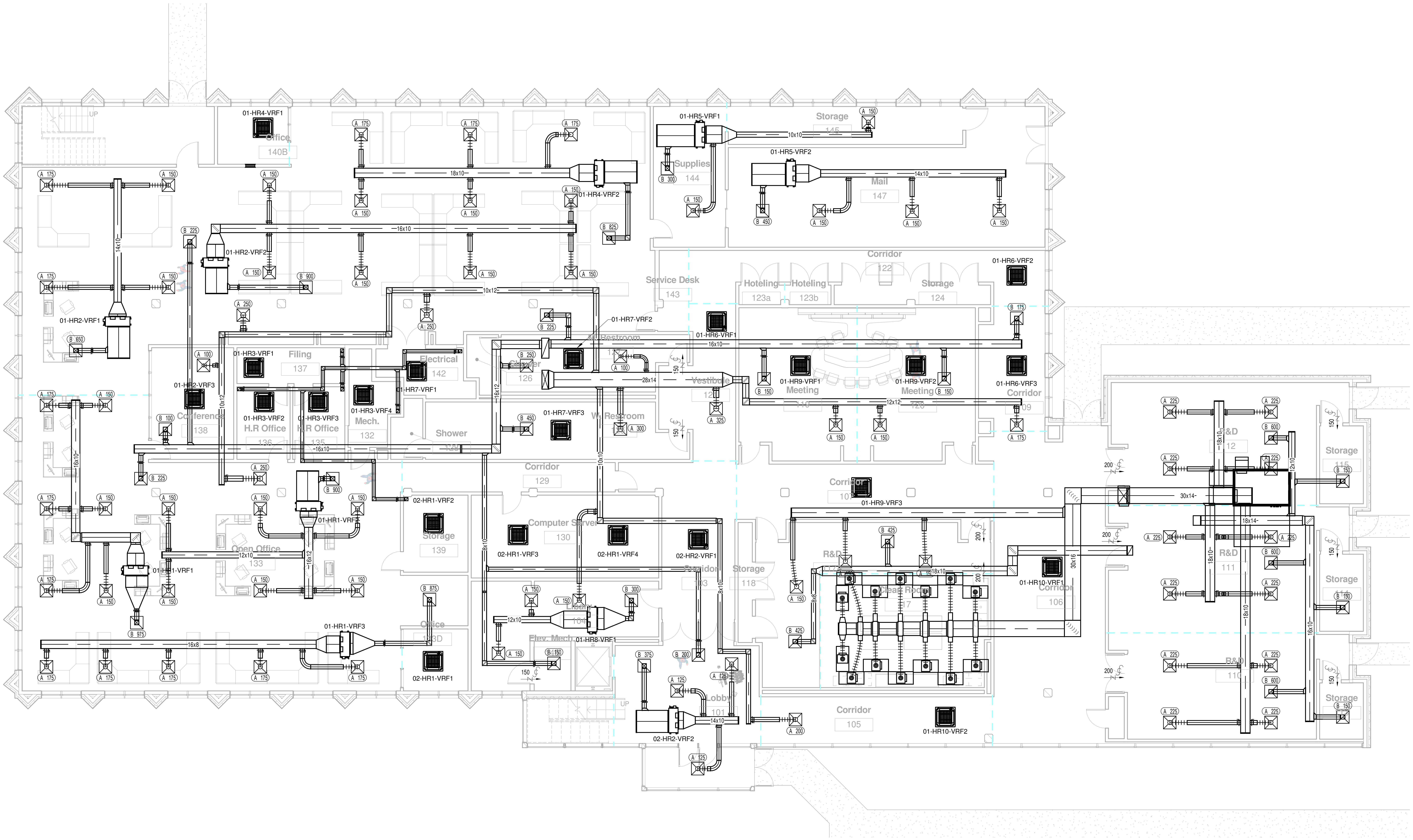
LABORATORY AIR VALVE SCHEDULE						
Mark	BASIS OF DESIGN			VALVE AIRFLOW CFM		MIN. ESP (IN-WG)
	SIZE	MODEL	USE	MAX	MIN	
SV-1A	10Ø	T-BVT2114-10	SUPPLY	1240	300	0.3
EV-1A	6Ø	T-BVT2114-06	EXHAUST	500	80	0.3
FEV-1A	10Ø	T-BVT2124-10	FUME	1440	250	0.3
SV-1B	10Ø	T-BVT2114-10	SUPPLY	1240	300	0.3
EV-1B	6Ø	T-BVT2114-06	EXHAUST	500	80	0.3
FEV-1B	10Ø	T-BVT2124-10	FUME	1440	250	0.3
SV-1C	10Ø	T-BVT2114-10	SUPPLY	1500	300	0.3
EV-1C	6Ø	T-BVT2114-06	EXHAUST	500	80	0.3
FEV-1C	4Ø	T-BVT2124-04	FUME	200	40	0.3
FEV-1C	10Ø	T-BVT2124-10	FUME	1500	250	0.3
SV-1C	10Ø	T-BVT2114-10	SUPPLY	1400	390	0.3
EV-1C	12Ø	T-BVT2114-12	EXHAUST	1600	350	0.3

DOAS PLAN MARK	UNIT TYPE	MODEL	AIR FLOW			TOTAL SP (IN. WG)	WHEEL DIA (IN.)/TYPE	MOTOR HP	RPM	ELECTRICAL V/C/P	VFD	COOLING COIL - DX				HEATING COIL - DX				CAPACITY - DX COOLING					FILTERS	
												DESIGN CONDITIONS - SUMMER				DESIGN CONDITIONS - WINTER										
												ENTERING - BEFORE WHEEL		LEAVING - AFTER WHEEL		ENTERING - WHEEL		LEAVING- WHEEL								
			VOL. (CFM)	OA (CFM)	RECIRC (CFM)							DB	WB	DB	WB	DB	WB	DB	WB	SEN. (MBH)	TOTAL (MBH)	NOM TON	REFRIGERANT TYPE	COMPRESSOR QUANTITY	MERV	INFO.
DOAS-1	CUSTOM	RVE-50-46P-30H-17.5	4400	4400	0	2.057	60"/PLENUM	3	1150	460/60/3	YES	87	73	82.3	69.3	38	31.9	51.4	42.6	131.9	214.2	17.5	410A	2	MERV 8	2" PLEATED
DOAS-2	CUSTOM	RN-050_R2	5380	5380	0	3.07	24.5"/PLENUM	7.5	1800	460/3/60	YES	93	75	87.5	74.7	13	12	87.3	53.8	282.67	503.34	50	410A	4	MERV 8	2" PLEATED

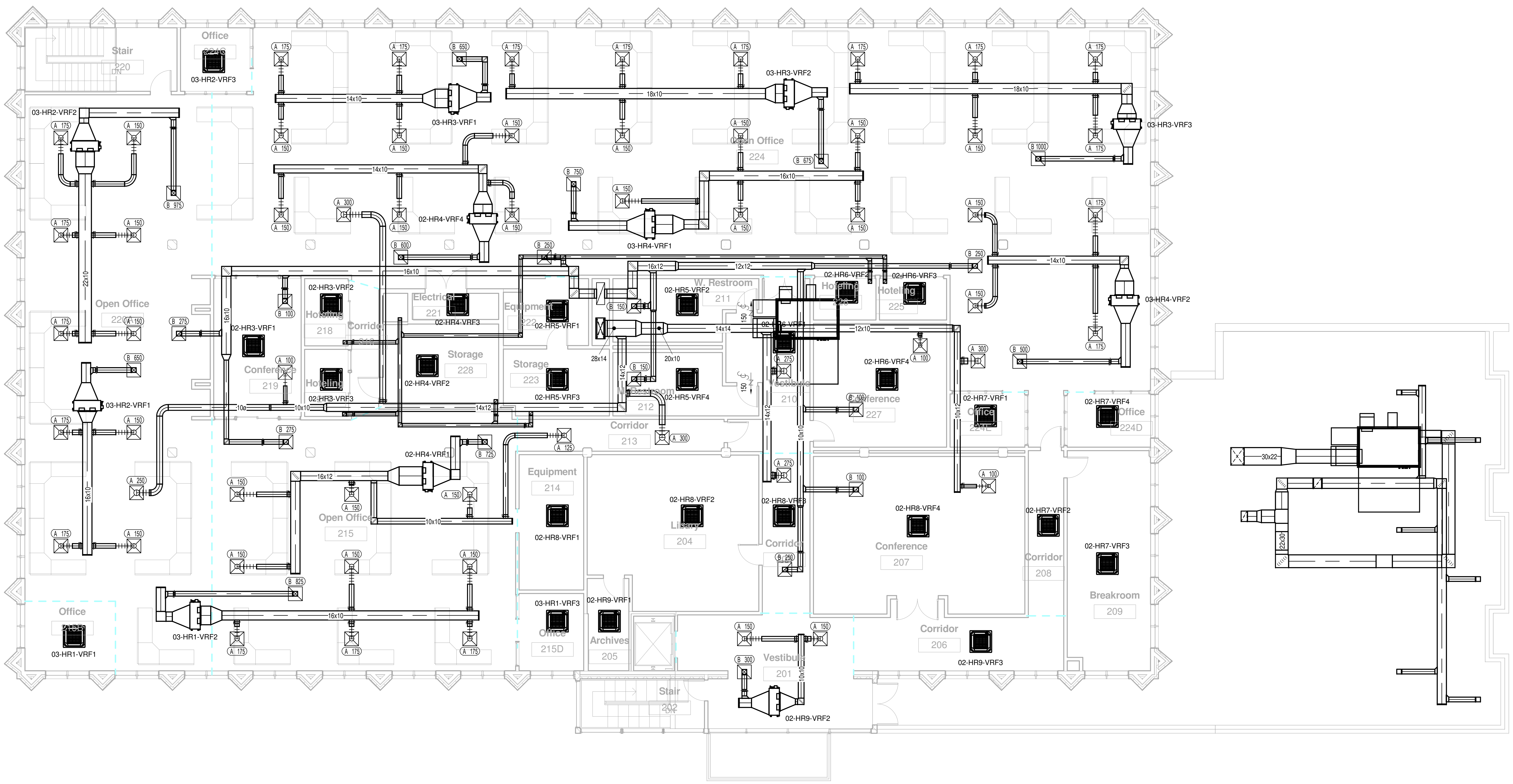
DDC POINT SCHEDULE

SYSTEM POINT DESCRIPTION	COMMUNICATION/DATA INTERFACE	ANALOG INPUT: TEMPERATURE	HUMIDITY	VRF VALVE POSITION	AIR VALVE POSITION	T-STAT ROOM TEMPERATURE	FLOW RATE	SPEED	ANALOG OUTPUT: SET POINT ADJUSTMENT	VALVE ACTUATOR	DAMPER ACTUATOR	DIGITAL INPUT: PULSE METER (B/O)	DIFFERENTIAL PRESSURE SWITCH	STATUS	SPEED SWITCH	CURRENT RELAY	DIGITAL OUTPUT: FLOW SWITCH	ON-OFF	DAMPER ACTUATOR	VALVE ACTUATOR	SYSTEM FEATURES ALARMS: PROOF	COMMUNICATION FAILURE	DIRTY FILTER	HIGH-LOW VALUE	PROGRAMS: TIME SCHEDULING	OPT. START/STOP	RESET	RUN TIME	SET BACK-SET UP	MORNING WARMUP	GRAPHIC
DOAS (TYPICAL)																															
ALL EXISTING POINTS TO REMAIN																															
OUTSIDE AIR																															
FAN VFD																															
VRF UNITS																															
RETURN AIR HUMIDITY																															
DISHARGE AIR																															
CLEAN ROOM PRESSURE MONITOR																															

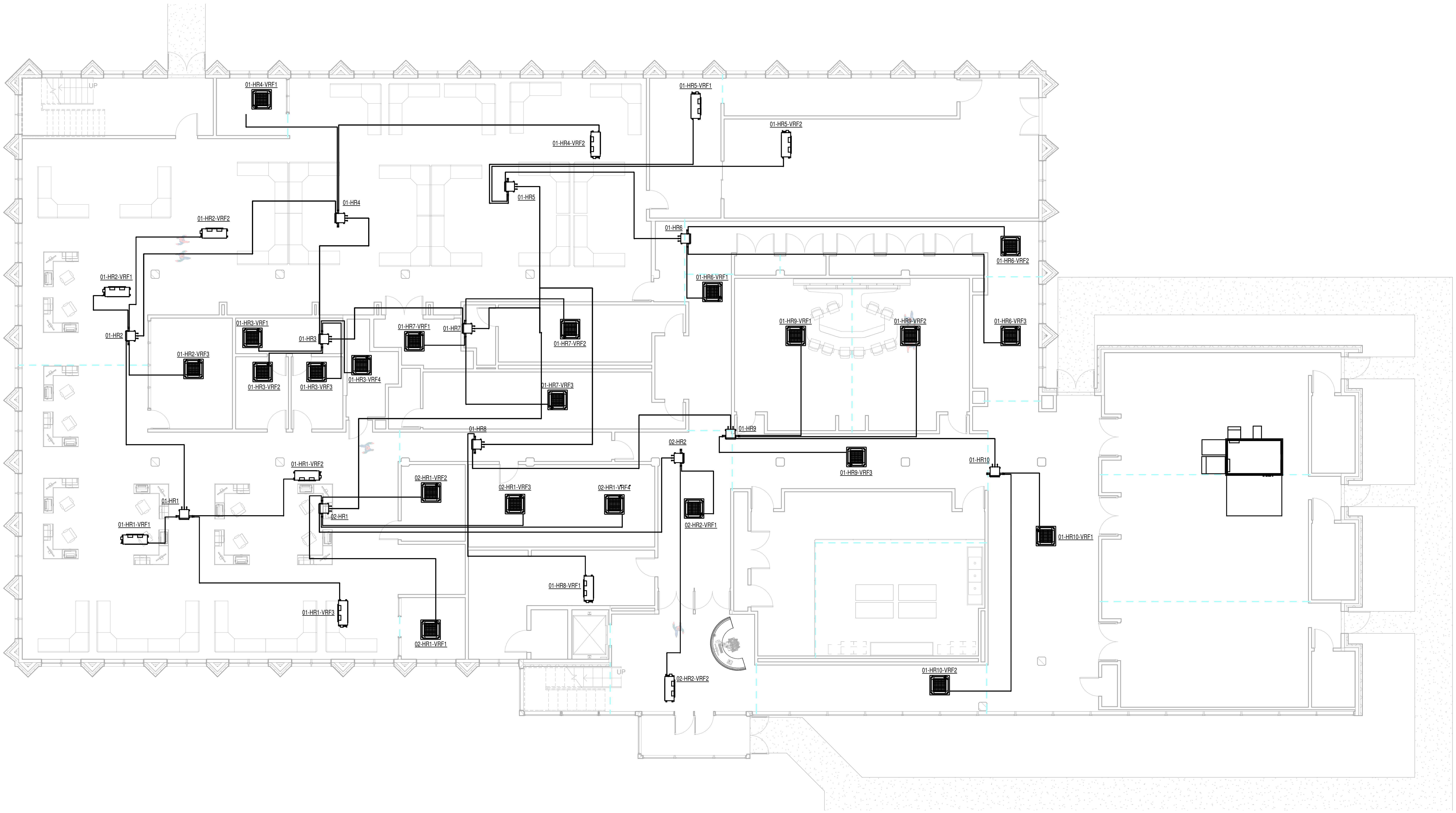
FAN SCHEDULE												
PLAN MARK	MODEL NO.	TYPE	CFM	STATIC PRESS	FAN RPM	MOTOR		VOLT/ PHASE	DRIVE TYPE	FAN SERVICE	FAN INTERLOCK	WEIGHT
						RPM	HP					
EF-1	G-203-B	UPBLAST	4400	1	1085	1140	2	460/3	DIRECT	GENERAL	DOAS-1	160
EF-2	EKTOR-H-22-2	HIGH PLUME	7230	2.2	1601	1725	7 1/2	460/3	BELT	LAB	DOAS-2	2136
EF-3	CUE-141-C	UPBLAST	900	0.3	860	860	1/8	115/1	DIRECT	EMERGENCY	DOAS-1	70

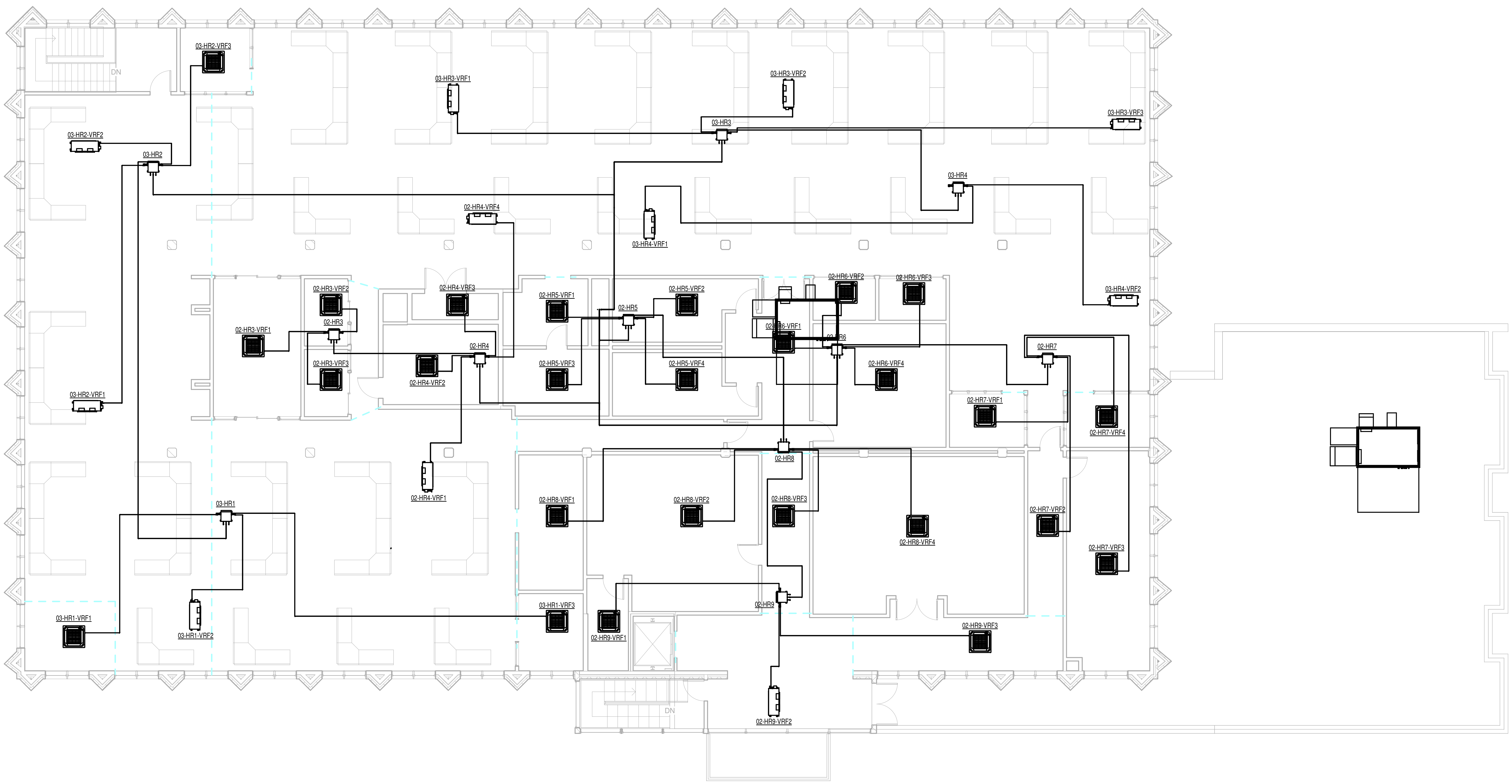


01-HR4-VRF1
01-HR4-VRF2
01-HR5-VRF1
01-HR5-VRF2
01-HR2-VRF1
01-HR2-VRF2
01-HR2-VRF3
01-HR3-VRF1
01-HR3-VRF2
01-HR3-VRF3
01-HR3-VRF4
01-HR7-VRF1
01-HR7-VRF2
01-HR7-VRF3
01-HR6-VRF1
01-HR6-VRF2
01-HR6-VRF3
01-HR9-VRF1
01-HR9-VRF2
01-HR9-VRF3
01-HR1-VRF1
01-HR1-VRF2
01-HR1-VRF3
02-HR1-VRF1
02-HR1-VRF2
02-HR1-VRF3
02-HR1-VRF4
02-HR2-VRF1
02-HR2-VRF2
01-HR8-VRF1
01-HR10-VRF1
01-HR10-VRF2
Office 140B
Storage 145
Supplies 144
Mail 147
Corridor 122
Service Desk 143
Hoteling 123a
Hoteling 123b
Storage 124
Filing 137
Electrical 142
Shower 126
Conference 138
H.R Office 136
H.R Office 135
Mech. 132
Shower
W. Restroom
Vestibule
Meeting
Corridor
Corridor 129
Computer Server 130
Storage 139
Open Office 133
Office
Elev. Mech.
Lobby 101
Corridor 105
Storage 118
R&D
Clean Room
R&D 111
Storage
18x10
16x10
14x10
10x12
16x12
28x14
12x12
12x10
16x8
10x10
8x10
30x14
30x16
18x14



Stair
220
Office
03-HR2-VRF3
03-HR2-VRF2
03-HR3-VRF1
03-HR3-VRF2
03-HR3-VRF3
14x10
18x10
16x10
02-HR4-VRF4
03-HR4-VRF1
03-HR4-VRF2
Open Office
224
Open Office
22x10
12x12
16x12
14x14
28x14
20x10
12x10
10x10
10x12
14x12
02-HR3-VRF2
02-HR3-VRF1
02-HR3-VRF3
Hoteling
218
Conference
219
Corridor
Electrical
221
02-HR4-VRF3
02-HR4-VRF2
Storage
228
Storage
223
Equipment
222
02-HR5-VRF1
02-HR5-VRF2
02-HR5-VRF3
02-HR5-VRF4
W. Restroom
211
212
02-HR6-VRF2
02-HR6-VRF3
02-HR6-VRF4
Hoteling
225
227
03-HR2-VRF1
02-HR7-VRF1
02-HR7-VRF2
02-HR7-VRF3
02-HR7-VRF4
Office
224D
Corridor
213
210
16x10
02-HR4-VRF1
Open Office
215
Equipment
214
02-HR8-VRF1
02-HR8-VRF2
02-HR8-VRF3
02-HR8-VRF4
Library
204
Corridor
Conference
207
Corridor
208
Breakroom
209
Office
03-HR1-VRF1
03-HR1-VRF2
03-HR1-VRF3
Office
215D
02-HR9-VRF1
Archives
205
Corridor
206
02-HR9-VRF3
Vestibule
201
Stair
202
02-HR9-VRF2
30x22


UP
01-HR4-VRF1
01-HR5-VRF1
01-HR5-VRF2
01-HR4-VRF2
01-HR5
01-HR4
01-HR2-VRF2
01-HR6
01-HR6-VRF2
01-HR2-VRF1
01-HR6-VRF1
01-HR3-VRF1
01-HR7-VRF1
01-HR7
01-HR9-VRF1
01-HR9-VRF2
01-HR6-VRF3
01-HR2
01-HR3
01-HR7-VRF2
01-HR2-VRF3
01-HR3-VRF2
01-HR3-VRF3
01-HR3-VRF4
01-HR7-VRF3
01-HR8
01-HR9
02-HR2
01-HR9-VRF3
01-HR10
01-HR1-VRF2
02-HR1-VRF2
02-HR1-VRF3
02-HR1-VRF4
01-HR1
02-HR1
02-HR2-VRF1
01-HR10-VRF1
01-HR1-VRF1
01-HR8-VRF1
01-HR1-VRF3
02-HR1-VRF1
UP
02-HR2-VRF2
01-HR10-VRF2


DN
03-HR2-VRF3
03-HR3-VRF1
03-HR3-VRF2
03-HR3
03-HR3-VRF3
03-HR2-VRF2
03-HR2
03-HR4
02-HR4-VRF4
03-HR4-VRF1
02-HR6-VRF2
02-HR6-VRF3
03-HR4-VRF2
02-HR3-VRF2
02-HR4-VRF3
02-HR5-VRF1
02-HR5
02-HR5-VRF2
02-HR3-VRF1
02-HR3
02-HR6
02-HR7
02-HR4
02-HR3-VRF3
02-HR4-VRF2
02-HR5-VRF3
02-HR5-VRF4
02-HR6-VRF4
03-HR2-VRF1
02-HR7-VRF1
02-HR7-VRF4
02-HR8
02-HR4-VRF1
02-HR8-VRF1
02-HR8-VRF2
02-HR8-VRF3
03-HR1
02-HR8-VRF4
02-HR7-VRF2
02-HR7-VRF3
02-HR9
03-HR1-VRF3
02-HR9-VRF1
02-HR9-VRF3
03-HR1-VRF1
03-HR1-VRF2
02-HR9-VRF2
DN