Mount Carmel Fitness & Health

7100 Graphics Way

Lewis Center

OH, 43035

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Abstract:

MC FITNESS & HEALTH

Lewis Center, Ohio

GENERAL INFORMATION

- Medical Office & Wellness Center
- Number of Stories: 3
- Size: 130,000 S.F.
- Date of Construction: September 2014 - January 2016
- Owner: NexCore Group, LLC
- Architect: Ohlson Lavoie Collaborative
- MEP Engineer: Karpinski Engineering
- Structural Engineer: JGA Engineering

MECHANICAL

- Thirteen Roof Top Units connected to multiple VAV boxes supplying correct CFM based on occupancy type.
- Three main Exhaust Fans located on the roof removing any contaminants from rooms such as Medical/Operation rooms.
- Majority of RTU's are equipped with Economizers to allow for "free cooling" and energy saving throughout the year

LIGHTING/ELECTRICAL

- The majority of the building interior spaces are equipped with a combination of LED and Fluorescent fixtures.
- Emergency/Standby generator with circuit breaker disconnect switch is connected to the building in case of any emergencies.
- (208/120V 3 Phase 4 Wire) & (480/277V 3 Phase 4 Wire) are found in the building.

STRUCTURAL

- Foundation: Shallow foundation with concrete slab on grade and cast-in-place spread footings
- Framing: Structural steel - joists, beams, girders and columns; composite metal deck with concrete slabs
- Enclosure: CMU bearing walls and exterior walls covered with brick veneer and metal panels over metal studs.

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Acknowledgements:

First of all, I would like to thank each individual of the Penn State Architectural Engineering Department for helping me through my thesis and guiding me throughout the road, allowing for a successful final product. I learned a lot from them throughout my thesis project and would have not been able to develop such work without their help and support.

Also, I would like to extend my sincerest thanks to Frank A. Eisenhower (Vice President of Karpinski Engineering) for providing me with my thesis building, along with helping me understand the building making sure to eliminate any errors or uncertainties. Moses D. F. Ling (Associate Professor of Architectural Engineering) for providing me with accurate mechanical design guidance when needed. Dr. James D. Freihaut (Professor of Architectural Engineering) for meeting with me on such short notices, making sure I am working and on the right track. Dr. Stephen Treado (Associate Professor of Architectural Engineering) for providing me with such great feedback on all my reports and meeting with me for advising.

Finally and most importantly, I would like to thank my family and friends for supporting me from day one of my thesis project.

Friends:

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Selma Benmakhlouf

Mohammed Ali

Samer El Sebaie

Executive Summary:

MC Fitness & Health Center, located in Lewis Center Ohio, is a one of a kind 130,000 S.F. ambulatory care center offering multiple medical/fitness services. The center consists of a 24/7 urgent care, ambulatory care, rehabilitation services, integrated medical fitness center, aquatics center, sports medicine services, wellness education, and lastly retail shops.

In terms of heating & cooling the building. The existing system is made up of thirteen Packaged Roof Top Units with various sizes depending of the zones assembled to each. Along with that, the building is supplied with VAV boxes taking care of the reheat needed in order to make each space thermally comfortable for the occupant. As for air exhaustion, the building has multiple that are required to be free of any contaminants. Therefore, there are three main exhaust fans located on the roof that are in charge of exhausting the air outside the building without any air leaking within the interior spaces.

Due to the existing system lack of efficiency in terms of energy consumption, a central plant idea was proposed. Rather than having a wide variety of RTU sizes, a geothermal closed loop system was proposed. It acts as a central plant for the building, allowing for no natural gas consumption. In addition, as a first alternative RTU WSHP were incorporated into the design making sure that the dependence is not completely on the geothermal system. RTU WSHP was an option in order to eliminate the need of individual heat pumps throughout the building. With that said, the second alternative was a DOAS coupled with individual self-contained vertical/horizontal heat pumps. After analysis it was found that alternative 1 would require 44% less annual energy consumption and alternative 2 would require 31% less annual energy consumption. Even though energy saving look promising, when looked at from an economical perspective the proposed systems weren't as promising. Alternative 1 would allow for 7% less annual energy costs and alternative 2 would require 14% more annual energy costs.

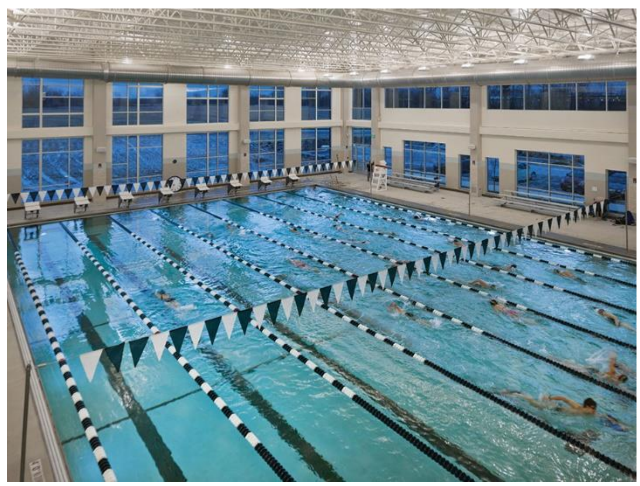
Furthermore, having RTU WSHP opposed to self-contained heat pumps in the building allowed for an acoustical breadth that analyzed both cases. The study focused on the effects of each alternative system on operation rooms. It was found that having the heat pumps in the building would require a lot of acoustical solutions in order to bring the room NC level to a comfortable level.

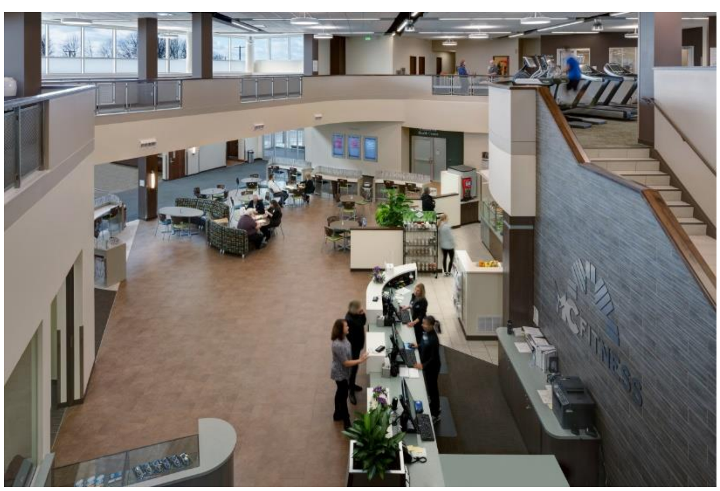
Finally, fixture types were changed in certain spaces to see if that will reduce lighting loads, allowing for annual operation costs. Analyzing 5 spaces only allowed for a total annual savings of $1800, 12% lower than the existing fixtures placed.

Building Overview:

MC Fitness & Health Center, located in Lewis Center Ohio, is a one of a kind 130,000 S.F. ambulatory care center offering multiple medical/fitness services. The center consists of a 24/7 urgent care, ambulatory care, rehabilitation services, integrated medical fitness center, aquatics center, sports medicine services, wellness education, and lastly retail shops. It has been open to the public on September 2014. This is not a typical commercial fitness center, it is a great resource that allows its occupants to attain optimal health and fitness. With today's generation, people are tending to focus on being healthy but can't achieve that for multiple reasons. MC Fitness & Health Center allows that process to be easier/smoother by helping the occupants to achieve their goals step by step.

The medical fitness center is the core of the project. It is the largest component within the building and can accommodate a large sum of people. It is designed in a way that differentiates it from commercial fitness centers. Providing medically integrated programming allows the occupants/patients to be able to work out making sure that their unique healthcare needs are being taken care of.





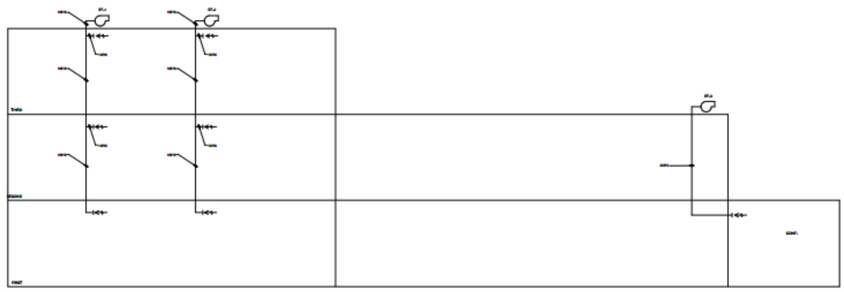
Mechanical System Overview:

The 130,000 SF Medical/Fitness facility is being taken care of in terms of heating/cooling and ventilation by thirteen Roof Top Units. Every RTU is supplying anywhere from 2500 – 15000 CFM depending on the individual unit and what parts of the building its serving. Furthermore, every RTU is connected to multiple VAV boxes to make sure every zone/space is being supplied with the correct amount of CFM depending on the occupancy type of the room. For example, medical/operation rooms require a different supply of airflow and ventilation in comparison with general spaces such as main entry lobbies or corridors.

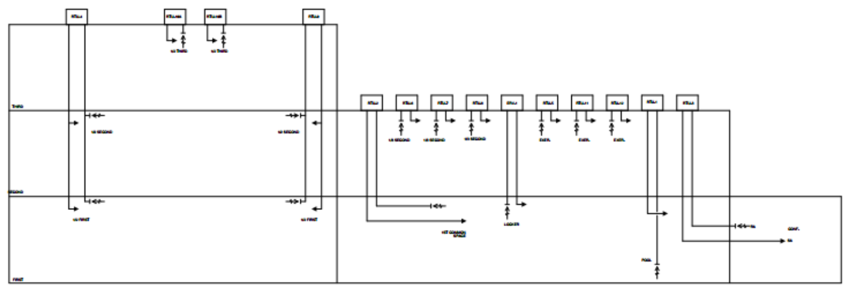
As for air exhaustion, the building has multiple spaces such as but not limited to: patient exam rooms, MRI rooms, and echo rooms that are required to be free of any contaminants. Therefore, there are three main exhaust fans located on the roof that are in charge of exhausting the air outside the building without any air leaking within the interior spaces.

As for the three pools located on the east side of the first floor, they have their own mechanical room. The room is equipped with jet pumps, circulation pumps, heaters, acid pumps, and chemical controllers. These equipment make sure that the pools are functioning correctly and efficiently. As for the space itself, multiple sensors are in use to make sure the space is not too humid or thermally uncomfortable.

As for the three pools located on the east side of the first floor, they have their own mechanical room. The room is equipped with jet pumps, circulation pumps, heaters, acid pumps, and chemical controllers. These equipment make sure that the pools are functioning correctly and efficiently. As for the space itself, multiple sensors are in use to make sure the space is not too humid or thermally uncomfortable.



EF CONCEPT & DUCT SIZES



RTU CONCEPT & DUCT SIZES

ASHRAE Standard 62.1 – 2007 Evaluation

Section 5 – System and Requirements

5.1 Natural Ventilation Evaluation: Satisfied

5.1.1 Location and Size of Openings

- The majority of the Windows, on the 1st floor, located on the North, East, and West sides of the building are operable. As for the 2nd floor, most windows are not operable. The several types of windows within the building have an area greater or equal to 4% of the occupiable floor area. Also, the operable windows are at least 25' from the outdoors.

5.1.2 Control and Accessibility

- Most of the spaces on the 1st floor have windows that are operable. As for the 2nd and 3rd floor, the majority of the windows are not operable. Therefore, the mechanical system takes care of ventilation with those spaces.

5.2 Ventilation Air Distribution Evaluation: Satisfied

5.2.1 Designing for Air Balancing

- This section requires the air distribution system in the building to provide at least the minimum ventilation airflow that is required by section 6. The 13 Roof Top Units within the building make sure that the spaces are getting at least the minimum ventilation required. Each RTU is responsible for bringing in a specific OA CFM to satisfy the minimum rate of ventilation for the spaces its cooling/heating

5.2.3 Documentation

- The construction drawing has mechanical schedules that provide specific OA CFM for each unit used in the building to make sure spaces are ventilated according to standard.

5.3 Exhaust Duct Location Evaluation: Satisfied

- There are 3 main exhaust fans (EF-1, EF-2, and EF-3) located on the roof to exhaust any contaminants within the building. They are negatively pressurized with respect to the spaces they pass. That is done to make sure no contaminants leak into any of the occupied spaces or ductwork.
- EF-1 is rated at 4180 CFM
- EF-2 is rated at 2000 CFM
- EF-3 is rated at 2000 CFM

5.4 Ventilation System Controls Evaluation: Satisfied

- All mechanical equipment include dampers, valves, and control devices such as but not limited to: Outside Air Sensors and CO2 Sensors to make sure the system operates when spaces are occupied and to maintain at least the minimum outdoor airflow.

5.5 Airstream Surfaces Evaluation: Satisfied

- Rigid sheet metal is specified for the ductwork throughout the building to make sure that mold does not grow and to protect from any possibility of erosion.

5.6 Outdoor Air Intakes Evaluation: Satisfied

- The Roof Top Units are installed to make sure that the distance between the units and the main exhaust fans exceeds the minimum distance required by Table 5-1 (Located in Appendix A).

- That allows the outdoor air intake to make sure that there's no contaminations entering the building/ductwork. Also a mesh screen is installed to help prevent interference from rain or snow.

5.7 Local Capture of Contaminants Evaluation: Satisfied

- Any contaminants generated from the mechanical and electrical equipment (Non-combustion) are immediately ducted to the outdoors.

5.8 Combustion Air Evaluation: Satisfied

- Located in the pool mechanical room are fuel – burning appliances such as, Men's and Women's Spa Heater, Exercise and Therapy Pool Heater, and the Lap pool Heater. The room is supplied the right amount of air to allow combustion and exhausted correctly to remove any combustion products.
- The air is taken out through the multiple exhaust grilles within the space and exhausted directly to the outdoors.

5.9 Particulate Matter Removal Evaluation: Satisfied

- According to the Roof Top Unit Schedule, all the RTU's cooling coils have a pre-filter of MERV 8 which exceeds ASHRAE Standard 52.1 minimum requirement (MERV 6). Also, some of the RTU's have a final filter of 12 MERV.

5.10 Dehumidification Systems

5.10.1 Relative Humidity Evaluation: Satisfied

- With the help of the humidistat, thermostat, temperature sensor, and ductwork humidity sensor. The air conditioning units were designed to deliver air to the occupied spaces at a relative humidity of 50% which is below the 65% RH requirement.

5.10.2 Exfiltration Evaluation: Satisfied

- According to the mechanical schedules provided:
  - The Roof Top Units intake a total of 32,965 CFM of outdoor air and the Exhaust fans exhaust a total of 21750 CFM. Therefore, the minimum outdoor air intake is greater than the design maximum exhaust air which complies with this section.

5.11 Drain Pans Evaluation: Satisfied

- All equipment that will have condensation are equipped with a drain pan that follows the slope requirements, an outlet, a drain seal, and the correct pan size and location.

5.12 Finned-Tube Coils and Heat Exchangers Evaluation: Satisfied

- Drain pans, in accordance with section 5.11, are installed under any dehumidifying cooling coil, finned-tubbed, and heat exchangers. They are placed in a way so that there is 18 or more inches of access space for purposes such as maintenance or cleaning.

5.13 Humidifiers and Water-Spray Systems Evaluation: Satisfied

- The humidifier within the Roof Top Units (eg. RTU-13, ¾" connection to humidifier) are connected to a quality water portable source.
- The dampers found in the humidifiers are located at a distance greater than the absorption distance recommended by the manufacturer in order to avoid obstruction.

5.14 Access for Inspection, Cleaning, and Maintenance

- Most of the mechanical equipment is placed on the roof and on top of the 2nd floor (Roof Top Units). This allows more than enough space to be able to access the units (free of obstruction).
- The main three exhaust fans are placed on the roof with allowable clearances for inspection, cleaning, and maintenance.
- As for the pools, all the equipment related to the pools (jet pumps, heaters, chlorinators, etc.) are located in a specified mechanical room (Figure 1: Pool Mechanical Room) with minimum clearances for inspection, maintenance, and cleaning.

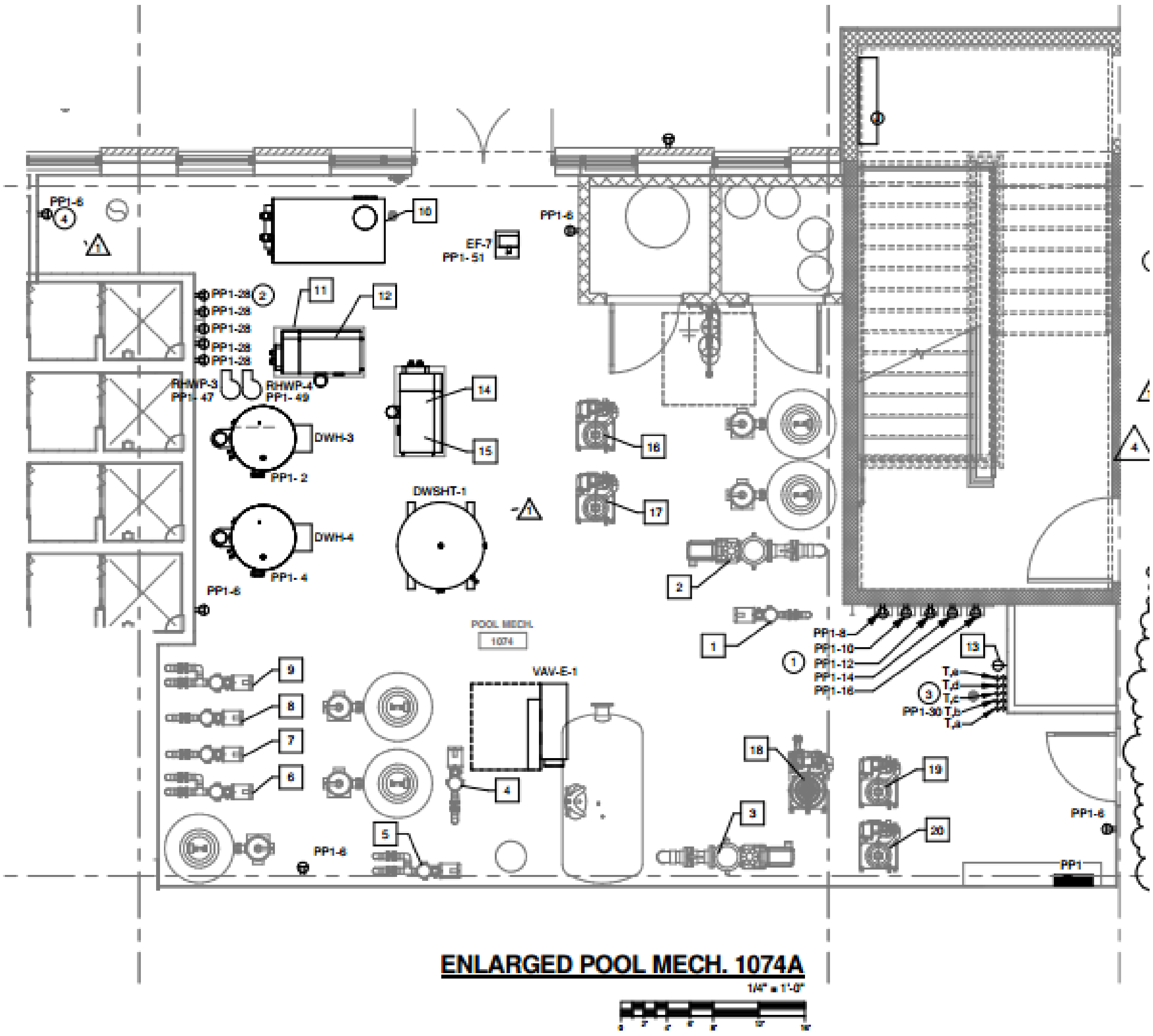


FIGURE 1: POOL MECHANICAL ROOM

5.15 Building Envelope and Interior Surfaces Evaluation: Satisfied

- The envelope of the building consists of certain materials to ensure no moisture or weather problems occurring within exterior and interior walls. Such materials prevent liquid water from penetrating into the envelope, also limiting water vapor diffusion.
- Figure 2: Curtain Wall Sill Detail is showing a curtain wall sill detail with materials such as a vapor retarder and a weather barrier to ensure the protection of the envelope.
- The majority of ductwork is well insulated preventing any condensation to occur.

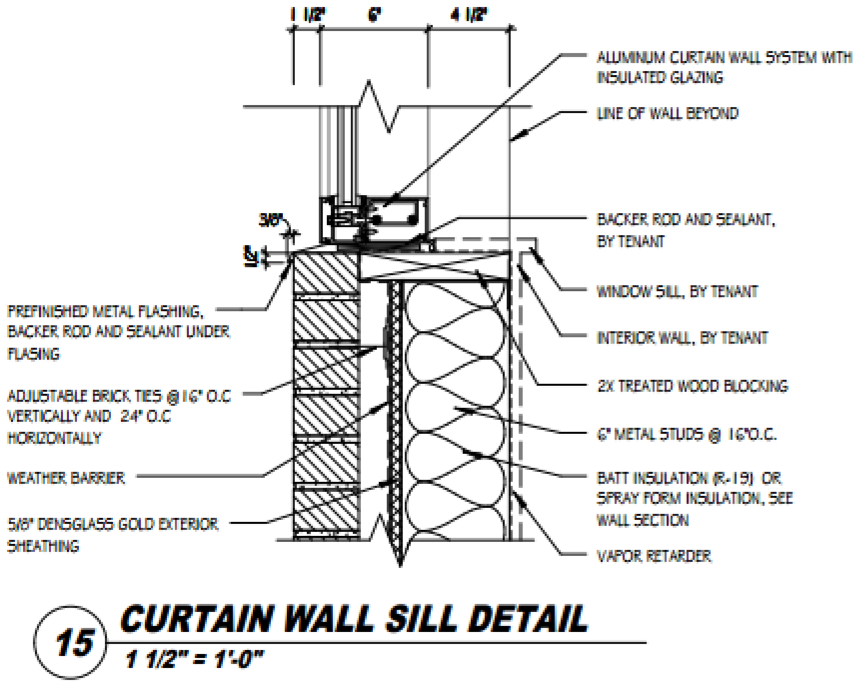


FIGURE 2: CURTAIN WALL SILL DETAIL

5.16 Building with Attached Parking Garages Evaluation: Not Applicable

- This section does not apply to the Mount Carmel Fitness & Health Center because there is no parking garage attached to the building.

5.17 Air Classification and Recirculation Evaluation: Satisfied

- The majority of spaces within the building are classified as Class 1 and Class 2 air, meaning that the air can be recirculated.
- Spaces such as the Pool Mechanical Room and the West Mechanical room are classified as Class 4 air generating a higher percentage of pollutants/contaminants. Therefore, air gets exhausted out of the building and cannot be recirculated.

5.18 Requirements for Buildings Containing ETS and ETS-Free Areas

- The Mount Carmel Health & Fitness Center is a smoke-free facility therefore is classified as an ETS-free area. The majority of outdoor air intake equipment is placed on the roof where no occupants will be smoking around. In other words, this section is not applicable.

ASHRAE Standard 62.1 – 2007 Evaluation

Section 6 – Procedures

6.2 Ventilation Rate Procedure

The main purpose of this section is making sure that every individual space/zone is receiving the correct amount of ventilation. In order to conduct such calculation, the net occupiable floor area is needed along with the zone population, outdoor airflow rate/person, and outdoor airflow rate/unit area.

Therefore, calculating the Breathing Zone Outdoor Airflow ($V\mathrm{bz}$) can be done by using equation (6-1) provided in the ASHRAE Handbook section 6.2.2.1.

$$V_{bz} = R_p * P_z + R_a * A_z$$

R_p = Outdoor Airflow Rate per Person

P_z = Maximum # of People in the Ventilated Zone

R_a = Outdoor Airflow Rate per Unit Area

A_z = Zone Floor Area

R_p and **R_a** will be obtained using Table 6-1 (Located in Appendix A)

Some rooms in the MC Fitness & Health Center are used for medical purposes. Therefore, Table E-1 (Located in Appendix A) will be used to obtain R_p and R_a.

Note: V_{bz} must be corrected by factoring in the Air Distribution Configuration (E_z) using the following equation (6-2) provided in the ASHRAE Handbook section 6.2.2.3.

$$V_{oz} = V_{bz} / E_z$$

V_{oz} = Design Zone Outdoor Airflow

V_{bz} = Breathing Zone Outdoor Airflow

E_z = Air Distribution Configuration

The Zone Air Distribution Effectiveness (E_z) can be obtained from Table 6-2 (Located in Appendix A)

All the calculations can be found in Table – 3 (Located in Appendix B)

6.5 Exhaust Ventilation

Table 6-4 (Located in Appendix A) was used in order to calculate the exhaust airflow for spaces that require air exhaust out of the building. Those calculations can be found in Table – 4 (located in Appendix B).

ASHRAE Standard 90.1 – 2007 Evaluation

Section 5 – Building Envelope

5.1.4 Climate Zone

- The Mount Carmel Fitness & Health Center is located in Lewis Center, Ohio. According to the ASHRAE 90.1 US Climate Zone Map, the building is classified with in Climate Zone 5. Therefore, it's with in a cool/humid area.

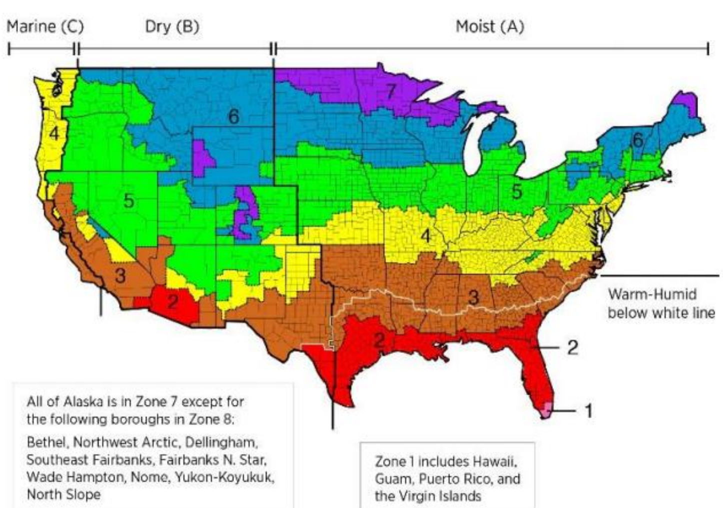


FIGURE 3: ASHRAE 90.1 US CLIMATE ZONE MAP

5.2 Compliance Paths Evaluation: No Satisfied

- This section mandates that any vertical fenestration should not exceed 40% of the gross wall area. As for the skylights fenestration, the area should not exceed 5% of the gross roof area for each space-conditioning category.
- MC Fitness & Health does not fulfil section 5.2. Most of the vertical walls located on the front, north, and west elevations exceed the 40% requirement.

Vertical							
Type of Area (SF)	Front Area (SF)	N Area (SF)	E Area (SF)	W Area (SF)		Total (SF)	
Wall	12074	9884	4188	641		26787	
Fenestration	6868	6504	1243	434		15049	
Percentage of Fenestration to Wall (%)	56.9	65.8	29.7	67.7		56.2	Total (%)

TABLE 1: VERTICAL WALL/FENESTRATION CALCULATIONS

5.5 Perspective Building Envelope Option Evaluation: Satisfied

- This section requires that the conditioned spaces shall comply with Tables 5.5-1 through 5.5-8.
- MC Fitness & Health Center is in the Climate Zone 5A region. Therefore, it should comply with Table 5.5-5 (Located in Appendix A) under the non-residential type.

Type of Area (SF)	Calculated U-Value (Btu/h*ft2*F)	Ashrae Maximum U-Value Requirement (Btu/h*ft2*F)	Evaluation (Y/N)
Wall	0.079365	0.09	Y
Window	0.345338	0.45	Y
Roof	0.042511	0.048	Y
Floor	0.062187	0.074	Y

TABLE 2: BUILDING ENVELOPE U-VALUE COMPLIANCE CHECK

Section 6 – Heating, Ventilating, and Air Conditioning

Section 6.4: Mandatory Provisions Evaluation: Satisfied

- This section requires that the mechanical equipment that are used within the building's HVAC system meet the requirements listed in Table 6.8.1A through 6.8.1G from ASHRAE 90.1-2007.
- All the mechanical equipment including the pools' mechanical equipment comply with the minimum equipment efficiencies listed in Tables 6.8.1A through 6.8.1G. This is mainly due to the multiple control systems that sensor (humidity sensors, thermostats, etc.) the heating/cooling based on occupant density within each zone.

Section 6.5: Mandatory Provisions Evaluation: Satisfied

- Following section 6.5 requirements, the Energy Recovery Ventilator servicing the lockers allows for "free cooling" by modulating the outside air dampers with respect to the OA temperature.
- As for the 13 RTU's, the equipment is equipped with economizer control to allow for "free cooling" supplied to the building. This occurs by modulating the OA dampers, making sure that the air discharge temperature meets the requirement for each zone.

Section 7 – Service Water Heating Evaluation: Satisfied

- In terms of efficiency, all the water heating equipment meet the minimum efficiency requirements found in Table 7-8. As for the piping insulation (used in the heated hot water system), they meet the requirements found in Table 6.8.3-1.
- The boilers are equipped with emergency shut down switches.

Section 8 – Power Evaluation: Satisfied

- Section 8 requires compliance with power and electrical codes.
- MC Fitness & Health Center follows all the requirements required by the National Grid for Electrical Service.
- According to the construction documents, the electrical contractor complies with NEC along with all the local/state codes.

Section 9 – Lighting Evaluation: Satisfied

- Using Table 9.5.1 (Located in Appendix A), the area of each space multiplied by the Lighting Power Density (LPD) was performed to acquire the wattage of each space.

Design Load Estimation:

Multiple assumptions were made in order to analyze the mechanical design of The Mount Carmel Fitness & Health Center. Trace 700 was used as the energy modeling program due to its user friendly interface. When grouping rooms to form zones, every RTU serving a specific area of the building was considered a zone. Furthermore, every block load was divided into sub-zones based on occupancy type and exterior exposure. That technique was put in place to make sure the results provided by Trace 700 were beneficial and as accurate as possible.

Design Conditions:

Location

- The Mount Carmel Fitness & Health Center is located in Lewis Center, Ohio. According to the ASHRAE 90.1 US Climate Zone Map, the building is classified with in Climate Zone 5. Therefore, it's with in a cool/humid area.

- The Outside Design Conditions were obtained from 2005 ASHRAE Handbook (Appendix A) for Columbus, Ohio.

Construction

- The building envelope construction was required by Trace 700 to take into consideration the exterior walls' effect on the zones that were assigned.
- Table 3 shows the Building Envelope Construction with the appropriate U-Values that were used when modeling.

Building Envelope Construction				
	Type	Description	U-Factor (Btu/hft^2F)	SC
Slab	4" LW Concrete	-	0.212615	-
Roof	4" LW Concrete	-	0.213535	-
Wall	Face Brick, 4" HW Concrete, 0.6" Insulation	Boral Main Street collection Phoenix city wire cut range	0.24983	-
Partition	1" Wood Frame	-	0.214548	-
Window	6mm Double Low-E Clear	Solexia Solarban 60 (2) Clear	0.293	0.48
Skylight	6mm Double Low-E Clear	Solexia Solarban 60 (2) Clear	0.293	0.48

TABLE 3: BUILDING ENVELOPE CONSTRUCTION

Block Layout

- When creating the energy model for The Mount Carmel Fitness & Health Center, all spaces where divided into blocks/zones. At first, every individual RTU was tracked to see which part/s of the building it served. Based on that, initial zones were created. In other words, the building was split into 13 zones based on the 12 RTU's and 1 ERV. After that, each zone was divided into sub zones constructed on occupancy type and whether or not the zone was attached to an exterior wall. This technique was followed to minimize the sizes of the zones in order to get the best results possible.
- Only the first and second floor were modeled due to the third floor being unfinished.
- Figure 6 – Figure 11 illustrate the different zones that were created to obtain the block loads by using Trace 700.
- Figure 4 & Figure 5 will help show where the equipment is located and the orientation of the building.

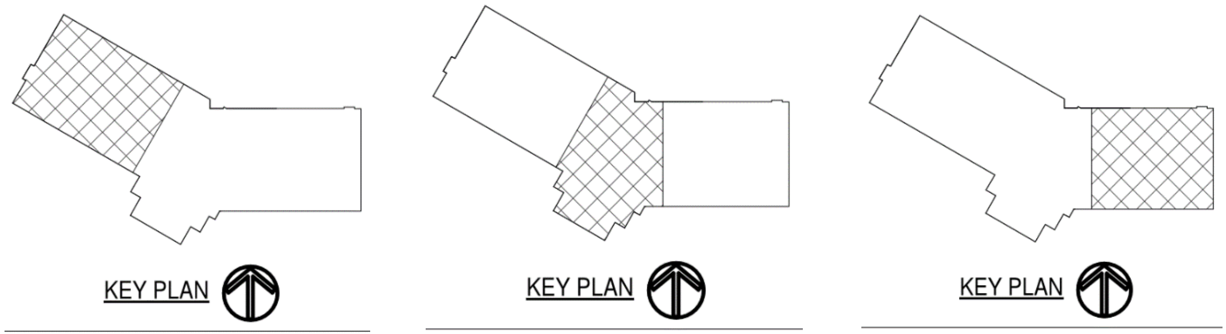


FIGURE 4: BUILDING ORIENTATION (WEST, CENTER, EAST)

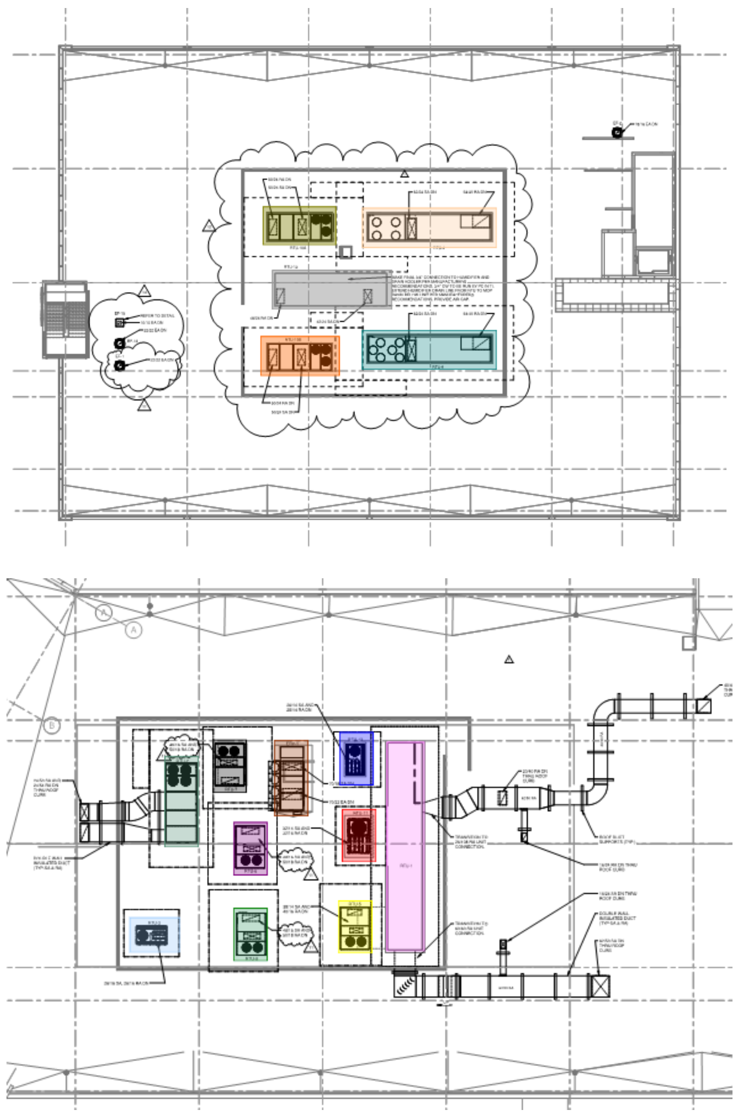


FIGURE 5: HVAC ROOF PLAN (WEST, EAST)

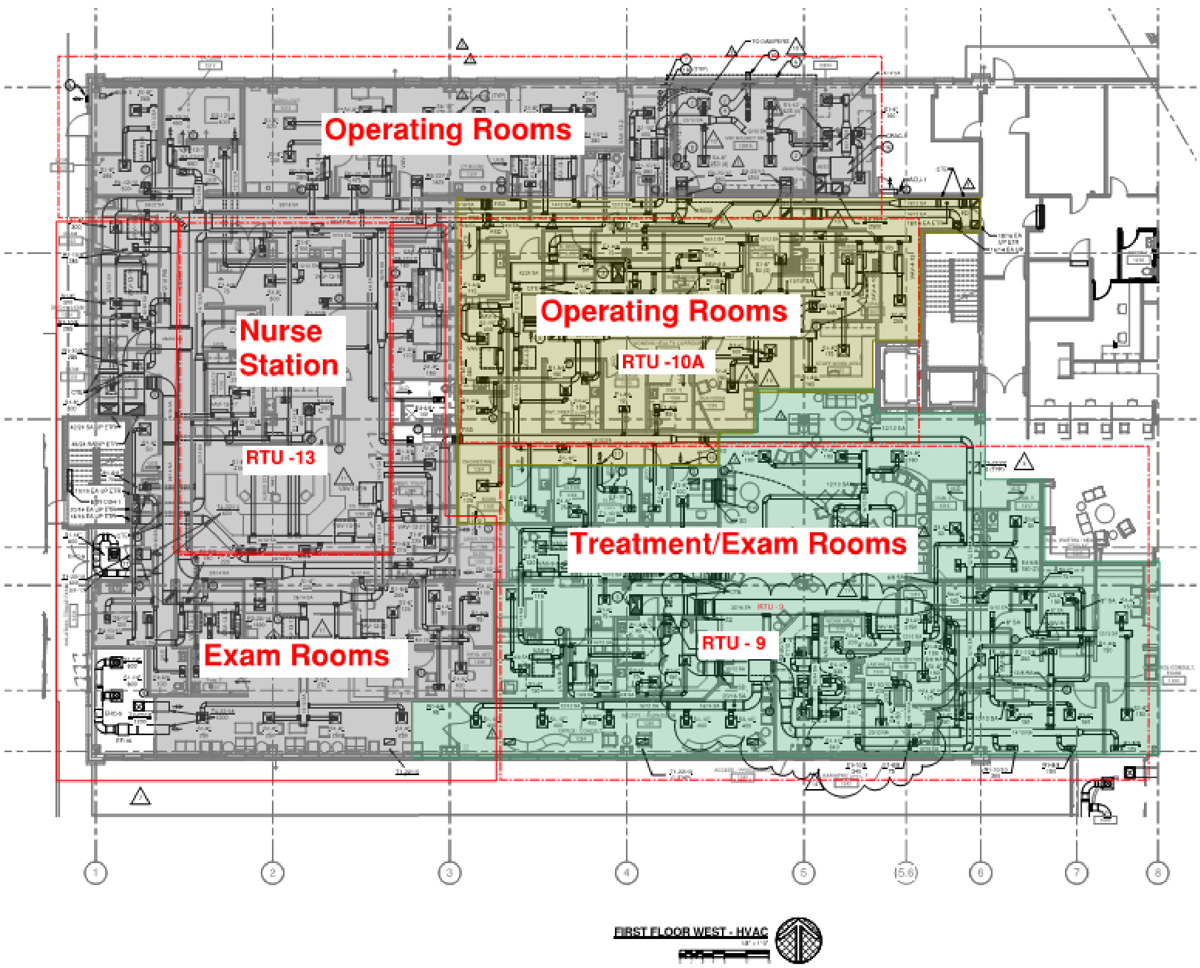


FIGURE 6: FIRST FLOOR WEST ZONES

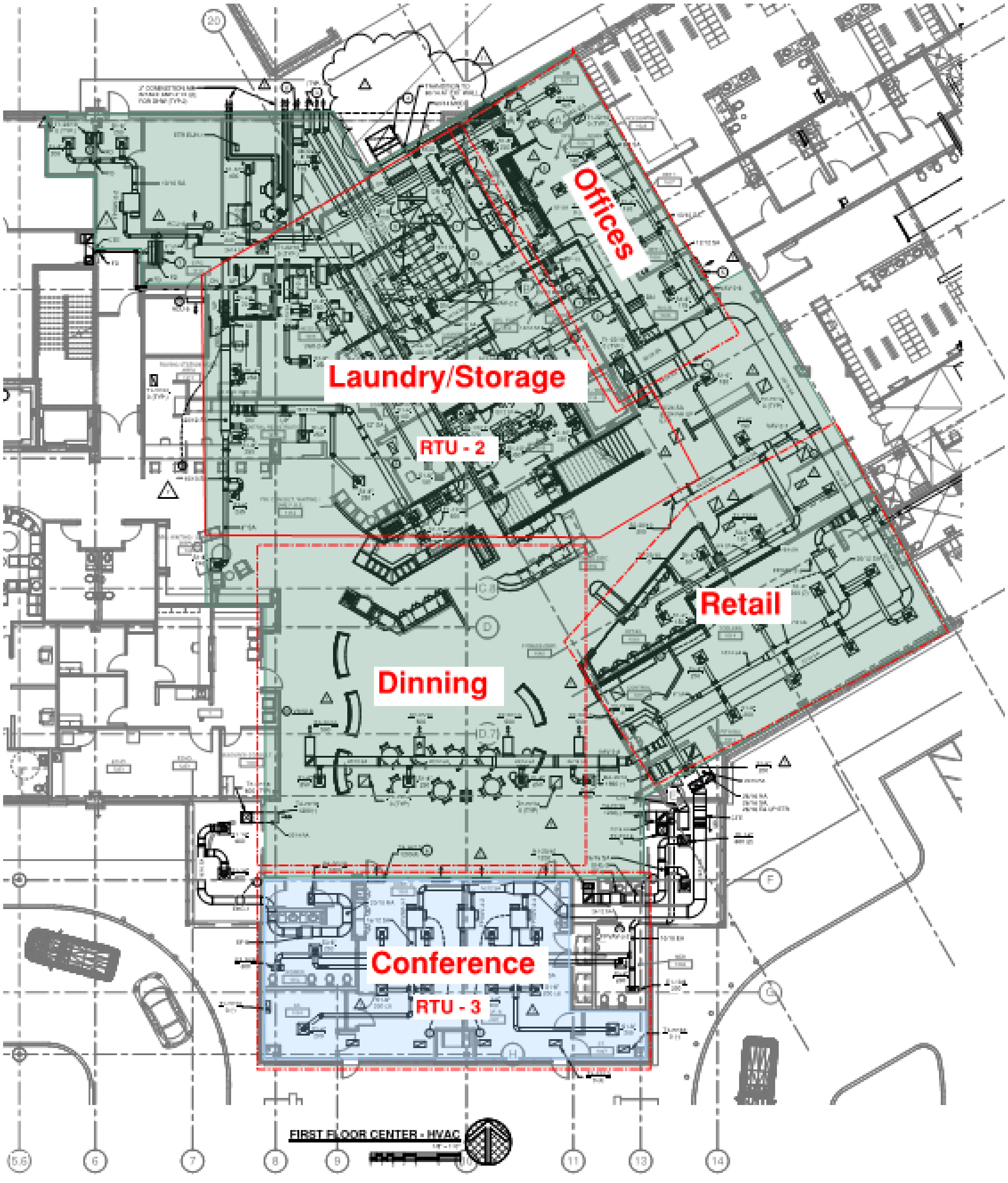


Figure 7: First Floor Center Zones

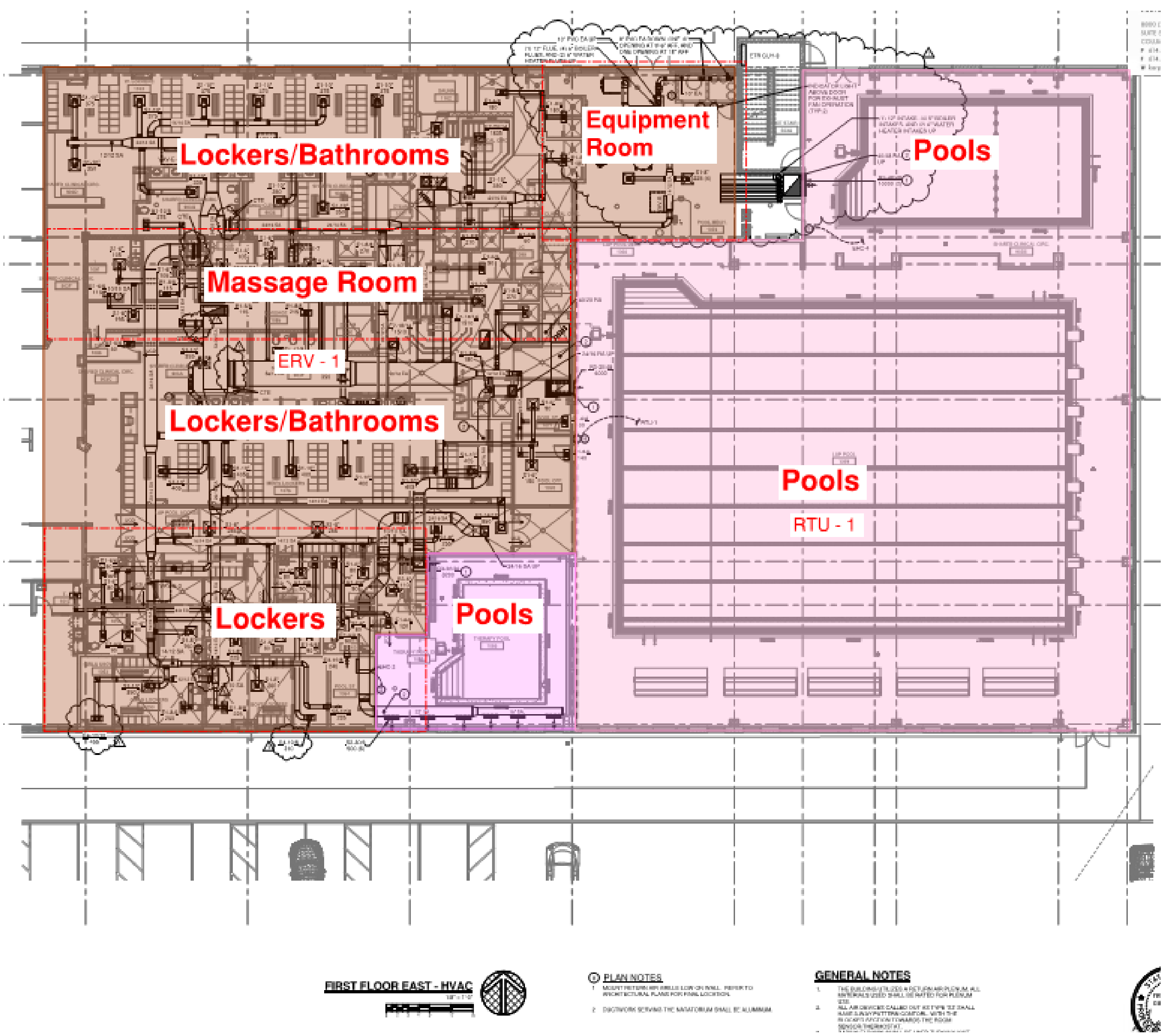


FIGURE 8: FIRST FLOOR EAST ZONES

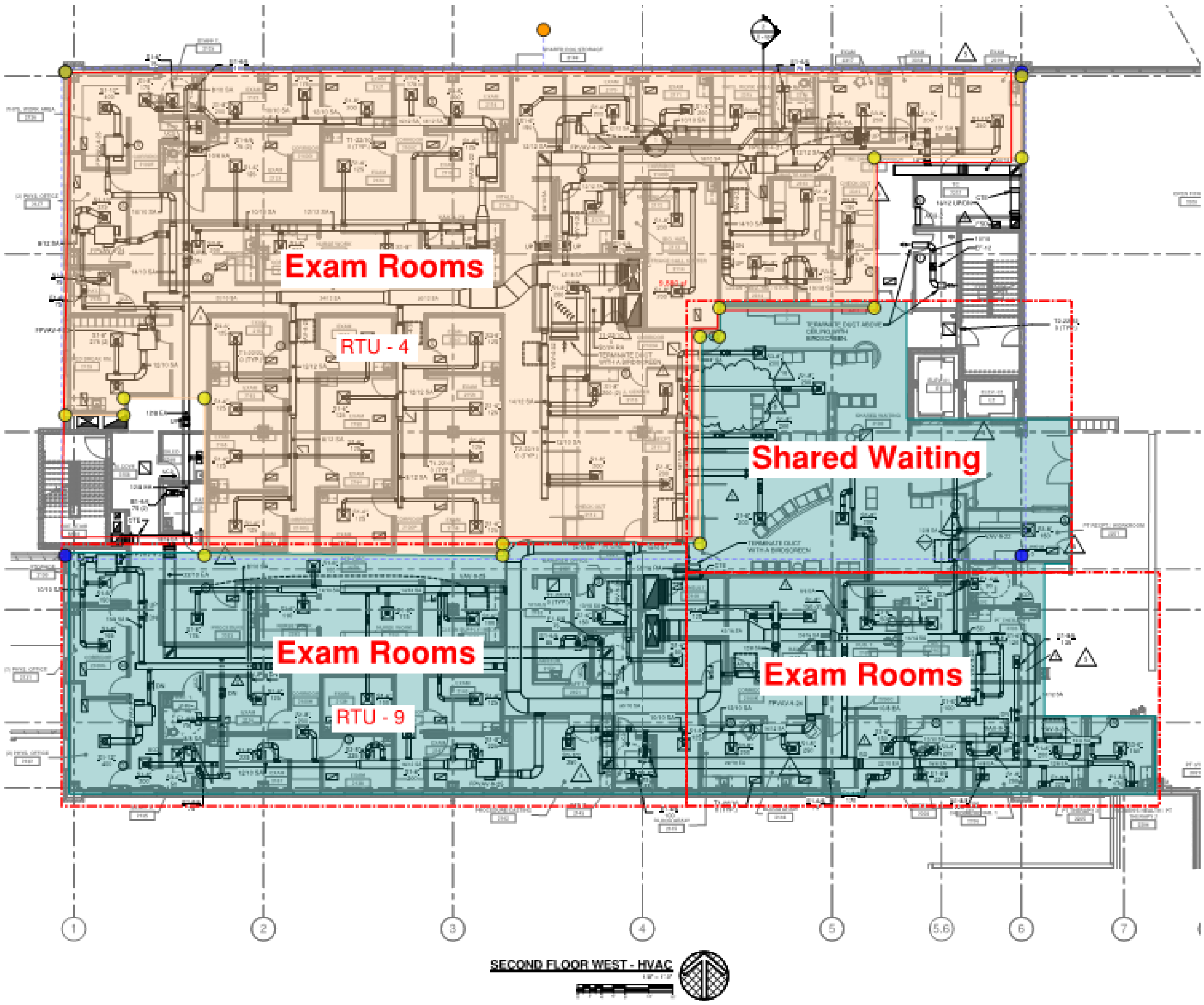


FIGURE 9: SECOND FLOOR WEST ZONES

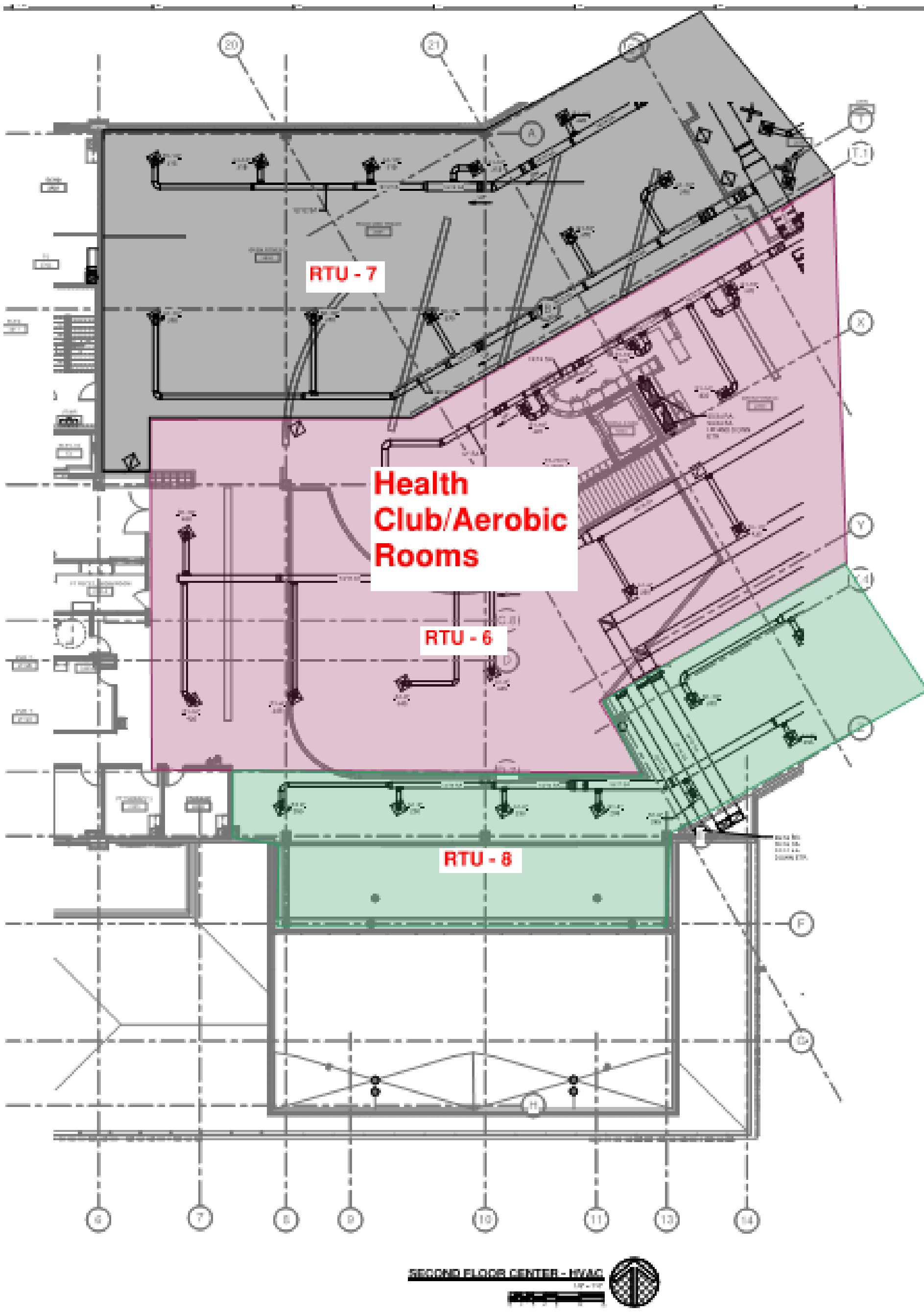


FIGURE 10: SECOND FLOOR CENTER ZONES

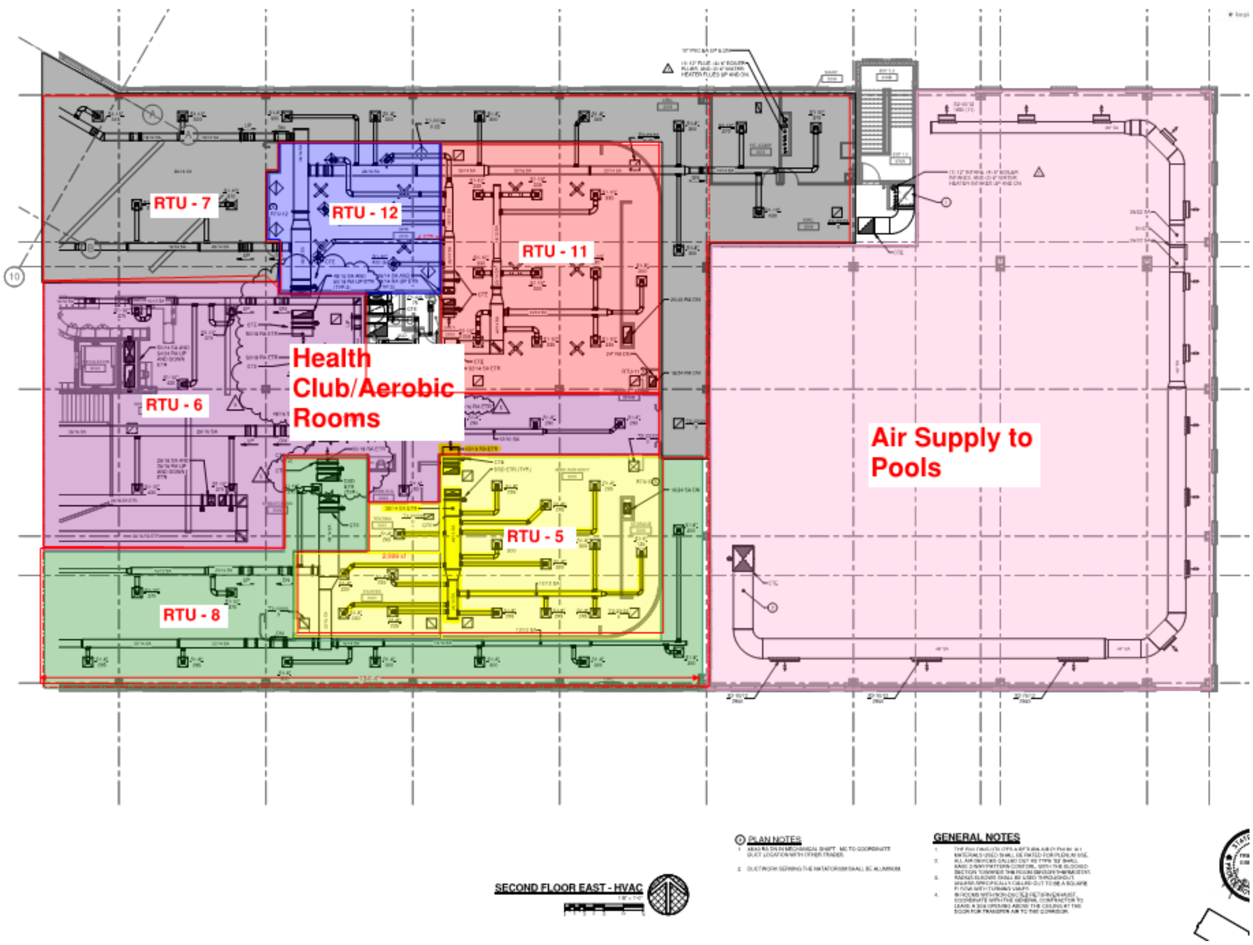


FIGURE 11: SECOND FLOOR EAST ZONES

Load Assumption:

Occupancy

- ASHRAE 62.1 Standards was used throughout the modeling process to find the most accurate occupancy densities. Defining the occupancy type was what determined the number of square ft. per person which provided the estimated total number of people in each space/zone.

- Also, Technical Report 1 was used for to make sure densities that were provided in Trace 700 matched.

- The sensible load was assumed to be anywhere from 250 – 275 Btu/hr and the latent load was anywhere from 155 – 275 Btu/hr which was dependent on the space/zone.

Lighting

- Lighting power densities were assumed by using Table 9.5.1 from ASHRAE 90.1 Standards.
- Based on the occupancy type, every space/zone had a different lighting heat gain.
- The lights were assumed to be putting 80% of their load to the space when occupied
- shows the different light heat gain per space/zone assigned.

Lighting Power Density	
Zone Type	Heat Gain Due to Lights (W/ft^2)
Examination Room	1.5
Health Club/Aerobics	0.9
Dinning	1.3
Laundry/Storage	1.2
Lobby	1.3
Lockers	1
Massage	0.8
Nurse Stations	1
Offices	1.1
Operating Rooms	2.2
Pool Equipment	1.2
Retail	1.5
Pools	1.7
Shared Waiting	-
Treatment Rooms	1.5

TABLE 4: LIGHT POWER DENSITY BASED ON OCCUPANCY TYPE

Miscellaneous Loads

- Miscellaneous loads were added depending on the occupancy type. For the majority of the spaces/zones, standard office equipment and microcomputers were assumed to in the space.
- Therefore, most spaces/zones were assumed to have miscellaneous loads anywhere ranging from 0.5 – 0.7 W/ft^2 or 300 – 350 Watts.

Thermostat

- Due to the multiple zone types found in the building, the thermostat settings were kept at the default template provided by Trace 700 to avoid confusion when modeling.
- As for the sensors, both the thermostat and humidistat were assumed to be located in the rooms.
- Table 5 illustrates the thermostat set points that were put in place.

Thermostat Setpoints		
	(F)	%
Cooling Dry Bulb	75	-
Cooling Driftpoint	81	-
Heating Dry Bulb	70	-
Heating Driftpoint	64	-
Relative Humidity	-	50

TABLE 5: THERMOSTAT SETPOINTS FOR ALL ZONES

Schedules

- Mount Carmel Fitness & Health center operates similar to a rehab center meaning that it operates 24 hours a day 7 days a week.
- Therefore to be on the conservative side, the equipment were assumed to be available 100%. In other words, they are operating from midnight to midnight.
- As for the thermostat schedule, it was assumed that the setpoints were similar throughout the entire week and not only weekdays because facility is operating 24/7.
- Table 6 – Table 7 illustrate the thermostat setpoint schedules for both heating and cooling.

Thermostat Schedule - Heating (January - December) (All Week)		
Start Time	End Time	Setpoint (F)
Midnight	7 a.m.	60
7 a.m.	8 a.m.	70
8 a.m.	5 p.m.	75
5 p.m.	6 p.m.	68
6 p.m.	Midnight	60

TABLE 6: THERMOSTAT SCHEDULE HEATING MODE

Thermostat Schedule - Cooling (January - December) (All Week)		
Start Time	End Time	Setpoint (F)
Midnight	7 a.m.	88
7 a.m.	8 a.m.	79
8 a.m.	5 p.m.	72
5 p.m.	6 p.m.	80
6 p.m.	Midnight	88

TABLE 7: THERMOSTAT SCHEDULE HEATING MODE

System Equipment:

Primary Heating & Cooling

Mount Carmel Fitness & Health Center primary heating and cooling consists of twelve Roof Top Units and one Energy Recovery Ventilator. The packaged roof top unit air conditioners installed do not require any chillers or boilers. Each unit is able to directly cool/heat the supply air to an occupied space/zone. The units are equipped with an evaporator, compressor, condenser, and thermal expansion control device. Furthermore, the units are equipped with a heat exchanger (drum and tube) that takes care of heating. A forced combustion blower supplies pre-mixed fuel through a single stainless steel burner screen into a sealed drum where ignition takes place. VAV reheat boxes are attached to the RTUs in order to provide the required amount of CFM and temperature for each space/zone.

This type of RTU is known as a packaged direct expansion air conditioning system. When assigning systems using Trace 700 Packaged RTU VAV Reheat, DX & Hot water seemed like the most appropriate choice. Figure 12 illustrates a schematic of the system chosen for the twelve RTUs.

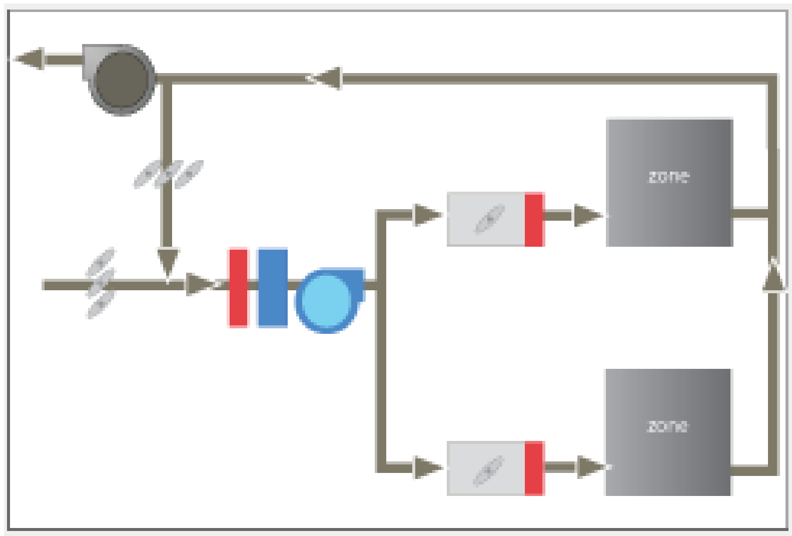


FIGURE 12: PACKAGED RTU VAV REHEAT, DX & HOT WATER SCHEMATIC

When modeling the RTU's using Trace 700, each unit had to be treated as a cooling/heating plant. This technique was performed because it was the only way to show Trace 700 that the units do not depend on a chiller or a boiler. In other words, no need for an external source of energy. That way it was possible to input the capacity (MBH) of each RTU for both cooling and heating modes. Figure 13 illustrates the technique used.

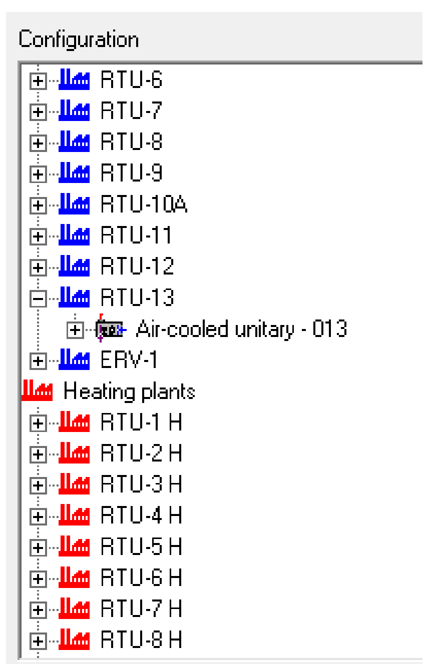


FIGURE 13: COOLING / HEATING PLANTS MODELED IN TRACE 700

As for the Lap pool, Exercise pool, and Therapy pool they require heating to make sure that the temperature of the water is maintained at 76-78 degrees F. For that, there are three boilers that are dedicated for this job. The Lap pool has a boiler with a capacity of 1261 MBH. The Exercise pool has a boiler with a capacity of 400 MBH. Lastly, the Therapy pool has a boiler with a capacity of 300 MBH. In addition, there are four domestic water heaters with a total capacity of 2000 MBH that are mainly used for storage.

Result Comparison:

After assigning every space/zone to a piece of equipment and plugging in energy rates based on the utility providers, it was possible to generate an energy model. Unfortunately, the owner did not request an energy model from the MEP firm. Therefore, it was not possible to compare outcomes. Table 8 shows the results generated from the energy model created.

Design Load (Calculated)					
		Cooling Loads (ft^2/ton)	Heating Loads (Btu/hr*ft^2)	Ventilation - Cooling (cfm/ft^2)	Ventilation - Heating (cfm/ft^2)
System	RTU-1	183.2	49.1	1.37	0.41
	RTU-2	232.67	39.02	1.41	0.43
	RTU-3	230.84	36.22	1.37	0.41
	RTU-4	283.43	97.9	1.1	1.1
	RTU-5	282.6	51.67	0.71	0.21
	RTU-6	305.73	42.21	0.57	0.22
	RTU-7	144.86	82.02	1.39	0.42
	RTU-8	216.01	43.66	1.35	0.41
	RTU-9	264.36	62.36	1.07	1.03
	RTU-10A	366.36	62.32	1.2	1.2
	RTU-11	240.14	65.25	0.87	0.26
	RTU-12	240.4	65.08	0.84	0.25
	RTU-13	292.56	60.28	0.88	1.2
	ERV-1	788.76	18.05	0.28	0.3
Total		4071.92	775.14	14.41	7.85

TABLE 8: CALCULATED DESIGN LOADS FROM ENERGY MODEL (TRACE 700)

In order to make a comparison HVAC: Equations, Data, and Rules of Thumb was used. Section 6: Rule of Thumb - Cooling and Section 7: Rule of Thumb – Heating were referenced to make a comparison. It was assumed that the building consists of Hospital Patient Rooms and Nursing Home Patient Rooms (Section 6.09). The rule of thumb for cooling loads ranges from 250 – 300 Sq.Ft/Ton. To be conservative, 300 Sq./Ton was chosen. As for heating, the rule of thumb ranges from 20 – 60 Btuh/Sq.Ft. To be conservative, 60 Btuh/Sq.Ft. was chosen. Table 9and Table 10 show the comparisons made.

Design Load Comparison - Cooling (Rule of Thumb)						
		Area (ft^2)	Cooling Loads (Calculated) (ft^2/ton)	Cooling Loads (Calculated) (ton)	Cooling Loads (Rule of Thumb) (ton)	Difference (ton)
System	RTU-1	12310	183.2	67	41	26
	RTU-2	9835	232.67	42	33	9
	RTU-3	1844	230.84	8	6	2
	RTU-4	9880	283.43	35	33	2
	RTU-5	2382	282.6	8	8	0
	RTU-6	11889	305.73	39	40	-1
	RTU-7	7078	144.86	49	24	25
	RTU-8	5980	216.01	28	20	8
	RTU-9	13094	264.36	50	44	6
	RTU-10A	3034	366.36	8	10	-2
	RTU-11	1962	240.14	8	7	2
	RTU-12	1049	240.4	4	3	1
	RTU-13	6492	292.56	22	22	1
	ERV-1	11371	788.76	14	38	-23
Total		98200	4072	383	327	56

TABLE 9: RULE OF THUMB COMPARISON - COOLING

Design Load Comparison - Heating (Rule of Thumb)						
		Area (ft^2)	Heating Loads (Calculated) (Btu/hr*ft^2)	Heating Loads (Calculated) (tons)	Heating Loads (Rule of Thumb) (ton)	Difference (ton)
System	RTU-1	12310	49.1	50	62	-11
	RTU-2	9835	39.02	32	37	-5
	RTU-3	1844	36.22	6	7	-1
	RTU-4	9880	97.9	81	37	44
	RTU-5	2382	51.67	10	9	1
	RTU-6	11889	42.21	42	45	-3
	RTU-7	7078	82.02	48	27	22
	RTU-8	5980	43.66	22	22	-1
	RTU-9	13094	62.36	68	49	19
	RTU-10A	3034	62.32	16	11	4
	RTU-11	1962	65.25	11	7	3
	RTU-12	1049	65.08	6	4	2
	RTU-13	6492	60.28	33	24	8
	ERV-1	11371	18.05	17	43	-26
Total		98200	775.14	441	384	57

TABLE 10: RULE OF THUMB COMPARISON - HEATING

Looking at the result comparison, the results generated from the energy model were greater than the comparison but not significantly. It was calculated that the building requires a total of 383 tons in cooling loads whereas the comparison suggested a total of 327 tons. As for heating, it was calculated that the building requires a total of 441 tons whereas the comparison suggested 384 tons.

The cooling/heating loads did not match the rule of thumb comparison for multiple reasons. When modeling it was assumed that the equipment will be on and available 100% of the time because the facility is operating 24/7. This assumption can have a major effect on the results. Even though the facility is operating 24/7 that does not mean that all the equipment is running fully the entire time. In other words, some systems might be running on part load when needed or turned off based on occupant density. There can be a lot of variables that determine the hours of operation for the equipment. Furthermore, all the RTU's were modeled as direct expansion in Trace 700. This assumption can be invalid because some systems could be running differently allowing for more energy saving which can explain the insignificant difference between the calculated results and the comparison.

Annual Energy Consumption:

Electricity Consumption

According to the energy model, Mount Carmel Fitness & Health consumes a total of 1,823,615 kWh annually. Figure 14 illustrates the breakdown of the building's annual electricity consumption.

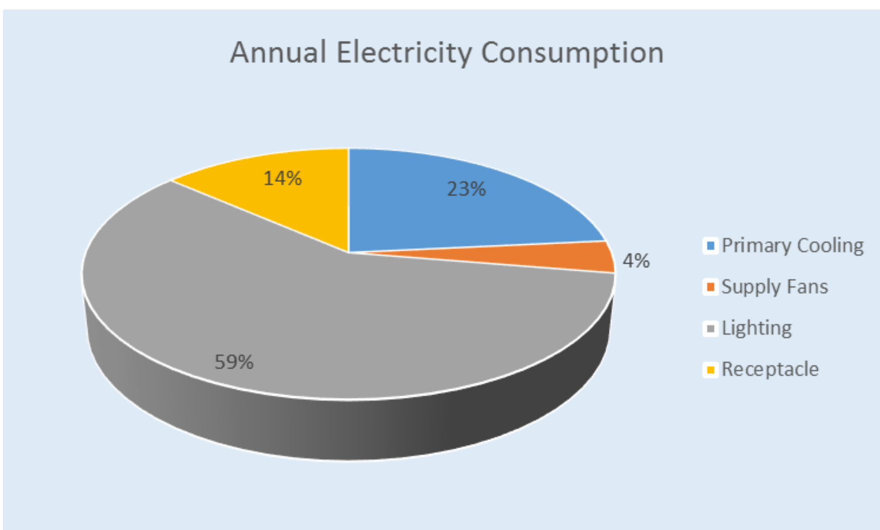


FIGURE 14: ANNUAL ELECTRICITY CONSUMPTION SUMMARY

Looking at the annual electricity consumption summary, it is reasonable that the lighting and receptacle are almost 75% of the total consumption. Most of the spaces within the facility are examination rooms, treatment rooms, and operating rooms. Those room require a large amount of lighting and receptacle loads due to medical reasons such as but not limited to medical equipment found in each room. Also the open fitness area which is the majority of the second floor require high intensity lights which result in increasing the electric consumption. Figure 15 illustrates the electric consumption broken down by month to have a better representation of the results.

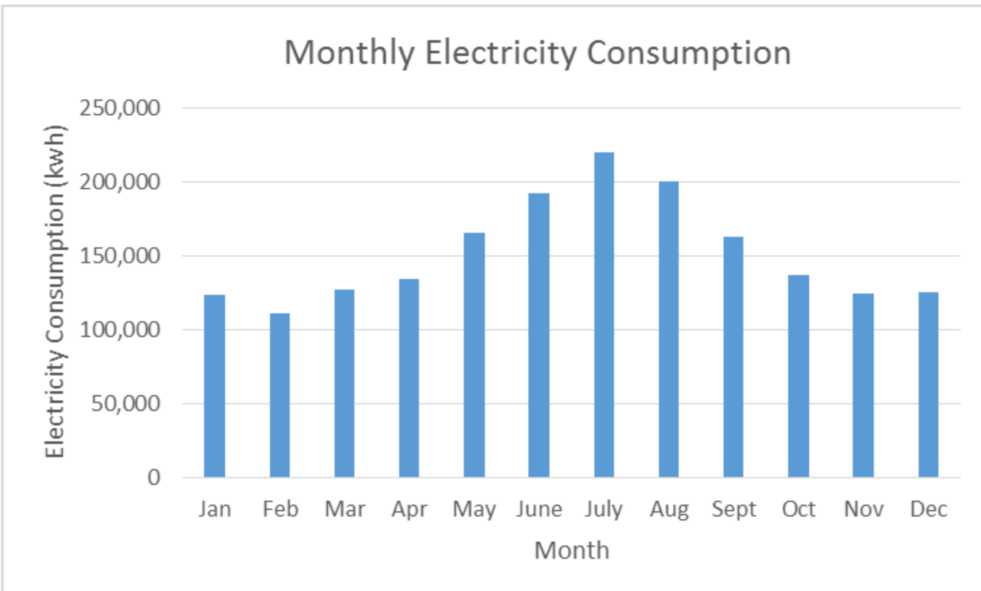


FIGURE 15: MONTHLY ELECTRICITY CONSUMPTION SUMMARY

Looking at the monthly results, it makes sense that the highest energy consumption would be within the summer periods where cooling is required.

Natural Gas Consumption

Natural consumption gas should have an inverse relation in terms of electricity consumptions. Due to the building located in Ohio, high natural gas consumption would be required in the winter for heating purposes. Figure 16 illustrates the natural gas consumption month by month.

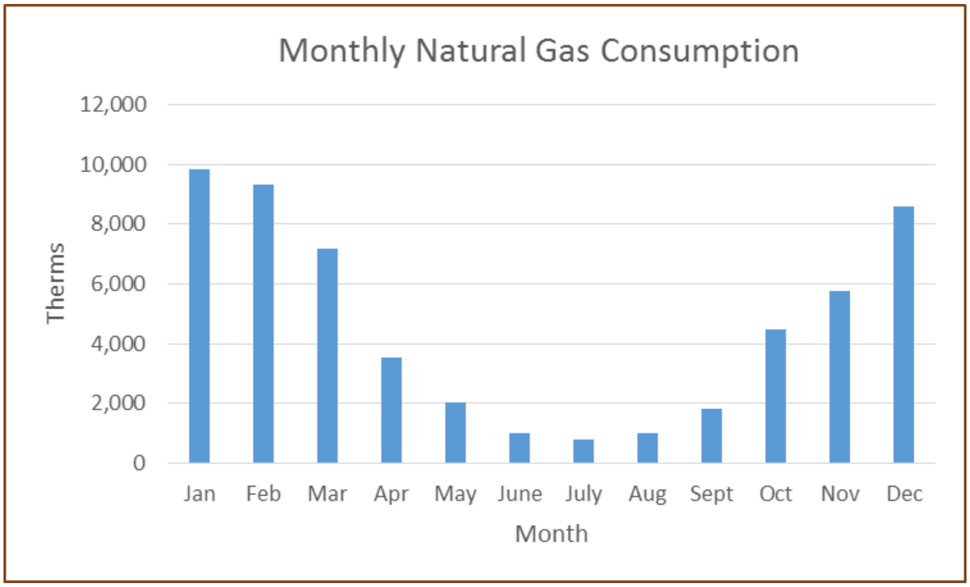


FIGURE 16: MONTHLY NATURAL GAS CONSUMPTION SUMMARY

As expected, from Jan – March and Oct – Dec the majority of natural gas in consumed. In other words, the winter season.

Cost Analysis and Breakdown by Usage

According to energy model performed by Trace 700, the building consumes a total annual operation cost of $133,810 per year. That is broken down into $108,726 for electricity per year and $25,084 per year gas. Utility cost per unit area is $1.36/ft^2. Figure 17 illustrates the monthly utility costs.

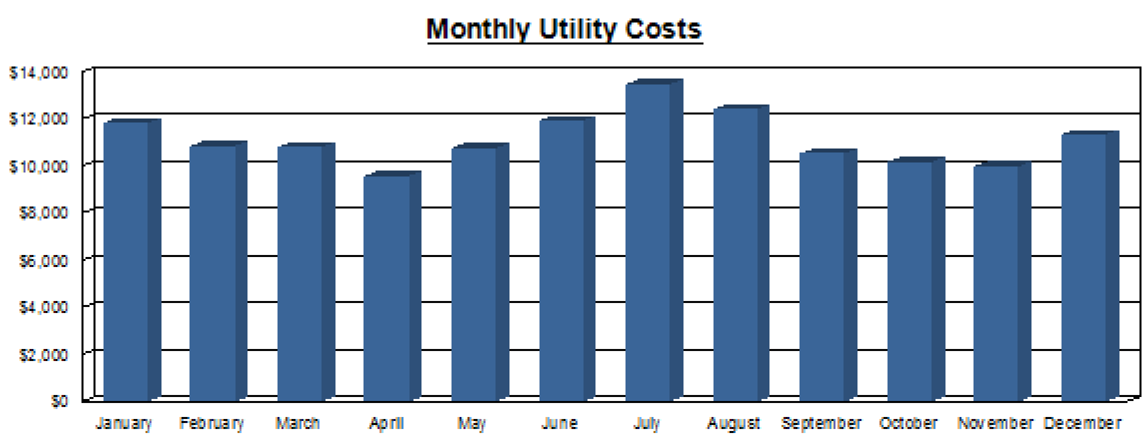


FIGURE 17: MONTHLY UTILITY COST

Looking at the result, money is being expended equally throughout the year due to the dependence of natural gas in the heating season and dependence of electricity in the cooling season. In addition, there are constant electricity usage throughout the year for such as but not limited to lighting and receptacle loads that are spread equally within each month.

Environmental Impact:

Throughout the building, emission is produced due to the boilers used by the Lap Pool, Exercise Pool, and Therapy Pool. In addition, each RTU is considered as a Cooling/Heating plant and is equipped with a heat exchanger which result in emissions too. Table 11 illustrates the emissions produced due to the operation of Mount Carmel Fitness & Health.

Environmental Impact Analysis		
Emission	Amount	Unit
CO2	3296332	lbm/year
SO2	22876	gm/year
NOX	5716	gm/year

TABLE 11: ENVIRONMENTAL IMPACT ANALYSIS

Design Considerations

Objectives

The objective of the mechanical system in the Mount Carmel Fitness & Health Center is to provide a thermally comfortable environment for all the staff and patients. The building has a wide variety of spaces such as but not limited to Aerobic rooms, Open fitness spaces, Running tracks, Pools, and Spas. Therefore, the mechanical systems focus on providing the correct amount of CFM making sure the spaces are not too humid or uncomfortable for the daily members and patients.

When designing for spaces such as Examination rooms, Treatment rooms, Nurse Stations, Locker rooms, and Massage rooms the objective was to make sure that all rooms are free from contaminations. Such spaces are treated like hospital rooms. Patients need to be assured that everything is clean and that fresh air is being supplied constantly. Therefore, there are multiple exhaust fans throughout the building making sure that this objective is met.

Sustainability throughout the design phase was not of importance. So it was not one of the design objectives that the MEP engineers focused on. The owner's focus was to complete the project with a tight budget and therefore the building's efficiency/performance was not a major objective.

Requirements

Outdoor Design Conditions

- The Mount Carmel Fitness & Health Center is located in Lewis Center, Ohio. According to the ASHRAE 90.1 US Climate Zone Map, the building is classified with in Climate Zone 5. Therefore, it's with in a cool/humid area.
- The Outside Design Conditions were obtained from 2005 ASHRAE Handbook (Appendix A) for Columbus, Ohio.
- Figure 18 illustrates that the average high temperatures are 35 – 85 F and the average low temperatures are 20 – 65 F. As for precipitation, the yearly total is about 39".

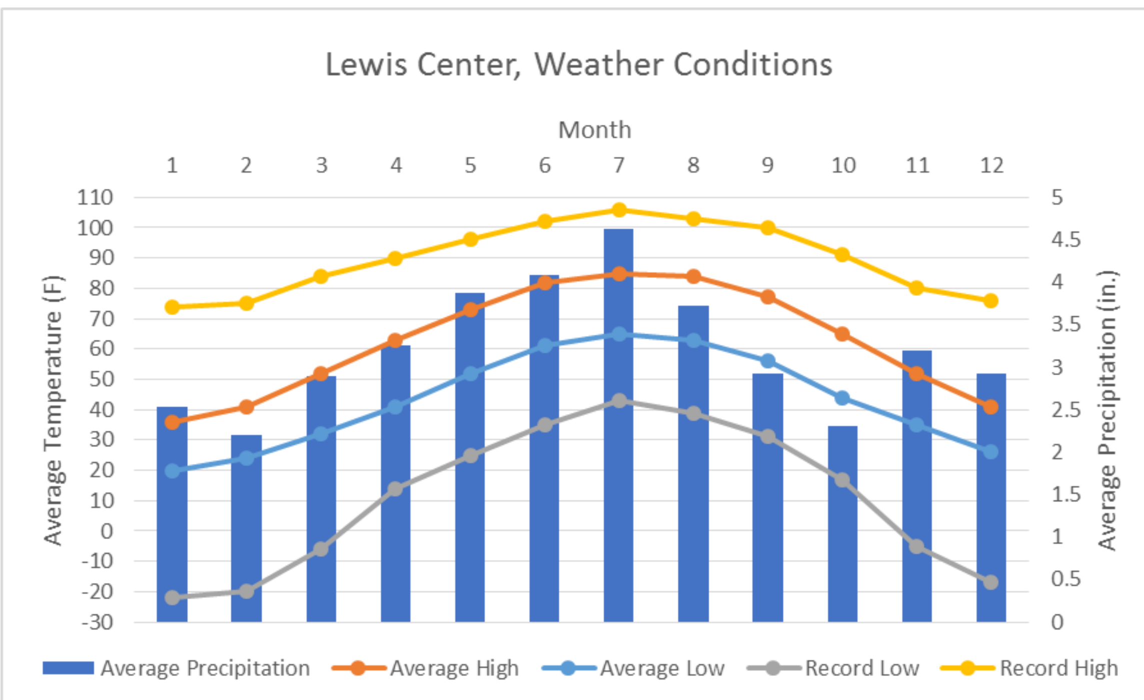


FIGURE 18: MONTHLY WEATHER CONDITIONS

Indoor Design Conditions

- The indoor design conditions vary within the building by zone and occupancy type. Each zone requires a different humidity set points. Therefore, the cooling and heating dry bulb temperatures differ
- Table 12 documents the indoor design conditions per zone.

Indoor Design Conditions		
Zone	Design Temperature (F)	Humidity (%)
Examination Rooms	72-76	30-60
Health Club/Aerobics	68-75	20-60
Laundry/Storage	72-76	40-50
Lobby	70-75	40-55
Lockers	70-78	30-60
Massage	72-80	30-60
Nurse Stations	72-78	30-60
Offices	70-75	40-50
Operating Rooms	62-80	45-55
Pools	78	50
Retail	70-75	40-55
Treatment Rooms	75	30-60

TABLE 12: INDOOR DESIGN CONDITIONS

Ventilation Requirements

- When evaluating the building's compliance with ASHRAE 62.1 ventilation rates in Technical Report 1, the required minimum outside air was calculated with respect to each floor not by equipment.
- Table 13 documents the design supply air and minimum outside air per piece of equipment. All the equipment provide about 30 – 40% outside air to their corresponding zones.
- Table 14 documents the total and required minimum outside air. About 17,000 cfm of additional outside air is being supplied to the building. Therefore, more than enough ventilation air is being supplied to the zones. This is because the majority of the spaces are either examination/operation rooms or health/aerobic rooms.
- Whenever some of the RTUs are not operating, the three main exhaust fans will be running to make sure all contaminants are removed.

Equipment	Design		
	Total Supply Air (CFM)	Minimum Outside Air (CFM)	Outside Air (%)
RTU-1	30000	6700	0.22
RTU-2	12000	4900	0.41
RTU-3	2600	630	0.24
RTU-4	13000	2600	0.20
RTU-5	4000	1420	0.36
RTU-6	6400	2000	0.31
RTU-7	6400	2000	0.31
RTU-8	5600	1660	0.30
RTU-9	15000	4800	0.32
RTU-10A	11200	3360	0.30
RTU-10B	11200	3360	0.30
RTU-11	3200	1250	0.39
RTU-12	2400	785	0.33
RTU-13	11500	4200	0.37

TABLE 13: EQUIPMENT DESIGN SUPPLY AND MINIMUM OUTSIDE AIR

Design Total Minimum Outside Air (CFM)	Required Total Minimum Outside Air (CFM)
39665	22397

TABLE 14: DESIGN VS. REQUIRED TOTAL MINIMUM OUTSIDE AIR

Heating & Cooling

The design heating and cooling loads were calculated in Technical Report 2 using Trace 700. Unfortunately, it was not possible to make a comparison with the actual model the designers created because the owner did not request one. Therefore, the design loads modeled on Trace 700 were compared to HVAC: Equations, Data, and Rules of Thumb sections 6 and 7. This comparison provided a better understanding of the results generated by the energy model. Table 15 and Table 16 show the comparison made.

Design Load Comparison - Cooling (Rule of Thumb)						
		Area (ft^2)	Cooling Loads (Calculated) (ft^2/ton)	Cooling Loads (Calculated) (ton)	Cooling Loads (Rule of Thumb) (ton)	Difference (ton)
System	RTU-1	12310	183.2	67	41	26
	RTU-2	9835	232.67	42	33	9
	RTU-3	1844	230.84	8	6	2
	RTU-4	9880	283.43	35	33	2
	RTU-5	2382	282.6	8	8	0
	RTU-6	11889	305.73	39	40	-1
	RTU-7	7078	144.86	49	24	25
	RTU-8	5980	216.01	28	20	8
	RTU-9	13094	264.36	50	44	6
	RTU-10A	3034	366.36	8	10	-2
	RTU-11	1962	240.14	8	7	2
	RTU-12	1049	240.4	4	3	1
	RTU-13	6492	292.56	22	22	1
	ERV-1	11371	788.76	14	38	-23
Total		98200	4072	383	327	56

TABLE 15: RULE OF THUMB COMPARISON - COOLING

Design Load Comparison - Heating (Rule of Thumb)						
		Area (ft^2)	Heating Loads (Calculated) (Btu/hr*ft^2)	Heating Loads (Calculated) (tons)	Heating Loads (Rule of Thumb) (ton)	Difference (ton)
System	RTU-1	12310	49.1	50	62	-11
	RTU-2	9835	39.02	32	37	-5
	RTU-3	1844	36.22	6	7	-1
	RTU-4	9880	97.9	81	37	44
	RTU-5	2382	51.67	10	9	1
	RTU-6	11889	42.21	42	45	-3
	RTU-7	7078	82.02	48	27	22
	RTU-8	5980	43.66	22	22	-1
	RTU-9	13094	62.36	68	49	19
	RTU-10A	3034	62.32	16	11	4
	RTU-11	1962	65.25	11	7	3
	RTU-12	1049	65.08	6	4	2
	RTU-13	6492	60.28	33	24	8
	ERV-1	11371	18.05	17	43	-26
Total		98200	775.14	441	384	57

TABLE 16: RULE OF THUMB COMPARISON - HEATING

Annual Energy Consumption Comparison

Luckily after the submission of Technical Report 2, utility bills of the building's gas and electricity usage were obtained by the owner representative. Therefore, a more accurate comparison was made between the energy model and the actual energy usage of the building. The utility bills were for the entire building. There are sub meters in the building but the owner representative was not able to obtain that information. Therefore, the comparison couldn't be made with respect to each piece of equipment individually. Instead, the total energy usage (Calculated vs. Actual) was compared. Table 17 documents the comparison between the actual and calculated gas consumption by the building.

Annual Energy Usage (Gas)		
Calculated (BTU/yr)	Actual (BTU/yr)	Difference (BTU/yr)
5.54E+09	6.87E+09	1.33E+09

TABLE 17: ANNUAL GAS USAGE COMPARISON

Looking at the results, the model generated values that are less than the actual usage. The difference is about 111,170 Tons which is significant. This difference can be due to multiple reasons but mainly it's because of the pools in the building. One of the pools, Lap Pool, is about 5,200 SF along with two other pools that are about 1000 SF and 400 SF play a major role in the building's energy consumption. The pools have to be constantly conditioned and maintained to make sure they are in an ideal shape for the patients. Therefore, the difference could be due to the modeling technique that was used in Trace 700 when investigating the pools.

As for annual electricity consumption by the building. Table 18 documents the comparison between the actual and calculated electricity consumption by the building.

Annual Energy Usage (Electricity)		
Calculated (KWH/yr)	Actual (KWH/yr)	Difference (KWH/yr)
1.62E+06	3.05E+06	1.43E+06
Calculated (BTU/yr)	Actual (BTU/yr)	Difference (BTU/yr)
5.5E+09	1.04E+10	4.9E+09

TABLE 18: ANNUAL ELECTRICITY USAGE COMPARISON

Looking at the results, there is a noteworthy difference in the values between the energy model created and the actual data. This can be due to the assumptions made when modeling for electricity consumption. When looking at the energy model electricity consumption in depth, it is predicted that the building is only using 843 x 10^6 Btu/yr for receptacle loads and 260 x 10^6 Btu/yr for fans. This could not be accurate because a building with such area and occupancy type would require a higher receptacle load due to the type of building. As for the fans, the same scenario is applicable. There are multiple fan powered VAV's along with exhaust fans that were not modeled individually on Trace 700.

In regards to the monthly energy consumption, a comparison was made between the calculated and actual energy consumptions. This comparison was performed to see how the systems are actually performing. Figure 19 illustrates the comparison between the monthly actual and calculated gas consumption by the building. The actual monthly energy consumption was obtained from the utility bills of the past year. Looking at figure 2, the trends in usage are similar between the calculated and actual excluding the last three months of the year. In terms of the values, there is an increase in the actual and that is due to the reasons explained previously when comparing the annual energy consumption.

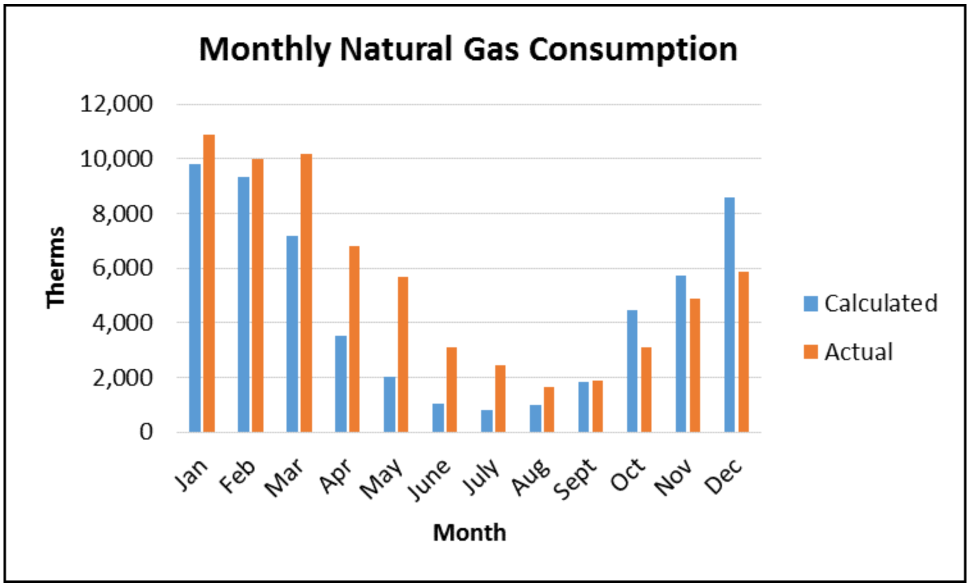


FIGURE 19: COMPARISON OF MONTHLY GAS CONSUMPTION

Figure 20 illustrates the comparison between the monthly actual and calculated electricity consumption by the building. The actual data was obtained from the 12 month history usage found in the utility bills.

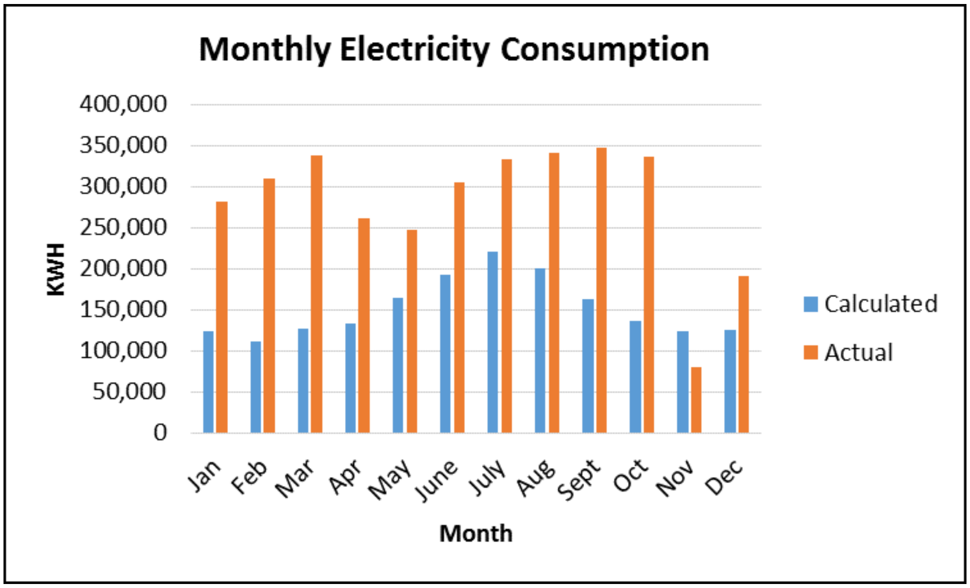


FIGURE 20: COMPARISON OF MONTHLY GAS CONSUMPTION

Here we can observe the significant difference between the calculated and actual electricity consumption by the building. Due to these values, the model is being revised to find a better technique when modeling to obtain more accurate results.

Annual Utility Costs

The annual utility cost for the Mount Carmel Fitness & Health center is summarized in Table 19. The actual utility rates for gas were obtained from the 2015-2016 American Electric Power Ohio electric bills. The rate per KWH is $0.047. As for gas, the actual utility rate was obtained from the 2015-2016 Suburban Natural Gas Company utility bills. The rate per therm is $0.6911.

Annual Utility Cost		
Source	Rate ($/Therm)	Actual Cost
Natural Gas	0.6911	$ 46,005.14
Source	Rate ($/kWh)	Actual Cost
Electricity	0.047	$ 143,549.28
Total		$ 189,554.42
Utillity Cost/SF.		$ 1.93

TABLE 19: ACTUAL ANNUAL (2015-2016) UTILITY COSTS

About 75% of the building's utility costs are due to electricity. $143,549 is spent annually of electricity consumption and $46,005 is spent annually on gas consumption.

Existing Mechanical System

Roof Top Units (Cooling & Heating)

The packaged roof top unit air conditioners installed do not require any chillers or boilers. Each unit is able to directly cool/heat the supply air to an occupied space/zone. The units are equipped with an evaporator, compressor, condenser, and thermal expansion control device. Furthermore, the units are equipped with a heat exchanger (drum and tube) that takes care of heating. A forced combustion blower supplies pre-mixed fuel through a single stainless steel burner screen into a sealed drum where ignition takes place. VAV reheat boxes are attached to the RTUs in order to provide the required amount of CFM and temperature for each space/zone. Table 20 documents the airflow, cooling, and heating capacities.

Roof Top Unit Schedule				Cooling Coil				Heating Section		
		Supply Air (CFM)	Outside Air (%)	Total MBH	Sensible MBH	EAT/LAT (F)	EER	Input MBH	Output MBH	EAT/LAT (F)
System	RTU-1	30000	22.60%	969	555	84/60	-	1062	850	75/101
	RTU-2	12000	40.8%	471	335	83.17/60.82	10.3	750	607	41.4/88.5
	RTU-3	2600	24.2%	88	65	79.85/58.36	12.6	150	120	43/96
	RTU-4	13000	20.0%	449	345	79/55.12	10.4	850	697	56/105
	RTU-5	4000	35.5%	144	101	82.1/60.52	12.1	250	203	45/92
	RTU-6	6400	31.3%	246	188	81.25/56.39	10	400	324	48/95
	RTU-7	6400	31.3%	246	188	81.25/56.39	10	400	324	48/95
	RTU-8	5600	29.6%	200	158	80.93/57.27	11	350	284	49/96
	RTU-9	15000	32.0%	570	432	81.4/55.7	10.6	850	697	47.6/90
	RTU-10A	11200	30.0%	396	306	81/59.24	10.3	600	486	49/89.5
	RTU-11	11200	30.0%	396	306	81/59.24	10.3	600	486	49/89.5
	RTU-12	3200	39.1%	115	88	82.81/59.23	12.5	250	200	43/101
	RTU-13	2400	32.7%	88	66	81.54/57.68	12.6	200	160	47/109

TABLE 20: ROOF TOP UNIT SCHEDULE

Air Conditioning Units (Cooling)

There are 7 (ACU 1-7) split system air conditioning units throughout the building. Each unit is in charge of cooling only with a capacity of 18,000 btu/h and an EER of 8 Btu/h/W. These units are wall mounted and placed in rooms such as I.T., Mechanical, Electrical, and Telecommunication rooms. Each unit supplies a total of 425 CFM. The ACU are sized based on a entering air temperature of 80F(DB) and 67F(WB). Table 21 documents the airflows and cooling coil capacities of the ACU's

Tenant Air Conditioning Unit Schedule				Cooling Coil		Configuration
		Supply Air (CFM)	CUA Mark	Total MBH	EAT (F)	
System	ACU-1	425	2	18	80	Wall
	ACU-2	425	4	18	80	Wall
	ACU-3	425	6	18	80	Wall
	ACU-4	425	7	18	80	Wall
	ACU-5	425	8	18	80	Wall
	ACU-6	425	9	18	80	Wall
	ACU-7	425	10	18	80	Wall

TABLE 21: AIR CONDITIONING UNIT SCHEDULE

Condensing Units (Air Cooled)

There are 7 air cooled condensing units (CUA 1-7) which serve the seven ACU 1-7 split systems. Each unit is equipped with a gas compressor that operates with an inverter. As for the condensing part, each condenser is equipped with a propeller fan operating at an ambient air temperature of 95F. R410 is the refrigerant type that is used by the condensing units. As for CUA – 8, the unit serves the computer room. Table 22 documents the condensing unit schedule.

Tenant Condensing Unit Schedule				Compressor Data	Condenser Data		Refrigerant Type
		Service	MBH	Type	Fan Type	AAT (F)	
System	CUA-1	ACU-1	18	Inverter	Propeller	95	R410
	CUA-2	ACU-2	18	Inverter	Propeller	95	R410
	CUA-3	ACU-3	18	Inverter	Propeller	95	R410
	CUA-4	ACU-7	18	Inverter	Propeller	95	R410
	CUA-5	ACU-4	18	Inverter	Propeller	95	R410
	CUA-6	ACU-5	18	Inverter	Propeller	95	R410
	CUA-7	ACU-6	18	Inverter	Propeller	95	R410
	CUA-8	CRAC-1	50.4	Scroll	Propeller	105	R407C

TABLE 22: CONDENSING UNIT SCHEDULE

FPVAV Terminal Units (Heating)

There are 17 fan powered VAV terminals of the parallel type. The fans only operate during unoccupied periods. Each system was sized base on a primary entering air temperature of 55F and a room entering air temperature of 70F. The fan inlet size varies from 6” – 14” and rated anywhere from 280 – 1400 CFM depending on the location/usage. These terminals are for heating only. Table 23 documents the FPVAV terminal unit schedule.

FPVAV Termianl Unit Schedule				Primary CFM		Fan (CFM)	Heating Coil
		Type	Inlet Size (in.)	Max	Min		LAT (F)
System	FPVAV 2-1	Parallel	10	1005	550	455	90
	FPVAV 2-2	Parallel	6	400	120	280	97
	FPVAV 2-3	Parallel	14	1825	535	1250	90
	FPVAV 3-1	Parallel	10	1000	240	560	90
	FPVAV 3-2	Parallel	6	400	120	280	97
	FPVAV 3-3	Parallel	10	1000	300	700	90
	FPVAV 4-20	Parallel	10	750	225	525	90
	FPVAV 4-21	Parallel	8	725	160	240	89
	FPVAV 4-22	Parallel	12	1200	360	840	90
	FPVAV 4-23	Parallel	8	550	220	330	89
	FPVAV 4-24	Parallel	6	400	120	280	97
	FPVAV 4-25	Parallel	6	400	120	280	97
	FPVAV 9-1	Parallel	14	2000	600	1400	91
	FPVAV 9-24	Parallel	12	1000	345	805	90
	FPVAV 9-25	Parallel	12	1325	610	915	90
	FPVAV 9-29	Parallel	8	315	145	330	89
	FPVAV 9-30	Parallel	6	400	120	280	97

TABLE 23: FAN POWERED VARIABLE AIR VOLUME TERMINAL UNIT SCHEDULE

VAV Terminal Units

The VAV terminal units in the building are digital single duct terminals. They are attached to the roof top unit's ducts to make sure that the specific CFM is being supplied to the rooms fed by the roof top units. The inlet sizes vary from 6" – 14" depending on CFM needed. These terminals help with energy savings due to the variety of control strategies they offer. The heating selection is based on an entering air temperature of 55F. Table 24 documents the VAV terminal unit schedule.

VAV Termianl Unit Schedule			Primary CFM		Heating Coil	
		Inlet Size (in.)	Max	Min	CFM	LAT (F)
System	VAV 2-1	8	700	210	210	85
	VAV 2-2	12	600	450	450	83
	VAV 2-3	8	500	165	165	93
	VAV 2-4	6	400	100	100	87
	VAV 2-5	14	1875	425	425	92
	VAV 2-6	8	675	240	240	88
	VAV 2-7	10	1100	550	550	89
	VAV 2-8	16	3000	1200	1200	97
	VAV 2-9	6	400	220	220	98
	VAV 4-3	8	440	185	185	84
	VAV 4-8	8	440	440	440	87
	VAV 4-10	10	805	400	400	87
	VAV 4-11	6	400	120	120	95
	VAV 4-12	6	125	100	100	87
	VAV 4-13	6	255	255	255	92
	VAV 4-20	10	600	310	310	86
	VAV 4-22	8	750	300	300	87
	VAV 4-23	10	1075	430	430	92
	VAV 4-24	10	750	265	265	91
	VAV 4-25	10	750	265	265	91
	VAV 4-32	10	1000	630	630	85
	VAV 9-1	8	775	160	160	84
	VAV 9-2	8	450	190	190	95
	VAV 9-3	12	1400	350	350	91
	VAV 9-4	12	1140	575	575	88
	VAV 9-5	8	500	190	190	88
	VAV 9-6	6	175	100	100	87

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System	VAV 9-7	6	265	265	265	91
	VAV 9-8	8	435	435	435	91
	VAV 9-10	6	325	100	100	87
	VAV 9-20	6	350	210	210	93
	VAV 9-21	8	550	360	360	90
	VAV 9-22	6	350	325	325	94
	VAV 9-23	6	220	130	130	92
	VAV 9-24	6	425	120	120	95
	VAV 9-25	10	950	380	380	88
	VAV 9-26	6	200	120	120	95
	VAV 9-27	12	1300	675	675	88
	VAV 13-1	12	1160	695	695	91
	VAV 13-2	6	400	120	120	95
	VAV 13-3	6	400	200	200	87
	VAV 13-4	6	400	400	400	87
	VAV 13-5	8	500	150	150	97
	VAV 13-6	12	1500	600	600	92
	VAV 13-7	6	400	120	120	95
	VAV 13-8	8	530	260	260	98
	VAV 13-9	6	300	240	240	95
	VAV 13-10	8	600	390	390	96
	VAV 13-11	6	350	350	350	91
	VAV 13-12	14	1535	1535	1535	88
	VAV 13-13	6	200	200	200	87
	VAV 13-14	10	975	975	975	88
	VAV 13-15	8	550	550	550	89
	VAV 13-16	6	370	125	125	93
	VAV 13-17	6	325	325	325	84
	VAV 13-18	6	360	360	360	90
	VAV 13-19	8	450	450	450	90
	VAV 13-20	8	475	165	165	93
	VAV 13-21	6	400	0	0	0
	VAV E-1	10	900	900	900	76
	VAV E-3	12	1360	1360	1360	76
	VAV E-4	12	1355	1355	1355	76
	VAV E-5	14	1965	1965	1965	76
	VAV E-6	14	2100	2100	2100	76
	VAV E-7	8	655	655	655	79
	VAV E-8	16	2555	2555	2555	76
	VAV E-9	14	1775	1775	1775	76

TABLE 24: VARIABLE AIR VOLUME TERMINAL UNIT SCHEDULE

Computer Room Air Conditioner

The building has 1 Computer Room Air Conditioner systems (CRAC-1) mounted on the ceiling. It is connected to condensing unit number 8 (CUA-8) with a refrigerant type of R407C. The system is equipped with both a cooling coil and a reheat coil. It is rated at 2500 CFM. Table 25 documents the CRAC schedule.

Computer Room Air Conditioner Schedule					Cooling Coil					Reheat Coil		Humidifier	
		Type	Mounting	Supply (CFM)	Total MBH	Sensible MBH	EAT (F)	FPM	CUA Mark	Type	KW	Type	PPH
System	CRAC-1	ACSS	Ceiling	2500	57.3	49.5	72	444	CUA-8	Electric	16.5	Steam Generator	8

TABLE 25: COMPUTER ROOM AIR CONDITIONER SCHEDULE

Exhaust Fans

There are 5 major exhaust fans, exhaust fans 1, 2, 3, and 14 are placed to provide general ventilation to the building rated at 2000 – 4180 CFM. They are considered to be down blast Centrifugal Exhaust Ventilators. As for EF-15, it is a utility ventilator for isolation ventilation purposes. Table 26 documents the exhaust fan schedule.

Exhaust Fan Schedule										
		Service	Type	CFM	SP ("WC)	OV (FPM)	Tip Speed (FPM)	RPM	Arrangement	Drive
System	EF-1	General	Pre	4,180	1.25	1970	6790	1441	Downblast	Belt
	EF-2	General	Pre	2,000	1.25	1357	5741	1462	Downblast	Direct
	EF-3	General	Pre	2,000	1.25	1357	5741	1462	Downblast	Direct
	EF 4	Kitchen	IC	1270	0.75	713	5249	1671	-	Belt
	EF 5	Vest.	IC	1200	0.45	431	3679	937	-	Direct
	EF 6	Vest.	IC	1200	0.45	431	3679	937	-	Direct
	EF 7	Chemical Storage	IC	1000	0.75	-	-	2825	-	Direct
	EF 9	MRI Emergency Exhaust	UPRE	1200	0.5	774	3866	1094	-	Belt
	EF 10	Medical Elec. Room 1st Floor	IC	500	0.5	200	4466	1706	-	Belt
	EF 11	Wellness Elec. 1st Floor	IC	500	0.5	200	4466	1706	-	Belt
	EF 12	Medical Elec. 2nd Floor	IC	500	0.5	200	4466	1706	-	Belt
	EF 13	Medical Elec. 3rd Floor	IC	500	0.5	200	4466	1706	-	Belt
	EF 14	General	Pre	3400	1.25	1603	6083	1291	Downblast	Belt
	EF 15	Isolation	US	500	1.25	870	7144	1910	-	Belt
	EF 16	Vest.	IC	1200	0.45	431	3679	937	-	Direct
	EF 17	Vest.	IC	600	0.45	736	4390	1677	-	Direct

TABLE 26: EXHAUST FAN SCHEDULE

Electric Cabinet Heaters

The building is equipped with 3 electric cabinet heaters (CUH 1-3) mounted on the wall. They at rated at 500 CFM and consume 10KW of energy. Furthermore, they are provided with a disconnect switch and an integral thermostat. They are used to heat the stairwells on the east and west side of the building. Table 27 documents the electric cabinet heater schedule.

Electric Cabinet Heater Schedule						
		Configuration	Inlet	Discharge	CFM	KW
System	CUH-1	Wall Mounted	Front	Front	500	10
	CUH-2	Wall Mounted	Front	Front	500	5
	CUH-3	Wall Mounted	Front	Front	500	10

TABLE 27: ELECTRIC CABINET HEATER SCHEDULE

Energy Recovery Ventilator

There is 1 energy recovery ventilator (ERV-1) that is servicing the locker rooms. It is equipped with a heat recovery wheel to allow for energy savings and at the same time providing the locker rooms with fresh pre conditioned outside air. Exhausting a total of 14,000 CFM and bringing in 12,000 CFM of outside air in. During summer conditions it brings in outside air entering at 95F and leaving at 80F (Preconditioned air) followed by cooling to make sure the air being supplied to the lockers is 75F. During winter conditions it brings in outside air entering at 0F and leaving at 51F (Preconditioned air) followed by heating to make sure the air being supplied to the lockers is 70F. The air goes through two sets of filters to make sure that the air being supplied is fresh and free of contaminants. Table 28 documents the energy recovery ventilator schedule.

Energy Recovery Ventilator Schedule			Recovery		Outside Air		Exhaust Air	
		Service	Type	Material	CFM	ESP ("WC)	CFM	ESP ("WC)
System	ERV-1	Lockers	Wheel	Aluminum	12000	1.3	14000	1.25
			Summer Conditions			Winter Conditions		
			OA - EAT (DB/WB F)	OA - LAT (DB/WB F)	EA - EAT (DB/WB F)	OA - EAT (DB/WB F)	OA - LAT (DB/WB F)	EA - EAT (DB/WB F)
			95/76	80.4/67.4	75/63	0/-1	51.2/41.4	70/53
			Cooling Coil				Heating Section	
			Total MBH	Sensible MBH	EAT (DB/WB F)	LAT (DB/WB F)	Input (MBH)	Output (MBH)
			592	390	80.4/67.3	50.9/50.9	1000	800
			OA Filters			EA Filters		
			Type	Merv	Depth	Type	Merv	Depth
			Flat	8	2"	Flat	8	2"

TABLE 28: ENERGY RECOVERY VENTILATOR SCHEDULE

Domestic Water Heaters

There are 4 domestic water heaters serving the building. DWH – 1,2 are rated at 300 MBH each with a 1.5” pipe diameter and a recovery rate of 342 GPH at 100F. DWH – 3,4 are rated at 700 MBH each with a 2” pipe diameter and a recovery rate of 815 GPH at 100F. Their main purpose is to serve as storage tanks and be used when needed. Table 29 documents the domestic water heater schedule.

Domestic Water Heater Schedule								
		Type	Fuel	Burner Type	Input	Recovery Rate @100F	Storage (Gallons)	Maximum Working Press. (PSI)
System	DWH-1,2	Storage	Gas	Power	300	342	100	150
	DWH-3,4	Storage	Gas	Power	800	815	130	150

TABLE 29: DOMESTIC WATER HEATER SCHEDULE

Boilers

The three main pools (Lap Pool, Therapy Pool, and Exercise Pool) are required to be maintained at a specific temperature. Therefore, a boiler is assigned to each pool for that purpose. The 3 boilers are rated at 1261, 300, and 400 MBH respectively. As for the 2 Spas, they each have a boiler serving the Men and Women Whirlpool. Both boilers are rated at 400 MBH.

Chillers

There are only two chillers in the building (Dimplex 5000 packaged air cooled chiller and Kraus packaged air cooled chiller) serving to cool some medical equipment. The Dimplex 5000 is located on the roof and is supplying primary chilled glycol to the heat exchanger cabinet, located on the first floor, through a 1.5" pipping. The heat exchanger cabinet then supplies the CT gantry with secondary chilled glycol through 1" piping. That process allows the CT gantry (medical equipment) located in the CT scanner room to cool down.

As for the Kraus packaged air cooled chiller, it is also located on the roof and is supplying the heat exchanger cabinet (located on the first floor) with chilled glycol through 2" piping. The same process explained earlier occurs here but the HEC is connect to a power gradient cabinet and a a cryocooler compressor. Finally the HED supplies the magnet equipment, located in the MRI magnet room, with chilled glycol solution through 1.5" flex hose furnished with MRI equipment package making sure the equipment doesn't overheat.

Space Consideration

The mechanical equipment designed for Mount Carmel Fitness & Health center does not take up a lot of space with respect to the overall area of the building. The majority of cooling and heating is provided by the roof top units with all the units being placed on the roof. Therefore, there is no space lost caused by the equipment. As for the shaft areas, it is so minimal due to the multiple RTU sizes. In other words, each unit does not require a lot of shaft area and definitely is not affecting any major loss of space in the building. In terms of actual floor area being used, all the boilers and domestic water heaters along with pool equipment is placed in the pool mechanical room located on the 1st floor. The size of the room is 975 SF. which is about less than 1% of the total building area.

In regards to the other systems such as the air handling units, FPVAV units, VAV units, and electric cabinet heaters do not require any significant space. The cabinet heaters are placed in the stairwells and the air handling units are placed in the I.T rooms and Elec. rooms. These spaces have no direct effect on the patients in terms of space and therefore the owner is not losing any money generating occupiable space. As for the VAV and FPVAV terminal units, generally they take up a part of the ceiling cavity space

System First Cost

The mechanical system first cost was not able to be obtained by the owner representative. The owner requested that the first cost not to be mentioned in this report. However, the first cost of the mechanical system was a primary key when designing. The owner wanted to make sure the first cost to be minimal which explains why the building relies heavily on the RTUs and did not invest in a main cooling/heating plant. Due to that decision, the 12 months history usage of gas and electricity shows that the owner is spending about $200,000 a year for system operation costs. This shows that it would’ve been more feasible for the owner to invest more in terms of first cost and allow for saving in the long run.

LEED Evaluation

Mount Carmel Fitness & Health was not LEED Certified. A LEED analysis was performed by following the LEED Checklist Version 4.4. The analysis was only performed for the mechanically related categories to see the total possible points that can be awarded. The final LEED score for the mechanically related categories were a total of 14 points. A total of at least 40 points had to be achieved for the building to be LEED certified.

Energy & Atmosphere Credits

Fundamental Commissioning and Verification (Prerequisite: Met)

This Section is intended to support the design, construction, and eventual operation of a project that meets the owner’s project requirements for energy, water, indoor environmental quality, and durability. Contracts were established with commissioning agents for the basic scope of commissioning services.

Minimum Energy Performance (Prerequisite: Met)

This prerequisite requires a demonstration of an improvement of 5% for new construction, 3% for major renovations, or 2% for core and shell projects in the proposed building performance rating compared with the baseline building performance rating according to ASHRAE 90.1-2010.

Building-Level Energy Metering (Prerequisite: Met)

The building is equipped with building-level energy meters and sub-meters that can illustrate the total building energy consumption as well as a breakdown of the usages to allow for tracking the building-level energy use.

Fundamental Refrigerant Management (Prerequisite: Met)

To help reduce stratospheric ozone depletion, all the refrigerants used in the equipment are either HFC or HCFC type. There are no CFC based refrigerants in any of the equipment.

Enhanced Commissioning (6/6 Points)

A contract was established to perform enhanced commissioning activities for mechanical, electrical, and plumbing systems. Also, an on-going commissioning plan was established.

Advanced Energy Metering (1/1 Point)

Advanced energy metering is installed for the whole-building energy sources. The system is capable of storing all meter data for at least 36 months and is remotely accessible.

Demand Response (0/2 Points)

The building is not eligible for the demand response program and therefore will not receive any points for this section.

Renewable Energy Production (0/3 Points)

The building has no form of renewable energy implemented and therefore will not receive any points for this section.

Enhanced Refrigerant Management (0/1 Points)

The building uses both R410A and R407C which both contribute to ozone depletion. The refrigerant did not meet the requirement of LCGWP+LCODP*10^5=100 and therefore will not receive any points for this section.

Green Power and Carbon Offsets (0/2 Points)

There was no implementation of green power on this project (use of grid-source or renewable energy technologies) and therefore no points will be awarded for this section.

Total: 7 Points

Indoor Environmental Air Quality Credits

Minimum Indoor Air Quality Performance (Prerequisite: Met)

From Technical Report 1 it was deduced that the building meets the minimum requirements of ASHRAE Standard 62.1-2010 sections 4 – 7. Therefore, the prerequisite is met.

Environmental Tobacco Smoke-Control (Prerequisite: Met)

This building is considered a non-smoking facility and there are signs throughout the building's interior and exterior prohibiting smoking within the vicinity of the building.

Enhanced Indoor Air Quality Strategies (0/2 Points)

The majority of systems brining in outside air to the building such as roof top units and energy recovery ventilator have a filter rated at MERV 8. For points to be awarded, the criteria requires a minimum efficiency reporting value of MERV 13 or higher. Therefore, the building will not receive any points for this section.

Low-Emitting Materials (1/3 Points)

This section is intended to reduce concentrations of chemical contaminants that can damage air quality, human health, productivity, and the environment. It was found that about 65% of the materials used were low emitting materials. Therefore, the building will be awarded 1 point only.

Construction Indoor Air Quality Management Plan (0/1 Point)

This section intends to enhance the well-being of the construction workers and building occupants by bettering the indoor air quality during construction and renovation phases. Unfortunately, it was unknown if there was an indoor air quality management plan for the construction and preoccupancy phases of the building. Therefore, no points will be awarded for this section.

Indoor Air Quality Assessment (1/2 Points)

This section focuses on providing a better indoor air quality after the construction phase and during occupancy. During occupancy, the building met the minimum requirements of ventilation at a rate of 0.3 CFM per SF of outdoor and therefore will be awarded 1 point. The air testing results were not obtained by the owner so no extra points will be awarded.

Thermal Comfort (1/1 Points)

This section focuses on thermal comfort and thermal comfort control to ensure the occupants'' productivity, comfort, and well-being. The building's mechanical systems ensure meeting the requirements of ASHRAE Standard 55-210 in terms of thermal comfort. As for thermal comfort conditions, the building is equipped with individual comfort controls for at least 50% of individual occupant spaces.

Interior Lighting (1/2 Points)

Lighting control is provided for at least 90% of individual occupant spaces. Therefore, 1 point will be awarded for this section.

Daylight (1/3 Pioints)

This section focuses on connecting the building occupants with the outdoor to help reduce the use of electrical lighting. 75% of the perimeter floor area is provided with spatial daylight. There was no illuminance simulation done so no point will be awarded of option 2 in this section.

Quality Views (1/1 Points)

All of the occupied spaces from the perimeter of the building have a view to the exterior. Therefore, full points will be awarded for this section.

Acoustic Performance (1/1 Point)

All the required STC and reverberation times have met the requirements of this section. Therefore, full point will be awarded.

Total: 7 Points

Overall Mechanical System Evaluation

Overall, the mechanical system of the building provides all the required cooling and heating loads along with occupants' thermal comfort. All that aside, the system is very inefficient and should not be used in a building with such purpose and area. Having 13 Roof Top Units that vary in size and serve specific zones is costing the building a significant amount of yearly energy consumption. There is no main cooling or heating plant that can serve the total building cooling and heating demands. All the reliance is on the size varying Roof Top Units. Even though the Roof Top Units have a significant amount of VAV and FPVAV terminal units, the control strategies provided by these terminals to help in energy savings are not sufficient enough.

The owner was able to save some money in terms of first costs but when looking at the 12 months history energy usage of the building it was found that a significant amount of money is being spent yearly to operate the systems. In addition, the three main pools in the building consume a lot of gas yearly. Therefore, a solution needs to be found in order to allow the systems to perform more efficiently or allow for an installation of new systems.

Proposed Alternatives

Overall, the mechanical system of the building provides all the required cooling and heating loads along with occupants' thermal comfort. All that aside, the system is very inefficient and should not be used in a building with such purpose and area.

Having 13 Roof Top Units that vary in size and serve specific zones is costing the building a significant amount of yearly energy consumption. There is no main cooling or heating plant that can serve the total building cooling and heating demands. All the reliance is on the size varying Roof Top Units. Even though the Roof Top Units have a significant amount of VAV and FPVAV terminal units, the control strategies provided by these terminals to help in energy savings are not sufficient enough.

The owner was able to save some money in terms of first costs but when looking at the 12 months history energy usage of the building it was found that a significant amount of money is being spent yearly to operate the systems. In addition, the three main pools in the building consume a lot of gas yearly.

Therefore, to solve these issues and aim for a better performing building a geothermal closed loop system is proposed for analysis

Geothermal Closed Loop System

Geothermal systems work by extracting latent heat from the ground or a nearby source of water, like a well or pond. That is because temperatures underground and in deep water remain at a consistent level year-round, this heat can be concentrated by a heat pump then dispersed through the building for warmth in winter. In summer, the process reverses as interior heat is removed and dispersed back to the earth or water well.

Assuming that the pond near the MC Fitness & Health center is deep enough and will not freeze completely, a geothermal closed loop system could be a great solution. A geothermal closed loop system operates by creating a circuit of pipe in the ground that circulates the same mixture of water and antifreeze through. This fluid is constantly circulated through the loop for the lifetime of the loop. Closed loops do not have any interference with ground water at all. The water antifreeze solution is circulated through the heat pump where heat is extracted from, then the fluid is re-circulated through the ground loop to recover the heat that has been extracted. In essence, we have created an independent energy source that is going to be able to heat forever.

As for the pond, it would be used as the medium for the closed loop. Instead of creating a circuit of pipe in the ground, the large pond near the facility could be used. This is because water makes a great conductor for heat transfer. When the closed loop is surrounded by the pond water there would be greater contact with the pipes and rapid convection. All that said, this application would be great for the cooling season but as for the winter season an ice cover is required to allow the pond to reach an average of 40F just below the ice cap.

Using the pond for a geothermal closed loop system might not be the best geothermal option during the winter season in Ohio. Therefore, further analysis and research will be conducted to decide whether to use the pond for a closed loop system, or take advantage of the excessive land space for piping underground. Also, a geothermal open loop system could be an option.

Having a geothermal central plant serving the facility will allow a drastic decrease in energy consumption specifically gas usage which is one of the main issue of the building’s performance. Such a system will be expensive when it comes to first costs, but would definitely have an acceptable payback period.

Along with the geothermal system, two systems will be analyzed/studied. The first alternative design is going to be a geothermal system coupled with Roof Top Unit Water Source Heat Pumps. The geothermal well field will act as the central plant of the building, along with the RTU WSHP as a conditioning and distribution system. Similarly to alternative 1, alternative 2 will have a DOAS with individual self-contained heat pumps placed throughout the building based on the building’s needs.

Proposed Breadth Topics

Acoustical Breadth

MC Fitness & Health Center is based on two main functions, medical procedures and fitness accommodations. The facility is divided in a way that provides patients with multiple services. Examination and Operation rooms make up a good portion of the building. Those types of spaces need to always be acoustically comfortable due to the sensitive kind of work being done. Also patients should always be comfortable not having to deal with acoustical discomfort. Therefore, with having the two alternatives studied. An acoustical analysis is going to be conducted to compare the noise generated due to the existing system, Alternative 1, and Alternative 2 on one of those spaces.

Lighting/Electrical Breadth

Due to MC Fitness & Health Center long hours of operation and lack of occupancy sensors, the lights are constantly turned on. It is complicated to control operation hours in such a facility due to its type of functions. When looking at the Trace model created previously, it was found that lighting loads consumed a good portion of the annual electricity consumption in the building. Therefore, a solution should be found, not including change of operation hours, to reduce that load allowing for economical savings. When looking at the fixture schedule of the building, it was found that most of the lamp types were either T8 or T5. In other words, not the most efficient choices.

An analysis will be conducted on 3 – 5 spaces that represent the whole building's function, seeing if change of existing fixtures could allow for a reduction in the annual electricity consumption.

Tools

In order to conduct such an analysis multiple tools are going to be needed.

First of all, in order to find out that the proposed system is feasible Trace 700 will be used to modify the energy model created and test the three different geothermal configurations. This will provide a better understanding in terms of performance and energy consumption. Furthermore, Revit will be used in order to study the different locations that the geothermal system can be placed/installed. That will allow an investigation related to space constraints. Finally, 12 months energy usage history of buildings with a geothermal system and similar scope will be obtained.

Also, more research will be conducted specifically about different geothermal system configurations and maybe other systems such as but not limited to variable refrigerant flow.

In regards to the Breadth topics, as mentioned earlier, tools such as but not limited to AGI and Pottoroff AIM will be used to conduct the necessary analysis.

Mechanical Depth: Geothermal Closed Loop System

Geothermal System Sizing and Calculations

In order to size the geothermal well fields, the needed lengths were calculated by using MC Fitness & Health Center's annual peak heating and cooling loads. The equations in chapter 34 of ASHRAE Handbook – HVAC Applications were used and are shown below. The first two equations provided below were utilized to calculate the overall needed lengths for both heating and cooling. Furthermore, each step is outlined below in order to explain how the equations were utilized.

$$L_c = \frac{q_a R_{ga} + (q_{lc} - 3.41W_c)(R_b + PLF_m R_{gm} + R_{gd} F_{sc})}{t_g - \frac{t_{wi} + t_{wo}}{2} - t_p}$$

$$L_h = \frac{q_a R_{ga} + (q_{lh} - 3.41W_h)(R_b + PLF_m R_{gm} + R_{gd} F_{sc})}{t_g - \frac{t_{wi} + t_{wo}}{2} - t_p}$$

$F_{sc} - short - circuit\ heat\ loss\ factor$

$L_c - required\ bore\ length\ for\ cooling, ft$

$L_h - reuqired\ bore\ length\ for\ heating, ft$

$PLF_m - part - load\ factor\ during\ design\ month$

$q_a - net\ annual\ average\ heat\ transfer\ to\ ground, Btu/h$

$q_{lc} - building\ design\ cooling\ block\ load, Btu/h$

$q_{lh} - buildling\ design\ heating\ block\ load, Btu/h$

$R_{ga} - effective\ thermal\ resistance\ of\ ground\ (annual\ pulse), (ft * h * °F)/Btu$

$R_{gd} - effective\ thermal\ resistance\ of\ ground\ (peak\ daily\ pulse), (ft * h * °F)/Btu$

$R_{gm} - effective\ thermal\ resistance\ of\ ground\ (monthly\ pulse), (ft * h * °F)/Btu$

$R_b - thermal\ resistance\ of\ bore, (ft * h * °F)/Btu$

$t_g - undistured\ ground\ temperature, °F$

$t_p - temperature\ penalty\ for\ interference\ of\ adjacent\ bores, °F$

$t_{wi} - liquid\ temperature\ at\ heat\ pump\ inlet, °F$

$t_{wo} - liquid\ temperature\ at\ heat\ pump\ outlet, °F$

$W_c - system\ power\ input\ at\ design\ cooling\ load, W$

$W_h - system\ power\ input\ at\ design\ heating\ load, W$

Short-Circuit Heat Loss Factor (F_{sc})

In order to find the F_{sc} factor, 3 gpm/ton was assumed per bore and the bores are piped in parallel. Table 16 from ASHRAE HVAC Application, chapter 34 was used and a short – circuit heat loss factor of 1.04 was found.

	F_{sc}	
Bores per Loop	**2 gpm/ton**	**3 gpm/ton**
1	1.06	1.04
2	1.03	1.02
3	1.02	1.01

Part Load Factor (PLF_m)

The part-load factor was chosen to be 1.0 assuming the worst case scenario because the actual PLF is unknown.

Net Annual Average Heat Transfer to Ground (g_a)

This value was obtained by finding the difference between the heating and cooling block loads (Btu/hr). This difference will estimate the annual heat transfer to the ground. For the MC Fitness and Health Center, the value was found to be 696,000 Btu/hr.

Building Design Cooling/Heating Block Load (q_{lc} q_{lh})

The well field was calculated using MC Fitness & Health Center design heating load and cooling load. These value were obtained from the Trace 700 model that was created, and was found to be 5,292,000 Btu/hr for heating and 4,596,000 Btu/hr for cooling.

Effective Thermal Resistance of Ground - Annual Pulse (R_{ga})

After understanding the geology around the location where the building is set on, table 5 of ASHRAE HVAC Applications was used to find both the diffusivity and conductivity values. These values were found to be, 1.7 for conductivity and 1.05 for diffusivity. These two values were used in order to find the effective thermal resistance of the ground (annual pulse). That value was found to be 0.217 All the calculations that were performed can be found under the ground thermal resistance calculations section.

Effective Thermal Resistance of Ground - Peak Daily Pulse (R_{gd})

The effective thermal resistance of the ground for a peak daily pulse was found to be 0.128. All the calculations that were performed can be found under the ground thermal resistance calculations section.

Effective Thermal Resistance of Ground—Monthly Pulse (R_{gm})

The effective thermal resistance of the ground for a monthly pulse was found to 0.207.All the calculations that were performed can be found under the ground thermal resistance calculations section.

Ground Thermal Resistance Calculations

The three effective thermal resistances that were provided in the previous sections were obtained by using the following equations:

$$R_{ga} = \frac{G_f - G_1}{k_g}$$

$$R_{gm} = \frac{G_1 - G_2}{k_g}$$

$$R_{gd} = \frac{G_2}{k_g}$$

In order to obtain the G – Factors, Figure 15 from Chapter 34 ASHRAE HVAC Applications was used along with Fourier Numbers.

$$\tau_1 = 3650\ days$$

$$\tau_2 = 3650 + 30 = 3680\ days$$

$$\tau_f = 3650 + 30 + 0.25 = 3680.25\ days$$

$$Fo_f = \frac{4 * 1.05 * 3680.25}{0.5^2} = 61828.2$$

$$Fo_1 = \frac{4 * 1.05 * (3680.25 - 3650)}{0.5^2} = 508.2$$

$$Fo_2 = \frac{4 * 1.05 * (3680.25 - 3680)}{0.5^2} = 4.2$$

Looking at Figure 15 in Chapter 34 of ASHRAE HVAC Applications, the factors were found to be:

Gf = 0.94

$G1$ = 0.57

$G2$ = 0.218

Below is the Figure 21 that was used in order to find the G – Factors,

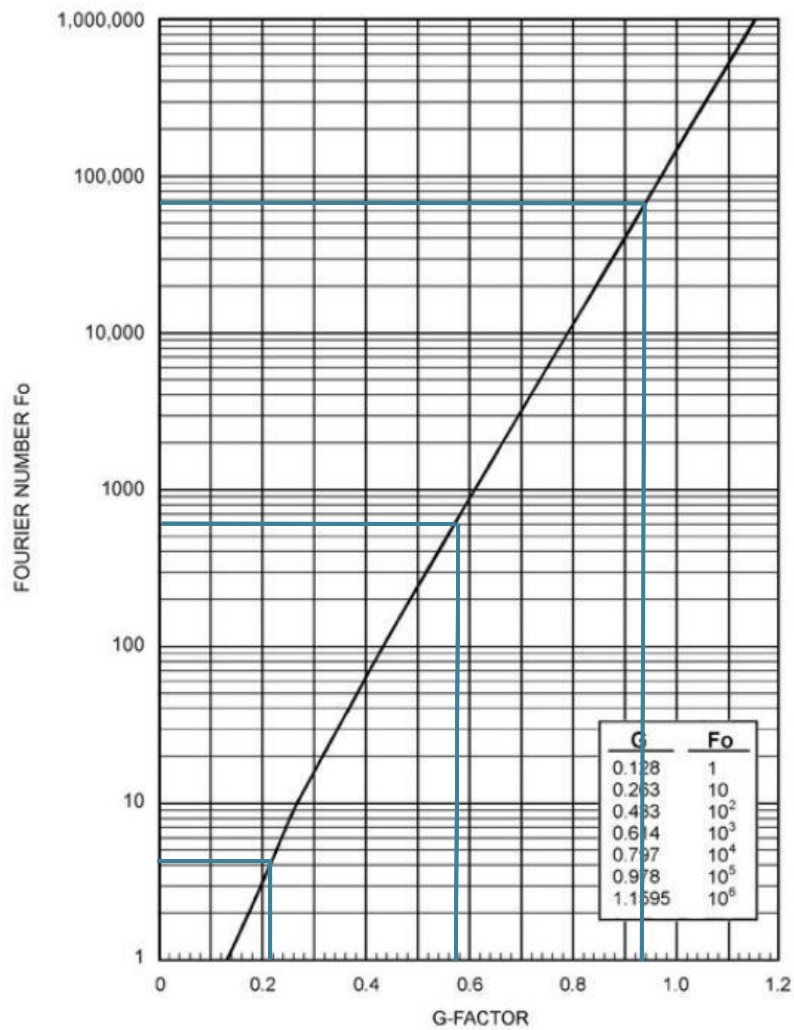


FIGURE 21: G-FACTOR GRAPH

Therefore, with the G-factors that were found, all the effective thermal resistances were found to be:

$$R_{ga} = 0.217$$

$$R_{gm} = 0.207$$

$$R_{gd} = 0.128$$

Thermal Resistance of Bore (R_b)

In order to find the thermal resistance of the bore, Table 6 in chapter 34 of ASHRAE HVAC Applications was utilized. A high-density polyethylene vertical U-Tube was specified with a diameter of 1.25" along with a 6" bore diameter and a fill with 1.0 Btu/(hr*ft*F) conductivity. With all that said, the thermal resistance of the bore was found to be 0.09. Below is the table that was used to allow for such finding.

Table 6. Thermal Resistance of Bores R_b for High-Density Polyethylene U-Tube Vertical Ground Heat Exchangers

	Bore Fill Conductivity,* Btu/h·ft·°F					
	4 in. Diameter Bore			6 in. Diameter Bore		
U-Tube Diameter, in.	0.5	1.0	1.5	0.5	1.0	1.5
3/4	0.19	0.09	0.06	0.23	0.11	0.08
1	0.17	0.08	0.06	0.20	0.10	0.07
1 1/4	0.15	0.08	0.05	0.18	0.09	0.06

* Based on DR 11, HDPE tubing with turbulent flow

Corrections for Other Tubes and Flows

DR 9 Tubing	Re = 4000	Re = 1500
+0.02 Btu/h·ft·°F	+0.008 Btu/h·ft·°F	+0.025 Btu/h·ft·°F

Sources: Kavanaugh (2001) and Remund and Paul (2000).

Undisturbed Ground Temperature (t_g)

In order to find the undisturbed ground temperature, Figure 17 from chapter 34 of ASHRAE HVAC Applications was utilized. Due to the building being located in Lewis Center, OH the undisturbed ground temperature was found to be 56 degrees F. Below is Figure 22 that was utilized from ASHRAE chapter 34.

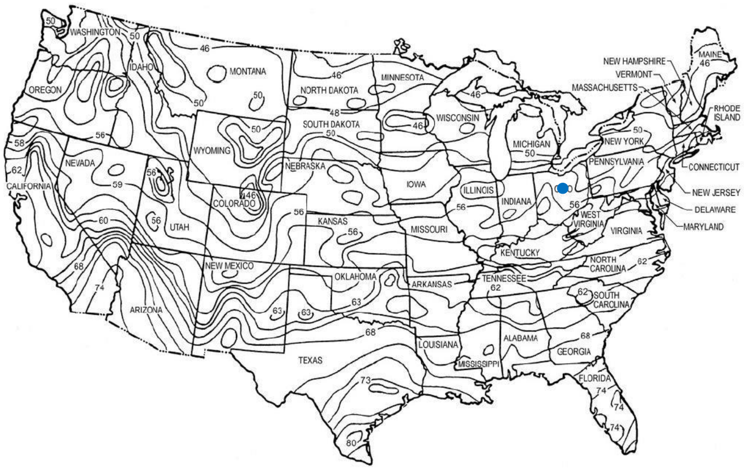


FIGURE 22: ASHRAE CHAPTER 34

Temporary Penalty for Interference of Adjacent Bores (t_p)

In order to find the temporary penalty for interference of adjacent bores, table 7 from Chapter 34 of ASHRAE HVAC Applications was utilized. The undisturbed ground temperature was found to be 56 degrees F, therefore 750 hours of cooling and 750 hours of heating per year was assumed. From table 7, the long-term temperature penalty was found to be 1.8 degrees F. Below is the table that was used.

Table 7 Long-Term Temperature Penalty for Worst-Case Nonporous Formations for 10 × 10 grid and 100 ton Load

$EFLH_c$, h/yr	$EFLH_h$, h/yr	EER, Btu/W·h	COP	T_g, °F	Bore Separation, ft	Bore Length, ft	$T_{penalty}$, °F
250	1250	17.6	3.6	42	15	230	−1.3
		17.6	3.6		20	221	−0.7
		17.6	3.6		25	217	−0.4
500	1000	16.8	3.7	45	15	218	−1.4
		16.8	3.7		20	210	−0.7
		16.8	3.7		25	206	−0.4
750	750	14.3	4.0	55	15	206	3.4
		14.3	4.0		20	195	1.8
		14.3	4.0		25	190	1.0
1000	500	13.3	4.4	65	15	284	6.9
		13.3	4.4		20	248	3.8
		13.3	4.4		25	231	2.0
1250	250	13.0	4.6	68	15	362	10.0
		13.0	4.6		20	289	5.7
		13.0	4.6		25	256	3.0
0	1500	Not recommended without solar or thermal regeneration					
1500	0	Not recommended without fluid cooler or cooling tower assist					

Note:
k_g = 1.4 Btu/h·ft·°F, k_{grout} = 0.85 Btu/h·ft·°F, rated EER/COP = 20.0/4.2 (GLHP).

Correction Factors for Other Grid Patterns:

1 × 10 grid	2 × 10 grid	5 × 5 grid	20 × 20 grid
C_f = 0.36	C_f = 0.45	C_f = 0.75	C_f = 1.14

Liquid Temperature at Heat Pump Inlet (t_{wi})

Due to the ground temperature being 56 degrees F, the cooling inlet temperature at the heat pump should be 81 degrees F. As for the heating inlet temperature, it should be 41 degrees F. These values were obtained due to a rule of thumb which says that for cooling the inlet temperature should be 20 – 30 degrees F higher and for heating 10 – 2- degrees F lower.

Liquid Temperature at Heat Pump Outlet (t_{wo})

The liquid temperature at the heat pump outlet should be higher than the inlet when cooling and lower than the inlet when heating. To avoid freezing, the outlet temperatures were chosen to be 5 degrees F higher/lower than the inlet. Therefore, the cooling outlet temperature was found to be 86 degrees F and heating outlet temperature was found to be 36 degrees F.

System Power Input at Design Cooling/Heating Load (W_c W_h)

In order to find the system power input at design cooling/heating load, Chapter 34 ASHRAE HVAC Application pumping power rule of thumb was used. The rule of thumb advised that the pumping power could be anywhere from 0.04 – 0.21 hp/ton of heat pump power. Therefore, 0.21 hp/ton was chosen assuming worst case conditions.

W_c = 0.21[hp/ton] x 383[ton] = 80.43[hp] x 745.7 [watt/hp] = 59,976.6[watt]

W_h = 0.21[hp/ton] x 441[ton] = 92.61[hp] x 745.7 [watt/hp] = 69059.2[watt]

Vertical Bores Length Calculation Summary

All the values that were found in the previous sections were used along with the two main equations in order to calculate the required bore length for cooling and heating. Table 30 provides a summary of the calculation for both L_c and L_h.

Cooling & Heating Bore Length Design			
Input		Heating	Cooling
Short-Circuit Factor	(Fsc)	1.04	1.04
Part-Load Factor	(PLFm)	1	1
Average Heat Transfer to Ground (Btu/hr)	(qa)	696000	696000
Block Loads (Btu/hr)	(qlh and qlc)	5292000	4596000
Resistance of Ground, Annual pulse	(Rga)	0.217	0.217
Resistance of Ground, Daily pulse	(Rgd)	0.128	0.128
Resistance of Ground, Monthly pulse	(Rgm)	0.207	0.207
Resistance of Bore	(Rb)	0.09	0.09
Undisturbed Ground Temperature (Degrees F)	(tg)	56	56
Temperature Penalty for Bore Spacing (Degrees F)	(tp)	1.8	1.8
Heat Pump Inlet Temperature (Degrees F)	(twi)	41	81
Heat Pump Outlet Temperature (Degrees F)	(two)	36	86
System Power Input (Watts)	(Wc and Wh)	69059.2	59976
Required Bore Length	(Lc and Lh)	**148148.9**	**69621.03**

TABLE 30: COOLING & HEATING BORE LENGTH DESIGN

When comparing both results, the design bore length for heating will constrain the required bore length of the building. This is because the design bore length for heating is larger than cooling.

Geothermal System Layout – Vertical Bore

When deciding on the layout of the bores, there were a couple of factors that needed to be analyzed in order to make the right decisions which are best for the building's needs. It was found that having vertical bores instead of horizontal would provide the most cooling when compared to the amount of land that is going to be used. The issue with having a vertical bore field was the spacing required between each bore. The goal here was to minimize the interaction effects between each bore. Therefore, each bore was placed 20 feet apart, minimizing interaction. The next step was deciding how deep the wells should be depending on the available land area. Looking at Figure 23, there were two options where the geothermal well field could be place. Option A allowed for a larger area but the issue was that it was further away from the building. Whereas, option B was closer to the building but had much smaller area to use.

FIGURE 23: GEOTHERMAL WELL FIELD OPTIONS

Looking at both options, it would be impossible to fit all the required bores within the available space provided in option B. Therefore, option A was used for the vertical bore well field to be installed.

After the location of the well field was found and the area was known, various calculations were performed in order to pick the most suitable depth. Table 31 illustrates the various depths with the required number of vertical bores.

Amount of Vertical Bores Required		
Well Depth	Bore Length Required (ft)	Amount of Wells
100	148148.9	1481
200	148148.9	741
300	148148.9	494
400	148148.9	370
500	148148.9	296
550	148148.9	269

TABLE 31: WELL-FIELD VERTICAL BORES REQUIRED

Based on the depth calculations and the area of the well field, 269 wells will be needed with a depth of 550’. The well field area allows for 296 bores having 20’ of spacing between each. Therefore, 550’ of depth is feasible for this system Figure 24 illustrates the geothermal well layout on the site, showing the supply and return lines. As the figure below shows, the system is piped in a reverse return pattern. This pattern was selected in order to ensure the best heat transfer between the ground and the field. Also, this pattern allows the pipes to be self-balanced ensuring the 3 gpm in each of the bores. Balancing valves will still be necessary to ensure consistent water flow.

FIGURE 24: GEOTHERMAL WELL-FIELD LAYOUT

Geothermal System Configuration

Looking at the geothermal system proposed, a majority of key factors are needed in order to make this system possible for operation. Starting from the vertical bore well field itself, multiple vertical bores need to be dug into the ground with a depth of 550'. Each hole is back-filled and grouted after the pipe is inserted, where the completed loop is concealed below ground. In addition, pumps are needed to pump the water from the loops into the header that is located in the pool mechanical room. In addition, pumps will be needed to pump the water from the header into the distributor.

Due to the lack of mechanical rooms in the buildings and excess roof space, rooftop WSHP units will be utilized. Piping will be running from the pool mechanical room, where the distributor is located, into the rooftop WSHP units.

Geothermal Equipment Selection

Looking at the geothermal system proposed, building pumps and piping will be required in order to service the system. Due to the reverse – return piping arrangement, the total head loss was calculated to the furthest bore. This calculation was performed to size the head loss for the pump. In order to accomplish that, the equivalent pipe length method was used. The maximum flow rate for the pump was based on the previous assumption of 3gpm of flow rate per bore. This resulted in a total maximum flow of 807 gal/min.

As for the calculations for the head loss per 100 ft of piping, the Hazens-Williams equation was used.

h = 0.2083 (100 / c)1.852 q1.852 / dh4.8655

h = friction head loss in feet of water per 100 feet of pipe (fth20/100 ft pipe)

c = Hazen-Williams roughness constant

q = volume flow (gal/min)

dh = inside hydraulic diameter (inches)

The roughness constant was chosen to be 140 due to the assumption that the geothermal piping will be Polyethylene, High Density Polyethylene (HDPE). After performing both calculations, the total head loss for the pump was found to be 33.7 ftH2O. Table 32 summarizes the head loss calculation for the geothermal pump needed for the proposed system.

Calculating Pressure Loss - Equivalent Pipe Length Method							
Pipe Size (inches)	Flow (gal/min)	Pressure Loss (ft/100ft)	System Components	Equivalent Length of Component (ft)	Number of Components	Equivalent Length (ft)	Section Pressure Loss (ftH2O)
3	807	128.87	90 deg Elbows	2.7	6	16.2	-
-			Straight Pipe	1	10	10	
			-	-		-	
Total	807	128.87				26.2	33.76394

TABLE 32: HEAD LOSS CALCULATION

Looking at the previous table, an appropriate pump needs to be selected for the geothermal system well field. This pump needs to be able to operate efficiently at the required maximum flow rate along with the calculated total head loss.

Bell and Gossett was chosen to be the supplier for the pumps due to their variety of pumps. The Figure 25: Bell & Gossett 1750 RPM Pumpsbelow provides a variety of their pumps, this graph was used to choose the appropriate pump based on the calculated maximum flow rate and total head loss.

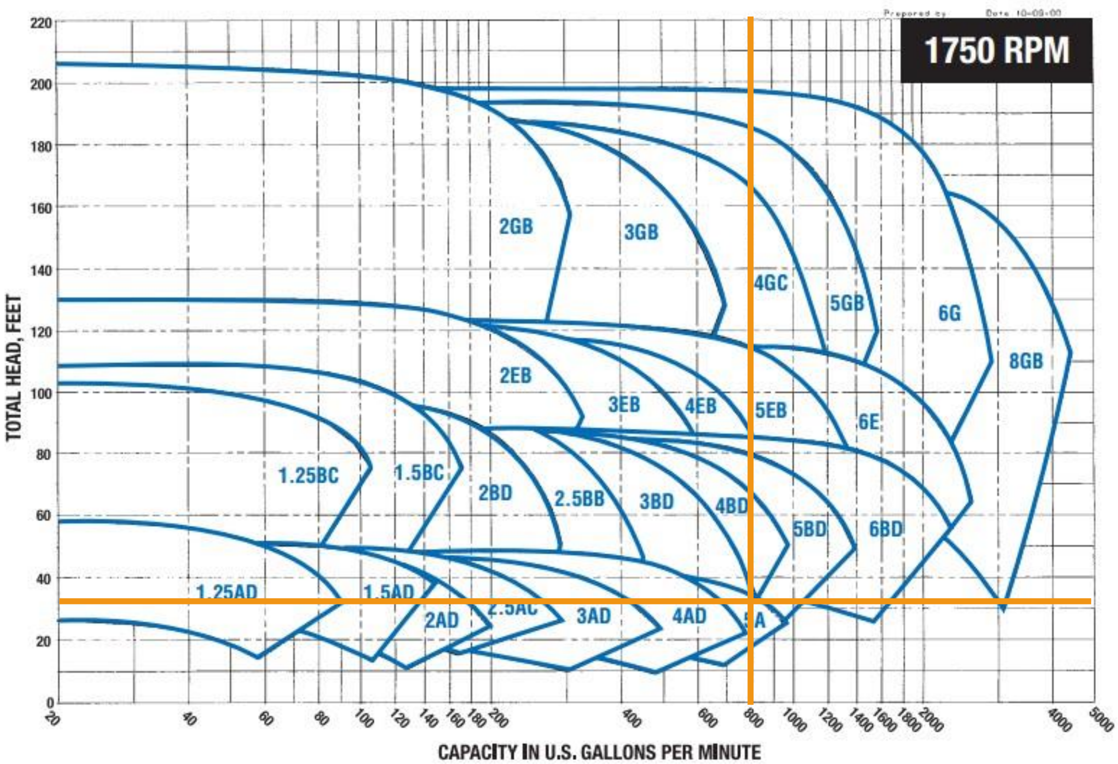


FIGURE 25: BELL & GOSSETT 1750 RPM PUMPS

Looking at the previous graph, pump type series e-1510 5A was selected based on a maximum flow rate of 807 gpm and a total head loss of 34 ftH2O. Figure 26 is the efficiency curve of the selected pump.

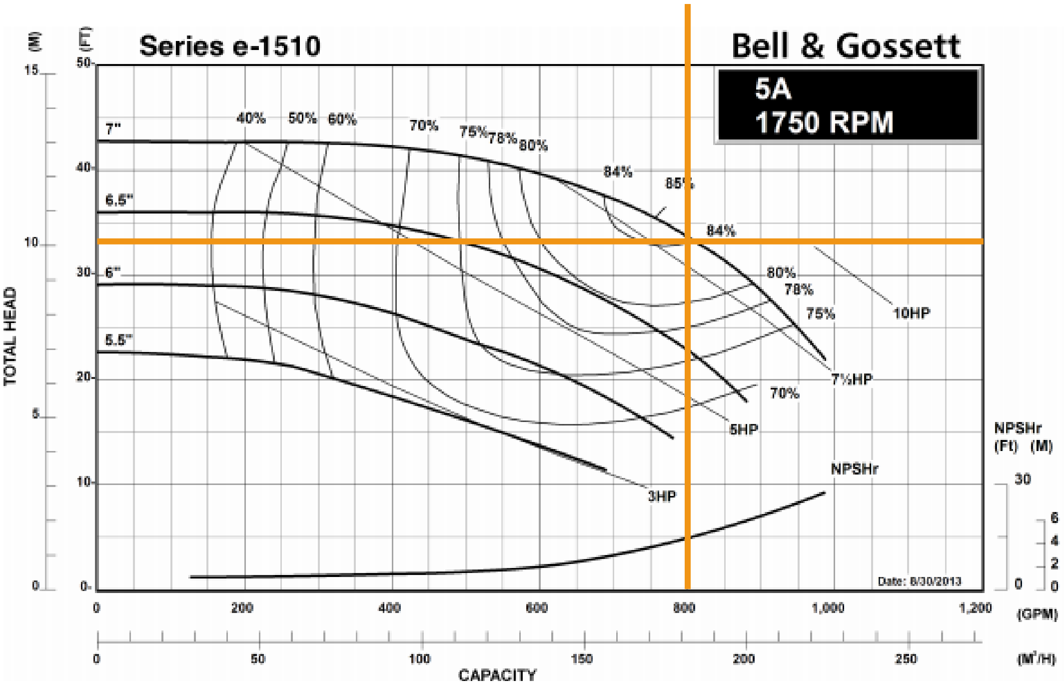


FIGURE 26: SERIES E-1510 EFFICIENCY CURVE

From the previous figure, we can see that the pump selected is a perfect fit. It will be operating at about 84% efficiency, therefore it would be a great selection for the proposed geothermal system. Next, the distributor pump that will be located in the pool mechanical room needs to be sized. For that, the piping length is taken from the mechanical room to the furthest point on the opposite side of the roof where the rooftop WSHP will be located. The same procedure will be done in order to size the distributor pump. Table 33 illustrates the head loss calculation for the distributor pump.

Calculating Pressure Loss - Equivalent Pipe Length Method							
Pipe Size (inches)	Flow (gal/min)	Pressure Loss (ft/100ft)	System Components	Equivalent Length of Component (ft)	Number of Components	Equivalent Length (ft)	Section Pressure Loss (ftH2O)
3	807	128.87	90 deg Elbows	2.7	5	13.5	-
-			Straight Pipe	1	7	7	
			45 deg Elbow	1.3	2	2.6	
Total	807	128.87				23.1	29.76897

TABLE 33: HEAD LOSS CALCULATION FOR DISTRIBUTOR PUMP

Figure 27 provides a variety of their pumps, this graph was used to choose the appropriate distributor pump based on the calculated maximum flow rate and total head loss.

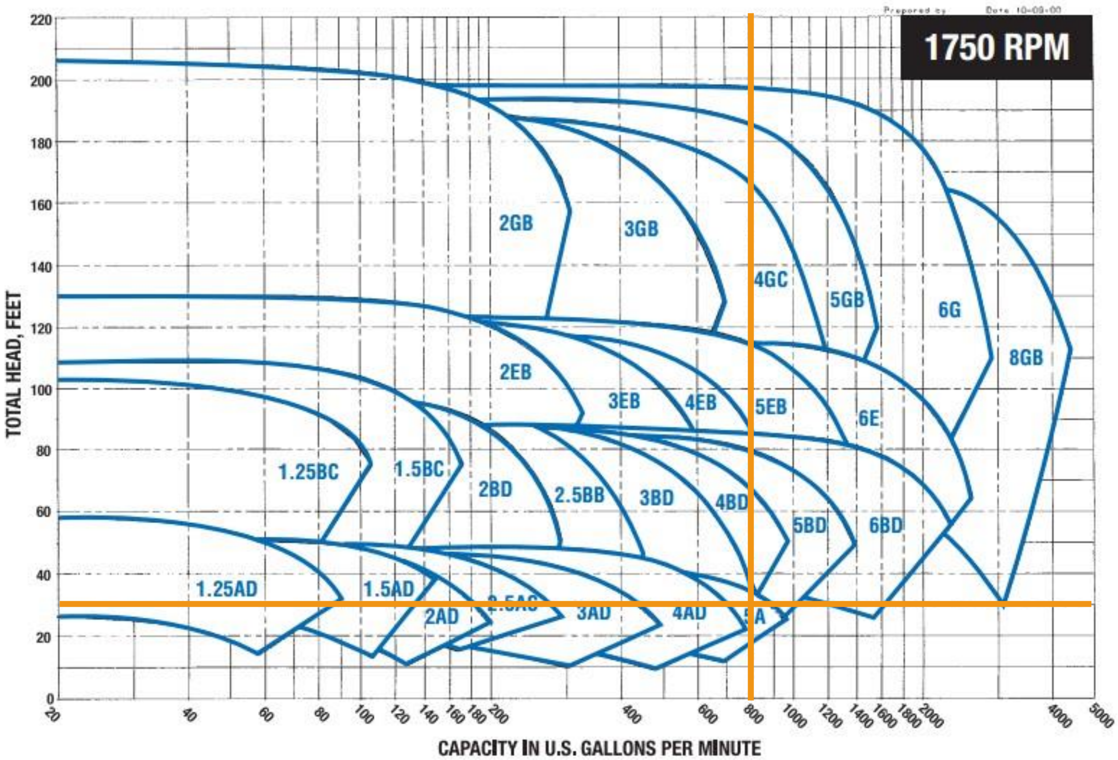


FIGURE 27: BELL & GOSSET 1750 RPM PUMPS

Looking at the previous graph, pump type series e-1510 5A will also be selected, based on a maximum flow rate of 807 gpm and a total head loss of 29.7ftH2O, for the pump distributor. Figure 28 is the efficiency curve of the selected pump.

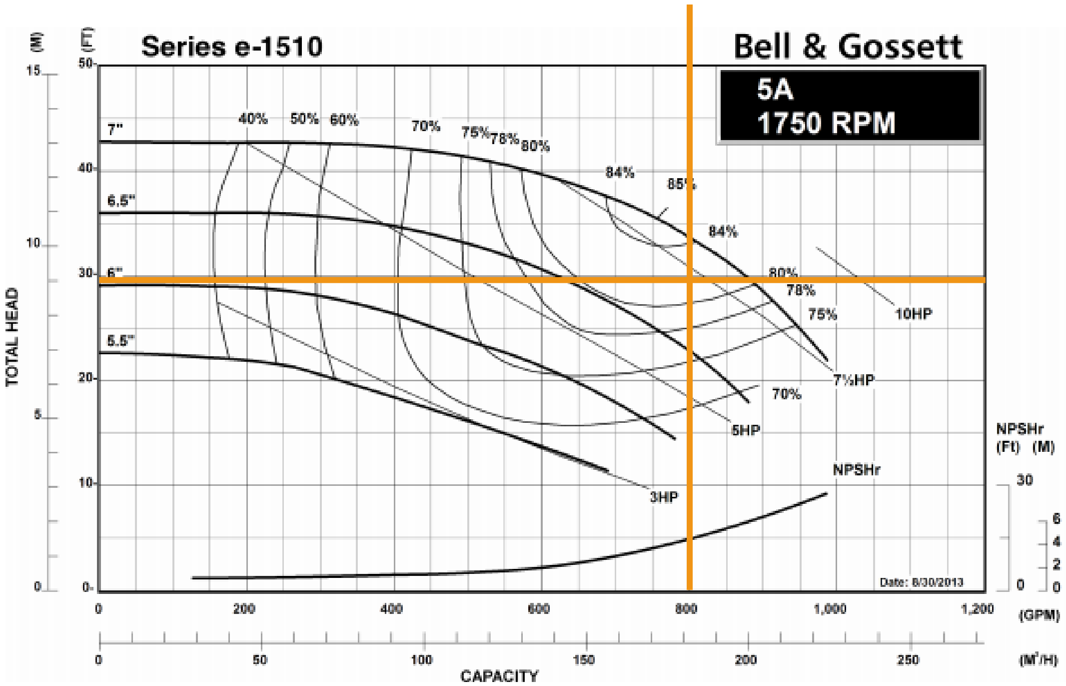


FIGURE 28: E-1510 SERIES EFFICIENCY CURVE

From the previous figure, we can see that the pump selected is a perfect fit. It will be operating at about 82% efficiency, therefore it would be a great selection for the proposed geothermal system in terms of distribution.

Alternative 1: Roof Top Unit – Water Source Heat Pumps

In order to install a geothermal closed loop system, two main requirements need to be met. First of all, the building needs to be equipped with heat pumps in order to condition the spaces/zones. In addition, there needs to be a source of airflow that meets the ASHRAE minimum ventilation requirement.

Due to the building being a medical/fitness facility, it was not preferable to have heat pumps inside the building. This is because most of the rooms are either examination rooms or treatment rooms. Therefore, it would be acoustically uncomfortable for the patients/occupants. Instead, Roof Top Unit Water Source Heat Pumps will be installed. That way, we can eliminate the heat pumps being inside the building. Also the RTU – WSHP will take care of the required ventilation. In addition, a boiler will be sized to provide supplemental hot water. This way, if the geothermal system can't fully meet the heating load then the back-up boiler would work hand in hand with the system.

AAON RN Series Rooftop Units will be used in collaboration with the geothermal system. Energy efficient cooling and heating can be achieved by reversing the flow of the unit's refrigeration circuits. This allows the indoor coil to be used as either a cooling coil or heating coil. Geothermal heat pumps take advantage of the relatively constant temperature of the earth below ground level to transfer heat to or from the building. Figure 29 illustrates the RN Series RTU WSHP that will be used.

FIGURE 29: RN SERIES RTU WSHP

AAON water-source heat pump rooftop units with variable capacity compressors and variable speed fans can be applied to Variable Air Volume (VAV) systems with VAV boxes and to Single Zone VAV systems. These systems combine the energy saving benefits of a water-source heat pump configuration with the variable airflow energy savings of a VAV system. Variable capacity scroll compressors provide energy efficient consistent supply air temperature.

Due to the building requiring a total capacity of 441 tons of heating, three RN-140 units will be specified along with one RN-30 unit. Allowing for a total capacity of 450 tons. These units will allow for 100% outside air.

Alternative 2: DOAS + Vertical/Horizontal Self-Contained Heat Pumps

Another analysis was made to compare the use of Rooftop Water Source Heat Pumps instead of having vertical and horizontal self-contained heat pumps. Therefore the 2nd alternative would be a DOAS, mainly for supplying 100% OA to the building, along with self-contained heat pumps located throughout the building. Even though this system is not acoustically preferable, it was proposed mainly to see if any savings would be possible.

The air supplied will be cold air as the DOAS will dehumidify the air and in the process lower the dry bulb temperature. This process is beneficial as this leads to a lessened overall cooling capacity and lowers required airflows to zones.

In order to size a DOAS, the design conditions of peak dry bulb (DB), peak wet bulb (WB) and dew point (DP) were collected based on the building location. Table 34 illustrates the design conditions.

Design Conditions	
Peak DB	88.3 deg F DB
	73.1 deg F WB
Peak WB	84.3 deg F DB
	75.4 deg F WB
Peak DP	80.5 deg F DB
	72.5 deg F WB

TABLE 34: DESIGN CONDITIONS

After collecting the design conditions, spaces with the highest latent loads need to be recognize to govern the equipment size. Table 35 illustrates the zone with the highest latent load.

Zone Latent Load		
Zone	Total Area (ft2)	Latent Load (Btu/hr)
Health Center / Aerobic Rooms	30,340	864,000

TABLE 35: ZONE LATENT LOAD

Now that the latent load is recognized, the total airflow that the dedicated outdoor air unit will provide needs to be calculated. The DOAS will need to provide at least the minimum ventilation required by ASHRAE 62.1 section 6.2.4. Table 36 illustrates the minimum ventilation required for the health center/aerobic zone.

System	Room Name	Room Number	Occupancy Type	Zone Floor Area (Az)	Outdoor Airflow Rate/Unit Area (Ra)	Outdoor Airflow Rate/Person (Rp)	Maximum # of People in the Ventilated Zone (Pz)	Breathing Zone Outdoor Airflow (Vbz)	Zone Air Distribution Effectiveness (Ez)	Design Zone Outdoor Airflow (Voz)	Exhaust
				(SF)	(CFM/SF)	(CFM/Person)	(# of People)	(CFM)		(CFM)	(CFM)
Zone	Health Center & Aerobic Rooms	2020, 2003, 2001, 2004, 2016,2005, 2010, 2024, 2207, 2205	Health Club/Aerobic Rooms	30340	0.06	20	1200	25820.4	1	25820.4	25820.4

TABLE 36: MINIMUM VENTILATION REQUIREMENT

According to the previous table, the Health Center/Aerobics zone will require a minimum ventilation of 25,821 CFM. Therefore, the DOAS needs to be able to at least provide this much CFM for the zone with the largest latent load. Furthermore, because the dedicated outdoor air unit will offset the latent loads in each space (as well as the total ventilation load), the conditioned outdoor air must be dry enough to enforce the maximum humidity limit in the worst-case space. The following equation was used in order to find that.

$$Q_L = 0.69 \times V_{oa} \times (W_{sp} - W_{ca})$$

where,

Q_L = latent load in the space, Btu/hr (kW)

V_{oa}= conditioned outdoor airflow, cfm (m³/s), which is supplied to the space by the dedicated outdoor air handler

W_{ca}= humidity ratio of the conditioned outdoor air, grains/lb (grams/kg)

W_{sp}= maximum limit for the humidity ratio in the space, grains/lb (grams/kg)

Therefore to assure that the humidity (W_{sp}) in the Health Center/Aerobic zone does not exceed the maximum limit of 118.65 gr/lb, the humidity ratio of the conditioned outdoor air, (W_{ca}), must be 70.15 gr/lb. Figure 30 illustrates the minimum supply air conditions that the DOAS will need to satisfy.

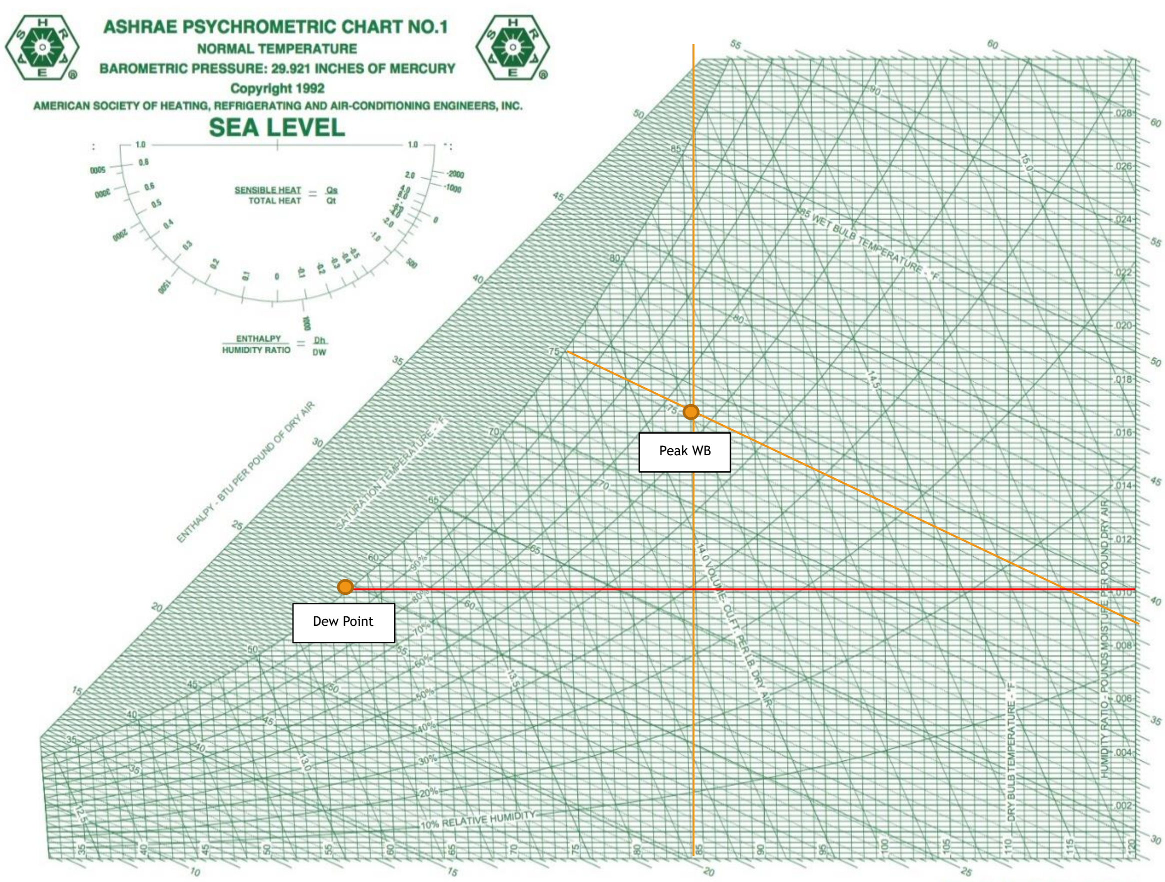


FIGURE 30: MINIMUM SUPPLY AIR CONDITIONS BY DOAS

Therefore, dehumidifying 25821 CFM of outdoor air from the peak wet-bulb condition to a 57°F dew point requires 134 tons of cooling capacity. This was found by using the following equation.

$$Q_T = 4.5(\text{CFM Required})(H_{sp}\text{-}H_{ca})$$

$$Q_T = 4.5(25821)(38.7 - 24.9)$$

$$Q_T = 1603484.1 \text{ Btu/hr} = \mathbf{133.6} \text{ Tons}$$

Vertical/Horizontal Self-Contained Heat Pumps

Now that the DOAS is sized, individual heat pumps will need to be sized and located throughout the building as well. Each heat pump is sized based on the room checksums, the required heating/ cooling for each zone. Heat pumps will be placed throughout Mount Carmel Fitness & Health Center based on occupancy type. This design technique was used due to each heat pump having an individual thermostat control. Therefore, zones with different occupancy types could not be supplied by the same heat pump because each zone would have a different required zone conditions. Table 37 illustrates the zone required heating/cooling capacity along with the sizes of the heat pumps required.

Masters Coursework

The integration of the Geothermal Closed Loop System with the RTU WSHP (Alternative 1) and DOAS + Individual Heat Pumps (Alternative 2) required a great portion of knowledge gained from previous masters classes. Specifically, AE 557 (Central Cooling Production and Distribution Systems) was used to be able to understand the pumps in the geothermal system designed. Also, the class was very helpful in particular when the pump layout along with the sizing was needed to be done. Throughout the depth, it was clear that such procedures were taken in order to compile the system together.

Heat Pump Schedule			
Occupancy Type	Location	Capacity Required (tons)	Specified Heat Pumps
Operating Rooms	1st Floor West	27.45	(1) 20 ton (1) 10 ton
Examination Rooms	1st Floor West	23	(1) 20 ton (1) 5 ton
Examination Rooms	2nd Floor West	117	(6) 20 ton
Nurse Station	1st Floor West	10	(1) 10 ton
Treatment Rooms	1st Floor West	25	(1) 20 ton (1) 5 ton
Shared Waiting Room	2nd Floor West	9	(1) 10 ton
Conference	1st Floor Center	8	(2) 5 ton
Retail	1st Floor Center	6.6	(1) 10 ton
Dining	1st Floor Center	18	(2) 10 ton
Offices	1st Floor Center	2	(1) 5 ton
Laundry/Storage	1st Floor Center	10	(1) 10 ton
Pools	1st Floor East	60	(3) 20 ton
Lockers/Bathrooms (Male)	1st Floor East	6	(3) 2 ton
Lockers/Bathrooms (Female)	1st Floor East	7.5	(1) 10 ton
Lockers (Kids)	1st Floor East	6	(1) 5 ton (1) 2 ton
Equipment Room	1st Floor East	5	(1) 5 ton
Health Center/ Aerobic Rooms	2nd Floor Center	60	(6) 10 ton
Health Center/ Aerobic Rooms	2nf Floor East	94	(2) 20 ton (5) 10 ton (1) 5 ton

TABLE 37: HEAT PUMP SCHEDULE

According to the previous table, MC Fitness & Health Center will need a total of 45 self-contained vertical/horizontal heat pumps distributed throughout the first and second floor.

Annual Energy Consumption & Cost Analysis

In order to see how the two proposed systems played a role in terms of savings, an annual energy along with a cost analysis was performed. Looking at the initial Trace 700 model that was created for the existing system, the annual energy consumption was simulated. After that, two models were created to see the effects of having a geothermal system coupled with RTU WSHP and a system coupled with individual heat pump units and a DOAS. Figure 31 illustrates the annual energy consumption, allowing for a clear comparison between the existing system and the two proposed alternatives.

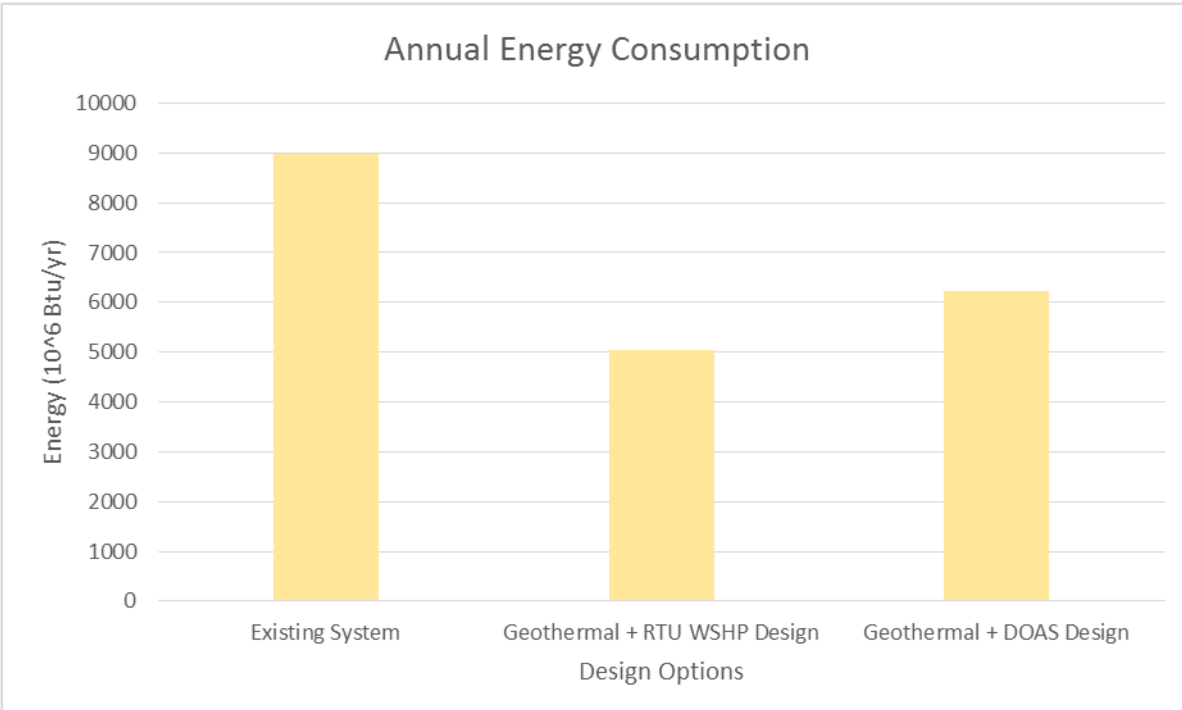


FIGURE 31: ANNUAL ENERGY CONSUMPTION

Analyzing the figure above, we can see that the existing system was using a total of **8970 x 10^6 Btu/yr** whereas the geothermal system coupled with RTU WSHP was only using a total of **5038 x 10^6 Btu/yr.** As for the geothermal system that was coupled with individual heat pumps and a DOAS, it consumed a total of **6228 x 10^6 Btu/yr.** Figure 31 illustrates the savings in annual energy consumptions between the three systems.

Annual Energy Consumption				
Existing System	8970 x 10^6 Btu/yr	Savings	x 10^6 Btu/yr	Percentage
Geothermal + RTU WSHP Design	5038 x 10^6 Btu/yr		**3932**	44
Geothermal + DOAS Design	6228 x 10^6 Btu/yr		**2742**	31

TABLE 38: ANUAL ENERGY CONSUMPTION SAVINGS

Therefore, implementing the geothermal system coupled with RTU WSHP could result in about **44%** of savings in annual energy consumptions. This is mainly due to the existing system lack of distribution. Initially there was thirteen Packaged RTU that served the whole buildings. In addition to various VAV boxes and a wide variety of duct sizes. Whereas, the geothermal system acts as the main plant for the building along with four RTU WSHP that allow for outside air to enter the building and be preconditioned.

As for the other alternative design, we can see that the savings were not that much when compared to the first alternative design. This is due to the multiple heat pumps that were placed throughout the building and had various sizes which can consume a lot of electric power. Focusing on the economics aspect, Figure 32 illustrates the annual energy cost regarding each of the systems.

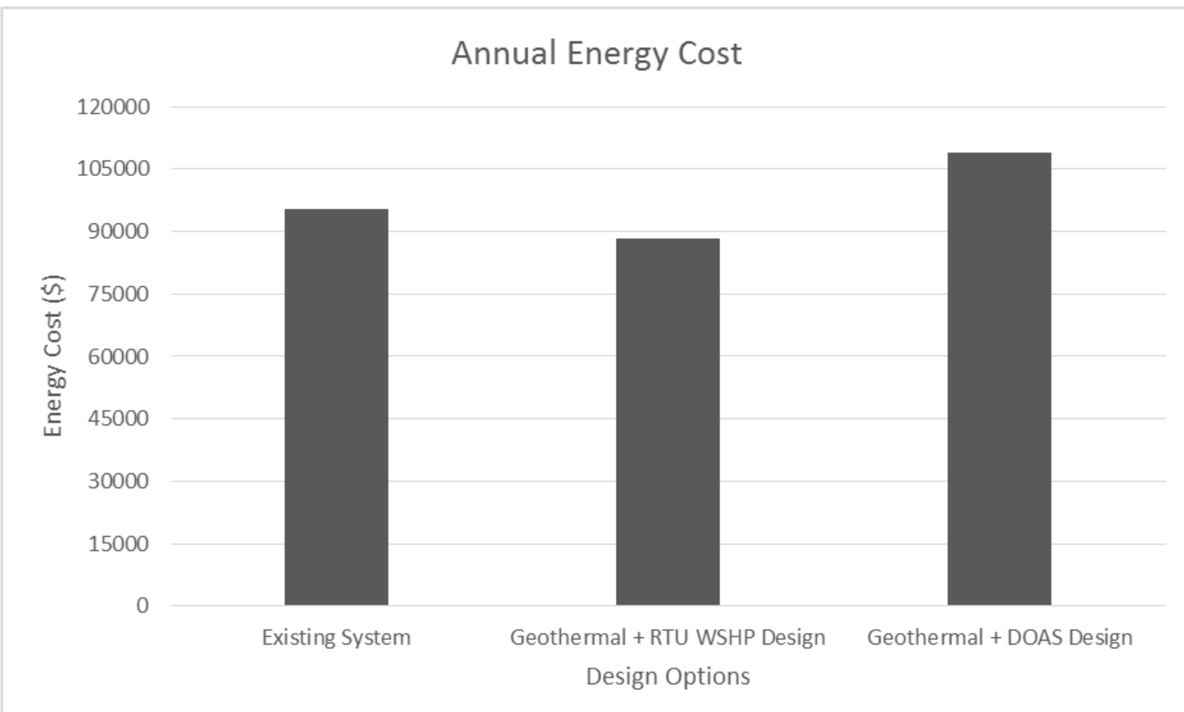


FIGURE 32: ANNUAL ENERGY COST

Looking at the previous figure, it is clear that economically speaking savings are not as much as energy. This is because the two alternatives completely depend on electricity only. Columbus, Ohio's electricity prices **(0.05 – 0.105 $/kWh)** are way higher than the natural gas prices **(0.5 – 0.49 $/CCF).** Looking closely at the geothermal + DOAS Design, we can see that even though it requires less energy, it costs more to operate. Figure 32 illustrates the annual energy cost regarding each of the systems.

Annual Energy Cost				
Existing System	$95,343	Savings	($)	Percentage
Geothermal + RTU WSHP Design	$88,273		**$7,070**	7
Geothermal + DOAS Design	$109,124		**($13,781)**	-14

TABLE 39: ANNUAL ENERGY COST

Looking at the previous figure, switching from the existing system to the Geothermal + RTU WSHP Design would only allow for **7%** of operation/cost savings. Whereas, having the Geothermal + DOAS Design would cost **14%** more than the existing system. As mentioned previously, this is mainly due to the price of gas being cheaper than the price of electricity usage. Going into more detail, Figure 33 – Figure 36 illustrate the month to month breakdown of energy consumption along with energy costs.

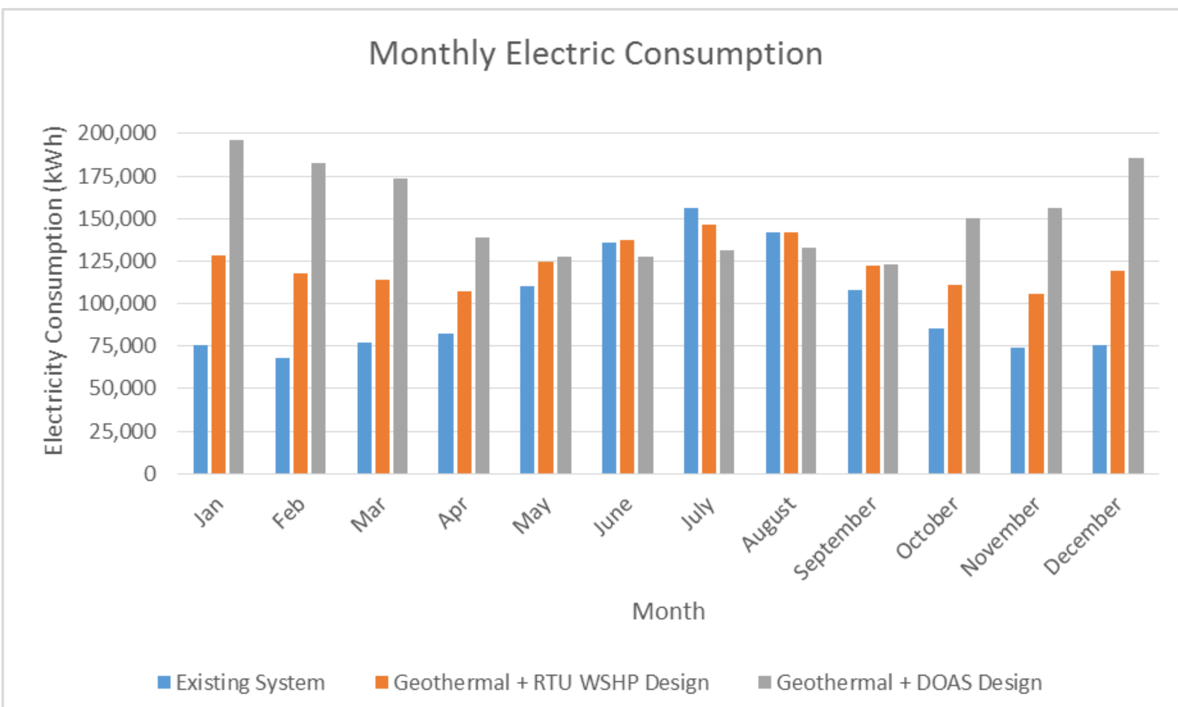


FIGURE 33: MONTHLY ELECTRIC CONSUMPTION

Analyzing the figure above, it is clear that the monthly electricity consumption is way higher for the proposed Geothermal + DOAS system design when compared to the existing system. Also the existing system is consuming less electricity when compared to the proposed Geothermal + RTU WSHP Design. This is mainly due to both proposed systems completely depending on electricity, whereas the existing system is consuming both electric and natural gas for energy.

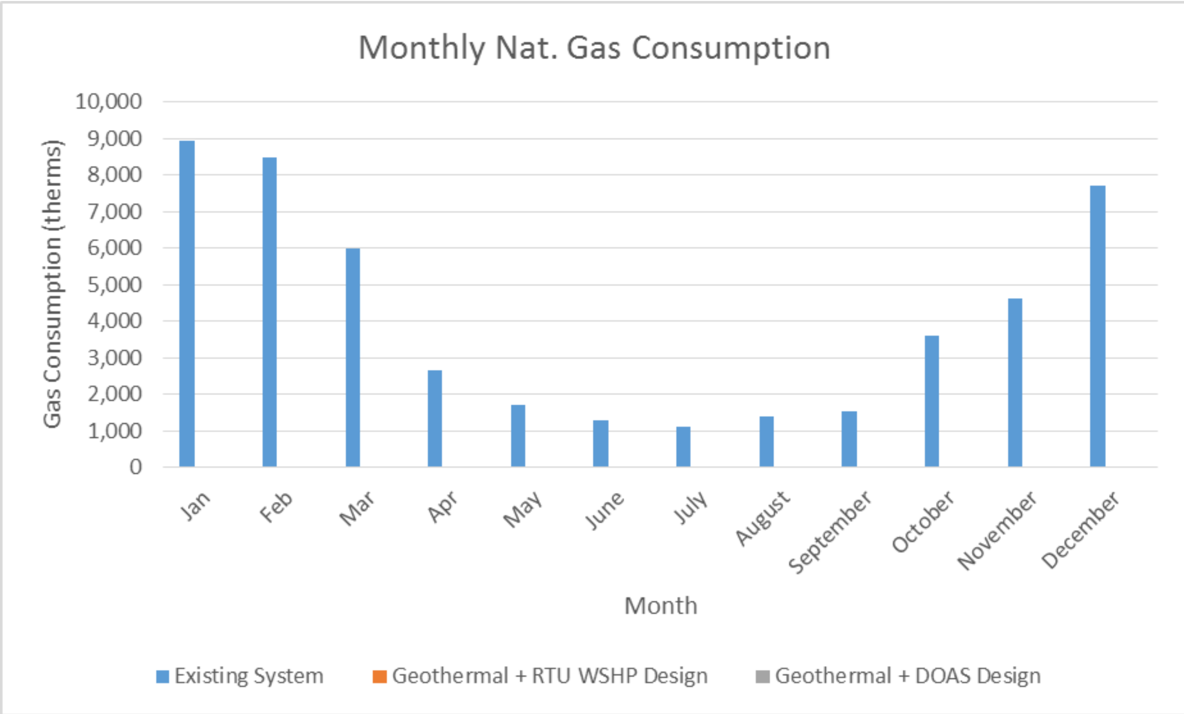


FIGURE 34: MONTHLY NATURAL GAS CONSUMPTION

The previous figure explains the reasoning why the electric usage of the existing system is lower than both proposed systems. It is clear that the geothermal system proposed along with wither the DOAS with individual heat pumps or the RTU WSHP depend completely on electricity. Therefore, this means that all the nat. gas usage is considered as savings when looking at the alternative proposed systems.

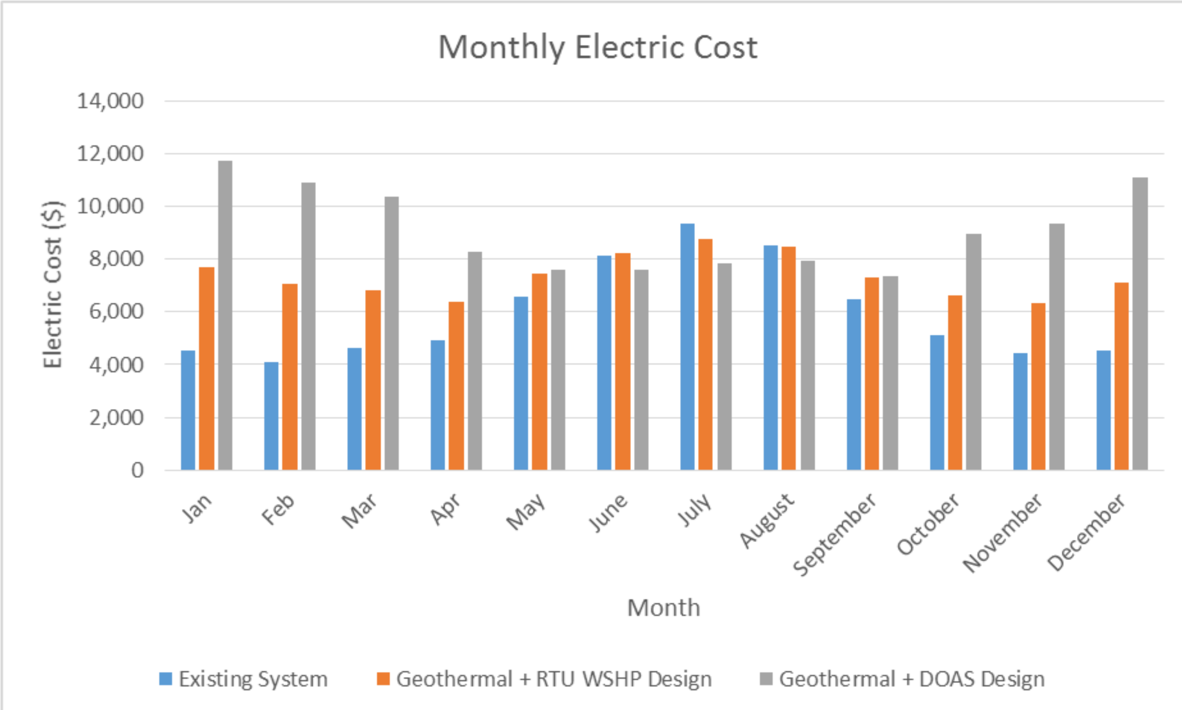


FIGURE 35: MONTHLY ELECTRIC COST

As for electricity consumption cost, it follows the same reasoning as the monthly electricity consumption. Electricity consumption costs are higher for both the proposed alternatives based on the existing system consuming both natural gas and electricity.

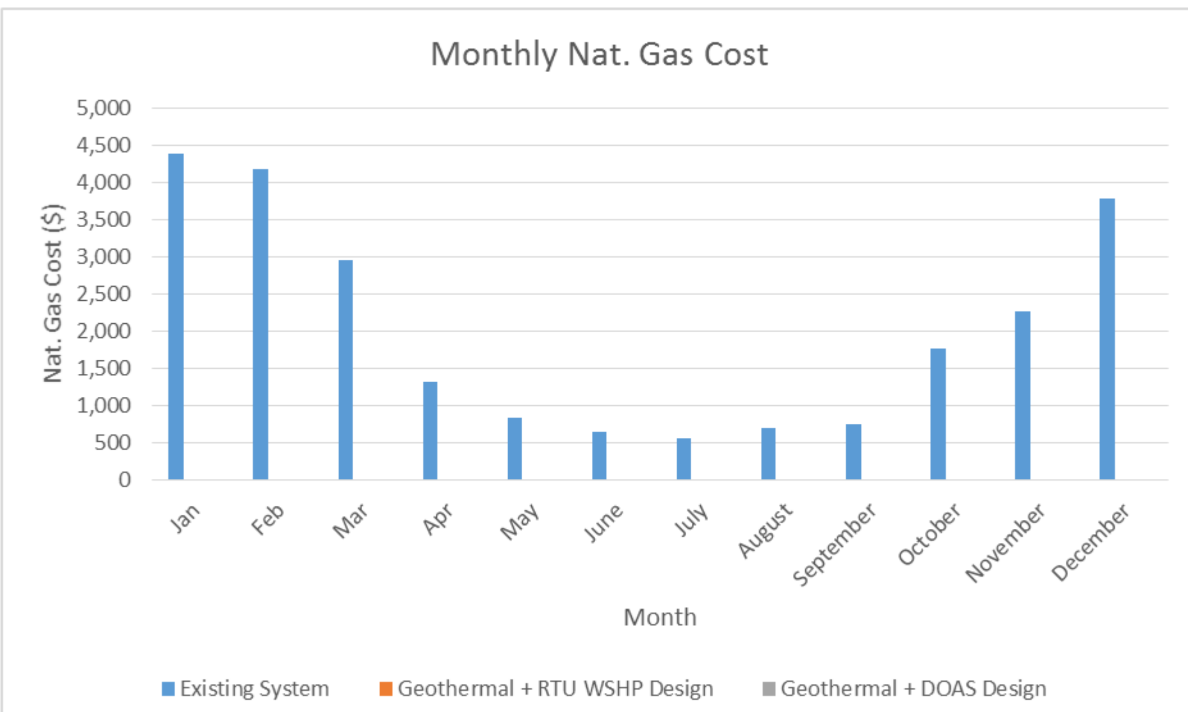


FIGURE 36: MONTHLY NATURAL GAS COST

SIMILARLY, ALL THE COSTS FOR NATURAL GAS CONSUMPTION CAN BE VIEWED AS SAVINGS WHEN LOOKING AT BOTH PROPOSED SYSTEMS DUE TO THE SYSTEMS DEPENDENCE ON **ELECTRICITY** CONSUMPTION ONLY**.**

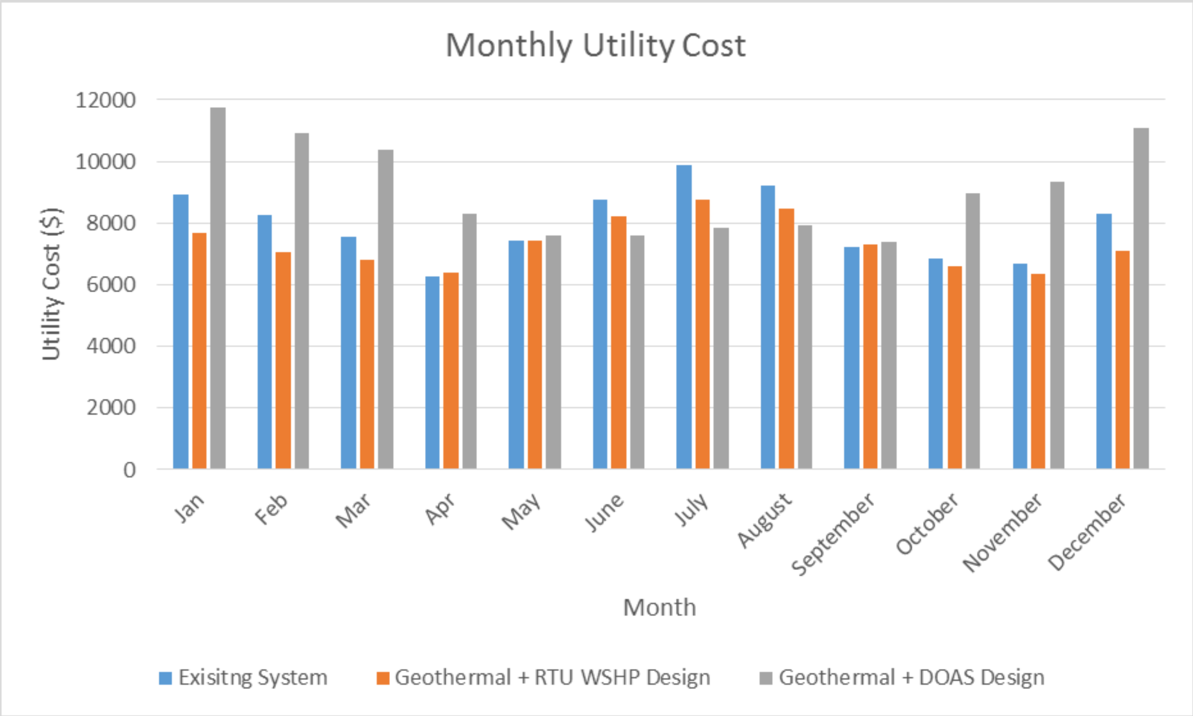


FIGURE 37: MONTHLY UTILITY COST

Finally, from the previous figure, it is clear that switching to the Geothermal System + RTU WSHP Design would be beneficial allowing for savings both economically and energy consumption wise. The pervious figure illustrates the total monthly utility cost for operation. It is clear that the existing system costs more in terms of operation throughout the whole year. Looking at the Geothermal + DOAS Design, the figure illustrates that during the heating season the proposed system will have higher operation costs than both the first alternative and the existing system. This is due to the system depending not only on the geothermal wells but also a DOAS along with individual heat pumps that are placed throughout the building. Having multiple heat pumps with various sizes consume more energy than central RTU WSHP. This is because 45 individual heat pumps were needed due to the various occupancy types throughout the building. Less heat pumps could have been specified with larger capacities but that would have an impact on thermostat controls.

System Emissions

When deciding on other alternative designs that would be a good fit for the Mount Carmel Fitness & Health Center, factors other than energy consumption and economical savings were considered. System emission was one of the major factors that we considered when designing alternative mechanical options. Even though there is no direct correlation when looking at savings and reduction in emissions, it still has an impact on the world around us. Figure 38 illustrates the emissions for the existing system along with the two proposed alternative designs. In addition,

Table 40 illustrates the change in major pollutants for the Mount Carmel Fitness & Health Cent

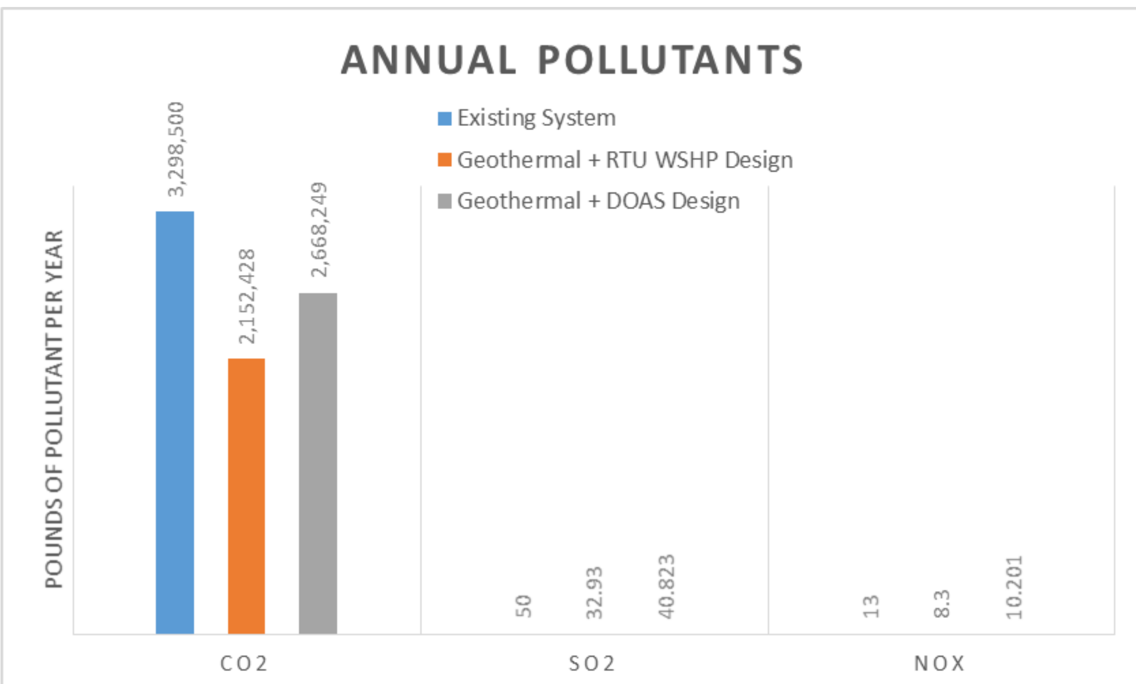


FIGURE 38: ANNUAL POLLUTANTS

Difference in Total Annual Emissions				
System	Pollutant	Total Emissions (lb/yr)	Percent Decrease	(%)
Existing System	CO2	3298500		
	SO2	50		
	NOX	13		
Geothermal + RTU WSHP Design	CO2	2152428		35
	SO2	33		34
	NOX	8.3		36
Geothermal + DOAS Design	CO2	2668249		19
	SO2	40.8		18
	NOX	10.2		22

TABLE 40: CHANGE IN ANNUAL POLLUTANTS

Due to the existing system that consists of a variety of different RTU sizes, the system as a whole is not running efficiently. When designing the goal was only to satisfy the building's needs and not reduction in energy consumption or operating efficiently. Therefore, from the figure above it is clear that the major difference in emissions between the existing system and the Geothermal + RTU WSHP Design is because there was a major reduction in natural gas consumption. Even though the alternative system does not allow for major operation cost savings, it is still operating very efficiently. Having four main RTU WSHP and a Geothermal system allows for less emissions.

One can argue that the second alternative should also show similar saving but when calculated, saving are only half of the first alternative. This could be because of the various heat pumps installed in the building. Even though heat pumps run efficiently, having 45 of them in the building along with DOAS can lead to higher emissions. With that said, the second alternative is still more efficient than the existing system in the Mount Carmel Fitness & Health Center.

System(s) Pay Back Period

A first-cost analysis was conducted for the existing system, alternative 1, and alternative 2 in order to compare each of the alternatives to the existing system in place. The existing system was priced by Elford, the general contractor of the project. Similar methods of pricing were used when looking at the 2 alternatives. This ensured that the pricing would be as accurate as possible. Table 41 –Table 43 illustrate the first costs of each of the alternatives proposed along with the existing system.

Existing System				
Unit	Takeoff Quantity		Total Cost/Unit ($)	Total Amount
RTU - 1	15000	CFM	4.38	$ 65,700.00
RTU - 2	13000	CFM		$ 56,940.00
RTU - 3	15000	CFM		$ 65,700.00
RTU - 4	11200	CFM		$ 49,056.00
RTU - 5	11200	CFM		$ 49,056.00
RTU - 6	25000	CFM		$ 109,500.00
RTU - 7	33000	CFM		$ 144,540.00
RTU - 8	35000	CFM		$ 153,300.00
Ductwork, Insulation, and air devices	122016	SF	4.12	$ 502,705.92
Ductless Split System @ Elevators	2	Each	14222	$ 28,444.00
Air Curtains	4	Each	10122	$ 40,488.00
Exhaust Fans	5	Each	6112	$ 30,560.00
Temperature Controls	122016	SF	4.63	$ 564,934.08
Natural Gas Piping	122016	SF	0.85	$ 103,713.60
HVAC Total				**$ 1,964,637.60**

TABLE 41: EXISTING SYSTEM 1ST COST

Alternative 1: Geothermal + RTU WSHP Design Cost				
Unit	Takeoff Quantity		Total Cost/Unit ($)	Total Amount
RTU - 1	26000	CFM	2.98	$ 77,480.00
RTU - 2	26000	CFM		$ 77,480.00
RTU - 3	26000	CFM		$ 77,480.00
RTU - 4	8500	CFM		$ 25,330.00
Ductwork, Insulation, and air devices	122016	SF	1.96	$ 239,151.36
Geothermal Cost + Installation	122016	SF	12.88	$ 1,571,566.08
E-1510 5A Water Pumps	2	Each	2894	$ 5,788.00
Exhaust Fans	2	Each	4285	$ 8,570.00
HVAC Total				**$ 2,082,845.44**

TABLE 42: ALTERNATIVE 1 1ST COST

Alternative 2: Geothermal + DOAS Design Cost				
Unit	Takeoff Quantity		Total Cost/Unit ($)	Total Amount
DOAS - 1	15000	CFM	2.13	$ 31,950.00
DOAS - 2	15000	CFM		$ 31,950.00
WSHP (5 ton)	8	Each	2490	$ 19,920.00
WSHP (10 ton)	19	Each	3652	$ 69,388.00
WSHP (20 ton)	14	Each	6588	$ 92,232.00
Ductwork, Insulation, and air devices	122016	SF	1.96	$ 239,151.36
Geothermal Cost + Installation	122016	SF	12.88	$ 1,571,566.08
E-1510 5A Water Pumps	2	Each	2894	$ 5,788.00
Exhaust Fans	3	Each	4285	$ 12,855.00
HVAC Total				**$ 2,074,800.44**

TABLE 43: ALTERNATIVE 2 1ST COST

Analyzing the previous figures, it is clear that some costs were eliminated due to requiring less air distribution/handling unit equipment such as but not limited roof top units. This does not mean that the alternatives would cost less due to having to install a geothermal system from scratch. This means the whole well field needs to be constructed and installed making sure it runs correctly having pipes from the ground feeding the building.

The existing system costs about **$1,965,000**, whereas alternative 1 costs about **$2,083,000** and alternative 2 costs **$2,075,000**. Even though alternative 2 costs less than alternative 1, it is not the best economical choice to choose. This is mainly due to the operation costs for alternative 2. Alternative 2 requires about **$14,000** more in operation costs when compared to the existing system. Therefore, the system would fail when it comes to a payback period. Table 44 illustrates the cost comparison between the three systems.

Cost Comparison			
Existing System	$ 1,964,638	Cost Difference	$ 118,208
Alternative 1	$ 2,082,845		
Alternative 2	$ 2,074,800		$ 110,163

TABLE 44: COST COMPARISON BETWEEN EXISTING & ALTERNATIVE SYSTEMS

The following equation was used when calculating the payback period alternative 1 when compared to the existing system.

$$Simple\ Payback\ Period = \frac{Alternative\ System\ 1st\ Cost - Exisitng\ System\ 1st\ Cost}{Annual\ Operation\ Cost\ Savings}$$

Table 45 illustrates the payback period of the Alternative 1: Geothermal + RTU WSHP Design when compared to the existing system.

System Payback Period			
System	1st Cost	Annual Operation Cost	Payback Period
Exisiting System	$ 1,964,637.60	$ 95,343.00	17
Alternative 1	$ 2,082,845.44	$ 88,273.00	

TABLE 45: ALTERNATIVE 1 PAYBACK PERIOD

The previous figure states that due to the $7,070 of annual operation cost savings, the Alternative 1 proposed would pay off itself within a 17 year span. In other words, after **17 years** the proposed system would allow Mount Carmel Health & Fitness Center to save **$7,070** in system operation costs yearly.

Acoustics Breadth

An acoustical analysis was conducted in order to see the effect of the different mechanical equipment used in the existing system and both proposed alternatives with respect to the operating rooms. Operating rooms need to be very acoustically comfortable for the occupants due to the sensitive activity that is performed within this space. In order to achieve an acoustically comfortable operating room, the room NC level should be anywhere from 25 to 35.

Therefore, the analysis performed studied the effect of RTU – 13 on one of the operating rooms. That was then compared to the acoustical effect of the RTU WSHP on one of the operating rooms. In addition, the effect of the DOAS along with the heat pump, located in the operating room, on the space. In other words, the analysis compared the acoustical impact due to the existing system, alternative 1, and alternative 2 on the operating rooms.

This analysis was mainly conducted to compare the acoustical impact of having an individual heat pump within the building as opposed to a RTU WSHP or a RTU.

Pottorff Aim was used in order to model the equipment, allowing the program to simulate the sound pressure levels in the room due to the equipment. Sound pressure levels were obtained from the manufacturer's product data. Table 46 illustrates the sound pressure levels of the equipment modeled. As for the room modeled, it was the Radiology room located on the 1st floor on the west side of the building. The room size was measured to be 19'-5" x 16'-1" x 8'-0" with 2 sources of discharge.

Equipment Sound Pressure Levels							
Equipment Type	63	125	250	500	1000	2000	4000
Existing System RTU -13	87	85	85	85	82	78	75
RTU WSHP	88	84	83	86	83	77	76
DOAS - 1	85	82	82	81	79	71	70
Heat Pump - 3	77	69	66	68	57	53	51

TABLE 46: EQUIPMENT SOUND PRESSURE LEVELS

Furthermore, when modeling, it was assumed that the existing system RTU along with the DOAS and the RTU WSHP were all located at the same location on the roof. Figure 39 illustrates the take-offs of the ducting that was used as an input in Pottorff Aim.

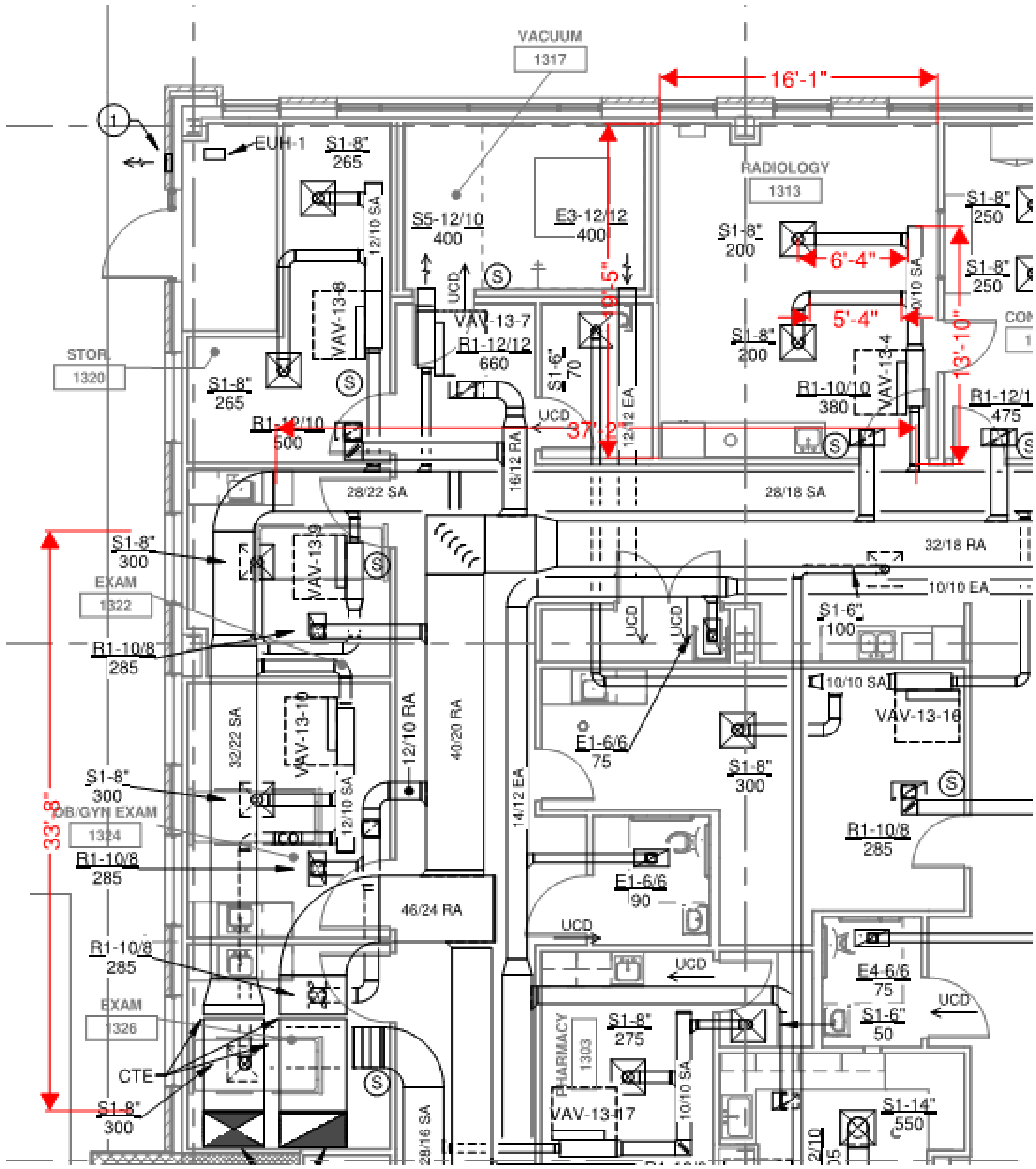


FIGURE 39: DUCTING TAKE-OFFS

After modeling the existing system RTU – 13, it turned out that the unit had no major acoustical impact on the space analyzed. As discussed earlier, the required NC level for the space analyzed should be somewhere between NC 25 – 35 in order to be acoustically comfortable. After modeling, it was proven that the space had a NC level of 34 which is very acceptable for the occupancy type of the space. This was not due to the RTU being acoustically friendly, but it is mainly due to the majority of ducts having 1” of lining. Excluding the lining, the room had a NC level of 64 which is considered very poor. Figure 40 illustrates the Radiology room NC level due to the existing system RTU.

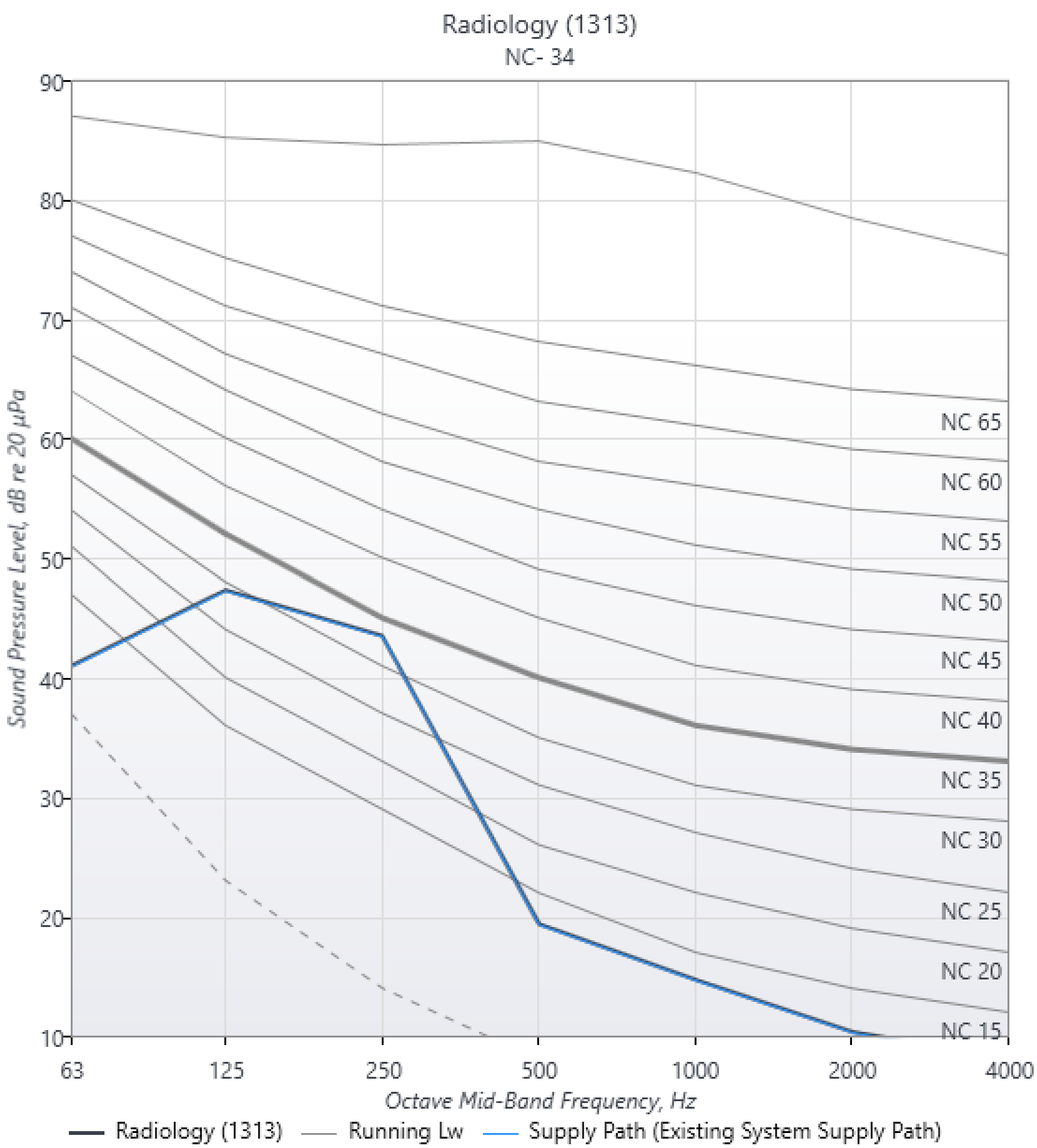


FIGURE 40: NC LEVEL DUE TO EXISTING SYSTEM

Next, Alternative 1 was modeled which consisted of a RTU WSHP. As mentioned previously, the location of the RTU WSHP was taken to be similar to the existing system RTU. This is mainly to have a good comparison of how the equipment is performing acoustically. Therefore, the takeoff inputs were similar but the sound pressure levels of the equipment were different. Figure 41 illustrates the radiology room NC level due to the RTU WSHP proposed by alternative 1.

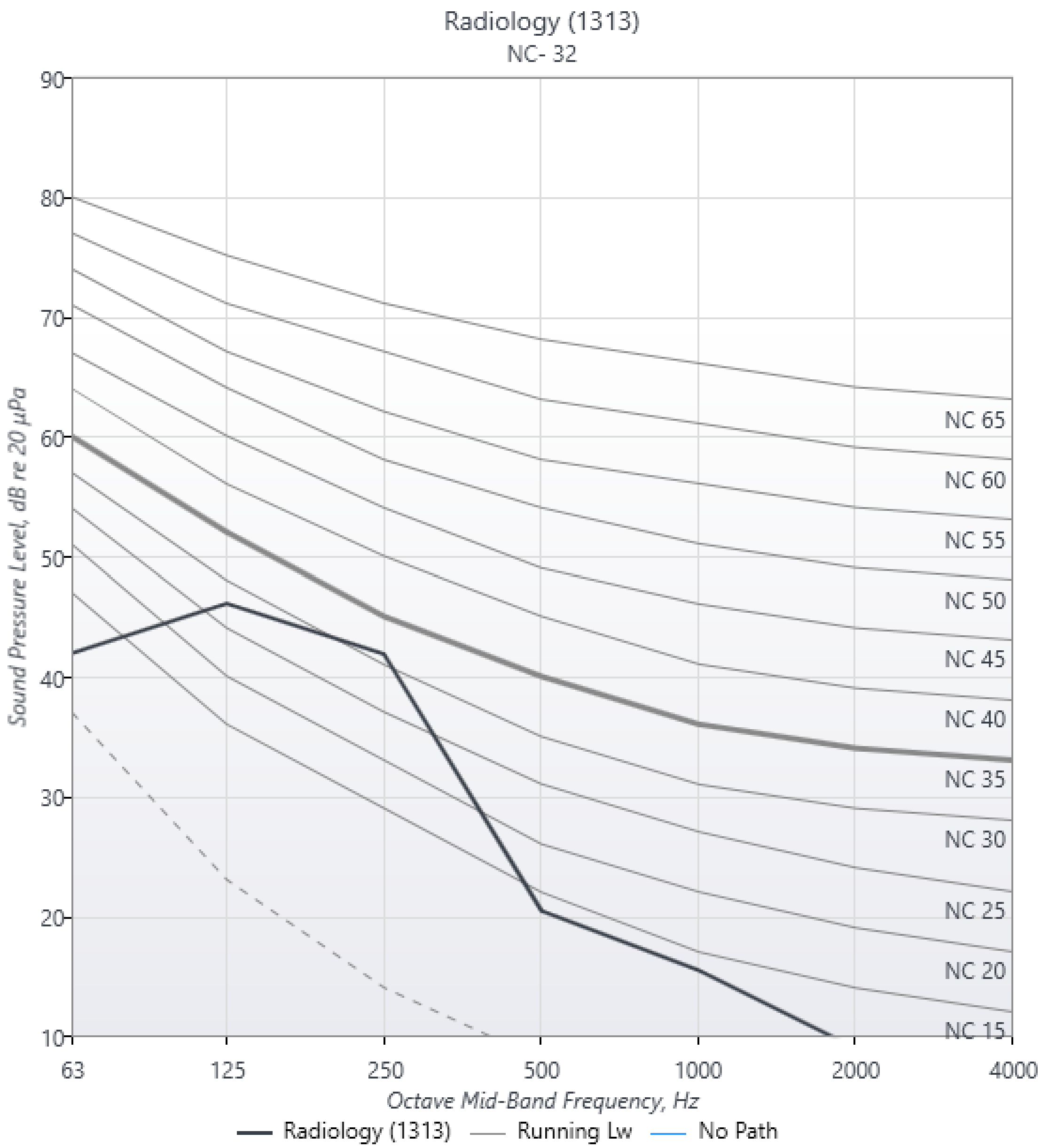


FIGURE 41: NC LEVEL DUE TO ALTERNATIVE 1

Looking at the previous figure, it is clear that the RTU WSHP is better when as a piece of equipment in terms of acoustics. This is due to the unit's variable speed water source heat pump which allows the compressor and fan to operate at reduced speeds matching the demand, resulting in minimizing noise and energy use.

Due to the unit's technology, the radiology room analyzed was able to achieve a NC level of 32 which is highly acceptable and acoustically comfortable. Something to mention is that in this case also duct lining was played a major role in reducing the NC level. Having a 1" duct lining dropped the NC level from 61 to 32 which is a huge improvement. Therefore, when looking at both options, the cost of lining should definitely be taken into consideration.

Finally the second alternative was modeled, having a DOAS along with a individual horizontal heat pump located in the radiology room. This setup proved to have the worst impact on the space in terms of acoustics. Figure 42 illustrates the radiology room NC level due to the DOAS + Heat pump proposed by alternative 2.

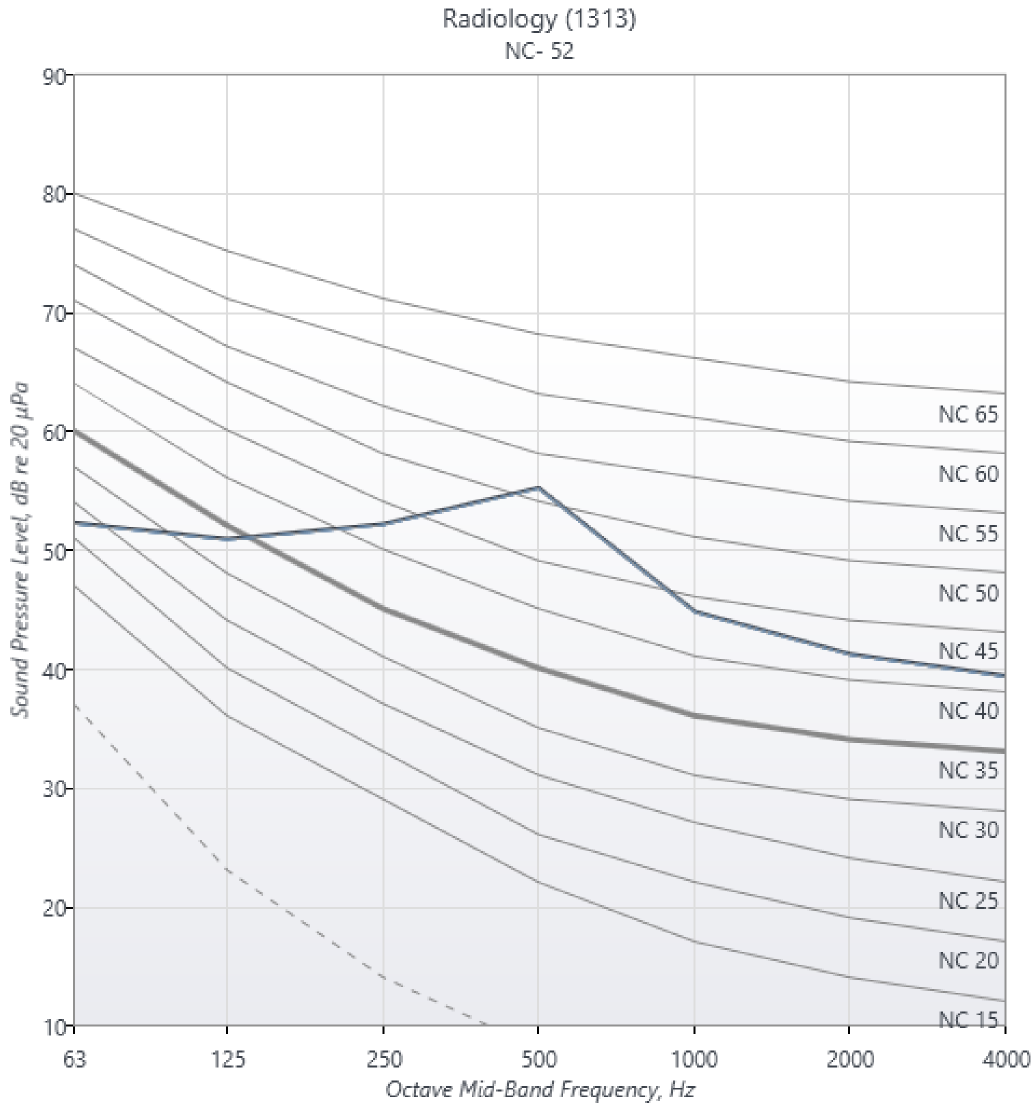


FIGURE 42: NC LEVEL DUE TO ALTERNATIVE 2

Even though the ducts were lined similarly to both the existing system and alternative 1, the equipment from alternative 2 failed to allow the room to be acoustically comfortable. The room analyzed resulted in a NC level of 52 which is very poor. Especially that the space is going to be used for sensitive procedures, it should be acoustically pleasing for the occupants. When proposing ideas for the mechanical depth, this system was not advised due to having multiple heat pump within the building, impacting the rooms' acoustics negatively.

In order to reduce the NC level of the radiology room to an acceptable range, multiple factors had to be adjusted. First of all, the duct lining was increased from 1" to 2". This adjustment was still not enough to allow for an acceptable NC level. Therefore, duct silencers were placed in specific locations that are very close to the heat pump allowing the NC level of the space analyzed to drop to NC-33. Figure 43 illustrates the radiology room NC level due to the DOAS + Heat pump proposed by alternative 2 after adjustment.

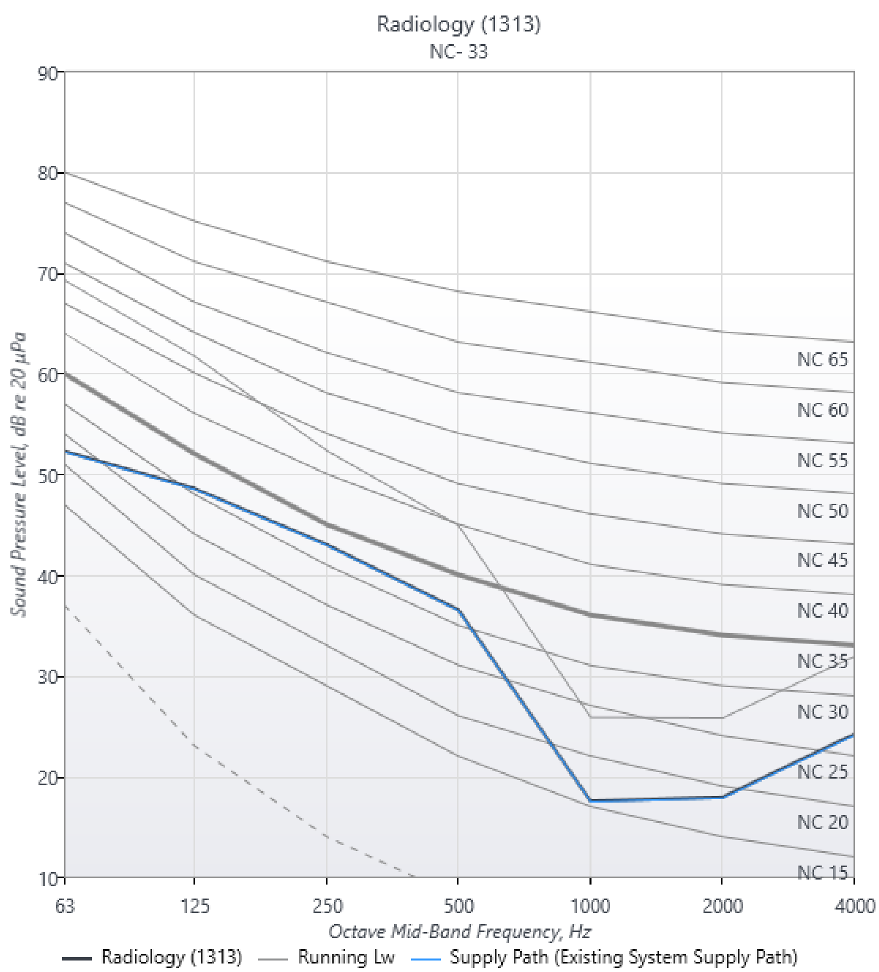


FIGURE 43: NC LEVEL DUE TO ALTERNATIVE 2 AFTER ADJUSTMENTS

Even though after adjustments the space was acoustically comfortable that does not mean that alternative 2 is a good choice from an acoustics perspective. A lot of major factors had to be added or changed which all could add up to the first costs of the system. Especially that the system itself is not allowing for any economical savings in operation costs, having to fix it from an acoustical perspective is just not worth it.

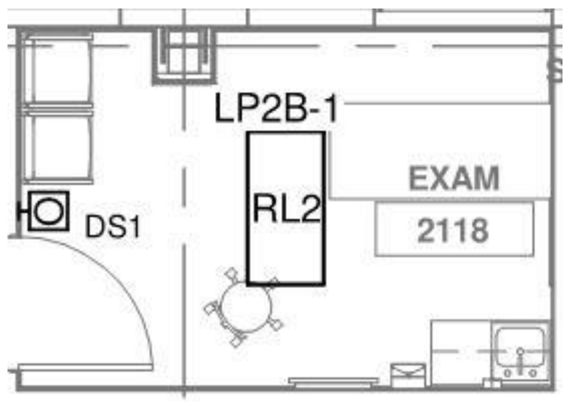
Lighting/Electrical Breadth

After analyzing the Trace 700 model that was created for the Mount Carmel Fitness & Health Center, it was found that the lighting and receptacle loads part take in a large majority of the annual electricity usage. Therefore, when looking at the lighting fixture schedule, it was found that the majority of the fixtures use fluorescent type lamps. Fluorescent type lamps are usually not advised especially in facilities that have long operation hours.

Due to this finding, an analysis was conducted in order to see how much money is spent annually due to operation costs of the lighting fixtures only. The goal of this breadth is to change the fixture types in order to lower down the operation costs, due to electricity consumption, allowing for savings.

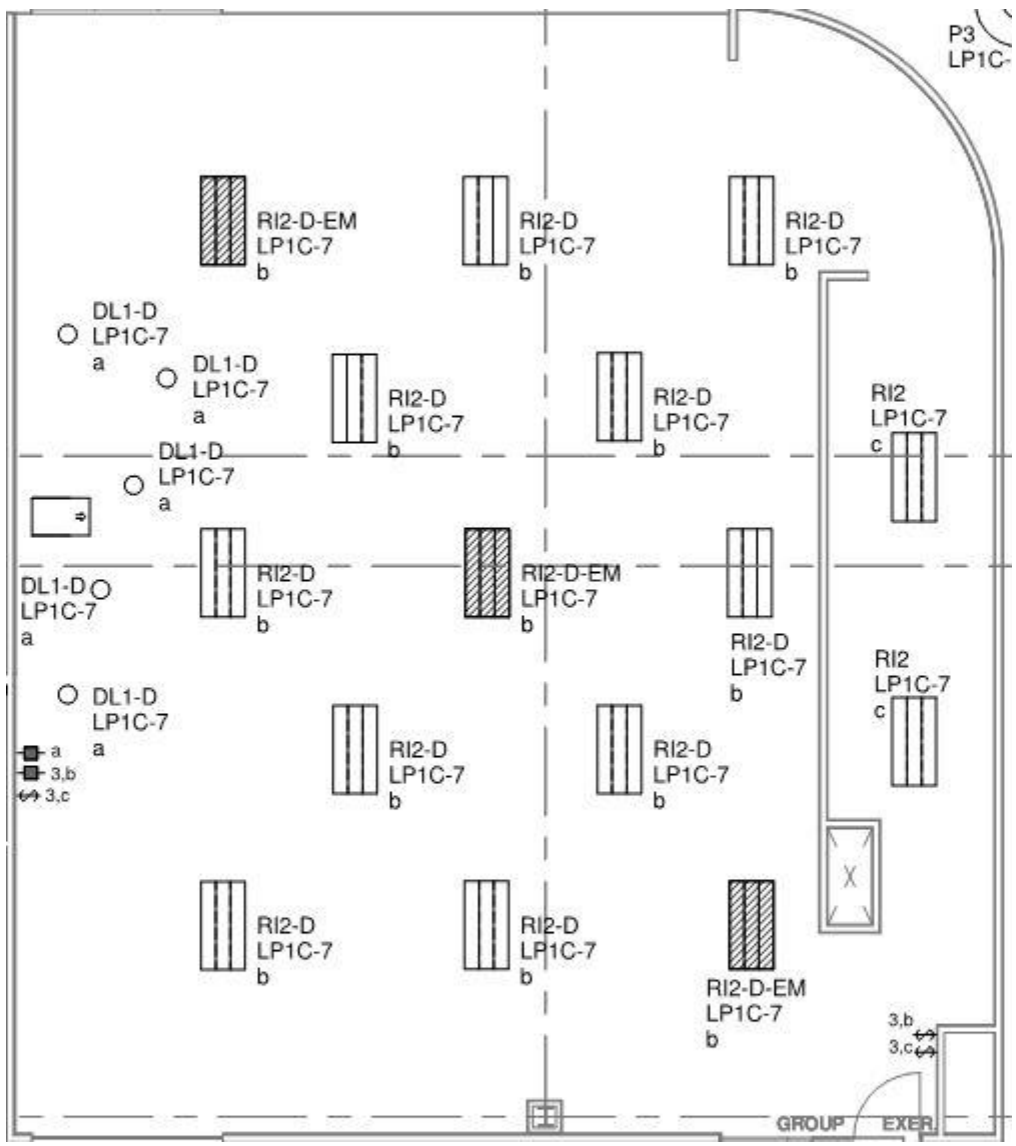
Due to the buildings massive floor area, only 5 spaces were analyzed. The spaces were: Examination Room, Operating Room, W. Lockers, Main Pool, and Group Exercise Room. Those spaces represent the building's functions and therefore were chosen. The Mount Carmel Fitness & Health Center was assumed to be operating 365 days a year, 24 hours a day. The electric rate was taken to be $0.08 per kWh.

In order for such an analysis, the five chosen spaces were modeled using AGI to figure out the amount of lumens required for each of the spaces. The new fixture selection needed to satisfy the required amount of lumens needed. Figure 44 – Figure 48 illustrate the rooms that were modeled/analyzed along with the existing types of fixtures in each room.



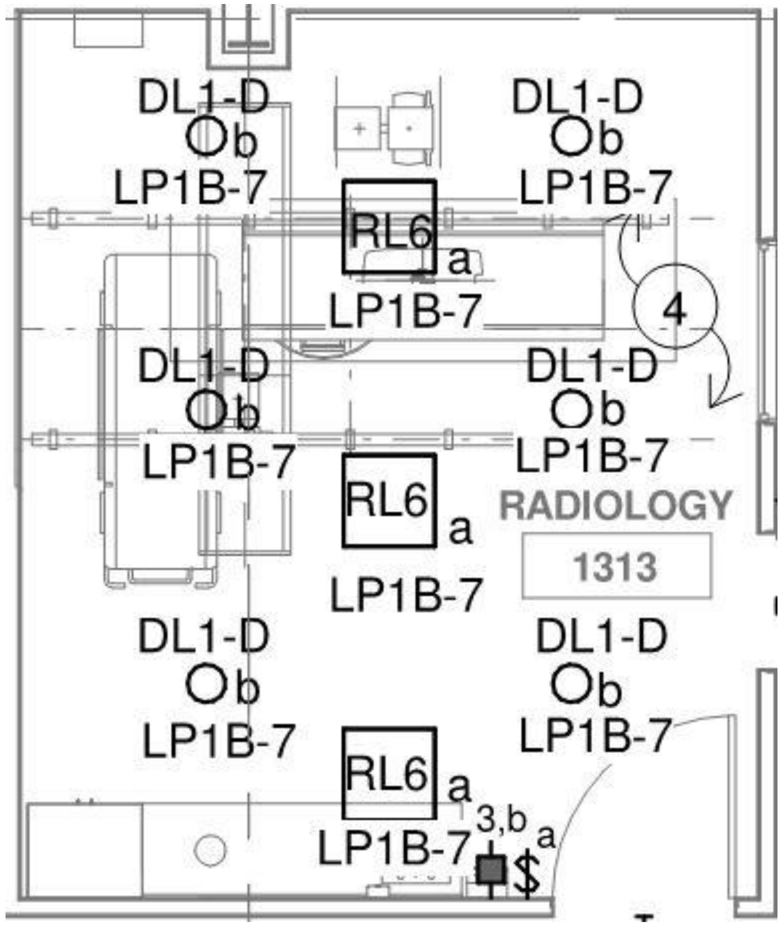
Examination Room	Lamp(s)			Fixture		Catalog Series
Fixture Mark	Type	Watts	Quantity	Wattage	Voltage	
RL2	T8	32	3	86W	Universal	Metalux 2GC8 Lithonia 2SPG8 Philips SPG

FIGURE 44: EXAMINATION ROOM FIXTURE TYPES & LAYOUT


P3
LP1C-
RI2-D-EM
LP1C-7
b
RI2-D
LP1C-7
b
RI2-D
LP1C-7
b
DL1-D
LP1C-7
a
DL1-D
LP1C-7
a
RI2-D
LP1C-7
b
RI2-D
LP1C-7
b
RI2
LP1C-7
c
DL1-D
LP1C-7
a
RI2-D
LP1C-7
b
RI2-D-EM
LP1C-7
b
DL1-D
LP1C-7
a
RI2-D
LP1C-7
b
RI2
LP1C-7
c
DL1-D
LP1C-7
a
a
3,b
3,c
RI2-D
LP1C-7
b
RI2-D
LP1C-7
b
RI2-D
LP1C-7
b
RI2-D
LP1C-7
b
RI2-D-EM
LP1C-7
b
3,b
3,c
GROUP
EXER.

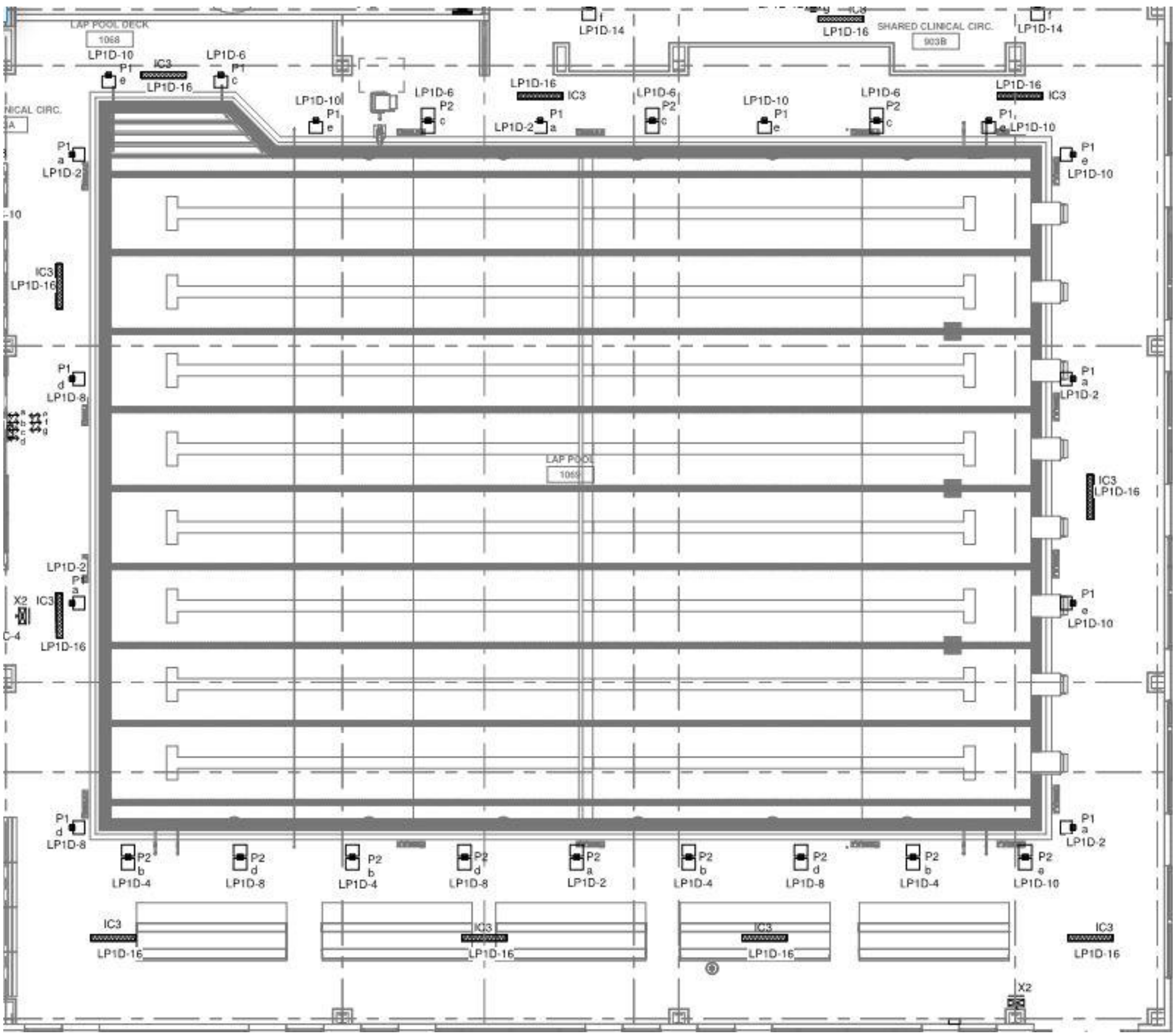
Group Excersice Room	Lamp(s)			Fixture		Catalog Series
Fixture Mark	Type	Watts	Quantity	Wattage	Voltage	
RI2	T8	32	2	60W	277V	Metalux RDI Lithonia VT Philips PFG
RI2-D	T8	32	2	60W	Universal	Metalux RDI Lithonia VT Philips PFG
RI2-D-EM	T8	32	2	60W	277V	Metalux RDI Lithonia VT Philips PFG
DLI-D	LED	39	2	39W	277V	Portfolio LD620 Gotham 6" EVO Philips CM

FIGURE 45: GROUP EXERCISE ROOM FIXTURE TYPES & LAYOUT



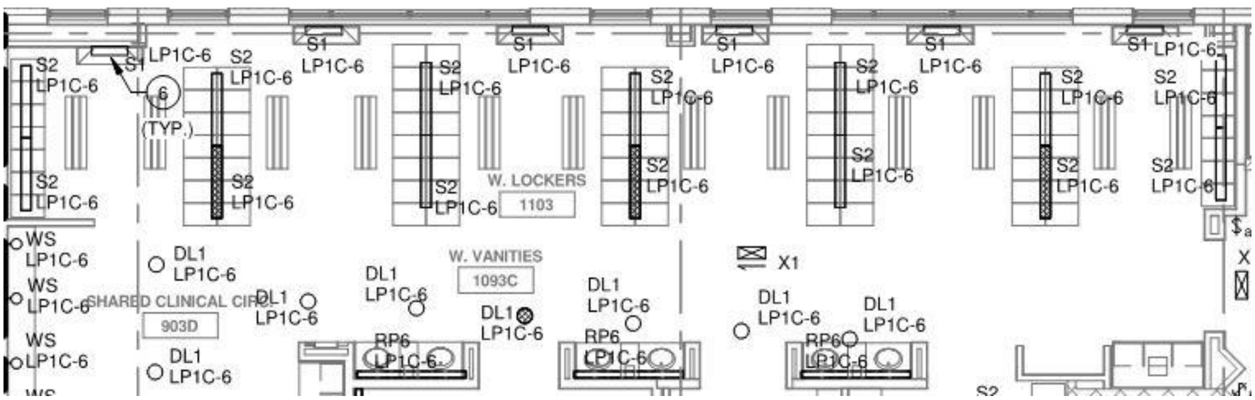
Operation Room	Lamp(s)			Fixture		Catalog Series
Fixture Mark	Type	Watts	Quantity	Wattage	Voltage	
RL6	T8 U6	31	2	60W	277V	Metalux 2GC8 Lithonia 2SPG8 Philips SPG
DL1-D	LED	39	2	39W	277V	Portfolio LD620 Gotham 6" EVO Philips CM

FIGURE 46: OPERATION ROOM FIXTURE TYPES & LAYOUT


LAP POOL DECK
1068
LP1D-14
LP1D-16
SHARED CLINICAL CIRC.
903B
LP1D-10
LP1D-6
IC3
P1
P2
LP1D-2
LP1D-8
LP1D-4
LAP POOL
X2

Main Pool	Lamp(s)			Fixture		Catalog Series
Fixture Mark	Type	Watts	Quantity	Wattage	Voltage	
P1	MH	400	1	460W	277V	Insight Lighting Taos TS2900 Series Ametrix Roundel Large Pinnacle Peak
P2	MH	400	2	920W	277V	Insight Lighting Taos TS2900 Series Ametrix Roundel Large Pinnacle Peak
IC3	T8	32	2	60W	Universal	Metalux VT Lumax VHI Philips ZPX Series

FIGURE 47: MAIN POOL FIXTURE TYPES & LAYOUT



W. Lockers	Lamp(s)			Fixture		Catalog Series
Fixture Mark	Type	Watts	Quantity	Wattage	Voltage	
S1	T8	32	2	30W	Universal	Lithonia Z Strip Metalux SNF Phillips N Series
S2	T8	32	2	60W	277V	Lithonia Z Strip Metalux SNF Phillips N Series
WS	T5HO	24	1	32W	277V	Eureka Moonset Acess Lighting 31004 Aspen Scott S
DL1	CF-DTT	26	2	56W	277V	Portfolio CD6226 Lithonia LF6N Philips CM

FIGURE 48: W. LOCKERS FIXTURE TYPES & LAYOUT

After laying out each space with the existing fixtures provided, a calculation was performed in order to figure out the annual cost of operation, due to the fixtures only, for each space analyzed. Table 47 –Table 51 illustrates the calculation performed along with the annual costs based on the assumptions discussed earlier.

Examination Room						
Fixtue Type	# of Fixtures	Wattage/ Fixtures	Hours of Operation	Total Yearly Days of Operation	Electricity Rate	Operation Cost
RL2	1	86	24	365	$ 0.08	$ 60.27
Total						$ 60.27

TABLE 47: EXAMINATION ROOM ANNUAL OPERATION COST

Group Excersice Room						
Fixtue Type	# of Fixtures	Wattage/ Fixtures	Hours of Operation	Total Yearly Days of Operation	Electricity Rate	Operation Cost
RI2	2	60	24	365	$ 0.08	$ 84.10
RI2-D	10	60	24	365	$ 0.08	$ 420.48
RI2-D-EM	3	60	24	365	$ 0.08	$ 126.14
DLI-D	5	39	24	365	$ 0.08	$ 136.66
Total						$ 767.38

TABLE 48: GROUP EXERCISE ROOM ANNUAL OPERATION COST

Operation Room						
Fixtue Type	# of Fixtures	Wattage/ Fixtures	Hours of Operation	Total Yearly Days of Operation	Electricity Rate	Operation Cost
RL6	3	31	24	365	$ 0.08	$ 65.17
DL1-D	6	39	24	365	$ 0.08	$ 163.99
Total						$ 229.16

TABLE 49: OPERATION ROOM ANNUAL OPERATION COST

Main Pool						
Fixtue Type	# of Fixtures	Wattage/ Fixtures	Hours of Operation	Total Yearly Days of Operation	Electricity Rate	Operation Cost
P1	14	460	24	365	$ 0.08	$ 4,513.15
P2	12	920	24	365	$ 0.08	$ 7,736.83
IC3	10	60	24	365	$ 0.08	$ 420.48
Total						$12,670.46

TABLE 50: MAIN POOL ANNUAL OPERATION COST

W. Lockers						
Fixtue Type	# of Fixtures	Wattage/ Fixtures	Hours of Operation	Total Yearly Days of Operation	Electricity Rate	Operation Cost
S1	6	30	24	365	$ 0.08	$ 126.14
S2	14	60	24	365	$ 0.08	$ 588.67
WS	3	32	24	365	$ 0.08	$ 67.28
DL1	8	56	24	365	$ 0.08	$ 313.96
Total						$ 1,096.05

TABLE 51: W. LOCKERS ANNUAL OPERATION COST

Looking at the figures above, it is clear that the fixtures used are not the most efficient, especially that the facility is constantly running with long hours of operation. Therefore, all the fixtures that are fluorescent will be changed and operation costs will be recalculated to see if any savings are allowable. Table 52 – Table 56 illustrates the new fixtures placed.

Examination Room	Lamp(s)			Fixture		Catalog Series
Fixture Mark	Type	Watts	Quantity	Wattage	Voltage	
LD1	LED	32	3	27W	Universal	Metalux 24GR LED

TABLE 52: EXAMINATION ROOM NEW FIXTURES

Group Excersice Room	Lamp(s)			Fixture		Catalog Series
Fixture Mark	Type	Watts	Quantity	Wattage	Voltage	
LD2	LED	32	3	27W	277V	Metalux 24GR LED
LD2 -A	LED	32	3	27W	Universal	Metalux 24GR LED
LD2-B	LED	32	3	27W	277V	Metalux 24GR LED
DLI-D	LED	39	2	39W	277V	Portfolio LD620 Gotham 6" EVO Philips CM

TABLE 53: GROUP EXERCISE NEW FIXTURES

Operation Room	Lamp(s)			Fixture		Catalog Series
Fixture Mark	Type	Watts	Quantity	Wattage	Voltage	
LD1	LED	31	2	27W	277V	Metalux 24GR LED
DL1-D	LED	39	2	39W	277V	Portfolio LD620 Gotham 6" EVO Philips CM

TABLE 54: OPERATION ROOM NEW FIXTURES

Main Pool	Lamp(s)			Fixture		Catalog Series
Fixture Mark	Type	Watts	Quantity	Wattage	Voltage	
P1	MH	400	1	460W	277V	Insight Lighting Taos TS2900 Series Ametrix Roundel Large Pinnacle Peak
LD5	LED	400	2	835W	277V	High Performance LED Type 4
LD6	LED	45	1	45W	277V	PLT FLP Series

TABLE 55: MAIN POOL NEW FIXTURES

W. Lockers	Lamp(s)			Fixture		Catalog Series
Fixture Mark	Type	Watts	Quantity	Wattage	Voltage	
LD7	LED	12	1	10W	277V	Neo Ray S22
WS	T5HO	24	1	32W	277V	Eureka Moonset Acess Lighting 31004 Aspen Scott S
DL1	CF-DTT	26	2	56W	277V	Portfolio CD6226 Lithonia LF6N Philips CM

TABLE 56: W.LOCKERS NEW FIXTURES

The previous figures illustrates the changes that were made to the existing fixtures in order to reduce the annual operational costs due to lighting loads only. Unfortunately, some of the fixtures were not changed due to lack of LED fixture options that would fit the space lumens criteria. The main pool was one of the spaces that faced such an obstacle. With that said, there was still savings in operation costs. Table 57 – Table 61 illustrates the calculation performed along with the annual costs of the new fixtures based on the assumptions discussed earlier.

Examination Room						
Fixtue Type	# of Fixtures	Wattage/ Fixtures	Hours of Operation	Total Yearly Days of Operation	Electricity Rate	Operation Cost
LD1	1	27	24	365	$ 0.08	$ 18.92
Total						$ 18.92

TABLE 57: EXAMINATION ROOM NEW FIXTURES ANNUAL OPERATION COST

Group Excersice Room						
Fixtue Type	# of Fixtures	Wattage/ Fixtures	Hours of Operation	Total Yearly Days of Operation	Electricity Rate	Operation Cost
LD2	2	27	24	365	$ 0.08	$ 37.84
LD2-A	10	27	24	365	$ 0.08	$ 189.22
LD2-B	3	27	24	365	$ 0.08	$ 56.76
DLI-D	5	39	24	365	$ 0.08	$ 136.66
Total						$ 420.48

TABLE 58: GROUP EXERCISE ROOM NEW FIXTURES ANNUAL OPERATION COST

Operation Room						
Fixtue Type	# of Fixtures	Wattage/ Fixtures	Hours of Operation	Total Yearly Days of Operation	Electricity Rate	Operation Cost
LD1	3	27	24	365	$ 0.08	$ 56.76
DL1-D	6	39	24	365	$ 0.08	$ 163.99
Total						$ 220.75

TABLE 59: OPERATION ROOM ANNUAL OPERATION COST

Main Pool						
Fixtue Type	# of Fixtures	Wattage/ Fixtures	Hours of Operation	Total Yearly Days of Operation	Electricity Rate	Operation Cost
P1	14	460	24	365	$ 0.08	$ 4,513.15
LD5	12	835	24	365	$ 0.08	$ 7,022.02
LD6	10	45	24	365	$ 0.08	$ 315.36
Total						$11,850.53

TABLE 60: MAIN POOL NEW FIXTURES ANNUAL OPERATION COST

W. Lockers						
Fixtue Type	# of Fixtures	Wattage/ Fixtures	Hours of Operation	Total Yearly Days of Operation	Electricity Rate	Operation Cost
LD7	6	10	24	365	$ 0.08	$ 42.05
LD7-1	14	10	24	365	$ 0.08	$ 98.11
WS	3	32	24	365	$ 0.08	$ 67.28
DL1	8	56	24	365	$ 0.08	$ 313.96
Total						$ 521.40

TABLE 61: W. LOCKERS NEW FIXTURES ANNUAL OPERATION COST

Looking at the previous figures, it is clear that performing such a change in the fixture types could allow for major savings. Table 62 illustrates the total savings in annual lighting operation cost due to the new fixtures.

Annual Operation Cost Savings					
Space	Existing Fixtures	New Fixtures	Savings	Total	Percentage
Examination Room	$ 60.27	$ 18.92	$ 41.35	**$ 1,791.24**	**12**
Group Exercise Room	$ 767.38	$ 420.48	$ 346.90		
Operation Room	$ 229.16	$ 220.75	$ 8.41		
Main Pool	$ 12,670.46	$11,850.53	$ 819.93		
W. Lockers	$ 1,096.05	$ 521.40	$ 574.65		

TABLE 63: ANNUAL OPERATION COST SAVINGS

From the previous figure it is clear that such a project would allow for savings in the long run for the MC Fitness & Health Center. Due to only 5 spaces of the building, a total of 12% savings was allowable resulting in almost $1800 in annual savings.

Appendix A

TABLE 5-1 Air Intake Minimum Separation Distance

Object	Minimum Distance, ft (m)
Significantly contaminated exhaust (Note 1)	15 (5)
Noxious or dangerous exhaust (Notes 2 and 3)	30 (10)
Vents, chimneys, and flues from combustion appliances and equipment (Note 4)	15 (5)
Garage entry, automobile loading area, or drive-in queue (Note 5)	15 (5)
Truck loading area or dock, bus parking/idling area (Note 5)	25 (7.5)
Driveway, street, or parking place (Note 5)	5 (1.5)
Thoroughfare with high traffic volume	25 (7.5)
Roof, landscaped grade, or other surface directly below intake (Notes 6 and 7)	1 (0.30)
Garbage storage/pick-up area, dumpsters	15 (5)
Cooling tower intake or basin	15 (5)
Cooling tower exhaust	25 (7.5)

Note 1: Significantly contaminated exhaust is exhaust air with significant contaminant concentration, significant sensory-irritation intensity, or offensive odor.
Note 2: Laboratory fume hood exhaust air outlets shall be in compliance with NFPA 45-1991[3] and ANSI/AIHA Z9.5-1992.[4]
Note 3: Noxious or dangerous exhaust is exhaust air with highly objectionable fumes or gases and/or exhaust air with potentially dangerous particles, bioaerosols, or gases at concentrations high enough to be considered harmful. Information on separation criteria for industrial environments can be found in the ACGIH Industrial Ventilation Manual [5] and in the *ASHRAE Handbook—HVAC Applications*.[6]
Note 4: Shorter separation distances are permitted when determined in accordance with (a) Chapter 7 of ANSI Z223.1/NFPA 54-2002[7] for fuel gas burning appliances and equipment, (b) Chapter 6 of NFPA 31-2001[8] for oil burning appliances and equipment, or (c) Chapter 7 of NFPA 211-2003[9] for other combustion appliances and equipment.
Note 5: Distance measured to closest place that vehicle exhaust is likely to be located.
Note 6: No minimum separation distance applies to surfaces that are sloped more than 45 degrees from horizontal or that are less than 1 in. (3 cm) wide.
Note 7: Where snow accumulation is expected, distance listed shall be increased by the expected average snow depth.

TABLE 6-1 MINIMUM VENTILATION RATES IN BREATHING ZONE ***(continued)***
(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Notes	Default Values: Occupant Density (see Note 4)	Default Values: Combined Outdoor Air Rate (see Note 5)		Air Class
	cfm/person	L/s·person	cfm/ft²	L/s·m²		#/1000 ft² or #/100 m²	cfm/person	L/s·person	
Office Buildings									
Office space	5	2.5	0.06	0.3		5	17	8.5	1
Reception areas	5	2.5	0.06	0.3		30	7	3.5	1
Telephone/data entry	5	2.5	0.06	0.3		60	6	3.0	1
Main entry lobbies	5	2.5	0.06	0.3		10	11	5.5	1
Miscellaneous Spaces									
Bank vaults/safe deposit	5	2.5	0.06	0.3		5	17	8.5	2
Computer (not printing)	5	2.5	0.06	0.3		4	20	10.0	1
Electrical equipment rooms	–	–	0.06	0.3	B	–			1
Elevator machine rooms	–	–	0.12	0.6	B	–			1
Pharmacy (prep. area)	5	2.5	0.18	0.9		10	23	11.5	2
Photo studios	5	2.5	0.12	0.6		10	17	8.5	1
Shipping/receiving	–	–	0.12	0.6	B	–			1
Telephone closets	–	–	0.00	0.0		–			1
Transportation waiting	7.5	3.8	0.06	0.3		100	8	4.1	1
Warehouses	–	–	0.06	0.3	B	–			2
Public Assembly Spaces									
Auditorium seating area	5	2.5	0.06	0.3		150	5	2.7	1
Places of religious worship	5	2.5	0.06	0.3		120	6	2.8	1
Courtrooms	5	2.5	0.06	0.3		70	6	2.9	1
Legislative chambers	5	2.5	0.06	0.3		50	6	3.1	1
Libraries	5	2.5	0.12	0.6		10	17	8.5	1
Lobbies	5	2.5	0.06	0.3		150	5	2.7	1
Museums (children's)	7.5	3.8	0.12	0.6		40	11	5.3	1
Museums/galleries	7.5	3.8	0.06	0.3		40	9	4.6	1
Residential									
Dwelling unit	5	2.5	0.06	0.3	F,G	F			1
Common corridors	–	–	0.06	0.3					1
Retail									
Sales (except as below)	7.5	3.8	0.12	0.6		15	16	7.8	2
Mall common areas	7.5	3.8	0.06	0.3		40	9	4.6	1
Barbershop	7.5	3.8	0.06	0.3		25	10	5.0	2
Beauty and nail salons	20	10	0.12	0.6		25	25	12.4	2
Pet shops (animal areas)	7.5	3.8	0.18	0.9		10	26	12.8	2
Supermarket	7.5	3.8	0.06	0.3		8	15	7.6	1
Coin-operated laundries	7.5	3.8	0.06	0.3		20	11	5.3	2

TABLE 6-1 MINIMUM VENTILATION RATES IN BREATHING ZONE
(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Notes	Default Values			Air Class
						Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		
	cfm/person	L/s·person	cfm/ft^2	L/s·m^2		#/1000 ft^2 or #/100 m^2	cfm/person	L/s·person	
Correctional Facilities									
Cell	5	2.5	0.12	0.6		25	10	4.9	2
Dayroom	5	2.5	0.06	0.3		30	7	3.5	1
Guard stations	5	2.5	0.06	0.3		15	9	4.5	1
Booking/waiting	7.5	3.8	0.06	0.3		50	9	4.4	2
Educational Facilities									
Daycare (through age 4)	10	5	0.18	0.9		25	17	8.6	2
Daycare sickroom	10	5	0.18	0.9		25	17	8.6	3
Classrooms (ages 5–8)	10	5	0.12	0.6		25	15	7.4	1
Classrooms (age 9 plus)	10	5	0.12	0.6		35	13	6.7	1
Lecture classroom	7.5	3.8	0.06	0.3		65	8	4.3	1
Lecture hall (fixed seats)	7.5	3.8	0.06	0.3		150	8	4.0	1
Art classroom	10	5	0.18	0.9		20	19	9.5	2
Science laboratories	10	5	0.18	0.9		25	17	8.6	2
University/college laboratories	10	5	0.18	0.9		25	17	8.6	2
Wood/metal shop	10	5	0.18	0.9		20	19	9.5	2
Computer lab	10	5	0.12	0.6		25	15	7.4	1
Media center	10	5	0.12	0.6	A	25	15	7.4	1
Music/theater/dance	10	5	0.06	0.3		35	12	5.9	1
Multi-use assembly	7.5	3.8	0.06	0.3		100	8	4.1	1
Food and Beverage Service									
Restaurant dining rooms	7.5	3.8	0.18	0.9		70	10	5.1	2
Cafeteria/fast-food dining	7.5	3.8	0.18	0.9		100	9	4.7	2
Bars, cocktail lounges	7.5	3.8	0.18	0.9		100	9	4.7	2
General									
Break rooms	5	2.5	0.06	0.3		25	10	5.1	1
Coffee stations	5	2.5	0.06	0.3		20	11	5.5	1
Conference/meeting	5	2.5	0.06	0.3		50	6	3.1	1
Corridors	–	–	0.06	0.3		–			1
Storage rooms	–	–	0.12	0.6	B	–			1
Hotels, Motels, Resorts, Dormitories									
Bedroom/living room	5	2.5	0.06	0.3		10	11	5.5	1
Barracks sleeping areas	5	2.5	0.06	0.3		20	8	4.0	1
Laundry rooms, central	5	2.5	0.12	0.6		10	17	8.5	2
Laundry rooms within dwelling units	5	2.5	0.12	0.6		10	17	8.5	1
Lobbies/prefunction	7.5	3.8	0.06	0.3		30	10	4.8	1
Multipurpose assembly	5	2.5	0.06	0.3		120	6	2.8	1

TABLE 6-1 MINIMUM VENTILATION RATES IN BREATHING ZONE *(continued)*
(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Notes	Default Values: Occupant Density (see Note 4)	Default Values: Combined Outdoor Air Rate (see Note 5)		Air Class
	cfm/person	L/s·person	cfm/ft^2	L/s·m^2		#/1000 ft^2 or #/100 m^2	cfm/person	L/s·person	
Sports and Entertainment									
Sports arena (play area)	–	–	0.30	1.5	E	–			1
Gym, stadium (play area)	–	–	0.30	1.5		30			2
Spectator areas	7.5	3.8	0.06	0.3		150	8	4.0	1
Swimming (pool & deck)	–	–	0.48	2.4	C	–			2
Disco/dance floors	20	10	0.06	0.3		100	21	10.3	1
Health club/aerobics room	20	10	0.06	0.3		40	22	10.8	2
Health club/weight rooms	20	10	0.06	0.3		10	26	13.0	2
Bowling alley (seating)	10	5	0.12	0.6		40	13	6.5	1
Gambling casinos	7.5	3.8	0.18	0.9		120	9	4.6	1
Game arcades	7.5	3.8	0.18	0.9		20	17	8.3	1
Stages, studios	10	5	0.06	0.3	D	70	11	5.4	1

GENERAL NOTES FOR TABLE 6-1

1 **Related requirements:** The rates in this table are based on all other applicable requirements of this standard being met.

2 **Smoking:** This table applies to no-smoking areas. Rates for smoking-permitted spaces must be determined using other methods. See Section 6.2.9 for ventilation requirements in smoking areas.

3 **Air density:** Volumetric airflow rates are based on an air density of 0.075 lb_{da}/ft^3 (1.2 kg_{da}/m^3), which corresponds to dry air at a barometric pressure of 1 atm (101.3 kPa) and an air temperature of 70°F (21°C). Rates may be adjusted for actual density but such adjustment is not required for compliance with this standard.

4 **Default occupant density:** The default occupant density shall be used when actual occupant density is not known.

5 **Default combined outdoor air rate (per person):** This rate is based on the default occupant density.

6 **Unlisted occupancies:** If the occupancy category for a proposed space or zone is not listed, the requirements for the listed occupancy category that is most similar in terms of occupant density, activities and building construction shall be used.

7 **Health-care facilities:** Rates shall be determined in accordance with Appendix E.

ITEM-SPECIFIC NOTES FOR TABLE 6-1

A For high school and college libraries, use values shown for Public Assembly Spaces—Libraries.

B Rate may not be sufficient when stored materials include those having potentially harmful emissions.

C Rate does not allow for humidity control. Additional ventilation or dehumidification may be required to remove moisture.

D Rate does not include special exhaust for stage effects, e.g., dry ice vapors, smoke.

E When combustion equipment is intended to be used on the playing surface, additional dilution ventilation and/or source control shall be provided.

F Default occupancy for dwelling units shall be two persons for studio and one-bedroom units, with one additional person for each additional bedroom.

G Air from one residential dwelling shall not be recirculated or transferred to any other space outside of that dwelling.

TABLE E-1 Outdoor Air Requirements for Ventilation of Health Care Facilities (Hospitals, Nursing and Convalescent Homes)*

Application	Estimated Maximum** Occupancy P/1000 ft^2 or 100 m^2	Outdoor Air Requirements: cfm/person	L/s · person	cfm/ft^2	L/s · m^2	Comments
Patient rooms	10	25	13			Special requirements or codes and pressure relationships may determine minimum ventilation rates and filter efficiency. Procedures generating contaminants may require higher rates.
Medical procedure	20	15	8			
Operating rooms	20	30	15			
Recovery and ICU	20	15	8			
Autopsy rooms	20			0.50	2.50	Air shall not be recirculated into other spaces.
Physical therapy	20	15	8			

* Table E-1 prescribes supply rates of acceptable outdoor air required for acceptable indoor air quality. These values have been chosen to dilute human bioeffluents and other contaminants with an adequate margin of safety and to account for health variations among people and varied activity levels.

** Net occupiable space.

TABLE 6-2 Zone Air Distribution Effectiveness

Air Distribution Configuration	E_z
Ceiling supply of cool air.	1.0
Ceiling supply of warm air and floor return.	1.0
Ceiling supply of warm air 15°F (8°C) or more above space temperature and ceiling return.	0.8
Ceiling supply of warm air less than 15°F (8°C) above space temperature and ceiling return provided that the 150 fpm (0.8 m/s) supply air jet reaches to within 4.5 ft (1.4 m) of floor level. ***Note:*** For lower velocity supply air, E_z = 0.8.	1.0
Floor supply of cool air and ceiling return provided that the 150 fpm (0.8 m/s) supply jet reaches 4.5 ft (1.4 m) or more above the floor. ***Note:*** Most underfloor air distribution systems comply with this proviso.	1.0
Floor supply of cool air and ceiling return, provided low-velocity displacement ventilation achieves unidirectional flow and thermal stratification.	1.2
Floor supply of warm air and floor return.	1.0
Floor supply of warm air and ceiling return.	0.7
Makeup supply drawn in on the opposite side of the room from the exhaust and/or return.	0.8
Makeup supply drawn in near to the exhaust and/or return location.	0.5

1. "Cool air" is air cooler than space temperature.
2. "Warm air" is air warmer than space temperature.
3. "Ceiling" includes any point above the *breathing zone.*
4. "Floor" includes any point below the *breathing zone.*
5. As an alternative to using the above values, E_z may be regarded as equal to air change effectiveness determined in accordance with ANSI/ASHRAE Standard 129[18] for all air distribution configurations except unidirectional flow.

TABLE 6-4 Minimum Exhaust Rates

Occupancy Category	Exhaust Rate, cfm/unit	Exhaust Rate, cfm/ft^2	Notes	Exhaust Rate, L/s·unit	Exhaust Rate, $L/s \cdot m^2$	Air Class
Arenas	–	0.50	B	–	–	1
Art classrooms	–	0.70		–	3.5	2
Auto repair rooms	–	1.50	A	–	7.5	2
Barber shops	–	0.50		–	2.5	2
Beauty and nail salons	–	0.60		–	3.0	2
Cells with toilet	–	1.00		–	5.0	2
Copy, printing rooms	–	0.50		–	2.5	2
Darkrooms	–	1.00		–	5.0	2
Educational science laboratories	–	1.00		–	5.0	2
Janitor closets, trash rooms, recycling	–	1.00		–	5.0	3
Kitchenettes	–	0.30		–	1.5	2
Kitchens—commercial	–	0.70		–	3.5	2
Locker/dressing rooms	–	0.25		–	1.25	2
Locker rooms	–	0.50		–	2.5	2
Paint spray booths	–	–	F	–	–	4
Parking garages	–	0.75	C	–	3.7	2
Pet shops (animal areas)	–	0.90		–	4.5	2
Refrigerating machinery rooms	–	–	F	–	–	3
Residential kitchens	50/100	–	G	25/50	–	2
Soiled laundry storage rooms	–	1.00	F	–	5.0	3
Storage rooms, chemical	–	1.50	F	–	7.5	4
Toilets—private	25/50	–	E	12.5/25	–	2
Toilets—public	50/70	–	D	25/35	–	2
Woodwork shop/classrooms	–	0.50		–	2.5	2

A Stands where engines are run shall have exhaust systems that directly connect to the engine exhaust and prevent escape of fumes.
B When combustion equipment is intended to be used on the playing surface additional dilution ventilation and/or source control shall be provided.
C Exhaust not required if two or more sides comprise walls that are at least 50% open to the outside.
D Rate is per water closet and/or urinal. Provide the higher rate where periods of heavy use are expected to occur, e.g., toilets in theatres, schools, and sports facilities. The lower rate may be used otherwise.
E Rate is for a toilet room intended to be occupied by one person at a time. For continuous system operation during normal hours of use, the lower rate may be used. Otherwise use the higher rate.
F See other applicable standards for exhaust rate.
G For continuous system operation, the lower rate may be used. Otherwise use the higher rate.

TABLE 5.5-5 Building Envelope Requirements For Climate Zone 5 (A, B, C)*

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-0.119	R-7.6 c.i.
Metal Building	U-0.065	R-19.0	U-0.065	R-19.0	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-0.090	R-11.4 c.i.	U-0.080	R-13.3 c.i.	U-0.151[a]	R-5.7 c.i.[a]
Metal Building	U-0.113	R-13.0	U-0.057	R-13.0 + R-13.0	U-0.123	R-11.0
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-0.064	R-13.0 + R-3.8 c.i.	U-0.051	R-13.0 + R-7.5 c.i.	U-0.089	R-13.0
Walls, Below-Grade						
Below-Grade Wall	C-0.119	R-7.5 c.i.	C-0.119	R-7.5 c.i.	C-1.140	NR
Floors						
Mass	U-0.074	R-10.4 c.i.	U-0.064	R-12.5 c.i.	U-0.137	R-4.2 c.i.
Steel-Joist	U-0.038	R-30.0	U-0.038	R-30.0	U-0.052	R-19.0
Wood-Framed and Other	U-0.033	R-30.0	U-0.033	R-30.0	U-0.051	R-19.0
Slab-On-Grade Floors						
Unheated	F-0.730	NR	F-0.540	R-10 for 24 in.	F-0.730	NR
Heated	F-0.860	R-15 for 24 in.	F-0.860	R-15 for 24 in.	F-1.020	R-7.5 for 12 in.
Opaque Doors						
Swinging	U-0.700		U-0.500		U-0.700	
Nonswinging	U-0.500		U-0.500		U-1.450	
Fenestration	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**
Vertical Glazing, % of Wall						
Nonmetal framing (all)[b]	U-0.35	SHGC-0.40 all	U-0.35	SHGC-0.40 all	U-1.20	SHGC-NR all
Metal framing (curtainwall/storefront)[c]	U-0.45		U-0.45		U-1.20	
Metal framing (entrance door)[c]	U-0.80		U-0.80		U-1.20	
Metal framing (all other)[c]	U-0.55		U-0.55		U-1.20	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}-1.17	$SHGC_{all}$-0.49	U_{all}-1.17	$SHGC_{all}$-0.49	U_{all}-1.98	$SHGC_{all}$-NR
2.1%–5.0%	U_{all}-1.17	$SHGC_{all}$-0.39	U_{all}-1.17	$SHGC_{all}$-0.39	U_{all}-1.98	$SHGC_{all}$-NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}-1.10	$SHGC_{all}$-0.77	U_{all}-1.10	$SHGC_{all}$-0.77	U_{all}-1.90	$SHGC_{all}$-NR
2.1%–5.0%	U_{all}-1.10	$SHGC_{all}$-0.62	U_{all}-1.10	$SHGC_{all}$-0.62	U_{all}-1.90	$SHGC_{all}$-NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}-0.69	$SHGC_{all}$-0.49	U_{all}-0.69	$SHGC_{all}$-0.49	U_{all}-1.36	$SHGC_{all}$-NR
2.1%–5.0%	U_{all}-0.69	$SHGC_{all}$-0.39	U_{all}-0.69	$SHGC_{all}$-0.39	U_{all}-1.36	$SHGC_{all}$-NR

*The following definitions apply: c.i. = continuous insulation (see Section 3.2), NR = no (insulation) requirement.

[a] Exception to Section A3.1.3.1 applies.

[b] Nonmetal framing includes framing materials other than metal with or without metal reinforcing or cladding.

[c] Metal framing includes metal framing with or without thermal break. The "all other" subcategory includes operable windows, fixed windows, and non-entrance doors.

TABLE 9.5.1 Lighting Power Densities Using the Building Area Method

Building Area Type[a]	*LPD* (W/ft^2)
Automotive facility	0.9
Convention center	1.2
Courthouse	1.2
Dining: bar lounge/leisure	1.3
Dining: cafeteria/fast food	1.4
Dining: family	1.6
Dormitory	1.0
Exercise center	1.0
Gymnasium	1.1
Health-care clinic	1.0
Hospital	1.2
Hotel	1.0
Library	1.3
Manufacturing facility	1.3
Motel	1.0
Motion picture theater	1.2
Multifamily	0.7
Museum	1.1
Office	1.0
Parking garage	0.3
Penitentiary	1.0
Performing arts theater	1.6
Police/fire station	1.0
Post office	1.1
Religious building	1.3
Retail	1.5
School/university	1.2
Sports arena	1.1
Town hall	1.1
Transportation	1.0
Warehouse	0.8
Workshop	1.4

[a] In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

Appendix B

Table – 3

	Room Name	Room Number	Occupancy Type	Zone Floor Area (Az)	Outdoor Airflow Rate/Unit Area (Ra)	Outdoor Airflow Rate/Person (Rp)	Maximum # of People in the Ventilated Zone (Pz)	Breathing Zone Outdoor Airflow (Vbz)	Zone Air Distribution Effectiveness (Ez)	Design Zone Outdoor Airflow (Voz)	Exhaust	Notes (According to ASHRAE)
				(SF)	(CFM/SF)	(CFM/Person)	(# of People)	(CFM)		(CFM)	(CFM)	
1th Floor East												
	W. Lockers	1103/1096	Lockers	535	-	-	-	-	-	-	267.5	
	W. Vanities	1093	Toilets - Public	442	-	-	-	-	-	-	150	
	Make Up Area	1093	Locker/Dressing Rooms	122	-	-	-	-	-	-	30.5	
	W. Toilets	1094	Toilets	180	-	-	-	-	-	-	250	
	SPA Lounge	1095	Cocktail Lounges	96	0.18	7.5	10	92.28	1	92.28	-	
	Steam	1097	Swimming (Pool & Deck)	101	0.48	0	0	48.48	1	48.48	-	C
	W. Entry	1092	Corridors	192	0.06	0	0	11.52	1	11.52	-	
	W. Showers	1098	Toilet - Public	477	-	-	-	-	-	-	245	
	W. Whirpool	1101	Swimming (Pool & Deck)	118	0.48	0	0	56.64	1	56.64	-	C
	Sauna	1102	Swimming (Pool & Deck)	60	0.48	0	0	28.8	1	28.8	-	C
	W. Pool Entry	1100	Corridors	131	0.06	0	0	7.86	1	7.86	-	
	Massage Rooms	1091	Cocktail Lounges	113	0.18	7.5	12	110.34	1	110.34	-	
	Men's Lounge	1078	Cocktail Lounges	223	0.18	7.5	23	212.64	1	212.64	-	
	Men's Toilets	1079	Toilets - Public	255	-	-	-	-	-	-	200	
	Men's Vanities	1077	Toilets - Public	257	-	-	-	-	-	-	100	
	Men's Lockers	1076	Lockers	613	-	-	-	-	-	-	306.5	
	Men's Showers	1081	Toilets - Public	606	-	-	-	-	-	-	245	
	M. Whirpool	1083	Swimming (Pool & Deck)	115	0.48	0	0	55.2	1	55.2	-	C
	JC	1099	Janitor, Trash, Recycle	52	-	-	-	-	-	-	52	
	Girls Showers	1053	Toilets - Public	70	-	-	-	-	-	-	105	
	Girls Lockers	1050	Lockers	249	-	-	-	-	-	-	224.5	
	Boys Lockers	1056	Lockers	229	-	-	-	-	-	-	164.5	
	Boys Showers	1058	Toilet - Public	80	-	-	-	-	-	-	105	
	Therapy Pool Deck	1065	Swimming (Pool & Deck)	500	0.48	0	0	240	1	240	-	C
	Therapy Pool	1066	Swimming (Pool & Deck)	400	0.48	0	0	192	1	192	-	C
	Lap Pool Access	1061	Corridors	605	0.06	0	0	36.3	1	36.3	-	
	Lap Pool Deck	1068	Swimming (Pool & Deck)	3925	0.48	0	0	1884	1	1884	-	C
	Lap Pool	1069	Swimming (Pool & Deck)	5189	0.48	0	0	2490.72	1	2490.72	-	C
	Exercise Pool Deck	1072	Swimming (Pool & Deck)	618	0.48	0	0	296.64	1	296.64	-	C
	Exercise Pool	1073	Swimming (Pool & Deck)	1115	0.48	0	0	535.2	1	535.2	-	C
	CHG 4	1059	Toilet - Private	80	-	-	-	-	-	-	25	

1st Floor Center												
	Conf. A/B	1003/1005	Main Entry Lobbies	1090	0.06	5	11	120.4	1	120.4	-	
	Vestuble	1009	Main Entry Lobbies	268	0.06	5	3	31.08	1	31.08	-	
	Lobby Circ.	1041	Main Entry Lobbies	879	0.06	5	9	97.74	1	97.74	-	
	Vestuble	1000	Main Entry Lobbies	268	0.06	5	3	31.08	1	31.08	-	
	Women's Restroom	1002	Toilet - Public	295	-	-	-	-	-	-	200	
	Men's Restroom	1008	Toilet - Public	176	-	-	-	-	-	-	100	
	F&B Seating	1040	Cafeteria/Fast-Food Dinning	1056	0.18	7.5	106	985.08	1	985.08	-	
	Café	1108	Cafeteria/Fast-Food Dinning	216	0.18	7.5	22	203.88	1	203.88	-	
	Sales	1016	Sales	138	0.12	7.5	2	31.56	1	31.56	-	
	Retail	1020	Sales	132	0.12	7.5	2	30.84	1	30.84	-	
	Store	1019	Sales	71	0.12	7.5	1	16.02	1	16.02	-	
	MBR. Lounge	1043	Cocktail Lounges	192	0.18	7.5	20	184.56	1	184.56	-	
	MBR. Lounge	1021	Cocktail Lounges	263	0.18	7.5	27	249.84	1	249.84	-	
	Laundry	1034	Laundry rooms, Central	198	0.12	5	2	33.76	1	33.76	-	
	Wellness IT	1035	Computer (Not Printing)	113	0.06	5	1	11.78	1	11.78	-	
	Open Admin	1024	Corridor	401	0.06	0	0	24.06	1	24.06	-	
	E.E.	1038	Electrical Equipment Rooms	50	0.06	0	0	3	1	3	-	B
	Accounting	1028	Office	111	0.06	5	1	11.66	1	11.66	-	
	Office	1027	Office	85	0.06	5	1	10.1	1	10.1	-	
	GM	1029	Office	153	0.06	5	1	14.18	1	14.18	-	
	Breake	1033	Reception Areas	304	0.06	5	10	68.24	1	68.24	-	
	Kitchen	1036	Kitchens - Commercial	987	-	-	-	-	-	-	690.9	

1th Floor West	Isolation/Triagae Exam	1332	Patient Rooms	155	0	25	2	50	1	50	-	
	Vestibule	1290	Main Entry Lobbies	204	0.06	5	3	27.24	1	27.24	-	
	Nurse Station	1301	Reception	217	0.06	5	7	48.02	1	48.02	-	
	ED. Circ.	1299	Main Entry Lobbies	1855	0.06	5	19	206.3	1	206.3	-	
	ED. Waiting	1291	Reception	797	0.06	5	24	167.82	1	167.82	-	
	Pharmacy	1303	Pharmacy (Prep Area)	151	0.018	5	2	12.718	1	12.718	-	
	Lab	1327	Pharmacy (Prep Area)	94	0.018	5	1	6.692	1	6.692	-	
	Clean Linen	1328	Storage	52	0.12	0	0	6.24	1	6.24	-	
	Exam Room	1326	Patient Rooms	125	0	25	2	50	1	50	-	
	Storage	1320	Storage	52	0.12	0	0	6.24	1	6.24	-	
	Soiled Utility	1308	Soiled Laundry Storage Rooms	69	-	-	-	-	-	-	103.5	F
	Radiology	1313	Medical Procedure	290	0	15	6	90	1	90	-	
	Control	1311	Electrical Equipment Rooms	146	0.06	0	0	8.76	1	8.76	-	B
	Supplies	1323	Storage	294	0.12	0	0	35.28	1	35.28	-	
	Nurse Workstation	1287	Reception	46	0.06	5	1	7.76	1	7.76	-	
	Emer. Trauma	1298	Operating Rooms	137	0	30	3	90	1	90	-	
	Emer. Treat.	1300	Operating Rooms	161	0	30	4	120	1	120	-	
	CT Room	1309	Medical Procedure	340	0	15	7	105	1	105	-	
	Ultra Sound	1275	Medical Procedure	216	0	15	5	75	1	75	-	
	M. Dress	1274	Dressing Rooms	60	-	-	-	-	-	-	15	
	W. Dress	1272	Dressing Rooms	60	-	-	-	-	-	-	15	
	MRI Magnet Room	1218A	Medical Procedure	387	0	15	8	120	1	120	-	
	MRI Control	1279	Electrical Equipment Rooms	116	0.06	0	0	6.96	1	6.96	-	
	Bio Haz.	1276	Operating Rooms	53	0	30	2	60	1	60	-	
	Bone Density	1256	Medical Procedure	154	0	15	4	60	1	60	-	
	Patient Prep Screening	1268	Patient Rooms	102	0	25	2	50	1	50	-	
	Tea Room	1259	Break Room	176	0.06	5	5	35.56	1	35.56	-	
	Staff Work Area	1251	Office	101	0.06	5	1	11.06	1	11.06	-	
	Dress	1253	Dressing Rooms	53	-	-	-	-	-	-	13.25	
	Womens Health Corridor	1250H	Corridor	390	0.06	0	0	23.4	1	23.4	-	
	MRI. Euip.	1281C	Electrical Equipment Rooms	168	0.06	0	0	10.08	1	10.08	-	
	I.T	1281D	Computer (Not Printing)	287	0.06	5	2	27.22	1	27.22	-	
	Shared Waiting	1220	Corridor	800	0.06	0	0	48	1	48	-	
	Resource Consult.	1202	Patient Rooms	112	0	25	2	50	1	50	-	
	Reg. Waiting	1209	Break Room	281	0.06	5	8	56.86	1	56.86	-	

2nd Floor East	Open Fitness	2020	Health Club/Aerobic Rooms	5737	0.06	20	228	4904.22	1	4904.22	-	
	Open Fitness	2003	Health Club/Weight Rooms	2204	0.06	20	23	592.24	1	592.24	-	
	Walk/Jog Track	2001	Gym (Play Area)	4760	0.3	0	0	1428	1	1428		
	Men Toilet	2015	Toilet - Private	45	-	-	-	-	-	-	50	
	Uni Toilet	2013	Toilet - Private	43	-	-	-	-	-	-	50	
	Pilates	2004	Health Club/Aerobic Rooms	490	0.06	20	20	429.4	1	429.4	-	
	Spin	2016	Health Club/Aerobic Rooms	1002	0.06	20	41	880.12	1	880.12	-	
	Women Toilet	2014	Toilet - Private	45	-	-	-	-	-	-	50	
	Mind And Body	2005	Health Club/Aerobic Rooms	1428	0.06	20	58	1245.68	1	1245.68	-	
	Group Exer.	2010	Health Club/Aerobic Rooms	1962	0.06	20	79	1697.72	1	1697.72	-	
	Testing	207	Medical Procedure	139	0	15	3	45	1	45	-	
	Fitness Staff	2024	Office	252	0.06	5	2	25.12	1	25.12	-	
	Circ.	2008	Corridor	512	0.06	0	0	30.72	1	30.72	-	

2nd Floor West	Cardiac Rehab.	2207	Medical Procedure	121	0	15	3	45	1	45	-	
	PT Therapy	2205	Medical Procedure	118	0	15	3	45	1	45	-	
	Blood Draw	2146	Medical Procedure	118	0	15	3	45	1	45		
	Lab/Rad. Waiting	2144	Corridor	66	0.06	0	0	3.96	1	3.96	-	
	Procedure/Casting	2142	Medical Procedure	204	0	15	5	75	1	75	-	
	Exam	2141	Patient Rooms	127	0	25	2	50	1	50	-	
	Shared Waiting	2100	Break Room	1798	0.06	5	45	332.88	1	332.88	-	
	Patient Toilet	2133	Toilet - Private	57	-	-	-	-	-	-	50	
	Phys. Office	2132	Office	151	0.06	5	1	14.06	1	14.06		
	Storage	2130	Storage	88	0.12	0	0	10.56	1	10.56	-	
	Nurse Workstation	2252	Reception	113	0.06	5	4	26.78	1	26.78	-	
	Procedure	2253	Medical Procedure	160	0	15	4	60	1	60	-	
	Shared Doc Storage	2169	Storage	95	0.12	0	0	11.4	1	11.4	-	
	Shared Break Room	2129	Break Room	247	0.06	5	7	49.82	1	49.82	-	
	Check Out	2112	Reception	258	0.06	5	8	55.48	1	55.48	-	
	Call Center	2113	Reception	184	0.06	5	1	16.04	1	16.04	-	
	Janitor	2152	Janitor, Trash, Recycle	77	-	-	-	-	-	-	77	
	Clean Supply/Med. Room	2113	Storage	133	0.12	0	0	15.96	1	15.96	-	
	Triangle Call Center	2114	Break Room	172	0.06	5	5	35.32	1	35.32	-	
	Blood Draw	2145	Medical Procedure	118	0	15	3	45	1	45	-	
	Timeshare Corridor	2310	Corridor	392	0.06	0	0	23.52	1	23.52	-	
	Timeshare Reception	2311	Reception	131	0.06	5	4	27.86	1	27.86	-	

Table – 4

Room Name	Room Number	Occupancy Type	Area (SF)	LPD (W/ft2)	Wattage
1st Floor					
W. Lockers	1103/1096	Lockers	535	1.2	642
W. Vanities	1093	Toilets - Public	442	1.2	530.4
Make Up Area	1093	Locker/Dressing Rooms	122	1.2	146.4
W. Toilets	1094	Toilets	180	1.2	216
SPA Lounge	1095	Cocktail Lounges	96	1.2	115.2
Steam	1097	Swimming (Pool & Deck)	101	1.2	121.2
W. Entry	1092	Corridors	192	1.2	230.4
W. Showers	1098	Toilet - Public	477	1.2	572.4
W. Whirpool	1101	Swimming (Pool & Deck)	118	1.2	141.6
Sauna	1102	Swimming (Pool & Deck)	60	1.2	72
W. Pool Entry	1100	Corridors	131	1.2	157.2
Massage Rooms	1091	Cocktail Lounges	113	1.2	135.6
Men's Lounge	1078	Cocktail Lounges	223	1.2	267.6
Men's Toilets	1079	Toilets - Public	255	1.2	306
Men's Vanities	1077	Toilets - Public	257	1.2	308.4
Men's Lockers	1076	Lockers	613	1.2	735.6
Men's Showers	1081	Toilets - Public	606	1.2	727.2
M. Whirpool	1083	Swimming (Pool & Deck)	115	1.2	138
JC	1099	Janitor, Trash, Recycle	52	1.2	62.4
Girls Showers	1053	Toilets - Public	70	1.2	84
Girls Lockers	1050	Lockers	249	1.2	298.8
Boys Lockers	1056	Lockers	229	1.2	274.8
Boys Showers	1058	Toilet - Public	80	1.2	96
Therapy Pool Deck	1065	Swimming (Pool & Deck)	500	1.2	600
Therapy Pool	1066	Swimming (Pool & Deck)	400	1.2	480
Lap Pool Access	1061	Corridors	605	1.2	726
Lap Pool Deck	1068	Swimming (Pool & Deck)	3925	1.2	4710
Lap Pool	1069	Swimming (Pool & Deck)	5189	1.2	6226.8
Exercise Pool Deck	1072	Swimming (Pool & Deck)	618	1.2	741.6
Exercise Pool	1073	Swimming (Pool & Deck)	1115	1.2	1338
CHG 4	1059	Toilet - Private	80	1.2	96
Conf. A/B	1003/1005	Main Entry Lobbies	1090	1.2	1308
Vestuble	1009	Main Entry Lobbies	268	1.2	321.6
Lobby Circ.	1041	Main Entry Lobbies	879	1.2	1054.8
Vestuble	1000	Main Entry Lobbies	268	1.2	321.6
Women's Restroom	1002	Toilet - Public	295	1.2	354
Men's Restroom	1008	Toilet - Public	176	1.2	211.2
F&B Seating	1040	Cafeteria/Fast-Food Dinning	1056	1.2	1267.2
Café	1108	Cafeteria/Fast-Food Dinning	216	1.2	259.2
Sales	1016	Sales	138	1.2	165.6
Retail	1020	Sales	132	1.2	158.4
Store	1019	Sales	71	1.2	85.2
MBR. Lounge	1043	Cocktail Lounges	192	1.2	230.4
MBR. Lounge	1021	Cocktail Lounges	263	1.2	315.6
Laundry	1034	Laundry rooms, Central	198	1.2	237.6
Wellness IT	1035	Computer (Not Printing)	113	1.2	135.6
Open Admin	1024	Corridor	401	1.2	481.2
E.E.	1038	Electrical Equipment Rooms	50	1.2	60

Accounting	1028	Office	111	1.2	133.2
Office	1027	Office	85	1.2	102
GM	1029	Office	153	1.2	183.6
Breake	1033	Reception Areas	304	1.2	364.8
Kitchen	1036	Kitchens - Commercial	987	1.2	1184.4
Isolation/Triagae Exam	1332	Patient Rooms	155	1.2	186
Vestibule	1290	Main Entry Lobbies	204	1.2	244.8
Nurse Station	1301	Reception	217	1.2	260.4
ED. Circ.	1299	Main Entry Lobbies	1855	1.2	2226
ED. Waiting	1291	Reception	797	1.2	956.4
Pharmacy	1303	Pharmacy (Prep Area)	151	1.2	181.2
Lab	1327	Pharmacy (Prep Area)	94	1.2	112.8
Clean Linen	1328	Storage	52	1.2	62.4
Exam Room	1326	Patient Rooms	125	1.2	150
Storage	1320	Storage	52	1.2	62.4
Soiled Utility	1308	Soiled Laundry Storage Rooms	69	1.2	82.8
Radiology	1313	Medical Procedure	290	1.2	348
Control	1311	Electrical Equipment Rooms	146	1.2	175.2
Supplies	1323	Storage	294	1.2	352.8
Nurse Workstation	1287	Reception	46	1.2	55.2
Emer. Trauma	1298	Operating Rooms	137	1.2	164.4
Emer. Treat.	1300	Operating Rooms	161	1.2	193.2
CT Room	1309	Medical Procedure	340	1.2	408
Ultra Sound	1275	Medical Procedure	216	1.2	259.2
M. Dress	1274	Dressing Rooms	60	1.2	72
W. Dress	1272	Dressing Rooms	60	1.2	72
MRI Magnet Room	1218A	Medical Procedure	387	1.2	464.4
MRI Control	1279	Electrical Equipment Rooms	116	1.2	139.2
Bio Haz.	1276	Operating Rooms	53	1.2	63.6
Bone Density	1256	Medical Procedure	154	1.2	184.8
Patient Prep Screening	1268	Patient Rooms	102	1.2	122.4
Tea Room	1259	Break Room	176	1.2	211.2
Staff Work Area	1251	Office	101	1.2	121.2
Dress	1253	Dressing Rooms	53	1.2	63.6
Womens Health Corridor	1250H	Corridor	390	1.2	468
MRI. Euip.	1281C	Electrical Equipment Rooms	168	1.2	201.6
I.T	1281D	Computer (Not Printing)	287	1.2	344.4
Shared Waiting	1220	Corridor	800	1.2	960
Resource Consult.	1202	Patient Rooms	112	1.2	134.4
Reg. Waiting	1209	Break Room	281	1.2	337.2

2nd Floor					
Open Fitness	2020	Health Club/Aerobic Rooms	5737	1.2	6884.4
Open Fitness	2003	Health Club/Weight Rooms	2204	1.2	2644.8
Walk/Jog Track	2001	Gym (Play Area)	4760	1.2	5712
Men Toilet	2015	Toilet - Private	45	1.2	54
Uni Toilet	2013	Toilet - Private	43	1.2	51.6
Pilates	2004	Health Club/Aerobic Rooms	490	1.2	588
Spin	2016	Health Club/Aerobic Rooms	1002	1.2	1202.4
Women Toilet	2014	Toilet - Private	45	1.2	54
Mind And Body	2005	Health Club/Aerobic Rooms	1428	1.2	1713.6
Group Exer.	2010	Health Club/Aerobic Rooms	1962	1.2	2354.4
Testing	207	Medical Procedure	139	1.2	166.8
Fitness Staff	2024	Office	252	1.2	302.4
Circ.	2008	Corridor	512	1.2	614.4
Cardiac Rehab.	2207	Medical Procedure	121	1.2	145.2
PT Therapy	2205	Medical Procedure	118	1.2	141.6
Blood Draw	2146	Medical Procedure	118	1.2	141.6
Lab/Rad. Waiting	2144	Corridor	66	1.2	79.2
Procedure/Casting	2142	Medical Procedure	204	1.2	244.8
Exam	2141	Patient Rooms	127	1.2	152.4
Shared Waiting	2100	Break Room	1798	1.2	2157.6
Patient Toilet	2133	Toilet - Private	57	1.2	68.4
Phys. Office	2132	Office	151	1.2	181.2
Storage	2130	Storage	88	1.2	105.6
Nurse Workstation	2252	Reception	113	1.2	135.6
Procedure	2253	Medical Procedure	160	1.2	192
Shared Doc Storage	2169	Storage	95	1.2	114
Shared Break Room	2129	Break Room	247	1.2	296.4
Check Out	2112	Reception	258	1.2	309.6
Call Center	2113	Reception	184	1.2	220.8
Janitor	2152	Janitor, Trash, Recycle	77	1.2	92.4
Clean Supply/Med. Room	2113	Storage	133	1.2	159.6
Triangle Call Center	2114	Break Room	172	1.2	206.4
Blood Draw	2145	Medical Procedure	118	1.2	141.6
Timeshare Corridor	2310	Corridor	392	1.2	470.4
Timeshare Reception	2311	Reception	131	1.2	157.2

Appendix A:

Columbus, Ohio Design Conditions

Design conditions for COLUMBUS, OH, USA

Station Information

Station name	WMO#	Lat	Long	Elev	StdP	Hours +/- UTC	Time zone code	Period
1a	1b	1c	1d	1e	1f	1g	1h	1i
COLUMBUS	724280	40.00N	82.87W	254	98.31	-5.00	NAE	7201

Annual Heating and Humidification Design Conditions

Coldest month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB	
			99.6%			99%			0.4%		1%			
	99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD
2	3a	3b	4a	4b	4c	4d	4e	4f	5a	5b	5c	5d	6a	6b
1	-17.0	-13.9	-22.3	0.5	-16.6	-18.8	0.7	-13.2	12.2	-1.3	11.0	-1.7	4.1	260

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest month	Hottest month DB range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB	
		0.4%		1%		2%		0.4%		1%		2%			
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
7	8	9a	9b	9c	9d	9e	9f	10a	10b	10c	10d	10e	10f	11a	11b
7	10.5	32.6	23.5	31.3	22.8	29.9	22.1	25.0	30.5	24.1	29.1	23.4	28.0	4.5	230

Dehumidification DP/MCDB and HR									Enthalpy/MCDB					
0.4%			1%			2%			0.4%		1%		2%	
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB
12a	12b	12c	12d	12e	12f	12g	12h	12i	13a	13b	13c	13d	13e	13f
23.3	18.6	27.7	22.5	17.8	27.0	21.8	16.9	26.4	77.0	30.7	73.7	29.2	70.5	28.0

Extreme Annual Design Conditions

Extreme Annual WS			Extreme Max WB	Extreme Annual DB				n-Year Return Period Values of Extreme DB							
				Mean		Standard deviation		n=5 years		n=10 years		n=20 years		n=50 years	
1%	2.5%	5%		Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
14a	14b	14c	15	16a	16b	16c	16d	17a	17b	17c	17d	17e	17f	17g	17h
9.8	8.5	7.7	28.7	34.6	-20.3	1.6	4.7	35.8	-23.7	36.7	-26.4	37.6	-29.1	38.7	-32.5

Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures

%	Jan		Feb		Mar		Apr		May		Jun	
	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB
	18a	18b	18c	18d	18e	18f	18g	18h	18i	18j	18k	18l
0.4%	16.1	13.4	18.3	12.0	24.8	15.6	28.1	17.6	31.1	21.4	33.7	23.1
1%	14.4	12.6	16.2	11.0	23.4	14.9	27.0	17.2	30.1	20.5	32.5	22.5
2%	12.8	10.8	14.5	10.6	21.4	13.9	25.6	16.9	29.1	20.0	31.6	22.4

%	Jul		Aug		Sep		Oct		Nov		Dec	
	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB
	18m	18n	18o	18p	18q	18r	18s	18t	18u	18v	18w	18x
0.4%	35.0	24.4	33.7	24.0	32.1	22.1	27.1	18.7	22.2	15.8	17.7	14.6
1%	33.8	24.2	32.8	24.0	30.9	21.7	25.9	18.1	20.9	15.2	16.3	13.5
2%	32.9	23.9	31.9	23.7	29.8	21.6	24.6	17.2	19.5	14.7	15.0	12.6

Monthly Design Wet Bulb and Mean Coincident Dry Bulb Temperatures

%	Jan		Feb		Mar		Apr		May		Jun	
	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB
	19a	19b	19c	19d	19e	19f	19g	19h	19i	19j	19k	19l
0.4%	13.9	15.4	13.6	16.3	16.9	22.8	19.2	25.1	23.5	28.8	25.1	30.8
1%	12.9	14.6	12.6	14.9	15.8	21.0	18.5	24.5	22.6	27.6	24.5	30.1
2%	11.0	12.6	11.4	13.7	14.9	19.6	17.8	23.5	21.8	26.6	24.0	29.4

%	Jul		Aug		Sep		Oct		Nov		Dec	
	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB
	19m	19n	19o	19p	19q	19r	19s	19t	19u	19v	19w	19x
0.4%	26.3	31.9	25.8	31.5	24.0	29.4	20.2	24.0	17.4	20.3	15.2	17.0
1%	25.6	31.4	25.4	31.0	23.3	28.4	19.5	23.4	16.6	19.4	14.1	15.8
2%	25.1	30.9	24.8	30.0	22.8	27.6	18.8	22.7	15.7	18.5	13.0	14.6

Monthly Mean Daily Temperature Range

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
20a	20b	20c	20d	20e	20f	20g	20h	20i	20j	20k	20l
7.8	8.6	10.1	11.3	11.2	10.9	10.5	10.5	11.0	11.0	8.8	7.4

WMO#	World Meteorological Organization number	Lat	Latitude, °	Long	Longitude, °
Elev	Elevation, m	StdP	Standard pressure at station elevation, kPa		
DB	Dry bulb temperature, °C	DP	Dew point temperature, °C	WB	Wet bulb temperature, °C
WS	Wind speed, m/s	Enth	Enthalpy, kJ/kg	HR	Humidity ratio, grams of moisture per kilogram of dry air
MCDB	Mean coincident dry bulb temperature, °C	MCWB	Mean coincident wet bulb temperature, °C	MCWS	Mean coincident wind speed, m/s
PCWD	Prevailing coincident wind direction, °, 0 = North, 90 = East				

System Checksums

By ACADEMIC

ERV-1 — **System 5 - 2010 - Packaged RTU VAV Reheat, DX & Hot Water**

ACADEMIC USE ONLY

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 8 / 19; Outside Air: OADB/WB/HR: 75 / 73 / 127

Clg Space Peak — Mo/Hr: 9 / 14; OADB: 85

	Cooling Coil Peak: Space Sens. + Lat. (Btu/h)	Plenum Sens. + Lat (Btu/h)	Net Total (Btu/h)	Percent Of Total (%)	Clg Space Peak: Space Sensible (Btu/h)	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	7,398	0	7,398	4	32,346	41
Glass/Door Cond	298	0	298	0	2,439	3
Wall Cond	2,817	717	3,534	2	1,539	2
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	29,262		29,262	17	6,592	8
Sub Total ==>	39,775	717	40,492	23	42,916	54
Internal Loads						
Lights	31,647	7,912	39,559	23	31,647	40
People	3,020	0	3,020	2	1,510	2
Misc	0	0	0	0	0	0
Sub Total ==>	34,666	7,912	42,578	25	33,157	42
Ceiling Load	3,148	-3,148	0	0	3,019	4
Ventilation Load	0	0	89,827	52	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-2,358	-2,358	-1		
Sup. Fan Heat			2,455	1		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	77,590	3,122	172,994	100.00	79,092	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 1

	Space Peak Space Sens (Btu/h)	Coil Peak Tot Sens (Btu/h)	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	-19,352	-19,352	8.89
Wall Cond	-23,702	-30,205	13.88
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-45,493	-45,493	20.90
Sub Total ==>	-88,547	-95,049	43.67
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-2,954	0	0.00
Ventilation Load	0	-69,951	32.14
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-55,401	-55,401	25.46
Exhaust Heat		3,514	-1.61
OA Preheat Diff.		0	0.00
RA Preheat Diff.		-754	0.35
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-146,902	-217,641	100.00

TEMPERATURES

	Cooling	Heating
SADB	52.1	110.1
Ra Plenum	75.9	69.2
Return	75.9	69.2
Ret/OA	74.7	50.9
Fn MtrTD	0.1	0.0
Fn BldTD	0.3	0.0
Fn Frict	0.8	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	3,196	3,390
Terminal	3,196	3,390
Main Fan	3,196	3,390
Sec Fan	0	0
Nom Vent	3,196	3,351
AHU Vent	3,196	3,351
Infil	613	613
MinStop/Rh	3,390	3,390
Return	3,809	3,965
Exhaust	3,809	3,927
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	100.0	98.9
cfm/ft²	0.28	0.30
cfm/ton	221.68	
ft²/ton	788.76	
Btu/hr·ft²	15.21	-18.05
No. People	5	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	14.4	173.0	51.5	1,883	74.7	73.5	127.1	50.9	43.4	31.0
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	14.4	173.0								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	11,371		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	2,646	879	33
Ext Door	42	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-204.5	3,196	50.9	110.1
Aux Htg	0.0	0	0.0	0.0
Preheat	-0.7	3,196	50.7	50.9
Reheat	-70.0	3,390	50.9	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-205.2			

System Checksums

By ACADEMIC

RTU-1 — **System 5 - 2010 - Packaged RTU VAV Reheat, DX & Hot Water**

ACADEMIC USE ONLY

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 11 / 13; Outside Air: OADB/WB/HR: 59 / 50 / 39

Clg Space Peak — Mo/Hr: 9 / 14; OADB: 85

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	193,667	0	193,667	50	166,468	50
Glass/Door Cond	-20,440	0	-20,440	-5	8,868	3
Wall Cond	-18,919	-6,243	-25,162	-6	9,521	3
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	-26,446		-26,446	-7	7,936	2
Sub Total ==>	127,862	-6,243	121,619	31	192,793	58
Internal Loads						
Lights	50,417	12,604	63,021	16	50,417	15
People	121,669	0	121,669	31	64,413	19
Misc	21,007	0	21,007	5	21,007	6
Sub Total ==>	193,092	12,604	205,697	53	135,837	41
Ceiling Load	1,238	-1,238	0	0	2,633	1
Ventilation Load	0	0	54,856	14	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-2,281	-2,281	-1		
Sup. Fan Heat			10,095	3		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	322,192	2,843	389,986	100.00	331,263	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 1

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	-77,220	-77,220	12.93
Wall Cond	-67,532	-88,788	14.87
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-54,773	-54,773	9.17
Sub Total ==>	-199,525	-220,780	36.97
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-8,154	0	0.00
Ventilation Load	0	-54,692	9.16
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	38,134	38,134	-6.39
Exhaust Heat		13,102	-2.19
OA Preheat Diff.		-359,195	60.16
RA Preheat Diff.		0	0.00
Additional Reheat		-13,675	2.29
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-169,545	-597,107	100.00

TEMPERATURES

	Cooling	Heating
SADB	56.8	101.0
Ra Plenum	75.3	67.9
Return	75.3	67.9
Ret/OA	86.0	60.0
Fn MtrTD	0.1	0.0
Fn BldTD	0.2	0.0
Fn Frict	0.4	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	16,864	5,059
Terminal	16,864	5,059
Main Fan	16,864	5,059
Sec Fan	0	0
Nom Vent	5,909	5,059
AHU Vent	5,909	5,059
Infil	739	739
MinStop/Rh	5,059	5,059
Return	17,603	5,798
Exhaust	6,647	5,798
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	35.0	100.0
cfm/ft²	1.37	0.41
cfm/ton	250.98	
ft²/ton	183.20	
Btu/hr·ft²	65.50	-49.10
No. People	286	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	38.2	457.9	457.9	14,195	86.0	63.7	55.4	56.2	52.6	55.2
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	29.0	348.5	127.3	5,909	77.5	74.3	127.1	57.6	57.5	73.0
Total	67.2	806.3								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	12,310		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	8,870	3,651	41
Ext Door	84	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-245.2	5,059	56.2	101.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Reheat	-75.6	5,059	56.2	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	-359.2	5,909	44.8	101.0
Total	-604.4			

System Checksums

By ACADEMIC

RTU-10A — **System 5 - 2010 - Packaged RTU VAV Reheat, DX & Hot Water**

ACADEMIC USE ONLY

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 8 / 15; Outside Air: OADB/WB/HR: 81 / 75 / 127

Clg Space Peak — Mo/Hr: 7 / 15; OADB: 91

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	0	0	0	0	0	0
Glass/Door Cond	0	0	0	0	0	0
Wall Cond	0	0	0	0	0	0
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	7,682		7,682	8	3,088	5
Sub Total ==>	7,682	0	7,682	8	3,088	5
Internal Loads						
Lights	18,225	4,556	22,781	23	18,225	30
People	13,653	0	13,653	14	7,585	12
Misc	5,178	0	5,178	5	5,178	8
Sub Total ==>	37,055	4,556	41,612	42	30,987	50
Ceiling Load	860	-860	0	0	860	1
Ventilation Load	0	0	51,211	52	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	26,661	43
Exhaust Heat		-1,349	-1,349	-1		
Sup. Fan Heat			232	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	45,597	2,347	99,387	100.00	61,596	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 1

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	0	0	0.00
Wall Cond	0	0	0.00
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-13,500	-13,500	7.14
Sub Total ==>	-13,500	-13,500	7.14
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	-89,998	47.60
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-57,344	-57,344	30.33
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		-28,233	14.93
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-70,844	-189,074	100.00

TEMPERATURES

	Cooling	Heating
SADB	59.4	88.0
Ra Plenum	75.9	70.0
Return	75.9	70.0
Ret/OA	79.1	47.1
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.1	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	3,641	3,641
Terminal	3,641	3,641
Main Fan	3,641	3,641
Sec Fan	0	0
Nom Vent	1,214	1,214
AHU Vent	1,214	1,214
Infil	182	182
MinStop/Rh	3,641	3,641
Return	3,823	3,823
Exhaust	1,396	1,396
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	33.3	33.3
cfm/ft²	1.20	1.20
cfm/ton	439.59	
ft²/ton	366.33	
Btu/hr·ft²	32.76	-62.32
No. People	30	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	8.3	99.4	43.6	1,953	79.1	71.4	107.3	59.2	56.2	64.8
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	8.3	99.4								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	3,034		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	0	0	0
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-113.2	3,641	59.2	88.0
Aux Htg	0.0	0	0.0	0.0
Preheat	-75.9	1,214	1.4	59.2
Reheat	-42.4	3,641	59.2	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-189.1			

System Checksums

By ACADEMIC

RTU-11 — **System 5 - 2010 - Packaged RTU VAV Reheat, DX & Hot Water**

ACADEMIC USE ONLY

COOLING COIL PEAK / CLG SPACE PEAK / HEATING COIL PEAK

	Cooling Coil Peak				Clg Space Peak		Heating Coil Peak			
Peaked at Time:	Mo/Hr: 8 / 15				Mo/Hr: 7 / 15			Mo/Hr: Heating Design		
Outside Air:	OADB/WB/HR: 81 / 75 / 127				OADB: 91			OADB: 1		
	Space Sens. + Lat.	Plenum Sens. + Lat	Net Total	Percent Of Total	Space Sensible	Percent Of Total		Space Peak Space Sens	Coil Peak Tot Sens	Percent Of Total
	Btu/h	Btu/h	Btu/h	(%)	Btu/h	(%)		Btu/h	Btu/h	(%)
Envelope Loads							**Envelope Loads**			
Skylite Solar	0	0	0	0	0	0	Skylite Solar	0	0	0.00
Skylite Cond	0	0	0	0	0	0	Skylite Cond	0	0	0.00
Roof Cond	0	0	0	0	0	0	Roof Cond	0	0	0.00
Glass Solar	0	0	0	0	0	0	Glass Solar	0	0	0.00
Glass/Door Cond	0	0	0	0	0	0	Glass/Door Cond	0	0	0.00
Wall Cond	0	0	0	0	0	0	Wall Cond	0	0	0.00
Partition/Door	0		0	0	0	0	Partition/Door	0	0	0.00
Floor	0		0	0	0	0	Floor	0	0	0.00
Adjacent Floor	0	0	0	0	0	0	Adjacent Floor	0	0	0
Infiltration	3,731		3,731	4	1,997	7	Infiltration	-8,730	-8,730	6.82
Sub Total ==>	3,731	0	3,731	4	1,997	7	*Sub Total ==>*	-8,730	-8,730	6.82
Internal Loads							**Internal Loads**			
Lights	4,821	1,205	6,027	6	4,821	17	Lights	0	0	0.00
People	37,525	0	37,525	38	19,750	69	People	0	0	0.00
Misc	1,195	0	1,195	1	1,195	4	Misc	0	0	0.00
Sub Total ==>	43,541	1,205	44,746	46	25,766	90	*Sub Total ==>*	0	0	0.00
Ceiling Load	290	-290	0	0	290	1	**Ceiling Load**	0	0	0.00
Ventilation Load	0	0	50,236	51	0	0	**Ventilation Load**	0	-37,770	29.50
Adj Air Trans Heat	0		0	0	0	0	**Adj Air Trans Heat**	0	0	0
Dehumid. Ov Sizing			0	0			**Ov/Undr Sizing**	-7,237	-7,237	5.65
Ov/Undr Sizing	0		0	0	688	2	**Exhaust Heat**		0	0.00
Exhaust Heat		-859	-859	-1			**OA Preheat Diff.**		-74,293	58.03
Sup. Fan Heat			188	0			**RA Preheat Diff.**		0	0.00
Ret. Fan Heat		0	0	0			**Additional Reheat**		0	0.00
Duct Heat Pkup		0	0	0						
Underflr Sup Ht Pkup			0	0			**Underflr Sup Ht Pkup**		0	0.00
Supply Air Leakage		0	0	0			**Supply Air Leakage**		0	0.00
Grand Total ==>	47,562	57	98,043	100.00	28,741	100.00	***Grand Total ==>***	-15,967	-128,030	100.00

TEMPERATURES

	Cooling	Heating
SADB	59.3	99.0
Ra Plenum	75.5	70.0
Return	75.5	70.0
Ret/OA	81.1	1.4
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.1	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	1,698	509
Terminal	1,698	509
Main Fan	1,698	509
Sec Fan	0	0
Nom Vent	1,698	509
AHU Vent	1,698	509
Infil	118	118
MinStop/Rh	509	509
Return	1,815	627
Exhaust	1,815	627
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	100.0	100.0
cfm/ft²	0.87	0.26
cfm/ton	207.79	
ft²/ton	240.14	
Btu/hr·ft²	49.97	-65.25
No. People	79	

COOLING COIL SELECTION

	Total Capacity		Sens Cap.	Coil Airflow	Enter DB/WB/HR			Leave DB/WB/HR		
	ton	MBh	MBh	cfm	°F	°F	gr/lb	°F	°F	gr/lb
Main Clg	8.2	98.0	37.5	1,585	81.1	75.2	127.1	59.2	57.9	72.0
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	8.2	98.0								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	1,962		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	0	0	0
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity	Coil Airflow	Ent	Lvg
	MBh	cfm	°F	°F
Main Htg	-21.9	509	59.2	99.0
Aux Htg	0.0	0	0.0	0.0
Preheat	-106.1	1,698	1.4	59.2
Reheat	-5.9	509	59.2	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-128.0			

System Checksums

By ACADEMIC

RTU-12 | **System 5 - 2010 - Packaged RTU VAV Reheat, DX & Hot Water**

ACADEMIC USE ONLY

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 8 / 15; Outside Air: OADB/WB/HR: 81 / 75 / 127

Clg Space Peak — Mo/Hr: 7 / 15; OADB: 91

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	0	0	0	0	0	0
Glass/Door Cond	0	0	0	0	0	0
Wall Cond	0	0	0	0	0	0
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	2,140		2,140	4	1,068	6
Sub Total ==>	2,140	0	2,140	4	1,068	6
Internal Loads						
Lights	2,578	644	3,222	6	2,578	16
People	19,475	0	19,475	37	10,250	62
Misc	1,195	0	1,195	2	1,195	7
Sub Total ==>	23,247	644	23,892	46	14,022	85
Ceiling Load	158	-158	0	0	158	1
Ventilation Load	0	0	26,674	51	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	1,179	7
Exhaust Heat		-436	-436	-1		
Sup. Fan Heat			93	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	25,545	51	52,363	100.00	16,427	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 1

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	0	0	0.00
Wall Cond	0	0	0.00
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-4,667	-4,667	6.84
Sub Total ==>	-4,667	-4,667	6.84
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	-19,643	28.77
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-6,357	-6,357	9.31
Exhaust Heat		0	0.00
OA Preheat Diff.		-37,602	55.08
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-11,024	-68,269	100.00

TEMPERATURES

	Cooling	Heating
SADB	57.8	108.5
Ra Plenum	75.5	70.0
Return	75.5	70.0
Ret/OA	81.1	1.4
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.1	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	883	265
Terminal	883	265
Main Fan	883	265
Sec Fan	0	0
Nom Vent	883	265
AHU Vent	883	265
Infil	63	63
MinStop/Rh	265	265
Return	946	328
Exhaust	946	328
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	100.0	100.0
cfm/ft²	0.84	0.25
cfm/ton	202.34	
ft²/ton	240.40	
Btu/hr·ft²	49.92	-65.08
No. People	41	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	4.4	52.4	19.9	785	81.1	75.2	127.1	57.7	56.2	67.3
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	4.4	52.4								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	1,049		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	0	0	0
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-14.6	265	57.7	108.5
Aux Htg	0.0	0	0.0	0.0
Preheat	-53.7	883	1.4	57.7
Reheat	-3.5	265	57.7	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-68.3			

System Checksums

By ACADEMIC

RTU-13 — **System 5 - 2010 - Packaged RTU VAV Reheat, DX & Hot Water**

ACADEMIC USE ONLY

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 8 / 16; Outside Air: OADB/WB/HR: 81 / 75 / 127

Clg Space Peak — Mo/Hr: 7 / 17; OADB: 89

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	38,054	0	38,054	14	37,410	30
Glass/Door Cond	2,480	0	2,480	1	6,657	5
Wall Cond	2,630	553	3,182	1	11,402	9
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	18,780		18,780	7	5,811	5
Sub Total ==>	61,944	553	62,496	23	61,279	50
Internal Loads						
Lights	32,212	8,053	40,265	15	32,212	26
People	29,214	0	29,214	11	16,230	13
Misc	11,079	0	11,079	4	11,079	9
Sub Total ==>	72,504	8,053	80,557	30	59,520	48
Ceiling Load	1,628	-1,628	0	0	2,049	2
Ventilation Load	0	0	125,197	47	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-2,555	-2,555	-1		
Sup. Fan Heat			588	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	136,076	4,422	266,283	100.00	122,848	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 1

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	-32,245	-32,245	6.73
Wall Cond	-47,208	-59,148	12.35
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-28,886	-28,886	6.03
Sub Total ==>	-108,338	-120,278	25.12
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-2,253	0	0.00
Ventilation Load	0	-192,572	40.21
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-91,525	-91,525	19.11
Exhaust Heat		3,536	-0.74
OA Preheat Diff.		0	0.00
RA Preheat Diff.		-78,065	16.30
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-202,117	-478,905	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.1	94.0
Ra Plenum	75.8	68.9
Return	75.8	68.9
Ret/OA	78.3	46.4
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.1	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	5,713	7,790
Terminal	5,713	7,790
Main Fan	5,713	7,790
Sec Fan	0	0
Nom Vent	2,597	2,597
AHU Vent	2,597	2,597
Infil	390	390
MinStop/Rh	7,790	7,790
Return	6,103	6,103
Exhaust	2,986	909
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	45.5	33.3
cfm/ft²	0.88	1.20
cfm/ton	257.47	
ft²/ton	292.56	
Btu/hr·ft²	41.02	-60.28
No. People	65	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	22.2	266.3	127.2	4,960	78.3	69.4	97.5	55.0	52.4	56.2
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	22.2	266.3								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	6,492		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	4,829	1,366	28
Ext Door	128	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-240.9	5,713	55.0	94.0
Aux Htg	0.0	0	0.0	0.0
Preheat	-150.5	2,597	1.4	55.0
Reheat	-126.3	7,790	55.0	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-391.3			

System Checksums

By ACADEMIC

RTU-2 — **System 5 - 2010 - Packaged RTU VAV Reheat, DX & Hot Water**

ACADEMIC USE ONLY

COOLING COIL PEAK / CLG SPACE PEAK

Peaked at Time: Mo/Hr: 8 / 15 — Outside Air: OADB/WB/HR: 81 / 75 / 127

CLG Space Peak: Mo/Hr: 7 / 9 — OADB: 77

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	6,092	0	6,092	1	18,045	8
Glass/Door Cond	690	0	690	0	139	0
Wall Cond	312	64	376	0	1,355	1
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	18,790		18,790	4	1,297	1
Sub Total ==>	25,884	64	25,948	5	20,835	9
Internal Loads						
Lights	35,825	8,956	44,782	9	35,825	16
People	282,931	0	282,931	56	151,492	68
Misc	12,858	0	12,858	3	12,858	6
Sub Total ==>	331,615	8,956	340,571	67	200,176	90
Ceiling Load	1,574	-1,574	0	0	1,560	1
Ventilation Load	0	0	141,600	28	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-2,451	-2,451	0		
Sup. Fan Heat			1,563	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	359,072	4,996	507,231	100.00	222,571	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design — OADB: 1

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	-8,485	-8,485	2.21
Wall Cond	-10,334	-13,233	3.45
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-39,011	-39,011	10.17
Sub Total ==>	-57,831	-60,730	15.83
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-1,091	0	0.00
Ventilation Load	0	-284,424	74.12
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-27,750	-27,750	7.23
Exhaust Heat		1,651	-0.43
OA Preheat Diff.		-8,173	2.13
RA Preheat Diff.		-4,318	1.13
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-86,672	-383,744	100.00

TEMPERATURES

	Cooling	Heating
SADB	60.1	88.9
Ra Plenum	75.5	69.7
Return	75.5	69.7
Ret/OA	77.2	8.1
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.1	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	13,827	4,249
Terminal	13,827	4,249
Main Fan	13,827	4,249
Sec Fan	0	0
Nom Vent	3,964	3,835
AHU Vent	3,964	3,835
Infil	526	526
MinStop/Rh	4,249	4,249
Return	14,353	4,775
Exhaust	4,490	4,361
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	28.7	90.3
cfm/ft²	1.41	0.43
cfm/ton	327.12	
ft²/ton	232.67	
Btu/hr·ft²	51.57	-39.02
No. People	578	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	42.3	507.2	245.0	13,190	77.2	69.0	97.1	60.0	57.4	68.4
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	42.3	507.2								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	9,835		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	1,190	417	35
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-132.6	4,249	60.0	88.9
Aux Htg	0.0	0	0.0	0.0
Preheat	-251.1	3,964	1.4	60.0
Reheat	-45.9	4,249	60.0	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-383.7			

System Checksums

By ACADEMIC

RTU-3 — **System 5 - 2010 - Packaged RTU VAV Reheat, DX & Hot Water**

ACADEMIC USE ONLY

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 8 / 17; Outside Air: OADB/WB/HR: 79 / 75 / 127

Clg Space Peak — Mo/Hr: 9 / 17; OADB: 84

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	15,487	0	15,487	16	17,803	33
Glass/Door Cond	294	0	294	0	559	1
Wall Cond	1,584	336	1,920	2	2,415	4
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	4,885		4,885	5	1,024	2
Sub Total ==>	22,249	336	22,585	24	21,801	40
Internal Loads						
Lights	6,545	1,636	8,182	9	6,545	12
People	36,880	0	36,880	38	22,589	41
Misc	3,147	0	3,147	3	3,147	6
Sub Total ==>	46,572	1,636	48,208	50	32,281	59
Ceiling Load	355	-355	0	0	366	1
Ventilation Load	0	0	25,237	26	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-449	-449	0		
Sup. Fan Heat			278	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	69,177	1,168	95,861	100.00	54,449	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 1

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	-4,235	-4,235	6.34
Wall Cond	-10,212	-12,459	18.65
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-8,205	-8,205	12.28
Sub Total ==>	-22,652	-24,899	37.28
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-861	0	0.00
Ventilation Load	0	-42,391	63.47
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	2,161	2,161	-3.24
Exhaust Heat		1,087	-1.63
OA Preheat Diff.		0	0.00
RA Preheat Diff.		-2,750	4.12
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-21,352	-66,793	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.1	96.0
Ra Plenum	75.6	68.5
Return	75.6	68.5
Ret/OA	76.5	18.0
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.1	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	2,532	760
Terminal	2,532	760
Main Fan	2,532	760
Sec Fan	0	0
Nom Vent	572	572
AHU Vent	572	572
Infil	111	111
MinStop/Rh	760	760
Return	2,643	870
Exhaust	682	682
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	22.6	75.2
cfm/ft²	1.37	0.41
cfm/ton	317.00	
ft²/ton	230.84	
Btu/hr·ft²	51.99	-36.22
No. People	92	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	8.0	95.9	54.6	2,349	76.5	66.2	83.0	55.0	52.7	57.5
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	8.0	95.9								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	1,844		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	938	208	22
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-33.7	760	55.0	96.0
Aux Htg	0.0	0	0.0	0.0
Preheat	-33.1	572	1.4	55.0
Reheat	-12.3	760	55.0	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-66.8			

System Checksums

By ACADEMIC

RTU-4 — **System 5 - 2010 - Packaged RTU VAV Reheat, DX & Hot Water**

ACADEMIC USE ONLY

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 15; Outside Air: OADB/WB/HR: 91 / 74 / 105

Clg Space Peak — Mo/Hr: 6 / 10; OADB: 77

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	30,157	0	30,157	8	98,127	42
Glass/Door Cond	7,818	0	7,818	2	28	0
Wall Cond	15,112	3,869	18,981	5	9,093	4
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	25,845		25,845	7	1,404	1
Sub Total ==>	78,932	3,869	82,801	23	108,652	46
Internal Loads						
Lights	40,465	10,116	50,581	14	40,465	17
People	44,460	0	44,460	12	24,700	11
Misc	16,860	0	16,860	5	16,860	7
Sub Total ==>	101,785	10,116	111,901	31	82,025	35
Ceiling Load	2,831	-2,831	0	0	2,506	1
Ventilation Load	0	0	172,297	47	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	40,499	17
Exhaust Heat		-4,072	-4,072	-1		
Sup. Fan Heat			811	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	183,548	7,082	363,738	100.00	233,681	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 1

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	-37,340	-37,340	4.83
Wall Cond	-64,001	-81,076	10.48
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-40,297	-40,297	5.21
Sub Total ==>	-141,638	-158,714	20.51
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-3,456	0	0.00
Ventilation Load	0	-268,648	34.72
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-242,605	-242,605	31.35
Exhaust Heat		4,972	-0.64
OA Preheat Diff.		0	0.00
RA Preheat Diff.		-108,838	14.06
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-387,699	-773,832	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.1	103.0
Ra Plenum	75.9	68.9
Return	75.9	68.9
Ret/OA	83.7	46.4
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.1	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	10,868	10,868
Terminal	10,868	10,868
Main Fan	10,868	10,868
Sec Fan	0	0
Nom Vent	3,623	3,623
AHU Vent	3,623	3,623
Infil	543	543
MinStop/Rh	10,868	10,868
Return	11,411	11,411
Exhaust	4,166	4,166
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	33.3	33.3
cfm/ft²	1.10	1.10
cfm/ton	311.78	
ft²/ton	283.43	
Btu/hr·ft²	42.34	-97.90
No. People	99	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	34.9	418.3	216.5	6,844	83.7	68.6	83.8	55.0	48.0	40.2
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	34.9	418.3								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	9,880		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	6,582	1,835	28
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-704.9	10,868	55.0	103.0
Aux Htg	0.0	0	0.0	0.0
Preheat	-262.4	3,623	1.4	55.0
Reheat	-220.3	10,868	55.0	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-967.3			

System Checksums

By ACADEMIC

RTU-5 | **System 5 - 2010 - Packaged RTU VAV Reheat, DX & Hot Water**

ACADEMIC USE ONLY

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 8 / 15; Outside Air: OADB/WB/HR: 81 / 75 / 127

Clg Space Peak — Mo/Hr: 7 / 15; OADB: 91

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	0	0	0	0	0	0
Glass/Door Cond	0	0	0	0	0	0
Wall Cond	0	0	0	0	0	0
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	4,581		4,581	5	2,424	8
Sub Total ==>	4,581	0	4,581	5	2,424	8
Internal Loads						
Lights	5,853	1,463	7,317	7	5,853	20
People	37,050	0	37,050	37	19,500	66
Misc	1,195	0	1,195	1	1,195	4
Sub Total ==>	44,098	1,463	45,561	45	26,548	90
Ceiling Load	402	-402	0	0	402	1
Ventilation Load	0	0	51,826	51	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-1,012	-1,012	-1		
Sup. Fan Heat			192	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	49,080	49	101,148	100.00	29,374	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 1

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	0	0	0.00
Wall Cond	0	0	0.00
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-10,599	-10,599	8.61
Sub Total ==>	-10,599	-10,599	8.61
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	-37,885	30.78
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-447	-447	0.36
Exhaust Heat		0	0.00
OA Preheat Diff.		-74,139	60.24
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-11,045	-123,070	100.00

TEMPERATURES

	Cooling	Heating
SADB	59.0	90.0
Ra Plenum	75.5	70.0
Return	75.5	70.0
Ret/OA	81.1	1.4
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.1	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	1,703	511
Terminal	1,703	511
Main Fan	1,703	511
Sec Fan	0	0
Nom Vent	1,703	511
AHU Vent	1,703	511
Infil	143	143
MinStop/Rh	511	511
Return	1,846	654
Exhaust	1,846	654
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	100.0	100.0
cfm/ft²	0.71	0.21
cfm/ton	202.03	
ft²/ton	282.60	
Btu/hr·ft²	42.46	-51.67
No. People	78	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	8.4	101.2	38.8	1,617	81.1	75.2	127.1	58.9	57.7	71.4
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	8.4	101.2								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	2,382		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	0	0	0
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-17.2	511	58.9	90.0
Aux Htg	0.0	0	0.0	0.0
Preheat	-105.9	1,703	1.4	58.9
Reheat	-6.1	511	58.9	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-123.1			

System Checksums

By ACADEMIC

RTU-6 — **System 5 - 2010 - Packaged RTU VAV Reheat, DX & Hot Water**

ACADEMIC USE ONLY

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 8 / 15; Outside Air: OADB/WB/HR: 81 / 75 / 127

Clg Space Peak — Mo/Hr: 7 / 15; OADB: 91

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	0	0	0	0	0	0
Glass/Door Cond	0	0	0	0	0	0
Wall Cond	0	0	0	0	0	0
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	23,752		23,752	5	12,099	8
Sub Total ==>	23,752	0	23,752	5	12,099	8
Internal Loads						
Lights	29,216	7,304	36,519	8	29,216	20
People	192,375	0	192,375	41	101,250	69
Misc	2,389	0	2,389	1	2,389	2
Sub Total ==>	223,980	7,304	231,284	50	132,855	90
Ceiling Load	1,956	-1,956	0	0	1,956	1
Ventilation Load	0	0	214,874	46	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-4,023	-4,023	-1		
Sup. Fan Heat			765	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	249,688	1,325	466,651	100.00	146,910	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 1

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	0	0	0.00
Wall Cond	0	0	0.00
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-52,900	-52,900	8.55
Sub Total ==>	-52,900	-52,900	8.55
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	-196,073	31.70
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-12,839	-12,839	2.08
Exhaust Heat		0	0.00
OA Preheat Diff.		-356,742	57.67
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-65,739	-618,553	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	93.0
Ra Plenum	75.5	70.0
Return	75.5	70.0
Ret/OA	81.1	1.4
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.1	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	6,795	2,644
Terminal	6,795	2,644
Main Fan	6,795	2,644
Sec Fan	0	0
Nom Vent	6,795	2,644
AHU Vent	6,795	2,644
Infil	713	713
MinStop/Rh	2,644	2,644
Return	7,509	3,357
Exhaust	7,509	3,357
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	100.0	100.0
cfm/ft²	0.57	0.22
cfm/ton	174.74	
ft²/ton	305.73	
Btu/hr·ft²	39.25	-42.21
No. People	405	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	38.9	466.7	184.2	6,453	81.1	75.2	127.1	54.9	54.2	63.6
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	38.9	466.7								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	11,889		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	0	0	0
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-108.9	2,644	54.9	93.0
Aux Htg	0.0	0	0.0	0.0
Preheat	-392.9	6,795	1.4	54.9
Reheat	-43.2	2,644	54.9	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-501.9			

System Checksums

By ACADEMIC

RTU-7 — **System 5 - 2010 - Packaged RTU VAV Reheat, DX & Hot Water**

ACADEMIC USE ONLY

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 8 / 17; Outside Air: OADB/WB/HR: 79 / 75 / 127

Clg Space Peak — Mo/Hr: 7 / 18; OADB: 87

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	75,888	0	75,888	13	84,416	40
Glass/Door Cond	2,263	0	2,263	0	5,981	3
Wall Cond	1,404	658	2,061	0	4,156	2
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	14,993		14,993	3	5,065	2
Sub Total ==>	94,549	658	95,206	16	99,618	47
Internal Loads						
Lights	17,393	4,348	21,741	4	17,393	8
People	175,750	0	175,750	30	92,500	43
Misc	2,389	0	2,389	0	2,389	1
Sub Total ==>	195,532	4,348	199,881	34	112,282	53
Ceiling Load	888	-888	0	0	1,063	0
Ventilation Load	0	0	293,709	50	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-3,521	-3,521	-1		
Sup. Fan Heat			1,067	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	290,969	596	586,341	100.00	212,964	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 1

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	-32,619	-32,619	5.62
Wall Cond	-14,173	-21,411	3.69
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-29,622	-29,622	5.10
Sub Total ==>	-76,414	-83,652	14.41
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-2,747	0	0.00
Ventilation Load	0	-221,949	38.23
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-2	-2	0.00
Exhaust Heat		4,491	-0.77
OA Preheat Diff.		-279,395	48.13
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-79,163	-580,507	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	94.5
Ra Plenum	75.4	68.8
Return	75.4	68.8
Ret/OA	78.7	1.4
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.1	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	9,851	2,993
Terminal	9,851	2,993
Main Fan	9,851	2,993
Sec Fan	0	0
Nom Vent	7,825	2,993
AHU Vent	7,825	2,993
Infil	399	399
MinStop/Rh	2,993	2,993
Return	10,250	3,392
Exhaust	8,224	3,392
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	79.4	100.0
cfm/ft²	1.39	0.42
cfm/ton	201.60	
ft²/ton	144.86	
Btu/hr·ft²	82.84	-82.02
No. People	370	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	48.9	586.3	231.8	8,999	78.7	73.5	120.8	54.9	54.3	63.8
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	48.9	586.3								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	7,078		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	2,860	1,603	56
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-128.1	2,993	54.9	94.5
Aux Htg	0.0	0	0.0	0.0
Preheat	-452.5	7,825	1.4	54.9
Reheat	-48.9	2,993	54.9	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-580.5			

System Checksums

By ACADEMIC

RTU-8 **System 5 - 2010 - Packaged RTU VAV Reheat, DX & Hot Water**

ACADEMIC USE ONLY

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 8 / 14; Outside Air: OADB/WB/HR: 81 / 75 / 127

Clg Space Peak — Mo/Hr: 11 / 14; OADB: 61

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	78,058	0	78,058	23	140,750	81
Glass/Door Cond	2,026	0	2,026	1	-6,269	-4
Wall Cond	1,184	530	1,713	1	-2,262	-1
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	20,137		20,137	6	-5,170	-3
Sub Total ==>	101,405	530	101,934	31	127,050	73
Internal Loads						
Lights	14,695	3,674	18,369	6	14,695	8
People	54,625	0	54,625	16	28,750	17
Misc	2,389	0	2,389	1	2,389	1
Sub Total ==>	71,709	3,674	75,383	23	45,834	26
Ceiling Load	907	-907	0	0	445	0
Ventilation Load	0	0	155,733	47	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-1,553	-1,553	0		
Sup. Fan Heat			717	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	174,020	1,744	332,214	100.00	173,329	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 1

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	-29,628	-29,628	11.35
Wall Cond	-14,293	-21,077	8.07
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-25,495	-25,495	9.77
Sub Total ==>	-69,417	-76,201	29.19
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-2,627	0	0.00
Ventilation Load	0	-180,182	69.02
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	4,427	4,427	-1.70
Exhaust Heat		4,157	-1.59
OA Preheat Diff.		-13,274	5.08
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-67,617	-261,072	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.1	95.7
Ra Plenum	75.5	68.6
Return	75.5	68.6
Ret/OA	77.7	1.4
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.1	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	8,061	2,430
Terminal	8,061	2,430
Main Fan	8,061	2,430
Sec Fan	0	0
Nom Vent	2,659	2,430
AHU Vent	2,659	2,430
Infil	344	344
MinStop/Rh	2,430	2,430
Return	8,405	2,774
Exhaust	3,003	2,774
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	33.0	100.0
cfm/ft²	1.35	0.41
cfm/ton	291.18	
ft²/ton	216.01	
Btu/hr·ft²	55.55	-43.66
No. People	115	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	27.7	332.2	148.5	6,049	77.7	66.7	83.8	55.0	47.9	39.6
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	27.7	332.2								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	5,980		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	2,694	1,456	54
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-107.0	2,430	55.0	95.7
Aux Htg	0.0	0	0.0	0.0
Preheat	-154.1	2,659	1.4	55.0
Reheat	-39.4	2,430	55.0	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-261.1			

System Checksums

By ACADEMIC

RTU-9 — **System 5 - 2010 - Packaged RTU VAV Reheat, DX & Hot Water**

ACADEMIC USE ONLY

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 8 / 17; Outside Air: OADB/WB/HR: 79 / 75 / 127

Clg Space Peak — Mo/Hr: 9 / 17; OADB: 84

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	125,887	0	125,887	21	149,017	49
Glass/Door Cond	2,682	0	2,682	0	5,142	2
Wall Cond	9,943	2,177	12,121	2	15,356	5
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	35,203		35,203	6	6,857	2
Sub Total ==>	173,716	2,177	175,893	30	176,372	58
Internal Loads						
Lights	44,499	11,125	55,623	9	44,499	15
People	102,282	0	102,282	17	59,863	20
Misc	18,541	0	18,541	3	18,541	6
Sub Total ==>	165,322	11,125	176,446	30	122,903	41
Ceiling Load	2,573	-2,573	0	0	2,671	1
Ventilation Load	0	0	244,504	41	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-3,948	-3,948	-1		
Sup. Fan Heat			1,466	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	341,610	6,781	594,361	100.00	301,946	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 1

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	-39,337	-39,337	4.82
Wall Cond	-79,949	-98,534	12.07
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-54,955	-54,955	6.73
Sub Total ==>	-174,241	-192,826	23.61
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-3,941	0	0.00
Ventilation Load	0	-358,011	43.84
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	-119,964	-119,964	14.69
Exhaust Heat		5,719	-0.70
OA Preheat Diff.		-18,469	2.26
RA Preheat Diff.		-133,038	16.29
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-298,146	-816,590	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	90.4
Ra Plenum	75.6	69.1
Return	75.6	69.1
Ret/OA	77.1	44.9
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.1	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	13,967	13,520
Terminal	13,967	13,520
Main Fan	13,967	13,520
Sec Fan	0	0
Nom Vent	5,147	4,828
AHU Vent	5,147	4,828
Infil	741	741
MinStop/Rh	13,520	13,520
Return	14,708	14,261
Exhaust	5,888	5,569
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	36.9	35.7
cfm/ft²	1.07	1.03
cfm/ton	281.98	
ft²/ton	264.36	
Btu/hr·ft²	45.39	-62.36
No. People	242	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	49.5	594.4	299.0	12,367	77.1	67.7	90.2	54.9	52.1	55.4
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	49.5	594.4								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	13,094		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	7,698	1,933	25
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-519.0	13,520	54.9	90.4
Aux Htg	0.0	0	0.0	0.0
Preheat	-297.6	5,147	1.4	54.9
Reheat	-220.8	13,520	54.9	70.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-816.6			

Load / Airflow Summary

By ACADEMIC

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														
	Lockers/Bathroom (boys/girls)	Rm Peak	2,400	0.0	20,986	69,417	2,880	6.00	864	30	-55,199	0	41.7	100.0
	Lockers/Bathroom East (Mens)	Rm Peak	3,440	0.0	20,019	66,298	2,752	6.00	826	30	-52,746	0	62.5	100.0
	Lockers/Bathrooms (Womens) East	Rm Peak	2,478	0.0	22,432	72,437	2,974	6.00	892	30	-56,993	0	41.7	100.0
	Massage Rooms East	Rm Peak	1,955	0.0	17,593	57,044	2,346	6.00	704	30	-44,964	0	41.7	100.0
	Pool Equipment Room	Rm Peak	1,098	5.5	6,858	14,699	347	1.58	104	30	-6,984	0	19.0	63.3
ERV-1		**Sys Peak**	**11,371**	**5.5**	**-17,682**	**174,324**	**11,298**				**-216,887**	**0**	**100.0**	**98.9**
ERV-1		**Sys Block**	**11,371**	**5.5**	**51,532**	**172,995**	**3,196**				**-225,792**	**0**	**100.0**	**98.9**
	Pools (RTU-1)	Rm Peak	12,310	286.3	457,851	389,985	16,864	6.85	5,059	30	-245,176	0	35.0	100.0
RTU-1		**Sys Peak**	**12,310**	**286.3**	**457,851**	**389,985**	**16,864**				**-245,176**	**0**	**35.0**	**100.0**
RTU-1		**Sys Block**	**12,310**	**286.3**	**457,851**	**389,985**	**16,864**				**-245,176**	**0**	**35.0**	**100.0**
	Operating Rooms West (RTU-10A)	Rm Peak	3,034	30.3	72,377	128,135	3,641	6.00	3,641	100	-113,192	0	33.3	33.3
RTU-10A		**Sys Peak**	**3,034**	**30.3**	**43,829**	**99,587**	**3,641**				**-113,192**	**0**	**33.3**	**33.3**
RTU-10A		**Sys Block**	**3,034**	**30.3**	**43,629**	**99,387**	**3,641**				**-113,192**	**0**	**33.3**	**33.3**
	Health Club/Aerobic Rooms (RTU-11)	Rm Peak	1,962	79.0	37,415	97,929	1,698	4.33	509	30	-21,896	0	100.0	100.0
RTU-11		**Sys Peak**	**1,962**	**79.0**	**37,415**	**97,929**	**1,698**				**-21,896**	**0**	**100.0**	**100.0**
RTU-11		**Sys Block**	**1,962**	**79.0**	**37,528**	**98,043**	**1,698**				**-21,896**	**0**	**100.0**	**100.0**
	Health Club/Aerobic Rooms (RTU-12)	Rm Peak	1,049	41.0	19,811	52,262	883	4.21	265	30	-14,552	0	100.0	100.0
RTU-12		**Sys Peak**	**1,049**	**41.0**	**19,811**	**52,262**	**883**				**-14,552**	**0**	**100.0**	**100.0**
RTU-12		**Sys Block**	**1,049**	**41.0**	**19,912**	**52,363**	**883**				**-14,552**	**0**	**100.0**	**100.0**
	Exam Room West (RTU-13)	Rm Peak	3,550	35.5	100,125	176,176	4,260	6.00	4,260	100	-179,600	0	33.3	33.3
	Operating Rooms West (RTU-13)	Rm Peak	2,942	29.4	77,407	140,433	3,730	6.34	3,530	95	-148,840	0	31.5	33.3
RTU-13		**Sys Peak**	**6,492**	**64.9**	**143,823**	**282,899**	**7,990**				**-328,440**	**0**	**45.5**	**33.3**
RTU-13		**Sys Block**	**6,492**	**64.9**	**127,207**	**266,283**	**5,713**				**-401,916**	**0**	**45.5**	**33.3**
	Dinning Center	Rm Peak	3,202	320.2	120,128	264,136	6,683	15.65	2,005	30	-61,773	0	26.8	89.4
	Laundry/Storage	Rm Peak	3,000	179.6	69,008	138,738	4,006	6.68	1,202	30	-37,028	0	31.4	100.0
	Office Center	Rm Peak	1,363	9.5	17,038	21,925	1,105	4.05	331	30	-10,750	0	11.7	39.0
	Retail Center	Rm Peak	2,270	68.2	42,191	82,614	2,370	5.22	711	30	-23,057	0	33.1	100.0
RTU-2		**Sys Peak**	**9,835**	**577.5**	**248,966**	**508,013**	**14,165**				**-132,608**	**0**	**28.7**	**90.3**
RTU-2		**Sys Block**	**9,835**	**577.5**	**245,013**	**507,231**	**13,827**				**-132,608**	**0**	**28.7**	**90.3**
	Conference Center (RTU-3)	Rm Peak	1,844	92.2	54,553	95,861	2,532	6.87	760	30	-33,670	0	22.6	75.2
RTU-3		**Sys Peak**	**1,844**	**92.2**	**54,553**	**95,861**	**2,532**				**-33,670**	**0**	**22.6**	**75.2**
RTU-3		**Sys Block**	**1,844**	**92.2**	**54,553**	**95,861**	**2,532**				**-33,670**	**0**	**22.6**	**75.2**
	Exam Rooms (RTU-4) West	Rm Peak	9,880	98.8	303,496	505,369	10,868	6.00	10,868	100	-563,926	0	33.3	33.3
RTU-4		**Sys Peak**	**9,880**	**98.8**	**216,975**	**418,848**	**10,868**				**-563,926**	**0**	**33.3**	**33.3**
RTU-4		**Sys Block**	**9,880**	**98.8**	**216,498**	**418,299**	**10,868**				**-563,926**	**0**	**33.3**	**33.3**

ACADEMIC USE ONLY

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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
	Health Club/Aerobic Rooms (RTU-5)	Rm Peak	2,382	78.0	38,697	101,049	1,703	3.57	511	30	-17,157	0	100.0	100.0
RTU-5		**Sys Peak**	**2,382**	**78.0**	**38,697**	**101,049**	**1,703**				**-17,157**	**0**	**100.0**	**100.0**
RTU-5		**Sys Block**	**2,382**	**78.0**	**38,796**	**101,148**	**1,703**				**-17,157**	**0**	**100.0**	**100.0**
	Health Center/Aerobic Rooms (RTU-6)	Rm Peak	4,112	155.0	67,921	174,047	3,347	4.07	1,004	30	-41,361	0	100.0	100.0
	Health Club/Aerobic Room (RTU-6)*	Rm Peak	7,777	250.0	113,588	289,955	5,467	3.51	1,640	30	-67,561	0	100.0	100.0
RTU-6		**Sys Peak**	**11,889**	**405.0**	**181,509**	**464,002**	**8,813**				**-108,922**	**0**	**100.0**	**100.0**
RTU-6		**Sys Block**	**11,889**	**405.0**	**184,158**	**466,651**	**6,795**				**-108,922**	**0**	**100.0**	**100.0**
	Health Club/Aerobic Rooms (RTU-7)	Rm Peak	5,048	260.0	176,843	426,014	7,644	8.26	2,293	30	-96,950	0	72.0	100.0
	Health Club/Aerobic Rooms (RTU-7)*	Rm Peak	2,030	110.0	60,106	159,114	2,332	5.74	700	30	-31,096	0	99.5	100.0
RTU-7		**Sys Peak**	**7,078**	**370.0**	**239,817**	**587,997**	**9,976**				**-128,045**	**0**	**79.4**	**100.0**
RTU-7		**Sys Block**	**7,078**	**370.0**	**231,817**	**586,341**	**9,851**				**-128,045**	**0**	**79.4**	**100.0**
	Health Club/Aerobic Rooms (RTU-8)	Rm Peak	3,000	60.0	74,892	169,634	4,028	7.32	1,208	30	-54,866	0	34.3	100.0
	Health Club/Aerobic Rooms (RTU-8)*	Rm Peak	2,980	55.0	73,087	162,108	4,071	6.83	1,221	30	-52,149	0	31.4	100.0
RTU-8		**Sys Peak**	**5,980**	**115.0**	**147,144**	**330,907**	**8,099**				**-107,015**	**0**	**33.0**	**100.0**
RTU-8		**Sys Block**	**5,980**	**115.0**	**148,451**	**332,214**	**8,061**				**-107,015**	**0**	**33.0**	**100.0**
	Exam Rooms (RTU-9) West	Rm Peak	4,455	44.5	145,839	242,771	7,131	8.00	5,346	75	-205,208	0	25.0	33.3
	Shared Waiting (RTU-9)	Rm Peak	2,229	133.5	38,192	97,119	1,606	5.40	482	30	-18,491	0	49.9	100.0
	Treatment / Exam Rooms West (RTU-9)	Rm Peak	6,410	64.1	186,405	325,874	7,692	6.00	7,692	100	-295,260	0	33.3	33.3
RTU-9		**Sys Peak**	**13,094**	**242.1**	**303,226**	**598,554**	**16,429**				**-518,959**	**0**	**36.9**	**35.7**
RTU-9		**Sys Block**	**13,094**	**242.1**	**299,033**	**594,361**	**13,967**				**-518,959**	**0**	**36.9**	**35.7**

*** This report does not display heating only systems.**

EQUIPMENT ENERGY CONSUMPTION

By ACADEMIC

Alternative: 1

------- Monthly Consumption -------

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Hpl 1: RTU-1 H [Maximum block coil load=604.4 mbh]													
Boiler - 009 [Nominal Capacity/F.L.Rate=850 mbh / 9.44 Therms] (Heating Equipment)													
Gas (therms)	3,009.9	2,715.9	2,907.0	1,773.9	842.4	61.8	0.0	0.0	770.2	1,994.9	2,629.1	2,986.6	19,691.6
Peak (therms/Hr)	6.7	6.7	4.0	4.0	3.4	2.2	0.0	0.0	3.4	4.0	4.0	5.0	6.7
Hpl 2: RTU-2 H [Maximum block coil load=148.6 mbh]													
Boiler - 010 [Nominal Capacity/F.L.Rate=607 mbh / 6.74 Therms] (Heating Equipment)													
Gas (therms)	576.9	568.9	284.8	54.4	0.0	0.0	0.0	0.0	0.0	109.3	190.1	465.8	2,250.1
Peak (therms/Hr)	1.7	1.5	0.9	0.4	0.0	0.0	0.0	0.0	0.0	0.6	0.8	1.1	1.7
Hpl 3: RTU-3 H [Maximum block coil load=20.32 mbh]													
Boiler - 011 [Nominal Capacity/F.L.Rate=120 mbh / 1.33 Therms] (Heating Equipment)													
Gas (therms)	86.8	87.3	37.2	6.8	0.0	0.0	0.0	0.0	0.0	16.3	25.4	69.7	329.5
Peak (therms/Hr)	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2
Hpl 4: RTU-4 H [Maximum block coil load=764.7 mbh]													
Boiler - 012 [Nominal Capacity/F.L.Rate=697 mbh / 7.74 Therms] (Heating Equipment)													
Gas (therms)	1,014.7	961.2	671.5	369.1	325.3	275.5	239.3	319.7	334.6	502.6	564.9	834.1	6,412.4
Peak (therms/Hr)	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
Hpl 5: RTU-5 H [Maximum block coil load=64.31 mbh]													
Boiler - 013 [Nominal Capacity/F.L.Rate=203 mbh / 2.26 Therms] (Heating Equipment)													
Gas (therms)	224.8	221.0	151.5	44.1	10.4	0.0	0.0	0.0	8.6	72.2	103.0	190.8	1,026.4
Peak (therms/Hr)	0.7	0.7	0.6	0.2	0.1	0.0	0.0	0.0	0.1	0.4	0.5	0.6	0.7
Hpl 6: RTU-6 H [Maximum block coil load=226.9 mbh]													
Boiler - 014 [Nominal Capacity/F.L.Rate=324 mbh / 3.60 Therms] (Heating Equipment)													
Gas (therms)	855.0	850.8	527.8	124.8	13.1	0.0	0.0	0.0	8.1	228.6	326.4	708.7	3,643.3
Peak (therms/Hr)	2.4	2.5	1.9	0.6	0.1	0.0	0.0	0.0	0.1	1.2	1.5	2.2	2.5
Hpl 7: RTU-7 H [Maximum block coil load=213.2 mbh]													
Boiler - 015 [Nominal Capacity/F.L.Rate=324 mbh / 3.60 Therms] (Heating Equipment)													
Gas (therms)	877.0	870.3	541.9	129.5	18.1	0.0	0.0	0.0	11.4	223.8	337.3	731.8	3,741.1
Peak (therms/Hr)	2.4	2.3	1.8	0.6	0.2	0.0	0.0	0.0	0.1	1.0	1.6	1.9	2.4
Hpl 8: RTU-8 H [Maximum block coil load=193.0 mbh]													

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Alternative: 1

------- Monthly Consumption -------

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Hpl 8: RTU-8 H [Maximum block coil load=193.0 mbh]													
Boiler - 016 [Nominal Capacity/F.L.Rate=284 mbh / 3.16 Therms] (Heating Equipment)													
Gas (therms)	572.0	561.2	345.1	112.8	16.7	0.0	0.0	0.0	11.4	168.9	239.6	483.0	2,510.7
Peak (therms/Hr)	2.1	2.1	1.8	0.6	0.1	0.0	0.0	0.0	0.1	0.6	1.2	2.0	2.1
Hpl 9: RTU-9 H [Maximum block coil load=584.8 mbh]													
Boiler - 017 [Nominal Capacity/F.L.Rate=697 mbh / 7.74 Therms] (Heating Equipment)													
Gas (therms)	1,139.4	1,085.6	708.8	415.6	394.1	353.0	295.9	350.0	322.9	494.0	558.2	905.6	7,023.2
Peak (therms/Hr)	6.4	6.5	5.9	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	6.2	6.5
Hpl 10: RTU-10A H [Maximum block coil load=53.64 mbh]													
Boiler - 018 [Nominal Capacity/F.L.Rate=486 mbh / 5.40 Therms] (Heating Equipment)													
Gas (therms)	183.8	186.1	87.8	30.4	34.0	35.4	33.1	36.8	30.7	47.4	60.0	132.9	898.4
Peak (therms/Hr)	0.6	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.6
Hpl 11: RTU-11 H [Maximum block coil load=64.66 mbh]													
Boiler - 019 [Nominal Capacity/F.L.Rate=200 mbh / 2.22 Therms] (Heating Equipment)													
Gas (therms)	226.9	224.3	154.6	45.4	10.7	0.0	0.0	0.0	9.1	74.3	105.9	193.4	1,044.5
Peak (therms/Hr)	0.7	0.7	0.6	0.2	0.1	0.0	0.0	0.0	0.1	0.4	0.5	0.6	0.7
Hpl 12: RTU-12 H [Maximum block coil load=32.15 mbh]													
Boiler - 020 [Nominal Capacity/F.L.Rate=160 mbh / 1.78 Therms] (Heating Equipment)													
Gas (therms)	111.6	110.8	73.7	19.9	3.7	0.0	0.0	0.0	2.9	34.1	48.6	94.3	499.6
Peak (therms/Hr)	0.4	0.4	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.3	0.4
Hpl 13: RTU-13 H [Maximum block coil load=387.0 mbh]													
Boiler - 021 [Nominal Capacity/F.L.Rate=640 mbh / 7.11 Therms] (Heating Equipment)													
Gas (therms)	707.7	671.4	463.8	255.3	228.9	195.3	166.7	214.7	219.1	335.2	380.0	578.3	4,416.5
Peak (therms/Hr)	4.3	4.3	3.9	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	4.0	4.3
Hpl 14: ERV-1 H [Maximum block coil load=217.4 mbh]													
Boiler - 022 [Nominal Capacity/F.L.Rate=800 mbh / 8.89 Therms] (Heating Equipment)													
Gas (therms)	239.9	211.2	224.9	149.3	127.8	103.0	71.7	98.7	106.8	165.1	174.6	211.9	1,885.1
Peak (therms/Hr)	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.4	2.4
Hpl 15: Pools [Sum of dsn coil capacities=0 mbh]													

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Alternative: 1

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Consumption -------								
Sys 1: RTU-1													
Coil loop (outdoor-air preconditioning) [Stage 1 Energy Recovery]													
Energy Recovered (therms)	0.0	0.0	0.0	29.4	27.0	35.6	31.4	26.9	38.5	29.5	21.5	0.0	239.8
Peak (therms/Hr)	0.0	0.0	0.0	0.4	0.5	0.4	0.3	0.2	0.5	0.4	0.4	0.0	0.5
Coil loop (outdoor-air preconditioning) [Stage 1 Parasitics]													
Electric (kWh)	0.0	0.0	0.0	19.6	40.1	50.1	51.2	45.8	47.1	19.7	13.3	0.0	286.8
Peak (kW)	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.2
None [Stage 2 Energy Recovery]													
Energy Recovered (therms)	0.0	0.0	0.0	29.9	28.0	35.7	31.2	25.9	41.3	31.5	21.4	0.0	245.0
Peak (therms/Hr)	0.0	0.0	0.0	0.5	0.5	0.5	0.3	0.2	0.5	0.5	0.5	0.0	0.5
None [Stage 2 Parasitics]													
Electric (kWh)	0.0	0.0	0.0	19.6	40.1	50.1	51.2	45.8	47.1	19.7	13.3	0.0	286.8
Peak (kW)	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.2
90.1-10 Min VAV AF Centrifugal [DsnAirflow/F.L.Rate=16,864 cfm / 4.95 kW] (Main Clg Fan)													
Electric (kWh)	670.7	616.2	858.5	1,015.5	1,250.5	1,302.4	1,274.7	1,386.6	1,250.6	1,101.3	941.9	674.2	12,342.9
Peak (kW)	4.9	4.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	5.0
FC Centrifugal var freq drv [DsnAirflow/F.L.Rate=16,864 cfm / 14.91 kW] (System Exhaust Fan)													
Electric (kWh)	2,555.7	2,304.4	3,020.3	2,771.9	2,259.4	2,152.2	2,182.9	2,213.8	2,160.6	2,988.2	3,041.9	2,570.5	30,221.7
Peak (kW)	15.0	15.0	15.0	15.0	6.4	3.4	3.4	3.4	15.0	15.0	15.0	15.0	15.0
Sys 2: RTU-2													
90.1-10 Min VAV AF Centrifugal [DsnAirflow/F.L.Rate=13,827 cfm / 0.68 kW] (Main Clg Fan)													
Electric (kWh)	195.5	178.8	211.9	197.7	213.3	213.0	206.7	221.1	200.1	211.5	200.8	194.0	2,444.2
Peak (kW)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Sys 3: RTU-3													
90.1-10 Min VAV AF Centrifugal [DsnAirflow/F.L.Rate=2,532 cfm / 0.12 kW] (Main Clg Fan)													
Electric (kWh)	25.4	23.4	30.0	31.9	35.7	35.3	33.5	36.8	33.1	34.4	31.2	25.8	376.4
Peak (kW)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Sys 4: RTU-4													

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Alternative: 1

------- Monthly Consumption -------

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Sys 4: RTU-4													
90.1-10 Min VAV AF Centrifugal [DsnAirflow/F.L.Rate=10,868 cfm / 0.53 kW] (Main Clg Fan)													
Electric (kWh)	395.3	357.1	395.3	382.6	395.0	382.6	395.3	395.3	382.6	395.3	382.6	395.3	4,654.1
Peak (kW)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sys 5: RTU-5													
90.1-10 Min VAV AF Centrifugal [DsnAirflow/F.L.Rate=1,702 cfm / 0.08 kW] (Main Clg Fan)													
Electric (kWh)	23.9	21.8	25.3	23.6	25.5	25.6	25.1	26.6	24.2	25.6	24.2	23.4	294.8
Peak (kW)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Sys 6: RTU-6													
90.1-10 Min VAV AF Centrifugal [DsnAirflow/F.L.Rate=6,795 cfm / 0.33 kW] (Main Clg Fan)													
Electric (kWh)	105.5	96.0	111.1	103.5	110.9	110.2	108.9	114.7	105.3	111.6	106.1	103.2	1,286.9
Peak (kW)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Sys 7: RTU-7													
90.1-10 Min VAV AF Centrifugal [DsnAirflow/F.L.Rate=9,850 cfm / 0.48 kW] (Main Clg Fan)													
Electric (kWh)	74.8	70.0	90.2	103.3	117.5	122.2	119.1	126.0	108.0	103.7	89.8	76.1	1,200.7
Peak (kW)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sys 8: RTU-8													
90.1-10 Min VAV AF Centrifugal [DsnAirflow/F.L.Rate=8,061 cfm / 0.39 kW] (Main Clg Fan)													
Electric (kWh)	50.3	45.0	52.4	53.5	57.6	59.9	64.8	74.1	74.4	66.0	60.8	50.6	709.4
Peak (kW)	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4
Sys 9: RTU-9													
90.1-10 Min VAV AF Centrifugal [DsnAirflow/F.L.Rate=13,966 cfm / 0.68 kW] (Main Clg Fan)													
Electric (kWh)	495.7	448.4	495.8	480.5	496.6	481.0	497.3	497.2	481.1	497.3	480.9	496.0	5,847.8
Peak (kW)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Sys 10: RTU-10A													
90.1-10 Min VAV AF Centrifugal [DsnAirflow/F.L.Rate=3,640 cfm / 0.18 kW] (Main Clg Fan)													
Electric (kWh)	132.4	119.6	132.4	128.2	132.4	128.2	132.4	132.4	128.2	132.4	128.2	132.4	1,559.2
Peak (kW)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Sys 11: RTU-11													

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EQUIPMENT ENERGY CONSUMPTION

By ACADEMIC

Alternative: 1

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Consumption -------								
Sys 11: RTU-11													
90.1-10 Min VAV AF Centrifugal [DsnAirflow/F.L.Rate=1,697 cfm / 0.08 kW] (Main Clg Fan)													
Electric (kWh)	23.9	21.9	25.4	23.6	25.5	25.5	25.0	26.6	24.1	25.6	24.3	23.4	294.5
Peak (kW)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Sys 12: RTU-12													
90.1-10 Min VAV AF Centrifugal [DsnAirflow/F.L.Rate=882.9 cfm / 0.04 kW] (Main Clg Fan)													
Electric (kWh)	12.4	11.4	13.2	12.3	13.3	13.3	13.0	13.8	12.6	13.3	12.6	12.2	153.3
Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sys 13: RTU-13													
90.1-10 Min VAV AF Centrifugal [DsnAirflow/F.L.Rate=7,790 cfm / 0.38 kW] (Main Clg Fan)													
Electric (kWh)	283.4	255.9	283.3	274.2	283.4	274.2	283.3	283.4	274.2	283.3	274.2	283.4	3,336.2
Peak (kW)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Sys 14: ERV-1													
Total-energy wheel (OA precondition) [Stage 1 Energy Recovery]													
Energy Recovered (therms)	555.8	556.1	278.5	53.3	18.6	47.1	73.6	52.4	23.6	117.2	176.7	448.6	2,401.4
Peak (therms/Hr)	1.1	1.1	0.7	0.3	0.2	0.3	0.3	0.3	0.2	0.5	0.6	0.9	1.1
Total-energy wheel (OA precondition) [Stage 1 Parasitics]													
Electric (kWh)	297.6	268.8	297.6	112.0	99.6	153.6	183.2	167.6	110.0	152.4	195.6	297.6	2,335.6
Peak (kW)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
None [Stage 2 Energy Recovery]													
Energy Recovered (therms)	10.4	14.4	0.0	0.0	13.2	34.7	57.4	39.1	17.9	0.0	0.0	0.0	187.1
Peak (therms/Hr)	0.4	0.4	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.0	0.0	0.0	0.4
None [Stage 2 Parasitics]													
Electric (kWh)	12.8	16.4	0.0	0.0	99.6	153.6	183.2	167.6	110.0	0.0	0.0	0.0	743.2
Peak (kW)	0.4	0.4	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.0	0.0	0.0	0.4
90.1-10 Min VAV AF Centrifugal [DsnAirflow/F.L.Rate=3,389 cfm / 1.82 kW] (Main Clg Fan)													
Electric (kWh)	766.2	702.1	739.7	351.3	535.9	755.6	882.2	817.6	575.0	439.0	524.5	739.7	7,828.9
Peak (kW)	1.8	1.8	1.0	1.0	1.8	1.8	1.8	1.8	1.8	1.0	1.0	1.0	1.8

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Energy Cost Budget / PRM Summary

By ACADEMIC

Project Name:	Date: October 28, 2016
City:	Weather Data: Columbus, Ohio

Note: The percentage displayed for the "Proposed/ Base %" column of the base case is actually the percentage of the total energy consumption.

* Denotes the base alternative for the ECB study.

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		* Alt-1		
		Energy 10^6 Btu/yr	Proposed / Base %	Peak kBtuh
Lighting - Conditioned	Electricity	3,661.6	31	418
Space Heating	Gas	5,537.2	47	3,897
Space Cooling	Electricity	1,276.2	11	883
Heat Rejection	Electricity	182.8	2	109
Fans - Conditioned	Electricity	260.1	2	92
Receptacles - Conditioned	Electricity	843.4	7	96
Total Building Consumption		**11,761.2**		

		* Alt-1
Total	**Number of hours heating load not met**	502
	Number of hours cooling load not met	80

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	* Alt-1	
	Energy 10^6 Btu/yr	Cost/yr $/yr
Electricity	6,224.0	108,726
Gas	5,537.2	25,084
Total	**11,761**	**133,810**

Refrences:

- Construction Documents (2014). Columbus, Ohio: Karpinski Engineering, OLC Architecture
- Electricity Gas Rates: (Champion Energy Services, LLC): http://www.energychoice.ohio.gov/ApplesToApplesComparision.aspx?Category=Electric&TerritoryId=2&RateCode=1
- Natural Gas Rates: (Ohio Natural Gas): http://www.energychoice.ohio.gov/ApplesToApplesComparision.aspx?Category=NaturalGas&TerritoryId=8&RateCode=1
- ANSI/ASHRAE. (2007). Standard 62.1-2007, Ventilation for Acceptable Indoor Air Quality
- ANSI/ASHRAE. (2007). Standard 90.1-2007, Energy Standard for Building Except Low Rise