MONGOMERY COLLEGE

Mechanical Systems Existing Conditions Report

TECHNICAL ASSIGNMENT 3

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EXECUTIVE SUMMARY

The Montgomery College New Science Center is a direct expansion to the East Science Center located in Rockville, Maryland a mixed-humid environment consisting of laboratories, offices, and classrooms on every floor. In a mixed environment both heating and cooling must be designed and integrated into the HVAC system. In Rockville the outdoor design conditions range from 94ºF in the summer to 14ºF in the winter, indicating neither the heating or cooling loads will be taken lightly.

In addition to the climate, the HVAC design needed to overcome the problems involved with laboratory contaminates, integrate the West Campus Loop, and be designed as a LEED building. The laboratory's negative pressure and central exhaust system is used to isolate and exhaust the laboratory contaminates. This exhaust system utilizes a large amount of energy and creates problems in reducing the energy for a LEED design. Integrating the New Science Center design into the West Campus Loop will help to reduce the energy by utilizing different combinations of systems to reach the optimal means of distribution and supply several buildings under this ideal combination as opposed to just the New Science Center. Designing a LEED building requires consideration to all building systems. The Montgomery College New Science Center integrated LEED design into every building system but specifically for the HVAC system design and this overall building design, energy efficiency became the focus of design. Various components were added and modeled to reach a 42% energy cost reduction.

The buildings energy usage and loads were modeled by the designer and for this report by the energy modeling software IES. The two models returned very different results due to variations in the model and model entries. The model was found to use 8,645,948 kwh per year. The majority of the energy is consumed by the direct-acting heaters, and the majority of the building load is attributed to chillers.

As a result the total initial HVAC cost is estimated to be $10.3 million. Therefore, the initial HVAC cost results to approximately $73 per square foot. This cost will be paid back very quickly due to the 42% energy cost reductions compared to the baseline building.

The HVAC system is a fairly typical system containing chillers, boilers, cooling towers, and rooftop units as some of the major components. The lack of complexity in the design made the water flow diagrams easy to follow. The air system maintains a typical flow diagram with the added laboratory's direct exhaust system and its role in the energy recovery wheel.

Overall the New Science Center HVAC design fulfills the university's design needs and requests, but leaves room to increase the complexity of the system to potentially further the energy reductions, decrease the emissions, and reduce the mechanical space needed.

INDOOR DESIGN CONDITIONS

The indoor design conditions used by BurtHill can be found in Table 1. These conditions were used to model The New Science Center's HVAC system within IES.

Space type	Summer Temperature Set-point & RH	Winter Temperature Set-point
Laboratories and Laboratory Support	74°F 50% +/- 5%	72°F
Classroom/Lecture Spaces	74°F 50% +/- 5%	72°F
Office and Office Support	74°F 50% +/- 5%	72°F
Conference, Lounge	74°F 50% +/- 5%	72°F
Telecommunication Spaces	74°F 50% +/- 5%	68°F
Mechanical Spaces	98°F (max)	60°F
Atrium	78°F 50% +/- 5%	68°F

Table 1: Indoor Design Conditions

The summer temperature set-point is kept higher than the winter temperature set-point by two degrees to save energy while maintaining air conditions within the thermal comfort zone. The mechanical space will typically be kept unoccupied. Maintaining the thermal comfort level for the mechanical spaces is therefore not as important and the set-points allow for much more flexibility, saving energy. The atrium and telecommunication spaces need to maintain thermal conditions but with less restrictions than typical spaces.

OUTDOOR AIR REQUIREMENTS

The external design conditions used to determine load, energy use and size equipment were found in the ASHRAE Fundamentals Handbook, 2005 edition. Refer to Appendix A - ASHRAE DESIGN CONDITIONS for further detail on the location weather data.

Building location: Baltimore Maryland

Latitude: 39.17 N

Longitude: 76.67 W

Elevation: 154

Summer Outdoor Air Conditions:
The summer design conditions are based on only 1% of the summer design conditions as opposed to the typical 0.4% since the New Science Center will not typically be occupied over the summer months.

Design Dry Bulb	90.9°F	Design Wet Bulb	76.9°F
Mean coincident wet bulb	74.3°F	Mean coincident dry bulb	86.4°F

Table 2: Summer Outdoor Air Design Conditions

Winter Outdoor Air Conditions:
The winter design conditions are based an 99% of the annual percentile.

Design Dry Bulb 16.7°F

The outdoor design wet bulb temperature for the cooling towers is 78 ° F.

Design Conditions:		
Summer		Winter
Dry Bulb	Wet Bulb	Dry Bulb
92°F	76°F	14°F

Table 3: Designer's Seasonal Design Conditions

DESIGN OBJECTIVES AND REQUIREMENTS

The Montgomery College New Science Center is intended to be used for general college level classes, college laboratories, and offices. The laboratory design requires the most attention to design and restrictions.

The mechanical system was designed with the following objectives:

- Chilled and Hot Water Plants Integration of West Campus Loop
- Energy Efficiency – LEED Silver
- Control Air-born Laboratory Contaminants
- Proper Laboratory Ventilation
- Maryland State Building

West Campus Loop

The Montgomery College New Science Center chilled and hot water plants were designed with room for future expansion. Proper piping will be installed and capped where additional equipment will be located and architectural additions will be made. The equipment to be installed for Phase I (The New Science Center) was also sized with the intent to be paired with the future equipment in the Phase II expansion.

Energy Efficiency

An energy model was performed using IES as the modeling software. Several alternatives were considered in the design process with the goal of energy efficiency, affordability, maintainability. A central air handling system, hot water system, chilled water system, and laboratory exhaust system was chosen as the final design. In order to achieve the energy efficiency desired, a heat recovery wheel, economizer, and high-efficiency boiler was integrated into the mechanical system. All of these components will help to reduce the energy needed, and energy cost for the HVAC design.

Laboratory Ventilation and Contaminant Control

All laboratories are maintained at negative pressure. Negatively pressurizing the laboratories will isolate the contaminants to the room and prevent them from exiting and mixing with any return air. Make-up air is transferred from the positively pressurized office area to the laboratory area to further isolate the office area from contaminants. To ensure proper ventilation, all laboratories are on a central exhaust system with localized fume hoods.

The complete designer ventilation calculations can be found in Appendix D- DESIGNER'S VENTILATION RATES.

COOLING AND HEATING LOADS

HEAT GAIN ASSUMPTIONS

Laboratory cooling load calculations are based on the following:

- 5 watts per square foot for laboratory equipment (unless able to calculate directly)
- Design lighting power density unique to each room (W/SF)
- # of people determined by lab program
- 250 BTUH/person

Classroom and lecture space cooling load calculations are based on the following:

- 1 laptop computer (90 watts) per student
- Design lighting power density unique to each room (W/SF)
- # of people per architectural plans
- 250 BTUH/person

Office cooling load calculations are based on the following:

- 1.5 watt per square foot equipment load
- Design lighting power density unique to each room (W/SF)
- One person per individual offices and two people per shared office.
- 250 BTUH/person

Heat gains for spaces such as copy rooms, vending alcoves, and other miscellaneous spaces were derived from the ASHRAE fundamental handbook.

DESIGN LOAD COMPARISON

In comparing the modeled building to the designed building the loads were significantly greater. No heat was recovered with the modeled system and therefore affected the rest of the calculated loads. The heating coil load increased almost 40 times and the boiler load increased almost 26 times as much as the designed energy model. This shows how much the heat recovery can reduce the load of the building. Other increases could be due to control data entry differences. The table below shows the complete breakdown of the system load comparison.

	Load	Computed MMBTU	Designed MMBTU	% increased
Heating	Room heating plant sensible load	7496.4	3772.8	99
Heating	Heating coil	6012	154.4	3794
Heating	Boiler	6123.4	235.57	2499
Heating	Recovered latent heat	0	1597.3	No recovered heat
Cooling	Room cooling plant sensible load	856.7	823.2	4
Cooling	Room dehumidification plant load	27.4	17.3	58
Cooling	Cooling coils latent load	4877.5	3657.4	33
Cooling	Chiller	19922	11866.3	68
	Summation	45315.4	22124.3	105

Table 4: Load Breakdown

Analyzing the loads, shows well over the majority of the load goes to the chiller.

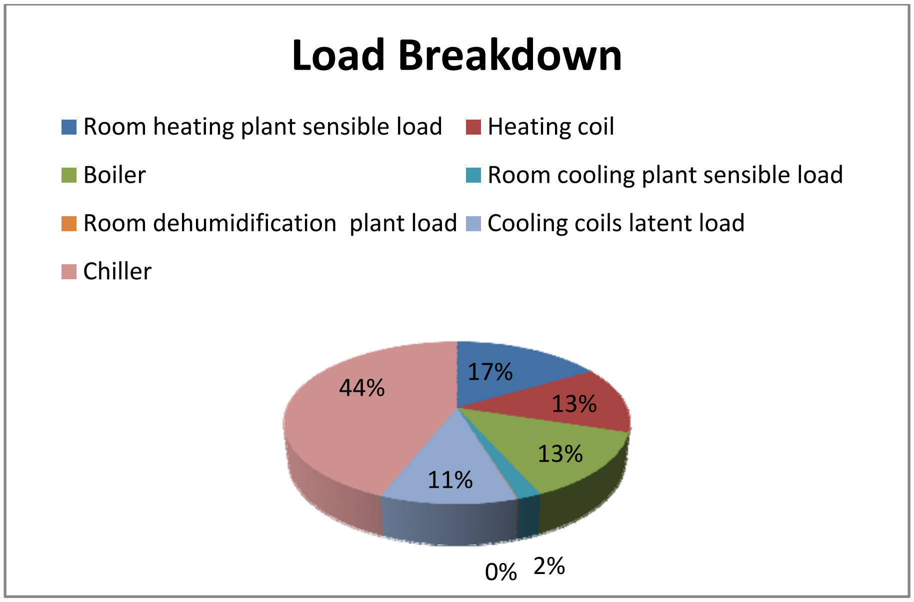

Figure 1: Load Breakdown

The New Science Center is an internal load dominated building. Looking at Classroom 105 for an example the internal gain was comprised of 85% of the load based on peak values. This type of building results in cooling for most of the year regardless of the fact the building is located in Rockville Maryland, a mixed but predominately cold climate. Due to the fact the building is cooling most of the time, the chiller resulted in the majority of the load for the building.

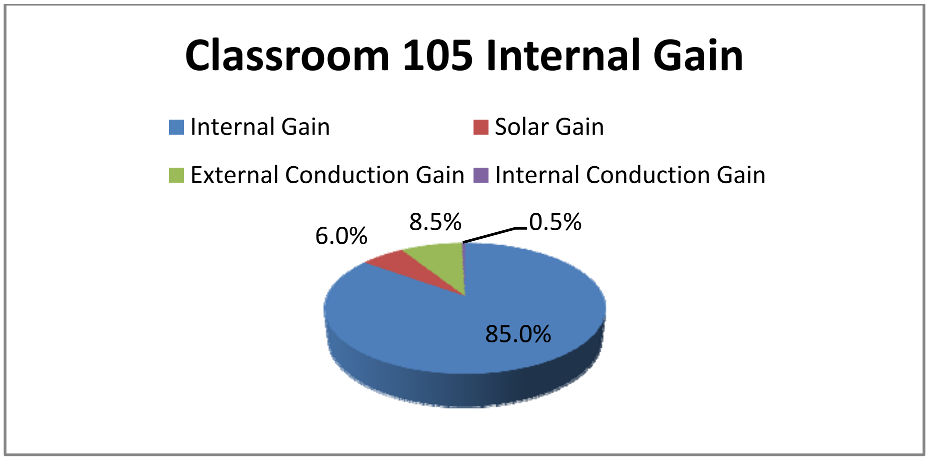

Figure 2: Classroom 105 Internal Gain

ENERGY ANALYSIS

The New Science center consumes 8,645,948 kilowatt hours annually. As expected the energy for the boiler energy increased with the boiler load. In addition, the pump energy increased drastically due to the increased pump power needed for the boiler.

Energy	Computed MMBTU	Designed MMBTU	% increased
Boilers	7,047.8	271.7	2,494
Chillers	4,422.8	2,613.4	69
Direct acting heaters	9,274.5	4,272.2	117
Fans	3,614.1	2,731.7	32
Pumps	5,142	327.6	1,470
Lights	1,432.744	1,432.744	0
Equipment	4,773.798	4,773.798	0
Total System Energy	29,501.2	10,216.6	189

Table 5: Energy Comparison – Computed vs. Designed

Over all the energy for both the designed and computer values were less than the baseline values, even though the energy was drastically increased due to the lack of energy recovered for the simulated model. This shows the HVAC design combined with the simulated schedules create an excellent system.

Analyzing the figure below, most of the energy went to the direct acting heaters followed by the boilers, pumps, and chillers. The previous load calculations showed the chiller as the dominate load and would therefore be assumed to use the highest percent of energy. This is quite the opposite since the chillers have a COP of 5.26 and boilers are 87% efficient. Although the boilers have a high efficiency they still require over six times the amount of energy as the chillers at equal loads. The pump energy is required regardless of the season and therefore also surpasses the chiller energy.

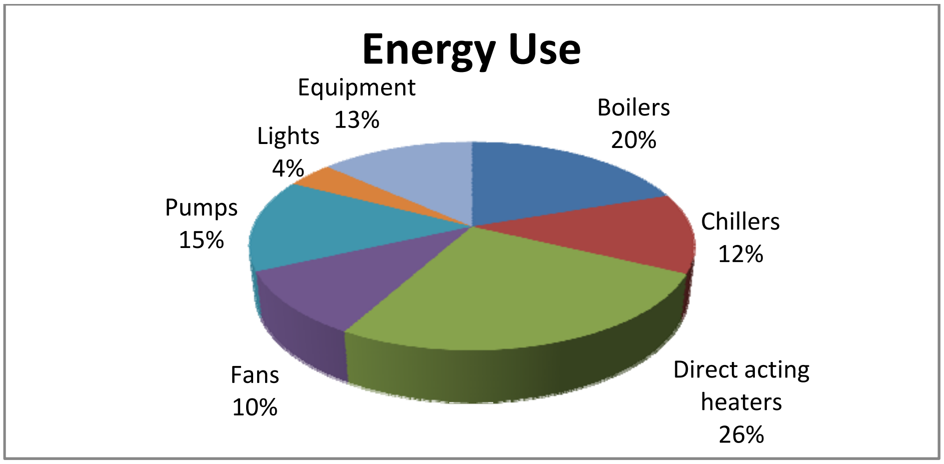

Figure 3: Energy Use Breakdown

UTILITY RATES

The Montgomery College New Science Center uses the following utility rates based on the rates for the entire campus:

- Natural Gas: $1.54 per therm (2008)
- Electric: $0.1321/kWh (2008 Projected)

UTILITY SOURCES

Some of the local utility sources include the following:

Princeton Energy Resources International, LLC	• Fossil Fuels • Clean Coal • Renewable Energy
Liberty Rockville	• Natural Gas
MDU Communications	• Natural Gas
Opis Energy Group	• Oil • Gas
Columbia Gas Transmission Corporation	• Natural Gas
Potomac Electric Power Company (PEPCO)	• Electric
JKJ Electric	• Electric
A/C Electric Company	• Electric
Washington Gas	• Natural Gas
GKRSE	• Electric • Natural Gas • Hydropower

Table 6: Utility Sources

MECHANICAL SYSTEM

The mechanical system consists of a central air handling system, central chilled water system, a central hot water system, and a laboratory exhaust system. The central air handling system consists of two custom air handling units located on the roof.

Chilled and Hot Water Plant:
Both a satellite chilled water plant and a satellite hot water plant in the new Science Building is sized to provide the cooling and heating capacity for the West Loop respectively. The West Campus Loop consists of the New Science Center (building of discussion), Science East, Science West, Macklin Tower and Computer Science. The West Loop has three different operational modes. The entire West Loop can be served by the campus loop or the new satellite plant. Or the new satellite plant can serve only the New Science Center with the rest of the west loop served by the existing campus central water plant. Isolation valves are used in accomplishing each operation option. Each building will have local secondary pumps.

The new satellite plant will have its own expansion tank and fill line. The new expansion tank provides additional expansion capacity to supplement the existing expansion tank in the central plant.

Chilled Water System Design:
The existing 225 ton chiller with variable frequency speed control in Science East, associated cooling tower, and condenser pumps were retained. An additional two 305 ton **electric centrifugal chillers** with variable frequency drives will be added to the chilled water system to accommodate for the expansion (New Science Center).

Chiller										
					Evaporator			Condenser		
Number	Tons	KW	KW/ TON	NPLV	GPM	Entering Water Temp	Leaving Water Temp	GPM	Entering Water Temp	Leaving Water Temp
2	305	204	0.669	0.448	410	60	42	580	85	100

Table 7: Chiller Schedule

The **two primary** and **two secondary** chilled water pumps have variable frequency drives, along with the two condenser pumps.

Two new **induced draft-cross flow cooling towers**, located on the roof, cool the chiller condenser water. The two towers in a two cell arrangement share a basin. Both towers have variable frequency drives for fan speed control.

Cooling Tower				
Number	GPM	Entering Air Wet Bulb	Leaving Water Temp	Entering Water Temp
2	500	78	85	100

Table 8: Cooling Tower Schedule

The two **condenser water pumps** are each sized for full flow of both towers. At ideal conditions the variable fan speed of the towers will reduce the condenser water temperature to allow the chillers to operate at peak efficiency.

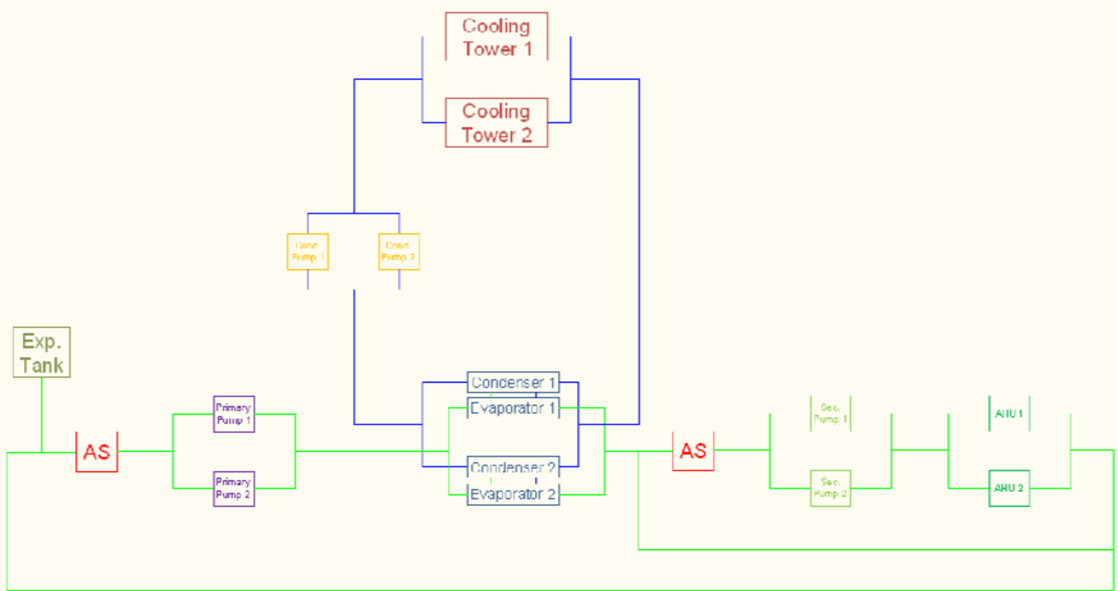

Figure 4: Cold Water Flow Diagram

Following the Cold Water Flow Diagram shown above, the **cooling towers** cool the chiller condenser water. The water is pumped by the **condenser pumps** to **chillers** where the water will be cooled to the optimal temperature. The water is then drawn through the **air separator** to ensure there is no bubbling in the water altering the pressure and **pumped** to the **air handling units**. The air handling units pull the air to be supplied to the building over the cooling coils. This process transfers the energy of the air into the water, allowing the chilled water to perform its main purpose. After leaving the air handling unit the water can then be overflowed into the **expansion tank** or continued through the cycle. The water is once again drawn through an **air separator** by the **primary pumps** and taken back through the **chillers** on the evaporator side and back up to the **cooling towers**.

Hot Water System Design:

Two high efficiency 3 million BTU **hot water boilers** are provided for the heating plant. 3 million is the input energy; each boiler can provide 2.61 million BTUS of heat at the minimum operating efficiency of 87%. Space has been allocated in the mechanical penthouse for two additional boilers if they would be required to boost the capacity of the west hot water loop in the future.

Boiler					
Number	MBH in	MBH out	GPM	Entering Water Temp	Leaving Water Temp
2	3000	2610	260	160	180

Table 9: Boiler Schedule

The hot water system consists of two hot water **campus distribution pumps** and two building **distribution pumps**. There are no boiler pumps. The boilers are all piped in reverse return to balance out flows. Water always flows through all boilers when there is a call for heat.

Following the Hot Water Schematic shown below, the **boilers** heat the water from the **air handling units** and campus return. The hot water is then either overflowed into the **expansion tank** or continued through the cycle drawn through an **air separator** by the **campus distribution pumps**. The campus distribution pumps supply the hot water to the campus hot water loop, the air handling unit loop or back through the boilers. If the water is taken through the air handling unit loop, the water is first drawn through an **air separator** and then pumped by the **building distribution pumps** up to the **air handling units** located on the roof and back into the boiler loop.

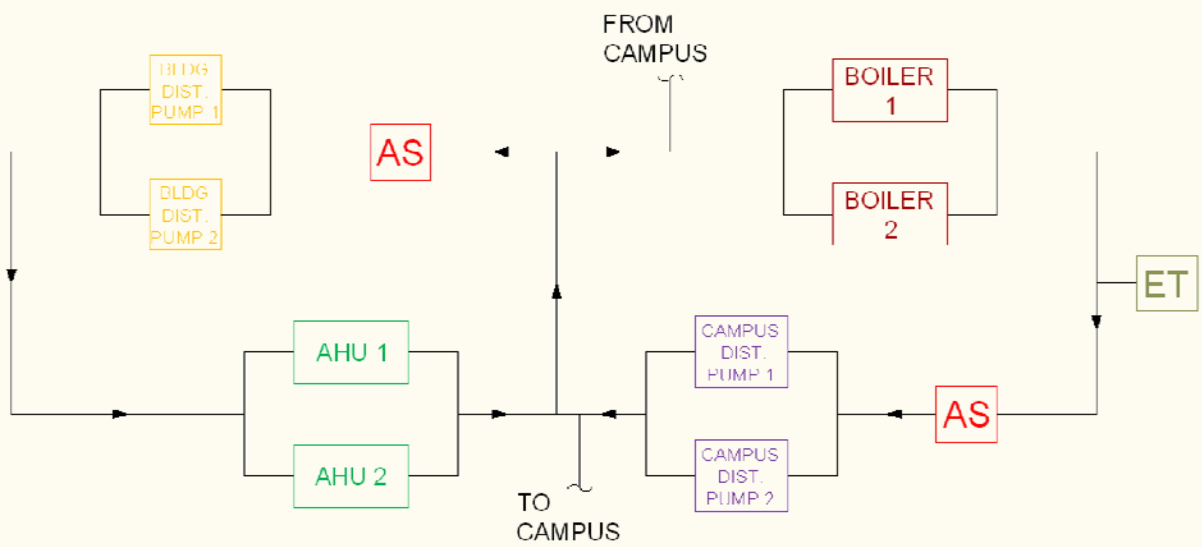

Figure 5: Hot Water Flow Diagram

This flow diagram shows that the hot water loop can be utilized locally or distributed to the west loop and/or campus loop.

Air System Design:
The central air handling system consists of two **roof top units** manifolded together by a common discharge plenum. Each unit has **dual fans** and isolation dampers to isolate one unit from the rest of the system. There is no return fan because the pressure drop across the outside air section including the **heat recovery coil** is approximately equal to the pressure drop in the plenum return system. The return air damper will modulate to maintain the pressurization of the building. Because of the high percentage of outside air, due to the amount of lab exhaust, there is no relief in the unit. The only relief is

required during economizer mode. This relief will be discharged from the building through the smoke exhaust fans.

The air system schematic shows how the air handling unit is connected to the rooms. The complete schematic can be found in Appendix E – SCHEMATICS to explore the entire building air distribution breakdown. This schematic is taken directly from the designers IES energy model. IES requires that the entire HVAC system be modeled in order to run the program with the correct results.

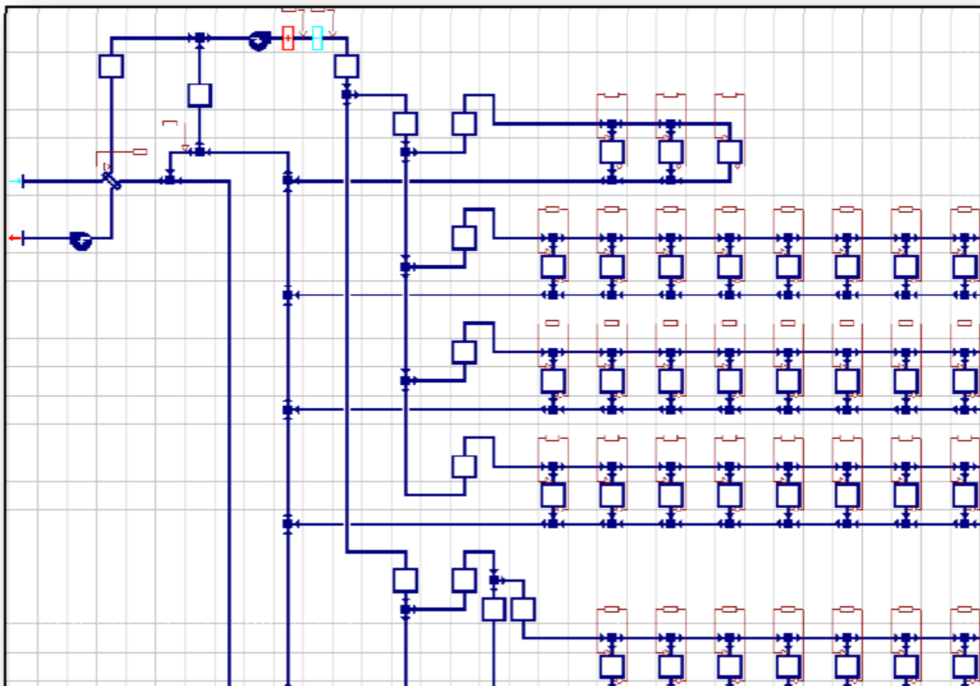

Figure 6: Air System Partial Schematic

The figure below focuses the Air System Schematic on the AHU of the system. It shows an exhaust fan, supply fan, mixing boxes, heating and cooling coils, controls, and the heat exchanger. All of these components need the corresponding values to complete the energy model. These values can be found in Appendix B- SYSTEM COMPONENTS.

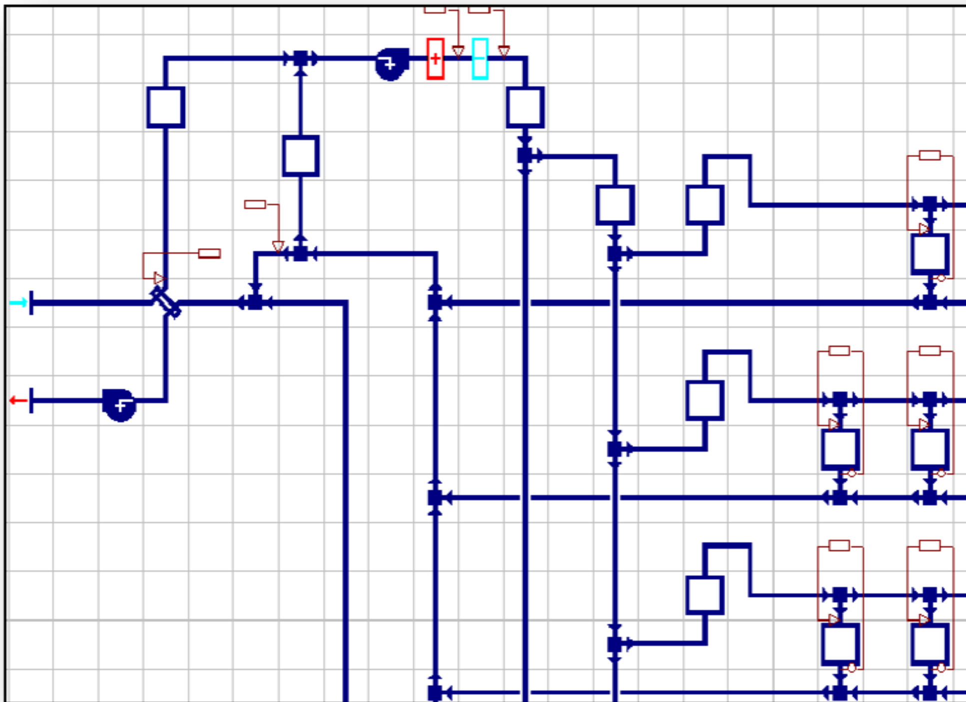

Figure 7: Air system schematic AHU

Air Handling Unit								
Number	**Mark**	**System Type**	**Capacity (CFM)**			**Components**		
			SA	**Design OA**	**Max. Vel**			
2	**AHU-1**	VAV	66730	47140	500	Cooling Coil	Pre-heat Coil	Heat Recovery Coil

Table 10: AHU Schedule

A 12 ft wide corridor runs between the two units connecting them. The hot water and chilled mains that serve the unit run across the ceiling of the service corridor. At the end of the corridor, there is a mechanical room that houses the rest of the equipment in the custom penthouse.

The air handling unit consists of the following sections:

- Storm Louver
- Intake section
- Pre-filter for outside air
- Heat Recovery coil
- Return mixing box with return air inlet, dampers and a pre-filter for the return air.
- Supply fan section with dual fans.
- 85% Supply air final filter
- Heating Coil
- Cooling Coil
- Isolation discharge dampers
- Discharge plenum.
- Requires access sections w/ 24” service doors.

More information on the coils used can be found in Appendix B- SYSTEM COMPONENTS.

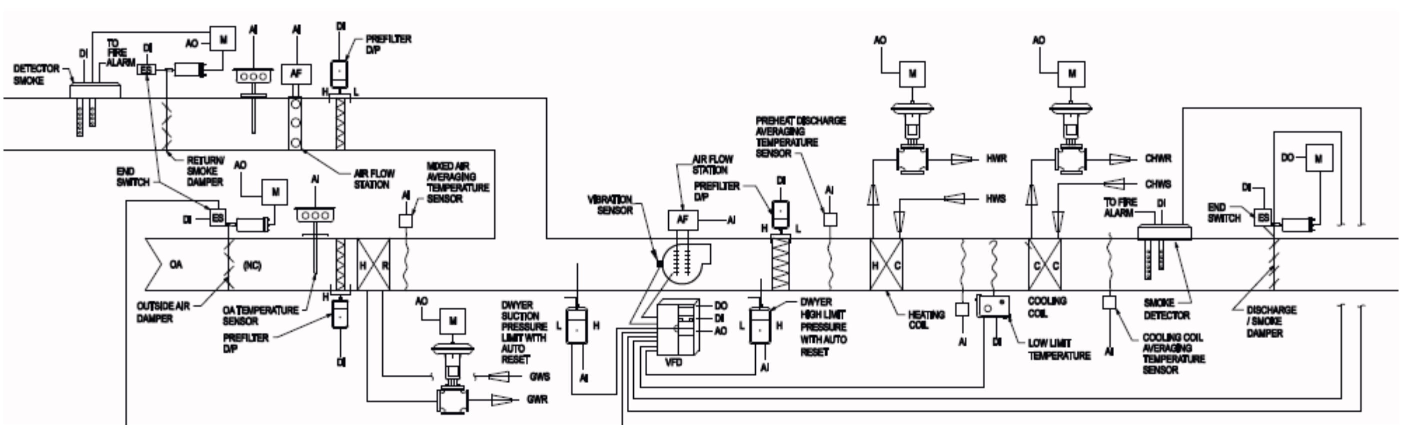

Figure 8: Partial Air Handling Unit Schematic

For full air handling unit schematic refer to Appendix E – SCHEMATICS.

Central Exhaust System Design:

The laboratory exhaust system consists of four high plume exhaust fans that are connected by a common plenum. The airflow through an individual fan is constant volume to maintain a constant discharge velocity out of the exhaust fan stack. The flow of exhaust air from the building is variable volume to minimize the amount of make-up air required at all times. To compensate, there is a make-up air damper in the exhaust plenum to mix enough outside air with the exhaust air from the building to maintain a constant exhaust flow rate. When the amount of make-up air exceeds the design flow rate through one whole fan, the exhaust fan with the longest run time shall shut off and the amount of make-up air will be varied accordingly to maintain a constant flow of exhaust air through the rest of the fans in operation. Of the four fans, one is a standby fan, in the event of a failure. The fan designations will be rotated based on run time.

Laboratory Exhaust Fans				
Number	Type	CFM	RPM	BHP
4	High Plume	24200	1000	38.6

Table 11: Laboratory Exhaust Fan Schedule

The fans create a constant negative static pressure at the local exhaust plenum. Each main exhaust riser has a modulating damper that is normally 100% open. The damper modulates close to maintain the remote duct static pressure less than the maximum duct static pressure set point in the exhaust riser.

INITIAL COST

The initial or first costs of the Montgomery College New Science Center were compiled from the 95% completion Cost Estimates. The bid documents are currently sealed until late December. The unit cost estimates were summarized into 23 of the 33 CSI master format divisions, one of which being the HVAC division. This division is then broken down into the seven categories listed below. Each category is broken down into further detail, where every item, quantity, and associated cost is accounted for to receive the total first cost for the HVAC installation and equipment.

HVAC Cost Breakdown	
Building Square Footage	**140,700**
HVAC Piping	$954,940
Metal Duct	$3,208,661
Duct Accessories	$326,430
Heating and Ventilation Related Piping	$3,298,818
Heating and Cooling Equipment	$639,430
Controls and Regulations	$1,441,300
Testing and Balancing	$588,030
TOTAL HVAC FIRST COST	**$10,457,609**
HVAC Cost Per Square Foot	**$74.33**

Table 12: HVAC Cost Breakdown without Deductions

After the estimate was completed deductions were made to help mitigate the overall building cost. The majority of the deductions were accomplished by transferring parts of the budget to the FFE (Fixtures, Furnishings, and Equipment). The only other deductions to the cost were fulfilled by removing one cooling tower and selecting construction alternatives. Since a cooling tower was removed from the initial estimate the HVAC first cost was therefore recalculated.

TOTAL HVAC FIRST COST	$10,457,609
Deduction of Cooling Tower	$125,411
TOTAL HVAC FIRST COST WITH DEDUCTIONS	**$10,332,198**
HVAC Cost Per Square Foot	**$73.43**

Table 13: HVAC Cost with Deductions

The total initial HVAC cost with deductions is estimated to be $10.3 million. As a result the initial heating ventilation and air conditioning cost for the Montgomery College New Science Center results to approximately $73.43 per square foot.

LEED NC ASSESSMENT

Leadership in Energy and Environmental Design (LEED) was created by the US Green Building Council to promote building that are environmentally responsible and provide a health place to work and/or live. LEED provides the building industry with a rating system. The rating system creates an economical incentive for building owners to become more "green", since the rating provides concrete evidence to the employees and inhabitants that the building is healthier and more environmentally friendly.

The LEED rating system is based on five major categories:

1. Sustainable Site
2. Water Efficiency
3. Energy and Atmosphere
4. Conserving Materials and Resources
5. Enhance Indoor Environmental Quality

These categories are broken down into individual points. This report focuses on but is not limited to the Energy and Atmosphere, and Enhanced Indoor Environmental Quality categories.

Category	Points Anticipated	Possible Points	% points possible achieved
Sustainable Site	8	14	57%
Water Efficiency	3	5	60%
Energy and Atmosphere	**13**	**17**	**76%**
Materials and Resources	4	13	31%
Indoor Environmental Quality	**12**	**15**	**80%**
Innovation and Design	2	5	40%
Total	**42**	**69**	

Table 14: LEED Point Distribution Breakdown

The New Science Center also focused on these categories, where over ¾ of the points possible for the two categories are anticipated. Overall these two categories alone accomplish 60% of the anticipated points.

Energy and Atmosphere

The Montgomery College New Science Center has designed to be a LEED building from the beginning. Establishing this goal as early as possible is vital in LEED design. Every step of the design process should be done with this goal in mind and design accordingly in order to achieve the LEED rating.

The building HVAC design focused on energy efficiency and overall reduction. The New Science center is estimated to reduce the energy cost by 42% compared to the ASHRAE 90.1 Baseline Building. This energy cost reduction equates to 9 out of the 10 points available for the Optimize Energy Performance Credit.

Photovoltaic panels are to be added to the roof towards the 2.5% of onsite renewable energy. These panels unfortunately are not anticipated to reach the 2.5% required. The panels will be used to educational purposes and in requesting innovation design credit for the educational apparatus.

The proper commissioning, refrigerants, and measurements will be used to gain the respective credits. In addition the university green power contract is anticipated to cover the required 35% green power.

Enhanced Indoor Environmental Quality

The New Science Center will have CO_2 sensors, MERV 8 filters, and low volatile organic compounds (VOC) materials. These features reduce the amount of air-born contaminants creating a healthier environment for the building occupants. The building will also be flushed out before occupancy, all towards bettering the air quality.

Individual lighting controls are provided to 90% of the occupants. This allows the occupants to maintain desired lighting while minimizing the energy use.

In order to achieve the thermal comfort controllability credit, thermal controls are provided for 50% of the occupants and thermal diffusers for the offices, which will be followed up with a post-occupancy survey and corresponding modifications.

A breakdown of all the LEED points, if it will be achieved, how it is planned to be accomplished, and which category it belongs to, can be found in Appendix C – LEED CREDIT BREAKDOWN.

EMISSIONS

The Montgomery College New Science Center is located in Rockville Maryland and therefore located in the RFC, Eastern Interconnection electric grid. The continental United States is separated up into three main grids of which little energy is transferred.

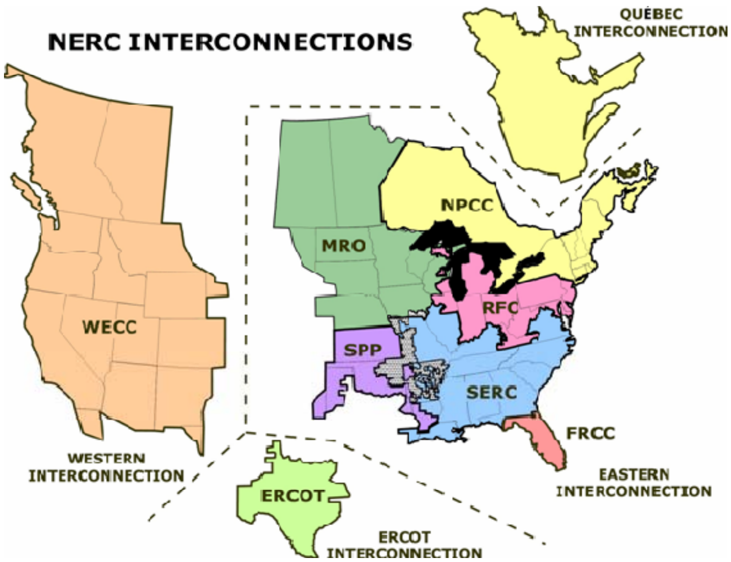

Figure 14: North American electrical interconnections

The energy model of the New Science Center revealed 8399377.68 kwh, as discussed earlier. Based on the location of the building the amount of major pollutants in the United States could be calculated.

The boiler's use of natural gas for the year must also be taken into account. The boiler uses 7047.823 mmbtu.

The calculations for this report were made on the assumption that for every 1010Btu, 1 cubic foot of fuel (Natural gas) is delivered to the building at 60 °F at 14.70 psia.

Pollutant	Eastern (lb/kwh)	lb of pollutant
CO2e	1.7400000	14,614,917
CO2	1.6400000	13,774,979
CH4	0.0035900	30,154
N2O	0.0000387	325
NOX	0.0030000	25,198
SOX	0.0085700	71,983
CO	0.0008540	7,173
TNMOC	0.0000726	610
Lead	0.0000001	1
Mercury	0.0000000	0
PM10	0.0000926	778
Solid Waste	0.2050000	1,721,872

Figure 15: New Science Center's Electrical Pollution

Pollutant	Natural Gas	lb of pollutant
CO2e	123.00000000	937,263
CO2	122.00000000	929,643
CH4	0.00250000	19
N2O	0.00250000	19
NOX	0.11100000	846
SOX	0.00063200	5
CO	0.09330000	711
VOC	0.00613000	47
Lead	0.00000050	0
Mercury	0.00000026	0
PM10	0.00840000	64

Figure 16: New Science Center's Natural Gas Pollution

MECHANICAL SYSTEMS EVALUATION

The Montgomery College New Science Center utilizes a typical heating ventilation and air-conditioning system for a mixed climate zone; where controls, heat recovery, and equipment efficiency are relied on to reduce the energy use. This type of system is easy to maintain in comparison to some of the new, innovative designs of today for the building operations engineer. This system is easily incorporated into the already existing campus loops and neighboring buildings. For these reasons this system was a good design for both the university and energy reductions.

If the university would be willing to upgrade to a more complex and innovative design the building could further the energy reductions, decrease the space needed by the mechanical system, and emissions. Unfortunately, increasing the complexity of the system could also lead to an increased initial cost, and facility engineer system training.

CRITQUES

The building does well in isolating the laboratory contaminants by directly exhausting all laboratories, keeping them negatively pressurized at all times along with the exhaust ducts.

Humidification was not addressed in the design and the thermal comfort levels desired by LEED were never reached.

The designer energy reductions may not be realistic. Comparing this reports energy model to the designer's energy model the energy reductions are found to be extremely low. Further research showed the designer's energy calculations were extreme for the energy reduction methods compared to typical laboratory design. Why these results vary so drastically will require further investigation.

The buildings hot and cold water systems were incorporated into the campus water plants with ease. The design gives the campus a lot of flexibility. The campus will be able to add to the campus loop as anticipated easily, since room was left and pipes were designed and located with the expansion in mind. The design will also integrate into the current system well, since the existing system and designed system are very similar. As a result, any combination of the campus plant or local satellite plant can be used to service any combination of the west campus loop or New Science Center.

Overall the design appears done very well, meeting and exceeding the campus expectations with a conservative system.

REFERENCES

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APPENDIX A – ASHRAE DESIGN CONDITIONS

2005 ASHRAE Handbook - Fundamentals (IP)

Design conditions for BALTIMORE, MD, 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
BALTIMORE	724060	39.17N	76.67W	164	14.614	-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	12.3	16.7	-3.5	4.8	16.4	1.1	5.8	20.8	27.3	33.0	24.9	30.9	8.8	270

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	18.7	93.6	75.0	90.9	74.3	88.2	73.1	78.1	88.3	76.9	86.4	75.6	84.3	10.6	280

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
75.4	133.6	82.4	74.1	128.0	81.2	72.9	122.9	80.1	33.8	88.7	32.6	86.4	31.4	84.6

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
23.0	19.6	17.7	84.8	97.8	4.8	3.0	6.3	100.0	0.3	101.7	-3.4	103.4	-7.0	105.6	-11.6

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%	64.8	58.7	70.2	58.1	80.1	62.7	86.7	66.3	90.6	71.2	94.4	74.6
1%	61.7	56.1	65.8	54.6	76.6	60.0	83.0	64.9	88.4	69.8	92.7	74.2
2%	58.2	53.1	62.1	53.4	71.1	58.0	79.2	62.9	86.2	68.9	91.0	73.7

%	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%	97.9	76.6	96.1	76.1	92.7	73.6	82.9	68.3	75.3	63.9	68.3	60.0
1%	96.0	76.2	94.1	75.6	90.2	73.2	80.2	67.2	72.6	61.8	65.0	58.8
2%	94.3	76.6	92.2	75.2	87.8	72.9	77.8	66.7	69.8	60.0	62.0	55.6

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%	60.2	63.6	60.0	66.0	64.8	77.7	68.7	80.2	74.7	86.6	78.6	88.2
1%	57.6	61.3	67.4	62.7	62.4	72.4	67.3	78.4	73.3	83.9	77.3	87.1
2%	54.4	57.8	64.4	60.0	60.0	68.6	65.6	76.9	72.0	81.7	76.3	85.8

%	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%	80.3	91.2	79.6	89.0	77.3	86.2	71.5	77.8	66.6	71.3	61.7	66.6
1%	79.3	90.5	78.4	88.1	76.3	84.7	70.5	76.4	64.7	68.9	58.5	63.1
2%	78.4	89.2	77.7	87.6	76.3	83.2	69.1	74.7	63.4	67.3	56.9	60.7

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
15.3	16.7	18.2	20.1	20.0	18.6	18.7	18.2	18.3	20.0	18.2	15.8

WMO# World Meteorological Organization number; Lat Latitude, °; Long Longitude, °
Elev Elevation, ft; StdP Standard pressure at station elevation, psi
DB Dry bulb temperature, °F; DP Dew point temperature, °F; WB Wet bulb temperature, °F
WS Wind speed, mph; Enth Enthalpy, Btu/lb; HR Humidity ratio, grains of moisture per lb of dry air
MCDB Mean coincident dry bulb temperature, °F; MCDP Mean coincident dew point temperature, °F; MCWB Mean coincident wet bulb temperature, °F
MCWS Mean coincident wind speed, mph; PCWD Prevailing coincident wind direction, °, 0 = North, 90 = East

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APPENDIX B – SYSTEM COMPONENTS

Air Handling Unit								
Number	Mark	System Type	Capacity (CFM)			Components		
			SA	Design OA	Max. Vel			
2	**AHU-1**	VAV	66730	47140	500	Cooling Coil	Pre-heat Coil	Heat Recovery Coil

Cooling Coil										
Number	CFM	Sensible kbtuh	Total kbtuh	Entering Dry Bulb	Entering Wet Bulb	Leaving Dry Bulb	Leaving Wet Bulb	Entering Water Temp	Leaving Water Temp	GPM
2	66730	2567	4264	85.3	71.8	52	52	42	60	474

Heating Coil							
Number	CFM	Coil Capacity MBH	Entering Dry Bulb	Leaving Dry Bulb	Entering Water Temp	Leaving Water Temp	GPM
2	60270	951.5	35.9	65	180	160	95

Heat Recovery Coil								
Summer								
Number	Function	CFM	Coil Capacity MBH	Temp Efficiency	Entering Exhaust Air	Leaving Exhaust Air	Entering Outdoor Air	Leaving Outdoor Air
2	**preheat**	47140	537	51.3			95	84.7
2	**heating**	44000	537	55.5	75	86.1		

Winter								
Number	**Function**	**CFM**	**Coil Capacity MBH**	**Temp Efficiency**	**Entering Exhaust Air**	**Leaving Exhaust Air**	**Entering Outdoor Air**	**Leaving Outdoor Air**
2	**preheat**	32730	1266	61.7			14	49.8
2	**heating**	32730	1266	46.2	72	45.2		

Chiller										
					Evaporator			**Condenser**		
Number	**Tons**	**KW**	**KW/ TON**	**NPLV**	**GPM**	**Entering Water Temp**	**Leaving Water Temp**	**GPM**	**Entering Water Temp**	**Leaving Water Temp**
2	305	204	0.669	0.448	410	60	42	580	85	100

Boiler					
Number	**MBH in**	**MBH out**	**GPM**	**Entering Water Temp**	**Leaving Water Temp**
2	3000	2610	260	160	180

Cooling Tower				
Number	**GPM**	**Entering Air Wet Bulb**	**Leaving Water Temp**	**Entering Water Temp**
2	500	78	85	100

Laboratory Exhaust Fans				
Number	**Type**	**CFM**	**RPM**	**BHP**
4	High Plume	24200	1000	38.6

APPENDIX C – LEED CREDIT BREAKDOWN

		LEED™ Credit Description	Possible Credits	Expected Score	Under Review	Not Possible
Sustainable Sites	SSp 1	Erosion and Sedimentation Control		R		
	SS 1	Site Selection - Avoid Inappropriate Sites	1	1		
	SS 2	Development Density & Community Connectivity	1		1	
	SS 3	Brownfield Development	1			1
	SS 4.1	Alternative Transportation- Public Access	1	1		
	SS 4.2	Alternative Transportation- Bicycles	1	1		
	SS 4.3	Alternative Transportation- Fuel-efficient vehicles	1	1		
	SS 4.4	Alternative Transportation- Parking	1	1		
	SS 5.1	Reduced Site Disturbance- Habitat	1		1	
	SS 5.2	Reduced Site Disturbance- Development	1		1	
	SS 6.1	Storm Water Management- Rate & Quantity	1		1	
	SS 6.2	Storm Water Management- Quality Control	1		1	
	SS 7.1	Reduce Heat Island- Non-roof	1	1		
	SS 7.2	Reduce Heat Island- Roof	1	1		
	SS 8	Light Pollution Reduction	1	1		
		SUBTOTAL - SS POINTS	14	8	5	1
Water	WE 1.1	Water Efficient Landscaping- 50% reduction	1	1		
	WE 1.2	Water Efficient Landscaping- No potable	1	1		
	WE 2	Innovative Wastewater Technologies	1			1
	WE 3.1	Water Use Reduction	1	1		
	WE 3.2	Water Use Reduction	1			1
		SUBTOTAL - WE POINTS	5	3	0	2

		LEED™ Credit Description	Possible Credits	Expected Score	Under Review	Not Possible
Energy and Atmosphere	EAp 1	Fundamental Commissioning		R		
	EAp 2	Minimum Energy Performance		R		
	EAp 3	CFC Reduction in HVAC&R Equipment		R		
	EA 1	Optimize Energy Performance (10.5% - 42%)	10	9	1	
	EA 2.1	Renewable Energy- 2.5%	1		1	
	EA 2.2	Renewable Energy- 7.5%	1			1
	EA 2.3	Renewable Energy- 12.5%	1			1
	EA 3	Enhanced Commissioning	1	1		
	EA 4	Enhanced Refrigerant Management	1	1		
	EA 5	Measurement & Verification	1	1		
	EA 6	Green Power	1	1		
		SUBTOTAL - EA POINTS	17	13	2	2
Conserving Materials & Resources	MRp 1	Storage and Collection of Recyclables		R		
	MR 1.1	Building Reuse- 75% Shell	1			1
	MR 1.2	Building Reuse- 95% Shell	1			1
	MR 1.3	Building Reuse- 50% nonshell	1			1
	MR 2.1	Construction Waste- 50%	1	1		
	MR 2.2	Construction Waste- 75%	1	1		
	MR 3.1	Resource Reuse- 5%	1			1
	MR 3.2	Resource Reuse- 10%	1			1
	MR 4.1	Recycled Content- 10%	1	1		
	MR 4.2	Recycled Content- 20%	1		1	
	MR 5.1	Regional Materials- 10%	1	1		
	MR 5.2	Regional Materials- 20%	1		1	
	MR 6	Rapidly Renewable Materials	1		1	
	MR 7	Certified Wood	1		1	
		SUBTOTAL - MR POINTS	13	4	4	5

	LEED™ Credit Description		Possible Credits	Expected Score	Under Review	Not Possible
Enhance Indoor Environmental Quality	EQp 1	Minimum IAQ Performance		R		
	EQp 2	Environmental Tobacco Smoke Control		R		
	EQ 1	Outdoor Air Delivery Monitoring	1	1		
	EQ 2	Increased Ventilation	1	1		
	EQ 3.1	Construction IAQ- During Construction	1	1		
	EQ 3.2	Construction IAQ- Before Occupancy	1	1		
	EQ 4.1	Low-Emitting Materials- Adhesives/Sealants	1	1		
	EQ 4.2	Low-Emitting Materials- Paints and Coatings	1	1		
	EQ 4.3	Low-Emitting Materials- Carpet	1	1		
	EQ 4.4	Low-Emitting Materials- Composite wood/agrifiber	1	1		
	EQ 5	Indoor Chemical Pollution Source Control	1	1		
	EQ 6.1	Controllability of Systems- Lighting	1	1		
	EQ 6.2	Controllability of Systems- Thermal Comfort	1	1		
	EQ 7.1	Thermal Comfort- Design	1			1
	EQ 7.2	Thermal Comfort- Verification	1	1		
	EQ 8.1	Daylighting	1			1
	EQ 8.2	Views	1		1	
		SUBTOTAL - EQ POINTS	15	12	1	2
Innovation in Design	ID 1.1	Innovation Credit	1	1		
	ID 1.2	Innovation Credit	1		1	
	ID 1.3	Innovation Credit	1		1	
	ID 1.4	Innovation Credit	1			1
	ID 2	LEED accredited Designer	1	1		
		SUBTOTAL - ID POINTS	5	2	2	1
		TOTAL POINTS	69	42	14	13

LEED Certified 26 - 32 Points
Silver 33 - 38 Points
Gold 39 - 51 Points
Patinum 52 or more Points

APPENDIX D – DESIGNER VENTILATION RATES

Room Information						Hood calculation					Airflow		
Level	Room Name	Room No.	SF	Occup.	Clg. Hgt.	# Large Hoods	Hood L.F.	# Small Hoods	Hood L.F.	Hood CFM (150 CFM/L.F.)	Design Airflow (CFM)	Design Airflow w/ Perimeter (CFM)	Min Set Point 27% of Max (CFM)
1	Lounge	[illegible]	400 NSF		[illegible]						330.0	330.0	82.5
1	Vending	[illegible]	186 NSF		[illegible]						126.0	138.6	34.7
1	Bio Tech Office	[illegible]	100 NSF	1	[illegible]						75.0	82.5	20.6
1	Animal Breeding	[illegible]	50 NSF		[illegible]						213.0	235.1	58.8
1	Animal Holding	[illegible]	50 NSF		[illegible]						218.5	240.4	60.1
1	Green House	[illegible]	744 NSF		[illegible]						558.0	613.8	153.5
1	Head House/Storage	[illegible]	294 NSF		[illegible]						220.5	242.6	60.6
1	Biology Stock Room	[illegible]	746 NSF		[illegible]						591.0	617.1	154.3
1	Classroom (Standard)	[illegible]	713 NSF	30	[illegible]						552.0	552.0	138.0
1	Classroom (Standard)	[illegible]	970 NSF	50	[illegible]						869.2	869.2	217.3
1	Classroom (Standard)	[illegible]	636 NSF	30	[illegible]						533.2	533.2	133.3
1	Environmental Science Lab Recitation	[illegible]	612 NSF	24	[illegible]						459.0	459.0	114.7
1	Anatomy/ Physiology Lab Recitation	[illegible]	612 NSF	24	[illegible]						459.0	459.0	114.7
1	Environmental Recitation	[illegible]	612 NSF	24	[illegible]						459.0	459.0	114.7
1	Biology Lab Preparation	[illegible]	532 NSF		[illegible]	2	6.0			1,800.0	1,800.0	1,980.0	495.0
1	Environmental Science Lab	[illegible]	1285 NSF	24	[illegible]	1	6.0			900.0	1,555.2	1,710.7	427.7
1	Environmental Science Lab	[illegible]	1,285 NSF	24	[illegible]	1	6.0			900.0	1,555.2	1,710.7	427.7
1	Volatile Chemistry Storage & Dispensary	[illegible]	119 NSF		[illegible]			1.0	4.0	0.0	142.0	167.1	38.3
1	Anatomy/ Physiology Lab	[illegible]	1285 NSF	24	[illegible]					0.0	1,555.2	1,710.7	427.7
1	Anatomy/ Physiology Lab	[illegible]	1285 NSF	24	[illegible]					0.0	1,555.2	1,710.7	427.7
1	General Biology Lab	[illegible]	1,285 NSF	24	[illegible]	1	6.0			900.0	1,555.2	1,710.7	427.7
1	[illegible]	[illegible]	103 NSF		[illegible]						77.3	85.0	21.2
1	Server Room	[illegible]	188 NSF		[illegible]						141.0	155.1	38.8
1	IT Staging & Repair	[illegible]	307 NSF		[illegible]						253.3	283.3	63.3
1	Hazardous Material Waste	[illegible]	117 NSF		[illegible]						87.8	96.5	24.1
1	Hazardous Material Supply	[illegible]	117 NSF		[illegible]						87.8	96.5	24.1
1	Receiving	[illegible]	604 NSF		[illegible]						453.0	498.3	124.6
1	[illegible]	[illegible]	167 NSF		[illegible]						125.3	137.8	34.4
1	Conference Room	[illegible]	286 NSF	12	[illegible]						214.5	236.0	59.0
	Totals		15,598	315		5		1		4,500	16,739.6	18,030.4	

Room Information						Hood calculation					Airflow			
Level	Room Name	Room No.	SF	Occup.	Clg. Hgt.	# Large Hoods	Hood L.F.	# Small Hoods	Hood L.F.	Hood CFM (150 CFM/L.F.)	Design Airflow (CFM)	Design Airflow w/ Perimeter (CFM)	Min Set Point 25% of Max (CFM)	Reheat (kBtu/hr)
2	Bio Tech Office	A202a	113 NSF	1	9.50						84.8	93.2	23.3	2.0
2	Bio Tech Office	A206a	100 NSF	1	9.50						75.0	82.5	20.6	1.8
2	Bio Part-Time Faculty Office	A207a	115 NSF	2	9.50						86.3	94.9	23.7	2.0
2	Bio Part-Time Faculty Office	A207b	115 NSF	2	9.50						86.3	94.9	23.7	2.0
2	Bio Part-Time Faculty Office	A207c	115 NSF	2	9.50						86.3	94.9	23.7	2.0
2	Bio Part-Time Faculty Office	A207d	115 NSF	2	9.50						86.3	94.9	23.7	2.0
2	Bio Faculty Office	A208a	100 NSF	1	9.50						75.0	82.5	20.6	1.8
2	Bio Faculty Office	A208b	100 NSF	1	9.50						75.0	82.5	20.6	1.8
2	Bio Faculty Office	A208c	100 NSF	1	9.50						75.0	82.5	20.6	1.8
2	Bio Faculty Office	A208d	100 NSF	1	9.50						75.0	82.5	20.6	1.8
2	Bio Faculty Office	A208e	100 NSF	1	9.50						75.0	82.5	20.6	1.8
2	Bio Faculty Office	A208f	100 NSF	1	9.50						75.0	82.5	20.6	1.8
2	Bio Faculty Office	A208g	100 NSF	1	9.50						75.0	82.5	20.6	1.8
2	Bio Faculty Office	A208h	100 NSF	1	9.50						75.0	82.5	20.6	1.8
2	Bio Faculty Office	A208i	100 NSF	1	9.50						75.0	82.5	20.6	1.8
2	Bio Faculty Office	A208j	100 NSF	1	9.50						75.0	82.5	20.6	1.8
2	Bio Faculty Office	A208k	100 NSF	1	9.50						75.0	82.5	20.6	1.8
2	Bio Faculty Office	A208l	100 NSF	1	9.50						75.0	82.5	20.6	1.8
2	Bio Faculty Office	A208m	100 NSF	1	9.50						75.0	82.5	20.6	1.8
2	Bio Faculty Office	A208n	100 NSF	1	9.50						75.0	82.5	20.6	1.8
2	Bio Faculty Office	A208o	100 NSF	1	9.50						75.0	82.5	20.6	1.8
2	Bio Faculty Office	A208p	100 NSF	1	9.50						75.0	82.5	20.6	1.8
2	Bio Faculty Office	A208q	100 NSF	1	9.50						75.0	82.5	20.6	1.8
2	Bio Faculty Office	A208r	100 NSF	1	9.50						75.0	82.5	20.6	1.8
2	Bio Administrative Assistant	A209	112 NSF	1	9.50						84.0	92.4	23.1	2.0
2	Bio Chair	A210	237 NSF	1	9.50						177.8	195.5	48.9	4.2
2	Bio Receptionist	A211	214 NSF	1	9.50						160.5	176.6	44.1	3.8
2	Bio Work Room	A213	100 NSF		9.50						75.0	82.5	20.6	1.8
2	Process Room	A222a	100 NSF	1	9.50						75.0	82.5	20.6	1.8
2	Bio Tech Office	B226a	100 NSF	1	9.50						75.0	82.5	20.6	1.8
2	Bio Study / Reference	B229	367 NSF	12	9.50						275.3	302.8	75.7	6.5
2	Bio Tech Office	B232a	100 NSF	1	9.50						75.0	82.5	20.6	1.8
2	Microbiology Genetics Recitation	A204	664 NSF	24	9.50						464.3	464.3	116.1	10.0
2	Environmental Recitation	B224	635 NSF	24	9.50						457.3	457.3	114.3	9.9
2	Biology Recitation	B228	638 NSF	24	9.50						458.0	458.0	114.5	9.9
2	Environmental Recitation	B234	623 NSF	24	9.50						454.4	454.4	113.6	9.8
2	Microbiology Lab Preparation	A202	985 NSF		9.50	2	6.0			1,800.0	1,800.0	1,980.0	495.0	42.8
2	Biology Lab Preparation	A206	524 NSF		9.50	2	6.0			1,800.0	1,800.0	1,980.0	495.0	42.8
2	Biology Lab Preparation	B226	525 NSF		9.50	2	6.0			1,800.0	1,800.0	1,980.0	495.0	42.8
2	Biology Lab Preparation	B232	525 NSF		9.50	2	6.0			1,800.0	1,800.0	1,980.0	495.0	42.8
2	Microbiology Lab	A203	1,285 NSF	24	9.50	4	6.0			3,600.0	3,600.0	3,960.0	990.0	85.5
2	Genetics Lab	A205	1,285 NSF	24	9.50	3	6.0			2,700.0	2,700.0	2,970.0	742.5	64.2
2	Biology Student / Facility Project Lab	A222	622 NSF	12	9.50			1	4.0	600.0	746.4	821.0	205.3	17.7
2	Cold Room	A222b	211 NSF	1	9.50			2	4.0	1,200.0	1,200.0	1,320.0	330.0	28.5
2	General Biology Lab	B223	1,281 NSF	24	9.50	1	6.0			900.0	1,537.2	1,690.9	422.7	36.5
2	General Biology Lab	B225	1,284 NSF	24	9.50	1	6.0			900.0	1,540.8	1,694.9	423.7	36.6
2	General Biology Lab	B227	1,299 NSF	24	9.50	1	6.0			900.0	1,558.8	1,714.7	428.7	37.0
2	General Biology Lab	B230	1,287 NSF	24	9.50	3	6.0			2,700.0	2,700.0	2,970.0	742.5	64.2
2	General Biology Lab	B231	1,282 NSF	24	9.50	3	6.0			2,700.0	2,700.0	2,970.0	742.5	64.2
2	General Biology Lab	B233	1,282 NSF	24	9.50	2	6.0			1,800.0	1,800.0	1,980.0	495.0	42.8
2	General Biology Lab	B235	1,281 NSF	24	9.50	2	6.0			1,800.0	1,800.0	1,980.0	495.0	42.8
2	Bio File Storage	A212	100 NSF		9.50						75.0	82.5	20.6	1.8
	Totals		21,421	371		28		3		27,000	33,844.4	37,045.4		

Room Information						Hood calculation					Airflow			
Level	Room Name	Room No.	SF	Occup.	Clg. Hgt.	# Large Hoods	Hood L.F.	# Small Hoods	Hood L.F.	Hood CFM (150 CFM/L.F.)	Design Airflow (CFM)	Design Airflow w/ Perimeter (CFM)	Min Set Point 25% of Max (CFM)	Reheat (kBtu/hr)
3	Chem Tech Office	A306a	100 NSF	1	9.50						75.0	82.5	20.6	1.8
3	Chem Part-Time Faculty Office	A307a	115 NSF	2	9.50						86.3	94.9	23.7	2.0
3	Chem Part-Time Faculty Office	A307b	115 NSF	2	9.50						86.3	94.9	23.7	2.0
3	Chem Part-Time Faculty Office	A307c	115 NSF	2	9.50						86.3	94.9	23.7	2.0
3	Chem Part-Time Faculty Office	A307d	115 NSF	2	9.50						86.3	94.9	23.7	2.0
3	Chem Faculty Office	A308a	100 NSF	1	9.50						75.0	82.5	20.6	1.8
3	Chem Faculty Office	A308b	100 NSF	1	9.50						75.0	82.5	20.6	1.8
3	Chem Faculty Office	A308c	100 NSF	1	9.50						75.0	82.5	20.6	1.8
3	Chem Faculty Office	A308d	100 NSF	1	9.50						75.0	82.5	20.6	1.8
3	Chem Faculty Office	A308e	100 NSF	1	9.50						75.0	82.5	20.6	1.8
3	Chem Faculty Office	A308f	100 NSF	1	9.50						75.0	82.5	20.6	1.8
3	Chem Faculty Office	A308g	100 NSF	1	9.50						75.0	82.5	20.6	1.8
3	Chem Faculty Office	A308h	100 NSF	1	9.50						75.0	82.5	20.6	1.8
3	Chem Faculty Office	A308i	100 NSF	1	9.50						75.0	82.5	20.6	1.8
3	Chem Faculty Office	A308j	100 NSF	1	9.50						75.0	82.5	20.6	1.8
3	Chem Faculty Office	A308k	100 NSF	1	9.50						75.0	82.5	20.6	1.8
3	Chem Faculty Office	A308l	100 NSF	1	9.50						75.0	82.5	20.6	1.8
3	Chem Faculty Office	A308m	100 NSF	1	9.50						75.0	82.5	20.6	1.8
3	Chem Faculty Office	A308n	100 NSF	1	9.50						75.0	82.5	20.6	1.8
3	Chem Faculty Office	A308o	100 NSF	1	9.50						75.0	82.5	20.6	1.8
3	Chem Faculty Office	A308p	100 NSF	1	9.50						75.0	82.5	20.6	1.8
3	Chem Faculty Office	A308q	100 NSF	1	9.50						75.0	82.5	20.6	1.8
3	Chem Admin	A309	112 NSF	1	9.50						84.0	92.4	23.1	2.0
3	Chem Chair	A310	237 NSF	1	9.50						177.8	195.5	48.9	4.2
3	Chem Receptionist	A311	214 NSF	1	9.50						160.5	176.6	44.1	3.8
3	Chem Work Room	A313	100 NSF		9.50						75.0	82.5	20.6	1.8
3	Chem Tech Office	A322a	100 NSF	1	9.50						75.0	82.5	20.6	1.8
3	Chemistry Oxbridge Room	B329	367 NSF	12	9.50						275.3	302.8	75.7	6.5
3	Tech Office	B332a	100 NSF	1	9.50						75.0	82.5	20.6	1.8
3	Chemistry Recitation	A304	701 NSF	24	9.50						473.2	473.2	118.3	10.2
3	Chemistry Recitation	A306	632 NSF	24	9.50						457.3	457.3	114.3	9.9
3	Chemistry Recitation	B324	635 NSF	24	9.50						127.1	127.1	31.8	2.7
3	Chemistry Lab Prep	A322	620 NSF		9.50			1.0	4.0	600.0	744.0	818.4	204.6	17.7
3	Chemistry / Stock Room	A322b	202 NSF		9.50			1.0	4.0	600.0	600.0	660.0	165.0	14.3
3	Chemistry Stock Room	B326	642 NSF		9.50			1.0	4.0	600.0	770.4	847.4	211.9	18.3
3	Organic Chemistry Instrumentation	B328	640 NSF		9.50			1.0	4.0	600.0	768.0	844.8	211.2	18.2
3	Chemistry Prep	B332	502 NSF		9.50			1.0	4.0	600.0	602.4	662.6	165.7	14.3
3	Chem Lab Prep	B334	525 NSF		9.50			1.0	4.0	600.0	630.0	693.0	173.3	15.0
3	Chemistry Student / Facility Project Lab & Prep	A302	1,202 NSF		9.50			2.0	4.0	1,200.0	1,442.4	1,586.6	396.7	34.3
3	General Chemistry Lab	A303	1,287 NSF	24	9.50	6	6.0	1.0	4.0	6,000.0	6,000.0	6,600.0	1,650.0	142.6
3	General Chemistry Lab	A305	1,285 NSF	24	9.50	6	6.0	1.0	4.0	6,000.0	6,000.0	6,600.0	1,650.0	142.6
3	General Chemistry Lab	B323	1,285 NSF	24	9.50	6	6.0	1.0	4.0	6,000.0	6,000.0	6,600.0	1,650.0	142.6
3	General Chemistry Lab	B325	1,286 NSF	24	9.50	6	6.0	1.0	4.0	6,000.0	6,000.0	6,600.0	1,650.0	142.6
3	Organic Chemistry Lab	B327	1,328 NSF	24	9.50	5	6.0	1.0	4.0	5,100.0	5,100.0	5,610.0	1,402.5	121.2
3	Organic Chemistry Lab	B330	1,287 NSF	24	9.50	7	6.0	1.0	4.0	6,900.0	6,900.0	7,590.0	1,897.5	163.9
3	Organic Chemistry Lab	B331	1,308 NSF	24	9.50	8	6.0	1.0	4.0	7,800.0	7,800.0	8,580.0	2,145.0	185.3
3	General Chemistry Lab	B333	1,284 NSF	24	9.50	6	6.0	1.0	4.0	6,000.0	6,000.0	6,600.0	1,650.0	142.6
3	General Chemistry Lab	B335	1,282 NSF	24	9.50	6	6.0	1.0	4.0	6,000.0	6,000.0	6,600.0	1,650.0	142.6
3	Chem File	A312	100 NSF		9.50						75.0	82.5	20.6	1.8
	Totals		21,523	331		56		17		60,600	65,107.3	71,512.2		

Room Information						Hood calculation					Airflow			
Level	Room Name	Room No.	SF	Occup.	Clg. Hgt.	# Large Hoods	Hood L.F.	# Small Hoods	Hood L.F.	Hood CFM (150 CFM/L.F.)	Design Airflow (CFM)	Design Airflow w/ Perimeter (CFM)	Min Set Point 25% of Max (CFM)	Reheat (kBtu/hr)
4	Phy/EE Tech Office	A402a	98 NSF	1	9.50						73.5	80.9	20.2	1.7
4	Phy/EE Part-Time Faculty Office	A407a	115 NSF	2	9.50						86.3	94.9	23.7	2.0
4	Phy/EE Part-Time Faculty Office	A407b	115 NSF	2	9.50						86.3	94.9	23.7	2.0
4	Phy/EE Part-Time Faculty Office	A407c	115 NSF	2	9.50						86.3	94.9	23.7	2.0
4	Phy/EE Part-Time Faculty Office	A407d	115 NSF	2	9.50						86.3	94.9	23.7	2.0
4	Phy/EE Faculty Office	A408a	100 NSF	1	9.50						75.0	82.5	20.6	1.8
4	Phy/EE Faculty Office	A408b	100 NSF	1	9.50						75.0	82.5	20.6	1.8
4	Phy/EE Faculty Office	A408c	100 NSF	1	9.50						75.0	82.5	20.6	1.8
4	Phy/EE Faculty Office	A408d	100 NSF	1	9.50						75.0	82.5	20.6	1.8
4	Phy/EE Faculty Office	A408e	100 NSF	1	9.50						75.0	82.5	20.6	1.8
4	Phy/EE Faculty Office	A408f	100 NSF	1	9.50						75.0	82.5	20.6	1.8
4	Phy/EE Faculty Office	A408g	100 NSF	1	9.50						75.0	82.5	20.6	1.8
4	Phy/EE Faculty Office	A408h	100 NSF	1	9.50						75.0	82.5	20.6	1.8
4	Phy/EE Faculty Office	A408i	100 NSF	1	9.50						75.0	82.5	20.6	1.8
4	Phy/EE Faculty Office	A408j	100 NSF	1	9.50						75.0	82.5	20.6	1.8
4	Phy/EE Faculty Office	A408k	100 NSF	1	9.50						75.0	82.5	20.6	1.8
4	Phy/EE Faculty Office	A408l	100 NSF	1	9.50						75.0	82.5	20.6	1.8
4	Phy/EE Faculty Office	A408m	100 NSF	1	9.50						75.0	82.5	20.6	1.8
4	Phy/EE Faculty Office	A408n	100 NSF	1	9.50						75.0	82.5	20.6	1.8
4	Phy/EE Faculty Office	A408o	100 NSF	1	9.50						75.0	82.5	20.6	1.8
4	Phy/EE Faculty Office	A408p	100 NSF	1	9.50						75.0	82.5	20.6	1.8
4	Phy/EE Faculty Office	A408q	100 NSF	1	9.50						75.0	82.5	20.6	1.8
4	Phy/EE Admin	A409	112 NSF	1	9.50						84.0	92.4	23.1	2.0
4	Phy/EE Chair	A410	237 NSF	1	9.50						177.8	195.5	48.9	4.2
4	Phy/EE Receptionist	A411	214 NSF	1	9.50						160.5	176.6	44.1	3.8
4	Phy/EE Work Room	A413	100 NSF		9.50						75.0	82.5	20.6	1.8
4	Phy/EE Tech Office	A422a	100 NSF	1	9.50						75.0	82.5	20.6	1.8
4	Tech Office	B427a	101 NSF	1	9.50						75.8	83.3	20.8	1.8
4	EE / Phy Oxbridge Room	B429	368 NSF	8	9.50						276.0	303.6	75.9	6.6
4	Astronomy Computer Lab	A404	665 NSF	24	9.50						464.5	464.5	116.1	10.0
4	Engineering Science Computer	B424	848 NSF	24	9.50						508.8	508.8	127.2	11.0
4	Engineering Science Computer Lab / Studio	B425a	414 NSF	12	9.50						252.0	252.0	63.0	5.4
4	Engineering Science Computer	B425b	855 NSF	24	9.50						510.5	510.5	127.6	11.0
4	Physics Recitation	B432	630 NSF	24	9.50						456.1	456.1	114.0	9.9
4	Geosciences Lab Prep Room	A402	768 NSF		9.50					0.0	921.6	1,013.8	253.4	21.9
4	Geosciences Reference / Workroom	A402b	311 NSF		9.50					0.0	373.2	410.5	102.6	8.9
4	Lapidary / Power Tool Room	A406	630 NSF		9.50					0.0	756.0	831.6	207.9	18.0
4	Physics Lab Prep Room	A422	834 NSF		9.50	1	6.0			900.0	1,000.8	1,100.9	275.2	23.8
4	Physics Student Workroom	B423a	414 NSF		9.50					0.0	496.8	546.5	136.6	11.8
4	Engineering Lab Shop	B427	1,068 NSF		9.50					0.0	1,281.6	1,409.8	352.4	30.5
4	Engineering Prep Lab	B428a	428 NSF		9.50					0.0	513.6	565.0	141.2	12.2
4	Engineering Student/Faculty Project Lab	B428b	640 NSF		9.50					0.0	768.0	844.8	211.2	18.2
4	Astronomy / Physical Science Lab	A403	1,287 NSF	24	9.50					0.0	1,544.4	1,698.8	424.7	36.7
4	Astronomy / Physical Science Lab	A405	1,287 NSF	24	9.50					0.0	1,544.4	1,698.8	424.7	36.7
4	EE / Phy Lab	B430	1,287 NSF	24	9.50					0.0	1,544.4	1,698.8	424.7	36.7
4	General Physics Lab	B431	1,285 NSF	24	9.50					0.0	1,542.0	1,696.2	424.1	36.6
4	General Physics Lab	B433	1,284 NSF	24	9.50					0.0	1,540.8	1,694.9	423.7	36.6
4	Geology / Collections Room	B434	638 NSF	6	9.50					0.0	765.6	842.2	210.5	18.2
4	Geology / Meterology Lab	B435	1,284 NSF	24	9.50					0.0	1,540.8	1,694.9	423.7	36.6
4	Phy/EE File	A412	100 NSF		9.50						75.0	82.5	20.6	1.8
4	Physics / Engineering Stock Room	B423b	855 NSF		9.50						641.3	705.4	176.3	15.2
4	Laptop Storage	B426a	99 NSF		9.50						74.3	81.7	20.4	1.8
4	Engineering Project Storage	B426b	312 NSF		9.50						234.0	257.4	64.4	5.6
			0	0		1				900	20,943.4	22,818.6		

APPENDIX E – SCHEMATICS