TECHNICAL REPORT 3

The New Offices for RLPS Architects

Lancaster, PA

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Mechanical Option

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Submitted 11.12.2012

Executive Summary

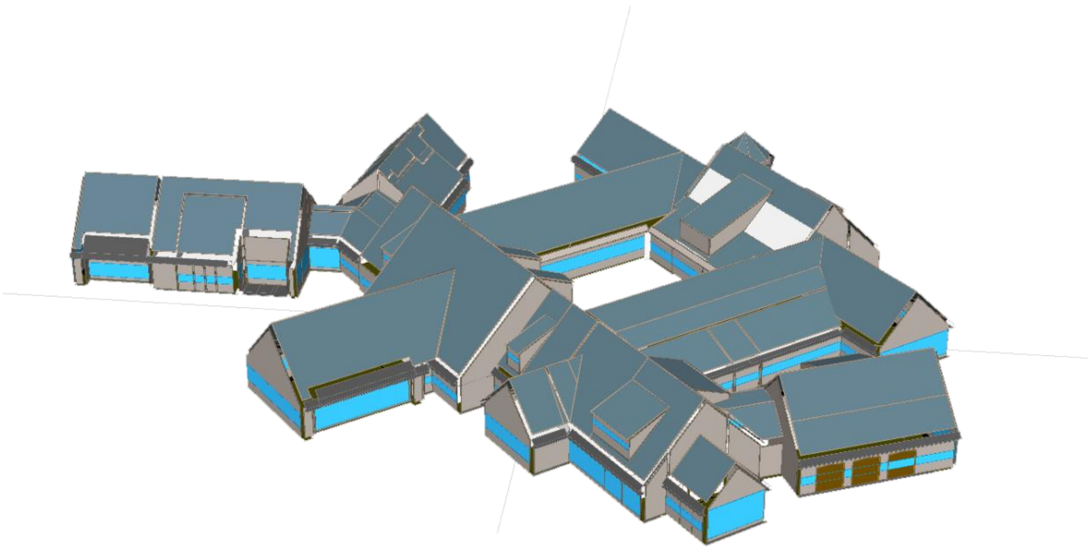
The objective of this report is to review the mechanical systems for the RLPS New Office Building. In collusion with previous technical assignments, this report discusses the mechanical system designs, operation, and energy consumption.

The overall mechanical design for the new office building is very sustainable design that uses a geothermal well that is connected to twenty eight water source heat pumps. These pumps, which are organized into smaller groups referred to in this report as 'hubs' are responsible for conditioning air for all of the zones throughout the building. Outdoor air for the building is provided by four large ventilation units that supply the heat pumps. Additionally, outdoor air rates can be achieved by a natural ventilation design when proper conditions are met and reported the buildings advanced BAS system by a number of sensors.

The primary energy source for mechanical equipment in the new office building is electricity. Research of the new office's surrounding area as well as the design documents for this project show that other fuel sources and design alternatives were considered. The alternatives and information from this report as well as previous reports will be considered and used for all future project assignments.

Building Overview

Building Description



The New Office Building for RLPS Architects is a new construction office building located in Lancaster County, PA. It totals 22,500 square feet which is split between one full ground level and a small mezzanine area, to be used for storage. The use of this building is primarily office spaces, studio space, or group work areas. Some unique features to the building include a bistro area and adjoined living room space. Additionally, there is an interior courtyard complete with a water feature. Overall, the building is classified as Business with an occupancy capacity just short of 230 people. The expected completion date is January 2013.

Architecture

The site of the building is primarily independent, but is situated in a more residential area. The new office has some styles of a colonial home, but with a modern feel. One focus is an interior courtyard with water feature that is visible from all of the studio spaces.

Occupant and Project Team

Owner & Architects: RLPS Architects Ltd.

General Contractor: Warfel Construction

Mechanical & Electrical Engineers: Reese Engineering Inc.

Structural Engineers: Zug & Associates, Ltd. Structural Engineers.

Civil Engineers; Harbor Engineering

Surveyor: Herbert, Rowland, & Grubic, Inc.

Landscaping: RLPS Architects Ltd.

Design Objectives and Requirements

1.1 Mechanical System Design Objectives

The overall objective of the mechanical system for the new office was to have a sustainable design. Though this is the case for most all of new construction, RLPS Architects really strived for their office to be an example of what they offer as an architecture firm. Minutes from the design team sustainability meeting show that a large number of ideas were considered in varying combinations; this includes photovoltaic cells, grey water storage cisterns, a natural 'cool tower' design, and window operability. Some of these ideas were ultimately selected these include an East-West building orientation to maximize day lighting and solar heat gain control. An additional major selection includes a ground source well system. Discussions with the project engineer indicated that RLPS Architects had not made a final decision on achieving a LEED certification, but designs and equipment selections were to be made as though LEED certification was the goal until a final decision was made.

Whether or not the new office can achieve a LEED certification will be discussed later in this report.

1.2 Mechanical System Design Requirements

The mechanical system design was primarily required to gain approval to the Manheim Township Code Compliance Plan Review, which is performed by a third party reviewer. The Plan Review in this area requires all buildings to acquire appropriate zoning from Lancaster County . Additionally, the design must comply with either International Energy Conservation Code 2009 or ASHRAE Standard 90.1 from 2007. The engineering team selected to use ASHRAE Standard 90.1 as it could be used for a LEED 2009 certification. Currently the Code Compliance Plan Review is still being completed, but the first round of official responses indicates only minor changes or clarifications are required.

Site Energy Sources

1.1 Source Options

With the site being located in Lancaster, PA there are a variety of energy source providers, however there is a limit to the types of energy sources. The only confirmed energy source options are electricity, fuel oil, and natural gas.

A variety of source providers were found for each fuel service, but the values in Figure 1 below were found to be the lowest price per unit. These values will be used as a general guide line for preliminary studies if an alternative fuel source is chosen as part of a depth or breadth study for the new office building. With that in mind, let it be noted that some factors were discounted for simplicity. These factors include delivery fees, variables due to contract length, and initial cost. The values below should are the 'price to compare' numbers in dollars per unit of fuel source.

Source Type	Provider	Price to Compare	Notes
Electricity	Pennsylvania Power & Light	0.10364 [$/kWh]	Commercial
Natural Gas	UGI Utilities Inc.	5.9076 [$/mcf]	Commercial
	UGI Utilities Inc.	5.7500 [$/mcf]	Commercial w. AC
Fuel Oil	Mid Atlantic Oil	3.712 [$/gal]	Commercial

Figure 1

Design Conditions

1.1 Environmental Design Criteria

The design engineer, using ASHRAE Standards developed a number of design criteria. The table below, Figure 2, is a summary provided by the project engineer for both indoor and outdoor design criteria.

Environmental Design Criteria				
Outdoor Design Conditions:				
Winter: 0°F db		Summer: 95°F db; 76°F wb		
Indoor Design Conditions:				
Area	Summer Temperature	Winter Temperature	Relative Humidity	Minimum Outside Air
Corridors	78°F db	68°F db	50%	0.05 cfm/sq. ft.
Assembly Areas	78°F db	68°F db	50%	15 cfm/person
Offices	78°F db	68°F db	50%	20 cfm/person
Public Toilet Rooms	78°F db	68°F db	50%	Note 1
Support Areas	78°F db	68°F db	50%	20 cfm/person
Meeting Rooms	78°F db	68°F db	50%	20 cfm/person
Fitness Areas	78°F db	68°F db	50%	25 cfm/person
Note 1: Outside Air will be based on exhaust requirements for the space.				

Figure 2

Design Ventilation Requirements

1.1 Design Values

The table below, Figure 3, lists the project engineer's design ventilation. These values were simulated in a model crated by the project engineer that used the baseline building with a geothermal well. Design documents include several alternates, several of which include a natural ventilation system. The system selected will include automated dampers that are controlled by the BAS and would require additional sensors for outdoor temperature and humidity. A form of these alternate designs may manifest itself in the project proposal and could drastically change these numbers.

Outdoor Supply Air [CFM]	Outdoor Supply [%]	Outdoor Supply Air [CFM/SF]
6552	47	0.261

Figure 3

Design Heating and Cooling Loads

1.1 Load Analysis

To calculate the cooling and heating loads Carrier Corporation's Hourly Analysis Program (HAP) was used. As discussed in Technical assignment 2, a number of assumptions were made.

The project engineer provided a series of energy models created in Bentley's eQuest platform. The model designed as a baseline with a geothermal well integrated was chosen as a comparison as it is most similar to the model created for this project. The engineer's other models included exterior shading tests or different air0side setups that would not be consistent with the HAP model.

Figure 4 below is a table displaying the design values for each model. The values vary greatly which is a concern. Some of the differences stem from the HAP model using inputs from standards like from organizations like ASHRAE and IES whereas more specific values could have been defined by the project engineer. Additionally, the eQuest model includes 3D geometries which would account for shading gains and losses. Furthermore, the eQuest model omitted internal loads like artificial lighting, people, and equipment. This would cause a great difference total loads. In summation the models are not exact comparisons, it is more akin to comparing apples and oranges.

	Designed (eQUEST)	Modeled (HAP v4.6)
Cooling [tons]	140	47.0
Cooling [SF/ton]	179	460
Cooling [cfm/ton]	132	N/A
Cooling [Btuh/SF]	67.1	26.1
Heating [Btuh/SF]	78.0	21.0

Figure 4

Energy Usage

1.1 Component Energy Consumption

In addition to heating and cooling loads the Hourly Analysis Program (HAP) also calculated energy usage. Table 5 below is a breakdown of the new offices energy by category and total energy usage. The project eQuest model did not include internal loads nor were any other schedule based energy consumption values, so comparisons cannot be made.

Operating History and metering is scheduled to begin in January 2013.

Components	Energy Used[kWh]	[kWh/SF]	[%]
Cooling Coil	549756	25.43	49.7
Heating Coil	352673	16.32	31.9
Loop Pump	34359	1.59	3.1
Lighting	79217	3.66	7.2
Elec. Equipment	89476	4.13	8.1
Total	1105491	18.5 weighted	100

Figure 5

Mechanical System Schematics

1.1 Overview

Figure 6 below is an outline of how the geothermal well is utilized. Depicted is the well, the pumps used to move the water to the heat pumps (P-1 and P-2) as well as sensors. The hubs of terminal heat pumps were simplified for this diagram.

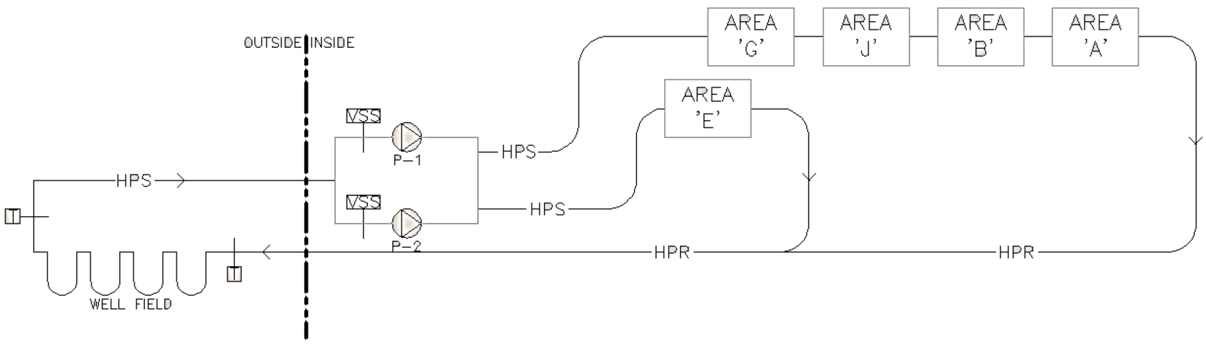


Figure 6

1.2 Water Side from the Hub Point of View

Figure 7 depicts Area 'E' which acts as a normal hub of heat pumps. Included are heat pumps 14 through 19, thermostats, a sensor relaying pressure differences to the VFD for pumps P-1 and P-2. The piping in the image includes hot water supply, hot water return, and a condensate line.

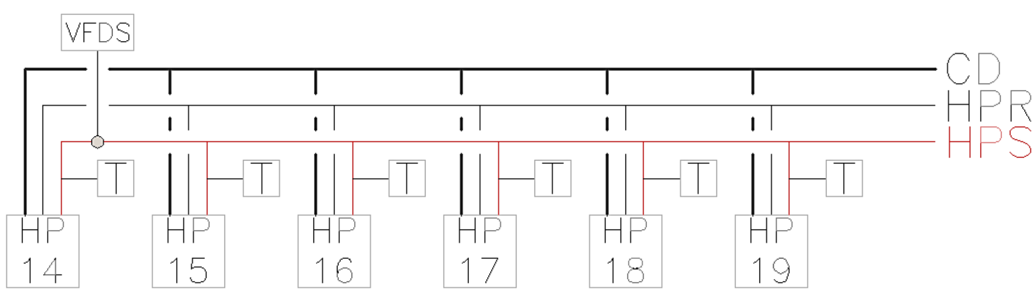


Figure 7

1.3 Air Side and Heat Pump Detail

Figure 8 is a simplified diagram of the mechanical system's air delivery. The heat pumps selected include an evaporative preconditioner, cooling coil, heating coil, and a supply fan. Additionally, temperature is measured before and after the heat pump for the building BAS. The outdoor air (OA) is from the ventilation units and the return air (RA) is used for heat recovery. In cases of heat pumps with flow rates of 2000 CFM or higher a smoke detector (Signified by the 'S' in a circle) is required for the return air. When alerted the BAS will initiate fire protection programs depending on the number of alarms.

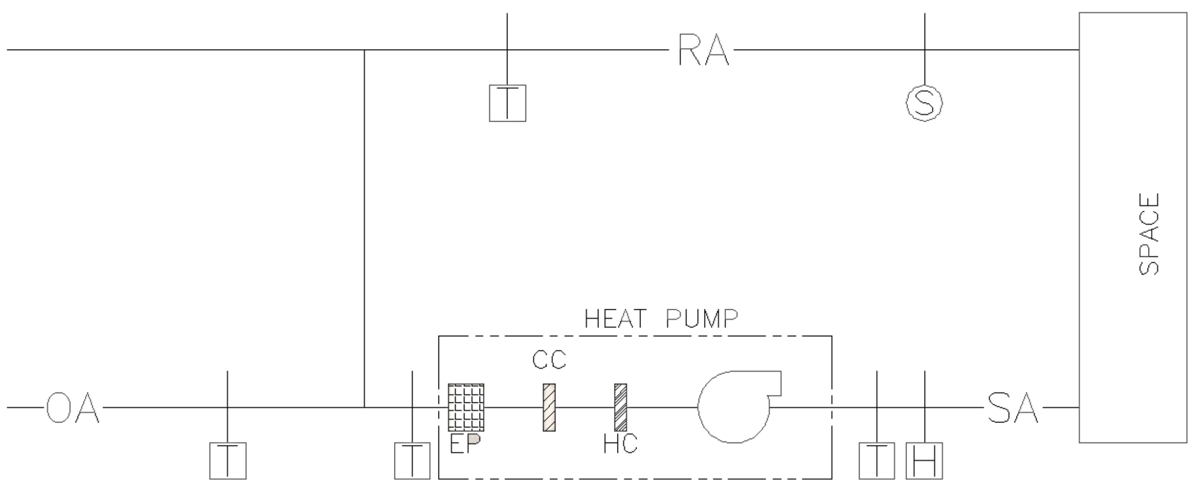


Figure 8

System Operation

1.1 Water Side

First, let it be noted that domestic water in the new office building is separate from any hydronic parts of the mechanical system. Domestic water has a connection the Lancaster Area Water Authority and uses two point of use water heaters located in the ground level mechanical space.

Additionally, there is a possibility of a grey water collection cistern that will also be separate from the hydronic systems.

Finally, any equipment mentioned in this section can be found in detail later in this report.

Now to discuss the system operation we can start at the geothermal well. In cooling mode the well will reject heat, in heating mode it gain heat. Once the water is conditioned it moves into mechanical room. From the mechanical room the water is then pumped to the various heat pumps throughout the building. The water is pumped by pumps P-1 and P-2 which use variable frequency drives as seen in Figure 6. These VFDs are controlled by the BAS with their frequency dependent on pressure sensors located prior to the last heat pump in Area A and Area E on the hot water supply. These sensors effectively measure the pressure at the end of each loop. As Figure 7 shows Area E is independent from the other mechanical hubs, while the other hubs act as a large loop, with Area A being the final hub.

Once the conditioned water is 'used' by the heat pump it continues in a return loop back to the geothermal well. This loop is still forced by pumps P-1 and P-2. Additionally, there is a condensate return line that leads back to the mechanical room to be conditioned for reuse in an expansion tank.. This condensate loop is forced by a condensate pump C-1. Figure 7 shows Area E. The other mechanicals hubs would look very similar. Omitted from Figure 7 is some air side equipment such as a ventilation unit, this was done for clarity in the diagram.

1.2 Air Side

The air side of the new office building is relatively simple once it is understood how the heat pumps use the geothermal well on the water side. For the air side, fresh air from the ventilation units combines with return air from the zone. The level of return air is managed by the building BAS which uses temperature sensors for the return air; the water temperature to the heat pump is also monitored. Once the air is mixed it is processed through the heat pump. First is an evaporative preconditioner to adjust humidity, followed by a cooling coil, heating coil, and supply fan. Each heat pump has a thermostat of incoming air and for the space that it serves. Figure 8 only shows outdoor air; as previously mentioned outdoor air is provided by the ventilation units. The four ventilation units are located in Areas A,E,G, and J, this means all of the hubs except for Area B has a ventilation unit to provide outdoor air to all of the heat pumps in the hub. Also depicted in Figure 8 is a smoke detector in return air ducts. It is specified that any heat pump with a flow rate over 2000 CFM requires a detector to alert the BAS.

Furthermore, it is specified that all restrooms, electrical rooms, and the mechanical space have independent exhaust fans and duct runs to the building exterior. Diagrams of these were omitted as they simple enough to describe.

Mechanical System Overhead

1.1 Space Usage

The new office building is very unique in its use of mechanical spaces. On the ground level there is a combined mechanical and electrical room that is just under 400 square feet. This room holds the pumps for the heat loop, a water softener, back up electrical instantaneous heaters, and other equipment that will be discussed later in this report. The only other mechanical space on the ground level is a 10 square foot closet that holds Heat Pump 13. This feat is only possible because of the utilization a large attic mechanical space, the use of underground ductwork in a few instances, and most of the ductwork being placed above acoustical drop ceilings.

The attic mechanical space consists of five main 'hubs' where equipment is placed in groups. Four of these hubs are interconnected by cat walks and can be accessed by a door from the mezzanine storage area. The fifth mechanical hub is isolated over the partners' offices and can be accessed by drop down stairs. The equipment found on each of these hubs will be discussed later in this report.

Figure 9 shows the building orientation. The letters correspond to different areas that will be used later in this report. This naming system was established by the project engineer and used for simplicity in comparing equipment.

Figure 9

Figure 10 depicts the ground level mechanical spaces in a black cross hatch. As previously mentioned there is very limited mechanical space. This space is found near the employee entrance on the east side.

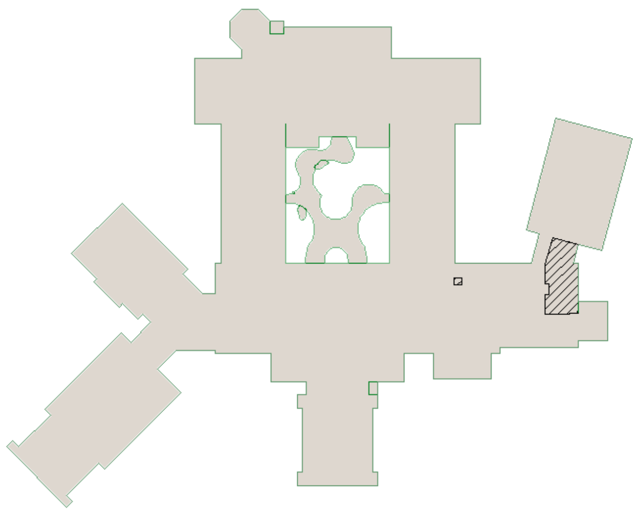


Figure 10

Figure 11 depicts the attic level mechanical spaces. The cross hatched areas the previously mentioned hubs. The pathways are the interconnecting catwalks, and the blue boxes represent entrances.

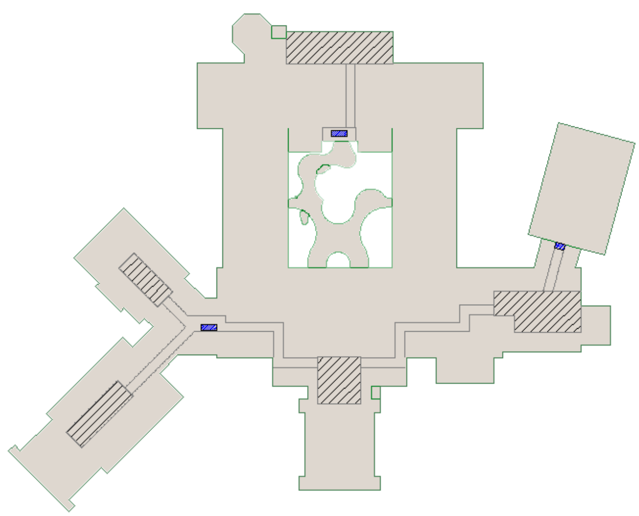


Figure 11

In total the mechanical space accounts 417 of the 22,718 square feet on the ground level or 1.8% of the area. On the mezzanine level 3221 of the 4885 square feet are for mechanical space or catwalks. This is 65.9% of the total area. However, the mezzanine level is considered unoccuapiable as it is either the mechanical space or the remaining storage space. In essence the usable area lost for mechanical equipment is uniquely minimal.

1.2 Mechanical System Costs

Figure 12 is a table of the initial cost breakdown for the mechanical systems in the new office building. The total is just above $1.3 Million with the largest portion being attributed heating and cooling piping. This is to be expected when using a geothermal well. Figure 13 is another table with the cost breakdown in percentages of the total cost.

Mechanical Item	Cost [$]	Mechanical Item	Cost [$]
Project Coordination	19,800*	Heating & Cooling Piping	280,456
Temporary Utilities	24,632	Air Handlers	46,037
Fire Protection	153,400	Heat Pumps	137,862
Plumbing Piping	99,736	Duct Work	182,241
Plumbing Specialties	73,642	Fans	24,049
Plumbing Fixtures	70,213	Air Devices	49,654
Plumbing Equipment	39,300	Building Controls	128,765
Total [$]		1,309,987	
Total [$/SF]		57.67	

*Project Coordination Costs were omitted from the total

Figure 12

Mechanical Item	Percentage of Cost [%]	Mechanical Item	Percentage of Cost [%]
Project Coordination	-	Heating & Cooling Piping	21.4
Temporary Utilities	1.9	Air Handlers	3.5
Fire Protection	11.7	Heat Pumps	10.5
Plumbing Piping	7.6	Duct Work	13.9
Plumbing Specialties	5.6	Fans	1.8
Plumbing Fixtures	5.4	Air Devices	3.8
Plumbing Equipment	3.0	Building Controls	9.8
Total Cost [$]		1,309,987	

Figure 13

LEED Analysis

1.1 LEED 2009 Evaluation

A LEED 2009 evaluation was performed for this project. The LEED 2009 Project checklist for New Construction. Since the project owner has not specified a level of LEED achievement yet, it was assumed that basic LEED certification was the only requirement. Let it be noted that only points that could be confirmed in the project specifications or project teams' sustainability discussions were awarded. The project has the ability to earn more credits than the ones listed below, but has not indicated a definite attempt at the other credits.

The following tables makeup the evaluation of LEED 2009 certification. The 'intent' of each credit is directly from the USGBC.

Sustainable Sites	Points: 7/26	
Credit	Action	Points
SS Prerequisite 1: Construction Activity Pollution Prevention Intent: To reduce pollution from construction activities by controlling soil erosion, waterway sedimentation and airborne dust generation.		N/A
SS Credit 2: Development of Density and Community Connectivity Intent: To channel development to urban areas with existing infrastructure, protect greenfields, and preserve habitat and natural resources.	Option 2: The new office building is located across the street from a residential neighborhood. Additionally, it provides pedestrian access to the Oregon Pike and a great number of basic services.	5
SS Credit 8: Light Pollution Reduction Intent: To minimize light trespass from the building and site, reduce sky-glow to increase night sky access, improve nighttime visibility through the glare reduction and reduce development impact from lighting on nocturnal environments.	Option 1: Non-essential interior lighting has been designed for automatic lighting control. The exterior lighting has a simulated power density of 0.056 [W/SF] which is below the LEED allowable of 0.12 [W/SF].	1

Water Efficiency	Points: 5/10	
Credit	Action	Points
WE Prerequisite 1: Water Use Reduction Intent: To reduce pollution from construction activities by controlling soil erosion, waterway sedimentation and airborne dust generation.		N/A
WE Credit 2: Innovative Wastewater Technologies Intent: To reduce wastewater generation and	The utilization of dual flush water closets has lowered the water consumption of the new office building. Additionally, an estimated 75,777 gallons of rain water	2

potable water demand while increasing the local aquifer recharge.	reuse helped qualify the building for 2 points.	
WE Credit 3: Water Use Reduction Intent: To further increase water efficiency within buildings to reduce burden on municipal water supply and wastewater systems.	High efficiency fixtures were selected across the building. Current calculations by the project engineer indicate a 36% water savings, which is more than the required 35% for 3 points.	3

Energy & Atmosphere	Points:7/35	
Credit	Action	Points
EA Prerequisite 1: Fundamental Commissioning of Building Energy Systems Intent: To verify that the project's energy-related systems are installed, and calibrated to perform according to the owner's project requirements, basis of design and construction documents.		N/A
EA Prerequisite 2: Minimum Energy Performance Intent: To establish the minimum level of energy efficiency for the proposed building and systems to reduce the environmental and economic impacts associated with excessive energy use.		N/A
EA Prerequisite 3: Fundamental Refrigerant Management Intent: To reduce stratospheric ozone depletion.		N/A
EA Credit 1: Optimize Energy Performance Intent: To achieve increasing levels of energy performance beyond the prerequisite standard to reduce environmental and economic impacts associated with excessive energy use.	The design engineer use the Performance Rating Method, defined by ASHRAE 90.1-2004, accepted by LEED to calculate predicted energy performance.	5/10
EA Credit 4: Enhanced Refrigerant Management Intent: To reduce ozone depletion and support early compliance with the Montreal Protocol while minimizing direct contributions to climate change.	Option 2: The heat pumps selected were also selected with a refrigerant management provisions. The overall refrigerant impact per ton is 71.6, less than the maximum 100 for the credit.	2

Materials & Resources	Points: xx/14	
Credit	Action	Points
MR Prerequisite 1: Storage and Collection of Recyclables Intent: To facilitate the reduction of waste generated by building occupants that is hauled to and disposed of in landfills.		N/A

Indoor Environmental Quality	Points: 5/15	
Credit	Action	Points
IEQ Prerequisite 1: Minimum Indoor Air Quality Performance Intent: To prevent or minimize exposure of building occupants, indoor surfaces and ventilation air distribution systems to environmental tobacco smoke (ETS).		N/A
IEQ Prerequisite 2: Environmental Tobacco Smoke (ETS) Control Intent: To establish the minimum level of energy efficiency for the proposed building and systems to reduce the environmental and economic impacts associated with excessive energy use.		N/A
IEQ Credit 1: Outdoor Air Delivery Monitoring Intent: To provide capacity for ventilation system monitoring to help promote occupant comfort and well-being.	CO2 monitoring is fitted in all ventilation systems, and report to the system BAS.	1
IEQ Credit 2: Increased Ventilation Intent: To provide additional outdoor air ventilation to improve indoor air quality (IAQ) and promote occupant comfort, well-being and productivity.	Option 1: All zones and terminal units were designed and sized to exceed minimum outdoor air by at least 30%. Supporting documentation was provided.	1
IEQ Credit 6.1: Controllability of Systems – Thermal Comfort Intent: To providea high level of thermal comfort system control by individual occupants or groups in multi-occupant spaces and promote their productivity, comfort and well-being.	80 of the 81 individual workspaces will be outfitted with lighting controls and occupancy sensors. The control options include dimming and dual level switching	1
IEQ Credit 6.2: Outdoor Air Delivery Monitoring Intent: To provide capacity for ventilation system monitoring to help promote occupant comfort and well-being.	The specifications call for a number of full color display units to both monitor and control the BAS. The system qualifies for multi-occupant space comfort control.	1
IEQ Credit 7.1: Outdoor Air Delivery Monitoring Intent: To provide comfortable thermal environment that promotes occupant productivity and well-being.	The system design utilizes the four ventilation units for outdoor air, the units have the ability to regulate temperature and humidity appropriately.	1

The current 19 awarded credits is insufficient for LEED Certification. Remember though that LEED is not yet a goal for the owner. Also there are a number of points that could be awarded (especially in the Materials & Resources Category) that only need further documentation or verification upon construction completion.

Mechanical System Tables

Note: The Following tables are listed by the area they are located in. The naming of the area was done by the project engineer and follows the image below, Figure 14.

Figure 14

1.1 Ground Level Mechanical Space

Mechanical Space						
		GPM	TDH [ft]	Motor HP	Voltage	Efficiency
CP-1	Condensate Pump	3	14	Jan-50	115/1/60	N/A
		Avg. Water Temp	Tank Volume	Accept Volume	Operating Weight	
ET-1	Expansion Tank	75	79	52	925	
		Total Air	Fan HP	Condenser GPM	Cooling Capacity	Heating Capacity
HP-25	WS Heat Pump	700	0.3	5	24.7	20
		GPM	TDH [ft]	Motor HP	Voltage	Efficiency
P-1	Heat Loop Pump	300	70	10	208/3/60	76.2
P-2	Heat Loop Pump	300	70	10	208/3/60	76.2
		Max Flow Rate [GPM]	Gas Input [MBH]	Operating Weight [Lbs]		
WH-1	Water heater	3.7	20-180	48	-	-
WH-2	Water Heater	3.7	20-180	48	-	-
		Max Flow [GPM]	Backwash [GPM]	Salt Use	Resin [CF]	Salt Storage [Lbs]
WS-1	Water Softener	28	3.5	22.5/9	1.5	320

1.2 Area A

Area A						
		Total Air	Fan HP	Condenser GPM	Cooling Capacity	Heating Capacity
HP-1	WS Heat Pump	1200	0.5	7.5	35.7	31.7
HP-2	WS Heat Pump	330	0.1	2.5	10.8	9.7
HP-3	WS Heat Pump	1200	0.5	7.5	35.7	31.7
		Supply Fan CFM	Supply Fan HP	Condenser GPM	Cooling Capacity	Heating Capacity
VU-1	Ventialtion Unit	1100	1	16	87.1	34.7

1.3 Area B

Area B						
		Total Air	Fan HP	Condenser GPM	Cooling Capacity	Heating Capacity
HP-4	WS Heat Pump	300	0.1	2	7.5	7.2
HP-5	WS Heat Pump	300	0.1	2	7.5	7.2
HP-6	WS Heat Pump	210	0.1	2	6.1	5.2
HP-7	WS Heat Pump	300	0.1	2	7.5	7.2
HP-8	WS Heat Pump	300	0.1	2	7.5	7.2
HP-9	WS Heat Pump	300	0.1	2	7.5	7.2
HP-10	WS Heat Pump	300	0.1	2	7.5	7.2
HP-11	WS Heat Pump	350	0.1	2.5	10.8	9.7

1.4 Area E

Area E						
		Total Air	Fan HP	Condenser GPM	Cooling Capacity	Heating Capacity
HP-14	WS Heat Pump	600	0.25	3.5	18.6	15.1
HP-15	WS Heat Pump	1,620	0.75	9.5	48.5	41.2
HP-16	WS Heat Pump	600	0.25	3.5	18.6	15.1
HP-17	WS Heat Pump	1,800	0.75	9.5	48.5	41.2
HP-18	WS Heat Pump	1,800	0.75	9.5	48.5	41.2
HP-19	WS Heat Pump	1,620	0.75	9.5	48.5	41.2
		Supply Fan CFM	Supply Fan HP	Condenser GPM	Cooling Capacity	Heating Capacity
VU-3	Ventialtion Unit	1225	1	16	89.5	35.1

1.5 Area G

Area G						
		Total Air	Fan HP	Condenser GPM	Cooling Capacity	Heating Capacity
HP-20	WS Heat Pump	330	0.1	2.5	10.8	9.7
HP-21	WS Heat Pump	1,300	0.5	8.5	39.9	35.9
HP-22	WS Heat Pump	300	0.1	2	7.5	7.2
HP-23	WS Heat Pump	700	0.3	5	24.7	20
HP-24	WS Heat Pump	720	0.3	5	24.7	20
HP-26	WS Heat Pump	700	0.3	5	24.7	20
HP-27	WS Heat Pump	330	0.1	2.5	10.8	9.7
HP-28	WS Heat Pump	760	0.25	5	24.7	20
		Supply Fan CFM	Supply Fan HP	Condenser GPM	Cooling Capacity	Heating Capacity
VU-4	Ventialtion Unit	1700	1	28	143.8	61.6

1.5 Area J

Area J						
EDH-2	Electric Duct Heater					
		Total Air	Fan HP	Condenser GPM	Cooling Capacity	Heating Capacity
HP-12	WS Heat Pump	1825	0.75	12.5	62.4	54.6
		Supply Fan CFM	Supply Fan HP	Condenser GPM	Cooling Capacity	Heating Capacity
VU-2	Ventialtion Unit	2650	2	35	149.2	72.3

1.6 Miscellaneous

The items in this table are placed throughout the building individually, not in groups. For example, the exhaust fans are normally found in a restroom.

Misc.						
		Type	Airflow	Static Pressure [IN. W.G.]	Fan RPM	Operating Weight [Lbs]
EF-1	Exhaust Fan	Ceiling	125	0.15	1100	15
EF-2	Exhaust Fan	Inline	500	0.5	975	111
EF-3	Exhaust Fan	Inline	6630	0.5	505	537
EF-4	Exhaust Fan	Inline	6130	0.5	486	537
EF-5	Exhaust Fan	Ceiling	200	0.2	900	21
EF-6	Exhaust Fan	Ceiling	200	0.2	900	21
		Heating Capacity [W]	Air Flow [CFM]	Voltage	Amps	Operating Weight [Lbs]
EWH-1	Electric Heater	3000	100	208/1/60	14.45	25
		Total Air	Fan HP	Condenser GPM	Cooling Capacity	Heating Capacity
HP-13	WS Heat Pump	1620	0.75	9.5	48.5	41.2

Overall System Evaluation

The mechanical system for the new office building is largely impressive. In terms of energy efficiency and sustainability it is clear that both the owner and design engineer were looking forward. As discussed in Technical Assignment 2 the new office building is well below the average for office buildings in annual energy costs and emissions.

In terms of design, it is a complex idea to combine a geothermal well with twenty eight heat pumps. However, the use of a large mechanical mezzanine and the grouping of the heat pumps and ventilation units on small hubs made the system easier to monitor, maintain, and understand.

Additionally, the $57.67 per square foot was well spent on a system that is sustainable and greatly reduces cost fluctuation with the fuel source market. Also the maintenance of the overall system should be affordable baring any major setbacks. Specifications required warranties for all items and a visual inspection of the equipment showed that all of the equipment is well protected and easily accessible. This means all units can easily be cleaned, repaired, or replaced if need be, reducing costs further in the lifetime.

Figure 13 shows that nearly 10% of the mechanical systems costs are attributed to the controls. Further inspection of the control specifications indicate that the new office's BAS will be monitoring both the air and the water side of the mechanical system as well as other items like energy usage. Other project documents indicate that the owner is dedicated to the goal of sustainability and will be using data from the BAS to improve the buildings systems well into the future.

References

Reese Engineering Inc. "Electrical Construction Documents". State College, PA.

Reese Engineering Inc. "Mechanical Construction Documents". State College, PA.

ASHRAE. Standard 62.1-2007, Ventilation for Acceptable Indoor Air Quality. Atlanta, GA. American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

ASHRAE. Stanard 90.1-2007, Energy Standards for Buildings Except Low-Rise Residential Builidngs. Atlanta, GA. American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

NREL. Source Energy and emission Factors for energy Use in Buildings. Golden Colorado, National Renewable Energy Laboratory.

"A Look at Office Buildings - How Do They Use Energy and How Much Does It Costs." *A Look at Office Buildings - How Do They Use Energy and How Much Does It Costs*. Department of Energy, n.d. Web. 12 Oct. 2012. <http://www.eia.gov/emeu/consumptionbriefs/cbecs/pbawebsite/office/office_howuseenergy.htm>.

"Carbon Emissions from Building Energy Use." *: ENERGY STAR*. Energy Star, n.d. Web. 12 Oct. 2012. <http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager_carbon>.