Integration of Mechanical System Redesign

Geothermal Heat Pumps with DOAS

Lutheran Theological Seminary at Philadelphia
The New Learning Center

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Lutheran Theological Seminary at Philadelphia, The New Learning Center
Philadelphia, Pennsylvania

PROJECT TEAM
Owner – The Lutheran Theological Seminary
Construction Manager – Alvin H. Butz, Inc.
Project Manager – Becker & Frondorf
Architect – GYA Architects, Inc.
MEP Engineer – Paul H. Yeomans, Inc.
Structural Engineer – O'Donnell & Naccarato, Inc.
Civil Engineer – Boles, Smyth Associates, Inc.

BUILDING STATISTICS
Project Cost – 60,000 square feet
Project Cost – Approximately $14,880,000
Delivery Method – Design-Bid-Build
Construction Start – March 2004
Construction End – February 2006
Levels Above Grade – 3 Stories

ARCHITECTURE
Function – First floor is comprised of reception halls, lounges and the kitchen. Second and third floors are mostly made up of classrooms, conference rooms, and offices. The New Learning Center is a cornerstone of the Philadelphia Campus quadrangle.
Envelope – The North stone wall was left standing when the previous building was torn down and integrated with the new portions. The new structure of the building has a metal clad façade decorated with various shapes of windows.

MECHANICAL SYSTEMS
(3) Packaged DX Rooftops
100% Outside Air Ranging From 1600-6300 cfm
Terminal Fan Coils with Heating and Cooling Coils
(2) 1250 MBH Gas Fired Boilers
(1) 150 Ton Air Cooled Chiller
(5) Split System Air Conditioning Units
Variable Speed Fans and Pumps

STRUCTURAL SYSTEMS
Basement has 5" SOG with WWF over 4" stone
Steel Column, Girder, and Beam Construction
K-Series Joint Supporting System
Concrete on Metal Decking Floor Construction
30'x35' Bays
Poured Concrete Foundation with Column Base Plates

ELECTRICAL / LIGHTING SYSTEMS
750 KVA, 13.2 KV Transformer
480/277 V, 3 Phase, 4 Wire Service
125 KW Emergency Generator
Recessed, Surface Mounted, and Suspended
Flourescent Lighting
Manual and Automatic Lighting Controls
Emergency Lighting by Code

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http://www.engr.psu.edu/ae/thesis/portfolios/2008/wsl120/

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Executive Summary

The New Learning Center is a building at the Lutheran Theological Seminary at Philadelphia. It is a four level building including the basement. The existing mechanical system is a DOAS system with fan coils controlled by chilled and hot water. This is a very effective and efficient system, but this report explores other mechanical system possibilities.

The main goals put forth by the owner were to have a system that would fit into a small plenum height, have an energy efficient system to result in low emissions and yearly operation costs, and provide individual comfort and control for the occupants. The existing mechanical system was successful at all three parts, so the new design would attempt to make at least one portion even better.

To attempt to lower the energy consumption used by The New Learning Center, a geothermal system was examined. There were two alternatives, Alternative 1 sized the ground loop for the heating capacity and included a cooling tower for the extra cooling capacity needed and Alternative 2 sized the ground loop for the largest capacity, cooling, needed. The geothermal loop feeds the HVAC equipment. The heat pumps for individual control and the 100% outdoor air rooftop units all operate on the same heat pump loop.

The positives of a geothermal system are that it reduces yearly energy consumption, and therefore emissions and yearly operation cost, as well as the elimination for the need of boilers and chillers. The negatives include the increased size of electrical system, higher initial cost, and increased construction cost and time. The individual comfort and control is equivalent with the performance of the fan coil design. The one additional benefit is the geothermal designs have a fourth rooftop unit with the ability for dehumidification, which would address the current humidity issues in the basement zones.

After complete analysis, my recommendation to the owner would the implementation of the geothermal heat pump system with a cooling tower. The initial cost is higher and the electrical system costs an additional $2.20 per square foot, but the geothermal systems make up for it in energy consumption. Along with the lower operation cost, The New Learning Center will qualify for a tax rebate of $0.60 per square foot yearly by the Energy Policy Act of 2005. The geothermal heat pump system will save the owner over $725,000 in a 20 year life cycle cost and therefore would be my recommendation.

Building Design Background

The New Learning Center is the most recent construction done on the Lutheran Seminary at Philadelphia Campus. The New Learning Center was designed and built after the last building was deemed structurally unsound and needed to be demolished. The North exterior wall was left standing in its original stone façade form to help the new building tie in with the remainder of the campus.

The New Learning Center is a 4 level building, including a basement. The basement is comprised of the mechanical room, electrical closet, as well as an archive and storage section. The large majority of first floor is comprised of reception halls, lounges, and the kitchen. The second and third floors are made up of classrooms, conference rooms, and offices.

The New Learning Center is one of the main pieces of the campus quadrangle. Aside from the North wall that was left standing, it was designed with a metal clad façade. The first floor is almost entirely glass with an overhang to control direct solar gain into the building. The second and third floors are decorated with a variety of window shapes including diamonds, circles, and rectangles. The typical areas of the building have tile floors with drywall partitions.

There are no site conditions that influenced the mechanical system design. The building is set on a flat site with no large obstruction or shadows cast by landscaping. The mechanical system, however, was designed to work with the neighboring buildings and handle the future expansion of the neighboring library.

Existing Mechanical System Conditions

The mechanical system for The New Learning Center is designed as a dedicated outdoor air system. The air is then mixed and reconditioned in the fan coil units before being delivered to the zones. It is designed for proper ventilation, heating, and cooling.

Chilled Water System

The chilled water system is fueled by the air cooled chiller on the roof. The chiller is made for low ambient conditions so it is capable for operation during the colder months to cool rooms with high cooling loads. It also has variable speed for low load conditions. The chiller is sized for 150 tons. The water arrives at the chiller evaporator at 42 F and leaves at 56 F.

Hot Water System

The hot water system consists of two gas fired boilers in the basement mechanical room. Each of these boilers is designed for 1250 MBH. This hot water is run through variable speed pumps to fan coil units and constant volume pumps to the fin tube radiation.

Air Side System

The mechanical system for The New Learning Center is designed as a dedicated outdoor air system. The system is controlled by DDC controls and is all tied back into the main controller. The system has three packaged DX rooftop units with 100% outside air. These units have integral heat recovery through a heat wheel, gas heat, direct expansion cooling, and hot gas reheat. RTU-1 and RTU-2 have 270 MBH of heating capacity and 320 MBH of cooling capacity. The smaller unit, RTU-3, has 90 MBH heating and 100 MBH of cooling capacity. These air handlers feed fan coil units in mechanical closets. The air is mixed within the closet, reconditioned, and then supplied to the rooms. The fan coils are various sizes, all based upon the room or group of rooms that they supply air to. In cooling mode the water is delivered to the coil at 45 F and leave at 55F. When heat is needed the water arrives at the coil at 180 F and leaves at 160 F. All of the fan coils are equipped with a two pipe system for heating and cooling coils.

ASHRAE Standards Analysis

HVAC System Compliance with ASHRAE 90.1

ASHRAE 90.1 provides minimum performances and codes for HVAC systems and individual units. For requirements to be met, all parts of the mechanical system for the Lutheran Theological Seminary at Philadelphia must comply with these codes. In this section, some of the analysis that must be done is of the chiller, boilers, motors, and service water heating.

The chiller is an air cooled absorption chiller with single effect. According to AHRAE 90.1, all sizes of this chiller must have a COP of 0.60. After the calculations were made, this chiller had a COP of 2.76. The calculations and work for this can be found in Appendix B. Since the chiller greatly exceeds ASHRAE, it was a good choice to provide the cooling for the building's HVAC system.

The Lutheran Theological Seminary at Philadelphia has two boilers that provide the heating capability. Both boilers are the same size and are slightly oversized for future expansion. For Gas-Fired boiler greater than 225,000 Btuh, the efficiency must be at least 80%. The analysis showed that the installed boilers were exactly 80% efficient. The calculations can be seen in Appendix B. These boilers meet the minimum efficiency and are a proper selection for the Lutheran Theological Seminary at Philadelphia.

Through inspection, all motors also comply with minimum efficiency specified by ASHRAE 90.1. ASHRAE also says that the service water heating system must have a minimum of 1" insulation throughout. This system meets minimum requirements as well.

All of this analysis shows that the HVAC system meets requirements set by ASHRAE 90.1. The systems in the building were designed and installed properly and should function correctly. There were no problems meeting any code.

Building Envelope Compliance with ASHRAE 90.1

ASHRAE 90.1 provides minimum requirements that the building envelope must meet. The insulation of the walls, floors, and roof can be determined by using ASHRAE Fundamentals. Compliance must be determined by staying below a maximum U-value (transmittance value) or above a minimum R-Value (insulation value). The glazing of the building must also be taken into account. The glass needs to have a minimum percentage of wall area, U-value, and shading coefficient. All of this information is evaluated by the design documents.

The summary of the walls, floors, and roof is summarized in Table 1. All portions of the exterior meet ASHRAE 90.1.

Table 1 – Building Envelope 90.1 Compliance

Envelope	ASHRAE 90.1 Max U Value	Designed U Value	Complies?
Roof	0.065	0.055	Yes
Exterior Walls Above Grade	0.124	0.09075	Yes
Exterior Walls Below Grade	1.14	0.12443	Yes
Slab on Grade	0.73	0.21261	Yes

ASHRAE 90.1 states that the maximum fenestration of a building is 50% of vertical facing walls. It also states that the maximum skylight exposure is 5%. The Lutheran Theological Seminary at Philadelphia does not have any skylights, so this requirement is met. Through calculations, the glazing of the vertical exterior walls is 15%, therefore it complies. After that, the energy transmission and shading coefficient of the windows must meet the requirements. These will be evaluated in the category of 10-20% fenestration. The results can be seen in the following table. The Minimum U-value is met but the shading coefficient comes up just short. These values are shown in Table 2.

Table 2 – Fenestration 90.1 Compliance

Envelope	ASHRAE 90.1 Max Value	Designed Value	Complies?
Fenestration U Value @ 15%	0.57	0.5	Yes
Fenestration SHGC @ 15%	0.39	0.55	No

Power and Lighting Compliance with ASHRAE 90.1

ASHRAE 90.1 has requirements that must be met by the power and lighting systems in the Lutheran Theological Seminary at Philadelphia. ASHRAE requires certain rules, energy saving methods, and safety factors that must be taken into account when designing the electrical systems in the building. While the building envelope and mechanical systems were based on energy savings and efficiency, the Power and Lighting requirements are more based on design methods.

The power requirements focus on the sizing of feeders and branch circuits. Both have a maximum voltage drop that can occur within the electrical system. ASHRAE states the feeders must have a maximum voltage drop of 2% at design load. It also says voltage drop of branch circuits at design load must remain below 3%. All of these requirements were taken into consideration during design, and therefore pass code. The power system was designed appropriately.

AHSRAE 90.1 has requirements on what the maximum watts per square foot can be used in a building for lighting. There are two approaches that can be used to verify the compliance. The first method is the watts that can be used when the overall building is evaluated by watts per square foot defined by the general building use. The allowance is then compared to the design of the building's lighting system. The more detailed analysis allows the same method to be performed on a zone by zone basis. A function is given to each zone, and all of the allowances by zone are summed up to make a total building allowance. This value is usually more forgiving and can sometimes allow the building to pass code when the overall building method would not. In this report the more detailed room specific method was used. The results are shown in the Table 3.

Table 3 – Power Compliance

Floor	Designed Power	ASHRAE Max Power	Complies?
Basement	14016	9829.6	
First Floor	17944	15958.3	
Second Floor	19994	13315.1	
Third Floor	20813	13711.9	
Total	72767	52814.9	**No**

The lighting system of the Lutheran Theological Seminary at Philadelphia does not comply with the requirement of ASHRAE 90.1. Lighting codes due to the conservation of energy and light pollution have become stricter in recent years. All city and ASHRAE codes were met at the time of the design.

Compliance with ASHRAE 62.1

The analysis of The New Learning Center slightly differs from a more conventional building because of where the mixing occurs in the system. Since the air mixing occurs in the mechanical closets where the fan coils reside, the closets themselves must be analyzed as their or single or multi zone systems. After that is finished, the fan coils can then be traced back to the AHU that serve them. The outdoor air requirement for these AHU's can be determined by the summation of the requirements for their designated fan coil zones.

Upon completion of the calculations, the requirements for the outdoor air delivered by the AHU's are compared to the design conditions. In this case, all of the units supply enough fresh air to meet and exceed code. All three Rooftop Units as well as the basement outdoor air plenum are sized properly. Therefore, the building as a whole has enough outdoor air supplied to properly operate and occupy The New Learning Center. This comparison is shown in brief in Table 4.

Table 4 – Minimum Outdoor Air Compliance

Unit	Calculated Min OA	Design OA	ASHRAE 62.1 Code Verification
RTU-1	5995	6225	Verified
RTU-2	3105	6125	Verified
RTU-3	1528	1685	Verified
Plenum	1711	2600	Verified

The analysis in this building is not only done for the AHU's, but also for each individual closet. These closets can be made up of anywhere from one to three fan coil units. There are 26 such mechanical closets in The New Learning Center. There are also 20 such zones that are served by console fan coil units only, all which comply. Of the 26 mechanical closet systems, only 5 do not meet code as the spaces were analyzed with ASHRAE and the assumptions made in this analysis. This does not make the design insufficient, it merely means that different assumptions, decisions, or functions were used in calculation. ASHRAE 62.1 has a chance to leave open the ability to assume various functions of the room depending on the owner's decisions, engineer's previous knowledge of occupancies, and a few other variations.

Two of the closets that were slightly short were in the basement, although the basement as a whole has enough outdoor air supplied. These zones may be short assuming that some of the extra outdoor air will be supplied to the corridor and transferred into the storage areas before being returned. This is not a very critical area since the occupancy of the entire basement is zero.

Two more of the closets that were slightly short of the calculated required outdoor air serve the large lecture space on the first floor. This is a situation that can be treated in several different ways. The large room has folding partitions that can split the room up into three smaller classrooms. If the occupancy and airflow is treated as three separate classrooms, the closets will have plenty of outdoor air. If the calculations are done as one large assembly area, the will be slightly short of the required outdoor air volume.

The final closet that is just shy of the calculated airflow serves a distance learning classroom on the third floor. As with the other space, if the airflow and occupancy is based as a regular classroom, the outdoor air is sufficient. However, if the room is calculated as if it is a lecture classroom, it comes up about 10% short.

Although there are a few discrepancies between the required outdoor air flow showed and the design, it does not mean there were any mistakes during design. With the proper assumptions and owner input, all of these calculations would be sufficient to supply all zones. The evaluation and verification of the Air Handling Units also suggests that the zones were calculated and designed properly. This building would absolutely exceed any code analysis.

Building Load Analysis

To design and estimate loads for the Lutheran Theological Seminary at Philadelphia, The New Learning Center, the building needed to be modeled in a building energy simulation program. The program used for the analysis of this report was Trane Trace. The majority of the input data was taken from AHSRAE 90.1. ASHRAE gives the outdoor design conditions, lighting watts per square foot depending on function of the room, sensible load from people, and values of the building envelope. Occupancies for the rooms, schedules of room use, and sensible loads from equipment were taken from the design documents. All of the rooms, windows, exteriors, and other values were entered into the program. All of the rooms were then assigned to the proper system, and then the system assigned to the proper plants.

The peak loads given in the analysis are very important. The heating and cooling plant capacities are based off of the peak load values. All of these loads will be reflected in the mechanical system sizing, schedules, and schematics. Regardless of the usual operation conditions, the system must have the capacity to ventilate and condition the air on any design day. Table 5 shows the peak loads which must be considered when sizing the mechanical system.

Table 5 – Peak Loads

Operation	Peak Load tons
Heating	125
Cooling	166

The design load for the initial design was very comparable to the computed load using Trane Trace. The loads are the same for the initial three rooftop units. In the redesign, the plenum is replaced with a fourth rooftop unit which contributes part of the load capacity plus has the ability to dehumidify. In the mechanical system redesign, the loads produced by the units matched the computed loads, to maximize energy performance and ensure proper capacity was achieved. The exact and not over sizing of equipment contributes directly to not only the initial cost, but also the operation cost and energy efficiency of yearly building use. With that said, the redesign should be slightly more efficient assuming that the building is modeled correctly. The analysis of the existing mechanical system is shown in Table 6-9.

Table 6 – RTU-1 Loads

RTU-1 and Terminal Units	Designed Load	Computed Load
Area	13970	13970
Cooling sf/ton	172.83	266.88
Supply Air cfm/sf	1.25	1.15
Ventilation Supply cfm/sf	0.45	0.46

Table 7 – RTU-2 Loads

RTU-2 and Terminal Units	Designed Load	Computed Load
Area	15723	15723
Cooling sf/ton	244.87	337.69
Supply Air cfm/sf	0.79	0.88
Ventilation Supply cfm/sf	0.39	0.43

Table 8 – RTU-3 Loads

RTU-3 and Terminal Units	Designed Load	Computed Load
Area	6947	6947
Cooling sf/ton	252.80	388.64
Supply Air cfm/sf	1.18	0.78
Ventilation Supply cfm/sf	0.24	0.32

Table 9 – Plenum Loads

Plenum and Terminal Units	Designed Load	Computed Load
Area	11755	11755
Cooling sf/ton	524.39	636.36
Supply Air cfm/sf	0.64	0.46
Ventilation Supply cfm/sf	0.14	0.22

Mechanical System Design Goals and Considerations

The objectives for the redesign of The New Learning Center should be based upon the initial objectives of the project. There were several design objectives laid out by Paul H. Yeomans, GYA Architects, and the Lutheran Theological Seminary at Philadelphia. First, they wanted the mechanical system that would fit in a small plenum height. The plenum was shallow since they wanted the floors of the building to coincide with the remaining exterior wall that would be integrated with the new design. Design was to create a DOAS with closets for the fan coil units to save space in the ceiling. Second, the owner wanted and energy efficient building. Since the owner of the building would continue to reap the long-term energy savings benefits, their wishes were to have a building that would save them operation costs over time. This was taken into consideration when the enthalpy wheel was installed in the rooftop unit and when the system was designed with variable frequency drives. Third, it was an objective to give individuals the greatest comfort and control possible. They designed the system with thermostats to control the fan coils units for optimal comfort.

There are a few goals that will attempt to be obtained with the redesign. First, the redesign will attempt to fix any humidity problems in the basement. With all of the storage and archives in the basement, the humidity concerns should be addressed. Second, the redesign will attempt to limit pollutants. Some mechanical equipment is capable of running on ozone-safe refrigerant. Third, the redesign will attempt to limit life cycle cost. Not only would it be good to reduce initial cost, but operating cost al well. The high and unstable prices of energy would allow for a brief payback period even if initial costs do rise slightly. Also, there will continue to be an energy recovery portion to the design to further limit energy consumption, which is being utilized in the design now. The capability for occupants to control their thermal comfort will be designed just as well as the original design.

Mechanical System Redesign

The proposed redesign will work to accommodate all design objectives. The New Learning Center HVAC system should have the capability to function just as well as before and hopefully have some added value. That value should come in the form of a better controlled system in the basement as well as value in initial and operating costs. A very energy and environmental efficient system was selected. One design has been selected to try to meet all of these goals.

System Redesign

The plenum feeding the outdoor air to the basement will be replaced by an air handling unit. This unit will be equipped with an enthalpy wheel to lower operating costs. The main function of the additional unit is to eliminate humidity control problems in the basement. The existing air handling units will be modified for operation on the heat pump system and will be resized. All four of the air handling units will be on the same secondary loop as the terminal geothermal heat pumps to condition the air. This is to keep all of the mechanical equipment on the same loop to reduce the mechanical system operating costs and make maintenance more efficient. The enthalpy wheel included in the basement air supply path should reduce the cost of conditioning the air supplied to the zones.

All of the fan coil units will be replaced with geothermal heat pumps. These geothermal heat pumps will help reach some of the goals. The heat pumps should reduce operating costs. One other advantage is the COP and EER capability of the heat pumps. A possible selection has the COP of 5.0 and the EER of 30, which are both very energy efficient. The use of energy efficient equipment will reduce the operation costs and energy consumption. The initial cost of replacing the fan coil units with geothermal heat pumps should not increase greatly if at all, but the operation costs will be substantially less. Implementing them in the system in place of the fan coil units should ensure the same individual thermal comfort in the system as previously designed. Pollutants will be greatly limited with the use of R-410A, and ozone-safe refrigerant used in the geothermal heat pump loops.

The most drastic difference in the implementation of the geothermal heat pumps is that the boilers can be eliminated. Domestic water heaters are already installed to take care of the domestic water supply capacity. The radiation will no longer have a boiler feed, so the hydronic radiation must be on the heat pump loop. The elimination of the boilers will decrease initial cost greatly. The majority of the boilers heating capacity will be replaced with geothermal energy, causing a great decrease in pollutant emissions. Operation costs will decrease greatly as well due to the substitution of the boilers with heat pumps.

The chiller will also be eliminated from the HVAC system. The cooling capacity offered from the chiller will be supplied by the geothermal heat pump system and a cooling tower. The air handling units will be fed by the same geothermal loop including a cooling tower. The elimination of the chiller will have the same advantages as the elimination of the boiler such as decreased initial cost, decreased operation cost, and reduction of emissions.

The pumps and piping for the primary loop of the heating and cooling systems will be able to be eliminated. They will be replaced by piping and pumps of the geothermal heat pump system and cooling tower. Labor costs will possibly be increased, but equipment and operation costs will be reduced vastly.

To ensure a proper choice is being made, two different options will be considered. The first choice is the geothermal loop sized for the heating load and the cooling tower will make up the capacity difference of the heating and cooling load, since the cooling load is greater. The other option would be sizing the geothermal loop to account for the entire load in the building. Analyzing these two different options, as well as the existing design, a proper choice can be made.

Breadth Redesign

The alteration of the mechanical system brings changes that must be made in the electrical system and the construction management process. The final cost analysis and design recommendations will be based upon not only the mechanical redesign but also the cost and efficiency results of the other systems.

Electrical Redesign

The implementation of a geothermal heat pump system will greatly affect the electrical system. Due to the compressors on each heat pump, the electrical system must be increased. The power panels on each floor must be resized. The original design had at times as many as six to eight fan coils on each circuit. Although the heat pumps can be wired as single phase motors, there will still be a cost associated with the resizing of the system as a whole. This cost will need to be taken into consideration when the redesign of the mechanical system is evaluated. The addition of extra panel boards is also a possibility. There is also a chance that the electrical schematic may slightly change.

Construction Management

The construction management phase of the redesign will need to be analyzed. The cost, time, and complexity of installation for the mechanical system must be looked into. The electrical redesign will also need to be analyzed from a construction management point of view. The cost of geothermal redesign will be largely affected by the use of construction technologies to design the ground loop. The extra piping, heat exchangers, and renting of specialized machinery may significantly contribute to the initial design cost. Without the use of a construction management cost estimate the mechanical system estimate would be incomplete and inconclusive.

Geothermal Heat Pump Design Analysis

There were several things that the owners wanted to accomplish with the design of The New Learning Center. The selection of the system and implementation for the redesign was also based on these specific criteria. These priority criteria are low emissions and pollutants, ability to fit into a small plenum height, optimal occupant comfort control, low yearly energy and operation cost, as well as low initial and lifecycle cost. As stated before, the initial design was a DOAS system with chilled and hot water for fan coil capacity supplied by two boilers and an air cooled chiller. The rooftop units were gas fired heating with direct expansion cooling. The basement was ventilated and conditioned by three supply air fans and three in duct heating coils. Both alternatives of the redesign are controlled by geothermal heat pumps. The ground loop is a closed loop system with heat exchangers for heat transfer. The heat pumps and rooftop units are all fed from the geothermal heat pump loop. Alternative 1 has a cooling tower running in parallel with the ground loop system to make up the difference in heating and cooling capacity needs. Alternative 2 has the ground loop sized for the cooling load, which exceeds the heating capacity.

Emissions

The reduction of emissions from the mechanical system is one of the main concerns for the Lutheran Theological Seminary at Philadelphia owners. The initial design is a relatively environmentally friendly design. The most environmentally friendly design of a mechanical system is a geothermal system. This is because the majority of the energy comes from heat transfer into the earth. A main concern when designing a geothermal system is to make sure not to overheat or overcool the ground surrounding the ground loop system. If the earth changes temperature, complications such as the proper heat transfer could arise. The boilers and chillers constitute most of the emissions by the mechanical system on site. The electricity used by the compressors comprises most of the emissions of a geothermal heat pump system. The benefit is that this energy comes from a power plant which has a mix of energy components. Some of this energy is more environmentally friendly because it comes from sources such as nuclear, hydro, wind, and natural gas as opposed to oil that can be used in boilers and chillers. The breakdown of pollutants and emissions for each individual system is shown in Table 10.

Table 10 – Emissions and pollutant

	Fan Coil Design	Alternative 1	Alternative 2
Pollutant	Emissions lbm / year	Emissions lbm / year	Emissions lbm / year
CO	1,001,358	766,431	789,128
SO	4,315	4,188	4,312
NO	2,942	2,466	2,539
Particulates	367	0	0

Feasible Mechanical System

The mechanical system must be designed to fit into a small plenum height. The building was originally built without the room to run a large amount of ductwork in the ceiling. To keep the floors in line with the remaining exterior façade, the mechanical system must adapt.

The original design accommodated the small size by doing a few things. First, the rooftop units supplied 100% outdoor air. This reduces the amount of air that has to be moved throughout the building and therefore the duct sizes. Closets were also made for the fan coil units that served as mixing boxes. This way, only the branch ductwork needed to be sized at full mixed air flow. The exterior spaces which are difficult to run ductwork to are console design, pulling air directly from the outside.

The redesign has also taken the necessary steps to accommodate the small plenum height. The rooftop units will continue to supply 100% outdoor air. The heat pumps will also be situated in the mechanical closets for air mixing. All heat pumps are capable of fitting in the mechanical closets where the fan coils resided without the need of expanding the rooms. The exterior room heat pumps will also be console design. The basement plenum will also be substituted with a fourth air handling unit for humidity control in the basement. Due to the over sizing of the previous rooftop units, there will be enough room for the air mains to get to the basement areas. There is enough room to run duct from the unit into the supply areas. The alteration of a fan coil four pipe system into a heat pump two pipe system will actually decrease the amount of room needed to run pipe throughout the building.

Occupant Comfort Control

It is proven that if individual building occupants have control over their indoor environment they are more satisfied and are more comfortable. This is why it is very important to have terminal units to recondition the air before it is supplied to individual zones. These heat pumps will be able to provide the proper control for the occupants. The sizing of the heat pumps in The New Learning Center is controlled by the airflow rather than the capacities, which allow the units to have excess ability for control is necessary. The community spaces, such as corridors, will be controlled automatically by the preset thermostats.

One major addition to the mechanical system of the building is the fourth air handling unit. This unit will control the indoor environment in the basement. The heat wheel will reduce the energy needed for the conditioning of the air supplied to the basement, as wanted by the owner. The addition of this unit will condition the air better than the supply fans and heat coils do now. Instead of merely heating and ventilating, the unit will have the ability to cool. The unit will also provide humidity control in the areas served. This is one added benefit of the mechanical system redesign.

Operation Cost

Depending on the owners and their business plans, either operation or initial costs are more important. Although all building owners want both numbers to be low, owners that will run their building for an extended period of time tend to lean towards long term cost reductions, which usually result in the want for lower operation cost. The New Learning Center is an example of these long term concerns. The Lutheran theological Seminary at Philadelphia has a campus they will use for the foreseeable future, and therefore fall into this category. These yearly operation costs have seemed to become more important than ever in the recent years with the dramatic increase of fuel costs. Although the fan coil system was energy efficient, the geothermal system is more energy efficient. This reduction in operating cost may influence the owners to go with the new geothermal system. Both alternatives have lower yearly costs to operate the mechanical system than the fan coil design. The majority of the energy in the initial design was used by the boiler and chiller to supply properly conditioned water to the fan coils. There was also a large amount of energy consumed by the rooftop units by burning gas for heating and the direct expansion cooling. The geothermal design has most of the energy consumed in the heat pump terminal units. The fluid pumps also consume more than 10 times more energy than was used in the original design. Table 11 will show the cost and energy difference.

Table 11 – Yearly Operation Costs

Source	Original Fan Coil Design		Alternative 1		Alternative 2	
	Total Energy kWh/yr	% of Total Energy	Total Energy kWh/yr	% of Total Energy	Total Energy kWh/yr	% of Total Energy
Boiler and accessories	312,554	45.9%	-	0.0%	-	0.0%
Heat Pump Heating	-	0.0%	165,505	29.8%	166,403	29.1%
Chiller and accessories	38,814	5.7%	-	0.0%	-	0.0%
Heat Pump Cooling	-	0.0%	57,205	10.3%	57,183	10.0%
Cooling Tower	-	0.0%	1,666	0.3%	-	0.0%
Fans	210,412	30.9%	108,855	19.6%	109,792	19.2%
Pumps	12,257	1.8%	76,088	13.7%	92,065	16.1%
Lighting	146,623	21.5%	146,623	26.3%	146,623	25.7%
Total Energy Consumption	**680,945**	100.0%	**555,385**	100.0%	**571,832**	100.0%
Total Cost per Year	**$88,523**		**$72,200**		**$74,338**	

The geothermal design gets all of the needed energy for the mechanical system from a plant in the form of electricity, while the initial design also needed gas. At times it is better to have a variety of energy in the case that one form of energy would increase dramatically. In either case, the cheaper the operation cost the better. The cost from a plant usually stays relatively level with the market since they use several forms of energy to make the electricity. The costs for the three designs were approximated with the energy costs in Table 12.

Table 12 – Energy Cost

	Cost of Energy
Gas	$0.92 / therm
Electric	$0.13 / kWh
Demand	$8.65 / kW

Initial Cost

The initial cost is always a concern for an owner. Coming up with the necessary funds to start construction on a new building can be daunting. There is usually a correlation between initial cost and operation cost. Higher initial costs usually result in lower operation cost for systems with the same control and comfort. The results usually remain in the reverse case as well. The new design saves initial cost by eliminating the boiler and chiller. However, cost is added because the heat pumps are more expensive than the fan coil units are, and with 66 units, there is a large difference of cost for the terminal unit difference. The cost of the initial mechanical system equipment was less expensive than the geothermal systems. The equipment cost was broken down by the different equipment that would be needed for the implementation of the different systems. The ductwork and additional mechanical equipment will remain unchanged. The cost breakdown is shown in Table 13-15.

Table 13 - Fan Coil Design

Mechanical System Component	Quantity	Cost per Quantity	**Total Cost**
Chiller	1	$96,000	**$96,000**
Boiler	2	$11,000	**$22,000**
Fan Coils	66	$2,500	**$165,000**
Heat Pumps	0	$0	**$0**
Cooling Tower	0	$0	**$0**
Heat Exchanger	0	$0	**$0**
12 hp Pumps	0	$0	**$0**
10 hp Pumps	2	$5,225	**$10,450**
2 hp Pumps	2	$2,225	**$4,450**
RTU-1	1	$32,000	**$32,000**
RTU-2	1	$32,000	**$32,000**
RTU-3	1	$20,000	**$20,000**
RTU-4	0	$0	**$0**
Supply Fans 1/2 HP	3	$1,025	**$3,075**
Heating Coils	3	$1,400	**$4,200**
		Total Cost =	**$389,175**

Table 14 – Alternative 1

Mechanical System Component	Quantity	Cost per Quantity	**Total Cost**
Chiller	0	$0	**$0**
Boiler	0	$0	**$0**
Fan Coils	0	$0	**$0**
Heat Pumps	66	$3,000	**$198,000**
Cooling Tower	1	$8,200	**$8,200**
Heat Exchanger	4	$13,325	**$53,300**
12 hp Pumps	0	$0	**$0**
10 hp Pumps	3	$5,225	**$15,675**
2 hp Pumps	0	$0	**$0**
RTU-1	1	$33,000	**$33,000**
RTU-2	1	$28,000	**$28,000**
RTU-3	1	$20,000	**$20,000**
RTU-4	1	$20,000	**$20,000**
Supply Fans 1/2 HP	0	$0	**$0**
Heating Coils	0	$0	**$0**
		Total Cost =	**$376,175**

Table 15 – Alternative 2

Mechanical System Component	Quantity	Cost per Quantity	**Total Cost**
Chiller	0	$0	**$0**
Boiler	0	$0	**$0**
Fan Coils	0	$0	**$0**
Heat Pumps	66	$3,000	**$198,000**
Cooling Tower	0	$0	**$0**
Heat Exchanger	4	$13,325	**$53,300**
12 hp Pumps	3	$5,375	**$16,125**
10 hp Pumps	0	$0	**$0**
2 hp Pumps	0	$0	**$0**
RTU-1	1	$33,000	**$33,000**
RTU-2	1	$28,000	**$28,000**
RTU-3	1	$20,000	**$20,000**
RTU-4	1	$20,000	**$20,000**
Supply Fans 1/2 HP	0	$0	**$0**
Heating Coils	0	$0	**$0**
		Total Cost =	**$368,425**

Mechanical Redesign Conclusions

When evaluating a variety of mechanical systems, many different criteria must be taken into consideration. The majority of the building will perform equally well. All of the regularly occupied areas are controlled designed to make all occupants thermally comfortable and provide them with individual control of most spaces. The key addition to the redesign is the air handling unit that serves the basement. The unit is the only component that that allows the building to perform better than the original design. The original design would need a retrofit for the basement to perform as well as the geothermal redesign will.

The best way select the most cost efficient system is to analyze the system on a life cycle basis. This life cycle is usually a twenty year lifetime. The life cycle cost takes into consideration the initial cost and twenty years of operation costs. Table 16 displays the cost of the alternatives.

Table 16 – 20 Year Life Cycle Cost

Cost	Fan Coil Design	Heat Pump Alternative 1	Heat Pump Alternative 2
Initial Cost	$389,175	$376,175	$368,425
Operation Cost	$88,523	$72,200	$74,338
20 Year Life Cycle Cost	**$2,159,635**	**$1,820,175**	**$1,855,185**

The twenty year life cycle analysis can give the owner a good idea of the long term cost of a mechanical system in their building. It seems from this estimation that the geothermal systems are a cheaper alternative to the fan coil system. Each alternative can save the owner over $300,000 in the twenty year life of the system. That amount is equivalent so saving 16% of the cost of the original design. Although this seems like a conclusion, it is not. The electrical and construction management portions need to be analyzed for the changes made in the mechanical system. With the mechanical information only we can not yet make a definitive choice on the proper system.

Electrical Breadth

Due to the transition from a fan coil mechanical system to a geothermal heat pump system, the electrical system must be altered. The heat pumps have the same electrical service as the fan coils. Both operate on 208 volts, single phase motors. There were some very drastic changes to the electrical system.

The original design is comprised of four power panels, one on each floor. Each of the fan coils operates on a relatively small motor. This allows as many as eight fan coils to be wired on the same circuit. Circuiting several terminal units together allow for less circuits on a panel being used, less power panels, smaller wires to be run, and less distance that need to be covered by branch wires.

The heat pump design demands a larger electrical system. A fifth power panel must be added on the third level to serve all of the heat pumps and rooftop units. The large compressors demand that each heat pump has its own circuit. This increases not only the size of the electrical equipment but also the cost. Higher current wires must be run, as well multiple sets of wires.

The Main Distribution Panel for the fan coil design had a service of 690 kVA. The geothermal design caused the electrical feed to rise to a value of 823 kVA, about a 20% increase. All of the new schematics and panel boards can be found in the appendix. The cost of the increased electrical system would have to be factored in with the mechanical cost to decide on the proper system. The difference of sizing was estimated with R.S. Means. The electricity used by the expended service will be factored in with the mechanical operation costs previously identified. The difference will be when it comes to initial cost. The larger wires, installation, excess distance, extra panel boards, and increased service will all be associated with a cost. Combining these costs with the mechanical system cost will give us a better understanding of the actual cost of implementing a different mechanical design. Not only will this value count the cost of equipment, but also the cost of labor for installation and maintenance. The summary of costs is in Table 17 and the further breakdown can be found in the appendix.

Table 17 – Electrical System Cost

Cost	Fan Coil Design	Heat Pump Alternative 1	Heat Pump Alternative 2
Initial Electrical Cost	$134,089	$260,962	$260,962

There clearly is a sufficient increase in cost to increase the electrical system. The alteration to the mechanical system nearly doubled the construction cost of the electrical system. The increase is only a one time initial cost. All of the increased cost of electrical use by the equipment is included in the mechanical operation cost. This value will be factored in with the mechanical equipment, labor, operation, and construction management costs to choose the proper mechanical design.

Another factor that must be considered is the time for installing the electrical system. Since all of the labor will be done within the building, any increase of time may slow the finish of the project. Without a fully installed and functional electrical system, the building will not be fit for occupancy. In this case, the building was needed for completion to act as classrooms for students and offices for the faculty. This building had plenty of extra time before it hit a necessary deadline, but keeping crews and construction managers on longer could result in an extra cost. The time for construction of the different alternatives are shown in Table 18 for the electrical design.

Table 18 – Electrical Time

Time (Hrs)	Fan Coil Design	Heat Pump Alternative 1	Heat Pump Alternative 2
Electrical Construction Time	297	1,086	1,086

Many times, increased construction time is not an issue. In this case, it may be different since it is such a dramatic increase. The two redesign alternatives demand more than 3.5 times the amount of labor hours than the fan coil design. Nearly all of these hours will take place within The New Learning Center, which could delay occupancy. Much of the extra hours could possibly be done when other interiors are being assembled. This would be an important piece of information for the owner to consider when choosing from the mechanical alternatives.

Construction Management Breadth

The construction management portion of a building design is just as important as investigating the mechanical or electrical systems. All are integrated and it is impossible to make a proper conclusion without knowing all information. The construction management process was used to value the alterations of the electrical system in the previous section. The same process was also used to evaluate construction cost of the mechanical system redesign. R.S. Means was used for cost and labor estimation. With all of the information and equipment known, it is possible to get a very accurate estimate using this database. The difference in construction for the mechanical alternatives was approximated. These values of construction cost are a one time initial cost. These costs will be factored in to make a correct alternative selection. Table 19 shows the summary and the breakdown can be seen in the appendix.

Table 19 – Mechanical Construction Cost Differences

Cost	Fan Coil Design	Heat Pump Alternative 1	Heat Pump Alternative 2
Mechanical Alternatives	$186,819	$368,622	$448,441

The cost of construction is a large part of initial cost for a mechanical system, especially for a geothermal heat pump system. The biggest downfall for a geothermal system is their high initial cost. Alternative 1, with ¾ of the bores of Alternative 2, has twice the initial construction cost as the fan coil design. Alternative 2 has a cost three times larger. The geothermal systems depend on a lower mechanical equipment and operation cost to make up for this increased construction value.

The construction management process is also used to come up with time constraints. R.S. Means provides the estimator with an accurate time of labor for installation of equipment. An analysis was done of the mechanical system alternatives to figure out the labor hours needed for completion of The New Learning Center. Depending on what the labor hours are used on may slow the completion of the building construction. Table 20 shows the time for construction of the mechanical system alternatives and the breakdown can be seen in the appendix.

Table 20 – Mechanical System Construction Time

Time (Hrs)	Fan Coil Design	Heat Pump Alternative 1	Heat Pump Alternative 2
Mechanical Alternatives	1,467	1,531	1,557

In this case the construction time values are close. The specific tasks that the time is used on can at times affect the overall building construction timeline. The geothermal heat pump alternatives have a slightly higher time consideration to account for. The most convenient thing is that the alternatives would actually need less construction time if the geothermal loop was not counted. This is important to notice because the outdoor geothermal loop could be done while other indoor construction is unaffected. One thing that has to be considered is that the quad outside of The New Learning Center has to be excavated to install the piping. This would have to correlate with class or office schedules. However, the heat pumps took almost three times as long to install. The heat pumps will have to be installed before the electrical construction can finish. Overall, there should not be any substantial building construction setbacks due to the installation of the geothermal alternatives.

Final Conclusions and Recommendations

The decision on the proper mechanical system choice has to be based on several different factors. The performance of the HVAC system should always be the most important factor. Without a properly operating system, cost is irrelevant. A mechanical system can be extremely inexpensive, but if it does not ventilate and keep occupants comfortable, it will need to be completely redesigned and constructed. Second, cost is a factor. A life cycle cost is widely considered the best way to make a decision to pick from the alternatives. At times, life cycle cost is not the most important cost for an owner or business. Some owners may have a problem with the large upfront cost and turn to a less expensive system. The amount of emissions produced by the system is also an important factor to consider. Not only will lowering emissions help the environment as a whole, but it will help the outdoor air quality all around the campus. The final issue is the time factor. If there is a deadline that the project must be finished by, there may be some issues. All people in the building design and construction process have to be careful to ensure everything is done correctly, regardless of time issues. If corners are cut, larger problems may arise.

Performance

The most important way to look at the mechanical system options for The New Learning Center is the performance. All of the options were designed to have proper ventilation and conditioning of the air as well as individual occupant control. This individual control will make many of the occupants feel better about their indoor environment and comfort merely because they have control. Each of the systems were designed and sized correctly to meet or exceed all standards and codes. Each piece of equipment in all options was also efficient enough to pass code. The one difference in performance is the basement operation. The original fan coil design was to provide only heating and ventilation to the basement. In the geothermal alternatives, the design was to include a fourth rooftop unit to serve those areas. The unit will have an enthalpy wheel to reduce operation cost. It will also have the capability to cool and dehumidify on top of the ability to heat and ventilate. This added ability has an increased cost, but is necessary to fix all previous issues with the building. Although the basement is very rarely occupied, proper precautions should be taken during design to account for dehumidification. Some building owners would prefer to have chilled and hot water systems in their buildings, aside from a heat pump system. That being said, the efficiency of the heat pump system and the added benefit of the unit serving the basement, the geothermal systems are a better choice for performance. My recommendation to the owner would be to implement one of the geothermal designs in The New Learning Center. Both of the geothermal options are designed to function identically within the building. Therefore, there is no added performance benefit from either of the two alternatives.

Cost

Now we must look at the cost estimates for the different design options. The three costs to look at are initial cost, operation cost, and life cycle cost. The initial cost considers more than merely the mechanical equipment. To make a proper estimate of the system initial cost, the cost of the electrical system and construction must be included. The yearly operation cost of the mechanical and electrical system is equally important. Using a building modeling program, such as Trane Trace in this case, the energy consumption and cost per year can be accurately estimated. The electrical system energy is estimated by the lighting, receptacle use, and the power consumed by the mechanical equipment. There is no yearly cost for construction other than regular maintenance. The life cycle cost is usually estimated on a twenty year time span. This is how it will be estimated in this case as well. The life cycle cost is a good estimate of the amount that the owner should expect to commit to the project for the twenty year construction and operation of the building. The analysis of these total and square foot costs are in Table 21 and Table 22.

Table 21 – Total Costs

Total Cost	Fan Coil Design	Heat Pump Alternative 1	Heat Pump Alternative 2
Mechanical Equipment Cost	$389,175	$376,175	$368,425
Mechanical Construction Cost	$186,819	$368,622	$448,441
Electrical Cost	$134,089	$260,962	$260,962
Total initial Cost	$710,083	$1,005,759	$1,077,828
Yearly Operation Cost	$88,523	$72,200	$74,338
Yearly Tax Rebate	$0	$6,960	$6,960
20 Year Life Cycle w/o Rebate	$2,480,543	$2,449,759	$2,564,588
20 Year Life Cycle Cost	**$2,480,543**	**$2,310,559**	**$2,425,388**
Cost Differential	-	**-$169,984**	**-$55,155**

Table 22 – Costs per Square Foot

Cost per SF	Fan Coil Design	Heat Pump Alternative 1	Heat Pump Alternative 2
Mechanical Equipment Cost	$6.71	$6.49	$6.35
Mechanical Construction Cost	$3.22	$6.36	$7.73
Electrical Cost	$2.31	$4.50	$4.50
Total initial Cost	$12.24	$17.34	$18.58
Yearly Operation Cost	$1.53	$1.24	$1.28
Yearly Tax Rebate	$0.00	$0.12	$0.12
20 Year Life Cycle Cost	**$42.77**	**$39.74**	**$41.78**
Cost Differential	-	**-$3.03**	**-$0.99**

The costs for the three alternatives need to be analyzed further to make a proper decision. First, the initial cost has to be contemplated. The downfall of geothermal systems is their high first cost. The fan coil design is substantially less expensive. The fan coil design is approximately $300,000 less than the geothermal system with a cooling tower and $360,000 less than the other geothermal system, Alternative 2. The mechanical equipment itself is cheaper for the geothermal system, mostly because it eliminates the need for the chiller and boilers. However, the electrical system must be increased in size because of the electrical demand of the 66 heat pumps. The initial cost of the electrical redesign is twice the cost of the design necessary to operate the fan coil system. The construction initial costs also need to be examined. The geothermal Alternative 1 costs twice as much as the fan coil design, and Alternative 2 is almost 2.5 times as much.

The low operation cost is the major benefit of geothermal systems. Both of the geothermal heat pump systems operate at 81-84% of the cost for running the fan coil system. The yearly pollutants are also considerably lower. Considering these systems as a long term approach, the operation cost is largely more important than the initial cost. The initial cost is only a one time thing as the operation cost must be accounted for every year.

The twenty year life cycle cost is what I would recommend the owner consider above all. In the life cycle cost, the initial and operation cost can be weighed evenly. At first look there is very little difference in the life cycle cost. Geothermal Alternative 1 saves the owner only $31,000, while Alternative 2 costs an extra $84,000. Over the course of twenty years, that little amount of money saved may not be worth the higher initial cost. However, with the low energy consumption for operation of the geothermal redesign the owner can qualify for tax deductions. According to the Energy Policy Act of 2005, any building that limits the energy consumed by 16 2/3% can qualify for tax rebates. These deductions are $0.60 per square foot of the building. In this case, it was assumed that the owner would be taxed 20%, and therefore receive that amount of the deductions as a rebate. This could not be received with the energy consumed by the fan coil system. This deductions amount to $34,800 per year, which equals a yearly rebate of almost $7,000, nearly 10% of the yearly operation cost. This rebate makes the geothermal system a much less expensive choice. When factored in to the life cycle cost, both are less expensive than the fan coil design. Alternative 1 saves almost $170,000, a substantial amount of money. Considering all costs, the geothermal system with the cooling tower, Alternative 1, is clearly the best choice for an owner that has the money for the larger initial cost. If the extra money is not available up front, the fan coil design is still a good mechanical system.

Construction Time

Time of construction is always a concern in the building process. In the case of a school, time may be a huge factor. If classes are set to begin on a certain date and the building is not finished, there could be a huge problem. If The New Learning Center was unable to act as offices for the faculty and as classrooms for a year of schooling, the construction time would result in an extreme amount of cost and inconvenience. The time of construction is shown in Table 23.

Table 23 – Construction Time

Time (Hrs)	Fan Coil Design	Heat Pump Alternative 1	Heat Pump Alternative 2
Construction Time	1,764	2,617	2,643

The fan coil design clearly has the lowest construction time. The difference in time is nearly all due to the installation of the larger electrical system. In this case, time was not constricted by the start of a school year. Naturally, the faculty would want to move into their new offices as soon as possible, but they do have old offices they could have stayed in for a small time longer. The owners, however, would not have to pay a construction management team to stay on longer since they have full time employees that do that for the campus. The fan coil design would be the correct choice if there were strict time constraints.

Emissions

It is important to consider the emissions produced by the different systems. The fan coil system has a boiler on site which produces pollutants. It also has three rooftop units that have gas fired heating. All of these pieces of equipment produce pollutant and toxins within and around the building. The geothermal heat pump systems do not require any of that on site energy. All of the energy for the geothermal systems will be supplied through electricity from a plant and will keep the emissions around the building to a minimum. The summary of pollutants is in Table 24.

Table 24 – Emissions

	Fan Coil Design	Alternative 1	Alternative 2
Pollutant	Emissions lbm / year	Emissions lbm / year	Emissions lbm / year
CO	1,001,358	766,431	789,128
SO	4,315	4,188	4,312
NO	2,942	2,466	2,539
Particulates	367	0	0

The pollutants are about 20% lower across the board for the geothermal systems. Also, there are absolutely no particulates deposited into the air by the geothermal systems. The geothermal systems are much more environmentally friendly.

Recommendations

After considering the performance, cost, time, and emissions of the systems, a proper conclusion can be made. After analyzing the systems, the geothermal system with a cooling tower, Alternative 1, is a much better system that Alternative 2. It has identical performance, lower initial, operation, and life cycle cost, less construction time, and lower emissions. Therefore, Alternative 2 should not be considered as a system of choice. If a geothermal system is to be implemented, Alternative 1 is clearly the correct decisions. That brings the decisions down to the fan coil design and Alternative 1. The performance is slightly better of the geothermal system since it has an added rooftop unit to serve the basement zones. Although the initial cost is higher, the life cycle cost is clearly better for the geothermal system when the tax deductions are considered. The fan coil design does have a substantial edge when the construction is considered. Not only will there be more time needed for construction within the building, but the geothermal will require the campus quad to be temporarily torn up to lay all of the geothermal ground piping. The emissions produced by the mechanical equipment also favor the geothermal system. With all that said, the geothermal system seems to be the clear choice. The tax deductions are the part that really makes the system better. Otherwise, it would be nearly an even call. This goes to show why geothermal systems are not always used. They do not greatly benefit the owner in every building, in all situations. In this case though, it would be beneficial and would be my recommendation to the owner.

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Appendix A

RTU-4 Calculated CFM= 2526

HP B-1

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Compact Storage	B04	Storage	351.8	0	355	355	1.00					
Total								355	352	1	1	**355**

HP B-2, 3

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Corridor	B07	Corridor	124.9	0	125	250	0.50					
Archives Region	B08	Storage	425.9	0	425	425	1.00					
Archives Region	B09	Storage	39.84	0	40	65	0.61					
Archives Region	B11	Storage	80.88	0	80	80	1.00					
Total								670	820	1	1	**670**

HP B-4, 5

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Breezeway	117	Lobbies	50.88	100	151	3090	0.05					
Total								151	3090	0.05	1	**151**

RTU-4

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Mechanical Room	B05	Storage	160.6	0	161	1350	0.12					
Total								161	1350	0.12	1	**161**

RTU-1 Calculated CFM= 6020

HP 1-1, 2

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Reception Hall / Class	101	Lecture Class	77.28	623	700	1580	0.44					
A/V Control	103A	Office	3.9	5	9	65	0.14					
Corridor	103H	Corridor	63.6	25	89	1880	0.05					
Total								797	3525	0.44	0.7	**1139**

HP 1-3, 4

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Reception Hall / Class	101	Lecture Class	154.6	1253	1407	3200	0.44					
Total								1407	3200	0.44	0.7	**2010**

HP 2-1

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Classroom	201	Lecture Class	91.5	525	617	1565	0.39					
Total								617	1565	0.39	0.7	**881**

HP 2-2, 3

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Seminar / Conference	202	Conference	23.4	80	103	570	0.18					
Total								103	570	0.18	0.9	**115**

HP 2-4, 5

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Seminar / Conference	203	Conference	22.68	80	103	570	0.18					
Total								103	570	0.18	0.9	**114**

HP 2-8, 9

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Faculty Conference	208	Conference	22.74	80	103	570	0.18					
Total								103	570	0.18	0.9	**114**

HP 3-1

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Distance Learning Class	301	Lecture Class	90.3	398	488	1480	0.33					
Total								488	1480	0.33	0.8	**610**

HP 3-2, 3

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Seminar / Conference	302	Conference	21.72	80	102	570	0.18					

Total								102	570	0.18	0.9	**113**

HP 3-4, 5

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Seminar / Conference	303	Conference	22.68	80	103	1720	0.06					
Total								103	1720	0.06	1	**103**

HP 3-6, 7

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Corridor	305	Corridor	82.32	15	97	630	0.15					
Classroom	306	Lecture Class	51.3	278	329	565	0.58					
Alcove	314	Storage	13.68	0	14	75	0.18					
Copy Room	317	Storage	12.24	0	12	325	0.04					
Total								452	1595	0.58	0.55	**822**

<u>RTU-2</u> **Calculated CFM=** **3677**

HP 1-5, 6

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Lounge	102	Office	57.18	100	157	950	0.17					
Pantry	102A	Storage	18.12	0	18	30	0.60					
Lounge	102C	Office	44.7	75	120	1065	0.11					
Coat	102F	Storage	13.32	0	13	220	0.06					
Total								308	2265	0.6	0.55	**561**

HP 1-7, 8, 9

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Corridor	103	Corridor	63.6	20	84	695	0.12	7				
A/V Control	103D	Office	3.9	5	9	135	0.07	7				
Corridor	106	Corridor	22.86	0	23	875	0.03	9				

Corridor	106A	Corridor	9.6	0	10	100	0.10	7				
Kitchen	107	Café	63.54	15	79	210	0.37	9				
Kitchen	107B	Café	68.22	7.5	76	220	0.34	9				
Storage	109	Storage	89.16	0	89	260	0.34	9				
Security / Receptionist	110	Lobbies	78.6	50	129	2380	0.05	8				
Lockers	111	Corridor	15.12	5	20	50	0.40	8				
Mailroom	111A	Office	30.24	0	30	90	0.34	8				
Copy Room	112	Storage	9.72	0	10	235	0.04	8				
Mail Prep Room	114	Office	19.98	5	25	70	0.36	8				
Total								582	5320	0.4	0.7	**831**

HP 2-6, 7

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Corridor	205	Corridor	69	15	84	325	0.26					
Faculty / Staff Lounge	206	Office	32.7	75	108	275	0.39					
Corridor	207	Corridor	41.1	0	41	150	0.27					
Copy Room	210	Storage	10.08	0	10	245	0.04					
Alcove	211	Storage	13.2	0	13	75	0.18					
Total								256	1070	0.39	0.7	**366**

HP 2-10, 11

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
UTI Classroom	204	Lecture Class	51.3	255	306	1215	0.25					
Classroom	209	Lecture Class	56.82	308	364	1055	0.35					
Storage	209A	Storage	15.6	0	16	30	0.52					
Total								686	2300	0.52	0.6	**1144**

HP 2-14

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Storage	216	Sotrage	32.4	0	32	32	1.00					
Conference Room	217	Conference	16.68	50	67	160	0.42					
Total								99	192	1	1	**99**

HP 3-10, 11

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Heinecken Room	304	Lecture Class	52.14	225	277	1420	0.20					
Board Room	309	Conference	58.14	125	183	875	0.21					
Pantry	309A	Storage	13.2	0	13	30	0.44					
Total								473	2325	0.44	0.7	**676**

RTU-3 **Calculated CFM=** **1712**

HP 2-20

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Corridor	220	Corridor	47.46	0	47	95	0.50					
Admission Assistant	222	Office	29.7	40	70	350	0.20					
Corridor	225	Corridor	18.9	0	19	30	0.63					
Work Room	226	Office	13.68	5	19	425	0.04					
Coffee Area	231	Corridor	5.1	5	10	275	0.04					
Total								165	1175	0.63	0.55	**300**

HP 3-14

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Computer Lab	315	Computer	54.84	170	225	1070	0.21					
Total								225	1070	0.21	0.9	**250**

HP 3-15, 16

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Seminar / Conference	316	Conference	22.44	80	102	695	0.15					
Total								102	695	0.15	1	**102**

HP 3-18, 19

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Breakout Space	319	Conference	19.08	60	79	315	0.25					
Breakout Space	320	Conference	18.9	60	79	190	0.42					
Total								158	505	0.42	0.7	**226**

HP 3-21, 22

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Corridor	312	Corridor	92.64	0	93	345	0.27					
Teaching Lab	322	Classroom	101	300	401	1035	0.39					
Storage	322C	Storage	16.32	0	16	45	0.36					
Total								510	1425	0.39	0.7	**729**

HP 3-23, 24

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
MMRC	323	Office	26.04	80	106	705	0.15					
Total								106	705	0.15	1	**106**

CONSOLE ONLY

HP 1-10

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Shipping / Receiving	113	Shipping	53.88	0	54	250	0.22					
Total								54	250	0.22	0.9	**60**

HP 1-11

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Custodian Office	115	Office	18.3	0	18	350	0.05					
Total								18	350	0.05	1	**18**

HP 2-12, 13, 15,16,18, 21,23

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Office	214	Office	11.04	5	16	260	0.06					
Total								16	260	0.06	1	**16**

HP 2-17,19,22,25

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Admission	221	Office	11.04	5	16	190	0.08					
Total								16	190	0.08	1	**16**

HP 2-24

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Financial Aid	230	Office	10.14	5	15	195	0.08					
Total								15	195	0.08	1	**15**

HP 2-26

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot

Grad Program Assistant	233	Office	11.4	5	16	260	0.06					
Total								16	260	0.06	1	**16**

HP 3-8

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Lay theo Office	307	Office	11.94	5	17	355	0.05					
Total								17	355	0.05	1	**17**

HP 3-9

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Media Tech Office	308	Office	11.94	5	17	265	0.06					
Total								17	265	0.06	1	**17**

HP 3-12, 13

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Server / Work / Control	313	Office	21.84	5	27	595	0.05					
Total								27	595	0.05	1	**27**

HP 3-17, 20

Room	Label	Function	Az*Ra	Pz*Rp	Voz	Vpz	Zp	Vou	Vps	Zp(max)	Ev	Vot
Tey Office	318	Office	10.38	5	15	410	0.04					
Total								15	410	0.04	1	**15**

Appendix B

LTSP Chilled Water System Components

Air Cooled Chiller Schedule									
	Capacity	Evaporator				Compressor			
No.	tons	GPM	EWT	LWT	PD	Type	kW	kW / ton	Referig.
1	150	255	42	56	18.4	Screw	188.6	1.273	R - 134a

LTSP Hot Water System Components

Boiler Schedule									
		Burner			Capacity				Gas
No.	Type	Fuel	HP	MBH	Gross	Net	HP	Fan HP	Volume
1	Forced Draft	Gas	43	1800	1440	1250	43	1/2	728
2	Forced Draft	Gas	43	1800	1440	1250	43	1/2	728

Heating Coil Schedule									
No.	Serves	CFM	EAT	LAT	MBH	GPM	EWT	WPD	APD
1	SF-1	1350	10	70	87.5	17.5	200	6.4	0.26
2	SF-2	1310	10	70	84.9	15	200	4.6	0.25
3	SF-3	2350	10	70	152.5	29	20	3.4	0.46

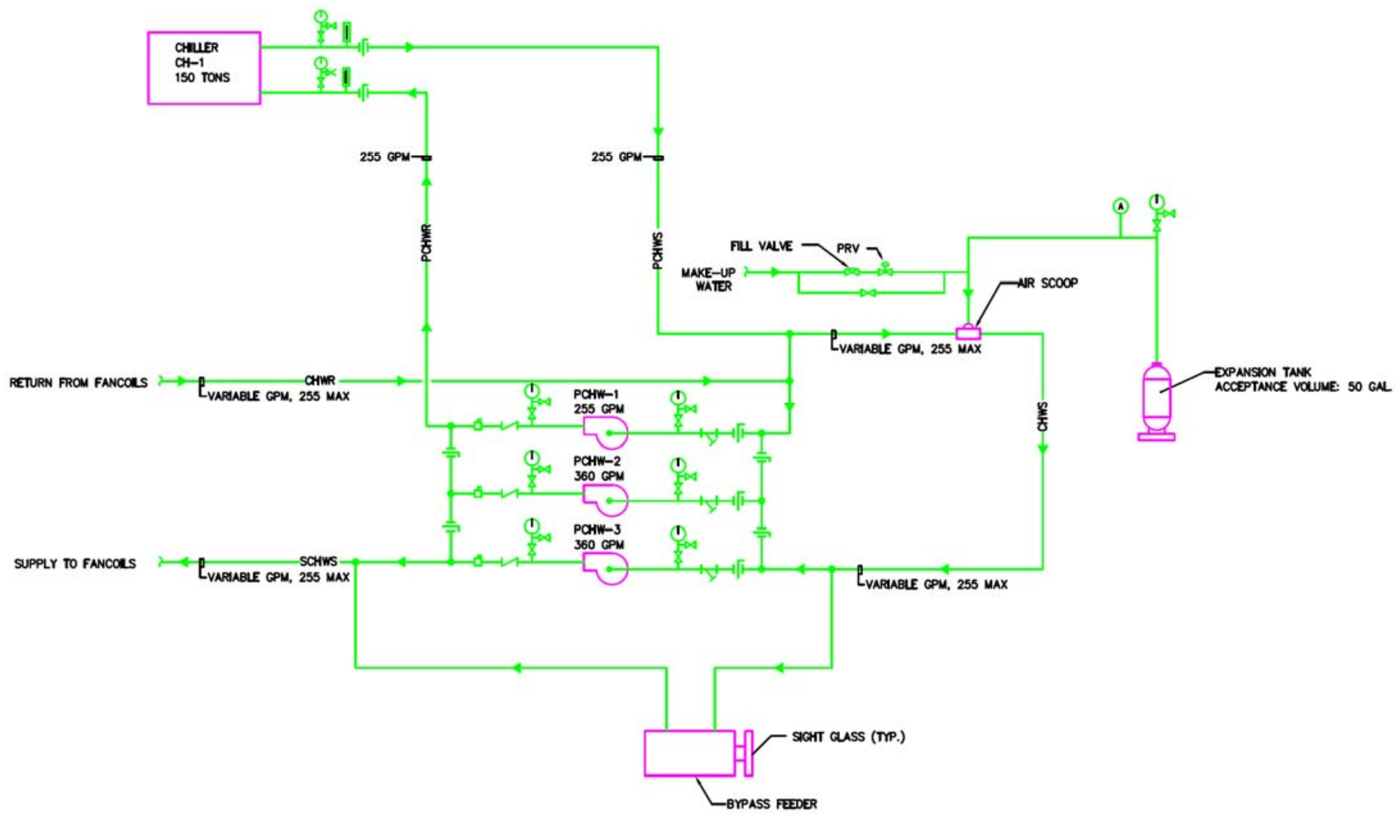
LTSP Air System Components

Gas-Fired Rooftop Air Conditioning Unit Schedule																
	Fan				Cooiling Capacity				Heating Capacity					Heat Recovery Wheel		
	Total	OA			Total	Sensible	EAT DB /	LAT DB /		Total	Sensible			Cooling	Heating	
No.	CFM	CFM	ESP	HP	MBH	MBH	WB	WB	Fuel	MBH	MBH	EAT	LAT	LAT	LAT	EER
1	6225	6225	1.5	10	322	200	85 / 71	55 / 54	Gas	270	219	45	77	85	45	10.3
2	6125	6125	1.5	10	320	199	85 / 71	55 / 54	Gas	270	219	45	78	85	45	10.3
3	1685	1685	1.5	3	101	62.9	85 / 71	52 / 51	Gas	90	72.9	25	68	85	25	10.3

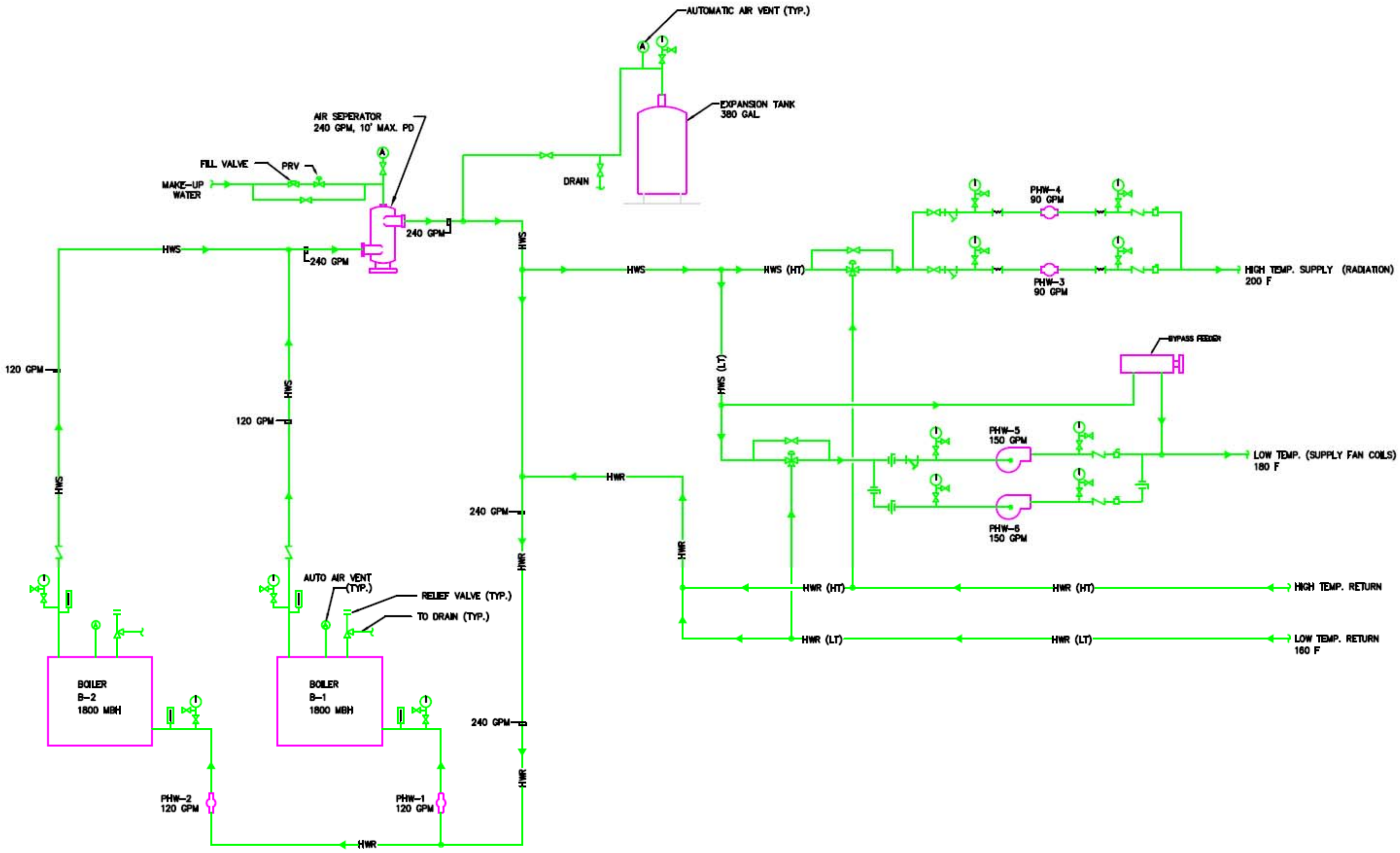
Fan Coil Unit Schedule																	
		Fan				Cooling Capacity						Heating Capacity					
		Total	OA		Total	Total	Sensible	Water					Water				
No.	Type	CFM	CFM	ESP	HP	MBH	MBH	GPM	EWT	LWT	WPD	MBH	GPM	EWT	LWT	WPD
B-1	Ducted	1215	360	0.25	1/4	43.3	30.4	12.5	45	55	11.2	33.9	1.5	180	160	1.8
B-2	Ducted	1565	360	0.25	1/2	46.7	35.8	8.5	45	55	3.1	50.9	3.5	180	160	9.4
B-3	Ducted	1565	350	0.25	1/2	48.2	36.5	9	45	55	3.6	40.6	1.5	180	160	2.6
B-4	Ducted	1750	120	0.25	1/2	65.4	45.4	16.5	45	55	10.9	65.8	2.5	180	160	2.1
B-5	Ducted	1750	120	0.25	1/2	65.4	45.4	16.5	45	55	10.9	65.8	2.5	180	160	2.1

1-1	Ducted	1750	-	0.25	1/2	67.1	46.2	18.5	45	55	13.1	90.8	5	180	160	8.9
1-2	Ducted	1675	-	0.25	1/2	62	42.8	17.5	45	55	10.4	55.1	3.5	180	160	11.8
1-3	Ducted	1565	-	0.25	1/2	55	39.5	14.5	45	55	7.3	50.2	3	180	160	8.4
1-4	Ducted	1565	-	0.25	1/2	55	39.5	14.5	45	55	7.3	50.2	3	180	160	8.4
1-5	Ducted	930	-	0.25	1/4	35.4	24.2	15	45	55	13.4	35.4	1.5	180	160	0.4
1-6	Ducted	930	-	0.25	1/4	35.4	24.2	15	45	55	13.4	35.4	1.5	180	160	0.4
1-7	Ducted	895	-	0.25	1/4	39.2	26.1	8.5	45	55	7.8	28.9	2	180	160	2.5
1-8	Ducted	1750	-	0.25	1/2	70	47.5	24	45	55	19.1	101	8	180	160	21.2
1-9	Ducted	1215	-	0.25	1/4	39.5	28.7	8.5	45	55	6.3	33.9	1.5	180	160	1.8
1-10	Console	385	70	0.05	1/6	13.6	9.6	3	45	55	14.5	18.8	4	180	160	8.4
1-11	Console	235	20	0.05	1/12	9	6.1	2	45	55	10.3	12.2	4	180	160	6.6
2-1	Ducted	1575	-	0.25	1/2	72.2	47.5	16.5	45	55	9.5	48.6	3	180	160	7
2-2	Console	420	80	0.05	1/6	16.3	9.4	9	45	55	13.2	20	4	180	160	12.1
2-3	Console	420	80	0.05	1/6	16.3	9.4	9	45	55	13.2	20	4	180	160	12.1
2-4	Console	420	80	0.05	1/6	16.3	9.4	9	45	55	13.2	20	4	180	160	12.1
2-5	Console	420	80	0.05	1/6	16.3	9.4	9	45	55	13.2	20	4	180	160	12.1
2-6	Ducted	895	-	0.25	1/4	37.9	25.5	7.5	45	55	6.5	23.6	1	180	160	0.8
2-7	Ducted	555	-	0.25	1/4	19.6	14	7	45	55	4.7	12.8	0.5	180	160	0.1
2-8	Console	385	80	0.05	1/6	14.9	10	4	45	55	8.5	18.8	4	180	160	8.4
2-9	Console	385	80	0.05	1/6	14.9	10	4	45	55	8.5	18.8	4	180	160	8.4
2-10	Ducted	930	-	0.25	1/4	33.5	23.4	11	45	55	8.3	35.2	1.5	180	160	0.4
2-11	Ducted	1360	-	0.25	2/5	45.1	32.5	10.5	45	55	8.7	40.1	2	180	160	3.6
2-12	Console	290	20	0.05	1/6	9.2	6.1	2.5	45	55	3	11.8	1.5	180	160	1.9
2-13	Console	290	20	0.05	1/6	9.2	6.1	2.5	45	55	3	11.8	1.5	180	160	1.9
2-14	Ducted	555	-	0.25	1/8	14.3	11.7	2.5	45	55	1	12.8	0.5	180	160	0.1
2-15	Console	290	20	0.05	1/6	9.2	6.1	2.5	45	55	3	11.8	1.5	180	160	1.9
2-16	Console	290	20	0.05	1/6	9.2	6.1	2.5	45	55	3	11.8	1.5	180	160	1.9
2-17	Console	290	20	0.05	1/6	9.2	6.1	2.5	45	55	3	11.8	1.5	180	160	1.9
2-18	Console	290	20	0.05	1/6	9.2	6.1	2.5	45	55	3	11.8	1.5	180	160	1.9
2-19	Console	290	20	0.05	1/6	9.2	6.1	2.5	45	55	3	11.8	1.5	180	160	1.9
2-20	Ducted	1215	-	0.25	1/4	40.3	29.1	9	45	55	7.1	38.5	2.5	180	160	4.3
2-21	Console	290	20	0.05	1/6	9.2	6.1	2.5	45	55	3	11.8	1.5	180	160	1.9
2-22	Console	290	20	0.05	1/6	9.2	6.1	2.5	45	55	3	11.8	1.5	180	160	1.9
2-23	Console	290	20	0.05	1/6	9.2	6.1	2.5	45	55	3	11.8	1.5	180	160	1.9
2-24	Console	245	20	0.05	1/6	10.8	6.8	3	45	55	4.6	12.8	4	180	160	7.9
2-25	Console	290	20	0.05	1/6	9.2	6.1	2.5	45	55	3	11.8	1.5	180	160	1.9
2-26	Console	180	20	0.05	1/12	6.5	4	1.5	45	55	5.4	9.5	3.5	180	160	5.2
3-1	Ducted	1465	-	0.25	1/2	69	44	18.5	45	55	10.2	44.9	2.5	180	160	5.8
3-2	Console	550	80	0.05	1/6	14.1	10.4	4	45	55	4.9	23.5	2.5	180	160	3.8
3-3	Console	550	80	0.05	1/6	14.1	10.4	4	45	55	4.9	23.5	2.5	180	160	3.8
3-4	Console	620	80	0.05	1/6	18.4	13.8	3	45	55	7.1	24.8	2.5	180	160	4.5
3-5	Console	620	80	0.05	1/6	18.4	13.8	3	45	55	7.1	24.8	2.5	180	160	4.5
3-6	Ducted	1700	-	0.25	1/2	78.2	51.1	13.5	45	55	8.2	53.8	3	180	160	10.5

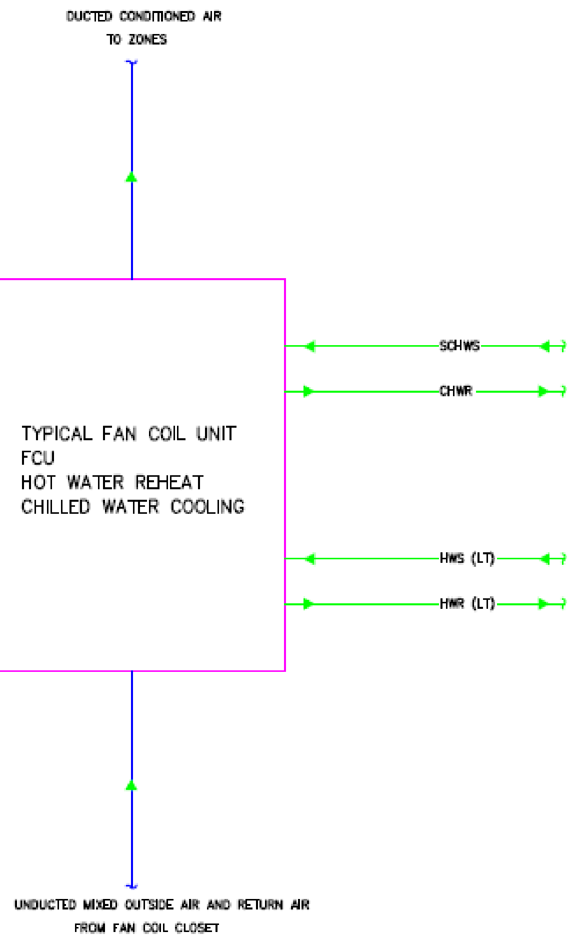
3-7	Ducted	720	-	0.25	1/5	29.6	20.2	5.5	45	55	4	20.4	1	180	160	0.6
3-8	Ducted	290	20	0.05	1/6	9.2	6.1	2.5	45	55	3	11.8	1.5	180	160	1.9
3-9	Ducted	290	20	0.05	1/6	9.2	6.1	2.5	45	55	3	11.8	1.5	180	160	1.9
3-10	Ducted	1180	-	0.25	1/4	35.7	26.7	6.5	45	55	4.1	42.1	1.5	180	160	0.6
3-11	Ducted	1180	-	0.25	1/4	45.1	30.9	16.5	45	55	17.6	55	3	180	160	1.7
3-12	Console	245	20	0.05	1/6	10.5	6.7	2.5	45	55	3.7	10.7	1.5	180	160	1.6
3-13	Console	245	20	0.05	1/6	10.5	6.7	2.5	45	55	3.7	10.7	1.5	180	160	1.6
3-14	Ducted	1215	-	0.25	1/4	38.6	28.3	8	45	55	5.6	29.3	1	180	160	0.9
3-15	Console	550	80	0.05	1/6	14.1	10.4	4	45	55	4.9	23.5	2.5	180	160	3.8
3-16	Console	550	80	0.05	1/6	14.1	10.4	4	45	55	4.9	23.5	2.5	180	160	3.8
3-17	Console	290	20	0.05	1/6	9.2	6.1	2.5	45	55	3	11.8	1.5	180	160	1.9
3-18	Ducted	720	-	0.25	1/5	26.1	18.5	3.5	45	55	2.4	24.6	2	180	160	2.1
3-19	Ducted	515	-	0.25	1/8	17.4	13	2.5	45	55	1.4	15.6	1	180	160	0.5
3-20	Console	290	-	0.05	1/6	9.2	6.1	2.5	45	55	3	11.8	1.5	180	160	1.9
3-21	Ducted	1215	-	0.25	1/4	41.8	29.7	10.5	45	55	8.8	38.5	2.5	180	160	4.2
3-22	Ducted	895	-	0.25	1/4	36.7	25	7	45	55	5.6	30.3	2.5	180	160	3.6
3-23	Console	550	80	0.05	1/3	14.1	10.4	4	45	55	4.9	23.5	2.5	180	160	3.8
3-24	Console	550	80	0.05	1/3	14.1	10.4	4	45	55	4.9	23.5	2.5	180	160	3.8



CHILLED WATER PIPING SCHEMATIC



HOT WATER SYSTEM SCHEMATIC



TYPICAL FAN COIL UNIT SCHEMATIC

Appendix C

Following Redesign Equipment Information:

RTU's Shared

Heat Pumps Shared

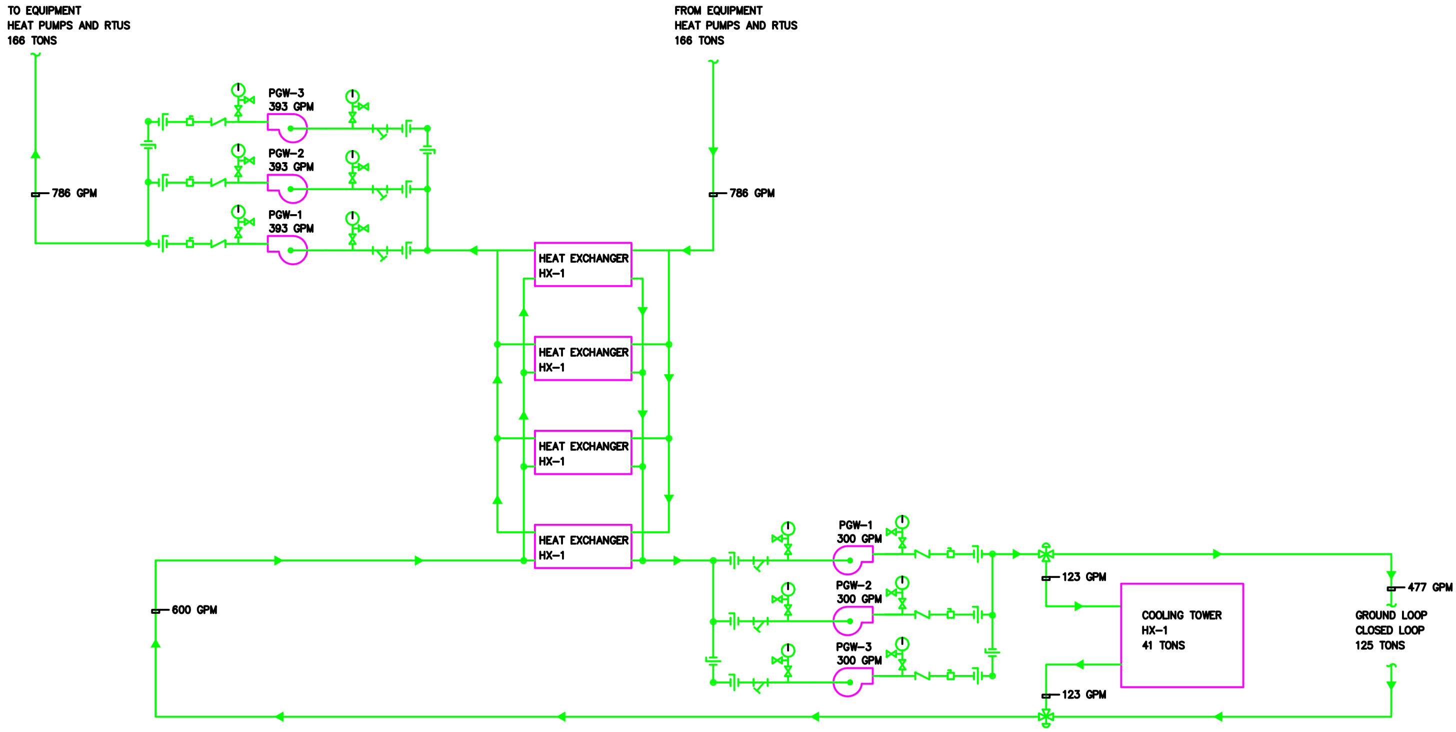
Other equipment and Schematics by Alternative

Heat Pump RooftopUnit Schedule

	Fan				Cooiling Capacity					Heating Capacity					Heat Recovery Wheel			RTU
	Total	OA			Total	Sensible	EAT	LAT			Sensible				Cooling	Heating		Sizing and
No.	CFM	CFM	ESP	HP	MBH	MBH	DB / WB	DB / WB	GPM	Fuel	MBH	EAT	LAT	GPM	LAT	LAT	EER	Selection
1	6020	6020	2.7	5	247.0	176.0	82 / 68	55 / 54	54	Ground Source	210.0	45	74	54	82	45	19.9	AAON RM020
2	3680	3680	2.1	2	180.0	120.0	81 / 67	49 / 48	44	Ground Source	154.0	52	87	44	81	52	20.7	AAON RM016
3	1720	1720	2	1	86.0	56.0	80 / 67	52 / 50	22	Ground Source	73.0	51	86	22	80	51	18.9	AAON RM008
4	2525	2525	2.54	2	122.0	82.0	82 / 68	54 / 52	44	Ground Source	104.0	25	68	44	82	44	18.7	AAON RM010

Heat Pump Unit Schedule																
						Cooling Capacity					Heating Capacity					HP
		Total	OA		Total	Capacity	Sensible	Water			Capacity	Design	Water			Size and
No.	Type	CFM	CFM	ESP	HP	MBH	MBH	GPM	EWT	EER	MBH	MBH	GPM	EWT	COP	Selection
B-1	Ducted	355	355	0.5	1/2	31.8	5.8	8	59	26.0	26.2	9.6	8	50	5.1	WaterFurnace GWHP026
B-2	Ducted	425	425	0.5	1/2	31.8	6.9	8	59	26.0	26.2	11.5	8	50	5.1	WaterFurnace GWHP026
B-3	Ducted	395	245	0.5	1/2	31.8	7.3	8	59	26.0	26.2	10.7	8	50	5.1	WaterFurnace GWHP026
B-4	Ducted	1545	75	0.5	1/2	54.6	28.4	12	59	22.7	48.3	41.7	12	50	4.7	WaterFurnace GWHP049
B-5	Ducted	1545	75	0.5	1/2	54.6	28.4	12	59	22.7	48.3	41.7	12	50	4.7	WaterFurnace GWHP049
												0.0				
1-1	Ducted	1945	100	0.75	1	81.8	35.7	18	59	21.6	73.4	52.5	18	50	4.5	WaterFurnace GWHP072
1-2	Ducted	1580	700	0.5	1/2	54.6	29.0	12	59	22.7	48.3	42.7	12	50	4.7	WaterFurnace GWHP049
1-3	Ducted	1600	705	0.75	1	75.8	29.4	16	59	22.7	60.3	43.2	16	50	4.6	WaterFurnace GWHP064
1-4	Ducted	1600	705	0.75	1	75.8	29.4	16	59	22.7	60.3	43.2	16	50	4.6	WaterFurnace GWHP064
1-5	Ducted	1315	150	0.5	1/2	54.6	24.1	12	59	22.7	48.3	35.5	12	50	4.7	WaterFurnace GWHP049
1-6	Ducted	950	155	0.5	1/2	31.8	17.4	8	59	26.0	26.2	25.7	8	50	5.1	WaterFurnace GWHP026
1-7	Ducted	1930	165	0.75	1	81.8	35.4	18	59	21.6	73.4	52.1	18	50	4.5	WaterFurnace GWHP072
1-8	Ducted	1825	155	0.75	1	81.8	33.5	18	59	21.6	73.4	49.3	18	50	4.5	WaterFurnace GWHP072
1-9	Ducted	1565	270	0.75	1	75.8	28.7	16	59	22.7	60.3	42.3	16	50	4.6	WaterFurnace GWHP064
1-10	Console	250	55	0.5	1/2	31.8	9.5	8	59	26.0	26.2	6.8	8	50	5.1	WaterFurnace GWHP026
1-11	Console	350	20	0.5	1/2	31.8	13.2	8	59	26.0	26.2	9.5	8	50	5.1	WaterFurnace GWHP026
2-1	Ducted	1565	620	0.75	1	75.8	28.7	16	59	22.7	60.3	42.3	16	50	4.6	WaterFurnace GWHP064
2-2	Console	285	55	0.5	1/2	31.8	10.8	8	59	26.0	26.2	7.7	8	50	5.1	WaterFurnace GWHP026
2-3	Console	285	55	0.5	1/2	31.8	10.8	8	59	26.0	26.2	7.7	8	50	5.1	WaterFurnace GWHP026
2-4	Console	285	55	0.5	1/2	31.8	10.8	8	59	26.0	26.2	7.7	8	50	5.1	WaterFurnace GWHP026
2-5	Console	285	55	0.5	1/2	31.8	10.8	8	59	26.0	26.2	7.7	8	50	5.1	WaterFurnace GWHP026
2-6	Ducted	325	85	0.5	1/2	31.8	6.0	8	59	26.0	26.2	8.8	8	50	5.1	WaterFurnace GWHP026
2-7	Ducted	745	170	0.5	1/2	31.8	13.7	8	59	26.0	26.2	20.1	8	50	5.1	WaterFurnace GWHP026
2-8	Console	285	55	0.5	1/2	31.8	10.8	8	59	26.0	26.2	7.7	8	50	5.1	WaterFurnace GWHP026
2-9	Console	285	55	0.5	1/2	31.8	10.8	8	59	26.0	26.2	7.7	8	50	5.1	WaterFurnace GWHP026
2-10	Ducted	1245	325	0.5	1/2	54.6	22.9	12	59	22.7	48.3	33.6	12	50	4.7	WaterFurnace GWHP049
2-11	Ducted	1055	365	0.5	1/2	40.5	19.4	9	59	24.1	35.8	28.5	9	50	5.0	WaterFurnace GWHP038
2-12	Console	260	20	0.5	1/2	31.8	9.8	8	59	26.0	26.2	7.0	8	50	5.1	WaterFurnace GWHP026
2-13	Console	260	20	0.5	1/2	31.8	9.8	8	59	26.0	26.2	7.0	8	50	5.1	WaterFurnace GWHP026
2-14	Ducted	195	100	0.5	1/2	31.8	3.6	8	59	26.0	26.2	5.3	8	50	5.1	WaterFurnace GWHP026
2-15	Console	260	20	0.5	1/2	31.8	9.8	8	59	26.0	26.2	7.0	8	50	5.1	WaterFurnace GWHP026
2-16	Console	260	20	0.5	1/2	31.8	9.8	8	59	26.0	26.2	7.0	8	50	5.1	WaterFurnace GWHP026
2-17	Console	190	20	0.5	1/2	31.8	7.2	8	59	26.0	26.2	5.1	8	50	5.1	WaterFurnace GWHP026
2-18	Console	260	20	0.5	1/2	31.8	9.8	8	59	26.0	26.2	7.0	8	50	5.1	WaterFurnace GWHP026
2-19	Console	190	20	0.5	1/2	31.8	7.2	8	59	26.0	26.2	5.1	8	50	5.1	WaterFurnace GWHP026
2-20	Ducted	1175	165	0.5	1/2	40.5	21.6	9	59	24.1	35.8	31.7	9	50	5.0	WaterFurnace GWHP038
2-21	Console	260	20	0.5	1/2	31.8	9.8	8	59	26.0	26.2	7.0	8	50	5.1	WaterFurnace GWHP026
2-22	Console	190	20	0.5	1/2	31.8	7.2	8	59	26.0	26.2	5.1	8	50	5.1	WaterFurnace GWHP026
2-23	Console	260	20	0.5	1/2	31.8	9.8	8	59	26.0	26.2	7.0	8	50	5.1	WaterFurnace GWHP026
2-24	Console	195	20	0.5	1/2	31.8	7.4	8	59	26.0	26.2	5.3	8	50	5.1	WaterFurnace GWHP026

2-25	Console	190	20	0.5	1/2	31.8	7.2	8	59	26.0	26.2	5.1	8	50	5.1	WaterFurnace GWHP026
2-26	Console	260	20	0.5	1/2	31.8	9.8	8	59	26.0	26.2	7.0	8	50	5.1	WaterFurnace GWHP026
3-1	Ducted	1480	490	0.5	1/2	54.6	27.2	12	59	22.7	48.3	40.0	12	50	4.7	WaterFurnace GWHP049
3-2	Console	285	55	0.5	1/2	31.8	10.8	8	59	26.0	26.2	7.7	8	50	5.1	WaterFurnace GWHP026
3-3	Console	285	55	0.5	1/2	31.8	10.8	8	59	26.0	26.2	7.7	8	50	5.1	WaterFurnace GWHP026
3-4	Console	860	55	0.5	1/2	31.8	32.5	8	59	26.0	26.2	23.2	8	50	5.1	WaterFurnace GWHP026
3-5	Console	860	55	0.5	1/2	31.8	32.5	8	59	26.0	26.2	23.2	8	50	5.1	WaterFurnace GWHP026
3-6	Ducted	955	110	0.5	1/2	31.8	17.5	8	59	26.0	26.2	25.8	8	50	5.1	WaterFurnace GWHP026
3-7	Ducted	640	355	0.5	1/2	31.8	11.8	8	59	26.0	26.2	17.3	8	50	5.1	WaterFurnace GWHP026
3-8	Console	355	20	0.5	1/2	31.8	6.5	8	59	26.0	26.2	9.6	8	50	5.1	WaterFurnace GWHP026
3-9	Console	265	20	0.5	1/2	31.8	4.9	8	59	26.0	26.2	7.2	8	50	5.1	WaterFurnace GWHP026
3-10	Ducted	1470	290	0.5	1/2	54.6	27.0	12	59	22.7	48.3	39.7	12	50	4.7	WaterFurnace GWHP049
3-11	Ducted	875	185	0.5	1/2	31.8	16.1	8	59	26.0	26.2	23.6	8	50	5.1	WaterFurnace GWHP026
3-12	Console	300	20	0.5	1/2	31.8	11.3	8	59	26.0	26.2	8.1	8	50	5.1	WaterFurnace GWHP026
3-13	Console	300	20	0.5	1/2	31.8	11.3	8	59	26.0	26.2	8.1	8	50	5.1	WaterFurnace GWHP026
3-14	Ducted	1070	225	0.5	1/2	40.5	19.6	9	59	24.1	35.8	28.9	9	50	5.0	WaterFurnace GWHP038
3-15	Console	350	50	0.5	1/2	31.8	13.2	8	59	26.0	26.2	9.5	8	50	5.1	WaterFurnace GWHP026
3-16	Console	350	50	0.5	1/2	31.8	13.2	8	59	26.0	26.2	9.5	8	50	5.1	WaterFurnace GWHP026
3-17	Console	410	20	0.5	1/2	31.8	15.5	8	59	26.0	26.2	11.1	8	50	5.1	WaterFurnace GWHP026
3-18	Ducted	315	80	0.5	1/2	31.8	5.8	8	59	26.0	26.2	8.5	8	50	5.1	WaterFurnace GWHP026
3-19	Ducted	190	80	0.5	1/2	31.8	3.5	8	59	26.0	26.2	5.1	8	50	5.1	WaterFurnace GWHP026
3-20	Console	410	20	0.5	1/2	31.8	15.5	8	59	26.0	26.2	11.1	8	50	5.1	WaterFurnace GWHP026
3-21	Ducted	1080	420	0.5	1/2	40.5	19.8	9	59	24.1	35.8	29.2	9	50	5.0	WaterFurnace GWHP038
3-22	Ducted	345	95	0.5	1/2	31.8	6.3	8	59	26.0	26.2	9.3	8	50	5.1	WaterFurnace GWHP026
3-23	Console	355	55	0.5	1/2	31.8	13.4	8	59	26.0	26.2	9.6	8	50	5.1	WaterFurnace GWHP026
3-24	Console	355	55	0.5	1/2	31.8	13.4	8	59	26.0	26.2	9.6	8	50	5.1	WaterFurnace GWHP026



GEOTHERMAL SYSTEM WITH HX AND COOLING TOWER

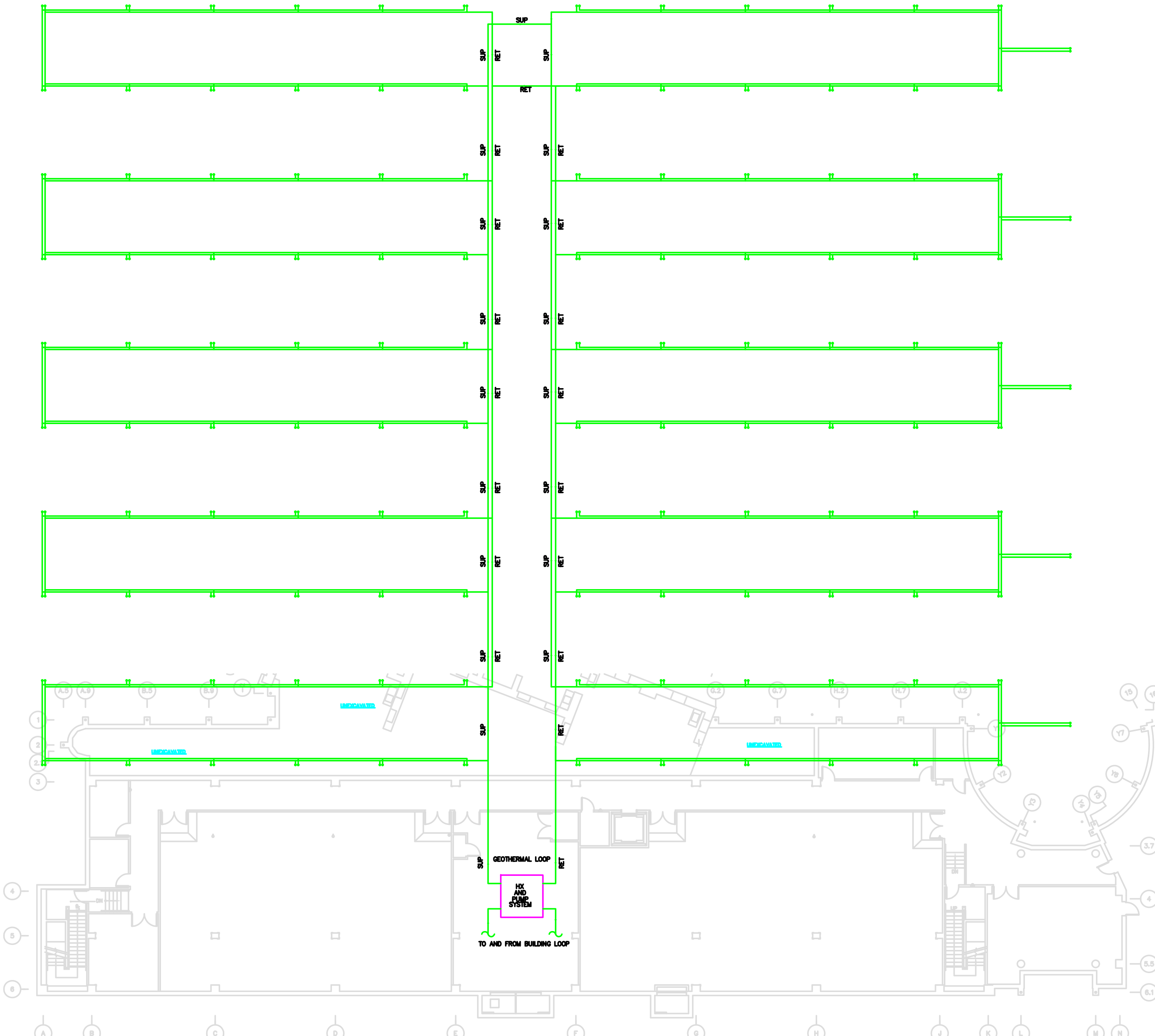
Cooling Tower Schedule					
	Capacity	Evaporator			Size and
No.	tons	GPM	Delta T	PD	Selection
CT - 1	41	123	10	15	Series Quiet

Ground Loop Schedule					
	Capacity		Pipe	Depth	
Type	tons	Bores	Diameter	Feet	Fill
Closed Loop	125	125	1 1/4"	145	Heavy Clay

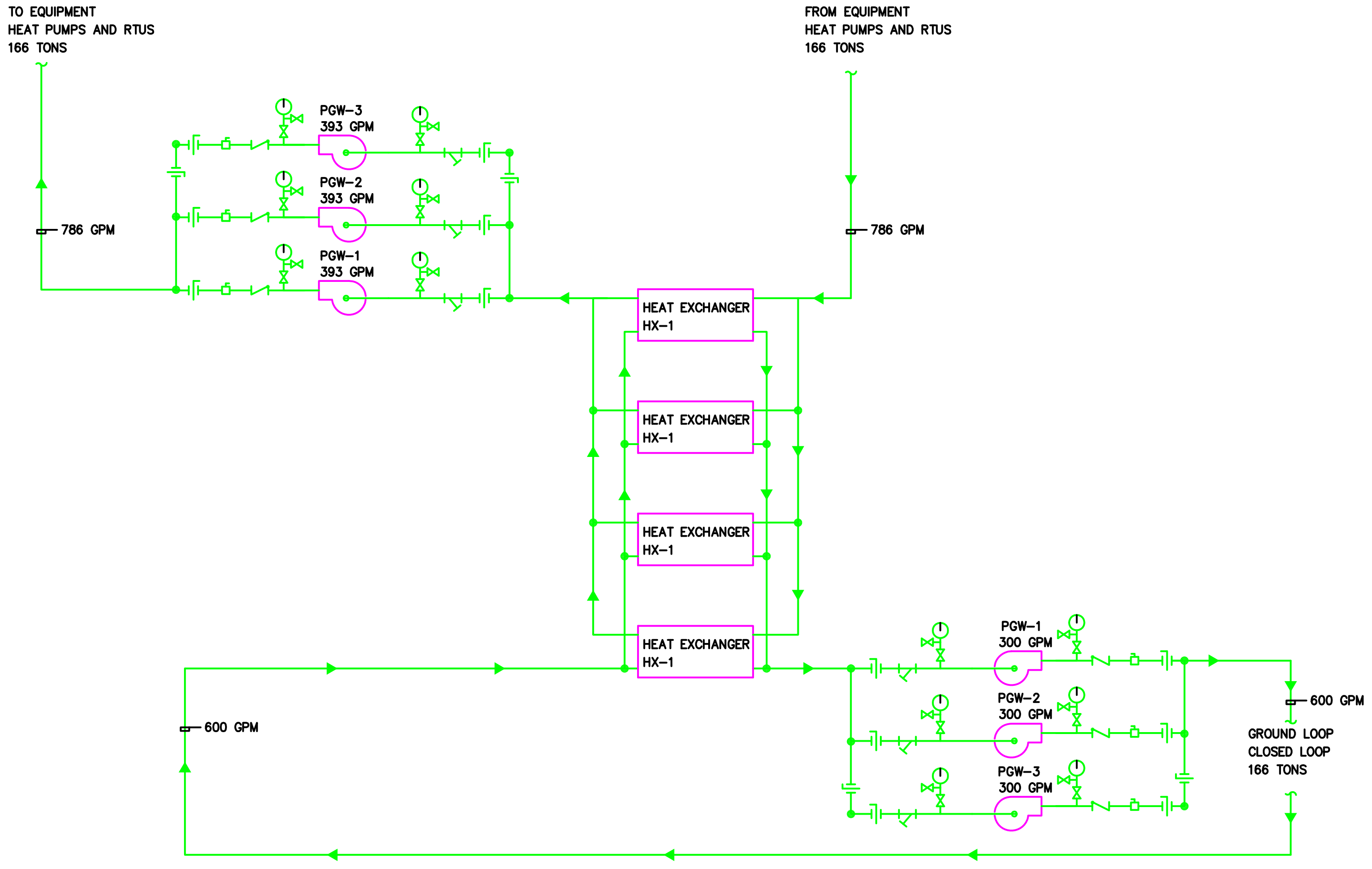
Pump Schedule						
					Motor	Size and
No.	Use	Type	GPM	RPM	HP	Selection
PGW-1	Ground Water Loop	End Suct	300	3500	10	B & G 1510
PGW-2	Ground Water Loop	End Suct	300	3500	10	B & G 1510
PGW-3	Backup to PGW-1	End Suct	300	3500	10	B & G 1510
SGW-1	Equipment Loop	End Suct	400	3500	10	B & G 1510
SGW-2	Equipment Loop	End Suct	400	3500	10	B & G 1510
SGW-3	Backup to SGW-1,2	End Suct	400	3500	10	B & G 1510

Heat Exchanger Schedule									
		Capacity			Ground Loop		Building Loop		Size and
Quantity	Type	tons	GPM	Sq Ft	EWT	LWT	EWT	LWT	Selection
4	Plate and Frame	166	200	1814	55	67	68	59	FP15-34H-130-FB

125 BORES 145 FEET DEEP. ALL BORES ARE 1 1/4" PIPE.



1 M1.00 GEOTHERMAL LOOP – MECHANICAL – ALTERNATIVE 1
SCALE: NONE



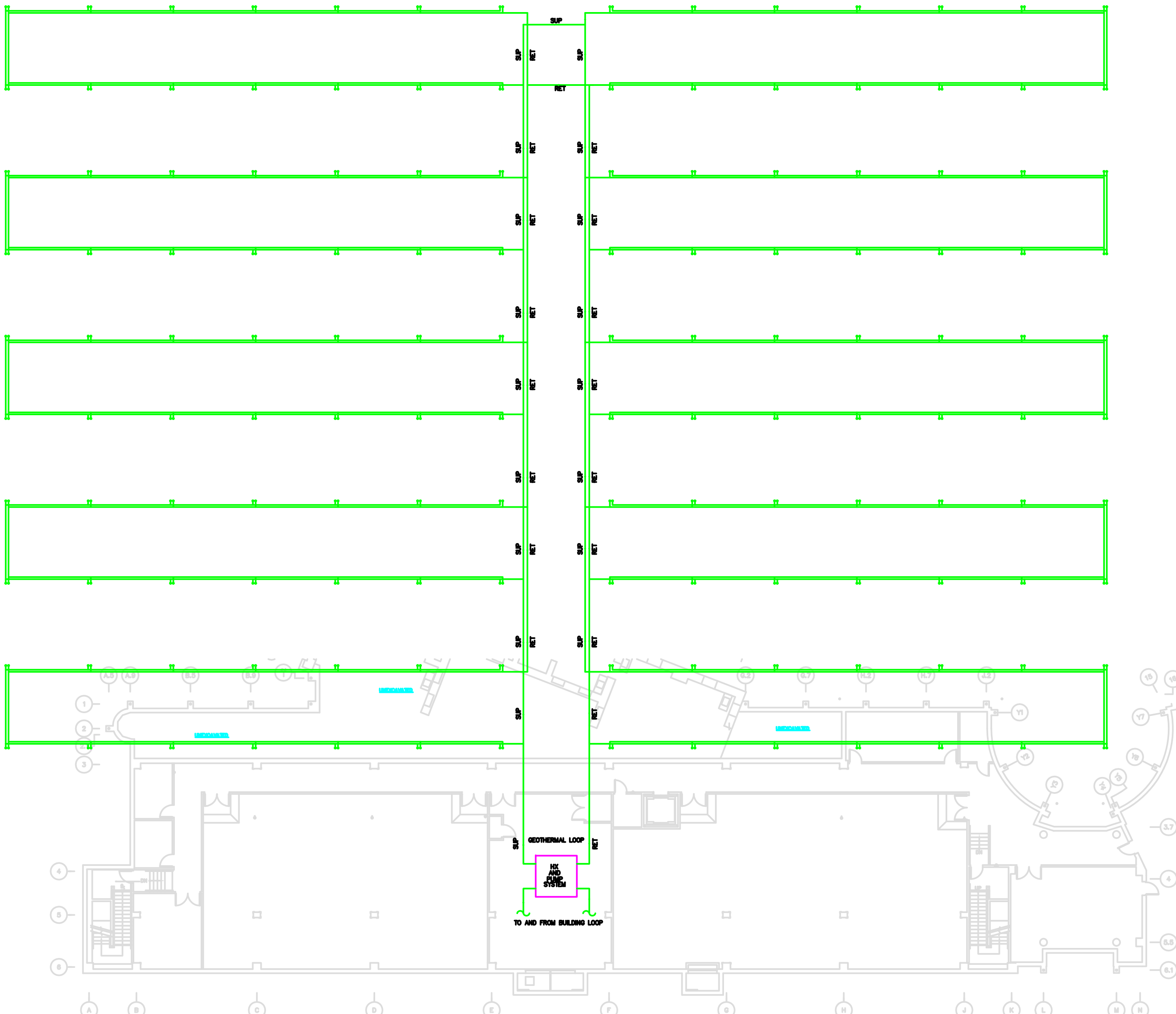
GEOTHERMAL SYSTEM WITH HX

Ground Loop Schedule					
Type	Capacity tons	Bores	Pipe Diameter	Depth Feet	Fill
Closed Loop	166	166	1 1/4"	145	Heavy Clay

Pump Schedule						
No.	Use	Type	GPM	RPM	Motor HP	Size and Selection
PGW-1	Ground Water Loop	End Suct	300	3500	10	B & G 1510
PGW-2	Ground Water Loop	End Suct	300	3500	10	B & G 1510
PGW-3	Backup to PGW-1	End Suct	300	3500	10	B & G 1510
SGW-1	Equipment Loop	End Suct	400	3500	10	B & G 1510
SGW-2	Equipment Loop	End Suct	400	3500	10	B & G 1510
SGW-3	Backup to SGW-1,2	End Suct	400	3500	10	B & G 1510

Heat Exchanger Schedule									
		Capacity			Ground Loop		Building Loop		Size and
Quantity	Type	tons	GPM	Sq Ft	EWT	LWT	EWT	LWT	Selection
4	Plate and Frame	166	200	1814	55	67	68	59	FP15-34H-130-FB

166 BORES 145 FEET DEEP. ALL BORES ARE 1 1/4" PIPE.



2 M1.00 GEOTHERMAL LOOP – MECHANICAL – ALTERNATIVE 2
SCALE: NONE

Appendix D

Initial Design of Mechanical System			
Mechanical System Component	Quantity	Cost per Quantity	**Total Cost**
Chiller	1	$96,000	**$96,000**
Boiler	2	$11,000	**$22,000**
Fan Coils	66	$2,500	**$165,000**
Heat Pumps	0	$0	**$0**
Cooling Tower	0	$0	**$0**
Heat Exchanger	0	$0	**$0**
12 hp Pumps	0	$0	**$0**
10 hp Pumps	2	$5,225	**$10,450**
2 hp Pumps	2	$2,225	**$4,450**
RTU-1	1	$32,000	**$32,000**
RTU-2	1	$32,000	**$32,000**
RTU-3	1	$20,000	**$20,000**
RTU-4	0	$0	**$0**
Supply Fans 1/2 HP	3	$1,025	**$3,075**
Heating Coils	3	$1,400	**$4,200**
		Total Cost=	**$389,175**

Alternative 1 Design of Mechanical System			
Mechanical System Component	Quantity	Cost per Quantity	**Total Cost**
Chiller	0	$0	**$0**
Boiler	0	$0	**$0**
Fan Coils	0	$0	**$0**
Heat Pumps	66	$3,000	**$198,000**
Cooling Tower	1	$8,200	**$8,200**
Heat Exchanger	4	$13,325	**$53,300**
12 hp Pumps	0	$0	**$0**
10 hp Pumps	3	$5,225	**$15,675**
2 hp Pumps	0	$0	**$0**
RTU-1	1	$33,000	**$33,000**
RTU-2	1	$28,000	**$28,000**
RTU-3	1	$20,000	**$20,000**
RTU-4	1	$20,000	**$20,000**
Supply Fans 1/2 HP	0	$0	**$0**
Heating Coils	0	$0	**$0**
		Total Cost=	**$376,175**

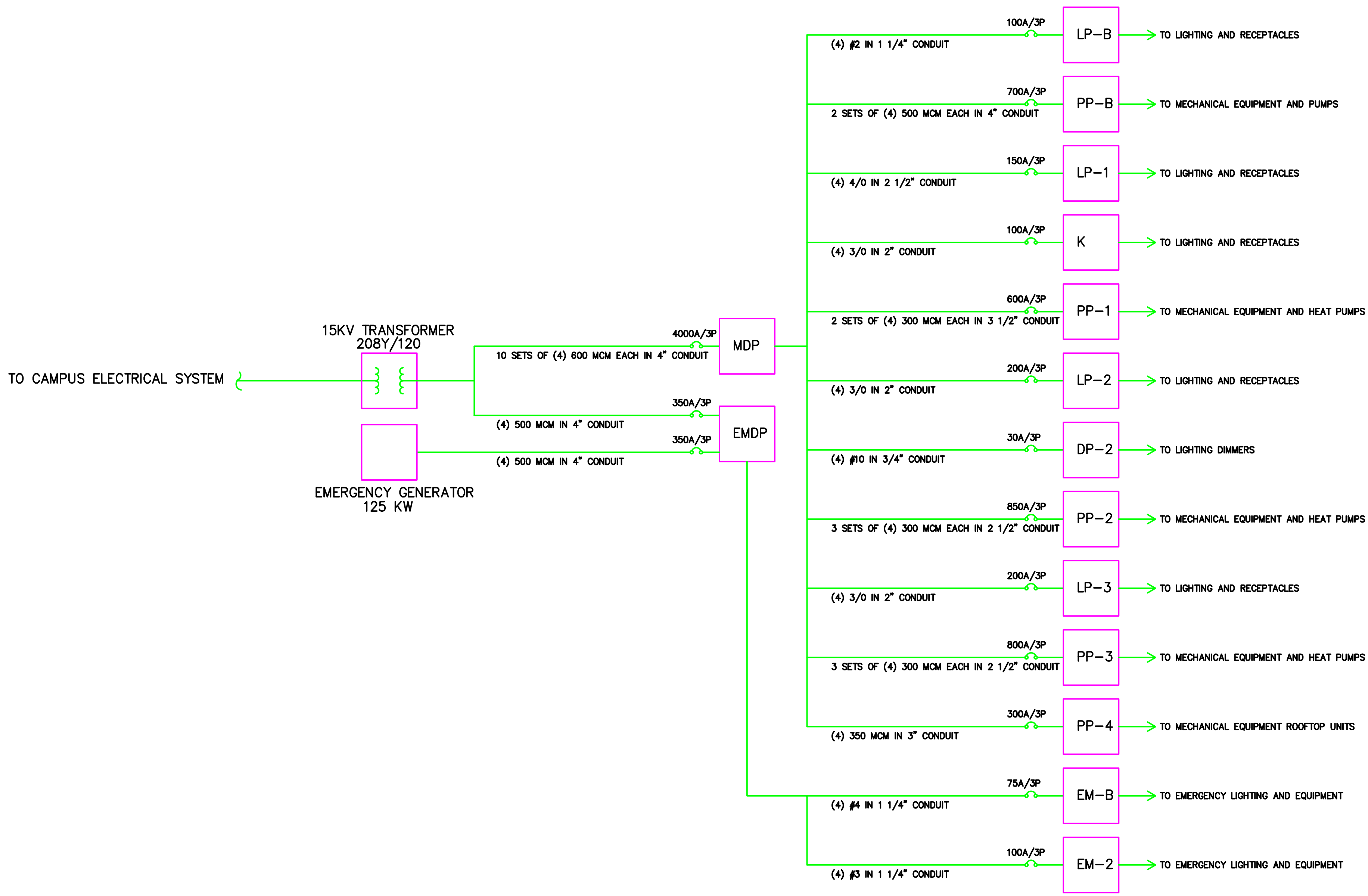
Alternative 2 Design for Mechanical System			
Mechanical System Component	Quantity	Cost per Quantity	**Total Cost**
Chiller	0	$0	**$0**
Boiler	0	$0	**$0**
Fan Coils	0	$0	**$0**
Heat Pumps	66	$3,000	**$198,000**
Cooling Tower	0	$0	**$0**
Heat Exchanger	4	$13,325	**$53,300**
12 hp Pumps	3	$5,375	**$16,125**
10 hp Pumps	0	$0	**$0**
2 hp Pumps	0	$0	**$0**
RTU-1	1	$33,000	**$33,000**
RTU-2	1	$28,000	**$28,000**
RTU-3	1	$20,000	**$20,000**
RTU-4	1	$20,000	**$20,000**
Supply Fans 1/2 HP	0	$0	**$0**
Heating Coils	0	$0	**$0**
		Total Cost=	**$368,425**

Appendix E

Initial Design of Electrical System					
Mechanical System Component	Quantity	Labor for Installation (hours)	Cost per Quantity	Cost per Hour of Labor	**Total Cost**
750 kVA Transformer	1	57.143	$30,600.0	$128	**$37,914**
Additional Power Panels	0	0	$0.0	$0	**$0**
#6 Breanch Wires (ft)	0	0	$0.0	$0	**$0**
#8 Branch Wires (ft)	0	0	$0.0	$0	**$0**
#12 Branch Wires (ft)	4460	32.6	$0.2	$44	**$2,326**
20 A Branch Breakers	29	72.5	$530.0	$44	**$18,560**
30 A Branch Breakers	0	0	$0.0	$0	**$0**
50 A Branch Breakers	0	0	$0.0	$0	**$0**
60 A Branch Breakers	0	0	$0.0	$0	**$0**
70 A Branch Breakers	0	0	$0.0	$0	**$0**
100 A Breakers	2	7	$605.0	$44	**$1,518**
300 A Breakers	1	20	$2,400.0	$88	**$4,160**
350 A Breakers	0	0	$0.0	$0	**$0**
600 A Breakers	0	0	$0.0	$0	**$0**
800 A Breakers	1	17	$4,525.0	$88	**$6,021**
850 A Breakers	0	0	$0.0	$0	**$0**
2500 A Breakers	1	25	$17,000.0	$88	**$19,200**
4000 A Breakers	0	0	$0.0	$0	**$0**
#3 Feeder Wires (ft)	350	5.6	$1.5	$88	**$1,018**
300 MCM Feeder Wires (ft)	0	0	$0.0	$0	**$0**
350 MCM Feeder Wires (ft)	120	5.3	$8.4	$132	**$1,708**
500 MCM Feeder Wires (ft)	2240	112	$12.0	$132	**$41,664**
600 MCM Feeder Wires (ft)	0	0	$0.0	$0	**$0**
	Total Time=	297		Total Cost =	**$134,089**

Alternative 1 Design of Electrical System					
Mechanical System Component	Quantity	Labor for Installation (hours)	Cost per Quantity	Cost per Hour of Labor	**Total Cost**
1000 kVA Transformer	1	62.5	$35,100.0	$128	**$43,100**
Additional Power Panels	1	20	$4,400.0	$88	**$6,156**
#6 Breanch Wires (ft)	860	10.3	$0.8	$44	**$1,098**
#8 Branch Wires (ft)	1445	14.45	$0.5	$44	**$1,286**
#12 Branch Wires (ft)	6495	474.1	$0.2	$44	**$22,030**
20 A Branch Breakers	0	0	$0.0	$0	**$0**
30 A Branch Breakers	49	122.5	$530.0	$44	**$31,360**
50 A Branch Breakers	3	8.5	$530.0	$44	**$1,964**
60 A Branch Breakers	8	23	$530.0	$44	**$5,252**
70 A Branch Breakers	7	24	$605.0	$44	**$5,291**
100 A Breakers	0	0	$0.0	$0	**$0**
300 A Breakers	1	20	$2,400.0	$88	**$4,160**
350 A Breakers	1	20	$2,400.0	$88	**$4,160**
600 A Breakers	1	13.3	$3,475.0	$88	**$4,645**
800 A Breakers	1	17	$4,525.0	$88	**$6,021**
850 A Breakers	1	17	$4,525.0	$88	**$6,021**
2500 A Breakers	0	0	$0.0	$0	**$0**
4000 A Breakers	1	35	$23,000.0	$88	**$26,080**
#3 Feeder Wires (ft)	0	0	$0.0	$0	**$0**
300 MCM Feeder Wires (ft)	1550	65.1	$7.2	$132	**$19,676**
350 MCM Feeder Wires (ft)	220	9.7	$8.4	$132	**$3,128**
500 MCM Feeder Wires (ft)	120	6	$12.0	$132	**$2,232**
600 MCM Feeder Wires (ft)	3000	186	$14.3	$132	**$67,302**
	Total Time=	1085.95		Total Cost =	**$260,962**

Alternative 2 Design of Electrical System					
Mechanical System Component	Quantity	Labor for Installation (hours)	Cost per Quantity	Cost per Hour of Labor	**Total Cost**
1000 kVA Transformer	1	62.5	$35,100.0	$128	**$43,100**
Additional Power Panels	1	20	$4,400.0	$88	**$6,156**
#6 Breanch Wires (ft)	860	10.3	$0.8	$44	**$1,098**
#8 Branch Wires (ft)	1445	14.45	$0.5	$44	**$1,286**
#12 Branch Wires (ft)	6495	474.1	$0.2	$44	**$22,030**
20 A Branch Breakers	0	0	$0.0	$0	**$0**
30 A Branch Breakers	49	122.5	$530.0	$44	**$31,360**
50 A Branch Breakers	3	8.5	$530.0	$44	**$1,964**
60 A Branch Breakers	8	23	$530.0	$44	**$5,252**
70 A Branch Breakers	7	24	$605.0	$44	**$5,291**
100 A Breakers	0	0	$0.0	$0	**$0**
300 A Breakers	1	20	$2,400.0	$88	**$4,160**
350 A Breakers	1	20	$2,400.0	$88	**$4,160**
600 A Breakers	1	13.3	$3,475.0	$88	**$4,645**
800 A Breakers	1	17	$4,525.0	$88	**$6,021**
850 A Breakers	1	17	$4,525.0	$88	**$6,021**
2500 A Breakers	0	0	$0.0	$0	**$0**
4000 A Breakers	1	35	$23,000.0	$88	**$26,080**
#3 Feeder Wires (ft)	0	0	$0.0	$0	**$0**
300 MCM Feeder Wires (ft)	1550	65.1	$7.2	$132	**$19,676**
350 MCM Feeder Wires (ft)	220	9.7	$8.4	$132	**$3,128**
500 MCM Feeder Wires (ft)	120	6	$12.0	$132	**$2,232**
600 MCM Feeder Wires (ft)	3000	186	$14.3	$132	**$67,302**
	Total Time=	1085.95		Total Cost =	**$260,962**



1 / E1.00 ELECTRICAL SCHEMATIC – ELECTRICAL
SCALE: NONE

PANELBOARD SCHEDULE

PANEL:	MDP	**EQUIP. GND. BUS:**	☐	**VOLTAGE:**	120/208 VOLT, 3PH, 4W
LOCATION:	BASEMENT	**ISOLATED GND BUS:**	■	**MAIN CIRCUIT BKR:**	4000 Amps
MOUNTING:	SURFACE	**NEUTRAL BUS:**	**100%** ☐ **200%** ■	**MLO:**	☐
FED FROM:	MDP	**A.I.C.:**	10000	**FEEDER:**	10 Sets of (4) 600 MCM each in 4" Conduit

LOAD DESCRIPTION	BKR. AMPS	BKR. POLE	CKT. NO.	LOAD - V.A. A	B	C	CKT. NO.	BKR. POLE	BKR. AMPS	LOAD DESCRIPTION
PANEL LP-B	**100**	**3**	**1**	6,370						A,T,8,9 BASEMENT
				12,370			**2**	**3**	**400**	
		/	**3**		6,370					
					12,370		**4**	**/**		
		/	**5**			6,370				
						12,370	**6**	**/**		
PANEL PP-B	**350**	**3**	**7**	21,600						PANEL K
				10,000			**8**	**3**	**150**	
		/	**9**		21,600					
					10,000		**10**	**/**		
		/	**11**			21,600				
						10,000	**12**	**/**		
PANEL PP-1	**600**	**3**	**13**	39,240						PANEL LP-1
				8,890			**14**	**3**	**150**	
		/	**15**		39,240					
					8,890		**16**	**/**		
		/	**17**			39,240				
						8,890	**18**	**/**		
PANEL PP-2	**850**	**3**	**19**	58,370						PANEL LP-2
				17,570			**20**	**3**	**200**	
		/	**21**		58,370					
					17,570		**22**	**/**		
		/	**23**			58,370				
						17,570	**24**	**/**		
PANEL PP-3	**800**	**1**	**25**	53,800						PANEL LP-3
				16,520			**26**	**3**	**200**	
		1	**27**		53,800					
					16,520		**28**	**/**		
		2	**29**			53,800				
						16,520	**30**	**/**		
PANEL PP-4	**300**	**2**	**31**	20,740						HYDRONIC ELEVATOR
				14,400			**32**	**3**	**175**	
		/	**33**		20,740					
					14,400		**34**	**/**		
		1	**35**			20,740				
						14,400	**36**	**/**		
SPARE		**3**	**37**							SPARE
							38	**3**		
		/	**39**							
							40	**/**		
		/	**41**							
							42	**/**		
	TOTAL VA			274,273	274,273	274,273	**TOTAL KVA**		822.8	
	TOTAL AMP/PHASE			1,319	1,319	1,319	**TOTAL AMP**		3,956	

REMARKS:

PANELBOARD SCHEDULE

PANEL:	PP-B	**EQUIP. GND. BUS:**	☐	**VOLTAGE:**	120/208 VOLT, 3PH, 4W
LOCATION:	BASEMENT	**ISOLATED GND BUS:**	■	**MAIN CIRCUIT BKR:**	350 Amps
MOUNTING:	SURFACE	**NEUTRAL BUS:**	**100%** ☐ **200%** ■	**MLO:**	☐
FED FROM:	MDP	**A.I.C.:**	10000	**FEEDER:**	(4) 500 MCM in 3 inch Conduit

LOAD DESCRIPTION	BKR. AMPS	BKR. POLE	CKT. NO.	LOAD - V.A. A	B	C	CKT. NO.	BKR. POLE	BKR. AMPS	LOAD DESCRIPTION
PGW-1	20	3	1	950						PGW-2
				950			2	3	20	
		/	3		950					
					950		4	/		
		/	5			950				
						950	6	/		
PGW-3	20	3	7	950						SGW-1
				950			8	3	20	
		/	9		950					
					950		10	/		
		/	11			950				
						950	12	/		
SGW-2	20	3	13	950						SGW-3
				950			14	3	20	
		/	15		950					
					950		16	/		
		/	17			950				
						950	18	/		
HP B-1	30	1	19	5,880						HP B-2
				5,880			20	1	30	
HP B-3	30	1	21		5,880					HP B-4
					10,195		22	1	60	
HP B-5	60	1	23			10,195				AC B-2
						1,000	24	1	20	
Motorized Shelves	20	1	25	1,000						Motorized Shelves
				1,000			26	1	20	
SPARE	20	1	27							SPARE
							28	1	20	
Motorized Shelves	20	1	29			1,000				Motorized Shelves
						1,000	30	1	20	
Motorized Shelves	20	1	31	1,000						SPARE
							32	1	20	
SPARE	20	1	33							SPARE
							34	1	20	
SPARE	20	1	35			1,000				Motorized Shelves
							36	1	20	
Duplex Sewage Ejector	20	3	37	900						SPARE
							38	3	20	
		/	39		900					SPARE
							40	/	20	
		/	41			900				SPARE
							42	/	20	
	TOTAL VA			21,360	22,675	20,795	TOTAL KVA		64.8	
	TOTAL AMP/PHASE			103	109	100	TOTAL AMP		312	

REMARKS:

PANELBOARD SCHEDULE

PANEL:	PP-1	**EQUIP. GND. BUS:**	☐	**VOLTAGE:**	120/208 VOLT, 3PH, 4W
LOCATION:	1ST FLOOR	**ISOLATED GND BUS:**	■	**MAIN CIRCUIT BKR:**	600 Amps
MOUNTING:	SURFACE	**NEUTRAL BUS:**	**100%** ☐ **200%** ■	**MLO:**	☐
FED FROM:	MDP	**A.I.C.:**	10000	**FEEDER**	2 Sets of (4) 300 MCM each in 3 1/2 inch Conduit

LOAD DESCRIPTION	BKR. AMPS	BKR. POLE	CKT. NO.	LOAD - V.A. A	LOAD - V.A. B	LOAD - V.A. C	CKT. NO.	BKR. POLE	BKR. AMPS	LOAD DESCRIPTION
HP 1-1	**70**	**1**	**1**	12,170						HP 1-2
				10,195			**2**	**1**	**60**	
HP 1-3	**70**	**1**	**3**		11,650					HP 1-4
					11,650		**4**	**1**	**70**	
HP 1-5	**60**	**1**	**5**			10,195				HP 1-6
						5,880	**6**	**1**	**30**	
HP 1-7	**70**	**1**	**7**	12,170						AC 2-2
				1,000			**8**	**1**	**20**	
HP 1-9	**70**	**1**	**9**		11,650					HP 1-11
					5,880		**10**	**1**	**30**	
HP 1-8	**70**	**1**	**11**			12,170				HP 1-10
						5,880	**12**	**1**	**30**	
Electric Door Operator	**20**	**1**	**13**	1,200						Electric Door Operator
				1,200			**14**	**1**	**20**	
UH 1-1	**20**	**1**	**15**		300					UH 1-2
					300		**16**	**1**	**20**	
Electric Door Operator	**20**	**1**	**17**			1,200				Electric Door Operator
						1,200	**18**	**1**	**20**	
UH 1-3	**20**	**1**	**19**	300						SPARE
							20	**1**		
SPARE		**1**	**21**							SP
							22	**1**		
SPARE		**1**	**23**							EWH 1
						1,500	**24**	**1**	**20**	
SPARE		**1**	**25**							SPARE
							26	**1**		
SPARE		**1**	**27**							SPARE
							28	**1**		
SPARE		**1**	**29**							SPARE
							30	**1**		
SPARE		**1**	**31**							SPARE
							32	**1**		
SPARE		**1**	**33**							SPARE
							34	**1**		
SPARE		**1**	**35**							SPARE
							36	**1**		
SPARE		**1**	**37**							SPARE
							38	**1**		
SPARE		**1**	**39**							SPARE
							40	**1**		
SPARE		**1**	**41**							SPARE
							42	**1**		
	TOTAL VA			38,235	41,430	38,025	**TOTAL KVA**		117.7	
	TOTAL AMP/PHASE			184	199	183	**TOTAL AMP**		566	

REMARKS:

PANELBOARD SCHEDULE

PANEL:	PP-2	**EQUIP. GND. BUS:**	☐	**VOLTAGE:**	120/208 VOLT, 3PH, 4W
LOCATION:	2ND FLOOR	**ISOLATED GND BUS:**	■	**MAIN CIRCUIT BKR:**	850 Amps
MOUNTING:	SURFACE	**NEUTRAL BUS:**	**100%** ☐ **200%** ■	**MLO:**	☐
FED FROM:	MDP	**A.I.C.:**	10000	**FEEDER**	3 Sets of (4) 300 MCM each in 2 1/2 inch Conduit

LOAD DESCRIPTION	BKR. AMPS	BKR. POLE	CKT. NO.	LOAD - V.A. A	LOAD - V.A. B	LOAD - V.A. C	CKT. NO.	BKR. POLE	BKR. AMPS	LOAD DESCRIPTION
HP 2-1	**70**	**1**	**1**	11,650						HP 2-2
				5,880			**2**	**1**	**30**	
HP 2-3	**30**	**1**	**3**		5,880					HP 2-4
					5,880		**4**	**1**	**30**	
HP 2-5	**30**	**1**	**5**			5,880				HP 2-6
						5,880	**6**	**1**	**30**	
HP 2-7	**30**	**1**	**7**	5,880						HP 2-8
				5,880			**8**	**1**	**30**	
HP 2-9	**30**	**1**	**9**		5,880					HP 2-10
					10,195		**10**	**1**	**60**	
HP 2-11	**50**	**1**	**11**			8,740				HP 2-12
						5,880	**12**	**1**	**30**	
HP 2-13	**30**	**1**	**13**	5,880						HP 2-14
				5,880			**14**	**1**	**30**	
HP 2-15	**30**	**1**	**15**		5,880					HP 2-16
					5,880		**16**	**1**	**30**	
HP 2-17	**30**	**1**	**17**			5,880				HP 2-18
						5,880	**18**	**1**	**30**	
HP 2-19	**30**	**1**	**19**	5,880						HP 2-24
				5,880			**20**	**1**	**30**	
HP 2-21	**30**	**1**	**21**		5,880					HP 2-22
					5,880		**22**	**1**	**30**	
HP 2-23	**30**	**1**	**23**			5,880				HP 2-20
						8,740	**24**	**1**	**50**	
HP 2-25	**30**	**1**	**25**	5,880						AC 3-1
				400			**26**	**1**	**20**	
HP 2-26	**30**	**1**	**27**		5,880					EWH-3
					2,250		**28**	**2**	**30**	
EWH-2	**20**	**2**	**29**			1,500				
						2,250	**30**	**/**		
SPARE		**1**	**31**							SPARE
							32	**1**		
SPARE		**1**	**33**							SPARE
							34	**1**		
SPARE		**1**	**35**							SPARE
							36	**1**		
SPARE		**1**	**37**							SPARE
							38	**1**		
SPARE		**1**	**39**							SPARE
							40	**1**		
SPARE		**1**	**41**							SPARE
							42	**1**		
	TOTAL VA			59,090	59,485	56,510	**TOTAL KVA**		175.1	
	TOTAL AMP/PHASE			284	286	272	**TOTAL AMP**		842	

REMARKS:

PANELBOARD SCHEDULE

PANEL:	PP-3	**EQUIP. GND. BUS:**	☐	**VOLTAGE:**	120/208 VOLT, 3PH, 4W
LOCATION:	3RD FLOOR	**ISOLATED GND BUS:**	■	**MAIN CIRCUIT BKR:**	800 Amps
MOUNTING:	SURFACE	**NEUTRAL BUS:**	**100%** ☐ **200%** ■	**MLO:**	☐
FED FROM:	MDP	**A.I.C.:**	10000	**FEEDER**	3 Sets of (4) 300 MCM each in 2 1/2 inch Conduit

LOAD DESCRIPTION	BKR. AMPS	BKR. POLE	CKT. NO.	LOAD - V.A. A	LOAD - V.A. B	LOAD - V.A. C	CKT. NO.	BKR. POLE	BKR. AMPS	LOAD DESCRIPTION
HP 3-1	**60**	**1**	**1**	10,195						HP 3-2
				5,880			**2**	**1**	**30**	
HP 3-3	**30**	**1**	**3**		5,880					HP 3-4
					5,880		**4**	**1**	**30**	
HP 3-5	**30**	**1**	**5**			5,880				HP 3-6
						5,880	**6**	**1**	**30**	
HP 3-7	**30**	**1**	**7**	5,880						HP 3-8
				5,880			**8**	**1**	**30**	
HP 3-9	**30**	**1**	**9**		5,880					HP 3-10
					10,195		**10**	**1**	**60**	
HP 3-11	**30**	**1**	**11**			5,880				HP 3-14
						8,740	**12**	**1**	**50**	
HP 3-13	**30**	**1**	**13**	5,880						HP 3-12
				5,880			**14**	**1**	**30**	
HP 3-15	**30**	**1**	**15**		5,880					HP 3-16
					5,880		**16**	**1**	**30**	
HP 3-17	**30**	**1**	**17**			5,880				HP 3-18
						5,880	**18**	**1**	**30**	
HP 3-19	**30**	**1**	**19**	5,880						HP 3-20
				5,880			**20**	**1**	**30**	
HP 3-23	**30**	**1**	**21**		5,880					HP 3-22
					5,880		**22**	**1**	**30**	
HP 3-21	**50**	**1**	**23**			8,740				HP 3-24
						5,880	**24**	**1**	**30**	
EWH-4	**20**	**1**	**25**	1,500						AC 3-2
				100			**26**	**1**	**20**	
UH 3-1	**20**	**1**	**27**		200					UH 3-2
					200		**28**	**1**	**20**	
UH-7	**20**	**2**	**29**			200				CU-1
						1,350	**30**	**2**	**20**	
CU-3	**20**	**2**	**31**	500						
				1,350			**32**	**/**		
		/	**33**		500					SPARE
							34	**1**		
SPARE		**1**	**35**							SPARE
							36	**1**		
SPARE		**3**	**37**							SPARE
							38	**3**		
		/	**39**							
							40	**/**		
		/	**41**							
							42	**/**		
	TOTAL VA			54,805	52,255	54,310	**TOTAL KVA**		161.4	
	TOTAL AMP/PHASE			263	251	261	**TOTAL AMP**		776	

REMARKS:

PANELBOARD SCHEDULE

PANEL:	PP-4	**EQUIP. GND. BUS:**	☐	**VOLTAGE:**	120/208 VOLT, 3PH, 4W
LOCATION:	3RD FLOOR	**ISOLATED GND BUS:**	■	**MAIN CIRCUIT BKR:**	300 Amps
MOUNTING:	SURFACE	**NEUTRAL BUS:**	**100%** ☐ **200%** ■	**MLO:**	☐
FED FROM:	MDP	**A.I.C.:**	10000	**FEEDER:**	(4) 350 MCM in 3 inch Conduit

LOAD DESCRIPTION	BKR. AMPS	BKR. POLE	CKT. NO.	LOAD - V.A. A	B	C	CKT. NO.	BKR. POLE	BKR. AMPS	LOAD DESCRIPTION
RTU-1	**125**	**3**	**1**	7,075						RTU-2
				5,270			**2**	**3**	**100**	
		/	**3**		7,075					
					5,270		**4**	**/**		
		/	**5**			7,075				
						5,270	**6**	**/**		
RTU-3	**50**	**3**	**7**	3,050						RTU-4
				3,540			**8**	**3**	**60**	
		/	**9**		3,050					
					3,540		**10**	**/**		
		/	**11**			3,050				
						3,540	**12**	**/**		
EF-1	**20**	**3**	**13**	450						EF-2A
				900			**14**	**3**	**20**	
		/	**15**		450					
					900		**16**	**/**		
		/	**17**			450				
						900	**18**	**/**		
EF-2B	**20**	**3**	**19**	300						SPARE
							20	**3**		
		/	**21**		300					
							22	**/**		
		/	**23**			300				
							24	**/**		
Rooftop Equipment Receptacles	**20**	**1**	**25**	400						SPARE
							26	**3**		
SPARE		**1**	**27**							
							28	**/**		
SPARE		**2**	**29**							
							30	**/**		
SPARE		**2**	**31**							SPARE
							32	**/**		
SPARE		**/**	**33**							SPARE
							34	**1**		
SPARE		**1**	**35**							SPARE
							36	**1**		
SPARE		**3**	**37**							SPARE
							38	**3**		
		/	**39**							
							40	**/**		
		/	**41**							
							42	**/**		
	TOTAL VA			20,985	20,585	20,585	**TOTAL KVA**		62.2	
	TOTAL AMP/PHASE			101	99	99	**TOTAL AMP**		299	

REMARKS:

Appendix F

CM Initial Design of Mechanical System					
Mechanical System Component	Quantity	Labor for Installation (hours)	Cost per Quantity	Cost per Hour of Labor	**Total Cost**
Chiller	1	102	$96,000	$172	**$113,544**
Boiler	2	212	$11,000	$172	**$58,464**
Fan Coils	66	370	$2,500	$81	**$195,118**
Heat Pumps	0	0	$0	$0	**$0**
Cooling Tower	0	0	$0	$0	**$0**
Heat Exchanger	0	0	$0	$0	**$0**
12 hp Pumps	0	0	$0	$0	**$0**
10 hp Pumps	2	20	$5,225	$81	**$12,064**
2 hp Pumps	2	10.6	$2,225	$81	**$5,305**
RTU-1	1	79	$32,000	$172	**$45,608**
RTU-2	1	79	$32,000	$172	**$45,608**
RTU-3	1	52.5	$15,000	$172	**$24,043**
RTU-4	0	0	$0	$0	**$0**
Supply Fans 1/2 HP	3	20.1	$1,025	$100	**$5,093**
Building Piping (ft)	3520	503.4	$12	$45	**$65,421**
Ground Piping (Bores)	0	0	$0	$0	**$0**
Heating Coils	3	18.75	$1,400	$81	**$5,726**
	Total Time=	1467.35		Total Cost =	**$575,994**

CM Alternative 1 Design of Mechanical System					
Mechanical System Component	Quantity	Labor for Installation (hours)	Cost per Quantity	Cost per Hour of Labor	**Total Cost**
Chiller	0	0	$0	$0	**$0**
Boiler	0	0	$0	$0	**$0**
Fan Coils	0	0	$0	$0	**$0**
Heat Pumps	66	1173.5	$3,000	$81	**$293,523**
Cooling Tower	1	10.5	$8,200	$127	**$9,529**
Heat Exchanger	4	48	$13,325	$127	**$59,377**
12 hp Pumps	0	0	$0	$0	**$0**
10 hp Pumps	3	30	$5,225	$81	**$18,096**
2 hp Pumps	0	0	$0	$0	**$0**
RTU-1	1	58.5	$33,000	$127	**$40,406**
RTU-2	1	51	$28,000	$127	**$34,457**
RTU-3	1	26.7	$20,000	$81	**$22,172**
RTU-4	1	51	$20,000	$127	**$26,457**
Supply Fans 1/2 HP	0	0	$0	$0	**$0**
Building Piping (ft)	0	0	$0	$0	**$0**
Ground Piping (Bores)	125	81.4	$1,740	$286	**$240,780**
Heating Coils	0	0	$0	$0	**$0**
	Total Time=	1530.6		Total Cost =	**$744,797**

CM Alternative 2 Design for Mechanical System					
Mechanical System Component	Quantity	Labor for Installation (hours)	Cost per Quantity	Cost per Hour of Labor	**Total Cost**
Chiller	0	0	$0	$0	**$0**
Boiler	0	0	$0	$0	**$0**
Fan Coils	0	0	$0	$0	**$0**
Heat Pumps	66	1173.5	$3,000	$81	**$293,523**
Cooling Tower	0	0	$0	$0	**$0**
Heat Exchanger	4	48	$13,325	$127	**$59,377**
12 hp Pumps	3	42.3	$5,375	$126	**$21,434**
10 hp Pumps	0	0	$0	$0	**$0**
2 hp Pumps	0	0	$0	$0	**$0**
RTU-1	1	58.5	$33,000	$127	**$40,406**
RTU-2	1	51	$28,000	$127	**$34,457**
RTU-3	1	26.7	$20,000	$81	**$22,172**
RTU-4	1	51	$20,000	$127	**$26,457**
Supply Fans 1/2 HP	0	0	$0	$0	**$0**
Building Piping (ft)	0	0	$0	$0	**$0**
Ground Piping (Bores)	166	105.6	$1,740	$286	**$319,042**
Heating Coils	0	0	$0	$0	**$0**
	Total Time=	1556.6		Total Cost =	**$816,866**