GROUND SOURCE HEAT PUMP ANALYSIS FOR THE LONGWOOD AT OAKMONT HEALTHCARE CENTER

Prepared by Tyler Lobb
April 9, 2008

The Pennsylvania State University
Department of Architectural Engineering
Mechanical Option
Senior Thesis

Faculty Advisor:
James Freihaut

LONGWOOD AT OAKMONT HEALTHCARE CENTER

VERONA, PENNSYLVANIA

PROJECT DELIVERY TEAM

Owner/Occupant: Presbyterian Senior Care
General Contractor: Mistick Construction
Architect: Reese, Lower, Patrick, and Scott, Ltd.
MEP Engineer: Reese Engineering Inc.
Structural Engineer: Zug and Associates
Civil Engineer: Gateway Engineering Inc.
Landscape Architects: Victor – Wetzel Associates
Food Services: S.S. Kemp and Co.

BUILDING INFORMATION

Overall Estimated Cost: $11,000,000
Project Size: 45,000 S.F.
Prject Height: Two Stories Above Grade
Project Delivery Method: Design-Bid-Build
Construction Dates: Start - November 2007
Finish - July 2008

ARCHITECTURE

- Combination of renovation and new construction
- Dementia Wing
- Rehabilitation Area
- Healthcare Center
- All areas include multifunctional public spaces as well as a number of varying resident rooms.
- Exterior facade consists of a combination of red brick, vinyl siding, and EIFS.

MECHANICAL

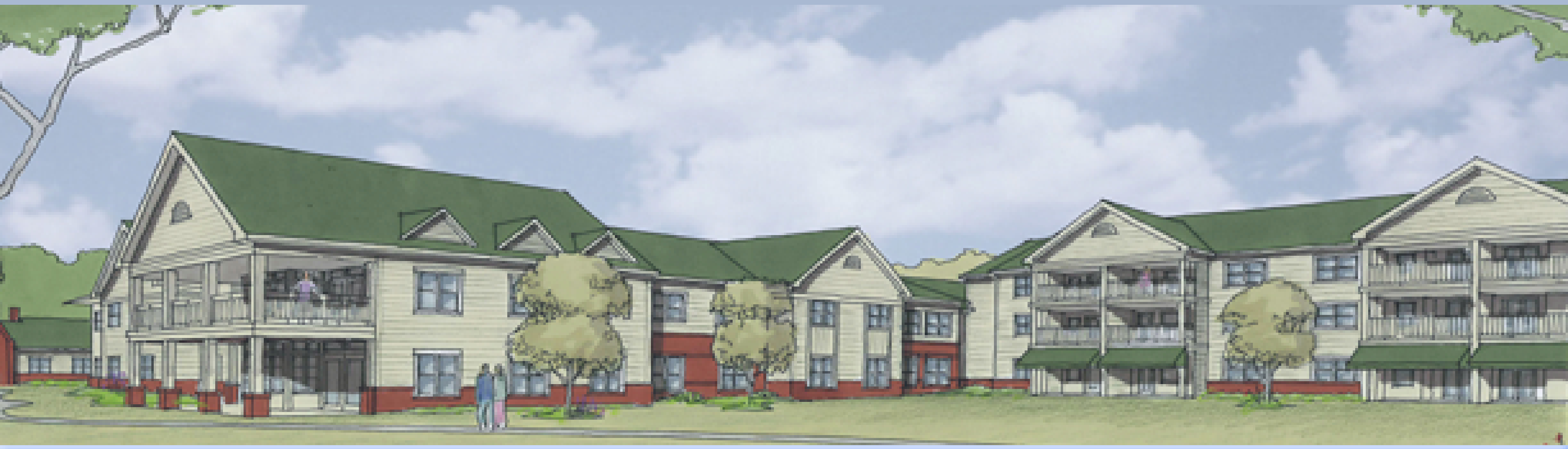
- Water source heat pumps serve individual spaces
- Gas fired boilers provide heat for closed water loop
- Closed circuit fluid cooler located on roof
- Ventilation air handled by single energy recovery unit, brought to "room neutral" before being supplied to heat pumps
- Exhaust air drawn through energy recovery unit with the exception of specified rooms which are exhausted directly outside

STRUCTURAL

- Concrete strip footings along exterior walls
- 6" concrete slab-on-grad reinforced with welded wire frame
- Load baring exterior masonry walls
- Steel wide-flange beams
- Unique roof trusses allow for mechanical and plumbing to run above corridor

LIGHTING/ELECTRICAL

- 3000 amp service switchboard at 208 volts
- 300 KW natural gas fired emergency generator
- Most lighting is energy efficient fluorescent
- Nurse call system throughout building
- Patient wandering system located in dementia wing



TYLER LOBB

MECHANICAL OPTION

http://www.engr.psu.edu/ae/thesis/portfolios/2008/tdl139/

The Pennsylvania State University

Department of Architectural Engineering

TABLE OF CONTENTS

1.0 - EXECUTIVE SUMMARY

The Longwood at Oakmont Healthcare Center is a 45,000 square foot senior care facility in Verona, Pennsylvania. Its existing mechanical system consists mainly of an energy recovery unit and a water source heat pump system, which uses a cooling tower and gas-fired boilers to condition the spaces. This report aims to analyze the existing system and compare it to a redesigned ground source heat pump system.

The main goal of this mechanical system redesign is to increase the building's energy efficiency. This is done by utilizing the constant temperature of the Earth's ground to condition the system's piping loop. Another goal is to analyze the cost of the system, both initially and farther down the line. As it is with any 'green' building technology, first costs tend to be rather high. It is the aim of this redesign to show that although initial costs are high utility savings can counteract the costs, and payback what is lost in equipment and installation fees.

By altering the mechanical system certain equipment is omitted and added to the project scope. By altering this equipment, electrical loads are also changed. As part of an electrical breadth study the affected panels will be resized. The change in panel sizes results in a minimal cost savings. Even though the cost is small it still helps in the long run.

A construction breadth study was also performed. The ground source heat pump well field was analyzed, sized, and laid out. The site is somewhat tight with an adjacent property line and a limited amount of site area that is not needed for future expansion. The time frame for installation was also analyzed. The excavation and installation of the well field proved to not affect the overall deadline of the project. It was also projected to be finished with sufficient time to bring the system on-line well prior to occupancy.

Although the redesigned system has a considerably high initial cost it was shown to create plentiful savings over a 20 year study. It was capable of paying itself back in less than 12 years. As utility rates tend to rise, these savings will only increase. It seems as though if the owner can manage the system's upfront costs, the switch to a ground source heat pump system is an environmental and economical choice.

2.0 - BUILDING DESIGN BACKGROUND

The Longwood at Oakmont Healthcare Center is a 45,000 square foot senior care facility located in Verona, Pennsylvania. The building can be easily broken down into three different zones. Zone A is the only zone that is entirely new construction. It is a two story healthcare wing. It consists of a variety of spaces. The majority of the wing is consumed by private and shared resident rooms. The zone also has a share of other occupancies, such as public gathering spaces, a dining room, conference rooms, kitchenettes, and small offices. The main mechanical room, which is 2,500 square feet, is also located on the second floor of this zone. Zone B is considered the rehab wing. The scope of this project calls for a complete interior renovation of this space, which includes the zone's mechanical system. This zone also has a number of private and shared resident rooms. This zone also houses the majority of the building's offices. Aside from that, spaces such as a beauty shop, dining room, kitchen, and public gathering spaces also exist. The final zone of the building, which is also a complete interior renovation of an existing space, is the dementia wing or Zone C. This zone has much of the same spaces as Zone A does, but is unique because the residents which reside in this wing are all suffering from dementia. The Figure 2.1below illustrates the layout of the building's zones.

Figure 2.1 – Building Zoning Diagram

2.1 - NON-MECHANICAL BUILDING SYSTEMS BACKGROUND

ELECTRICAL AND LIGHTING SYSTEM BACKGROUND

The Longwood at Oakmont Healthcare Center is to be provided with a 3000 amp service switchboard. The switchboard shall be fed from a pad-mounted transformer owned by Duquesne Light with commercial secondary metering. The service switchboard will also be rated at 208 volts. There will be a diesel-fired emergency generator located outside of the building. It is to be sized to a 300 kW capacity and is to have a fuel storage tank large enough to provide power for 48 hours. Most lighting in the building is to be energy efficient fluorescent with the exception of nightstand lamps in the resident rooms.

STRUCTURAL SYSTEM BACKGROUND

The foundation of the Longwood at Oakmont Healthcare Center is comprised of strip footings underneath the exterior walls and a six inch thick concrete slab. The exterior walls are load baring masonry walls. In areas where multiple stories exist a few wide flange beams are used to distribute the load across spans onto the load baring masonry walls. Typical beams are W 8x31. A unique truss system was designed for this project. The bottom center of the roof trusses were boxed out to allow for mechanical ducts and piping to run above the corridor without compromising ceiling heights.

FIRE PROTECTION SYSTEM BACKGROUND

A wet-pipe fire protection system shall be installed throughout the entire Longwood at Oakmont Healthcare Center, with the exception of the attic spaces which will be a dry-pipe system. Both systems shall be in compliance with NFPA 13 and 20 for light and ordinary hazard occupancies. All sprinkler heads shall be recessed and centered within a ceiling tiles.

TELECOMMUNICATIONS SYSTEM BACKGROUND

The telecommunications system within the Longwood at Oakmont Healthcare Center consists of telephone, data, and cable television throughout the entire building. Local overhead sound systems will also be provided within the multi-purpose, dining, and family rooms.

SPECIAL SYSTEMS BACKGROUND

There are two function specific electrical systems within this building that are unique to the buildings function. One of which is a nurse call system located throughout the entire facility and the other is a patient wandering system which is located only around the perimeter of the dementia wing to alert staff members should a dementia patient go beyond his designated area.

2.2 - MECHANICAL SYSTEMS DESIGN OBJECTIVES AND REQUIREMENTS

The Longwood at Oakmont Healthcare Center is a 45,000 square foot senior care facility. It consists of a wide variety of functional spaces. The building's mechanical systems must be equipped to handle all of the loads produced by each space. The design team at Reese Engineering Inc. settled on the decision of a large energy recovery unit feeding single zone water source heat pumps to condition the spaces throughout the building.

This decision was made based on some of the principles of the firm and also on previous results of similar projects. Some of the main design objectives are listed as follows:

- Adhere to all applicable codes and standards, such as the International Building Code and ASHRAE Standard 62.1, which apply to the HVAC system.
- Design the most energy efficient, yet realistic, mechanical system as possible.

- Fulfill the needs and budget requirements of the client as best as possible in order to maintain a good working relationship with the owner.

- Minimize the amount of rooftop equipment to the best of your ability. This can provide easier access to mechanical equipment, increase the equipment's lifespan and diminish the negative effect to the building's exterior aesthetics.

Due to the variety of spaces within the Longwood at Oakmont Healthcare Center other minor mechanical items were used to cover the demand of the given space. For example, over head electric heaters were installed in the resident spas to handle the higher latent load within that space. Larger exhaust hoods were installed within the kitchen and were ducted directly to the outside to minimize the amount of odor and heat that would diffuse through the surrounding spaces.

3.0 - MECHANICAL SYSTEMS EXISTING CONDITIONS

3.1 – INDOOR & OUTDOOR DESIGN CONDITIONS

The Longwood at Oakmont Healthcare Center is located in Verona, Pennsylvania which is just north-east of Pittsburgh. The energy recovery unit brings outside air to "room neutral conditions" which are described below. The air is then further treated by individual water source heat pumps. Table 3.1 includes a summary of indoor supply temperatures for given heat pumps and the energy recovery unit. Each zone that is served by this equipment is then controlled by an occupant controlled thermostat.

Table 3.1 – Design Indoor Conditions

	ERU	HP-1	HP-2	HP-3	HP-4	HP-5	HP-6	HP-7	HP-8	HP-9	HP-10	HP-11
Summer T_{SA} (°F)	75	62	63	61	62	60	60	58	55	57	57	56
Winter T_{SA} (°F)	72	100	100	102	100	101	104	103	108	106	106	106

The outdoor design conditions that were used in design calculations for thermal loads, and sizing HVAC equipment were obtained from the ASHRAE Handbook of Fundamentals 2007. Because data for Verona, Pennsylvania is not provided in the handbook, data from Pittsburgh, Pennsylvania was used. Table 3.2 includes a summary of the design outdoor conditions used in the design of the Healthcare Center's HVAC systems.

Table 3.2 – Design Conditions for Verona, PA

Latitude	40°, 30' N
Longitude	79°, 50' W
Elevation	853'
Summer DBT	90°F
Summer WBT	71°F
Winter DBT	4°F

3.2 - MECHANICAL SYSTEM DESCRIPTION OF OPERATION

COOLING TOWER

The Longwood at Oakmont Healthcare Center used a Baltimore Aircoil cooling tower to help aid in the air conditioning process. The cooling tower provided cooled condenser water for the heat pump loop. The water was fed to each individual heat pump and used to cool the air for its designated space.

The cooling tower is a closed circuit cooling tower. This means that the heat to be rejected is removed from the fluid being cooled to the ambient air via an exchange coil. By using a closed circuit the fluid being used is isolated from the surrounding environment and therefore remains clean and contaminant free.

WATER SOURCE HEAT PUMPS

Water source heat pumps are located in virtually every conditioned space, or combination of smaller spaces, throughout the building. These units can operate at both heating and cooling conditions, which is one main reason why they were incorporated in the design of this project. The units are also energy efficient and allow for occupant control which improves the indoor environmental quality.

In the summer, cooling, months the water from the cooling tower is used to chill the air within the heat pump. The air is cooled to the desired set point and then supplied to the space.

In the winter, heating, months the water from the gas-fired boilers is used to warm the air within the heat pump. The air is heated to the desired set point and then supplied to the space.

ENERGY RECOVERY UNIT

A Desert Aire energy recovery unit with an integral energy wheel was used to distribute ventilation air throughout the building. Outside air flows through the unit and exchanges characteristics with return air passing through the energy wheel. The outside air is then treated to “room neutral” conditions, 79°F DB for cooling and 34°F DB for heating. Cooling and heating coils are used inside the unit to reach these “room neutral” conditions. The air is then fed to the water source heat pumps where they will be fully conditioned and supplied to the designated spaces.

BOILERS

Three Patterson Kelley boilers are used to heat the heat pump loop for the Longwood at Oakmont Healthcare Center. Two of the boilers will be active and the third boiler will be stand-by for emergency purposes, maintenance issues, or high demand circumstances.

PUMPS

The Longwood at Oakmont Healthcare Center utilizes two Bell & Gossett pumps to circulate the warm and chilled water through the heat pump loop.

EXHAUST FANS

A number of Greenheck exhaust fans are used throughout the facility. Most of the fans are located on the roof or in the attic of the building, with architectural louvers located under the roof gables. The fans service areas within the building that require immediate exhaust so that the air is not mixed with other return air. Such areas include the kitchens, the beauty salon, soiled utility rooms, attic spaces, and machine rooms.

MAKE-UP AIR UNIT

The main kitchen area directly exhausts so mush air that extra outside air needs to be supplied to the space to maintain air quality and sufficient pressure. This requires a Greenheck gas-fired make-up air unit. The unit brings in fresh air, heats the air using a gas-fired heat exchanger, and supplies the air to the space.

Figure 3.1 – Air Side Flow Diagram

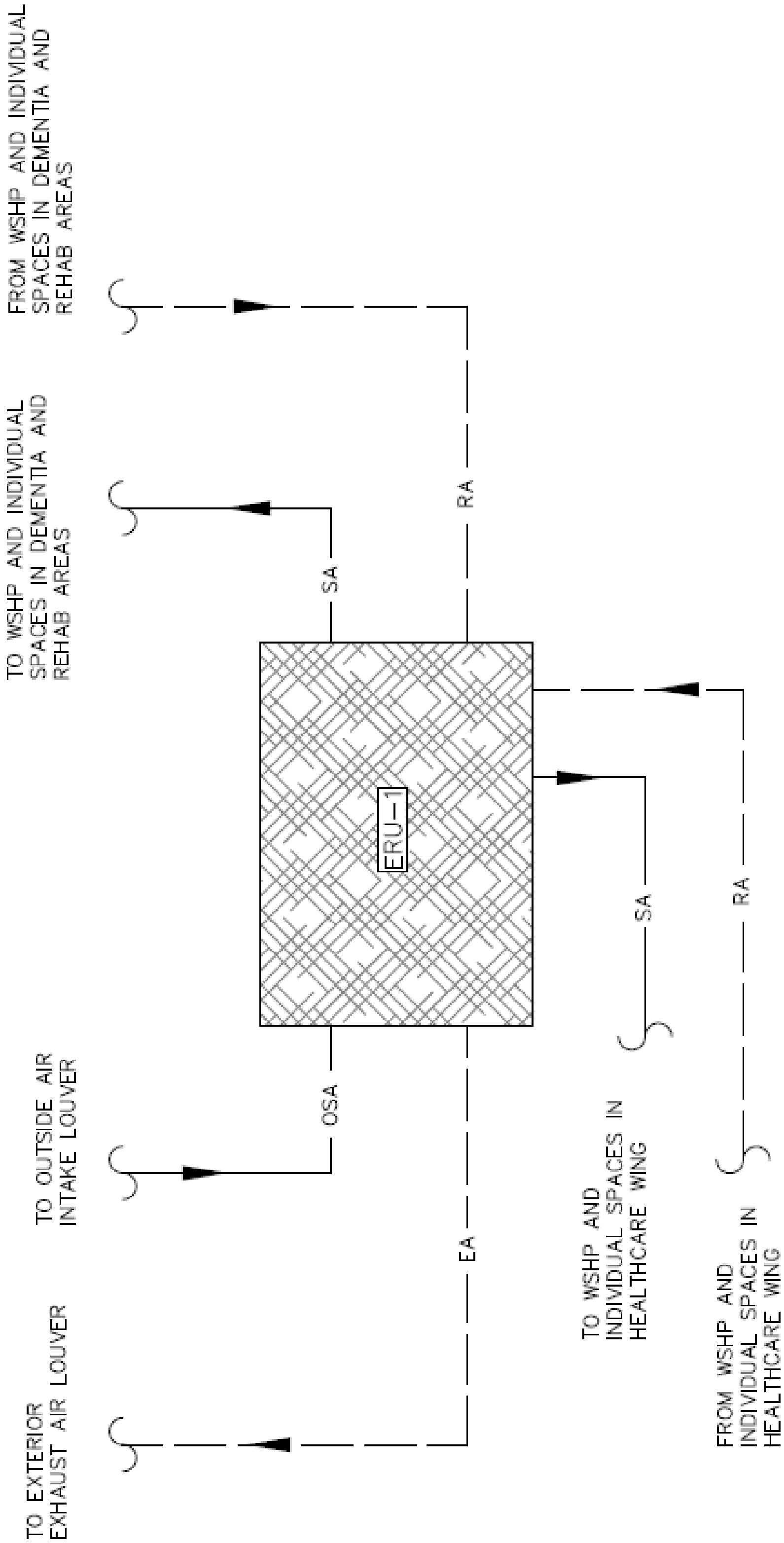
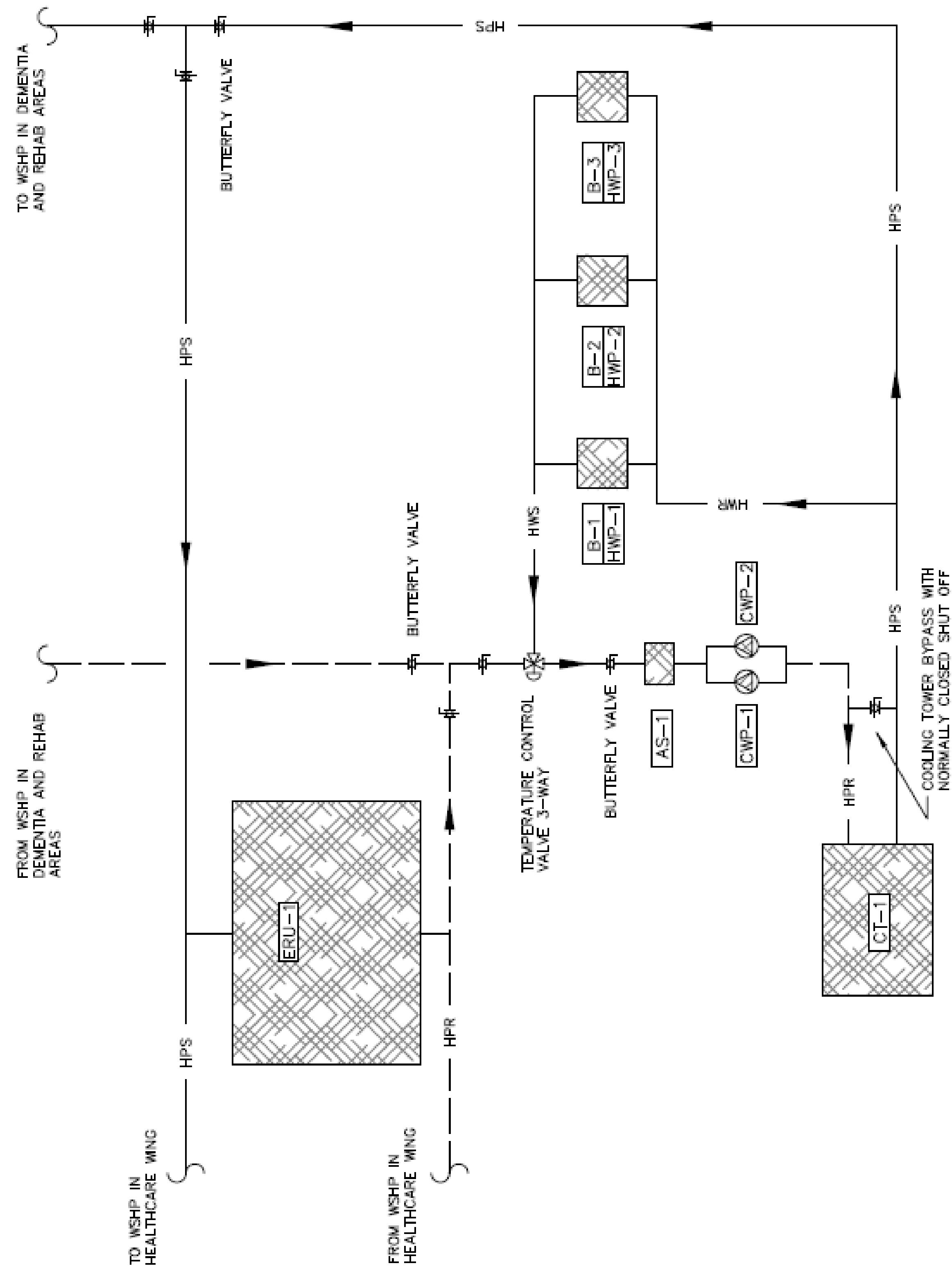


Figure 3.2 – Water Side Flow Diagram



4.0 - ASHRAE COMPLIANCE SUMMARY

4.1 - ASHRAE STANDARD 62.1 COMPLIANCE

ASHRAE Standard 62.1-2007 Table 6-1 provides requirements for minimum ventilation rates for zones and administers the design outdoor air requirements for the Longwood at Oakmont Healthcare Center and other buildings of the like. Table 6-1 includes a list of occupancy categories and minimum outdoor air rates on a per-person and per square foot basis.

While performing the Ventilation Rate Procedure laid out in Standard 62.1 a number of equations and tables are used to calculate the quantity of ventilation air required for each space based on a number of characteristics; such as floor area, use, and occupancy. The amount of outdoor air required is then calculated to guarantee that each space receives at least the minimum level of outdoor air. Table 4.1 below summarizes the amount of outdoor air that is used in order to adhere to the standard and the amount of outside air that is scheduled to be supplied per the design documents provided by Reese Engineering Inc.

Table 4.1 – Ventilation Rates

Space Name	V_{ou} (cfm)	V_{pz} (cfm)	Z_p (max)	E_v	V_{ot} (cfm)
Calculated Totals	6733	58073	0.34	0.8	8416
Designed Totals		58073			13200

There is a significant difference between the ASHRAE required outside air quantity and the designed outside air quantity. This could be looked at in two different lights.

On one side, this could be looked at as over engineering. If the designed value of outside air were to be closer to the minimum amount of outside air required by ASHRAE standards a smaller and subsequently less expensive energy recovery unit could be used. This would pose a great asset to the owner of the building.

On the other hand, an increased amount of ventilation air within a building has some great benefits. The building could have been designed this way to improve the indoor air quality for improved occupant comfort, well-being and productivity. By adding an additional 5000 cfm of outside air the ventilation system is in compliance with LEED Indoor Environmental Quality Credit 2. Although this building was not being considered for LEED certification it seems as though it was the engineer's intent to practice good indoor environmental quality methods.

A fully encompassed analysis of the building's compliance with the ventilation rate procedure is located in Appendix B.

4.2 - ASHRAE STANDRAD 90.1 COMPLIANCE

ASHRAE Standard 90.1 provides minimum requirements for the design of energy efficient buildings. The following sections provide summarized reports of the Longwood at Oakmont Healthcare Center's compliance with the requirements laid out by the standard.

4.2.1 - BUILDING ENVELOPE COMPLIANCE

Checking compliance with Section 5 of ASHRAE Standard 90.1 was done using the Prescriptive Building Envelope Option. This was capable because the Longwood at Oakmont Healthcare Center amount of total vertical fenestration is less than 50% of the gross wall area and there are no skylights located within the building. Verification of this is located below in Table 4.2.

Table 4.2 – Fenestration Percentage

Total Vertical Glass Area	Total Wall Area	% Total Vertical Fenestration Area
4146 Ft^2	15461 Ft^2	27 %

The Longwood at Oakmont Healthcare Center is located in Verona, Pennsylvania which falls into climate zone 5-A. This was determined by using Table B-1 in Appendix B of ASHRAE Standard 90.1. Due to this climate designation Table 5.5-5 was used to check building envelope requirements. The following tables exemplify the buildings compliance with building envelope standards:

Table 4.3 – R-Value Compliance

	Roof (Attic)	Wall 1 (Mass)	Wall 2 (Wood Framed)	Slab-On-Grade Floors (Unheated)
Minimum Required R-Value (ASHRAE 90.1)	R-30	R-7.6	R-13	N/A
Specified	R-38	R-18.6	R-26.3	N/A
Compliance	Yes	Yes	Yes	N/A

Table 4.4 – Fenestration U-Value and SHGC Compliance

Vertical Fenestration	Assembly Max U (Fixed)	Assembly Max SHGC (All Orientations)
Required (ASHRAE 90.1)	0.57	0.39
Specified	0.34	0.38
Compliance	Yes	Yes

All R-values, U-values, and SHGC were either obtained from design documents from Reese Engineering Inc. or from specifications written by RLPS Architects Ltd. As shown from the tables the Longwood at Oakmont Healthcare Center is in full compliance with ASHRAE Standard 90.1 for an energy efficient building envelope.

4.2.2 - POWER & LIGHTING COMPLIANCE

POWER (SECTION 8)

In Section 8 of ASHRAE Standard 90.1 power distribution standards are established for buildings. There are two mandatory provisions called out in this section. One provision is that feeder conductors are sized for a maximum voltage drop of 2% at design load. The other is that branch circuit conductors shall be sized for a maximum voltage drop of 3% at design load. The Longwood at Oakmont Healthcare Center's electrical system was designed to meet these voltage drop stipulations and therefore complies with ASHRAE 90.1 Section 8.

LIGHTING (SECTION 9)

Lighting power allowances for buildings are set up in Section 9 of ASHRAE Standard 90.1. Two methods are laid out to determine such allowances. One method is the Building Area Method which is a simplified method computing the wattage allowed for a zoned space on a square foot basis. The other method is the Space-by-Space method which is a more detailed approach and allows for individual space occupancy/function to be accounted for while computing the wattage allowance. For the analysis of the Longwood at Oakmont Healthcare Center the Building Area Method was used. The building's spaces were broken down into the following categories: Dormitory (for resident rooms), Office, Health-Care Clinic, and Dining: Family. All spaces, with the exception of the dining area, have equal power density levels and were therefore grouped together for easier calculation. All necessary values, constants, and lighting information were collected from the design drawings and Table 9.5.1 of ASHRAE 90.1. The Longwood at Oakmont Healthcare Center was not in compliance with ASHRAE 90.1 Section 9. A main reason for the excessive watt consumption was due to architectural track lighting located in accentuated public spaces. It contributed to nearly 40% of the overall lighting wattage.

Table 4.5 – Lighting Compliance

	Total Used Watts	Power Density (W/ft^2)	Floor Area (ft^2)	Allowed Watts	Compliance
Dining Space	6230	1.6	4152	6643.2	YES
General Space	82872	1	40848	40848	NO

4.2.3 - HVAC SYSTEMS COMPLIANCE

EQUIPMENT EFFICIENCY

In ASHRAE 90.1 Section 6 efficiency requirements are instituted for mechanical systems and equipment. They are set up in order to minimize the amount of energy required to properly operate the building. Because the Longwood at Oakmont Healthcare Center is greater than 25000 square feet the Mandatory Provisions portion of Section 6 was used to determine its compliance. Tables 6.8.1(A-J) provide a thorough description of all necessary provisions and requirements for different mechanical components. A summarized list of equipment is provided below in Table 4.6.

Table 4.6 – HVAC Equipment Efficiency Compliance

Equipment	Efficiency Value	Required	Installed	Compliance	Table or Standard
HP-1	COP EER	4.2 11.2	4.7 13.5	YES YES	6.8.1B 6.8.1B
HP-2	COP EER	4.2 11.2	4.3 12.1	YES YES	6.8.1B 6.8.1B
HP-3	COP EER	4.2 11.2	4.6 13.3	YES YES	6.8.1B 6.8.1B
HP-4	COP EER	4.2 12	4.6 13.3	YES YES	6.8.1B 6.8.1B
HP-5	COP EER	4.2 12	4.3 12	YES YES	6.8.1B 6.8.1B
HP-6	COP EER	4.2 12	4.3 12	YES YES	6.8.1B 6.8.1B
HP-7	COP EER	4.2 12	4.2 12	YES YES	6.8.1B 6.8.1B
HP-8	COP EER	4.2 12	4.3 13.1	YES YES	6.8.1B 6.8.1B
HP-9	COP EER	4.2 12	4.4 12.6	YES YES	6.8.1B 6.8.1B
HP-10	COP EER	4.2 12	4.3 12.8	YES YES	6.8.1B 6.8.1B
HP-11	COP EER	4.2 12	4.3 13	YES YES	6.8.1B 6.8.1B
Boilers	%	75	85	YES	6.8.1F
Cooling Tower	gpm/hp	38.2	30.5	NO	6.8.1G
Energy Recovery Unit	%	50	58	YES	6.5.6.1

5.0 - MECHANICAL SYSTEM REDESIGN OBJECTIVES

The designers at Reese Engineering Incorporated always practice energy efficient design methods and look to incorporate as many ‘green’ ideas into a project as possible. The Longwood at Oakmont Healthcare Center was no exception. The mechanical system in the existing design is a fairly energy conscious system utilizing water source heat pumps and an energy recovery unit. However, as it is with any project, numerous other solutions or systems could be analyzed. The goal of this redesign is to compare the costs and benefits of a ground source heat pump system to the current water source heat pump system. Alterations to the existing mechanical system design could result in changes in initial costs, operating costs, the construction time schedule, and electrical power consumption. It is important to take a look at all of these variables and determine whether or not the benefits of adding a ground source heat pump system out weight the costs.

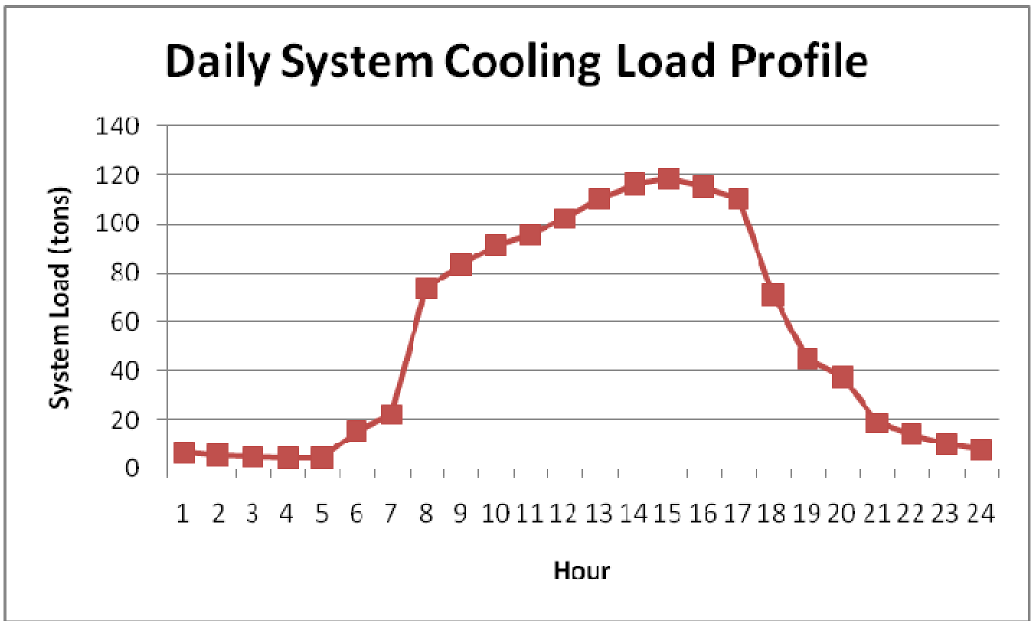
Increasing the energy efficiency of the building is the main goal of this redesign. However this is to be done in a feasible manner. Practicality is key when dealing with the majority of clients and Presbyterian Senior Care is no exception. Most energy efficient mechanical systems or methods tend to be pretty expensive up front. It is important to analyze the energy consumption of the newly designed system so that the monthly utility costs will offset the higher initial costs and provide the owner with a reasonable payback period. Although it would be nice to assume that all building owners would opt on designing their buildings with the utmost energy efficient systems, money is almost always the driving issue when selecting final designs.

The overall goal of this redesign process is to hopefully provide a more energy conscious mechanical system alternative while still keeping the overall cost of the design within limits. This redesign is also intended to serve as an educational tool for the comparison of ground source heat pumps to water source heat pumps. Hopefully it will shed a bit of light on some of the reasons why more owners, designers, or contractors are not utilizing the technologies of ground source heat pumps.

6.0 - BUILDING LOAD ANALYSIS

The Longwood at Oakmont Healthcare Center, once again, is located in Verona, Pennsylvania and therefore operates like the majority of the buildings in the Northeast. In the summer cooling months the buildings peak loads occur during the middle of the day during occupancy and the warmest parts of the day. Trane's Trace 700 Version 4.1.1 was used to model the Healthcare Center and perform energy calculation for a strong protion of this redesign analysis. Figure 6.1 illustrates a peak demand load for the Healthcare Center in cooling mode.

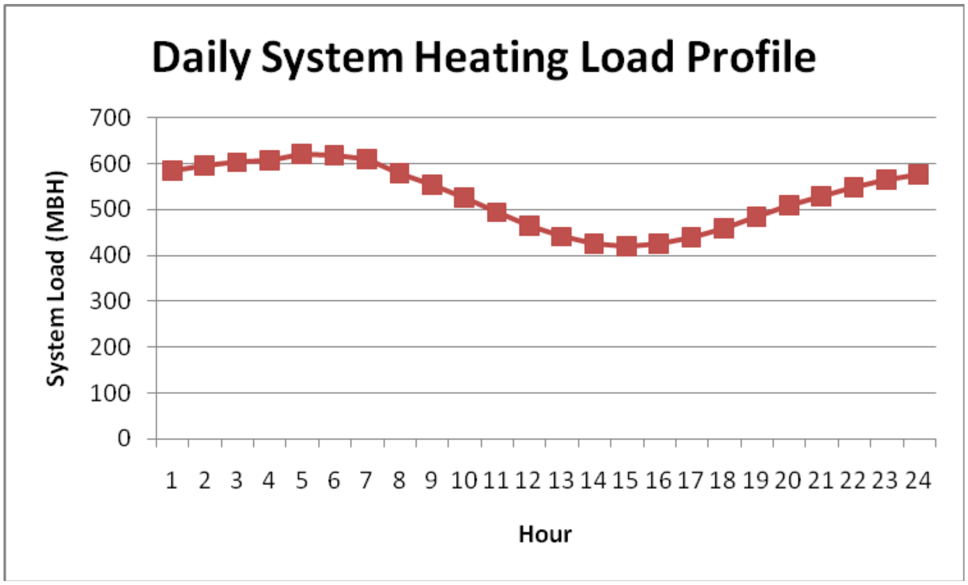
Figure 6.1 – Daily System Cooling Load Profile



As you can see from above even when the day is at its coolest point there is still a minor cooling load on the building. This is a result of the building's function. As a senior care facility there is always occupancy and even though the majority of the residents are asleep there is still a demand load created by the staff. It could also be noticed that the demand load really cranks up between the hours of seven and eight in the morning. This is a result of the initiation of a typical work day.

On the contrary, the winter heating months create sort of an inverse demand, as would be expected. Figure 6.2 demonstrates the trends of a peak heating day. Here the highest load occurs in the hours just before the sun rises, which again is typical of buildings in the Northeast.

Figure 6.2 – Daily System Heating Load Profile



As the building's mechanical system is changed from water source heat pump to ground source heat pump there is no change in the daily system heating and cooling load profiles. The building is still operating in the same manner. The benefit in changing systems is not in decreasing the demand load, but by increasing the efficiency in how that load is conditioned. A ground source heat pump system utilizes less energy to heat or cool a building to it's desired state, when compared to a water source heat pump system.

7.0 - GROUND SOURCE HEAT PUMP SYSTEM

Ground source heat pumps utilize the Earth's constant underground temperature to heat and cool the building throughout the year. A series of pipes or wells are drilled into the ground either horizontally or vertically, as illustrated in Figure 7.1 below. The pipes act as a sort of heating/cooling coil. The pipes are filled with water or a water/antifreeze mixture. In the summer cooling months the heat that is produced by cooling the air for the building's conditioned spaces is distributed through the loop. The heat is then absorbed by the surrounding soil or underground reservoir. The cooled fluid is then circulated back into the building to be used again. The exact opposite is true during the winter months. The heat from the Earth is absorbed by the fluid loop and then distributed back into the building. The now warm water is used to heat the air, which is then distributed throughout the building. Basically the Earth (beneath the surface) acts as a heat source in the winter and a heat sink in the summer.

In the Longwood at Oakmont Healthcare Center ground source heat pumps will take the place of the existing water source heat pumps. The hope is to decrease the amount of energy it takes to condition the building. By using the Earth's constant temperature, equipment such as boilers and cooling towers can either be down sized or eliminated. This will also help offset the higher initial cost as well.

Figure 7.1 – GSHP Loop

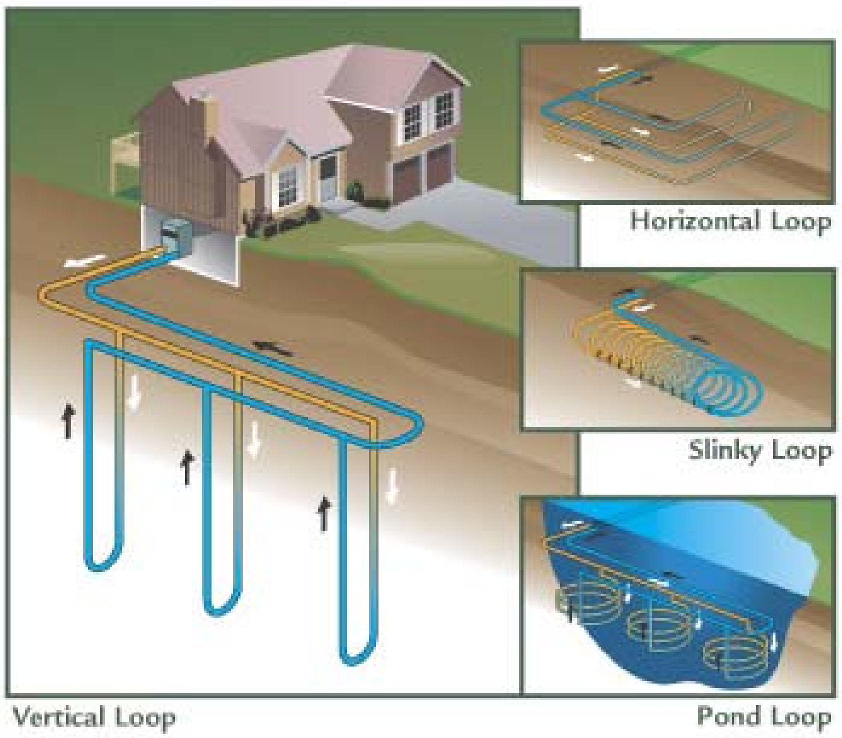


Photo taken from <http://www.daviddarling.info/images/geothermal_heat_pump.jpg>.

There are numerous elements to consider when designing a ground source heat pump system and the well field that coincides with it. One such element is the physical space in which the well field will occupy. Local potable water wells and wet lands need to be located and kept at an acceptable distance. For the Longwood at Oakmont Healthcare Center, neither of these issues was a problem.

Another facet of designing a well field is deciding whether to install a vertical or horizontal well system, both of which have their costs and benefits. For the Healthcare Center a vertical well field was chosen because of the lack of usable space. Vertical systems require less square footage when considering the site plan.

Designing the piping loop itself depends on a number of items. Actual geotechnical reports were not able to be acquired for this project. However, after talking with some engineers at Reese Engineering Incorporated, a few assumptions were made based off of past soil properties of projects in the surrounding Pittsburgh area. A ground resistance of 0.325 (hr*ft*F/BTU) was used for cooling and a ground resistance of 0.30 (hr*ft*F/BTU) was used for heating. A thermal conductivity of 1.79 (BTU/hr*F*ft) was also used for the loop piping.

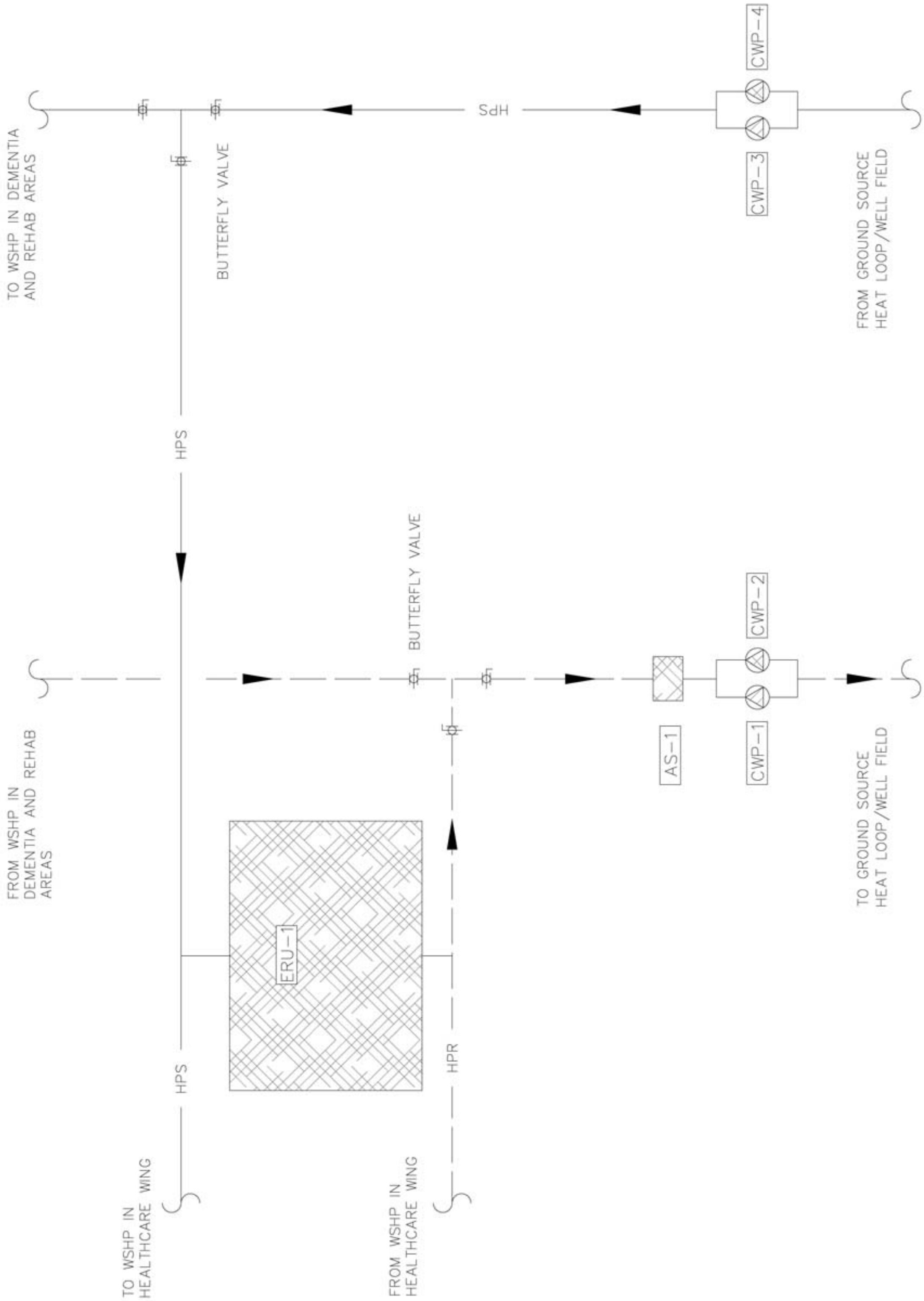
These values were used in calculating the amount of piping needed to meet the heating and cooling demand loads of the building. A free trial of GCHPCalc was used to size the well field, by using the values mentioned above and some of the temperature values listed below in Table 7.1. This program was based off of the work of well known ground source heat pump designer, Steve Kavanaugh. The required length of piping was equal to 19,650 linear feet. By drilling each bore to roughly 200 feet a total of 100 well bores will need to be excavated and installed in order to condition the building properly.

Table 7.1 – Heat Pump Loop Temperatures

COOLING	INLET	79 F
	OUTLET	89 F
HEATING	INLET	50 F
	OUTLET	44 F
GROUND TEMPERATURE		54 F

The redesigned ground source heat pump system creates enough heating and cooling capacity to eliminate the existing systems cooling tower and three gas-fired boilers. However, with the addition of the large piping loop two additional circulating pumps are needed. The following figure (Figure 7.2) provides an illustration of the redesigned water-side system.

Figure 7.2 – Redesigned Water-Side Flow Diagram



8.0 - BUILDING ENERGY UTILIZATION

There are many aspects within a building that can be used in a manner that decreases the amount of the energy they consume. It is the focus of this redesign to minimize the amount of energy it takes to operate the mechanical systems of the Healthcare Center. The below figures (Figure 8.1 & 8.2) illustrate the yearly energy usage for different building loads.

Figure 8.1 – Annual Building Energy Utilization

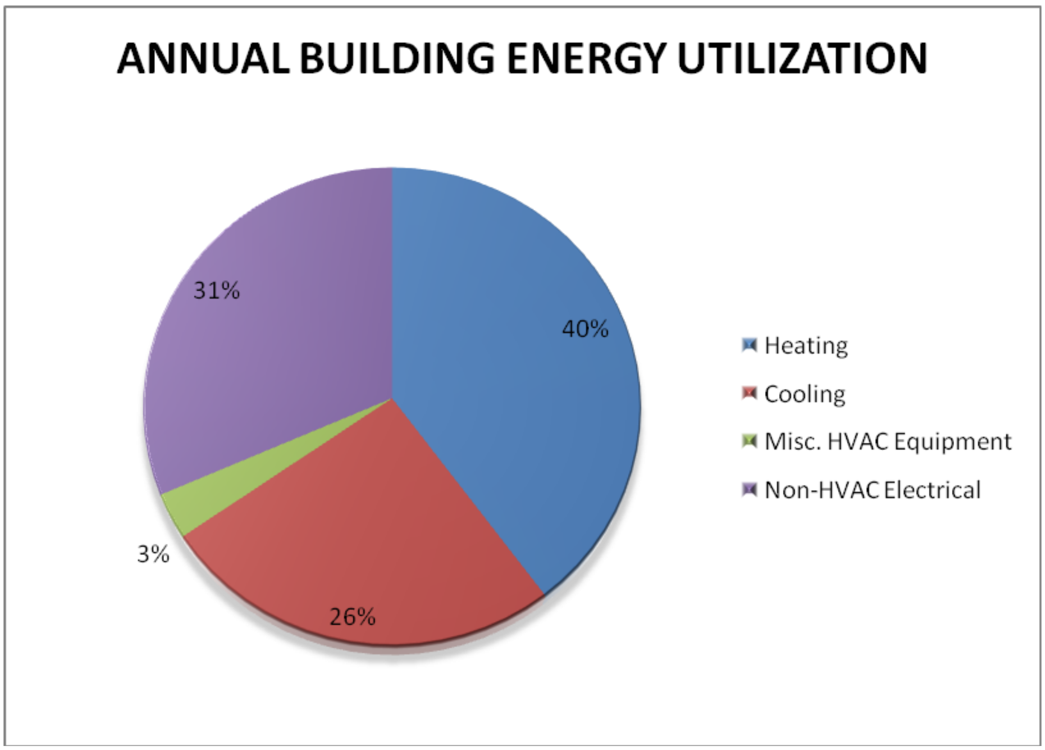
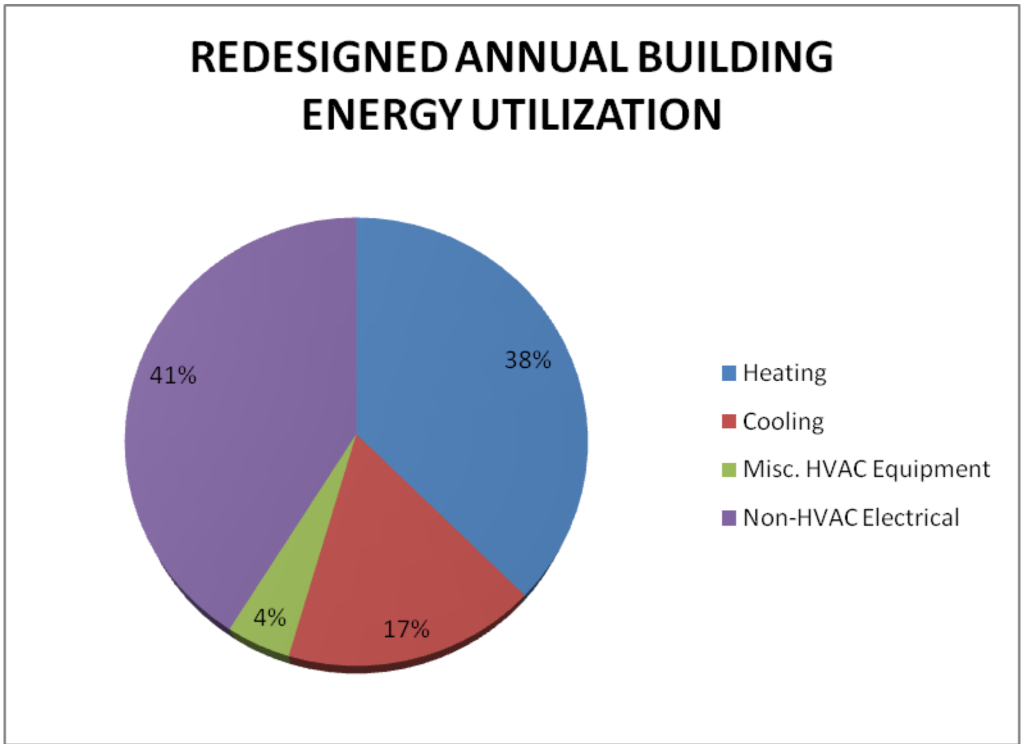


Figure 8.2 – Redesigned Annual Building Energy Utilization



The figures above show how different demands have altered their energy usage after the implementation of the ground source heat pump system. Prior to the redesign the building's energy was primarily consumed by the heating demands. After the redesign, however, it is now consumed by the building's non-HVAC electrical demands. In other words more energy is required to operate the Healthcare Center's lighting and recepticals than it does to heat or cool it. Now although the fraction of energy being consumed by non-HVAC electrical equipment increases the quantity of energy being used by this equipment remains the same. Figures 8.3 and 8.4 illustrate the gross amounts of energy consumed by the different facets of the building over the period of a year.

Figure 8.3 – Annual Building Energy Utilization

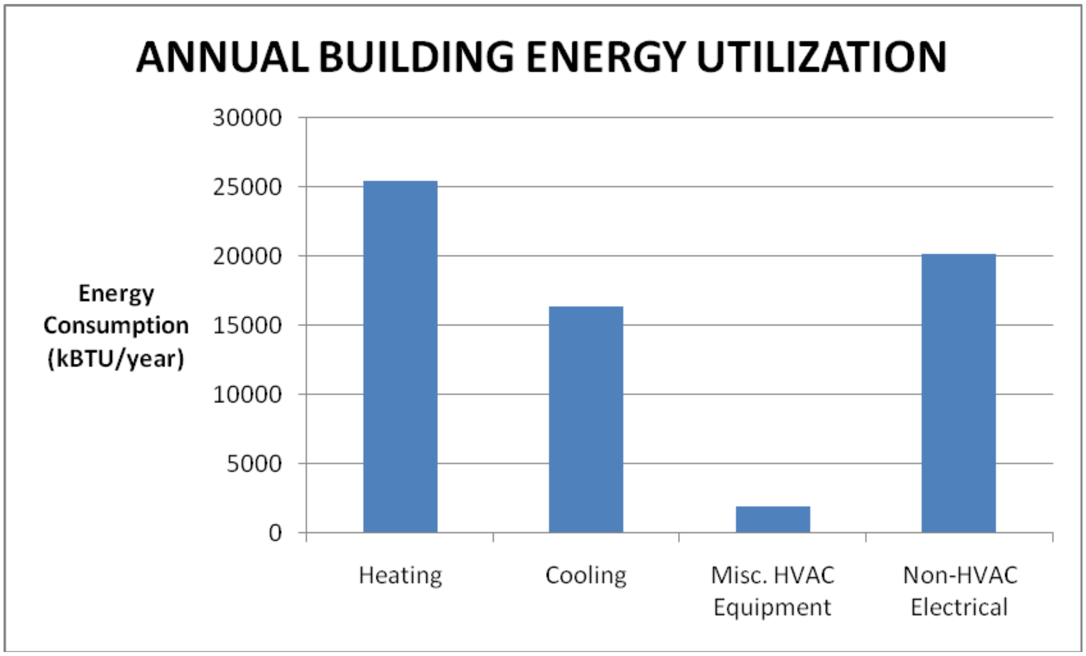
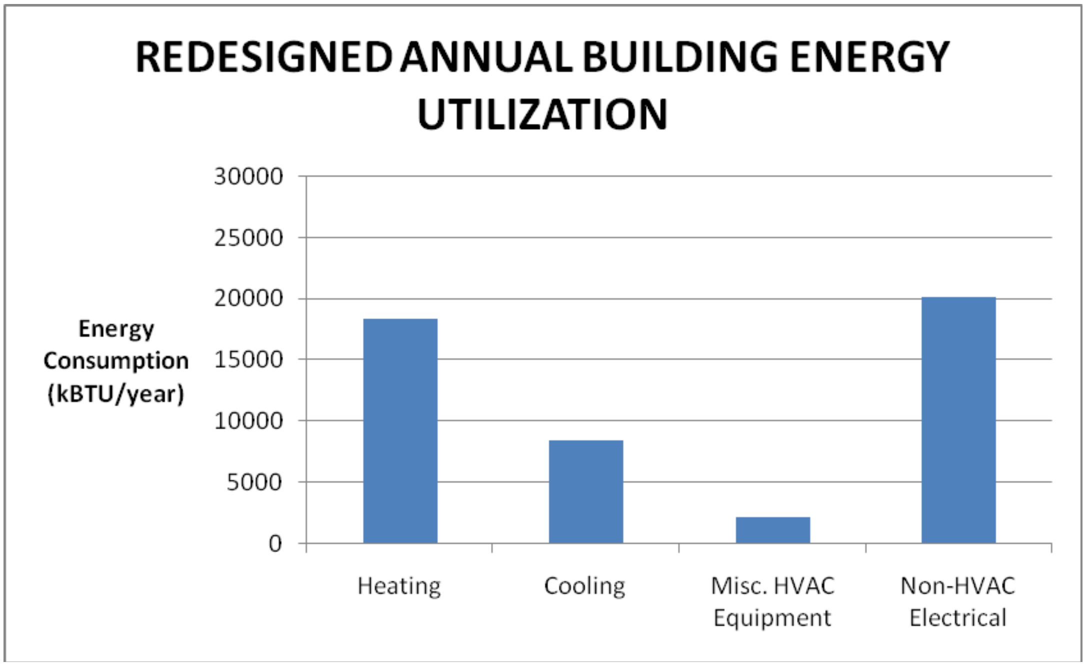


Figure 8.4 – Redesigned Annual Building Energy Utilization



Like mentioned prior the non-HVAC electrical demand does not change with the redesign, because that was not the focus of this research depth. Both the heating and cooling energy consumption values decrease which was the main goal of the mechanical system redesign. The heating energy decreases by a little more than 7000 kBTU/year. The heating energy consumption decreases from 0.56 kBTU per square foot to 0.41 kBTU per square foot. This is almost a 30% decrease in heating energy consumption per year. The cooling load also experiences a decrease, from 0.36 kBTU per square foot to 0.19 kBTU per square foot. This is almost a 50% decreases in energy consumption, which is remarkable. The only aspect of energy consumption that increases is the miscellaneous HVAC equipment load. Two additional circulating pumps are added to the mechanical system, which require more energy. Although there is an energy increase it is only an 8% increase and is minimal in the overall percentage of building usage, as seen in Figures 8.1 & 8.2.

9.0 - REDESIGN ECONOMIC ANALYSIS

By decreasing the amount of energy consumed by the mechanical systems on a yearly basis the overall electrical bill will subsequently decrease. This is the way to make any sustainable or energy efficient technology affordable. Figures 9.1 and 9.2 below represent the annual energy costs for the original water source heat pump system and the redesigned ground source heat pump system.

Figure 9.1 – Building Monthly Energy Costs

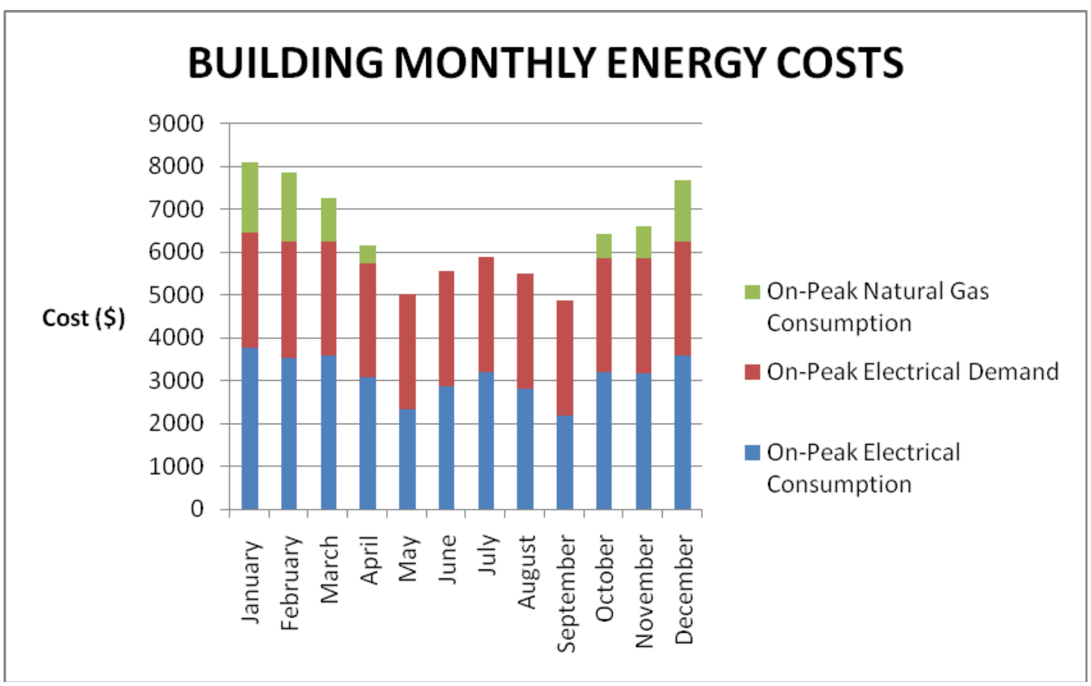
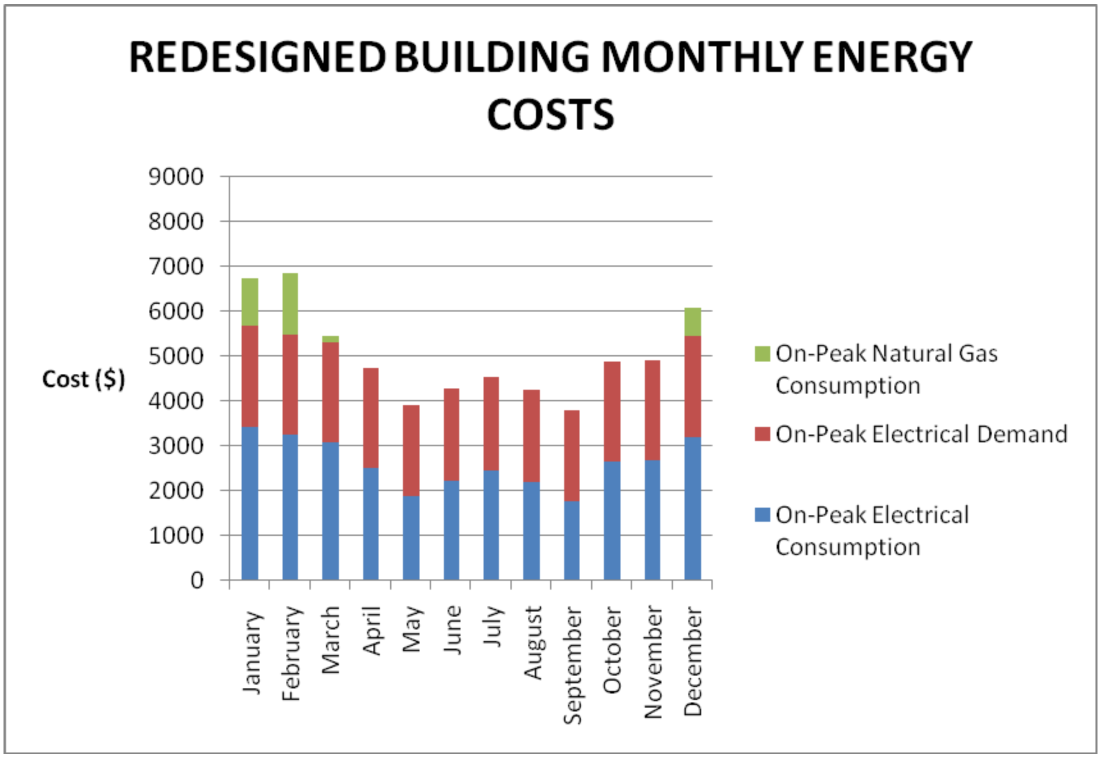


Figure 9.2 – Redesigned Building Monthly Energy Costs



The graphs clearly illustrate that a considerable amount of money is saved over the year by decreasing the utility costs of the mechanical system. An annual savings of $16,648 is achieved by switching to ground source heat pumps. This is a 22% decrease in utility bills every year. Instead of paying $1.71 per square foot a year to operate the building the owner is now paying $1.34 per square foot a year.

Although $16000 a year is a great savings, one still needs to consider the substantial first cost of installing a ground source heat pump system. As noted before the ground source heat pump system itself costs $294,750. Other elements are also considered in the initial cost of the redesigned system. Table 9.1 provides a breakdown comparison of the initial costs of the original system and the redesigned system of the Longwood at Oakmont Healthcare Center.

Table 9.1 – Initial Cost Comparison

Equipment	Existing WSHP System ($)	Redesign GSHP System ($)
Cooling Tower	43200	0
Gas-Fired Boilers	72900	0
Circulating Pumps	15360	30720
Ground Piping (Excavation/Installation)	0	294750
Equivalent Electrical Savings	4040	0
TOTAL	**135500**	**325470**

The redesigned ground source heat pump system is a considerably higher first cost system. In fact it is over twice as expensive as the existing water source heat pump system. However the energy savings it provides on a yearly basis are also considerably high. Table 9.2 offers a twenty year cost analysis of the two differing systems. Over the twenty year span the ground source heat pump system actually saves the owner almost $150,000. That is almost a 10% savings in mechanical systems costs.

Table 9.2 – 20 Year Cost Comparison

Year	Cost Description	WSHP System Costs ($)	GSHP System Costs ($)
1	Utility	76920	60270
2	Utility	76920	60270
3	Utility	76920	60270
4	Utility	76920	60270
5	Utility	76920	60270
6	Utility	76920	60270
7	Utility	76920	60270
8	Utility	76920	60270
9	Utility	76920	60270
10	Utility	76920	60270
11	Utility	76920	60270
12	Utility	76920	60270
13	Utility	76920	60270
14	Utility	76920	60270
15	Utility	76920	60270
16	Utility	76920	60270
17	Utility	76920	60270
18	Utility	76920	60270
19	Utility	76920	60270
20	Utility	76920	60270
	Utility Sub-total	1538400	1205400
	Initial Cost	135500	325470
	TOTAL	**1673900**	**1530870**

This data was also used to perform a simple payback period analysis. It was calculated that the redesigned system would pay itself off in a little over 11 years. Now for most systems this would be considerably long. However, after talking with some of the engineers at Reese Engineering Incorporated, the 11 year payback period was not unreasonable. They have seen typical payback periods of around 8-12 years in the surrounding Pittsburgh area. This value is also a little more bearable because Presbyterian Senior Care is a long term owner. This means that they will be able to benefit from all of the added utility savings.

10.0 - CONSTRUCTION BREADTH: GROUND SOURCE HEAT PUMP WELL FIELD ANALYSIS

The largest factor in designing a ground source heat pump system is the physical well field that is associated with it. The ground source water loop well field for the Longwood at Oakmont Healthcare Center mechanical redesign poses a number of issues when considering it for use. Those issues include initial cost, time of construction, and location of the well field itself. The initial cost of the ground source well field has already been addressed in the mechanical depth cost analysis.

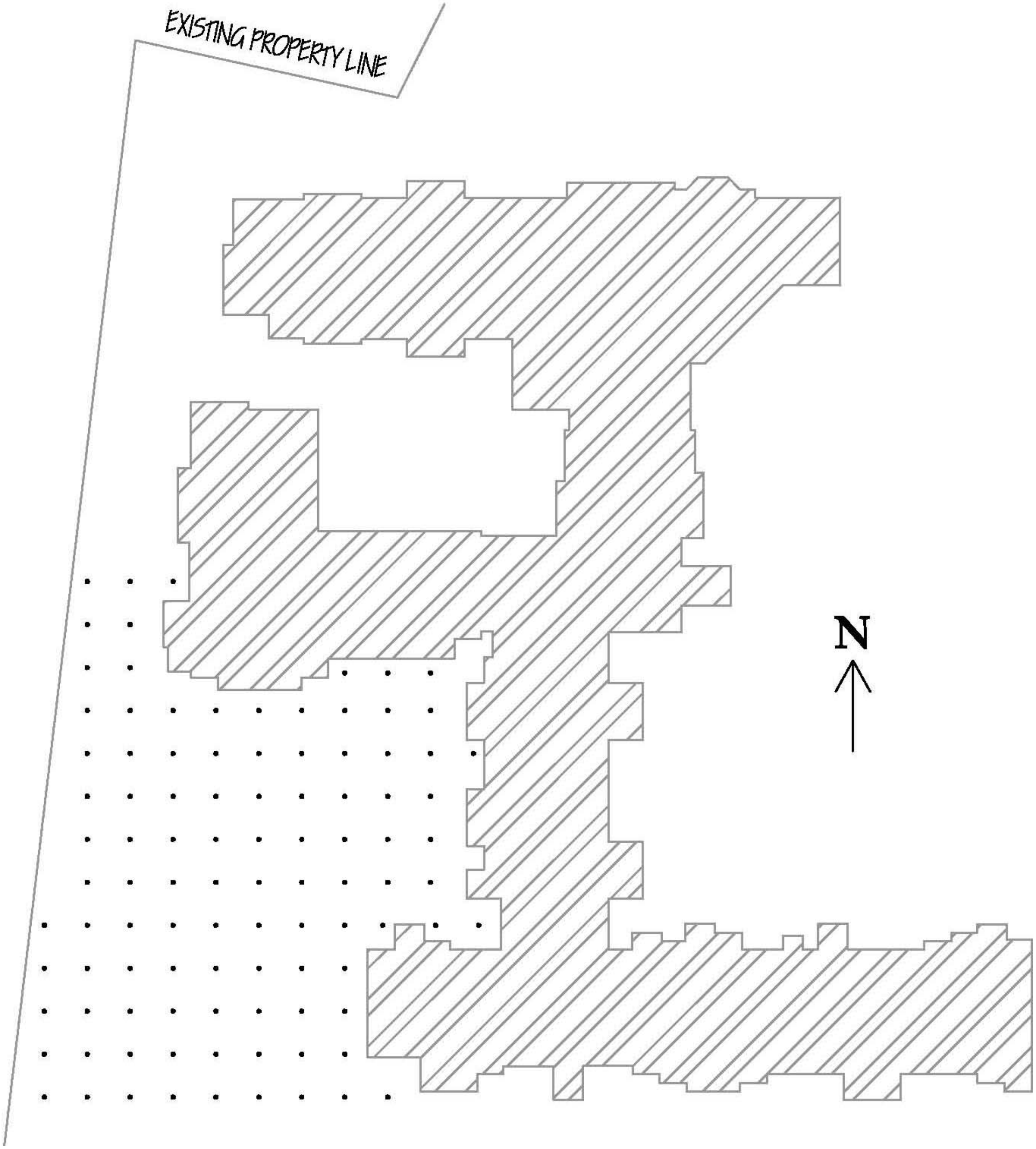
The location of a well field can be a hard factor when designing a ground source heat pump system due to space limitations. However, for this project the site was pretty receiving to the introduction of a well field. There were a few limitations that did exist on the Longwood at Oakmont site, but none that could not be worked around.

Obviously existing structures cannot be avoided. There is a parking lot just east of the Healthcare Center, which is usually a great place to locate a well field, but only when the parking lot is being constructed after the well field is in place, which eliminates this area as an option. The site property line also runs along the west side of the building which restricts the area of the well field.

The space needed is determined by the number of wells. Typically each well bore requires a 20' by 20' grid from any surrounding well bores. Therefore with 100 well bores, the well field for the Healthcare Center is of considerable size.

The field was located east of the existing buildings and south of the Healthcare Center's Zone A (Figure 2.1). This location was able to fit in between the property line and the building. The well field area also terminated parallel with the southernmost portion of the standing buildings. Any space further south of this would be an ideal location for future building, and seeing it as the Longwood at Oakmont campus is almost in continual growth buildable space is at a premium. The location of the ground source heat pump well field can be seen below in Figure 10.1.

Figure 10.1 – Proposed Well Field

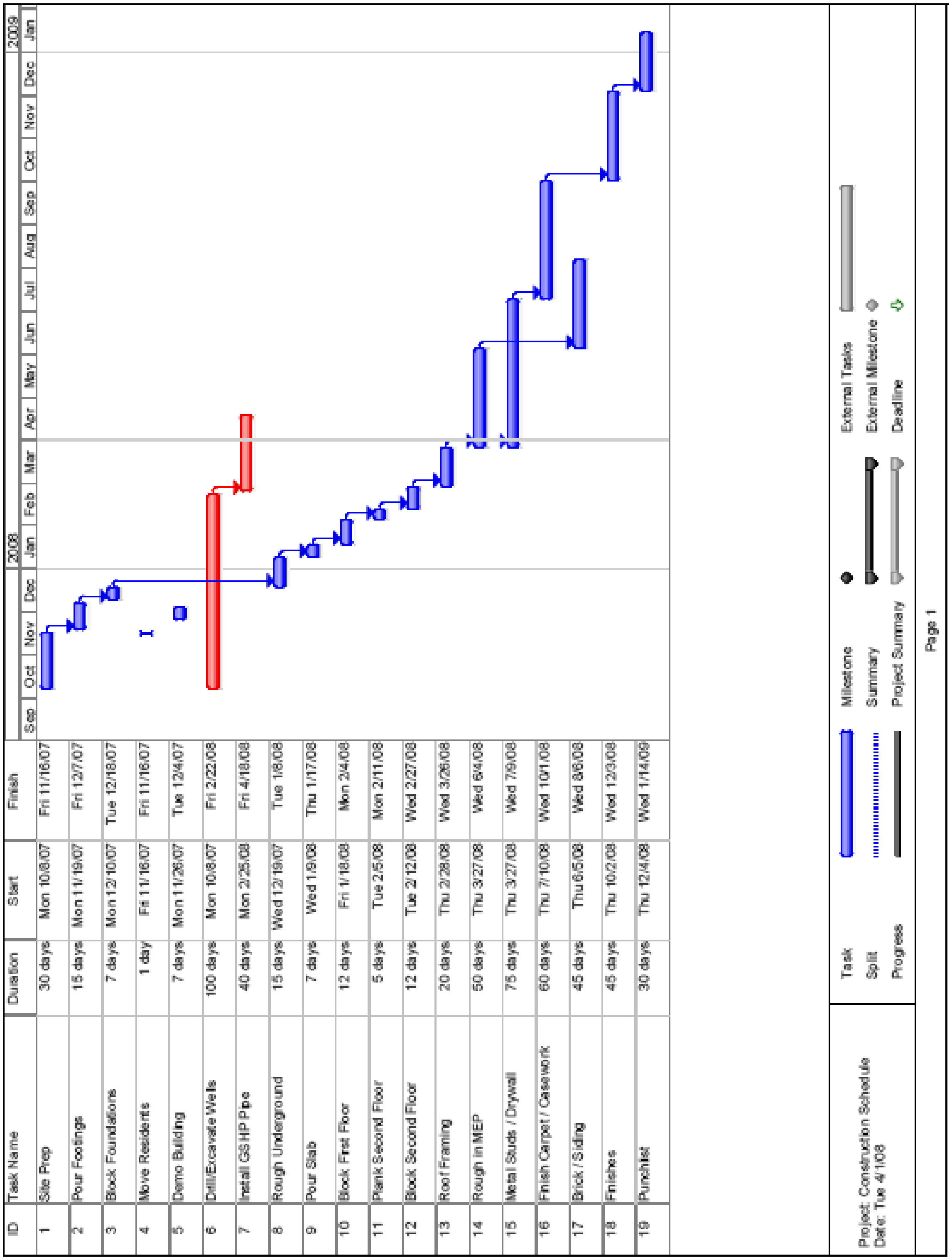


Another key factor of designing a ground source heat pump system is considering the added time it will take to install. Typically, with one crew and one drill, it takes about one day to drill one well and roughly two days to install the added piping for every group of five wells. This added an extra one hundred days for drilling and forty days for installing to the project's schedule.

Although added work and time is added to the project it does not affect the overall completion date of the construction. All of the added work that has to be done is exterior work. This allows the rest of the project to continue while the well field is being excavated and installed. In other words the ground source well field is not linked to anything else substantial within the project's scope.

The only other thing that is dependent on the completion of the well field is the mechanical system's operation. If the excavation of the well field is started at the same time as the site work then it should be completed nine months prior the substantial completion of the project. This allows ample time to get the heat pump system on-line and balanced before the job is punched out. Figure 10.2 below diagrams the updated construction schedule and highlights the ground source well field in red.

Figure 10.2 – Redesigned Construction Schedule



11.0 - ELECTRICAL BREADTH: POWER REQUIRMENTS AND ASSOCIATED COSTS FOR MECHANICAL REDESIGN

As the Longwood at Oakmont Healthcare Center's mechanical system is changed over to ground source heat pump electrical requirements are also changed. Certain equipment is added to the system and certain equipment is omitted from the system. For this redesign scheme two primary pumps (CWP) were added, the cooling tower (FC) was removed, and three gas fired boilers (B) and their associated circulating pumps (HWP) were removed.

All of these pieces of equipment have an effect on their associated panel boards. The panel boards were adjusted to handle the newly introduced loads. Appendix A illustrates all of the original panels with altered loads highlighted. The adjusted panels are also displayed with an emphasis on the new demand load. The panel board feeders were then resized based on the newly acquired loads.

The feeders were resized using Table 11.1 below and Table 11.1 from Hughes's *Electrical Systems in Buildings*.

Table 11.1 – Panel Board Feeder Sizing

PANEL BOARD	DEMAND LOAD(AMPS)	GROWTH	AMPS	FRAME SIZE	TRIP	FEEDER SIZE	GROUND
PG	196.3	1.25	245.375	250	250	250kcmil	#4
CG	409.9	1.25	512.375	600	600	350kcmil	#4

Voltage drop was also checked for the edited feeders. If an overabundant amount of voltage is lost over the length of the feeder, it would need to be resized yet again. Certain assumptions and/or initial conditions were made during the voltage drop calculations, such as; 75 °C temperature copper conductors, magnetic conduit, and 90% power factor. Below demonstrates how this was done.

Ampere-Feet = [I (amps) * L (feet)] / 1000
Voltage Drop (line-neutral) = ampere-feet * voltage drop coefficient (from Table 11.5 from Hughes's *Electrical Systems in Buildings*)

Voltage Drop (line-line) = (line-neutral voltage drop) * (1.73)
Percent Voltage Drop = [(line-line voltage drop) / (system voltage)]

If the percent voltage drop is less than two then the assigned feeder size is adequate. If the percent voltage drop is greater than two then the feeder should be increased to the next conductor size up. Table 11.2 illustrates the feeders used in this system redesign and their voltage drops.

Table 11.2 – Voltage Drop Checks

Panel	Feeder Size (kcmil)	Distance (ft)	Voltage Drop Compliant
PG	250	5	OK
CG	350	65	OK

By altering equipment and resizing feeders, initial costs of the electrical equipment are also changed. Certain feeders are changed and certain conductors are omitted, because their assigned equipment was also omitted. This could also coincide with a change in conduit sizes. Table 11.6 from Hughes's *Electrical Systems in Buildings* was used to resize this equipment. Tables 11.3 and 11.4 below illustrate the costs and savings associated with these changes.

Table 11.3 – Redesigned Conduit Costs and Savings

Equipment Tag	Distance from Panel (ft)	Conduit Size (in)	Unit Cost ($/LF)	Saving (1)/ Cost (-1)	Cost ($)
HWP-1	42	1	11.05	1	464.1
B-1	42	1	11.05	1	464.1
HWP-2	47	1	11.05	1	519.35
B-2	47	1	11.05	1	519.35
HWP-3	64	1	11.05	1	707.2
B-3	64	1	11.05	1	707.2
CWP-3	60	1.5	15.25	-1	-915
CWP-4	45	1.5	15.25	-1	-686.25
FC-1	40	1.5	15.25	1	610
Existing Panel PG	5	2.5	26.5	1	132.5
Redesigned Panel PG	5	3	33	-1	-165
Existing Panel CG	65	3.5	41.5	1	2697.5
Redesigned Panel CG	65	3	33	-1	-2145
Total Savings					**2910.05**

Table 11.4 - Redesigned Conductor Costs and Savings

Equipment Tag	Distance from Panel (ft)	Conductor Size	Number of Conductors	Unit Cost ($/LF)	Saving (1)/ Cost (-1)	Cost ($)
HWP-1	42	#12	4	0.67	1	112.56
B-1	42	#10	3	0.81	1	102.06
HWP-2	47	#12	4	0.67	1	125.96
B-2	47	#10	3	0.81	1	114.21
HWP-3	64	#12	4	0.67	1	171.52
B-3	64	#10	3	0.81	1	155.52
CWP-3	60	#1	3	3.5	-1	-630
CWP-3	60	#8	1	1.13	-1	-67.8
CWP-4	45	#1	3	3.5	-1	-472.5
CWP-4	45	#8	1	1.13	-1	-50.85
FC-1	40	#1/0	3	4.2	1	504
FC-1	40	#6	1	1.52	1	60.8
Existing Panel PG	5	#3/0	4	6.2	1	124
Existing Panel PG	5	#6	1	1.52	1	7.6
Redesigned Panel PG	5	250	4	8.95	-1	-179
Redesigned Panel PG	5	#4	1	2.09	-1	-10.45
Existing Panel CG	65	500	4	15.5	1	4030
Existing Panel CG	65	#3	1	2.44	1	158.6
Redesigned Panel CG	65	350	4	11.5	-1	-2990
Redesigned Panel CG	65	#4	1	2.09	-1	-135.85
Total Savings						**1130.38**

By redesigning the mechanical system changes in the electrical system are also needed, as made clear from above. In this circumstance the redesign provides savings for the building's owner. Both the conductor and conduit savings add up to $4040, which is not much with respect to the overall cost of the project, but saving money is always a good idea.

12.0 - REDESIGN CONCLUSIONS AND RECOMMENDATIONS

The alteration of the Longwood at Oakmont's Healthcare Center not only affects how the mechanical system will operate but also affects other building systems. One such system is the electrical system of the building. By eliminating and adding certain mechanical equipment the electrical load of the building was altered. Through panel reevaluation it was found that cost savings could be achieved, even if they were minute in comparison to the overall project cost. However, any cost saving is always welcomed.

The mechanical redesign also affected the construction process of the project. Without the use of site specific geotechnical reports certain assumptions had to be made about the site's soil properties. Taking these assumptions as accurate, it seemed feasible to install a ground source heat pump well field. There was enough space to drill the needed 100 bores without entering into valuable real estate. The excavation and installation of the well field also did not affect the overall time frame of the project's construction and the system provided ample time for it to get up and running before punch lists were started.

The mechanical redesign itself also came away with its own benefits. The ground source heat pump system utilizes 23% less energy per year than the existing water source heat pump system. This energy decrease obviously equates to a decrease in operations costs. In fact an annual savings of $16,648 is achieved by switching systems. This value is surely to increase as well with the trends in utility rates that the area has been seeing over the years. This would even further defend the proposal of the redesigned system.

With these savings a payback period of 11.5 years is achieved. Like mentioned before, this is not incredibly long when considering ground source heat pump systems. Presbyterian Senior Care is also a long term building owner which gives them more reason to look at utility rate savings. One thing that might strongly deter the owner from going with the redesigned system is the high initial cost. Presbyterian Senior Care, like a lot of religious senior care organizations, is a non-profit group. This means that there tends to be tight budgets and shorter funds than the majority of other clients.

Although the initial cost is fairly high, I feel as though the pros outweigh the cons. I feel as though a redesigned ground source heat pump system is overall beneficial to the Longwood at Oakmont Healthcare Center.

13.0 - REFERENCES

"Additions and Renovations to Health Center for Presbyterian Senior Care – Longwood at Oakmont." Plans and schedules. Reese, Lower, Patrick, and Scott, Ltd. September 2007.

"ANSI/ASHRAE Standard 62.1-2007 – Ventilation for Acceptable Indoor Air Quality." ASHRAE, Inc. Atlanta, GA. 2007.

"ANSI/ASHRAE Standard 90.1-2007 – Ventilation for Acceptable Indoor Air Quality." ASHRAE, Inc. Atlanta, GA. 2007.

ASHRAE. *2005 ASHRAE Handbook – Fundamentals*. Atlanta: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc., 2001.

Hughes, S. David. Electrical Systems in Buildings. Albany: Delmar Publishers Inc.,1988.

GHCPCalc 4.2.1. Energy Information Services. Northport, AL 35475. 2007.

R.S. Means, Mechanical Cost Data, 30th Annual Edition. R.S. Means, Kingston, MA. 2008.

Trane TRACE 700 Comprehensive Building Analysis Software Version 4.1.11. Trane. 2005.

14.0 – ACKNOWLEDGEMENTS

Thesis Advisor

James D. Freihaut, PhD

External Consultants

Eric Endres, AIA / Reese, Lower, Patrick, and Scott Ltd.
- Associate / Project Architect

James Hackman, PE / Reese Engineering Inc.
- Partner / Project Manager

Bob Mistick / Mistick Construction
- Project General Contractor

Presbyterian Senior Care
- Owner

Timothy Scharf, PE / Reese Engineering Inc.
- Associate / Project Manager

Sam Snyder / Reese Engineering Inc.
- Project Engineer

Brian Walker / Reese Engineering Inc.
- Project Engineer

AE Students

Doug Boswell
Steve Haines
Kristin Maruszewski
Jason Witterman

APPENDIX A

EXISTING PANELS

PANEL SCHEDULE

PANEL PG

PROJECT:		LONGWOOD AT OAKMONT HEALTH CENTER			VOLTAGE L-L (V):			208			
LOCATION:		MECHANICAL ROOM A240			VOLTAGE L-N (V):			120			
MINIMUM BUS CAPAC 225					TYPE:			3PH, 4W			
MAIN O.C. DEVICE (A) MLO					SHORT CIRCUIT RATING (A):						
DESIGN CAPACITY (A) 200					MOUNTING:			SURFACE			
DEVICE AMPS	POLE	M/LM/E/A/S (VA)	DESCRIPTION	CKT NO.	PHASE	CKT NO.	DESCRIPTION	M/LM/E/A/S (VA)	POLE	DEVICE AMPS	
25	1	M 1656	BOILER B-3 - A240	1	A	2	HP-2 - A240	E 718	2	15	
15	3	M 576	HWP-3 - A240	3	B	4	-	E 718	-	-	
-	-	M 576	-	5	C	6	HP-7 - A240	E 2423	2	35	
-	-	M 576	-	7	A	8	-	E 2423	-	-	
100	3	LM 7452	CWP-2 - A240	9	B	10	EWH-1 - A241	E 1000	2	15	
-	-	LM 7452	-	11	C	12	-	E 1000	-	-	
-	-	LM 7452	-	13	A	14	CP-1 - A240	M 828	3	15	
15	1	M 264	EF-9 - A240	15	B	16	-	M 828	-	-	
			SPACE	17	C	18	-	M 828	-	-	
			SPACE	19	A	20	CP-2 - A240	M 828	3	15	
15	3	M 444	EF-10 - A240	21	B	22	-	M 828	-	-	
-	-	M 444	-	23	C	24	-	M 828	-	-	
-	-	M 444	-	25	A	26	SPACE				
			SPACE	27	B	28	SPACE				
			SPACE	29	C	30	SPACE				
			SPACE	31	A	32	SPACE				
			SPACE	33	B	34	SPACE				
			SPACE	35	C	36	SPACE				
			SPACE	37	A	38	SPACE				
			SPACE	39	B	40	SPACE				
			SPACE	41	C	42	SPACE				
CONNECTED VA PHASE A:			14925		DEMANDED VA PHASE A:			16788			
CONNECTED VA PHASE B:			12110		DEMANDED VA PHASE B:			13973			
CONNECTED VA PHASE C:			13551		DEMANDED VA PHASE C:			15414			
			CONNECTED	D.F.			DEMAND				
LIGHTING LOAD:			0	1.25			0	DEMAND LOAI 128			
RECEPTACLE (FIRST 10 KVA)			0	1.00			0	SPARE CAPA(72			
RECEPTACLE (REMAINDER)			0	0.50			0				
LARGEST MOTOR:			22356	1.25			27945				
REMAINING MOTORS:			9948	1.00			9948				
APPLIANCES:			0	0.65			0				
EQUIPMENT:			8282	1.00			8282				
SUB FED PANEL:			0	1.00			0				
TOTAL:			40586				46175				
LOAD (AMPS):			112.7				128.2				
M = MOTOR			S = SUB FEED PANEL								
LM = LARGEST MOTOR											

PANEL SCHEDULE

PANEL CG

PROJECT:	LONGWOOD AT OAKMONT HEALTH CENTER	VOLTAGE L-L (V):	208
LOCATION:	MECHANICAL ROOM A240	VOLTAGE L-N (V):	120
MINIMUM BUS CAPACITY (A):	400	TYPE:	3PH, 4W
MAIN O.C. DEVICE (A):	MLO	SHORT CIRCUIT RATING (A):	
DESIGN CAPACITY (A):	400	MOUNTING:	SURFACE

DEVICE AMPS	POLE	M/LM/E/A/S (VA)		DESCRIPTION	CKT NO.	PHASE	CKT NO.	DESCRIPTION	M/LM/E/A/S (VA)		POLE	DEVICE AMPS
25	1	M	1656	BOILER B-1 - A240	1	A	2	BOILER B-2 - A240	M	1656	1	25
15	3	M	576	HWP-1 - A240	3	B	4	HWP-2 - A240	M	576	3	15
-	-	M	576	-	5	C	6	-	M	576	-	-
-	-	M	576	-	7	A	8	-	M	576	-	-
100	3	M	7452	CWP-1 - A240	9	B	10	DWH-1 - A240	E	600	1	20
-	-	M	7452	-	11	C	12	DWH-1 - A240	E	600	1	20
-	-	M	7452	-	13	A	14	DWH-1 - A240	E	600	1	20
200	3	M	11040	ELEVATOR NO. 3	15	B	16	DWH-1 - A240	E	600	1	20
-	-	M	11040	-	17	C	18	CP-1 - A240	M	828	3	15
-	-	M	11040	-	19	A	20	-	M	828	-	-
20	1	E	500	DDC PANEL - A240	21	B	22	-	M	828	-	-
20	1	M	1176	DRY PIPE AIR COMPRESSOR - A240	23	C	24	CP-2 - A240	M	828	3	15
225	3	S	24201	PANEL CH	25	A	26	-	M	828	-	-
-	-	S	19316	-	27	B	28	-	M	828	-	-
-	-	S	16002	-	29	C	30	SPARE			1	20
15	2	E	510	HP-1 - A240	31	A	32	SPARE			1	20
-	-	E	510	-	33	B	34	SPARE			1	20
				SPACE	35	C	36	SPACE				
				SPACE	37	A	38	SPACE				
				SPACE	39	B	40	SPACE				
				SPACE	41	C	42	SPACE				

CONNECTED VA PHASE A:	49923	DEMANDED VA PHASE A:	49923
CONNECTED VA PHASE B:	42826	DEMANDED VA PHASE B:	42826
CONNECTED VA PHASE C:	39078	DEMANDED VA PHASE C:	39078

	CONNECTED	D.F.	DEMAND
LIGHTING LOAD:	0	1.25	0
RECEPTACLE (FIRST 10 KVA)	0	1.00	0
RECEPTACLE (REMAINDER)	0	0.50	0
LARGEST MOTOR:	0	1.25	0
REMAINING MOTORS:	68388	1.00	68388
APPLIANCES:	0	0.65	0
EQUIPMENT:	3920	1.00	3920
SUB FED PANEL:	59519	1.00	59519
TOTAL:	131827		131827
LOAD (AMPS):	365.9		365.9

DEMAND LOAI 366
SPARE CAPA(-366

M = MOTOR S = SUB FEED PANEL
LM = LARGEST MOTOR

REDESIGNED PANELS

PANEL SCHEDULE
PANEL PG

PROJECT:	LONGWOOD AT OAKMONT HEALTH CENTER	VOLTAGE L-L (V):	208
LOCATION:	MECHANICAL ROOM A240	VOLTAGE L-N (V):	120
MINIMUM BUS CAPACITY (A):	250	TYPE:	3PH, 4W
MAIN O.C. DEVICE (A):	MLO	SHORT CIRCUIT RATING (A):	
DESIGN CAPACITY (A):	200	MOUNTING:	SURFACE

DEVICE AMPS	POLE	M/LM/E/A/S	(VA)	DESCRIPTION	CKT NO.	PHASE	CKT NO.	DESCRIPTION	M/LM/E/A/S	(VA)	POLE	DEVICE AMPS
				SPACE	1	A	2	HP-2 - A240	E	718	2	15
100	3	LM	7452	CWP-2 - A240	3	B	4	-	E	718	-	-
-	-	LM	7452	-	5	C	6	HP-7 - A240	E	2423	2	35
-	-	LM	7452	-	7	A	8	-	E	2423	-	-
100	3	LM	7452	CWP-3 - A240	9	B	10	EWH-1 - A241	E	1000	2	15
-	-	LM	7452	-	11	C	12	-	E	1000	-	-
-	-	LM	7452	-	13	A	14	CP-1 - A240	M	828	3	15
15	1	M	264	EF-9 - A240	15	B	16	-	M	828	-	-
				SPACE	17	C	18	-	M	828	-	-
				SPACE	19	A	20	CP-2 - A240	M	828	3	15
15	3	M	444	EF-10 - A240	21	B	22	-	M	828	-	-
-	-	M	444	-	23	C	24	-	M	828	-	-
-	-	M	444	-	25	A	26	SPACE				
				SPACE	27	B	28	SPACE				
				SPACE	29	C	30	SPACE				
				SPACE	31	A	32	SPACE				
				SPACE	33	B	34	SPACE				
				SPACE	35	C	36	SPACE				
				SPACE	37	A	38	SPACE				
				SPACE	39	B	40	SPACE				
				SPACE	41	C	42	SPACE				

CONNECTED VA PHASE A:	20145	DEMANDED VA PHASE A:	23871
CONNECTED VA PHASE B:	18986	DEMANDED VA PHASE B:	22712
CONNECTED VA PHASE C:	20427	DEMANDED VA PHASE C:	24153

	CONNECTED	D.F.	DEMAND	
LIGHTING LOAD:	0	1.25	0	DEMAND LOAI 196
RECEPTACLE (FIRST 10 KVA)	0	1.00	0	SPARE CAPA(-196
RECEPTACLE (REMAINDER)	0	0.50	0	
LARGEST MOTOR:	44712	1.25	55890	
REMAINING MOTORS:	6564	1.00	6564	
APPLIANCES:	0	0.65	0	
EQUIPMENT:	8282	1.00	8282	
SUB FED PANEL:	0	1.00	0	
TOTAL:	59558		70736	
LOAD (AMPS):	165.3		196.3	

M = MOTOR S = SUB FEED PANEL
LM = LARGEST MOTOR

PANEL SCHEDULE
PANEL CG

PROJECT:	LONGWOOD AT OAKMONT HEALTH CENTER	VOLTAGE L-L (V):	208
LOCATION:	MECHANICAL ROOM A240	VOLTAGE L-N (V):	120
MINIMUM BUS CAPACITY (A):	400	TYPE:	3PH, 4W
MAIN O.C. DEVICE (A):	MLO	SHORT CIRCUIT RATING (A):	
DESIGN CAPACITY (A):	400	MOUNTING:	SURFACE

DEVICE AMPS	POLE	M/LM/E/A/S	(VA)	DESCRIPTION	CKT NO.	PHASE	CKT NO.	DESCRIPTION	M/LM/E/A/S	(VA)	POLE	DEVICE AMPS
				SPACE	1	A	2	SPACE				
100	3	M	7452	CWP-1 - A240	3	B	4	SPACE				
-	-	M	7452	-	5	C	6	SPACE				
-	-	M	7452	-	7	A	8	SPACE				
100	3	M	7452	CWP-4- A240	9	B	10	DWH-1 - A240	E	600	1	20
-	-	M	7452	-	11	C	12	DWH-1 - A240	E	600	1	20
-	-	M	7452	-	13	A	14	DWH-1 - A240	E	600	1	20
200	3	M	11040	ELEVATOR NO. 3	15	B	16	DWH-1 - A240	E	600	1	20
-	-	M	11040	-	17	C	18	CP-1 - A240	M	828	3	15
-	-	M	11040	-	19	A	20	-	M	828	-	-
20	1	E	500	DDC PANEL - A240	21	B	22	-	M	828	-	-
20	1	M	1176	DRY PIPE AIR COMPRESSOR - A240	23	C	24	CP-2 - A240	M	828	3	15
225	3	S	24201	PANEL CH	25	A	26	-	M	828	-	-
-	-	S	19316	-	27	B	28	-	M	828	-	-
-	-	S	16002	-	29	C	30	SPARE				
15	2	E	510	HP-1 - A240	31	A	32	SPARE				
-	-	E	510	-	33	B	34	SPARE				
				SPACE	35	C	36	SPACE				
				SPACE	37	A	38	SPACE				
				SPACE	39	B	40	SPACE				
				SPACE	41	C	42	SPACE				

CONNECTED VA PHASE A:	52911	DEMANDED VA PHASE A:	52911
CONNECTED VA PHASE B:	49126	DEMANDED VA PHASE B:	49126
CONNECTED VA PHASE C:	45378	DEMANDED VA PHASE C:	45378

	CONNECTED	D.F.	DEMAND	
LIGHTING LOAD:	0	1.25	0	DEMAND LOAI 409
RECEPTACLE (FIRST 10 KVA)	0	1.00	0	SPARE CAPA(-409
RECEPTACLE (REMAINDER)	0	0.50	0	
LARGEST MOTOR:	0	1.25	0	
REMAINING MOTORS:	83976	1.00	83976	
APPLIANCES:	0	0.65	0	
EQUIPMENT:	3920	1.00	3920	
SUB FED PANEL:	59519	1.00	59519	
TOTAL:	147415		147415	
LOAD (AMPS):	409.2		409.2	

M = MOTOR S = SUB FEED PANEL
LM = LARGEST MOTOR

APPENDIX B

Space Name	Occ. Density (#/1000ft^2)	A_z (ft^2)	R_a (cfm/ft^2)	P_z (person)	R_p (cfm/person)	V_{ou} (cfm)	V_{pz} (cfm)	Z_p	E_v	V_{ot} (cfm)
DEMENTIA										
DEM. MED ROOM		128	0.06	1	5	13	200	0.07	0.8	16
DEM. FAMILY ROOM		415	0.06	5	5	50	400	0.13	0.8	63
DEM. CHARTING		142	0.06	4	5	29	200	0.15	0.8	36
DEM. GREAT ROOM		391	0.06	3	5	39	500	0.08	0.8	49
DEM. DINING ROOM/ COUNTRY KITCHEN		978	0.18	8	7.5	237	1500	0.16	0.8	296
DEM. CARE BASE		240	0.06	2	5	25	200	0.13	0.8	31
DEM. STAFF HALLWAY		65	0.06	0	0	4	50	0.08	0.8	5
DEM. CLEAN UTILITY		116	0	0	0	0	175	0.00	0.8	0
DEM. STAFF TOILET		58	0	0	0	0	0	0.00	0.8	0
DEM. RESIDENT TOILET		58	0	0	0	0	0	0.00	0.8	0
DEM. CORRIDOR		1180	0.06	0	0	71	750	0.09	0.8	89
NEW DEMENTIA PRIVATE ROOM 101		310	0	3	25	75	280	0.27	0.8	94
NEW DEMENTIA PRIVATE ROOM 102		310	0	3	25	75	280	0.27	0.8	94
NEW DEMENTIA PRIVATE ROOM 103		310	0	3	25	75	280	0.27	0.8	94
NEW DEMENTIA PRIVATE ROOM 104		310	0	3	25	75	280	0.27	0.8	94
NEW DEMENTIA PRIVATE ROOM 114		310	0	3	25	75	280	0.27	0.8	94
NEW DEMENTIA PRIVATE ROOM 115		310	0	3	25	75	280	0.27	0.8	94
NEW DEMENTIA PRIVATE ROOM 116		310	0	3	25	75	280	0.27	0.8	94
NEW DEMENTIA PRIVATE ROOM 124		310	0	3	25	75	280	0.27	0.8	94
NEW DEMENTIA PRIVATE ROOM 125		310	0	3	25	75	280	0.27	0.8	94
NEW DEMENTIA PRIVATE ROOM 126		310	0	3	25	75	280	0.27	0.8	94
NEW DEMENTIA PRIVATE ROOM 127		310	0	3	25	75	280	0.27	0.8	94
NEW DEMENTIA PRIVATE ROOM 128		310	0	3	25	75	280	0.27	0.8	94
NEW DEMENTIA PRIVATE ROOM 130		310	0	3	25	75	280	0.27	0.8	94
NEW DEMENTIA PRIVATE ROOM 131		310	0	3	25	75	280	0.27	0.8	94
NEW DEMENTIA PRIVATE ROOM 132		310	0	3	25	75	280	0.27	0.8	94
NEW DEMENTIA PRIVATE ROOM 133		310	0	3	25	75	280	0.27	0.8	94
TOTALS						**1668**	**8455**			**2085**

Space Name	Occ. Density (#/1000 ft^2)	A_z (ft^2)	R_a (cfm/sq ft)	P_z (person)	R_p (cfm/person)	V_{ou} (cfm)	V_{pz} (cfm)	Z_p	E_v	V_{ot} (cfm)
HC FIRST FLOOR										
HC CONFERENCE ROOM		238	0.06	10	5	65	630	0.10	0.8	81
HC ACTIVITIES OFFICE		143	0.06	2	5	19	330	0.06	0.8	24
HC MULT-PURPOSE		998	0.06	12	5	120	750	0.16	0.8	150
HC STORAGE		94	0.12	0.00	0	12	100	0.12	0.8	15
HC RESIDENT TOILET		60	0	0	0	0	50	0.00	0.8	0
HC VISITOR TOILET		60	0	0	0	0	50	0.00	0.8	0
HC CORR / ENT HALL/ ELEV		1260	0.06	0	0	76	950	0.08	0.8	95
HC RESIDENT LAUNDRY	10	90	0.12	1	5	16	280	0.06	0.8	20
HC STAFF TOILET		78	0	0	0	0	50	0.00	0.8	0
HC FAMILY ROOM		257	0.06	4	5	36	280	0.13	0.8	45
HC CLEAN UTILITY		100	0.12	0	0	12	50	0.24	0.8	15
HC EQUIPMENT ROOM		165	0.06	0	0	10	480	0.02	0.8	13
HC CORR		785	0.06	0	0	48	430	0.11	0.8	60
HC CARE BASE		599	0.06	5	5	61	660	0.09	0.8	76
HC DINING ROOM		800	0.18	10	7.5	219	1120	0.20	0.8	274
HC COUNTRY KITCHEN		204	0	0	0	0	400	0.00	0.8	0
HC LIVING RM / ACT AREA		670	0.06	10	5	91	525	0.17	0.8	114
HC CHARTING		125	0.06	4	5	28	130	0.22	0.8	35
HC ELEC		47	0.06	0	0	3	0	0.00	0.8	4
HC MED ROOM		77	0.06	2	5	15	220	0.07	0.8	19
HC SOILED UTILITY		109	0	0	0	0	280	0.00	0.8	0
HC RESIDENT TOILET		63	0	0	0	0	50	0.00	0.8	0
HC RESIDENT SPA		250	0.48	0	0	120	350	0.34	0.8	150
HC CART CORRAL		70	0.12	0	0	9	0	0.00	0.8	11
HC JC		40	0	0	0	0	0	0.00	0.8	0
HC RESIDENT ROOM TYPE A 101		456	0	3	25	75	560	0.13	0.8	94
HC RESIDENT ROOM TYPE B 134		491	0	3	25	75	760	0.10	0.8	94
HC RESIDENT ROOM TYPE C 136		250	0	2	25	50	560	0.09	0.8	63
HC RESIDENT ROOM TYPE C 135		250	0	2	25	50	560	0.09	0.8	63
HC RESIDENT ROOM TYPE C 114		250	0	2	25	50	560	0.09	0.8	63
HC RESIDENT ROOM TYPE C 113		250	0	2	25	50	560	0.09	0.8	63
HC RESIDENT ROOM TYPE C 102		250	0	2	25	50	560	0.09	0.8	63
HC RESIDENT ROOM TYPE C 103		250	0	2	25	50	560	0.09	0.8	63
HC RESIDENT ROOM TYPE C 116		250	0	2	25	50	960	0.05	0.8	63
HC RESIDENT ROOM TYPE C 117		250	0	2	25	50	960	0.05	0.8	63
HC RESIDENT ROOM TYPE C 118		250	0	2	25	50	960	0.05	0.8	63
HC RESIDENT ROOM TYPE C 119		250	0	2	25	50	960	0.05	0.8	63
HC RESIDENT ROOM TYPE C 124		250	0	2	25	50	960	0.05	0.8	63
HC RESIDENT ROOM TYPE C 125		250	0	2	25	50	960	0.05	0.8	63
TOTALS						**1710**	**18605**			**2138**

Space Name	Occ. Density (#/1000 ft^2)	A_z (ft^2)	R_a (cfm/sq ft)	P_z (person)	R_p (cfm/person)	V_{ou} (cfm)	V_{pz} (cfm)	Z_p	E_v	V_{ot} (cfm)
HC SECOND FLOOR										
HC VISITOR TOILET		60	0	0	0	0	50	0.00	0.8	0
HC CORR / ENT HALL/ ELEV		1069	0.06	0	0	65	950	0.07	0.8	81
HC RESIDENT LAUNDRY	10	90	0.12	1	5	16	280	0.06	0.8	20
HC STAFF TOILET		78	0	0	0	0	50	0.00	0.8	0
HC FAMILY ROOM		257	0.06	4	5	36	280	0.13	0.8	45
HC CLEAN UTILITY		100	0.12	0	0	12	50	0.24	0.8	15
HC EQUIPMENT ROOM		165	0.06	0	0	10	480	0.02	0.8	13
HC CORR		785	0.06	0	0	48	430	0.11	0.8	60
HC CARE BASE		599	0.06	5	5	61	660	0.09	0.8	76
HC DINING ROOM		800	0.18	10	7.5	219	1120	0.20	0.8	274
HC COUNTRY KITCHEN		204	0	0	0	0	400	0.00	0.8	0
HC LIVING RM / ACT AREA		670	0.06	10	5	91	525	0.17	0.8	114
HC CHARTING		125	0.06	4	5	28	130	0.22	0.8	35
HC ELEC		47	0.06	0	0	3	0	0.00	0.8	4
HC MED ROOM		77	0.06	2	5	15	220	0.07	0.8	19
HC SOILED UTILITY		109	0	0	0	0	280	0.00	0.8	0
HC RESIDENT TOILET		63	0	0	0	0	50	0.00	0.8	0
HC RESIDENT SPA		250	0.48	0	0	120	350	0.34	0.8	150
HC CART CORRAL		70	0.12	0	0	9	0	0.00	0.8	11
HC JC		40	0	0	0	0	0	0.00	0.8	0
HC RESIDENT ROOM TYPE A 201		456	0	3	25	75	560	0.13	0.8	94
HC RESIDENT ROOM TYPE B 234		491	0	3	25	75	760	0.10	0.8	94
HC RESIDENT ROOM TYPE C 236		250	0	2	25	50	560	0.09	0.8	63
HC RESIDENT ROOM TYPE C 235		250	0	2	25	50	560	0.09	0.8	63
HC RESIDENT ROOM TYPE C 214		250	0	2	25	50	560	0.09	0.8	63
HC RESIDENT ROOM TYPE C 213		250	0	2	25	50	560	0.09	0.8	63
HC RESIDENT ROOM TYPE C 202		250	0	2	25	50	560	0.09	0.8	63
HC RESIDENT ROOM TYPE C 203		250	0	2	25	50	560	0.09	0.8	63
HC RESIDENT ROOM TYPE C 216		250	0	2	25	50	960	0.05	0.8	63
HC RESIDENT ROOM TYPE C 217		250	0	2	25	50	960	0.05	0.8	63
HC RESIDENT ROOM TYPE C 218		250	0	2	25	50	960	0.05	0.8	63
HC RESIDENT ROOM TYPE C 219		250	0	2	25	50	960	0.05	0.8	63
HC RESIDENT ROOM TYPE C 224		250	0	2	25	50	960	0.05	0.8	63
HC RESIDENT ROOM TYPE C 225		250	0	2	25	50	960	0.05	0.8	63
TOTALS						**1483**	**16745**			**1854**

Space Name	Occ. Density (#/1000 ft^2)	A_z (ft^2)	R_a (cfm/sq ft)	P_z (person)	R_p (cfm/person)	V_{ou} (cfm)	V_{pz} (cfm)	Z_p	E_v	V_{ot} (cfm)
REHAB AREA										
REHAB RESIDENT ROOM TYPE E 130		298	0.00	3	25	75	590	0.13	0.8	94
REHAB RESIDENT ROOM TYPE E 139		298	0.00	3	25	75	590	0.13	0.8	94
REHAB RESIDENT ROOM TYPE F 131		186	0.00	2	25	50	220	0.23	0.8	63
REHAB RESIDENT ROOM TYPE F 138		186	0.00	2	25	50	220	0.23	0.8	63
REHAB RESIDENT ROOM TYPE D 140		186	0.00	2	25	50	220	0.23	0.8	63
REHAB RESIDENT ROOM TYPE D 141		186	0.00	2	25	50	220	0.23	0.8	63
REHAB RESIDENT ROOM TYPE D 142		186	0.00	2	25	50	220	0.23	0.8	63
REHAB RESIDENT ROOM TYPE D 127		186	0.00	2	25	50	220	0.23	0.8	63
REHAB RESIDENT ROOM TYPE D 128		186	0.00	2	25	50	221	0.23	0.8	63
REHAB RESIDENT ROOM TYPE D 129		186	0.00	2	25	50	222	0.23	0.8	63
RESIDENT SPA B156/HALL B157		261	0.48	0	0	126	375	0.34	0.8	158
SHOWER B157A		43	0.00	0	0	0	0	0.00	0.8	0
MED RECORDS B160		81	0.06	2	5	15	160	0.09	0.8	19
CORRIDOR B158		200	0.06	0	0	12	160	0.08	0.8	15
VISITOR TOILET B160		63	0.00	0	0	0	0	0.00	0.8	0
JC B163		46	0.00	0	0	0	0	0.00	0.8	0
TRAINING TOILET B155		57	0.00	0	0	0	0	0.00	0.8	0
CART CORAL B153/HALL B154		104	0.12	0	0	13	100	0.13	0.8	16
RESIDENT LAUNDRY B152	10	53	0.12	1	5	12	0	0.00	0.8	15
LIVING ROOM B150		458	0.06	5	5	53	380	0.14	0.8	66
KITCHEN EQUIPMENT B149		119	0.06	0	0	8	480	0.02	0.8	10
DINING ROOM B147/COUNTRY KITCHEN B148		730	0.18	6	7.5	177	1415	0.13	0.8	221
CHARTING B146		136	0.06	4	5	29	280	0.10	0.8	36
LIVING ROOM B145		557	0.06	10	5	84	860	0.10	0.8	105
LOBBY B149/CARE BASE B144		338	0.06	4	5	41	380	0.11	0.8	51
RESIDENT TOILET B125		71	0.00	0	0	0	50	0.00	0.8	0
SOCIAL WORKER B126		124	0.06	2	5	18	180	0.10	0.8	23
STAFF TOILET B124		71	0.00	0	0	0	50	0.00	0.8	0
MED ROM B123		81	0.06	2	5	15	280	0.05	0.8	19
LOBBY B121/COFFEE SHOP B122		732	0.06	9	5	89	820	0.11	0.8	111
BEAUTY SHOP B115		264	0.12	4	20	112	380	0.29	0.8	140
RECEPTION B120		76	0.06	2	5	15	175	0.09	0.8	19
SC ADMIN B116		120	0.06	2	5	18	130	0.14	0.8	23
WORK ROOM B117		170	0.06	2	5	21	175	0.12	0.8	26
DON B119		119	0.06	2	5	18	140	0.13	0.8	23
ADON/RNAC B118		90	0.06	2	5	16	140	0.11	0.8	20
CORRIDOR B171		455	0.06	0	0	28	190	0.15	0.8	35
AL KITCHEN B176		650	0.00	0	0	0	1400	0.00	0.8	0
TRASH B178		109	0.00	0	0	0	100	0.00	0.8	0
WAITRESS STATION B174		111	0.06	2	5	17	0	0.00	0.8	21

Space Name	Occ. Density (#/1000 ft^2)	A_z (ft^2)	R_a (cfm/sq ft)	P_z (person)	R_p (cfm/person)	V_{ou} (cfm)	V_{pz} (cfm)	Z_p	E_v	V_{ot} (cfm)
REHAB AREA (cont.)										
VISITOR TOILET B168		64	0.00	0	0	0	0	0.00	0.8	0
RESIDENT TOILET B167		62	0.00	0	0	0	0	0.00	0.8	0
AL PREDINING ROOM B166		279	0.06	6	5	47	160	0.29	0.8	59
CORRIDOR B164/165		700	0.06	0	0	42	380	0.11	0.8	53
SOILED UTILITY B132		100	0.00	0	0	0	280	0.00	0.8	0
CLEAN UTILITY B136		120	0.00	0	0	0	175	0.00	0.8	0
J.C. B133		32	0.00	0	0	0	0	0.00	0.8	0
OXY B134		32	0.00	0	0	0	50	0.00	0.8	0
CART CORRAL B137		64	0.12	0	0	8	0	0.00	0.8	10
CORRIDOR B135		695	0.06	0	0	42	300	0.14	0.8	53
TOTALS						**1626**	**13088**			**2033**