# Thesis Proposal

## Preliminary Proposal for Spring 2011 Project

# APPELL LIFE SCIENCES

York College of Pennsylvania

York, PA

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Mechanical Option

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# Executive Summary


The life sciences building consists of two classroom buildings. The main building houses offices, classrooms, computer labs, and many science labs. The smaller greenhouse building houses a few labs and has five greenhouses in it. Since this is a university building there is a high level of electrical equipment in the offices, computer labs, classrooms, and laboratories.

The design requirements set forth by the client were to be smart about the building systems with respect to longevity, maintenance, maintenance cost, efficiency, first cost, and the ability of the systems to be modified/expanded over time.

The primary system for the life sciences building includes a VAV system to condition the office spaces and primary air Fan Coil Units to condition the laboratory spaces. The central plant for the life sciences includes a chiller and three boilers to supply chilled and hot water to the other systems. There are five air handling units for the building, two for the VAV system and three for the FCU system.

Analyses will be performed involving the use of a Ground-Source Heat Pump System to replace the chiller/boiler plant. The GSHP will also be implemented to just replace the chiller and just replace the boilers to see which will be more efficient, cost and energy use effective. The laboratories will be conditioned using chilled beams. Because they do not dehumidify supply air well a run-around coil system will be analyzed for the air handling units.

Once these analyses are complete they will be compared to the original mechanical systems to see if any effective drop in energy usage and cost occurred. A life cycle cost analysis and payback period for the new systems will also be done to ensure there effectiveness.

# System Description

## Design Objectives and Requirements

The purpose of any HVAC system is to properly ventilate the building for the specified occupancy while maintaining a comfortable temperature and humidity level for the buildings occupants. The life sciences building has a large amount of laboratories that require appropriate ventilation and exhaust. The design of the systems for the laboratories allowed for proper ventilation and exhaust with having heat recovery wheels in the air handling units that service the laboratories. These are required because of the high exhaust rates that laboratories have. The rest of the requirements for the systems were met by the design engineer. The systems were also designed with the budget of the college in mind.

## Equipment Summary

The primary systems for the life sciences building include VAV for offices, FCU's for laboratories and classrooms, and Wall Hung Radiation Units and Evaporative Coolers, heating and cooling respectively, for the Greenhouses. These systems are supplied with chilled water by a water-cooled centrifugal chiller. There are two cooling towers on the roof that supply water to the chiller. They are supplied with hot water by three gas-fired boilers. The chiller and boilers are located in the central plant in the basement of the life sciences building. Along with the chiller and boiler there is a plate and frame heat exchanger used as a water-side economizer. Also located in the central plant are the chilled water and hot water pumps. They are run on a primary secondary loop. The secondary pumps, for the greenhouse building are located in the basement mechanical room of that building because of limited space.

Air Handling Units provide air to the VAV boxes and FCU's for the spaces in the life sciences building. There are five AHU's total for servicing the different spaces included in the life sciences building. The main air supply for the greenhouse building labs is from FCU's with OA brought in from directly outside. For the greenhouses heating is done by Wall Hung Radiation Units. Cooling for the greenhouses is done by a combination of natural ventilation and Evaporative Coolers.

# Discussion of System

The mechanical systems first cost for the life sciences building will be taken from the bid cost given by the lead design engineer on the project. The price for mechanical systems in the greenhouse building was $870,720. The cost for mechanical systems in the life sciences building was $4,150,000. This brings the total cost of mechanical systems to $5,020,720. The cost per square foot for mechanical systems ends up being about $49.22/sf.

The operating cost per square foot for the life sciences building ended up being about an average of $1.21/sf. The Energy Information Administration estimated that universities spend an average of about $1.05/sf. The operating cost for the life sciences is larger because of the heating cost per square foot which is much larger than the average. The cost could be larger because of the inaccuracies in the energy analysis run in Carrier HAP from Tech Report 2.

With having many laboratories to condition Indoor Air Quality can become an issue. This was taken into account when ventilating the offices on floors two and three where the laboratories are located. The ventilation load for these offices was oversized to make sure no chemicals would contaminate the spaces surrounding the labs. AHU-3, which conditions these offices, has much more ventilation air than required by ASHRAE Std. 62.1. With VAV boxes being used to condition the offices IAQ can also be an issue. If the system were to be designed or installed incorrectly, the modulated supply air by the VAV boxes can occur with no change in the outdoor air fraction. This would result in a ventilation air deficiency. Also the correct placement of filters is important to maintain that no contaminants from inside the building can be re-circulated into other spaces.

The design of the systems for the life sciences building was found to meet the requirements set forth by the college to be efficient, low first cost, low maintenance, and the ability of the systems to be modified/expanded over time.

# Proposed Alternative Systems

The laboratories are a big part of the requirement for the systems in the life sciences building. They are conditioned with fan coil units served with pretreated outdoor air. To try to reduce loads and airflow rates to the labs Chilled Beams will be implemented in the place of the fan coil units. After the loads are found from the new system they will be applied to a Ground-Source Heat Pump (GSHP) system or a Thermal Storage system for the chiller/boiler plant. The results of these studies will be compared to the design case of the chiller/boiler plant and air systems for the life sciences building.

## Ground Source Heat Pumps

Once a new energy model is run with the chilled beams in the laboratories, an analysis of a ground-source heat pump (GSHP) system will be done to compare with the chiller/boiler plant in place at the life sciences building.

The life sciences building is located on a part of the campus that has a few parking lots located around it. The parking lots around the building are on different sides of the building. To account for this a considerable amount of work should be done to figure out how many bores for the vertical piping can be dug on each side of the building. The bores for the vertical piping range from 200-300 feet below ground level for effective thermal gains from the earth. This will have an effect on the cost and schedule of construction of the building. With this amount of land around the building a vertical closed loop system could be implemented for the GSHPs. This system could provide a considerable amount of savings because the temperature below the earth's surface, in the York, PA region, is about 50-51 ºF constant. The GSHP system will be the primary supplier of chilled and hot water to the systems, replacing the chiller/boiler plant. Also an analysis will be done with using a GSHP to replace just the boilers and also to replace just the chiller to see which is more efficient. The energy analysis of the GSHP will be compared to the original system designed for the life sciences and the replacing of the boiler and chiller with GSHP.

Ground-source heat pump systems do have a significant initial cost, however maintenance costs are generally low and the life cycle of this system can outlast any other system. By reducing excessive pump energy from the GSHPs only pumps with 5-7.5 hp should be needed per 100 tons of cooling. The GSHP system should provide considerable reduction in energy usage and cost.

## Seasonal Thermal Energy Storage

Seasonal thermal energy storage (STES) enables buildings to use heat collected during the summer to heat the building during winter, and use snow collected during the winter to cool the building during summer. This can be very effective in lowering the use of a chiller during the cooling months and a boiler during heating months. Because of the more Northern climate of the York region the energy and cost savings would be more significant than an area with a warmer climate. This is because it would be able to store more solar energy during the summer due to the longer days.

The most commonly used seasonal thermal storage is aquifer of bore-hole which both use the ground to store heat. However both of these systems require suitable ground conditions. Some seasonal systems use a smaller diurnal system to act as a thermal buffer between the STES and heat sources and sinks. A diurnal thermal storage system is one that uses stored ice or chilled water in anticipation of cooling loads within the next 24 hours.

Although the STES is effective it requires a very large area to store the collected energy. The life sciences building central plant in the current building does not have enough room to employ this type of system. The central plant in the basement only covers half of the first floor area. The thermal storage area could be placed in that area, but since it is currently unexcavated it would require a significant cost and schedule change in construction to employ. This would most likely be inefficient to change the cost of construction that much as well as adding cost to structural design.

## Chilled Beams

Chilled beams will be implemented in the design by replacing the fan coil units that currently condition the laboratories. Chilled beams can offer many benefits when conditioning a laboratory space. They can reduce reheat energy, accurately meet outdoor air requirements, and reduce building-wide system requirements.

They can be a good solution for laboratories that have a low amount of fume hoods. Most of the lab classrooms in the life sciences building have only one fume hood. The chilled beam system can reduce building energy use and costs compared to a standard system. There are two types of chilled beams, passive and active. Passive beams use the natural convection from a space to condition the ventilation air. Active beams use direct outdoor for ventilation splitting the sensible and latent loads. Active beams will need to be used for the labs because of their higher ventilation rate requirements.

Although chilled beams can be beneficial in labs, they do not do a great job of dehumidifying the air. If the relative humidity of the supply air is not controlled, water can condense on the chilled beam cooling coils and drop into the space below. An air handling unit will be needed to dehumidify the air. This can be done by cooling the outside air with chilled water, then condensing it at the coil, and then reheating the air at a hot water coil. This method can add to the electrical demand from the heating system. Another method that can be done is using a run-around coil to reheat the air.

The run-around coil is a closed loop pair of heat exchangers that run around a cooling coil to reheat the supply air.

# Proposed Redesign

## Mechanical System Redesign

I have had the opportunity to learn more about the design behind the life sciences building by studying the design documents and completing this semester's technical reports. After research on the buildings systems they were found to be efficient, low in maintenance, and operating cost. Since the design engineer has meet the requirements set forth by the college, the life sciences building systems were not in question.

The mechanical design changes will focus on using a GSHP system to replace the chiller/boiler plant located in the basement. Along with this the GSHP system will be implemented separately to just replace the boilers and separately to just replace the chiller. These analyses will be compared to see which one is found to be most efficient and cost effective for the college. The laboratories will be conditioned using chilled beams, replacing the fan coil units to see if any energy consumption can be saved, along with helping to meet the ventilation loads required by laboratories. To help with dehumidification when needed, a run-around coil system will be analyzed for the air handling units that serve the labs.

## Construction Breadth

Since the use of a GSHP system is being implemented the construction first cost and schedule will change. An analysis of excavation costs for GSHP systems will be done to compare first cost. An analysis of the change in schedule will also be done to compare the change in time for completion of the project. Excavation will most likely occur in the parking lots which will increase first cost a bit and add to schedule by having to repave the lots.

### Electrical Breadth

Since the use of a GSHP system is being implemented there are many pumps being added to the system. The adding of these pumps will change the electrical demand from the mechanical systems. A new electrical system to serve the mechanical systems will be explored in order to not increase the electrical demand from the new system or have too much electricity supplied to the systems.

### Integration of Studies

With the implementation of a GSHP system comes a high first cost and addition to construction time. The construction breadth will be done to ensure that GSHP's are a good choice to replace the chiller/boiler plant. Along with the implementation of the ground-source heat pumps should come a smaller electrical demand depending on how many pumps are needed. The electrical breadth will be done to design a new electrical system to supply the mechanical systems. The chilled beams being used in the labs

# Tools for Analysis

### Proposed Redesign Systems

The tools used to analyze the mechanical systems include using Carrier HAP to model the loads and energy consumption from the GSHP system and chilled beams. Also, research on the property soil make up will need to take place. Also information on emissions will be calculated to compare to the original system emissions output. Research on equipment will need to be done possibly by contacting manufacturers or researching their websites on products.

## Proposed Breadths

For the construction breadth research on excavation costs will need to be implemented. Also, a schedule of construction from the project might be needed to add and make changes to, so a comparison of time for completing the initial project and redesign can be done.

Information about the current electrical system will be needed to help compare the new system that will supply the mechanical systems. Research will have to be done to ensure that the system will be efficient enough for the new mechanical systems.

# Appendix A: Preliminary Research


1. Kavanaugh, PhD, Steve. “Ground Source Heat Pumps.” ASHRAE Journal vol. 40 (October 1998): p. 31-36.

2. “Commercial Geothermal Heat Pumps”. http://www.energy.wsu.edu/Documents/geo_heat_pumps.pdf

3. Kavanaugh, PhD, Steve. “Ground Source Heat Pumps for Commercial Buildings.” September 2008. HPAC Engineering. 8 Dec. 2009 < http://hpac.com >

4. “Chilled Beams in Laboratories: Key Strategies to Ensure Effective Design, Construction, and Operation”. Laboratories for the 21st Century: Best Practice Guide. June 2009.

http://www.labs21century.gov/pdf/bp_chilled-beam_508.pdf

5. Weale, John, P.E.; and Rumsey, Peter, P.E. “Chilled Beams in Labs: Eliminating Reheat & Saving Energy on a Budget”. ASHRAE Journal vol. 49 (January 2007): p. 18-23.

6. Roth, Kurt, Ph.D; and Brodrick, James, Ph.D. “Seasonal Energy Storage”. ASHRAE Journal vol. 51 (January 2009): p. 41-43.

# Appendix B: Work Plan for Spring Semester

**Proposed Thesis Semester Schedule January 2011-April 2011**

**Josh Martz-Mechanical Option**
**Appell Life Sciences Building**
**Advisor: Dr. Srebric**

| Week | Senior Thesis |
|---|---|
| 10-Jan-11 | Senior Thesis |
| 17-Jan-11 | Senior Thesis |
| 24-Jan-11 | 1/29 Milestone 1 |
| 31-Jan-11 | |
| 7-Feb-10 | |
| 14-Feb-11 | 2/18 Milestone 2 |
| 21-Feb-11 | |
| 28-Feb-11 | 3/4 Milestone 3 |
| 7-Mar-11 | Spring Break |
| 14-Mar-11 | |
| 21-Mar-11 | 3/25 Milestone 4 |
| 28-Mar-11 | |
| 4-Apr-11 | |
| 11-Apr-11 | |
| 18-Apr-10 | |
| 25-Apr-11 | |

| Task | Start | End |
|---|---|---|
| Addon/Correct Energy Models | 10-Jan-11 | 17-Jan-11 |
| Analyze Building Site/Potential Space | 17-Jan-11 | 24-Jan-11 |
| Research GSHP and Chilled Beams/Determine Method for Energy Calculation | 17-Jan-11 | 7-Feb-10 |
| Set Up Excel and Energy Modeling/Calculate Energy Use for GSHP and Chilled Beam Systems | 24-Jan-11 | 21-Feb-11 |
| Set Up GSHP Schematic / Analyze Energy Consumption for GSHP and Chilled Beams | 14-Feb-11 | 7-Mar-11 |
| Cost Analysis/Research Prices | 7-Mar-11 | 21-Mar-11 |
| Obtain Information on Construction Schedule/Cost for excavation of GSHP system | 10-Jan-11 | 31-Jan-11 |
| Research/Obtain Information on Electrical Systems | 17-Jan-11 | 7-Feb-10 |
| Construct New Construction Schedule/Cost Analysis Based on Number of GSHP needed | 31-Jan-11 | 21-Feb-11 |
| Design of Electrical System for New Mechanical Systems/Cost Analysis of System | 7-Feb-10 | 28-Feb-11 |
| Organize and Format Final Report | 21-Mar-11 | 4-Apr-11 |
| Organize and Format Final Presentation | 28-Mar-11 | 11-Apr-11 |
| Final Reports Due April 7th | 4-Apr-11 | 4-Apr-11 |
| Faculty Jury Presentaions | 11-Apr-11 | 11-Apr-11 |
| ABET Evaluation | 18-Apr-10 | 25-Apr-11 |
| Senior Banquet April 30th | 25-Apr-11 | 25-Apr-11 |

| Milestones | |
|---|---|
| 1 | Complete Correction for Energy Models and Begin Research |
| 2 | Completion of Research and Begin Modeling |
| 3 | Complete Analysis for Breadth Topics and Begin Analysis for Main Proposal |
| 4 | Completion of All Research and Analysis/Begin Final Report |

| Legend |
|---|
| Geothermal and Chilled Beam Redesign Analysis |
| Breadth Topic 1: Construction Analysis |
| Breadth Topic 2: Electrical Analysis |