MONGOMERY COLLEGE

Architectural Engineering Thesis Proposal

Senior Thesis Proposal

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EXECUTIVE SUMMARY

The Montgomery College New Science Center is a 140,700 square foot four story addition to the Science East university building consisting of laboratories, offices, and classrooms on every floor complimented by an observatory on the roof. The building wishes to achieve LEED accreditation and maintain a safe and healthy environment by meeting all the laboratory ventilation requirements.

The mechanical system consists of a central air handling system, central chilled water system, a central hot water system, and a laboratory exhaust system. All equipment runs on variable speed drives. The central chilled water system consists of cooling towers, chillers, and pumps. The central hot water system utilizes a gas high efficiency boiler and pumps. The central air handling system has two custom roof top units encompassed in the penthouse. And the laboratories are exhausted through four high plume exhaust fans. Overall the current system design is relatively standard for a laboratory building, directly exhausting all labs.

In the pursuit of education, several system alternatives are considered and proposed to be simulation and evaluated over the course of the spring 2009 semester. The system alternatives chosen were combined heat and power and a geothermal system coupled with chilled beams. Combined heat and power systems are based on the concept of recovering thermal energy for heating, cooling, and generating electricity onsite. An open-loop geothermal system transfers heat from a local water retention pond during the heating season, and extracts heat from the building to be dispersed into the pond. Both systems will decrease the energy consumption, lowering the life-cycle costs and improving the environmental quality.

In addition to the mechanical system redesign, two breadth topics will be developed. For the first breadth topic, the lighting fixtures, arrangements and schedules will be potentially altered with the goal of reducing internal loads, and energy use while maintain required task lighting. The second breadth will asses the affects of the new mechanical system on the building acoustics and then potential modifications will be made to improve the space acoustics.

To achieve these results over the course of the semester a schedule for was developed and analysis tools were selected including IES for the load and energy simulations and EASE for acoustic evaluations.

BUILDING OVERVIEW

The Montgomery College New Science Center is located on the southwest sector of the Maryland Rockville Campus. The 140,700 square foot, four story building is a direct addition to Science East and bridge connected to Science West.

Each floor contains laboratories, classrooms, and offices. The majority of the building is for educational purposes. The new, bigger labs allow the professors to conduct experiments they were unable to before, and lecture to a larger group of students at one time. Complimenting the laboratories, the building is complete with animal receiving and holding rooms, a green house, and numerous laboratory preparation and recitation rooms.

The northwest entrance opens up to a four story atrium over looked by the roof observatory. This atrium is used as a transition to the existing Science East building and a student gathering space. A green roof surrounds the roof observatory. The observatory will be used for educational purposes, equipped with a power switch operated sliding roof and a view of the photovoltaic panels.

On the northeast entrance there is a small exterior amphitheatre. The amphitheatre's main purpose is to provide the students with a place to sit read and gather while keeping in touch with nature. It will also be used to tie in the existing pond. The pond will be used for water retention, collecting roof runoff water, assisting their LEED certification goal.

DESIGN OBJECTIVES

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

The mechanical system was designed with the following objectives:

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

West Campus Loop

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

Energy Efficiency

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

Laboratory Ventilation and Contaminant Control

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

MECHANICAL SYSTEM DESIGN

The mechanical system consists of a central air handling system, central chilled water system, a central hot water system, and a laboratory exhaust system.

CHILLED AND HOT WATER PLANT

Both a satellite chilled water plant and a satellite hot water plant in the new Science Building is sized to provide the cooling and heating capacity for the West Loop respectively. The West Campus Loop consists of the New Science Center (building of discussion), Science East, Science West, Macklin Tower and Computer Science. The West Loop has three different operational modes. The entire West Loop can be served by the campus loop or the new satellite plant. Or the new satellite plant can serve only the New Science Center with the rest of the west loop served by the existing campus central water plant.

CHILLED WATER SYSTEM

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

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

HOT WATER SYSTEM

The hot water system consists of two hot water campus distribution pumps and two building distribution pumps. Two high efficiency 3 million BTU hot water boilers are provided for the heating plant. The boilers are all piped in reverse return to balance out flows. Water always flows through all boilers when there is a call for heat.

AIR SYSTEM

The central air handling system consists of two custom roof top units manifolded together by a common discharge plenum. Each unit has dual fans and isolation dampers to isolate one unit from the rest of the system. Because of the high percentage of outside air, due to the amount of lab exhaust, there is no relief in the unit. The only relief is required during economizer mode. This relief will be discharged from the building through the smoke exhaust fans.

The complete schematic can be found in Appendix A – SCHEMATICS to explore the entire building air distribution breakdown. This schematic is taken directly from the designers IES energy model.

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

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

CENTRAL EXHAUST SYSTEM

The laboratory exhaust system consists of four high plume exhaust fans that are connected by a common plenum. The airflow through an individual fan is constant volume to maintain a constant discharge velocity out of the exhaust fan stack. The flow of exhaust air from the building is variable volume to minimize the amount of make-up air required at all times. Of the four fans, one is a standby fan, in the event of a failure. The fan designations will be rotated based on run time.

MECHANICAL SYSTEMS EVALUATION

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

CRITQUES

The Montgomery College New Science Center isolates the laboratory contaminants well by directly exhausting all laboratories, keeping them negatively pressurized at all times along with the exhaust ducts.

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

The building envelope was well designed. Each wall meets compliance for the nonresidential space, with the exception of wall type 4. Wall type 4 was evaluated as a semi-heated wall, and met compliance. The glazing which encompasses 38% of the wall U-values and solar heat gain coefficient go well beyond the ASHRAE 90.1 requirements without even taking the shading devices into account.

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

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

PROPOSED ALTERNATIVES SYSTEMS

Although the Montgomery College New Science Center's mechanical system as described above accomplishes the goals of the university, other alternatives could be found to be better overall. Alternative systems were selected through preliminary research to determine the best solution for the New Science Center. These alternatives loads, initial costs, life-cycle costs, emissions, accomplished LEED rating, and integration into the existing and future systems will be analyzed and compared to the current New Science Center design.

COMBINED HEAT AND POWER

Combined heat and power (CHP) systems generates both electricity and thermal energy as opposed to the traditional systems and New Science Center's mechanical system that use electricity generated from a central power plant to create onsite heating and cooling. The thermal energy generated can then be recovered for heating or cooling and the generation of electricity. The recovery of the thermal energy will increase overall system efficiency. CHP should be a very effective alternative; given the New Science Center is an internal load based building. CHP also incorporates cleaner fuels reducing the emissions per KW. Overall the CHP system is anticipated to reduce emissions and increase energy efficiency.

According to the Department of Energy's CHP data collection throughout the United States, Maryland already has 18 known buildings utilizing CHP. The majority of these buildings (11) chose a boiler/steam turbine, three chose a reciprocating engine, two chose a combined cycle, and the remaining two chose to use a combustion turbine. All of these forms of CHP will be explored and narrowed down to the most compatible options for a comprehensive analysis.

COMBINED HEAT AND POWER BENEFITS/ JUSTIFICATION

Implementing a CHP system increases the system efficiency and electrical demand, reducing the energy costs and life-cycle costs, even though there is an increased initial cost. In addition, since the power is generated onsite the system improves power reliability. Overall the system selection would decrease the energy demand, decreasing the costs and environmental impacts, while increasing the power reliability.

GEOTHERMAL HEAT PUMP AND CHILLED BEAMS

Geothermal systems conceptually transfer heat from once source to another. The standard closed-loop geothermal system uses buried piping known as bore holes. The refrigerant runs through the pipes absorbing heat from the ground during the heating seasons and disperses energy from the building into the ground during the cooling season. The ground maintains a relatively constant temperature around 55ºF year round depending on the site location. This constant temperature allows the geothermal system to utilize a heat source to draw from during the winter regardless of the local air temperature.

Fortunately the Montgomery College New Science Center has the option of placing an open-loop geothermal system. Although the closed-loop system could improve the current system design, the open-loop geothermal system is typically a more economical and environmental choice when possible. In order to implement an open-loop geothermal system a water source must be available as the heat reservoir. Given the Montgomery College New Science Center chose to create a water retention pond onsite as part of their LEED goal in water efficiency, an open-loop system is a possible alternative. Therefore the water retention pond would become even more economical for its dual purpose.

An open-loop system works on the same concept as the closed-loop system. As opposed to pumping refrigerant through the buried pipes, water is pumped from the pond or water source. The water is pumped to the heat pump from the pond where the heat is extracted. The heat is then used to heat the building and the water is returned to the pond. During the cooling seasons, which will be minimal due to decreased use of the university buildings during the summer, heat is extracted from the air and then transferred to the pond by the water running through the heat pump.

This system coupled with chilled beams may return a larger initial cost but will pay back in just a few years. The chilled beams would be used to diffuse the supply air into the building. For active chilled beams, the ventilation air is cooled or heated providing a fraction of the sensible load during the winter and part of the latent loads during the summer. The ventilation air is distributed in the room through the beam nozzles inducing the room air to pass over the chilled beam. Water is run through the chilled beams locally to heat or cool the induced room air. The room air then mixes with the ventilation air and drops into the space.

GEOTHERMAL HEAT PUMP AND CHILLED BEAM BENEFITS/ JUSTIFICATION

Chilled beams air movement creates a uniform air temperature throughout the space. As opposed to dumping air on to the occupants and or creating a draft, the occupants will experience better thermal comfort levels and indoor air quality. In addition, using piping and pumps improves the overall system efficiency over fans and ductwork.

The use of the geothermal system will create a larger initial cost but will payback faster than the current system design due to the decreased annual energy consumption. The system provides both heating and cooling as opposed to the need for a boilers to heat and chillers and cooling towers to cool. The heat pump is naturally renewable and nonpolluting, in addition to the open-loop selection eliminating the need to pump refrigerant. With the phase two, expansion in mind the geothermal system is very flexible where is can be down sized or increased by altering the pump capacity. As a result to the form of heat transfer the geothermal system can move three units of heat energy for every one unit of electric energy (This goes well beyond the high efficiency boiler, 87%, of the current system design).

BREADTHS TOPICS

For the mechanical system redesign of the Montgomery College New Science Center other areas of design will be explored. When redesigning any mechanical systems, the effects and changes made to the mechanical system on the other building systems should always be considered. Achieving the optimal mechanical system means achieving optimal conditions for every aspect of the building including, thermal comfort, energy efficiency, acoustics, lighting, electrical systems, construction costs and schedules, aesthetics, and structural systems. Two of these additional areas of focus are chosen for an in-depth analysis on how they will be affected and altered to improve the mechanical system redesign.

LIGHTING

The Montgomery College New Science Center is an internal load based building. Therefore, decreasing the internal load of the building is one of the major focus areas when trying to achieve optimal energy efficiency while maintaining desired task lighting levels. Both the building lighting schedules and lighting fixture efficiency will be investigated and potentially altered to decrease the internal loads and in-turn decreasing the energy required to light the building and energy needed to maintain desired room temperatures.

ACOUSTICS

Improving the acoustics of the building will create a better learning and working environment for the building occupants. The potential removal of the rooftop equipment will directly influence the mechanical sound transmission and building acoustics. Removing the rooftop equipment will reduce the sound attributed to the building decreasing the noise criteria. The noise reduction and space acoustics will be evaluated based on the changes made to the mechanical systems and space materials.

The acoustical simulations and analysis will be conducted by Microsoft Excel, and EASE, Enhanced Acoustic Simulator for Engineers. This program provides the capability to model the spaces and calculate the reverberation time which will then be compared to the desired levels based on the occupancy type.

PROJECT METHODS

For a complete evaluation of two alternatives and two breadth topics discussed above a structured method is needed over the course of the spring 2009 semester.

RESEARCH

The mechanical alternatives and breadth topics discussed will be thoroughly researched. In the research process, case studies, system design and integration will be assessed. The various forms of CHP will be narrowed down to the best solutions.

ANALYSIS CALCULATIONS AND SIMULATIONS

After the research has been completed, the building will be analyzed through hand calculations, Microsoft Excel, and the building modeling software IES, Integrated Environmental Solutions. Many combinations and changes to the building and system can be entered into the IES software. In summary the following changes will be modeled and taken into account:

- Building envelope changes
- HVAC changes
- Building loads
- Building energy
- Illumination simulations

The geothermal heat pump and chilled beam alternative will be modeled using IES, but the CHP alternative energy and load calculations will be done by hand calculations and Microsoft excel, due to the limitations of IES. The acoustical simulations and analysis will be conducted by Microsoft Excel, and EASE, Enhanced Acoustic Simulator for Engineers. This program will allow me to model the spaces and calculate the reverberation time which will then be compared to the desired levels based on the occupancy type. The following figure shows how the EASE program processes the data entered.

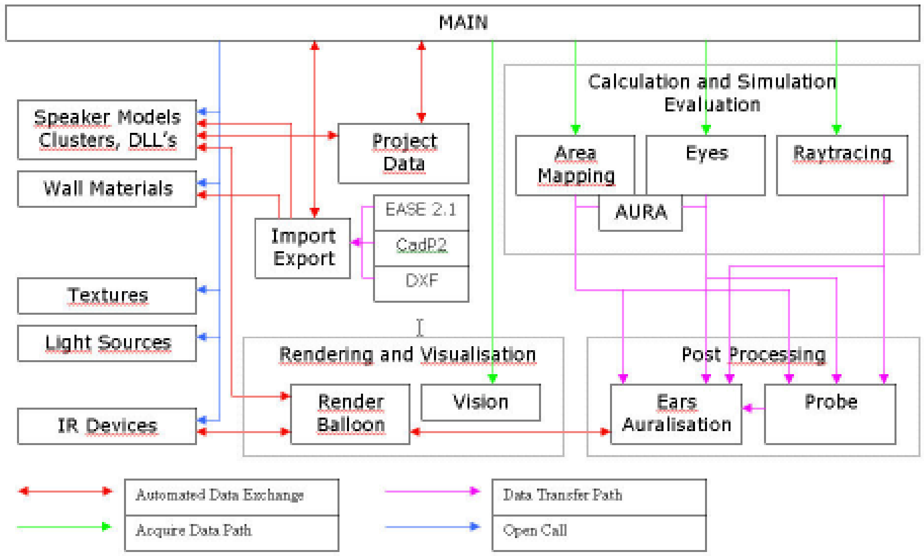

Figure 1: EASE Process Diagram

RESULTS EVALUATION

The results will need to be evaluated and compared to every simulated alternative. The energy reductions will be compared by both energy cost reductions and emissions. These conversions will be made by collecting initial cost and equipment data from R.S. Means or manufactures, calculating the payback period based on the cost of fuel and its use per year, and converting the known emissions for the energy rates. Finally the results will be compared and weighted based on the owners needs by energy costs savings, emission reductions, LEED ratings, system ease of integration, ease of maintainability, and initial costs. All of these calculations will be compared using the program Microsoft Excel.

WORK SCHEDULE

The following schedule, Table 1, has been created to help streamline and organize the thesis report and analysis process. The schedule has been broken down into a weekly calendar with important dates listed, tasks to be completed, and the status of the work as a result of the tasks completed over the course of the spring 2009 semester.

Week	Begin date	End Date	Academic Calendar	Tasks	Status
1	11-Jan	17-Jan	First Week of Classes	System Research	Complete System Understanding
2	18-Jan	24-Jan			
3	25-Jan	31-Jan			
4	1-Feb	7-Feb		Component Selection	Mechanical System Redesign Complete
5	8-Feb	14-Feb			
6	15-Feb	21-Feb		Building Simulations (IES and EASE) for every alternative	Load, Energy, Lighting, and Acoustic Information Attained
7	22-Feb	28-Feb			
8	1-Mar	7-Mar			
9	8-Mar	14-Mar	Spring Break	Cost and Comparison Data Collection	Analysis Information Collected
10	15-Mar	21-Mar			
11	22-Mar	28-Mar		System Comparison Analysis	Recommended System Selected and Results
12	29-Mar	4-Apr		Write Final Report/ Power Point Presentation	Thesis Completion
13	5-Apr	11-Apr	Summary Due April 8th		
14	12-Apr	18-Apr	Presentation	Present Thesis/ Presentation Preparation	Presentation Competition

Table 1: Spring 2009 Work Plan

REFERENCES

ASHRAE. 2005, ANSI/ASHRAE, 2005 ASHRAE Handbook –Fundamentals. IP ed. American Society of Heating Refrigeration and Air Conditioning Engineers, Inc., Atlanta, GA. 2005.

ASHRAE. 2007, ANSI/ASHRAE, Standard 90.1 – 2007, Energy Standard for Building Except Low-Rise Residential Buildings. American Society of Heating Refrigeration and Air Conditioning Engineers, Inc., Atlanta, GA. 2007.

BurtHill. 2008, Construction Documents. BurtHill, Washington, DC. 2008.

"Combined Heat and Power Units located in Maryland." Department of Energy. 21 Dec. 2008 http://www.eea-inc.com/chpdata/States/MD.html.

> The respective link provided by the department of energy lists every known application of CHP in the state of Maryland. The information is broken down into tables showing the details of every application including fuel source used and type of CHP implemented.

Colella, W.G.; Niemoth, C.R.; Lim, C.Y.; Hein, A.Ph. "Evaluation of the Financial and Environmental Feasibility of a Network of Distributed 200 kW_e Combined Heat and Power Fuel Cell Systems on the Stanford University Campus." Fuel Cells 5.1 (2005): 148-166.

> The article provides information on a CHP university application. The fuel cell form of CHP is defined and discusses the benefits. The data recorded before CHP and after the implementation of the system are compared and evaluated. This article was very helpful in defining what CHP is and the university application benefits for preliminary research.

DADANCO. "Active Chilled Beam" DADANCO—MESTEK Joint Venture, LLC. 21 Dec. 2008 http://www.dadanco.com/ACB/air_conditioning_literature.asp.

> This online manufacture's brochure provided a brief description of how active chilled beams work and the benefits they provide by implementing them into your HVAC system.

APPENDIX A – SCHEMATICS