PSUAE

MECHANICAL PROJECT PROPOSAL (Revised)

REDESIGN PROJECT

Nicholas B Scheib

Advisor: Dustin Eplee

2011

Mechanical Option-IP

Table of Contents

Executive Summary

The main objective of this report is to summarize the information gathered from previous Technical reports, propose new design considerations and layout a tentative schedule of work of the spring 2011 semester. The Sunshine Elementary School design has been analyzed throughout the fall 2010 semester. The findings of the research and analysis have led to ideas of possible energy savings which will be investigated.

The first part of the redesign proposal will focus on changing the water-to-air heat pump system to a water-to-water heat pump system thus reducing energy usage by inefficient fans and replacing with highly efficient pumps. The redesign is to include radiant floor heating and cooling for all areas of the Sunshine Elementary School where small heat pumps were originally utilized. The larger areas, where the load was designed to be handled by larger AHU's, will not be redesigned due to quick loading issues. The ventilation of the proposed redesign will utilize a centralized DOAS system with larger more efficient fans.

The second part of the proposal is to install BIPV's in attempt to create a net-zero heating and cooling system. This will include a redesign of the complicated roof structure to a more simplistic gable roof along with rotating the building to face due south. This will allow for photovoltaic shingles to be installed on the entire south facing roof. The solar array will be grid tied and attempt to, at the least, offset the energy used by the pumps, fans and condensers of the mechanical system.

The breadth of the proposal will be in the structural and construction impacts of proposed changes. The structural impacts of a radiant floor system will be investigated along with the impact on constructability of the new roof structure. The construction impacts of both these changes will also be investigated. This will include scheduling changes, staging and cost analysis of the proposed design.

The requirement of the integrated program to utilize my Master's course work will be done in the third part of the proposal. A solar thermal collection system will also be added to the design. This is for domestic hot water. This will utilize information I have learned in Dr. Treado's 597 Solar Thermal Collection Systems and Design. The system will be sized to have enough capacity to handle the demand of DHW of the Sunshine Elementary School. This is to tie into the above prosed design by furthering the redesigns ability to be a net-zero energy building.

Project Summary

The Sunshine Elementary School went under construction in March of 2010 and is planned to be finished in June 2011. The School is located in the Hershey, PA area. At 103,000 ft^2 the building houses kindergarten through 5th grade students along with faculty. The building includes a gymnasium, large kitchen, cafeteria, classrooms, and large administration area. The project goal is to receive a Silver rating by the Leadership of Environmental and Energy Design (LEED).

The new elementary school is located in a rural area connecting two townships. The building is to be used for both kindergarten and 1st through 5th grade students. Due to this a "school within a school" was a major concept of the design. The youngest of the students will be in the center. This area will function independently as a smaller environment allowing the students to acclimate to the school experience. This area consists of two, single story, eight room class pods with shared spaces and also includes a kitchen area and a multi-purpose room.

The 1st through 5th grade wing is two-story and has an adjacent gymnasium at one end and a multi-purpose room at the other end. This wing connects with the kindergarten center through shared spaces, which include a library, production kitchen, building storage, mechanical and electrical spaces, the nurse suite and building administration.

Existing Mechanical System Summary

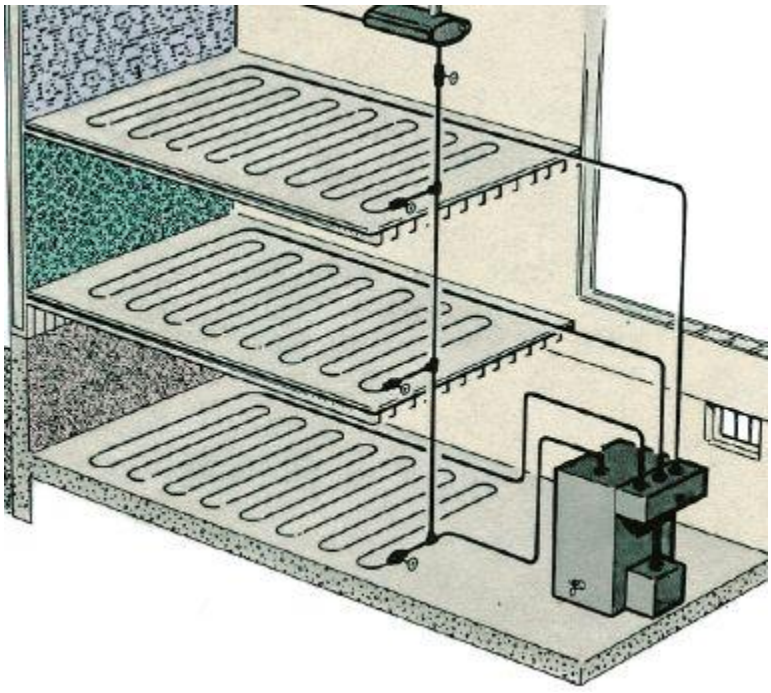
The total cost, given by the project manager, of the MEP system was $5,271,200. The total area of the building was 103,000 ft^2, yielding a cost of $51.17/$ft^2$. This does not include approximate costs of $100,000 for commissioning and $69,100 for air balancing, hydronic balancing and commissioning support.

A highly efficient ground source heat pump system was chosen for the mechanical design. Ninety-two ground wells were designed in order to create the capacity needed. The water loop

is then pumped to small heat pumps severing individual spaces and five larger air handling units serving lager spaces such as the cafeteria and gymnasium. The heat pumps are a water-to-air system. The ventilation is ducted through the corridor to each space and is controlled by demand control ventilation by the way of CO^2 sensors located in each space. To further conserve energy, energy recovery units with variable speed fans are located to exchange temperatures between exhausted air and outdoor air.

Redesign Considerations

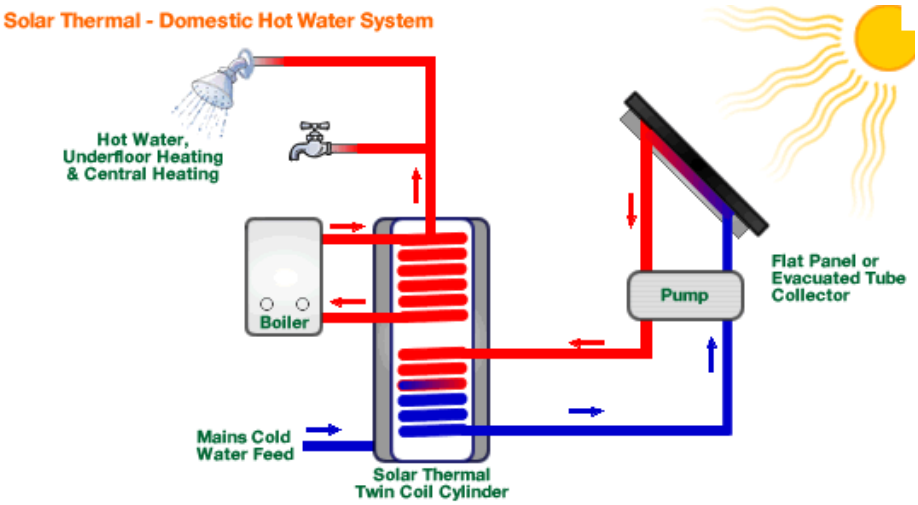
The proposed redesign consists of three major parts; Convert the water-to-air heat pump design to a water-to-water design utilizing radiant floor heating and cooling, Install a photovoltaic array on a newly design roof structure, Install a solar thermal water collection system for domestic hot water demand.



The conversion from water-to-air system to water-to-water system is to reduce the wasted energy of inefficient small fans within each heat pump unit throughout the entire building. The energy used by efficient pumps is predicted to be much less. This is expected to incur a larger first cost but will be evaluated through a life cycle cost analysis to prove if it is economically

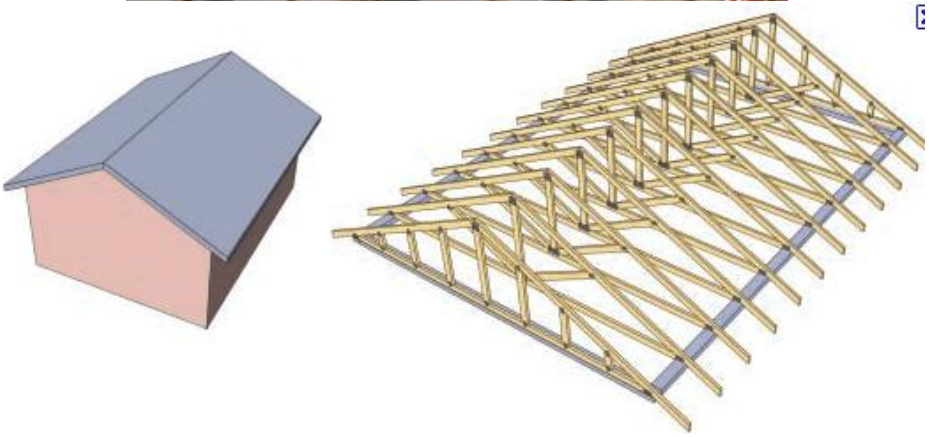
feasible. The cost of sheet metal used by ducting in each class room will be saved and exterior ceiling heights have the potential to be higher allowing for more daylighting thus less overall energy usage. Also with a dedicated outdoor air ventilation system indoor air quality will improve.

The installation of a photovoltaic array is in attempt to supply all electricity used by the mechanical system, thus creating a net-zero heating and cooling system for the school. This will include a redesign of the roofing structure to a simpler gable roof as opposed the complicated hip roof design originally designed. The final part of this is to rotate the building to face due south to take full advantage of the solar gain. This is expected to increase the photovoltaic gain along with heat gain reducing heating costs throughout the heating season. Although cooling costs are anticipated to increase this is not of large concern because due to a school's schedule heating is predominate over cooling. A prediction of a high initial first cost is expected but again a life cycle cost analysis will be performed to prove if it is economically feasible.



The installation of a solar thermal water collection system is due to the DHW of the Sunshine Elementary School being the largest user of Natural Gas in the building at 61%. This will help the redesign to reach the goal of a net-zero mechanical system.

Breadth Work



The breadth work of the proposal is within the impact of the proposed redesign. The installation of a radiant floor system will impact both the structure of the building, being the slab and the construction of the building, being cost, staging and scheduling. The radiant floor is expected to change the structural design of the slab properties such as depth and possible additives. It is also expected to increase construction time and decrease constructability. An analysis comparing original designed construction schedule to proposed redesign will be performed. This will include a life cycle cost analysis of both the original design and the redesign. The benefits will be weighed against these impacts.

The changing of the roof line will also affect the structure and construction of the building. I will design the new truss system as a structural breadth. The original design included 17 different designed trusses. I am proposing a newly designed roof line which will include 3 different trusses. For the construction breadth I will perform a schedule, cost and constructability analysis on the proposed design compared to the original design. The redesigned roof is expected to reduce cost, increase constructability, and decrease construction time.

Integrated Program Work

The addition of proposed solar thermal water collection system will heavily rely on information from Dr. Treado's 596, Solar Thermal Collection Systems and Design, course. Within the course I learned how to size and design a solar thermal collection system to fit the capacity of a building and the given climate of any location. Using weather data for the Hershey, PA area I will size the system in attempt to provide 100% of DHW demand.

Project Methods

Several tools will be utilized to perform the proposed analysis. The evaluation of the in floor radiant heating and cooling system will heavily rely on an eQuest model which will be reconstructed with proposed changes allowing for a direct comparison to original design. The new overall energy consumption will be found by these means. The feasibility of in floor radiant cooling will be analyzed to ensure condensation will not be a concern. All maintenance, operation cost, and troubleshooting of said system will be a part of the analysis.

Revit will be utilized when redesigning the roof structure and rotating the axis of the building. The rotated axis will also be analyzed by eQuest to understand the impact of additional solar gain by rotating the building to face due south. Revit will be utilized to create the gable roof trusses, simplifying the original 17 different heavy timber trusses to three roof trusses.

The Manufacture's data will be a key part of success when analyzing the proposed solar array. The efficiencies given by the data along with weather data for the Hershey, PA area will determine the capable electric gain of the solar array. This gain will then be compared to the total electrical usage of the proposed design. A life cycle cost analysis will be performed to investigate economic feasibility.

The solar thermal water collection system analysis will use both hand calculations given weather data and manufacture's data to assess the size requirement and feasibility of the system. A storage tank will be sized and control sequence will be created to ensure no possibilities of legionella or other biological contamination.

All proposed systems will be analyzed through a life cycle cost analysis to investigate economic feasibility.

Prediction

I predict the proposed redesign will incur a large initial first cost, but that a life cycle cost analysis will prove it to be economically feasible. I also predict the ability to achieve a net-zero heating and cooling system along with a net-zero domestic hot water system. The benefits of this achievement go beyond cost. The reductions of environmental impacts of the building are a major success. This reduction of emissions will also be added to the report to prove additional advantages of the redesign which must be taken in account in addition to the economics of the project.

Preliminary Research

The following is a list of resources used in the preliminary research conducted for proposed design. The list of sources will be updated as the analysis is performed and the project progresses. Beyond this list meetings and discussions with a mechanical engineer have helped develop this proposal.

ASHRAE Handbook, HVAC Systems and Equipment. American Society of Heating, Refrigeration, and Air Conditioning Engineers, INC., Atlanta, GA 2004

ASHRAE Handbook, HVAC Fundamentals. American Society of Heating, Refrigeration, and Air Conditioning Engineers, INC., Atlanta, GA 2004

ASHRAE Handbook, HVAC Applications. American Society of Heating, Refrigeration, and Air Conditioning Engineers, INC., Atlanta, GA 2004

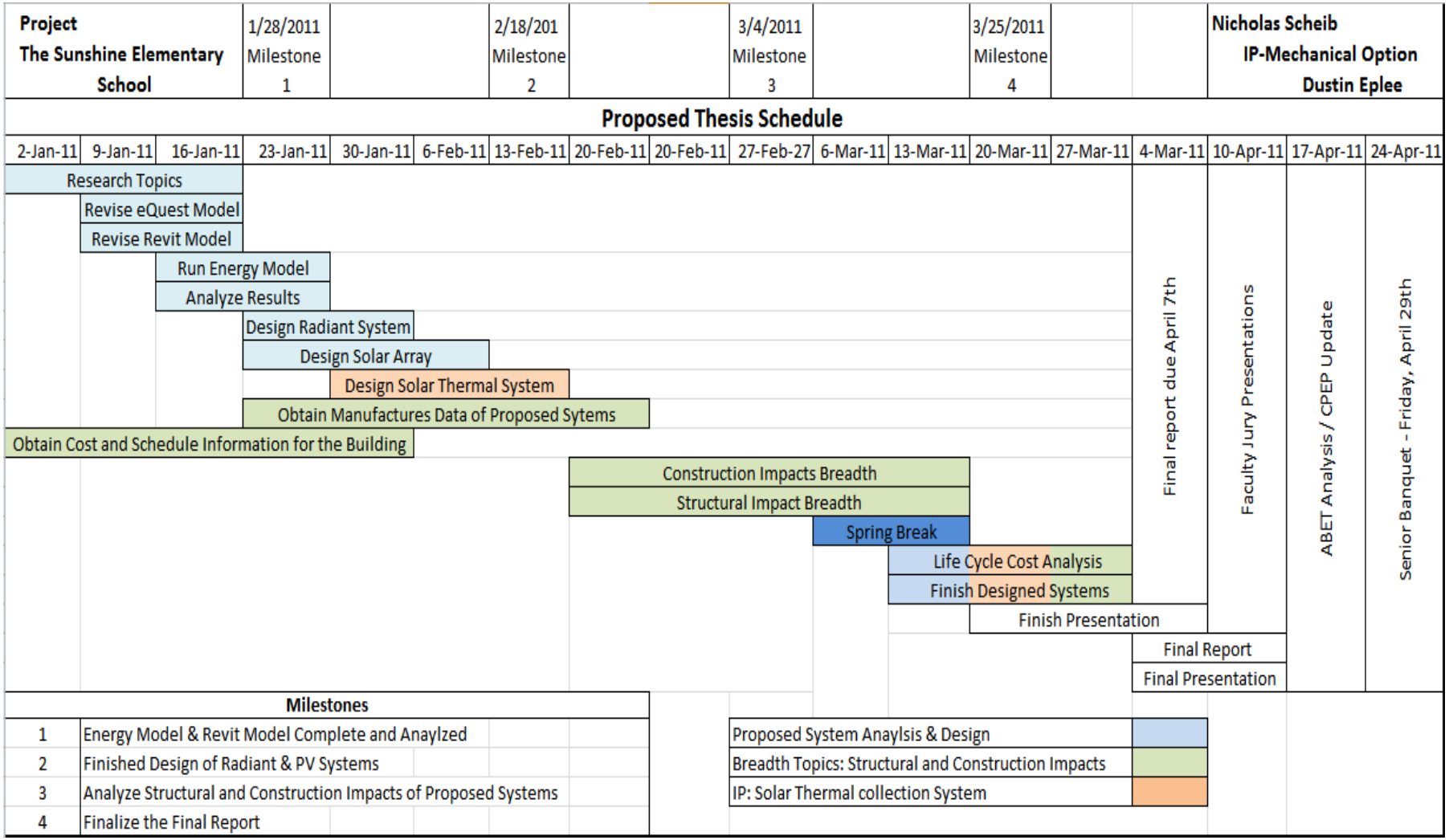
Beckman, Duffie (2006), *Solar Engineering of the Thermal Processes*, John Wiley & Sons, Inc.

McQuiston, Parker, Spitler (2005*), Heating, Ventilating, and Air Conditioning*, John Wiley & Sons, Inc.

Tentative Work Schedule

This is only a tentative schedule and will possibly change as the research is performed. All dates are available for adjustment except for the presentation date of 4/07/2010.

Task Name	Duration	Start	Finish
Research Topics	22 days	Fri 12/17/10	Mon 1/17/11
Reconstruct eQuest Mod	6 days	Mon 1/10/11	Mon 1/17/11
Reconstruct Revit Model	6 days	Mon 1/10/11	Mon 1/17/11
Run Energy Model	4 days	Mon 1/17/11	Thu 1/20/11
Analyze Results	5 days	Mon 1/17/11	Fri 1/21/11
Design Radiant System	6 days	Fri 1/21/11	Fri 1/28/11
Design Solar Array	10 days	Mon 1/24/11	Fri 2/4/11
Design Solar Thermal Sys	10 days	Tue 2/1/11	Mon 2/14/11
Manufatures Data of Proj	11 days	Thu 2/10/11	Thu 2/24/11
Begin Breadth	16 days	Tue 2/22/11	Tue 3/15/11
Spring Break	5 days	Mon 3/7/11	Fri 3/11/11
Finish Designed Systems	14 days	Mon 3/14/11	Thu 3/31/11
Finish Presentation	12 days	Tue 3/22/11	Wed 4/6/11
Life Cycle Cost Analysis	8 days	Thu 3/24/11	Mon 4/4/11
Presentation	1 day	Thu 4/7/11	Thu 4/7/11


Project
The Sunshine Elementary School
1/28/2011 Milestone 1
2/18/201 Milestone 2
3/4/2011 Milestone 3
3/25/2011 Milestone 4
Nicholas Scheib
IP-Mechanical Option
Dustin Eplee
Proposed Thesis Schedule
2-Jan-11
9-Jan-11
16-Jan-11
23-Jan-11
30-Jan-11
6-Feb-11
13-Feb-11
20-Feb-11
20-Feb-11
27-Feb-27
6-Mar-11
13-Mar-11
20-Mar-11
27-Mar-11
4-Mar-11
10-Apr-11
17-Apr-11
24-Apr-11
Research Topics
Revise eQuest Model
Revise Revit Model
Run Energy Model
Analyze Results
Design Radiant System
Design Solar Array
Design Solar Thermal System
Obtain Manufactures Data of Proposed Sytems
Obtain Cost and Schedule Information for the Building
Construction Impacts Breadth
Structural Impact Breadth
Spring Break
Life Cycle Cost Analysis
Finish Designed Systems
Finish Presentation
Final Report
Final Presentation
Final report due April 7th
Faculty Jury Presentations
ABET Analysis / CPEP Update
Senior Banquet - Friday, April 29th
Milestones
1 Energy Model & Revit Model Complete and Anaylzed
2 Finished Design of Radiant & PV Systems
3 Analyze Structural and Construction Impacts of Proposed Systems
4 Finalize the Final Report
Proposed System Anaylsis & Design
Breadth Topics: Structural and Construction Impacts
IP: Solar Thermal collection System