University Medical Center of Princeton

Plainsboro, NJ

Thesis Proposal

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Executive Summary

The University Medical Center of Princeton is currently saving energy with a glycol heat recovery system. This heat recovery system is located on the roof of the patient tower and is connected directly to the roof top air handling units. Although this system is very effective with the 100% outside air requirements, I propose to explore the replacement and integration of a ground (or water) source heat pump system.

As a way to evaluate alternative forms of energy reduction, I plan to design a ground source heat pump. This system will take advantage of the 171 acre healthcare campus. The size of UMCP will require a very large system, and the large amount of land will be perfect to maximize the amount of cooling (or heating) potential from the ground.

To further analyze the effectiveness of these two energy reduction systems, I will analyze a joint model. By creating a mathematical model that analyzes the initial cost, operating cost, and energy savings for both systems, I will be able to determine if there is maximized savings with a combination of both systems.

Another system that I will be investigating is a Microsteam Power Generator. The medical center is supplied with 120 psi steam, from a central utility plant, and reduces it down to 15psi. Currently this is done with a series of pressure reducing valves. By replaces these valve stations with a Microsteam generator, the pressure will still be reduce to 15psi while generating approximately 275kW per generator. There are two pressure reducing stations giving a potential 550kW to offset electricity costs in the building.

The proposed changes will create a need to redesign the power distribution system. Removing equipment from the roof could allow for smaller equipment supplying electricity to the roof. However, the heat pumps will require electricity and the system must be adjusted to handle these new loads. The implementation of Microsteam generators will require special equipment to tie the generated electricity into the building power distribution system.

The University Medical Center of Princeton is dedicated to provide the best healing environment possible. A common complaint by patients, nurses and doctors over the years has been the increasing noise within hospitals. I will be analyzing the acoustical conditions and properties of the patient rooms. I will then make adjustments to the room materials and or partition wall construction to increase noticeability of auditory cues and increase patient comfort.

Building Overview

The University Medical Center of Princeton Replacement Hospital is a new 639,000 square foot state of the art faciltiy located in Plainsboro, New Jersey. It is to be part of a 171 acre healthcare campus located conveniently off of US route 1. The new faciltiy is being built to fullfill furutre ocupancy needs anticipated by the University Medical Center of Princeton. The main patient tower consists of 269 single bed rooms within its six floors along with state-of-the-art treatment and tesing equipment.

Design Objective

The University Medical Center of Princeton has multiple design objectives such as architectural design, patient experience, improved operating performance, and environmental responsibility. To achieve these and other goals, the design is well integrated and comprised of state-of-the-art equipment. The result of the collaboration of the design teams produced a complex building that meets the specific needs of operating, exam, imaging and patient rooms as well as office, educational and general use spaces.

The Princeton Healthcare System spared no cost to provide the best equipment possible. Through vigorous fundraising the "Design for Healing" campaign is raising $115 million to support the $447 million project ($315 million for construction). Of the fundraised money, $15 million is allocated to program and department needs of the hospital including a fully computerized patient records system. The campaign feels no reason for money to be a deciding factor in providing the best possible care and healing for patients.

Mechanical Overview

The University Medical Center of Princeton has a large multi zone mechanical system to provide the required cooling and ventilation air for each type of space. There are 11 air handling units within the scope of this report (17 total for the building); eight of these units are atop the roof of the bed tower, while the other three are placed in the basement. The six roof top units supply 100% outside air and each is connected to glycol heat recovery system.

However, each floor is not serviced by its own air handler. The basement, first floor and lobby are supplied by the three basement units. The remainder of the building is separated into sectors. Each sector is supplied from its own air handler via a vertical supply shaft. See the Figure 1 to see how the sectors correspond to the building.

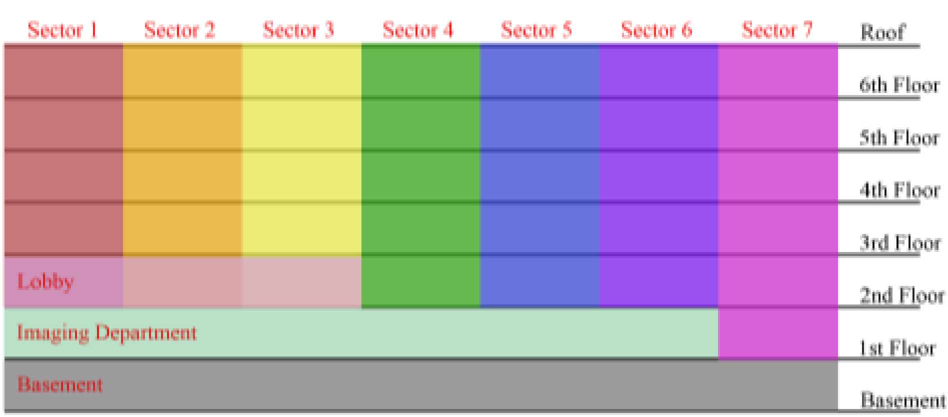

Figure 1. Sector Layout Diagram

The following table describes the designed sector and supply air for each air handler.

Design Sectors and Supply Air by AHU		
Air Handler	Sector	Supply Air (CFM)
AHU -1	Lobby	60,000
AHU -2	Imaging Department	35,000
AHU -4	Basement	33,000
AHU -7	Sector 1	46,000
AHU -8	Sector 2	50,000
AHU -9	Sector 3	35,000
AHU -10	Sector 4	42,000
AHU -11	Sector 5	50,000
AHU -12	Sector 6	30,000
AHU -13	Sector 7	30,000

Table 1. Designed Sectors and Supply Air

The hot and chilled water used by the air handlers is supplied by a central utility plant located next to the medical center. Steam provided from the utility plant is reduced from 120psi to 15psi on the sixth floor and used to generate hot water. The chilled water is used as supplied at 50.5 degrees Fahrenheit.

Using a simplified block model the operating costs and emissions were calculated. Using utility rates from PSE&G, the annual cost to operate the building is approximately $1.11 million or $5.51/ft^2$. To calculate the emissions, factors for CO_2, NO_x, SO_x, PM10, and CO_{2e} were taken from National Renewable Energy Laboratory. The annual CO_{2e} is estimated at 257 lb/ft^2.

Proposed Alternatives

Ground Source Heat Pump

Energy conservation has been implemented with heat recovery units, an alternative could be ground (or water) source heat pumps. By implementing a series of deep wells on the 171 acre health care campus, I believe it would be possible to supplement the energy consumption comparably to the heat recovery units. The benefits of the ground source heat pump are similar to the heat recovery units in that it will reduce the cooling energy needed in the summer and the preheat energy for the winter.

To compare the GSHP system to the heat recovery, I will be analyzing the installing and operating costs. It is likely that the two systems will be providing different amounts of energy savings, therefore I will determine the simple payback period for each system. I will further analyze the two systems by determining a minimum payback period between the two systems. To complete this I will be creating a mathematical model relating the installation cost and operating cost to the payback period using the variables from the two systems.

Microsteam Power System

The central utility plant provides high pressure steam which must then be reduced to a usable pressure for the rest of the building equipment. Currently this is accomplished with a series of pressure reducing valves. I will explore replacing these pressure reducing valve stations with Microsteam Power Systems. These systems will take the 120 psi steam and reduce it to 15psi while producing electricity. There will be two of these each system is capable of producing around 275kW of electricity. This electricity can be used to offset electricity usage throughout the building. The total potential of 550kW (from two generators) could possibly power the all of the lights in the patient tower. Figure 2 below demonstrates how the Microsteam Power System is configured.

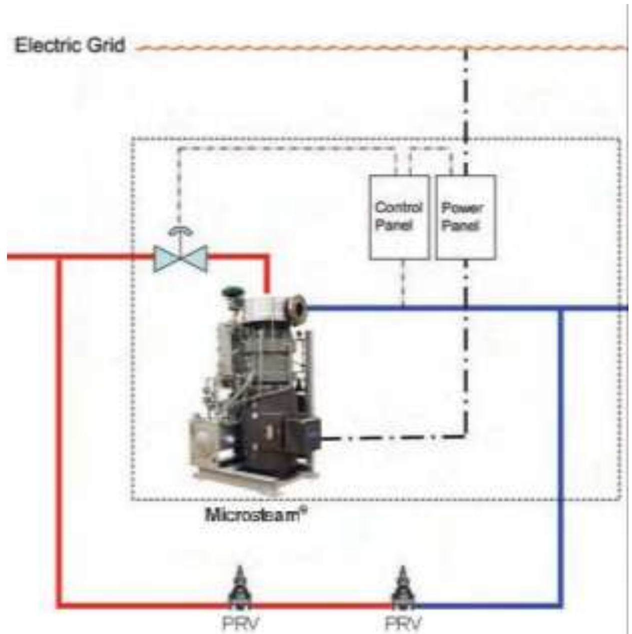

Figure 2. Configuration of Microsteam Power System.
<http://www.docs.hvacpartners.com/idc/groups/public/documents/marketing/04-811-50017-25.pdf>

Breadth Topics

Electrical

The proposed implementation of a ground source heat pump and Microsteam Power Systems will affect the power distribution system. Adding the GSHP system, less power will be needed at the roof; this reduction could allow for smaller thus cheaper equipment, reducing the payback period of the GSHP. The power system will also need resized to support the pumps of the GSHP system. The electrical system must also be restructured to distribute the steam generate electricity to the building.

Acoustic

A major complaint by both patients and medical staff is the noisy environments in hospitals. Research has been done relating the noise in patient and operating rooms to decreased patient care and recovery. High levels of background noise make patients uncomfortable and retard their recovery. Medical nurses and doctors can have difficulty concentrating do the noisy environment causing medical malpractice as well as missing auditory cues. I will analyze the acoustical environment of the patient rooms by predicting the background noise level with a series of measurements and calculations. I will also estimate the sound absorption within the room. After determining the acoustic characteristics, I will propose reselections of materials to improve the room and evaluate the increased probability of noticing auditory cues.

Software and Tools

Energy Analysis

To analyze the current energy savings of the glycol heat recovery system as well as the potential savings from the ground source heat pump I will be using Trane Trace. The floor by floor block model will be modified to be more accurate. I will also break the floors into sectors as done by Syska Hennessey so as to better model the heat recovery and ground source heat pump systems.

Excel

I will be using Microsoft Excel extensively to complete energy calculations, generate tables and charts for the final report and presentation. I will also be using my progress schedule generated in excel to continually track my progress.

Sound Level Meter

I plan to make a trip to the University Medical Center of Princeton to measure the noise level generated by the air diffuser into the patient room, as well as measure other characteristics such as transmission loss between patient rooms.

Preliminary Research

Ground Source Heat Pump

Preliminary research on ground source (or water source) heat pump systems has been done to increase my knowledge of what is required to design such a system. My original idea was to use the nearby Carnegie Lake and tributary as a cold well for a water source heat pump. After researching such a system I found that because of the cold winter climate, the water become too cold decreasing efficiency and increase risk of damage to the equipment. Because of the large acreage of land owned by the University Medical Center and the constant 55^{o}F temperature of the earth, I found it plausible to implement a ground source heat pump. A major source for this research is a publication by Virstar Corporation.

Microsteam Power System

My knowledge of Microsteam power systems has come from a pamphlet published by Carrier on their product. From this pamphlet I have gathered that such systems can produce up to 275kW and make use of the loss of energy from the steam pressure reduction. Because of the constant supply of high pressure steam along with the constant flow of this steam for use within the building, the UMCP is a prime candidate for such a system.

Patient Room Acoustics

My first introduction to the topic of healthcare acoustics was at the 2011 ASHRAE winter conference. I have further looked into research by Dr. Erica Ryherd and her team. I have also begun to look into research conducted by Dr. James West and Ilene Busch-Vishniac. After discussing this breadth with Ryan TerMulen (AE 458 instructor) I have determined that this is possible and have his support and assistance if needed.

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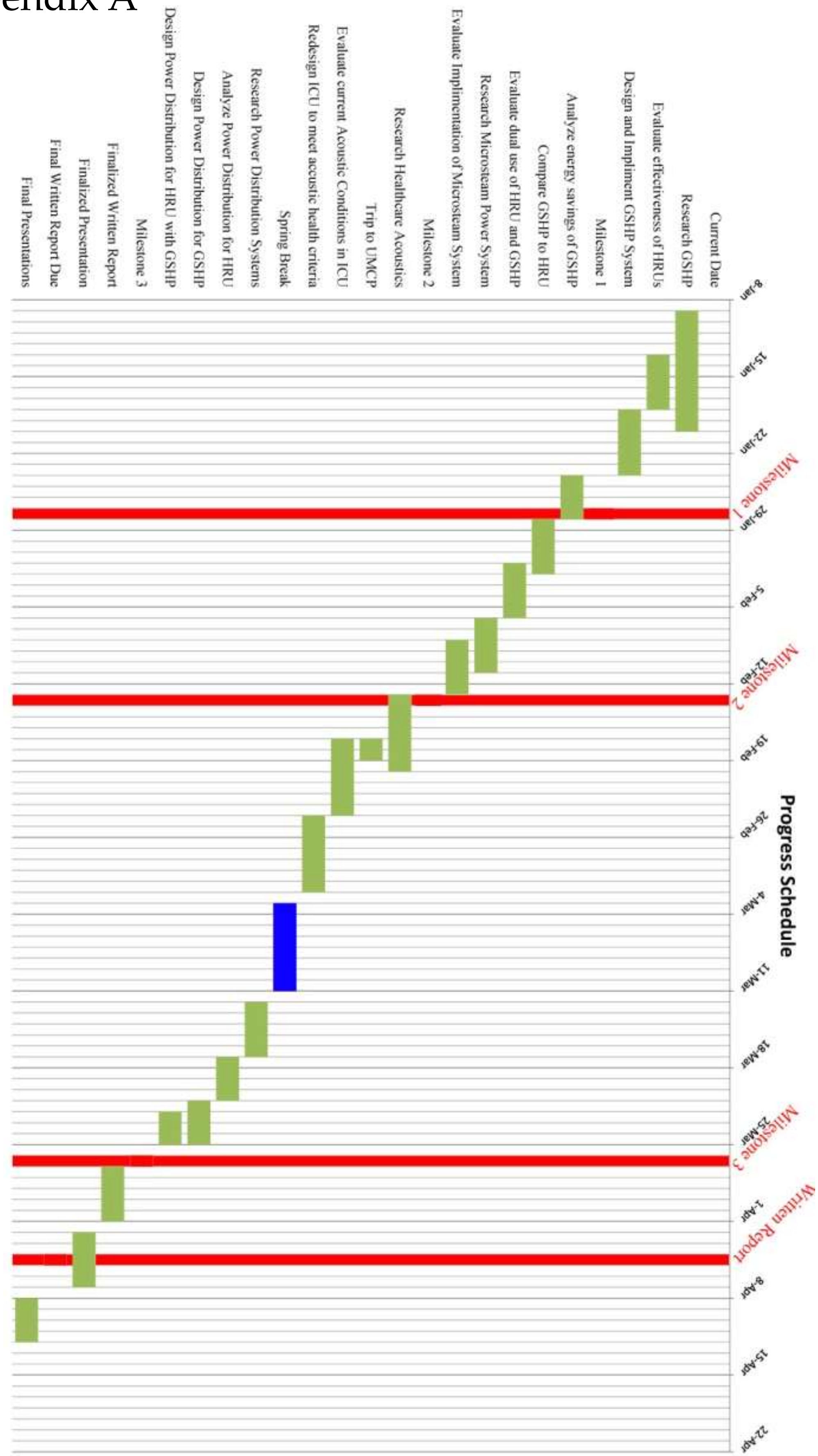
Appendix A


Progress Schedule
Current Date
Research GSHP
Evaluate effectiveness of HRUs
Design and Impliment GSHP System
Milestone 1
Analyze energy savings of GSHP
Compare GSHP to HRU
Evaluate dual use of HRU and GSHP
Research Microsteam Power System
Evaluate Implimentation of Microsteam System
Milestone 2
Research Healthcare Acoustics
Trip to UMCP
Evaluate current Acoustic Conditions in ICU
Redesign ICU to meet accustic health criteria
Spring Break
Research Power Distribution Systems
Analyze Power Distribution for HRU
Design Power Distribution for GSHP
Design Power Distribution for HRU with GSHP
Milestone 3
Finalized Written Report
Finalized Presentation
Final Written Report Due
Final Presentations
8-Jan
15-Jan
22-Jan
29-Jan
5-Feb
12-Feb
19-Feb
26-Feb
4-Mar
11-Mar
18-Mar
25-Mar
1-Apr
8-Apr
15-Apr
22-Apr
Milestone 1
Milestone 2
Milestone 3
Written Report