Thesis Proposal

Mechanical Systems Redesign Proposal

Morton Hospital Expansion

Taunton, MA

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Executive Summary

The purpose of this report is to investigate alternative mechanical system designs for the Morton Hospital expansion project, and how these alternatives will be implemented. Although the current system meets codes and standards, the goal of the system redesign is to improve upon energy consumption while also reducing annual and life cycle cost. It should be noted that these recommendations are in no way an implication of the insufficiency of the current design of the Morton Hospital Addition, and are only being evaluated for educational purposes.

Currently, the addition utilizes the existing building steam plant to supply heating, and utilizes a new air-cooled chiller to supply the majority of the cooling. There are two air handling units that supply each phase of the project. AHU-1, supplying Phase 1, employs a steam preheat coil and direct expansion cooling coil. The zones in Phase 1 are all supplied with electric reheat coils. AHU-2, supplying Phase 2, employs a hot water preheat coil and chilled water cooling coil. Phase 2 zones employ VAV terminal boxes with a hot water reheat coil to maintain the desired air distribution. A more detailed description of the current mechanical design can be found in Technical Report 3.

To improve upon the current mechanical design of the addition, several alternatives were considered. The alternative considerations took into account the impact on overall energy consumption, first and life cycle cost, controllability, indoor air quality, and system feasibility. Based on these concerns, three alternatives will be evaluated in detail: a water cooled chiller (WCCH) with no air distribution changes, variable refrigerant flow in conjunction with WCCH, and ground coupled heat pumps in conjunction with WCCH. All three alternative will also evaluate exhaust air energy recovery in the form of runaround coils to avoid cross contamination in critical zones. The water cooled chiller will also need a new cooling tower and economizer, which will have the potential for free cooling considering the climate. A grey water usage analysis within the new cooling tower will also be completed for additional energy savings.

With the addition of the cooling tower located on the roof, a reevaluation of the roof structure must be completed because of the large increase in dead load. Also, with the implementation of a ground couple heat pump system, construction duration and cost must be reevaluated considering the extensive amount of time it takes to excavate the required well field.

A detailed progress schedule can be found below, as well as a description of the tools to be used and technical papers used for research.

Building Overview

Morton Hospital, originally built in 1988, is located in Taunton, MA serving the Greater Taunton Area. In 2010, Steward Healthcare acquired ownership of the hospital and soon after decided to expand its facility. It is currently a 100,000 SF 2-story hospital providing services including emergency and expressMed care, cardiology, orthopedics, maternity, and Outpatient surgery. The expansion will be split into two phases totaling 40,000 SF. Phase 1 is a new MRI, while the Phase 2 includes the Emergency Department, Psychiatric Ward, imaging suite, various treatment and triage rooms, and decontamination and isolation rooms. *Figure 1* below shows the key plan with the Phase 1 expansion being the boxed out grey section directly in the middle, Phase 2 expansion in white, and the existing hospital in the remaining grey.

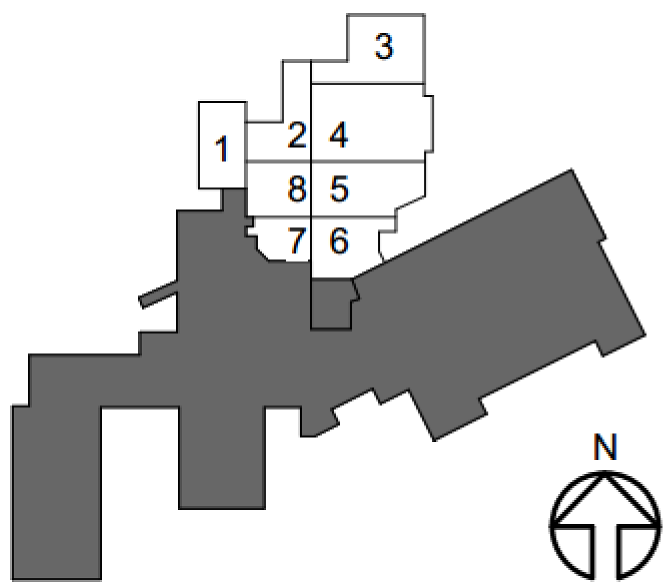


Figure 1: Key plan of existing versus expansion

This expansion will be built around an existing covered parking area that will be fit out for interior space. Both phases will begin construction at the same time, and Phase 1 will be complete and opened while phase 2 remains under construction. The addition will be accessed from the existing building through an additional vestibule, and will also have multiple entryways from the exterior including an ambulance entry vestibule and emergency room vestibule. Because of possible future expansion vertically above this addition, the roof slab was constructed to work as a floor slab.

Current Mechanical System Overview

The primary source for the building addition heating is provided by the existing hospital steam system. The low pressure steam system will employ heat exchangers to provide building reheat, preheat, perimeter heating, and domestic water heating. The steam connection will originate from the existing basement below the proposed MRI space. The primary cooling source will be a new 155 ton air-cooled chiller. The chilled water system is a variable primary flow type.

The central air handling system will be served by two modular air handling units. Phase 1 will be provided by a rooftop packaged DX unit containing a steam preheat coil and direct expansion cooling coil, provided by existing steam plant and air cooled condensing unit respectfully. Phase 2 will employ a roof mounted chilled water air handling unit containing a hot water preheat coil and chilled water cooling coil, supplied by a steam-to-water heat exchanger and air cooled chiller respectfully. Both will be variable air volume, supply return type, controlled by minimum outside air monitoring and airside economizer control. Humidifiers are included within the units, and supply and return fans are driven by variable frequency drives. Phase 1 will have electric reheat coils at each zone, while Phase 2 will utilize terminal supply boxes with hot water reheat coils.

Mechanical system first cost was estimated at $2,965,365, or $73.95/SF of total building area. The Phase 1 mechanical cost per square foot is significantly higher than the Phase 2 cost, $158.13/SF versus $68.21/SF, respectively.

The current design utilizes no form of exhaust air energy recovery and is therefore not in compliance with ASHRAE 90.1 - 2013. This is because as of July 1, 2014, Massachusetts adopted ASHRAE 90.1 – 2010 which states that there are no exhaust air energy recovery requirements when there is less than 30% outdoor air. Therefore, the addition satisfies the state code, but does not satisfy the more stringent requirements of ASHRAE 90.1 – 2013, which states that an exhaust air recovery system is required. The proposed design plans to enact a design that does comply with this standard.

For a more comprehensive evaluation of the current mechanical design including design considerations, energy consumption, and a LEED evaluation, please refer to Technical Report 3.

Alternatives Considered

To improve upon the current mechanical design of The Morton Expansion, several alternatives were considered. The following investigations considered the impact on overall energy savings, first and operating cost, controllability, and system feasibility:

- Energy Recovery
  - Enthalpy wheel
  - Runaround Coils/Heat Recovery Coils
- Chilled water distribution
  - Tapping into the existing building plant
  - A new water cooled chiller with cooling tower
- Ground Coupled Heat Pumps
- Variable Refrigerant Flow
- Displacement Ventilation/Underfloor Air Distribution
- Dedicated Outdoor Air System for Ventilation
- Photovoltaics
- Solar Domestic Hot Water

Because of time constraints and limited information provided, some alternatives cannot be evaluated. Since obtaining the existing building drawings and documents is not possible, an evaluation of the chilled water plant would not be accurate. Also, ASHRAE 170 – 2013 Table 6.7.2 *Supply Air Outlets* only permits the use of vertical discharge floor diffusers in single patient rooms. Considering the hospital is a single story, UFAD would require the floor to be raised, and would not be a practical solution. The main focus of the redesign will be on the use of a water cooled chiller, energy recovery, and evaluating the benefits of ground coupled heat pumps versus various VRF systems.

Proposed Redesign

An analysis of four systems will be evaluated: the current system, a water cooled chiller (WCCH) with no additional changes, variable refrigerant flow in conjunction with WCCH, and ground coupled heat pumps in conjunction with WCCH. All three alternatives will also evaluate energy recovery systems and grey water usage. These alternatives will be compared primarily based on their first cost, energy usage, and life cycle cost to determine which option is the most practical, while also being sustainable. An important note is that these recommendations are in no way an implication of the insufficiency of the current design of the Morton Hospital Addition, and are only being evaluated for educational purposes.

Depth

Energy Recovery

Considering that Morton is a health care facility, cross contamination must be avoided in critical zones within the addition in order to satisfy ASHRAE 170 – 2013 Section 6.8.3. Therefore, AHU-2 which supplies air to spaces including the ER waiting room, isolation rooms, and operating rooms, must utilize an exhaust air recovery system that ensures the separation of exhaust air with supply air. Runaround coils, or heat recovery coils, is one possibility of a system that does not create cross-contamination. AHU-1, which supplies air to the MRI and supporting spaces, can utilize an enthalpy wheel between exhaust and supply air because those spaces do not have the risk of harmful contaminants within it.

Water Cooled Chiller and Cooling Tower

Currently, Phase 1 cooling is provided by an air cooled condenser supplying a direct expansion coil in AHU-1. Phase 2 is provided by an air cooled chiller supplying a chilled water coil within AHU-2. The basis of the current design was a lower first cost. The proposed plan is to include a chilled water coil in AHU-1, and connect this as well as the AHU-2 chilled water coil to a water cooled chiller. In order to do so, a new cooling tower must also be provided. An evaluation on the increased first cost versus the expected decrease in life cycle cost will be completed.

Also, considering the climate, the use of an economizer with the cooling tower will provide the benefit of free cooling. Not only will this improve the life cycle cost, but will also result in a lower overall energy use. Another method of decreasing energy usage is to evaluate the benefits of using grey water within the cooling tower.

Ground Coupled Heat Pumps

A ground coupled heat pump is a system that transfers heat from the ground, using the earth as a heat source in the winter and a heat sink in the summer. The average ground water temperature of Massachusetts ranges from 47-55 °F 15 feet below the surface, providing an optimal nearly constant temperature. Compared to a conventional system, GCHP increases efficiency and reduces operational cost of the heating and cooling system. However, the initial cost is expected to drastically increase because the excavation of a well field increases construction cost and duration. An analysis of the life cycle cost will be completed in order to weigh the benefits of GCHP over a conventional system.

Variable Refrigerant Flow

VRF systems have many advantages over the typical VAV system and DX system design that Morton currently has. Mainly, the increase in controllability and efficiency, and decrease in energy consumption and footprint. This system allows for operation at varying speeds, therefore only supplying as much refrigerant as needed to a specified zone. This is done with the use of an inverter driven compressor that varies motor speed to precisely meet all zone load requirements, reducing power consumption. Utilizing heat recovery VRFs allows each zone to heat or cool while the internal heat recovery reduces the compressor load. A VRF system can allow patients to set their own temperature to individualize comfort. In addition, VRF systems have small footprints, and do not require ductwork which would greatly free up plenum space.

Another aspect that must be evaluated is how outside air minimum requirements will be met. Because of the spaces that require 100% exhaust air, a DOAS is needed for those zones, discussed below. This DOAS will also supplement the VRF system OA requirements.

As well, an evaluation of ASHRAE Standard 15 – *Safety Standard for Refrigeration Systems* will be done to ensure compliance.

Dedicated Outdoor Air System

Many critical spaces within the addition require 100% outside air, including the ER waiting room and isolation rooms. Because of this, these spaces will not utilize the VRF technology, and will employ a DOAS AHU in conjunction with a heat recovery system, as described above. Because of the VRF technology, the AHU size will drastically decrease compared to the original design.

Breadth

Structural

The addition of a cooling tower located on the roof of the addition requires a reevaluation of the roof structure. This is a large increase in the dead load that the roof must be able to support. Currently, the roof includes a light colored membrane roof over rigid insulation on a concrete and metal deck roof slab.

Construction

Implementing a ground coupled heat pump system requires an extensive amount of additional construction time and cost in terms of excavating the well field. This well field will most likely be located beneath the hospital parking lot. An analysis on whether this is a cost and time effective system will be done. This will be completed by developing a modified construction schedule to evaluate its impact on overall construction time and a modified schematic design estimate to evaluate its impact on overall construction cost.

Masters Coursework

The proposed alternatives will include aspects from the MAE coursework. Utilizing a water cooled chiller and cooling tower will use knowledge from AE 557 – Centralized Cooling Production and Distribution Systems when evaluating chilled water systems and cooling tower selection. Also, when implementing a VRF system, knowledge from AE 557 will be used to determine the impact of refrigerants. Knowledge from AE 552 – Indoor Air Quality will also be used to evaluate the hospital's possible ventilation systems.

Tools

Energy Modeling

IES Virtual Environment will be used to examine the mechanical systems in more detail. Both a load simulation and energy analysis will be completed using this software. First it will be used to model the current design, and then will be modeled to evaluate both a ground coupled heat pump system and variable refrigerant flow system to determine which system will be the most appropriate considering efficiency, energy consumption, and operating cost.

Construction Cost and Schedule

RS Means will be used to develop the schedule for constructing a ground coupled heat pump system. It will also be used to determine excavation/installation costs. The schedule will determine whether a GSHP system has an impact on the current dates of construction, while the cost will be evaluated on whether it has a large impact on the overall cost of the project.

Schedule

The current progress schedule for Spring 2015 can be found in Table A-1 of Appendix A. Milestones were set to keep in check with the overall project goals and are as follows:

- Milestone #1 – January 23: Completed preliminary research, existing IES Model developed, and CPEP up-to-date

- Milestone #2 – February 14: Completed IES model for the proposed redesign, chilled water plant redesign complete, and VRF/GSHP design in progress
- Milestone#3 – March 9: VRF/GSHP design complete, structural & construction breadth complete
- Milestone #4 – April 3: Completed cost analysis. Only revisions on final report and final presentation are needed.

Research

Ninomura, Paul, Chris Rousseau, and Tyler Ninomura. "Current Trends for Health-Care Ventilation." *ASHRAE Journal* 56.4 (2014): 32-42. Print.

The technical feature found in the April 2014 ASHRAE Journal discusses the updates to ASHRAE Standard 170, Ventilation of Health Care Facilities – 2013, and how they are applicable to designing efficient ventilation in hospitals. Changes include a lower humidity limit, energy recovery that avoid cross-contamination, displacement ventilation applications, etc. These notable changes account for the constant evolution of health care design. The original design of Morton was based on the original 2008 standard, and these new previsions have all been considered in the redesign of Morton.

Turpin, Joanna R. "Alternative HVAC Systems Popular in Hospital Applications." *AchrNews*. N.p., 3 Nov. 2014. Web. 15 Jan. 2015.

This article discusses the issues in designing a system for a hospital considering the need for it to be run continuously, and provide patient comfort. Specifically, Turpin outlines systems including VRFs, air curtains, and GSHPs. A VRF system can provide individualized comfort in patient rooms, while also saving energy. Other benefits include quiet operation, and easy maintenance. The use of VRFs greatly reduces the mechanical system footprint, making it easier on the contractor.

Vaughn, Michael R. 2014. “Lessons learned from ASHRAE HQ renovation.” *ASHRAE Journal* 56.4:14-30. Print.

Michael Vaughn discusses the successes and lessons learned from the ASHRAE HQ Renovation after more than five years of occupancy. With regards to the relevance to the Morton Hospital proposed redesign, he examines the first floor system: VRF heating and cooling, second floor system: GSHP heating and cooling, and the ventilation system: DOAS. One of the biggest lessons learned was that the VRF system will have optimal performance when the VRF manufacturer and building automation manufacturer have previous experience together. Or if the VRF system had its own built-in controls, it would perform best. Overall, the renovation cooling capacity is 100 tons: 40 ton capacity DOAS system, 28 ton VRF system, and 32 ton GSHP system, compared to the previous 70 ton air-cooled chiller.

References

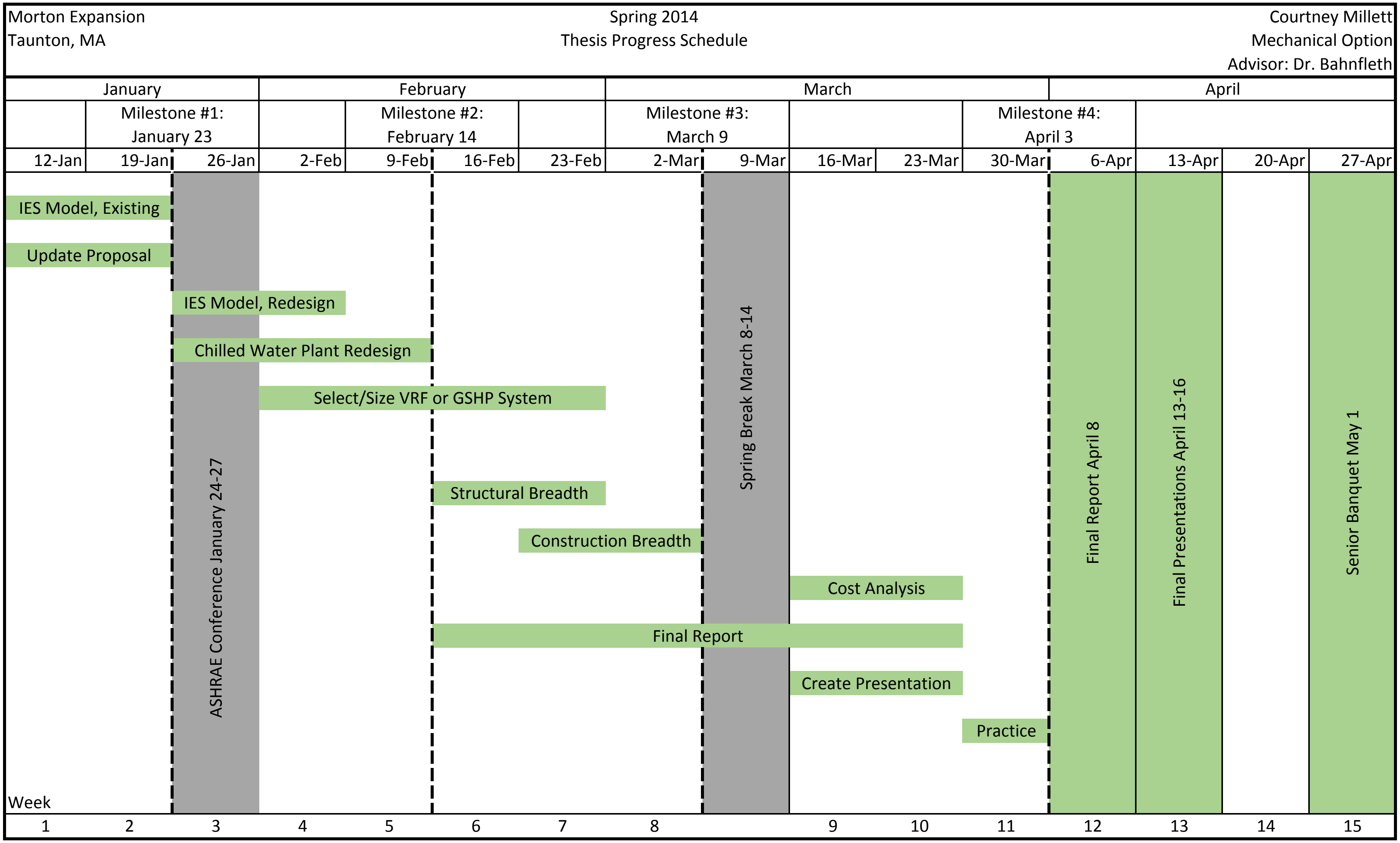
Afify, Ramez. "Designing VRF Systems." ASHRAE Journal 50.6 (2008): 52-55. Web. 9 Dec. 2014.

ANSI/ASHRAE/IES Standard 90.1 – 2013, Energy Standard for Buildings Except Low-Rise Residential Buildings. Atlanta, GA: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

ANSI/ASHRAE/IES Standard 170 – 2013, Ventilation of Healthcare Facilities. Atlanta, GA: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

ASHRAE Handbook – 2009, Fundamentals. Altanta, GA: American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc.

Appendix



Milestones
1: Completed preliminary research, existing IES Model developed, and CPEP up-to-date
2: Completed IES model for the proposed redesign, chilled water plant redesign complete, and VRF/GSHP design in progress
3: VRF/GSHP design complete, structural & construction breadth complete
4: Completed cost analysis. Only revisions on final report and final presentation are needed.