THESIS PROPOSAL:

Mechanical System Redesign and Breadth Topics

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INOVA South Patient Tower
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Executive Summary

The South Patient Tower at the INOVA Fairfax Hospital Campus is currently served with four (4) main air-handlers supplying a constant air volume system. To support the air-handling cooling and heating coil loads, the tower gets chilled water and steam from a district plant located on the hospital campus grounds. The steam is used in heat exchangers in the building to create the heating hot water requirement for both the heating coils and reheat coils located throughout the building. This steam is also reduced in pressure to serve both the domestic water heaters and the steam dehumidification devices in the air handlers.

Due to the current district cooling plant nearing capacity with the addition of the South Patient Tower loads, a dedicated centralized chilled water plant is being proposed for the building. Having such a plant located within the building to help serve the necessary loads will help eliminate any strain that is placed on the current district plant. This will also serve as an educational investigation into various chilled water plant design techniques. Four alternatives will be considered involving two types of chillers, both electric-driven and absorption, and two pumping arrangements, primary-secondary and variable primary. Through the study of these plants, the most efficient choice will be selected for further study on other energy saving techniques. These techniques have been narrowed down to heat recovery chillers and condensate recovery.

The heat recovery chiller will help the chilled water plant system also produce some heating for the necessary reheating that currently exists in the design. By including the heat recovery chiller it is hoped to show a limited supply of steam to the heating hot water and thus a savings on the use and cost of the steam. Cooling coil condensate return is the other option being investigated to help reduce the use of water for the cooling tower makeup. Condensate will be collected from the air-handler cooling coils and piped directly into the cooling tower make up. This relatively "pure" water will need little to no chemical treatment before entering the tower and should help reduce the need for outside water purchases.

Along with the redesign of the centralized cooling plant, a study is proposed of how the plant being place on the fifth floor of the building will effect and add to the loads on the concrete structure. Calculations will be performed to resize the floor slab and beams. Also, an electrical feeder study is proposed to calculate the needed feeder and electrical equipment sizes for the additional loads on the building.

The following proposal includes details on the redesigned plant and energy saving additions that includes a description of existing conditions, tools that are expected to be used for analysis, the initial sources of research and a schedule of the redesign process.

Mechanical System Description

Design Criteria

The main design objective of the South Patient Tower was to create a world-class patient bed-tower to help serve the INOVA Fairfax Hospital and its growth towards being one of the top trauma centers in Virginia. In order to achieve this, the hospital is expanding and updating buildings to reach the level of care currently expected from patients and families. From a mechanical standpoint, the designers reached the elevated design goal by providing full redundancy on all the systems put in place. The air-handlers are on a loop system and headered together to help serve the various loads of the hospital under normal conditions. If the building were to lose an air-handler due to failure or maintenance, the redundancy would help maintain the load. Since the building is connected to a campus loop system, redundancy is already built in with the additional loads picked up by new equipment in the plant.

Designers were influenced by the existing hospital when approaching the design of the tower. Since this building will be an addition to the current patient tower, the mechanical systems were designed to maintain the appropriate air pressure relationships with the existing tower systems. To ease connections between the new and old buildings, the architect kept a tight floor to floor height which influences the design of the mechanical distribution systems. It should be noted that no design strategies were based upon rebates or tax relief.

Due to the nature of the patient tower, a great deal of the thermal and energy loads can be attributed to the lighting and hospital equipment in operation. Both of these are fairly constant as the hospital is a 24 hour operation. The loads that can be seen as variable are due to infiltration, solar gain, conditioning of ventilation air and the mechanical equipment.

The outside air fraction for the systems in the South Patient Tower well exceeds the required percentage by ASHRAE 62.1. The design is maintained at 40% outside air, with the hopes of improved air quality with increased air changes. The minimum ventilation rates used by the design engineers exceeds what is recommended in both ASHRAE 62.1 and ASHRAE 170, which helps to show a concern for proper quality of air in the tower.

Loads due to solar gains were design considerations for the South Patient Tower due to the fenestration being located largely on the southern facing facades of the building. A design goal of the tower was to provide adequate day lighting to help the healing process in each of the patient rooms. Also large expanses of glass exist around the two-storied atrium entry lobby on the South and Southwest sides of the building, which contribute to the cooling load. To provide heating in the winter months due to the large fenestration, designers placed reheat coils on perimeter zones as well as fin-tube radiators in the lobby area.

Operation of the mechanical equipment contributes the most to the overall energy consumption of the South Patient Tower. This can be partly attributed to the oversized equipment selections; however this oversizing was done with good intent to help maintain redundancy, reliability, and indoor air quality rather than efficiency. The approach the designers took is understandable due to the goal of a world-class healing and recovery facility.

Design Conditions

The INOVA South Patient Tower is located in Falls Church, VA. To estimate the weather data, values were taken from ASHRAE Fundamentals 2009 for Washington, D.C. Reagan Airport. A brief summary of the data inputs for the TRACE weather data can be seen below in ***Table 1***.

Table 1: Weather Conditions

Washington, D.C. Reagan Airport	
Latitude	38.87N
Longitude	77.03W
Heating DB (99.6%)	16.3 F
Cooling DB (0.4%)	94.3 F
Cooling WB (0.4%)	76.0 F

The thermostat set points do not vary throughout the hospital. The thermostats are located in the room and the drift points were not specified, rather assumed in previous analyses. ***Table 2*** below summarizes the set points for heating and cooling for the South Patient Tower as determined by the mechanical designer.

Table 2: Summary of Thermostat Settings

South Patient Tower Temperature Set Points	
Cooling Dry Bulb	72 F
Heating Dry Bulb	72 F
Relative Humidity	50 %
Cooling Drift Point	81 F
Heating Drift Point	64 F

Mechanical Equipment Summary

The primary heating, air-conditioning, and ventilation for the South Patient Tower is done through a constant air volume system with four (4) 50,000 CFM air-handlers located in the fifth floor mechanical space. These units are coupled together in a loop system to serve all areas of the tower excluding the kitchen and the electrical and IT rooms which are served by separate air handlers or fan coil units. Natural redundancy is built into the system through the coupled system which allows every air-handler to provide air to all diffusers in the tower. Cooling is provided by connection to the existing campus loop for the hospital. The chilled water enters in the basement and is delivered by a riser to the 5th floor mechanical space.

Rooftop air-handlers (AHU-5 and AHU-6) provide the necessary heating, air-conditioning and ventilation for the kitchen in the South Patient Tower. AHU-5 is a 100% outdoor air make-up unit serving the kitchen hoods only. AHU-6 provides the necessary supply and ventilation air for the kitchen. Each is served from the campus loop cooling system and heating hot water system for cooling and heating purposes. Both units are located on the low podium roof (second floor roof).

On the heating side, the building is served from the campus steam loop. Located in the basement are three (3) 715 GPM steam to hot water heat exchangers, which provide the heating hot water for the air-handlers and reheat coils in the tower. The hot water is circulated through the building by three (3) 715 GPM pumps that supply 60 feet of head. These pumps are served with variable frequency drives (VFDs). Additional recirculating pumps are provided for necessary distribution to the reheat coils on each floor.

System Evaluation

The constant air volume method of meeting space loads has been used for many years with varying success. It was utilized in the South Patient Tower due to it being an addition to the existing patient tower which also applied constant air volume. This helps maintain the appropriate pressurization that is required in a hospital setting. The first cost of the mechanical system is approximately **$10 million** or about **$42/SF**.

The only major equipment in the building mechanical systems are the air-handlers and heat exchangers which have a proposed long-term maintenance or 10 plus years. Routine maintenance will be necessary for the air-handler filters, HEPA filters on the exhaust, cleaning the coils, sensor re-calibration, and any unforeseen maintenance such as a burned up fan or pump or a problematic control value.

One downfall that seems to be apparent when constant air is used in a hospital setting is the ducted supply and returns causing usable space to be eaten up by shafts and associated equipment. A potential solution would be to investigate a system such as a hydronic system to help with space utilization and allow the hospital to use that saved space due to the decreased duct sizes for additional rooms or service areas.

Another drawback of this system is the use of reheat coils at the terminal boxes. This provides an extra load on the heating hot water portion of the system and although created via steam to water heat exchanger, savings could be found in the steam plant for the entire hospital. Economically, reheating the already conditioned air seems wasteful.

Proposed Alternatives

As previously determined the South Patient Tower currently is made up of a constant volume air system and supplied from a district cooling and steam plant for cooling and heating needs. The following includes alternative designs to limit or eliminate the use of the district utilities of steam and chilled water.

Chilled Water Plant Design

The district chilled water and steam plant of the INOVA Fairfax Hospital is reaching its design capacity with the addition of the South Patient Tower. To help solve this issue, a centralized cooling plant is being proposed to serve only the South Patient Tower loads. An investigation will be made into the design of a plant which will include; the type of chiller (absorption vs. electric compressor) and the pumping arrangement (primary-secondary vs. variable primary flow). This investigation will be done using an economic analysis along with showing energy usage and emission differences between the system designs, ultimately using these factors to determine the best option for further study.

The existence of high pressure steam supply to the building, the use of absorption chillers may prove to be the more efficient option limiting the use of electricity by the device. However, the cost of the steam generation may prove to be higher than that of purchasing electricity and the electric compression chiller may be the best choice.

Once the most optimal system arrangement is selected, a further investigation into energy savings will be investigated. This will serve as both a technical study and an education study into chilled water plant design.

Heat Recovery Chiller

The first proposed investigation into additional energy saving techniques includes the implementation of a heat recovery chiller for the South Patient Tower plant. The heat recovery chiller will help supplement the creation of hot water from the steam to hot water heat exchangers, thus limiting the amount of steam required for heating. Heat recovery chillers can produce 130 F water, which is sufficient to supply the buildings heating hot water needs. By adding the heat recovery chilled and limiting the need for steam from the district plant, cost savings are expected to overcome the additional first costs associated with the device.

Condensate Recovery

In an effort to conserve the usage of water by the cooling towers associated with the new chilled water plant design, a condensate recovery system is being proposed. Condensate from the cooling coils will be collected and pumped back to help feed the cooling tower make-up water. Cooling towers use make-up water during operation due to losses from evaporation and drift. If the condensate can help make up just a small portion if not more of the make-up water significant water consumption savings can be seen. The cost of this system is relatively low and is expected to pay back quickly with the water savings.

Breadth Topics

Structural

The South Patient Tower's mechanical space is placed on the fifth floor of the building to help conserve space on the roof for a helipad. To help conserve this necessary roof space, it is being proposed to place the new chilled water plant in this mechanical space on the fifth floor. This will create various new structural loads that need to be adjusted. An investigation into the structural concrete redesign is being proposed to mesh with the newly placed chilled water plant by recalculating the loads on the structural members.

Electrical

With the increased large equipment being added with the new chilled water plant redesign, the electrical load will be affected. To investigate the changes, a study will be done into the feeder sizes of the electrical system and resizing will occur for the new loads. The feeders will be resized from the fifth floor back to the building's main switchgear and a sizing calculation will be done on all equipment that supplies this branch of the electrical system.

MAE Course Relation

The requirement for the Master of Architectural Engineering program is the direct relation of the redesign to 500-level course studies. A major portion of the system redesign will be related to the AE 557, Centralized Cooling Production and Distribution Systems subject matter. The course centers on the comparison between various cooling plant equipment and the primary/secondary pumping and variable primary flow arrangements, as well as discussing the benefits and downfalls of each system.

Tools for Analysis

Load/Energy Modeling

Trane TRACE 700 will be used to determine the South Patient Tower's annual energy consumption. TRACE will be used to determine existing loads to help with sizing of chilled water equipment. TRACE will also be used to do energy modeling of the new system designs and help with the life cycle cost analyses.

Engineering Equation Solver (EES)

EES is a complex equation solving program with built-in material properties that allows for accurate solving of various processes that occur in mechanical systems. EES, along with Microsoft Excel, will aid in the determination of the pumping and chiller configurations in the new plant design. It will also help with the modeling of the condensate recovery and heat recovery chiller.

AutoCAD

AutoCAD will be used to develop new flow diagrams for the chilled water plant and the various pumping arrangements. Due to the plant being developed these flow diagrams and schematics will help with the modeling aspect of the various system components.

Codes/Standards

Codes and standards such as ASHRAE Standard 90.1, the International Mechanical Code, and the LEED Checklist will be used during these studies in order to assume the South Patient Tower's compliance as well as to meet certain objectives of the studies.

Preliminary Research

Avery, G. "Improving the Efficiency of Chilled Water Plants." ASHRAE Journal. (May 2001): 14-18.

This article discusses the options for chilled water plant optimization and increasing the efficiency of the plant as a whole. It discusses the various styles of pumping and pros and cons for each. This source provides more information on improving plant design that will be useful when designing the chilled water plant.

Rishel, James B. "Reducing Energy Costs with Condensing Boilers & Heat Recovery Chillers." (March 2007):46-53.

This article describes the implementation of a heat recovery chiller to help serve cooling loads in the winter and heating loads in the summer. It also explains the costs associated with the system and the potential energy savings that can occur.

Taylor, S. "Primary-Only vs. Primary-Secondary Variable Flow Systems." ASHRAE Journal. (February 2002): 25-29.

This article discusses the pros and cons of primary-only chilled water systems. It includes information about first costs, plant space and pump power consumption as well as chiller staging strategies. This will aid in the design of the new chilled water plant pumping arrangement.

Wilson, A. "Alternative Water Sources: Supply-Side Solutions for Green Buildings." Environmental Building News. (May 2008).

This article describes the various recollection methods of storm water, gray water, and condensate and methods of reuse while maintaining quality required in codes and standards. There is a large discussion on the reuse of air-handler cooling coil condensate in cooling towers due to the high quality of the water and low pollutants. This article will help in the investigation into condensate recovery.

Proposed Schedule