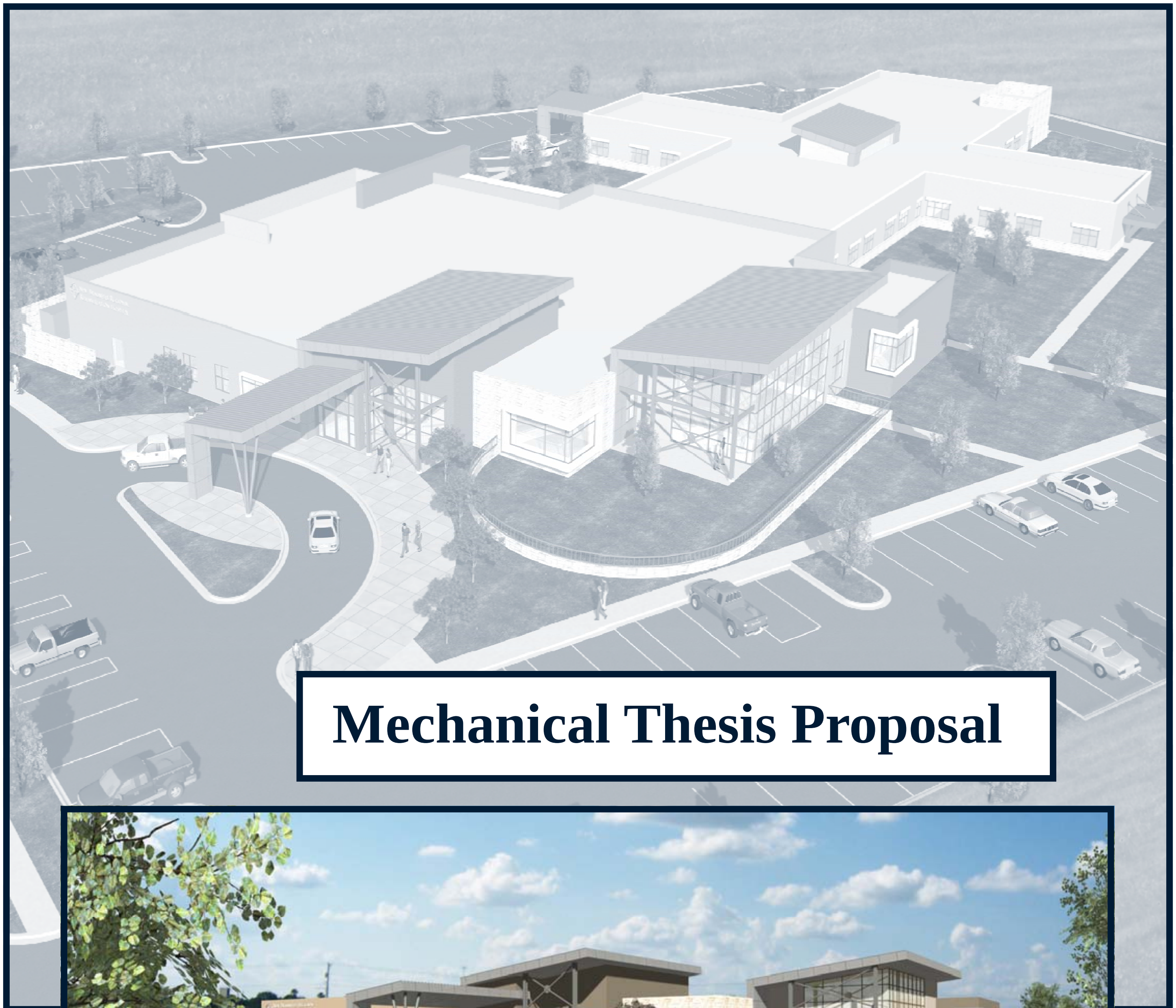

Mechanical Thesis Proposal

New Braunfels Regional Rehabilitation Hospital

New Braunfels, TX

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Mechanical Option

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(1.0) Executive Summary

This report describes the proposed redesign of the mechanical system of the New Braunfels Regional Rehabilitation Hospital (NBRRH). The nearly 50,000 square foot facility began construction in July of 2010 and was completed 11 months later in June of 2011. The building consists of a patient room wing as well as a physical therapy center and administrative, kitchen, and dining functions.

The existing mechanical system consists of three air-cooled rooftop air handling units that utilize gas-fired furnaces for heating. Air is distributed to variable air volume terminal units with zone level reheat. This reheat is served by hot water from two non-condensing boilers located in the southwest mechanical room. Additional equipment includes a 100% outdoor air makeup air unit for the kitchen and dining area of the building and a specialized pool dehumidification unit in the therapy pool area.

The proposed redesign outlined in this report aims to reduce the energy consumption of the mechanical systems in NBRRH, minimize the operating cost for the owner, and increase the reliability and controllability of the system for the building occupants. In order to achieve this goal, several alternatives were considered. These alternatives ranged from creating brand new systems by introducing a chilled water plant to reusing and improving the existing equipment by doing things such as water-cooling the rooftop units in place. With attention paid to facility use and size, cost considerations, and climatic conditions, a combination of several different alternatives was decided upon.

In order to increase the controllability of the systems that serve the patient rooms in the building, this thesis will investigate replacing one of the rooftop units with several multi-split systems that will utilize variable refrigerant flow. By doing this, each room can be heated or cooled independently based on the occupant's input. Converting the other two rooftop units to be water-cooled will also be investigated. Converting to multi-split systems in the patient room wing will eliminate some of the zone level reheat boxes, which will change the load on the hot water system. For this reason, converting to condensing boilers will be investigated and different piping arrangements will be explored.

Also included in the mechanical depth studies will be the installation of a solar thermal system, which will utilize solar collectors on the roof of the facility. This system will primarily offset the energy used to heat domestic hot water, but secondary space heating applications or using the therapy pool as a heat sink will be explored. An additional study will also be taken to improve the performance of the building envelope in the therapy pool room. Specifically, this thesis will explore the benefit of placing all structural members and service utilities inside the building envelope in this building region.

Two breadth studies that relate to the mechanical redesign will also be performed. Because of the changing of rooftop equipment, a structural breadth will be used to determine if the roof structure would need to be redesigned based on increased loads or increased vibrations. An acoustical breadth will also focus on the change of mechanical equipment near the patient rooms to see if sound transmission to the patient rooms is noticeably different.

Careful consideration has been taken to determine the extent of the redesign of the mechanical system for NBRRH and to create a reasonable schedule of work. This will allow for a comprehensive study of the proposed system and a thorough analysis of this system compared to what is existing.

(2.0) Facility Description

The New Braunfels Regional Rehabilitation Hospital is a 40-bed, acute-care hospital and physical rehabilitation clinic located about 30 miles northeast of San Antonio, Texas. Managed by Ernest Health, Inc., the nearly 50,000 square foot facility is located on what was previously the Sundance Golf Club. Ernest Health operates 14 similar acute-care hospitals in various regions of the United States.

The hospital sits on a several hundred thousand square foot tract of land with no adjacent buildings. There is a fairly large retaining pond across the street. A birds-eye view of the site before the facility was built and a plan view of after the facility was built can be seen in the Figures 1 and 2 below, taken from the map function of bing.com.

Figure 1: Pre-Construction Birds Eye View

Figure 2: Post-Construction Plan View

(3.0) Mechanical System Overview

(3.1) Heating and Cooling Loads

The design heating and cooling loads for NBRRH were determined by modeling the facility in Trane Trace 700. Design loads were determined through ASHRAE minimum requirements or by typical engineering judgment. The complete space-by-space load calculation process is included in Technical Report 2. Results of the design load estimation yielded significantly smaller heating and cooling loads than what the existing systems are sized for, as seen in Table 1 below. This is likely a result of different assumptions from the mechanical designer and absence of any safety factors in the Trace model.

Table 1: Heating and Cooling Loads

Unit	As Designed		As Modeled	
	Cooling MBh	Heating MBh	Cooling MBh	Heating MBh
RTU-1	913.2	520.0	495.6	241.3
RTU-2	417.6	400.0	387.6	172.1
RTU-3	686.4	400.0	410.4	136.3

Before continuing with any of the proposed system alternatives that are discussed later in this report, the Trace load calculation and energy model will be updated to include safety factors and assume higher loads in some areas of the building. This will be done to ensure that the systems are sized adequately and so that a comparison of existing systems to proposed alternatives will yield straightforward results.

(3.2) Equipment

Packaged Rooftop Air-Handling Units

Three packaged rooftop units supply most of the facility with conditioned air. RTU-1 serves the patient room wing of the facility, while RTUs 2 and 3 serve the patient therapy and dining/ administration portions of the building, respectively. A 100% outdoor air makeup unit serves the kitchen and dining functions in the area served by RTU-3. All of these units are air-cooled and utilize direct, modulating gas-fired heating.

RTUs 1-3 are supplies with factory-mounted variable frequency drives on the supply air and exhaust air fans to save fan energy. These VFDs range from 5 to 40 horsepower and operate at 3 phase and 460 volts.

Rooftop units also contain two sets of filter banks, each with a filter differential pressure transducer. These filters are rated MERV 7 and MERV 14, in compliance with ASHRAE Standard 170.

Pool Dehumidification Unit

A split-system, air-cooled dehumidification unit maintains occupant comfort at 50%-60% relative humidity in the therapy pool area. This system is automatically controlled to dehumidify the pool room while recycling latent energy back into the pool water and air. By doing so, the pool water heating and space heating requirements are reduced.

Heating Hot Water Boilers

Zone-level reheat in the VAV terminal units are served by hot water from two gas-fired boilers located in the mechanical room. These non-condensing boilers utilize a Cupro-Nickel heat exchanger and have a glass-lined cast iron lining to limit the common erosion problems associated with Texas's hard water. Each boiler exceeds the less than 10 ppm NOx emission requirement of the Texas Department of Health Services.

Domestic Hot Water Heaters

Two gas-fired commercial water heaters serve the domestic hot water load of NBRRH. Each unit operates with 96% thermal efficiency that results from a glass-lined tank that prevents lime scale buildup and reduces associated energy losses.

(3.3) System Energy Consumption

There currently exists no data on the annual energy consumed by NBRRH because the facility has only been occupied for six months. Additionally, the mechanical designer did not perform an energy analysis that attempted to model the facility's energy consumption because of the accelerated project schedule. In order to accurately model the system energy consumption, an energy analysis will be performed using an updated Trane Trace model, as discussed earlier. The result of the energy analysis using an updated model is more likely to be an accurate representation of energy consumed by the existing system.

If the same design parameters and load assumptions are used in the energy model of the proposed alternatives as in the existing model, an energy-focused comparison of the two systems will yield useful results in determining whether or not the alternative will produce energy savings.

(3.4) Mechanical System Evaluation

The mechanical system currently being used by the New Braunfels Regional Rehabilitation Hospital adequately meets all space heating, cooling, and ventilation requirements as well as maintains proper indoor air quality and relative humidity required for a medical facility. Many choices made in system design were made with an accelerated schedule and strict budget in mind.

While the system currently performs the required functions for the building occupants, it is worth looking at alternative systems to investigate possible energy or operating cost savings.

(4.0) Alternatives Considered

Several components of the mechanical system could be redesigned to minimize operating cost and energy consumption or to improve the reliability and controllability of the systems. A list of redesign options that were considered are shown in the list below.

- Introducing a chilled water system
- Converting the existing rooftop units to be water-cooled
- Converting to energy-efficient condensing boilers
- Using several multi-split units with variable refrigerant flow (VRF)
- Installing radiant panels or chilled beams in non-critical spaces
- Lowering the ceiling in patient rooms to reduce ventilation requirements
- Using a solar thermal system for domestic hot water heating
- Improving the building envelope that encloses the therapy pool

Many of these alternatives will be investigated further for this thesis. Some system changes will only be made to certain parts of the facility while other changes affect the entire building system. The alternatives that will be explored were chosen with practicality, integration to other systems, and sustainability in mind.

Due to time restrictions, a few of the considered alternatives will not be investigated. Installing a chilled water system may not be a practical redesign for this particular building due to space and first-cost limitations. A chilled water system should be explored for a larger facility with higher cooling loads. Additionally, installing radiant panels and supplementing with a dedicated outdoor air system was not further investigated due to concerns of system control and reliability as well as first cost limitations.

(5.0) Proposed Redesign

The following alternatives were considered the most appropriate for the New Braunfels Regional Rehabilitation Hospital based on building function and geographic location. Several areas of the redesign were also chosen for the educational benefit of learning about these systems in depth.

The following alternative suggestions do not imply in any way that there is anything wrong with the existing systems. These are merely to investigate potential operating cost or energy savings that could be realized with different systems.

(5.1) Multi-Split Systems with VRF

Multi-split systems utilize one external condensing unit or heat pump connected to several indoor terminal units. When these systems use variable refrigerant flow, the system becomes very versatile by allowing the individual indoor units to heat or cool independently of one another. These systems tend to be good options for buildings with small spaces that have varying requirements.

Replacing RTU-1, the existing rooftop air handling unit that serves the patient room wing, with several multi-split units will increase the controllability of each individual patient room. The reliability of space pressurization is also improved with a constant air volume system in these areas. There is also a potential for energy savings associated with switching to a multi-split system in this area of the facility, including eliminating gas-fired heating and eliminating zone-level reheat coils.

Replacing one large rooftop unit with several smaller external units will change the loads on the roof and possibly have acoustical implications due to potential vibration of the new units.

(5.2) Therapy Pool Envelope Redesign

The building envelope design can affect several aspects of the mechanical system, including heating and cooling loads and indoor environmental quality. Several envelope configurations will be investigated and analyzed psychrometrically to determine the highest performing envelope design.

The location of the envelope will also be considered. Locating all structural and service components inside the envelope can prevent issues of exterior condensation on these elements and the movement of contaminants to other areas of the facility.

(5.3) Condensing Boiler Investigation

Condensing boilers are fundamentally the same as conventional boilers except for the fact that the latent heat from waste gases that result from the combustion process is recovered for an increase in boiler efficiency. The tradeoff between first cost and annual energy savings due to the increased boiler efficiency will be investigated to determine the simple payback period of choosing condensing boilers for NBRRH.

Additionally, the elimination of the reheat coils in the patient room wing will change the load on the boilers and the hot water piping system, so different hydronic configurations will be explored.

(5.4) Converting to Water-Cooled DX Units

The physical therapy and dining/administration regions of the building contain larger spaces where a multi-split system might not be viable option. Room pressurization is not as critical in these areas, so the issues of pressurization control associated with the variable air volume system are not unacceptable for these areas. For this reason, this thesis project will not change the airside of these systems and will investigate converting the condensers in the existing rooftop units to be water-cooled instead of air-cooled. While this change will increase system first cost, there are significant energy savings associated with using evaporative cooling.

(5.5) Solar Thermal System

Harnessing solar energy to primarily offset the domestic water heating load, which can be relatively high for a medical facility, will be investigated through the installation of a rooftop solar thermal system. Secondary functions of the solar thermal system could include using additional heating capacity for space heating or using the therapy pool as a heat sink.

Several different configurations exist for solar thermal systems, and an in-depth analysis will be used to determine the most practical and efficient system. Different solar collectors will be examined, including evacuated tubes and flat plate collectors. Temperature can be modulated in various ways as well, including having an anti-freeze based system or eliminating the anti-freeze and installing a drainback system. All of these options will be studied for this alternative design.

(6.0) Breadth Studies

Acoustical Breadth

The changes made to all of the rooftop air handling equipment could potentially have significant implications to the architectural acoustics of the building. Because the system supplying air to the patient rooms is being decentralized and there will be an increase in hydronic piping, there will likely be higher sound propagation into the patient rooms.

An acoustical analysis will determine whether this change in air-borne and structural-borne noise will be significant, based on room noise criteria (NC) levels and will investigate potential ways to counteract the increase in room noise. These measures could include vibration isolation or changing wall construction to either minimize sound transmission or flanking noise.

Structural Breadth

The changes made to all of the rooftop air handling equipment could potentially have significant implications to the architectural acoustics of the building. Because the system supplying air to the patient rooms is being decentralized and there will be an increase in hydronic piping, there will likely be higher sound propagation into the patient rooms.

(7.0) Tools for Analysis

Trane Trace 700

To this point, Trane Trace 700 has been used to perform analyses, including economic and energy studies, of the existing mechanical systems, so it will also be used to analyze the proposed alternatives. If necessary, supplemental programs such as Design Builder or eQuest by DOE2 will be used to model the more complex systems.

PolySun Simulation Software

PolySun software offers a solar thermal demonstration program that allows users to plan, design, and design parameters of a solar thermal system. This program yields data in energy savings and provides an economic analysis of the input system. This particular demo program will be used to model the rooftop solar thermal system.

Engineering Equation Solver (EES)

In order to solve complex equations for analysis, Engineering Equation Solver will be utilized. EES has built-in functions for many properties or equations that relate to HVAC system design. Other equation-solving programs may be utilized as necessary.

(8.0) Proposed Schedule of Work

A full schedule of proposed tasks and milestones for the Spring 2012 semester are provided in Appendix B of this report. The first few weeks of the semester will be spend updating and improving the Trace Model as discussed in this proposal and performing initial research on the redesign alternatives. If needed, this proposal and the schedule will be revised in this time period as well.

The mechanical depth studies enumerated in this proposal will then be investigated. The redesign of the therapy pool envelope, while not the most challenging or time-consuming task associated with these depth studies, will be a focus in the beginning of the semester because this could potentially change the other systems that will be investigated.

Breadth studies will be focused on after the depth studies, as they deal with the consequences of the mechanical system design on other facets of the building design. Following spring break in early March, the focus of the schedule is compiling a thorough report and presentation to adequately describe the work performed and the results of the comparison of alternatives.

Appendix A: Preliminary Research

- **ASHRAE (2011). 2011 ASHRAE Handbook - HVAC Applications. Atlanta, GA: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.**

  This handbook describes the design and operation of various HVAC systems. It was used to perform a preliminary investigation of multi-split systems and variable refrigerant volume. This reference may also be useful for the condensing boiler investigation and many other aspects of the design of alternatives.

- **ASHRAE (2008). 2008 ASHRAE Handbook - HVAC Systems and Equipment. Atlanta, GA: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.**

  This handbook considers the equipment that comprises various systems. This reference was used to examine possible alternatives and to determine whether or not they were viable options for the New Braunfels Regional Rehabilitation Center.

- **Caleffi Hydronic Solutions. "Idronics: Solar Thermal Combisystems." Milwaukee, WI. 2009.**

  This journal discusses solar thermal systems in various configurations. This catalog will be one of many references that will be used to select the most appropriate solar thermal system and to design it for the facility.

- **Lstiburek, Joseph W., Ph.D., P.End., Fellow ASHRAE. "In the Deep End." ASHRAE Journal, September 2011.**

  Lstiburek's article, published in the ASHRAE Journal from September, 2011, discusses the challenges of indoor environmental quality management for indoor swimming pool areas. The article suggests several envelope configurations that could be a good starting point for the redesign of NBRRH's therapy pool envelope.

Appendix B: Spring 2012 Thesis Schedule

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