TECHNICAL REPORT 3

MECHANICAL SYSTEMS EXISTING CONDITIONS EVALUATION

New Braunfels Regional Rehabilitation Hospital

New Braunfels, TX

Adam Bernardo

Mechanical Option

Faculty Advisor: Dr. William Bahnfleth

Date Submitted: 11/16/11

Table of Contents

List of Tables

List of Figures

(1.0) Executive Summary

The New Braunfels Regional Rehabilitation Hospital (NBRRH) is a 40-bed, acute-care hospital and physical rehabilitation clinic located approximately 30 miles northeast of San Antonio, Texas. Managed by Ernest Health, Inc., the nearly 50,000 square foot facility is located on a several hundred thousand square foot tract of land that previously held a country club. Several similar acute-care hospitals exist around the nation and are managed by Ernest Health, Inc.

Three rooftop air handling units are used to supply conditioned air to most of the facility. One large rooftop unit serves the entire north wing of the facility, which houses all patient rooms and several other clinical functions. Two smaller units serve the more public dining/administration and therapy/exam areas of the building, which are located in the south portion of the building. Additionally used to provide thermal comfort and ventilation are a dehumidification unit serving the therapy pool and a 100% makeup air unit serving the dining and kitchen areas. Supply air reheat and hydronic water heating is facilitated through the use of hot water boilers. Cooling and dehumidification of supply air is done through direct expansion within each rooftop unit; there is no chilled water being used in the mechanical system. This report includes schematic flow diagrams of the air handling units, heating hot water system, pool dehumidification process, and major components of the plumbing system.

The first cost of the mechanical system, which includes material raw costs and labor estimates, is $1.3 million, which equates to $26.29 per square foot. An annual operating cost cannot be accurately determined because the facility has only been in use for about 6 months. Utility rate structure is known, however, and an annual energy analysis was performed in Technical Report 2. This information has been included in an appendix of this report, but is likely a low estimate of actual energy usage and system operating cost.

NBRRH was designed and constructed in an accelerated process and on a limited budget, so a LEED certification was not attempted for this project. However, several aspects of the mechanical system were designed with the environment in mind. A LEED analysis was performed to determine the number of points the facility could receive from the Energy and Atmosphere (EA) and Indoor Environmental Quality (EQ) categories of the LEED Version 2.2 checklist.

The straightforward system that is being used in the facility allows for a wide range of possible changes or modifications, some of which are mentioned in the conclusion of this report based on the findings of this analysis of systems.

(2.0) Mechanical System Design Requirements

(2.1) Design Conditions

Outdoor Design Conditions

The weather data used to estimate the design heating and cooling loads on the facility came from the 2009 ASHRAE Handbook of Fundamentals. Measurements for this data were taken 32 miles southwest of the New Braunfels Regional Rehabilitation Hospital at the San Antonio International Airport, so these values are assumed to be an accurate representation of the actual weather conditions of the site. A summary of dry bulb and wet bulb design values is included in Table 1 below.

Table 1: ASHRAE Weather Data

Design Condition	Outdoor DB	Outdoor WB	DB Range
Cooling (0.4%)	98.5 ˚F	73.5 ˚F	20.1 ˚F
Heating (99.6%)	27.4 ˚F		

Indoor Design Conditions

Indoor design dry bulb temperatures were determined by the system's mechanical designer for proper occupant safety and comfort. Humidity threshold values for the rehabilitation hospital were obtained from ASHRAE Standard 170-2008: Ventilation of Health Care Facilities. A summary of these design conditions is shown in Table 2 below.

Table 2: Indoor Design Conditions

Zone	Condition	Indoor Design DB	Relative Humidity
Typical Spaces	Cooling	75 ˚F	60% maximum
	Heating	72 ˚F	
Therapy Pool	Cooling	86 ˚F	50% - 60%
	Heating	82 ˚F	

(2.2) Ventilation Requirements

The ventilation requirements for NBRRH were determined through a detailed analysis of ASHRAE Standard 62.1-2007: Ventilation for Acceptable Indoor Air Quality. ASHRAE Standard 170-2008 was also used, in conjunction with Standard 62.1, to assure that the complex ventilation requirements of a medical facility were met. The entire ventilation assessment can be found in Technical Report 1, while a summary of calculated values versus the engineer's design values are shown in Table 3 below.

Table 3: System Ventilation Rates

Unit	As Designed		Calculated Minimum Rates	
	Total CFM	Ventilation CFM	Total CFM	Ventilation CFM
RTU-1	26,000	6,850	12,962	3,730
RTU-2	12,000	2,015	8,789	1,326
RTU-3	17,500	4,550	6,150	2,313

Ventilation calculations for each rooftop unit confirmed compliance with the requirements of Standard 62.1; the minimum outdoor air rates were significantly smaller than what the systems are designed to bring in. The total supply airflow calculated is significantly lower due to assumptions made in the load estimation, as discussed in the next section of this report. The calculated and design outdoor airflow rates are in the 15% - 35% of total airflow range, which is representative of industry standards.

(2.3) 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 this user's best 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 systems are sized for, as seen in Table 4 below. This is likely a result of different assumptions from the mechanical designer and the absence of any safety factors in the Trace model.

Table 4: 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

(3.0) Existing Mechanical and Plumbing Systems

(3.1) Equipment

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. A summary of the rooftop units are shown in Table 5 below.

Table 5: Packaged Rooftop Units

Tag	Airflows			Fans		Cooling MBH	Heating MBH
	Supply CFM	Return CFM	OA CFM	Supply RPM	Return RPM		
RTU-1	26,000	26,000	6,850	1,238	652	913	650
RTU-2	12,000	12,000	2,015	1,508	1,023	418	500
RTU-3	17,500	17,500	4,550	1,478	637	686	500
MAU-1	3,500	-	3,500	2,274	-	128	200

RTUs 1-3 are supplied 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.

Air Terminal Units

Conditioned air is distributed from each rooftop unit to Variable Air Volume terminal units associated with that unit. RTU-1 supplies 58 VAV boxes in the patient-room wing, while RTU-2 supplies 20 VAV terminal units and RTU-3 delivers air to 30 VAV boxes. Each terminal unit is pressure-independent and is controlled by a supply duct temperature sensor. All VAV boxes also contain zone-level reheat, with the exception of the four terminal units that serve electrical or telecommunication rooms.

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. A summary of the dehumidification unit's characteristics are shown below in Table 6.

Table 6: Pool Dehumidification Unit

Tag	Total Airflow	Hot Water Flow	Moisture Removal	Cooling MBH	Water Reheat MBH
PAC-1A/1B	1900 CFM	10 GPM	20 lb/hr	43	56

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. A summary of each boiler's flow and heating capacity are shown in Table 7 below. 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.

Table 7: Heating Hot Water Boilers

Tag	Flow Rate	Input MBh	Output MBH
HWB-1	57 GPM	999	849
HWB-2	57 GPM	999	849

Hydronic Pumps

Two parallel in-line, close-coupled pumps circulate hydronic hot water to the VAV reheat coils throughout the facility. Each pump has a maximum flow of 95 GPM and is furnished with a 5 horsepower variable frequency drive motor for pumping energy savings.

Water Heaters

Two gas-fired commercial water heaters serve the domestic hot water load of the New Braunfels Regional Rehabilitation Hospital. Each unit operates with 96% thermal efficiency that results from a glass-lined tank that prevents lime scale buildup and reduces associated energy losses. Capacity and temperature difference data for these water heaters is shown below in Table 8.

Table 8: Domestic Water Heaters

Tag	Storage Capacity	ΔT	Set Temperature	Input BTUh
WH-1	130 Gallons	100˚F	120˚F	400
WH-2	130 Gallons	100˚F	140˚F	400

Hot Water Circulating Pumps

An in-line, close-coupled pump is headered with each of the water heaters and circulate domestic water to plumbing fixtures throughout the facility. These pumps operate at different flow rates to accommodate the difference in set points of the water heaters.

(3.2) System Operations

Air-Side Operation

As outside air enters each of the packaged outdoor rooftop units, it is mixed with return air via the air-side economizer contained within each unit. The volume of outside and return air that is mixed is based on readings from temperature and humidity sensors located in the outside air duct and return air duct, respectively. This mixed air is drawn through following sections of the air handler by the supply air fan located downstream.

Mixed air then passes through the first bank of filters, which is monitored by a differential pressure transducer (labeled as DPT in Figure 1 below) to ensure the system operator is aware of any flow rate changes through the filter.

Air is then drawn through direct expansion cooling coils arranged in a multi-row, staggered tube configuration. Each unit is equipped with two independent refrigerant loops and interlaced coil circuiting to keep the coils fully active at any load condition.

Cool air then passes through the stainless steel heat exchanger associated with the natural gas fired furnace. The combustion furnace and the combustion air fan are only operational in periods of heating and can modulate between 33% and 100% of the rated capacity.

Conditioned air is then drawn through the supply air fan, which is controlled by a variable frequency drive motor that acts in response to measurements from a pressure sensor in the supply air duct. Supply air passes through a second filter bank before being delivered to each VAV terminal unit. Before return air mixes with outdoor air in the economizer, a portion of air is exhausted via the exhaust air fan, which is controlled through fan tracking.

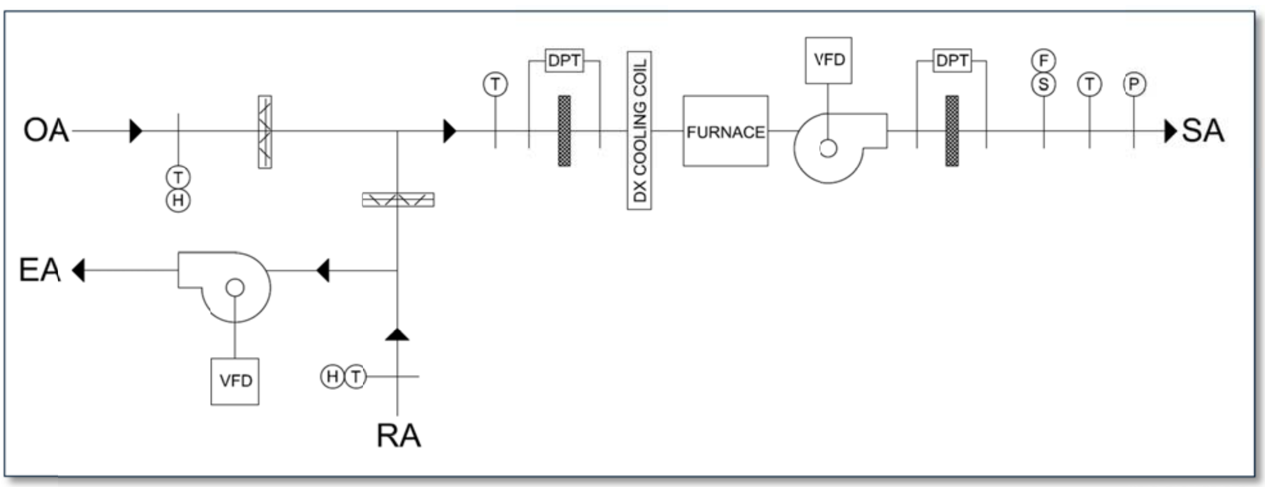


Figure 1: Rooftop Air Handler Schematic

Room humidity level in the therapy pool area is controlled with a specialized pool dehumidification unit that uses vapor compression to both dehumidify air and help heat pool water. Warm, humid air from the pool area passes through the unit's evaporator, causing condensation on the evaporator coil and thus dehumidifying and cooling the air. Refrigerant then gains heat in the compressor before being used to reheat the pool air and then rejecting its remaining heat to pool water to reduce pool heating energy and cost. A schematic of this process is shown below in Figure 2.

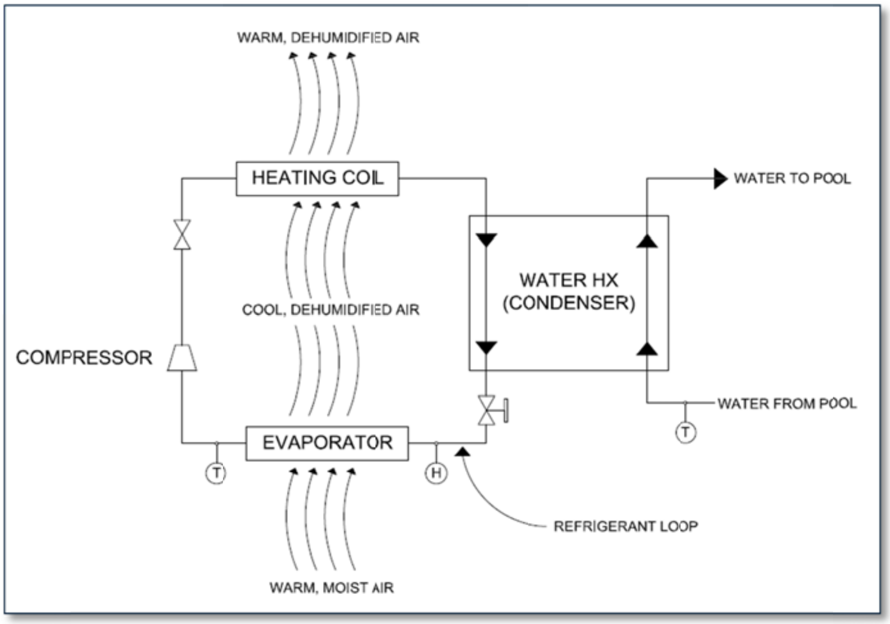


Figure 2: Pool Dehumidification Process

Water-Side Operation

The heating hot water system for the facility utilizes two hot water boilers to heat the primary-secondary loop hydronic hot water system. Heating hot water is primarily circulated through the system by pumps header mounted on each boiler. These pumps are controlled by a boiler control panel that processes differential pressure measurements across space heating loads at various points throughout the facility.

Two auxiliary heating hot water pumps (labeled HP-1 and HP-2 in Figure 3 on the next page) are arranged in parallel and included on the hydronic supply line. Only one auxiliary pump is operational at a given time; both are controlled by a pressure sensor monitor that allows the stand-by pump to ramp up upon failure of the leading pump.

A schematic flow diagram for the hydronic hot water system is also shown in Figure 3. Note that the facility does not currently utilize any chilled water, so there is no central cooling plant included in the facility or this report.

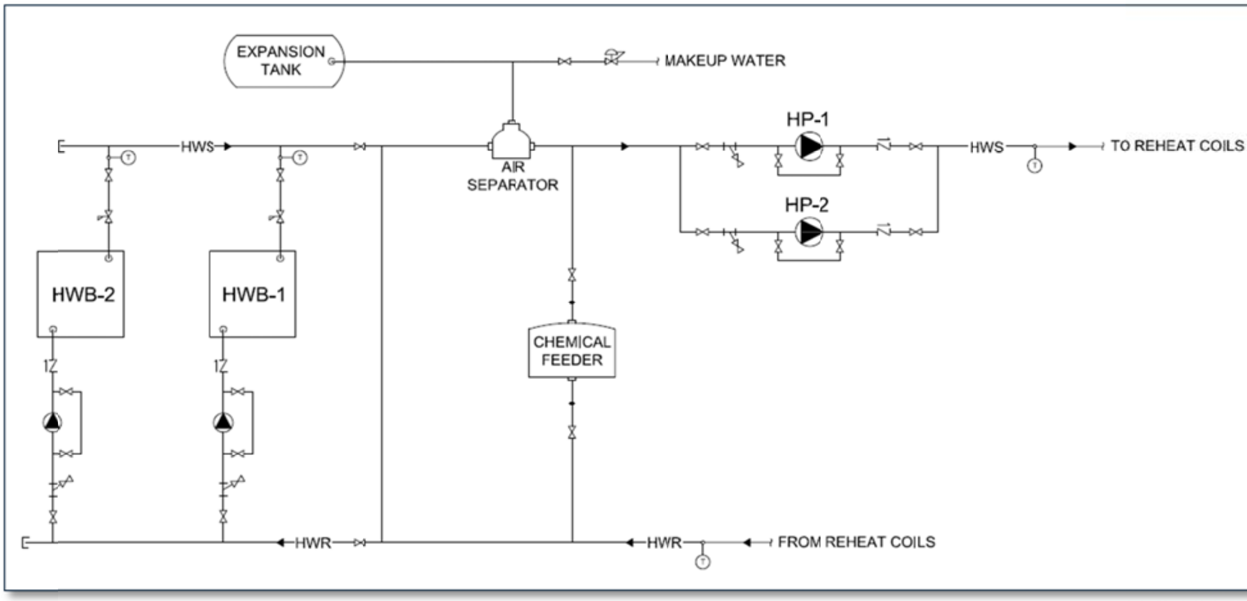


Figure 3: Hydronic Hot Water Piping Schematic

Plumbing Operation

City cold water enters the building and has four possible paths: it could be delivered to the building directly as domestic cold water, be mixed with 140ºF or 110ºF hot water return, or be mixed with 110ºF domestic hot water supply out of Water Heater 1. WH-1 is set to operate at 120ºF and supplies to two three-way mixing valves before being delivered to plumbing fixtures at 110ºF. Water heater 2 supplies high-temperature domestic water directly to plumbing fixtures at 140ºF. A schematic flow diagram of mechanical room plumbing features is shown in Figure 4 below.

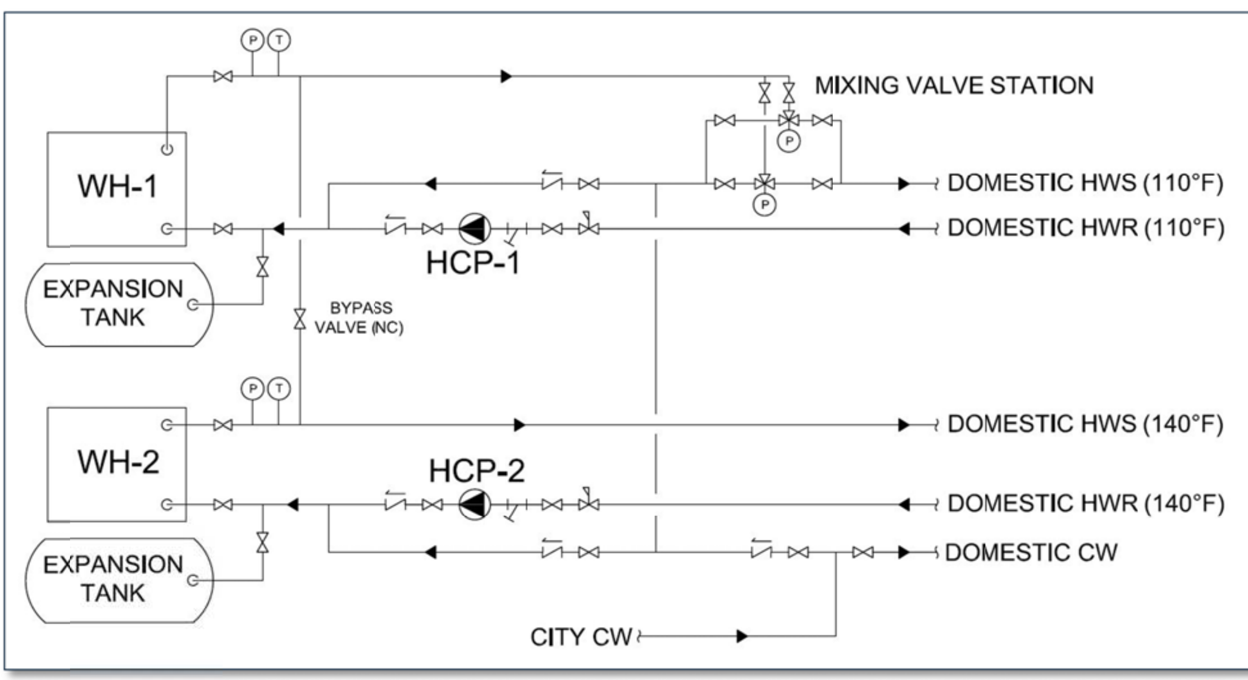


Figure 4: Domestic Water Piping Schematic

(3.3) Space Requirements

The space used by mechanical and plumbing systems is listed below in Table 9. Included in the total lost usable space are the mechanical room, which houses the hot water boilers, domestic water heaters, and all associated pumps. The pool equipment room that contains the pool dehumidification equipment is included as well as medical gas pump rooms and medical gas access rooms.

Table 9: Lost Usable Space

Room	Area (SF)
Mechanical Room	276
Pool Equipment	323
Medical Gas Pump Room	188
Medical Gas Access	99
Total Lost Usable Space:	886

The total space used by mechanical, plumbing, and medical gas systems is only 1.8% of the total building area, which is significantly lower than industry average and may cause space issues when considering system alterations. Not included in this lost usable space calculation are electrical and telecommunication rooms.

(4.0) System Energy

(4.1) Energy Sources and Rates

NBRRH receives electricity and city water from the New Braunfels Utility (NBU) company, which delivers electricity and water to the entire municipality. The utility company designates the rehabilitation hospital as a large general service facility, the rate structure of which is shown for these utilities in Table 10 below. NBU also charges large general service facilities an annual fee of $1,437.53 for potable water delivery.

Also delivered directly to the facility is natural gas for all space and water heating processes. NBU does not deliver natural gas, so an average natural gas price for the state of Texas was taken from Center Point Energy and used for the energy analysis previously performed in Technical Report 2.

Table 10: Energy Rates

Utility	Rate	
	October - May	June - September
Electric Consumption	$0.04 / kWh	$0.05 / kWh
Electric Demand	$4.40 / kW	
Natural Gas	$0.9573 / therm	
City Water	$1.922 / thousand gallons	

(4.2) Energy Use

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. The only available indication of the actual energy used within the facility is the Trane Trace analysis performed in Technical Report 2, a summary of which is given in Appendix B.

While this analysis was fairly comprehensive, it is still impossible to assert these results as accurate due to several assumptions made, the variability of weather conditions, and the limitations of the modeling software available. The heating and cooling loads calculated in this model were significantly lower than what the mechanical engineer designed the equipment to handle, so it is likely that the facility will see higher energy consumption than is shown in Appendix B.

(5.0) Mechanical System First Cost

The total cost of material and labor associated with the mechanical system of the New Braunfels Regional Rehabilitation Hospital is $1.3 million. A breakdown of each component's equipment and labor costs is shown below in Table 11. The two largest contributors to this total include ductwork and mechanical piping, which are very labor-intensive. This total mechanical system cost translates to $26.29 per square foot. Not included in this system cost summary are plumbing, fire protection, and medical gas equipment.

Table 11: Mechanical System Cost Breakdown

Item	Material	Labor	Total
RTUs	$ 199,391	$ 12,000	$ 211,391
Air Distribution Equipment	$ 114,480	$ 18,000	$ 132,480
Ductwork and Insulation	$ 190,277	$ 206,566	$ 396,843
MAU System	$ 91,797	$ 20,000	$ 111,797
Pool Dehumidification Unit	$ 20,757	$ 5,000	$ 25,757
Boilers and Control Interface	$ 23,624	$ 7,000	$ 30,624
Hydronic Distribution Equipment	$ 4,450	$ 7,000	$ 11,450
Mechanical Piping	$ 73,889	$ 155,869	$ 229,758
DDC Controls	$ 44,700	$ 105,200	$ 149,900
Totals:	**$ 763,365**	**$ 536,635**	**$ 1,300,000**

(6.0) LEED Analysis

Leadership in Energy and Environmental Design (LEED) is a rating system developed by The United States Green Building Council (USGBC) to promote the benefits of sustainable building design and construction. The New Braunfels Regional Rehabilitation Hospital did not strive for LEED certification during its design or construction phase due to the accelerated project schedule and cost concerns, but several measures were taken with the environment and energy efficiency in mind.

Energy and Atmosphere and Indoor Environmental Quality are two categories through which a building can gain multiple LEED version 2.2 credits that are particularly important when discussing environmentally-conscious mechanical system design. Each credit in these two categories will be investigated in this report. A more explicit breakdown of how many points each category and credit can earn is included in Appendix C of this report.

(6.1) Energy and Atmosphere (EA)

✓ EA Prerequisite 1: Fundamental Commissioning of the Building Energy Systems

The purpose of this prerequisite is to verify that the facility's mechanical systems are installed to meet the design and construction documents as well as the owner's project requirements. To meet this prerequisite, a Commissioning Authority must oversee the proper installation and of the commissioning activities described in the LEED version 2.2 checklist.

Specification 230800 – Commissioning of HVAC states the Commissioning Authority's responsibilities, which are compliant with this prerequisite.

✗ EA Prerequisite 2: Minimum Energy Performance

The purpose of this prerequisite is to establish a minimum energy efficiency that the building and its systems must meet. In order to meet this prerequisite, the building design must comply with the mandatory provisions and prescriptive requirements of ASHRAE 90.1-2004.

An analysis of Standard 90.1 is included in Technical Report 1, which finds that NBRRH is not completely compliant with the standard's requirements, and thus this prerequisite is not met.

Although the facility will not be able to gain any Energy and Atmosphere credits because this prerequisite is not met, each credit will still be investigated for the purpose of potential future LEED Certification.

✓ EA Prerequisite 3: Fundamental Refrigerant Management

The purpose of this prerequisite is to ensure ozone depletion reduction through the building's use of non-CFC-based refrigerants. No CFC-based refrigerants were used in the facility's systems, so this prerequisite is met.

✗ EA Credit 1: Optimize Energy Performance

Because the facility does not already comply with the baseline building performance prescribed in ASHRAE Standard 90.1-2004, this credit cannot be obtained until improvements are made to bring the building systems to comply with this standard.

✗ EA Credit 2: On-Site Renewable Energy

No techniques are currently used to garner on-site renewable energy, so this credit cannot be obtained. Several renewable energy sources, including geothermal, solar, and hydro, are available on or near the site, so this credit could be obtained through a system re-design.

✓ EA Credit 3: Enhanced Commissioning

Specification 230800 indicates that the Commissioning Agent shall conduct commissioning design reviews at all phases of construction necessary to gain this credit. Additionally, the Commissioning

Agent is required to meet all other requirements of this credit, including having documented experience in two previous projects, and developing a future operating systems manual. This credit would be obtained if all EA prerequisites were met.

✓ EA Credit 4: Enhanced Refrigerant Management

This credit can be achieved with refrigerant performance above EA Prerequisite 3. None of the equipment used in the mechanical system of the facility uses refrigerants, so this credit is achieved with the current system design.

✗ EA Credit 5: Measurement and Verification

There is no measurement and verification plan currently employed in the operation of the facility at the point of five months occupancy, so this credit cannot be obtained for the project.

✗ EA Credit 6: Green Power

Because there is no electricity being generated by renewable resources in the facility, this credit cannot be obtained until a renewable energy source is implemented in system design. This credit could be obtained if future system upgrades are able to provide 35% of the building's electricity through a renewable source.

(6.2) Indoor Environmental Quality (EQ)

✓ EQ Prerequisite 1: Minimum IAQ Performance

The purpose of this prerequisite is to enhance the comfort and well-being of building occupants through proper indoor air quality. In order to meet this prerequisite, the facility must comply with the minimum requirements of Sections 4-7 in ASHRAE Standard 62.1-2004. These sections govern the issues of outdoor air quality, systems and equipment, procedures, and construction and system start-up.

Technical Report 1 includes a detailed analysis of Sections 5 and 6 of Standard 62.1 and determines that NBRRH is completely compliant with those two sections.

Specification section 234100 – Particulate Air Filtration states that compliance with ASHRAE Standard 62.1 Sections 4 and 7 is mandatory. Thus, this prerequisite is completely met.

✓ EQ Prerequisite 2: Environmental Tobacco Smoke (ETS) Control

The intent of this prerequisite is to reduce the exposure of occupants and ventilation air to environmental tobacco smoke. One way to meet this prerequisite is to prohibit smoking in the building and designate smoking areas 25 feet from any air entries, including air intakes.

As a hospital and physical therapy facility, smoking is prohibited on premises and thus this requirement is met.

✗ EQ Credit 1: Outdoor Air Delivery Monitoring

The facility has no system that permanently monitors the ventilation system, so this credit cannot be obtained at this time.

✓ EQ Credit 2: Increased Ventilation

The mechanical system in NBRRH has been designed to provide over 30% additional ventilation air above that require by ASHRAE Standard 62.1, as seen in Table 12 below. Therefore, this credit can be obtained.

Table 12: Increased Ventilation Compliance

Unit	Required OA	130% Required OA	Designed OA
RTU-1	3730 CFM	4850 CFM	6850 CFM
RTU-2	1327 CFM	1725 CFM	2015 CFM
RTU-3	2314 CFM	3010 CFM	4550 CFM

✗ EQ Credit 3.1: Construction IAQ Management Plan: During Construction

An Indoor Air Quality Management plan was not implemented during the construction phase of the NBRRH project, and thus this credit cannot be obtained.

✓ EQ Credit 3.2: Construction IAQ Management Plan: Before Occupancy

An Indoor Air Quality Management plan was implemented in the pre-occupancy phase of the building project. The mechanical contractor performed baseline IAQ testing that demonstrated contaminant levels below the prescribed values in this credit description. These tests were performed to the extent of the requirements outlined in the LEED checklist, so this credit can be acquired.

✓ EQ Credit 4.1: Low-Emitting Materials: Adhesives and Sealants

All water-based sealants and adhesives used in the mechanical system are specified to have a maximum VOC content of 75 g/L (less water) according to Specification section 233113 – Metal Ducts. This is below the maximum VOC content prescribed by this credit, so Credit 4.1 can be achieved.

✗ EQ Credit 4.2: Low-Emitting Materials: Paints and Coatings
✗ EQ Credit 4.3: Low-Emitting Materials: Carpet Systems
✗ EQ Credit 4.4: Low-Emitting Materials: Composite Wood and Agrifiber Products

The emittance properties of the architectural coatings within the facility are unknown, so it is impossible to determine if the facility would achieve Credits 4.2 through 4.4. For the purpose of this hypothetical assessment, it is assumed that these credits would not be earned.

✓ EQ Credit 5: Indoor Chemical and Pollutant Source Control

Permanent entrances to the facility each have vestibules that are at least 10 feet long in the direction of travel, which exceeds the minimum requirement of 6 feet prescribed by Credit 5's requirements. Additionally, all areas with potentially hazardous gases and chemicals (including soiled linen rooms, the laundry room, and medical gas storage rooms) are mechanically exhausted per the minimum requirements of this credit. Filtration of all supply air occurs through both a MERV 14 and MERV 7 filter, which exceeds the minimum MERV 13 requirement.

Because the three minimum requirements of this credit are achieved, Credit 5 can be obtained.

✘ **EQ Credit 6.1: Controllability of Systems: Lighting**

Because of the critical function of several spaces within the facility, individual lighting controls are provided for less than 90% of the facility, which is the minimum requirement to earn this credit. With the current lighting control strategy and the critical functions occurring within the spaces, this credit cannot be obtained.

✘ **EQ Credit 6.2: Controllability of Systems: Thermal Comfort**

As an acute-care hospital, it is important that many spaces be maintained at a relatively constant temperature and humidity level. For this reason, individual comfort controls are provided for less than 50% of the spaces in the facility, so this credit cannot be obtained with the current control structure.

✓ **EQ Credit 7.1: Thermal Comfort: Design**

Credit 7.1 requires that the building's mechanical system provide a comfortable thermal environment by following minimum requirements of ASHRAE Standard 55-2004: Thermal Comfort Conditions for Human Occupancy. Complete compliance with this standard has been achieved, as the mechanical engineer designed the system to comply with this standard. Thus, Credit 7.1 can be obtained.

✘ **EQ Credit 7.2: Thermal Comfort: Verification**

No thermal comfort survey is planned for the building occupants, and thus Credit 7.2 will not be obtained.

✘ **EQ Credit 8.1: Daylight and Views: Daylight 75% of Spaces**

✘ **EQ Credit 8.2: Daylight and Views: Views for 90% of Spaces**

While all of the patient rooms are day-lit, many of the exam, therapy, and procedure rooms contain private or critical functions that are not exposed to daylight. Less than 75% of the spaces in the facility are exposed to daylight and less than 90% have a line of sight to the outdoor environment. Therefore, this credit has not been obtained.

(6.3) LEED Conclusions

A possible combined 32 points is available from both the Energy and Atmosphere (EA) and Indoor Environmental Quality (EQ) categories of the LEED Version 2.2 rating system. Through this analysis, it was realized that all 17 points available in the EA category could not be obtained due to not meeting the minimum energy performance prerequisite. If this had been met, NBRRH would have received 2 points from this category. All of the prerequisites were met in the EQ category and 5 points were obtained through credits in this grouping.

The facility did not strive for LEED Certification, but should the owner decide to renovate the mechanical system, 7 of the 32 points for these two categories have already been achieved. It is important to note, however, that certain changes may require revisiting of previously achieved credits, such as those involving refrigerants.

(7.0) Overall Mechanical System Evaluation

The complete 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 the system design were done so with an accelerated schedule and strict budget in mind.

So, while the system design currently performs the required functions for the building occupant, there are several system design changes that can be made to increase energy efficiency and overall system reliability. One such option that should be explored is the installation of a chilled water system. While this would greatly increase the first cost of the mechanical system, it could significantly decrease the electrical consumption used to cool the building and thus save the owner on yearly operating costs. However, with such a small amount of mechanical space, this could have repercussions on other important areas in the building.

Improvements could be made to existing air distribution and hydronic systems, as well. There exist many new technologies in airside operations, including chilled beams or radiant panels in non-critical spaces. More expensive condensing boilers could potentially save energy to reheat supply air, and different pumping arrangements could be explored.

Additionally, several renewable energy sources could be explored for this particular site. Solar water heating or photovoltaic cells could be utilized in the sunny Texas climate. The tract of land on which the facility sits is large compared to the building footprint, so a geothermal system could also be a viable option.

With a very basic system, such as exists currently in NBRRH, there are many possible alternatives. Those that are deemed to be most effective for the building's loads and functions as well as the geographic location will be discussed further in the coming Thesis Proposal.

Appendix A: Resources

- ANSI/ASHRAE (2010). Standard 62.1 - 2004, Ventilation for Acceptable Indoor Air Quality. Atlanta, GA: American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc.

- ANSI/ASHRAE (2010). Standard 90.1 - 2004, Energy Standard for Buildings Except Low-Rise Residential Buildings. Atlanta, GA: American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc.

- ANSI/ASHRAE (2010). Standard 170- 2008, Ventilation of Health Care Facilities. Atlanta, GA: American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc.

- ASHRAE (2009). 2005 ASHRAE Handbook - Fundamentals. Atlanta, GA: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

- ASHRAE (2007). 2007 ASHRAE Handbook - HVAC Applications. Atlanta, GA: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

- Center Point Energy. Natural Gas and Electricity. 2011. http://www.centerpointenergy.com/services/naturalgas/business/naturalgasprices/energycostcomparison.

- Dekker/Perich/Sabatini. "Architectural Design Documents." Albuquerque, NM. 2010.

- JBA Consulting Engineers. "Mechanical Design Documents." Las Vegas, NV. 2010.

- JBA Consulting Engineers. "Plumbing Design Documents." Las Vegas, NV. 2010.

- New Braunfels Utilies. Current Rates, 2009. http://www.nbutexas.com

- Trane Trace 700 v.6.2.6.5 (2010) Tyler, TX, United States of America.

- United States Green Building Council. "LEED 2009 For New Construction and Major Renovations." Washington, DC. 2008.

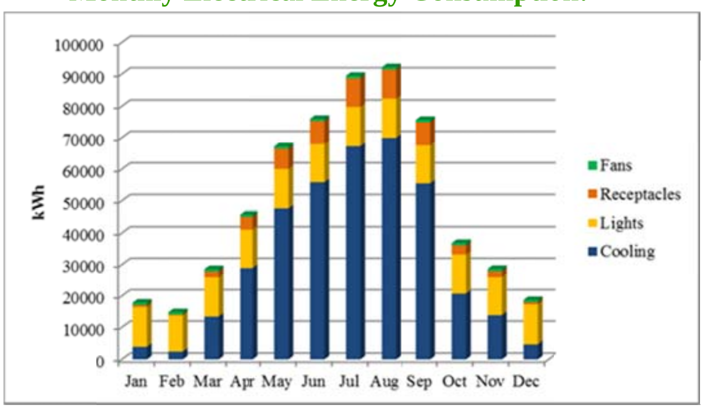
Appendix B: Technical Report 2 Energy Analysis Summary

Monthly Energy Consumption:

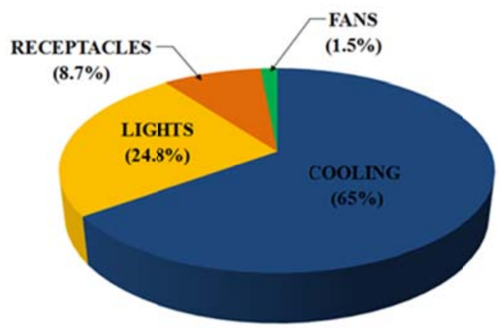
Month	Cooling (kWh)	Lights (kWh)	Fans (kWh)	Receptacles (kWh)	Heating (therms)
Jan	4002	12505	588	739	598
Feb	2490	11295	369	667	541
Mar	13428	12505	1905	739	112
Apr	28958	12102	3996	715	47
May	47601	12505	6351	739	21
Jun	55883	12102	7279	715	7
Jul	67256	12505	8946	739	3
Aug	69962	12505	8943	739	3
Sep	55478	12102	7343	715	11
Oct	20730	12505	2867	739	72
Nov	13874	12102	1973	715	99
Dec	4768	12505	701	739	525

Total Electrical Consumption (kWh): 591629
Total Gas Consumption (therms): 2039

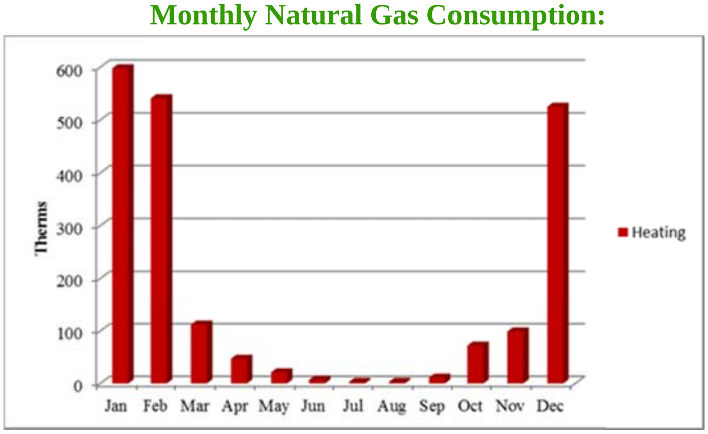
Monthly Electrical Energy Consumption:



Equipment Electricity Percentages:



Monthly Natural Gas Consumption:



Appendix C: Possible LEED Credits

Energy & Atmosphere — 17 Possible Points

Prereq 1	**Fundamental Commissioning of the Building Energy Systems**	Required
Prereq 2	**Minimum Energy Performance**	Required
Prereq 3	**Fundamental Refrigerant Management**	Required
Credit 1	**Optimize Energy Performance**	1–10
Credit 2	**On-Site Renewable Energy**	1–3
Credit 3	**Enhanced Commissioning**	1
Credit 4	**Enhanced Refrigerant Management**	1
Credit 5	**Measurement & Verification**	1
Credit 6	**Green Power**	1

Indoor Environmental Quality — 15 Possible Points

Prereq 1	**Minimum IAQ Performance**	Required
Prereq 2	**Environmental Tobacco Smoke (ETS) Control**	Required
Credit 1	**Outdoor Air Delivery Monitoring**	1
Credit 2	**Increased Ventilation**	1
Credit 3.1	**Construction IAQ Management Plan**, During Construction	1
Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1
Credit 4.2	**Low-Emitting Materials**, Paints & Coatings	1
Credit 4.3	**Low-Emitting Materials**, Carpet Systems	1
Credit 4.4	**Low-Emitting Materials**, Composite Wood & Agrifiber Products	1
Credit 5	**Indoor Chemical & Pollutant Source Control**	1
Credit 6.1	**Controllability of Systems**, Lighting	1
Credit 6.2	**Controllability of Systems**, Thermal Comfort	1
Credit 7.1	**Thermal Comfort**, Design	1
Credit 7.2	**Thermal Comfort**, Verification	1
Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1
Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1