Prepared For: James D. Freihaut, PhD, Associate Professor

»*Building Name*: Sinai Hospital South Tower Vertical Expansion

»*Building Location*: 2401 W. Belvedere Ave. | Baltimore, MD 21215

Technical Report 3

Mechanical Systems Existing Conditions Evaluation

Anly Lor | Mechanical Option | November 21

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Executive Summary

The Sinai Hospital South Tower Vertical Expansion is a three-story addition to the existing three-story South Tower which provides space for various medical services. Additional loads generated by these services demand for an increase in chilled water capacity. However, other mechanical systems, including sanitary, heating hot water, steam, domestic water, and medical gases, were adequate enough to use existing infrastructure.

In addition to providing a new chiller plant, two new custom-fabricated air handling units were added to the project to provide additional heating and cooling capacity. Although utilizing existing piping saved money on the mechanical system first cost, it was still relatively high. The mechanical system first cost represented approximately one-fourth of the overall project cost, with the bid estimate from Whiting-Turner equaling around $7.3 million dollars. Combined with the annual operating cost of the mechanical systems (determined through an energy analysis simulation), the rate per square foot of the building's real estate was valued at $59.26.

Unfortunately, there were no cost incentives during the design process. A majority of concerns were site-related, with noise isolation and link construction being priorities. In addition, the lost usable space caused by duct shafts, pipe shafts, and mechanical equipment rooms, although inevitable, contributed to a higher net project cost.

Design Requirements & Objectives

The Sinai Hospital Tower South Tower Vertical Expansion is a three-story addition to the existing three-story tower, providing space for an intensive care unit, post anesthesia care unit, and operating rooms on the fourth floor, traumatic brain injury care and sterile processing expansion on the fifth floor, and an intermediate care unit on the sixth floor. A six-story link enclosing a four-story atrium lobby connects the South Tower to the North Tower.

The mechanical systems for the expansion include heating, ventilating & air conditioning, plumbing, fire protection, medical gases, and vacuum. A majority of the existing infrastructure is adequate to accommodate the additional loads. Sanitary, vent, storm water, and fire protection risers are extended vertically from capped risers on the third floor. Heating hot water, steam, domestic water, and medical gas mains in the chase south of the service elevator are also extended up to the sixth floor (figure 1).

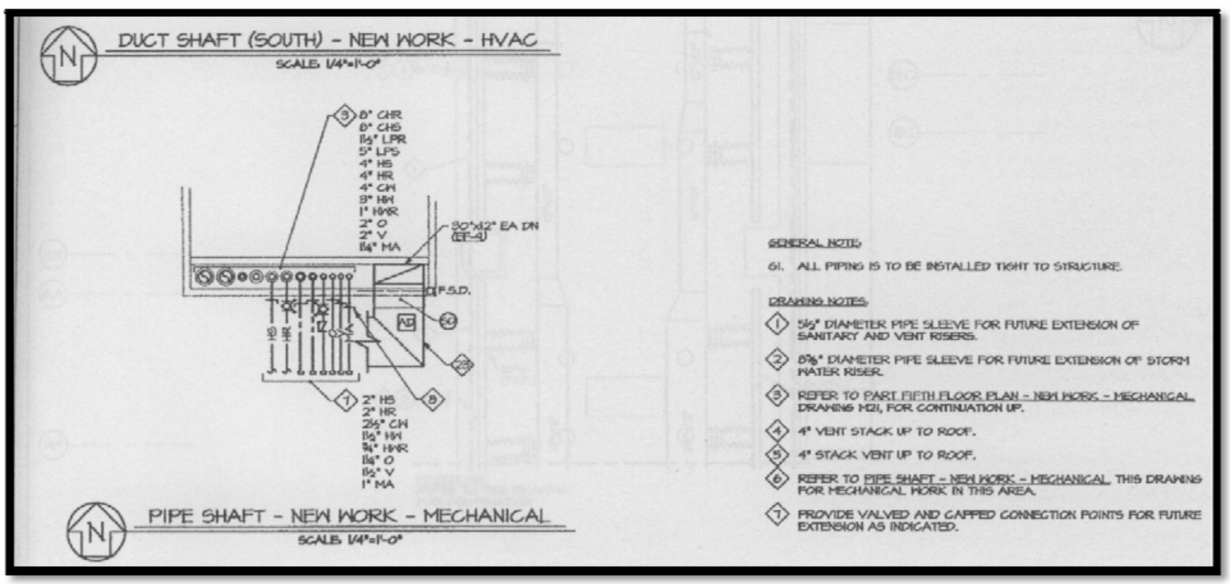

Figure 1

However, an increase in chilled water capacity was required in order to fully support the addition loads from the vertical expansion and previous renovations. A new chilled water plant was designed and located in the penthouse on the sixth floor roof. The design called for a 2,000-ton variable speed centrifugal chiller, cooling tower, and chilled water and condenser water pumps. In addition, two new custom-fabricated air handling units were added to the project. Existing air handling units were moved from the third floor roof to the sixth floor roof, providing redundancy in the air distribution system. Emergency power is provided for the equipment which allows for operation on all six floors in emergency situations.

Major Equipment

The following tables describe the major equipment used in the South Tower Vertical Expansion. In order to simplify the schedules with respect to the design documents, only key qualitative and quantitative data have been included with each item.

Air Handling Units

Designation	Location	Service	Size	Min. OA
EX. AHU-2032	South Tower Roof	South Tower Building	37,500 cfm	11,250 cfm
EX. AHU-2033	South Tower Roof	South Tower Building	37,500 cfm	11,250 cfm
AHU-2036	South Tower Penthouse	South Tower Building	105,000 cfm	105,000 cfm
AHU-2037	South Tower Penthouse	Hospital Link & Lobby	31,000 cfm	31,000 cfm

Fan Coil Units

Designation	Location	Size	Ext. Static P	Total Capacity
FCU-1	Service Area 1	530	0.40 in wg	18.3 MBH
FCU-2	Helistop Lobby	640	0.40 in wg	19.3 MBH
FCU-3	Helistop Lobby	440	0.30 in wg	13.5 MBH
FCU-4	Service Area 4	770	0.37 in wg	22.9 MBH

Variable Frequency Controller Schedule

Designation	Location	Service	Size
VFC-1	South Tower Penthouse	Cooling Tower Cell, CT-1A, Fan	75 hp
VFC-2	South Tower Penthouse	Cooling Tower Cell, CT-1A, Fan	75 hp
VFC-3	South Tower Penthouse	Chilled Water Pump, P-CH-1	200 hp
VFC-4	South Tower Penthouse	Chilled Water Pump, P-CH-1	200 hp
VFC-5	Ex. Relocated AHU-2032	Ex. Relocated SF-2032	100 hp
VFC-6	Ex. Relocated AHU-2032	Ex. Relocated RF-2032	50 hp
VFC-7	South Tower Penthouse	Supply Fan, SF-2036A	125 hp
VFC-8	South Tower Penthouse	Supply Fan, SF-2036B	125 hp
VFC-9	South Tower Penthouse	Return Fan, RF-2036A	75 hp
VFC-10	South Tower Penthouse	Return Fan, SF-2036B	75 hp
VFC-11	South Tower Penthouse	Supply Fan, SF-2037	50 hp
VFC-12	South Tower Penthouse	Return Fan, RF-2037	25 hp
VFC-13	Ex. Relocated AHU-2033	Ex. Relocated SF-2033	100 hp
VFC-14	Ex. Relocated AHU-2033	Ex. Relocated RF-2033	50 hp

Chillers

Designation	Location	Type	Size	Efficiency
CH-1	South Tower Penthouse	Electric Centrifugal	200-2000 tons	0.62 kW/ton
CH-2 (future)	South Tower Penthouse	Electric Centrifugal	200-2000 tons	0.62 kW/ton

Cooling Towers

Designation	Location	Cells	Size	Approach	Range	Flow Rate
CT-1	South Tower Roof	2	1000 tons/cell	85°F - 79°F	95°F - 85°F	3,000 gpm
CT-2 (future)	South Tower Roof	2	1000 tons/cell	85°F - 79°F	95°F - 85°F	3,000 gpm

Pumps

Designation	Location	Service	Size	Head
P-CH-1	South Tower Penthouse	Primary Chilled Water	3,200 gpm	175 ft wg
P-CH-2	South Tower Penthouse	Standby Primary Chilled Water	3,200 gpm	175 ft wg
P-CH-3	South Tower Penthouse	Future Primary Chilled Water	3,200 gpm	175 ft wg
P-CW-1	South Tower Penthouse	Condenser Water	6,000 gpm	100 ft wg
P-CW-2	South Tower Penthouse	Standby Condenser Water	6,000 gpm	100 ft wg
P-CW-3	South Tower Penthouse	Future Condenser Water	6,000 gpm	100 ft wg
P-2032-HS	Ex. AHU-2032	Ex. AHU-2032 Preheat Coil Circ.	28 gpm	20 ft wg
P-2033-HS	Ex. AHU-2033	Ex. AHU-2033 Preheat Coil Circ.	28 gpm	20 ft wg
P-2036-HS	South Tower Penthouse	AHU-2036 Preheat Coil Circulator	42 gpm	15 ft wg
P-2037-HS	South Tower Penthouse	AHU-2037 Preheat Coil Circulator	20 gpm	10 ft wg
P-3	ER-7 Basement MER	Primary Heating Hot Water	303 gpm	30 ft wg

Mechanical System First Cost

As depicted in the major mechanical equipment schedules, the first cost the mechanical systems are likely to be very high and a large percentage of the overall project cost. Base bids for each division of the South Tower Vertical Expansion are listed below:

Division	Description	Base Bid
1	General Requirements	$1,744,321
2	Site Work	$984,415
3	Concrete	$4,190,000
4	Masonry	$231,350
5	Metals	$1,246,568
6	Woods & Plastics	$83,100
7	Thermal & Moisture Protection	$736,400
8	Doors & Windows	$1,835,412
9	Finishes	$2,225,803
10	Specialties	$40,715
13	Special Construction	$364,000
14	Conveyances	$1,170,407
15	Mechanical	$7,288,500
16	Electrical	$4,435,691

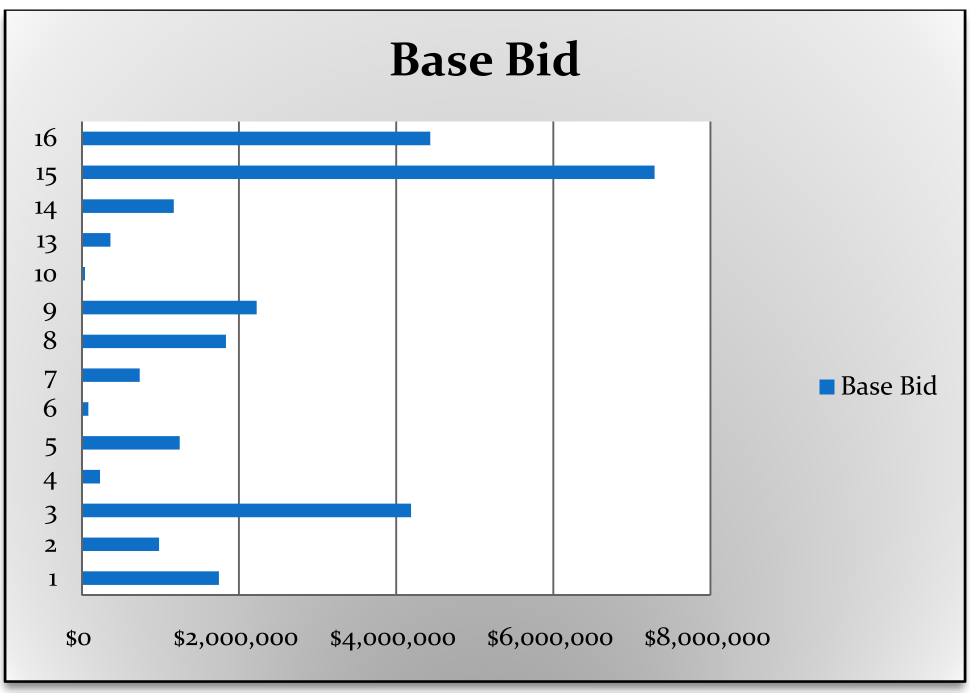

Figure 2

As shown in figure 2, the first cost of the building's mechanical systems is high and above the second most expensive division of the project, the electrical system at $4,435,691. The mechanical division represents 27.4% of the $28,477,681 bid estimate by Whiting-Turner. Although the mechanical system is just one of sixteen separate division bids, it is more than one-fourth of the South Tower Vertical Expansion's overall cost.

A calculation of the cost of the mechanical systems per square foot of floor area is shown below:

Bid	$7,288,500
Area	127,502 ft²
	$57.16/ft²

Site Energy Sources & Rates

Energy is provided by BGE, Sinai's utility company situated in Baltimore County, Maryland. The following tables describe BGE's general service (large) electric rates:

Monthly Net Rates

	Rate
Delivery Service Customer Charge	$110.00/month

Demand Charges

	Charge
Transmission Market-Priced Service	$1.27/kW
Delivery Service	$2.67/kW

Energy Charges (June 1 – August 31, 2008)

	Charge
Peak	$0.204/kWh
Intermediate	$0.139/kWh
Off-Peak	$0.115/kWh

»Peak: 10 AM – 8 PM (summer); 7 AM – 11 AM, 5 PM – 9 PM (non-summer)
»Intermediate: 7 AM – 10 AM, 8 PM – 11 PM (summer); 11 AM – 5 PM (non-summer)
»Off-Peak: All other times

Electric rates that could be used if district heating and cooling and cogeneration (with a generating capacity of 1,000 kWh or less) were utilized are described in the following tables:

Energy Charges (Summer)

	Charge
Peak	$0.0287/kWh
Intermediate	$0.0218/kWh
Off-Peak	$0.0168/kWh

Energy Charges (Non-Summer)

	Charge
Peak	$0.0264/kWh
Intermediate	$0.0255/kWh
Off-Peak	$0.0189/kWh

»Source: http://www.bge.com/

Annual Energy Use

An energy analysis by the mechanical engineer was not performed for this project. A decision was made not to follow through with LEED accreditation, and the energy analysis, typically performed using DOE-2 or Trane's Trace Software, was no longer in the firm's scope of services. Carrier's Hourly Analysis Program was then used to calculate air balance values for the spaces while using Guidelines for Construction and Equipment of Hospital and Medical Facilities.

Technical Report 2 Energy Analysis

Equipment	***Annual Cost***
Electric	$135,042
»Heating	$2,296
»Lighting	$73,328
»Chiller	$19,446
»Cooling Tower/Condenser Fans	$5,132
»Miscellaneous Equipment	$34,706
Water	$2,121
Gas	$556
Total	$137,719

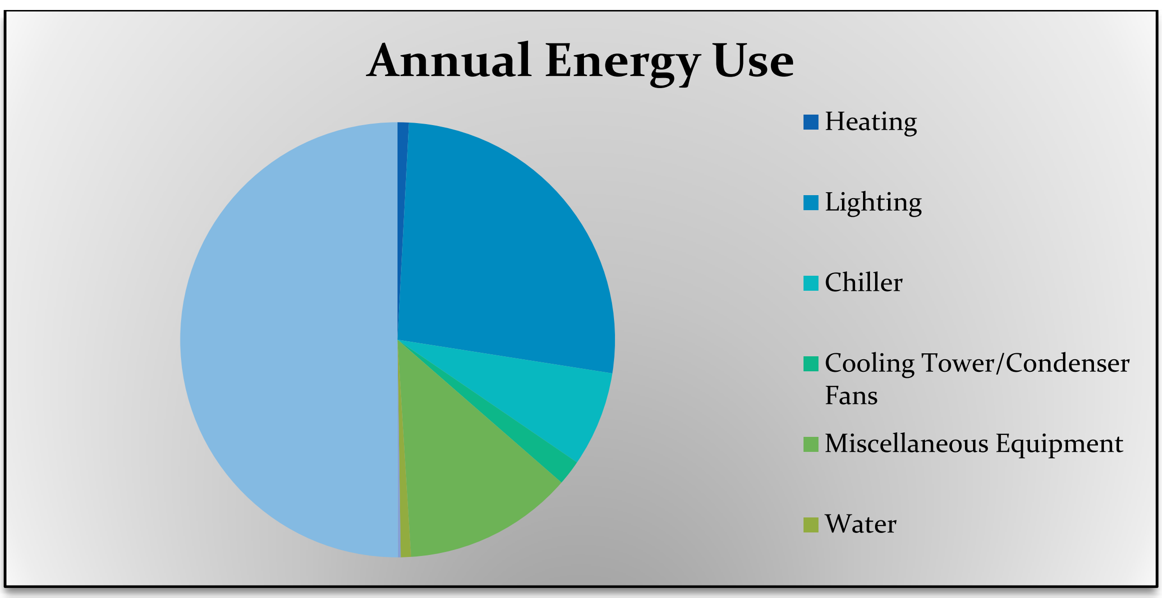

Figure 3

Lighting is responsible for the majority of annual energy use. The cost of electricity to run Sinai Hospital's lights is $894,000. This represents over 50% of the total energy consumption. An annual operating cost of $2.10 per square foot in a simulated energy analysis.

Operating History

An operating history of the mechanical systems in the South Tower Vertical Expansion is not available. Fit-out construction is still in progress on the fourth and sixth floors and will not begin on the fifth floor until May 2009 at the earliest, and therefore, utilization data has not yet been recorded. Construction and occupancy dates are listed below:

	Construction	***Occupancy***
Fourth Floor	June 2008	July 2009
Fifth Floor	May 2009	Feb 2010 – Dec 2010
Sixth Floor	June 2008	May 2009

Design Influences

The design of the mechanical systems in the South Tower Vertical Expansion was not influenced by cost factors. There were no rebates or tax relief.

With regards to site factors, some key decisions which influenced system design were about noise isolation. Noise generated by mechanical equipment in the penthouse could have had adverse affects on the occupied floors below. Measures were taken to eliminate this concern.

In addition, several meetings between the owner, architects, engineers, and general contractors focused on the construction of the link and lobby in such a confined space on the site (figure 4). Construction of the vertical expansion and emergency procedures in the event of an accident were also discussed extensively.

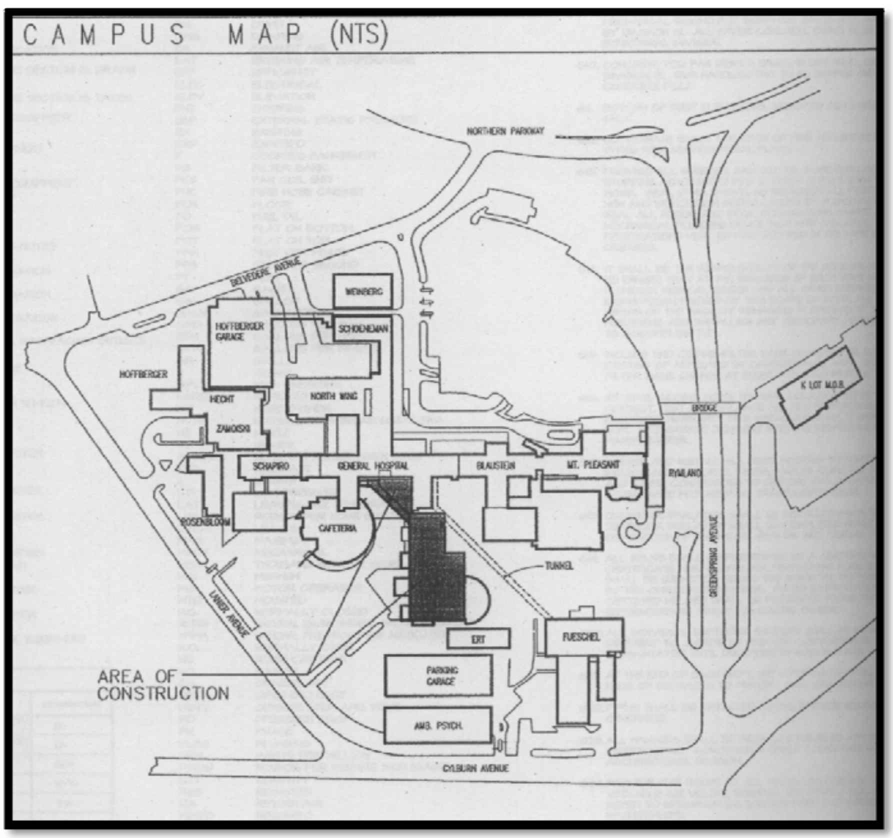

Figure 4

Source: Jim Gleba, Project Manager, Leach Wallace Associates, Inc.

Design Summary

Design Parameters For Central Equipment Selection

	T_{DB}	T_{WB}
Exterior Winter	0°F	
Exterior Summer	95°F	79°F

Indoor Design Conditions

	T_{DB}	***RH***
Nurse Stations, Work Rooms, & Ancillary Spaces	70-75°F	30-60%
Patient Rooms	70-75°F	30-60%
Airborne Infection Isolation Rooms	70-75°F	30-60%
Offices, Conference Rooms, & Waiting Rooms	72°F	30-60%

Design Ventilation Requirements

	Outside Air	***% OA***
Link & Lobby	0 cfm	0%
Fourth Floor	3,495 cfm	9.9%
Sixth Floor	3,056 cfm	13.5%
Design Documents Total:	**6,551 cfm**	
Computed Value Total:	**6,503 cfm**	

Design Heating & Cooling Loads

	Heating	***Cooling***
Link & Lobby	15 tons	31 tons
Fourth Floor	70 tons	148 tons
Sixth Floor	70 tons	148 tons
Design Documents Total:	**155 tons**	**327 tons**
Computed Value Total:	**N/A**	**152 tons**

»Note: The fifth floor has not yet been fit out
»Note: Heating loads includes shell heating loss (28.6%) and reheat load (71.4%)

The design document value of the total building cooling load is 115% greater than the computed value. Several factors may have contributed to this discrepancy, including varying outdoor and indoor design conditions, different schedules utilized, overcompensated loads in the design documents, or unaccounted occupancy or load changes in the final design.

Lost Usable Space

The lost usable space from shafts in the South Tower Vertical Expansion is fairly minor. There are two duct shafts (one to the north and one to the south) and one pipe shaft (located south of the service elevator). See figure 5. The penthouse (located on the sixth floor roof), however, sits on a rather large footprint and contributes heavily to the lost usable space.

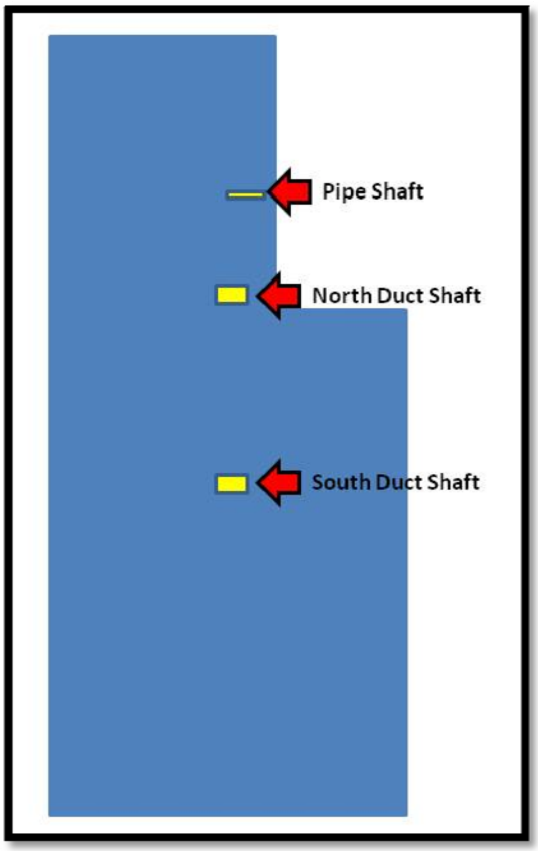

Figure 5 (typical floor plan)

	Dimensions	*Area (per floor)*	*Area (all floors)*
Pipe Shaft	1' x 6'	6 ft²	18 ft²
North Duct Shaft	3' x 5'	15 ft²	45 ft²
South Duct Shaft	3' x 5'	15 ft²	45 ft²
Penthouse	90' x 36'		3,240 ft²
Total			3,348 ft²

Schematic Drawings

Existing Mechanical Systems

Chilled Water System

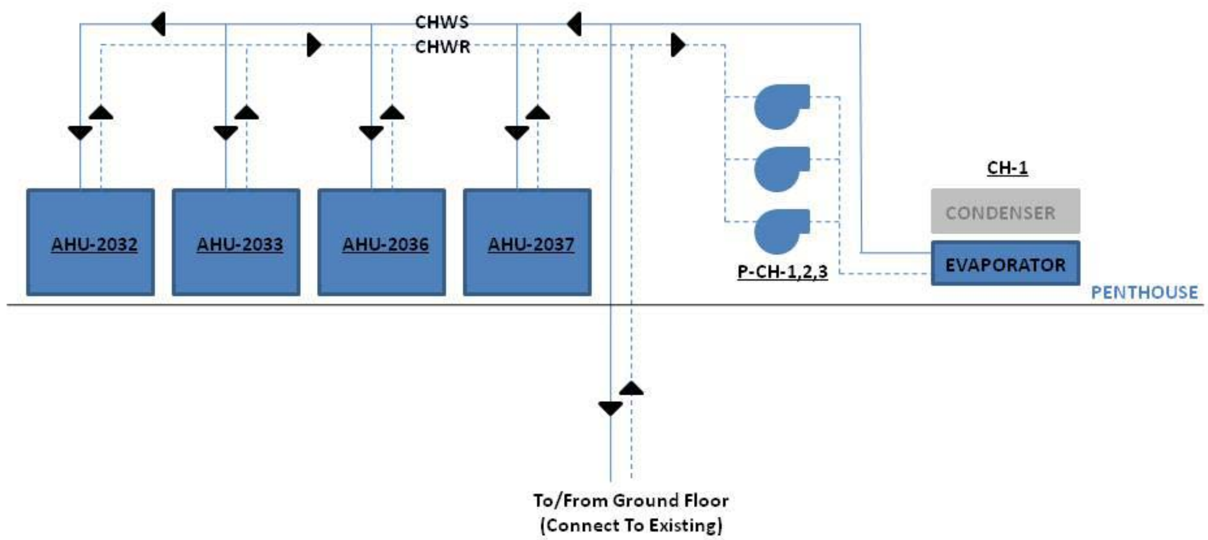

Figure 6.1

Condenser Water System

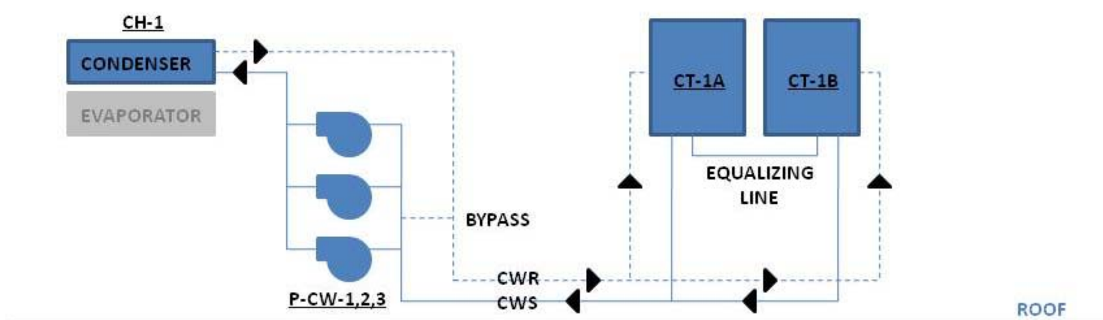

Figure 6.2

Figure 6.1 and 6.2 detail the chilled and condenser water systems for the South Tower Vertical Expansion. In figure 6.1, two new air handling units provide additional capacity while two existing air handling units provide redundancy. Combined, they provide up to 211,000 cfm of air flow for floors four through six in addition to the link and lobby. In figure 6.2, 3,000 gpm of water flow is cooled by a two-cell cooling tower.

System Operation

Chilled Water Distribution System

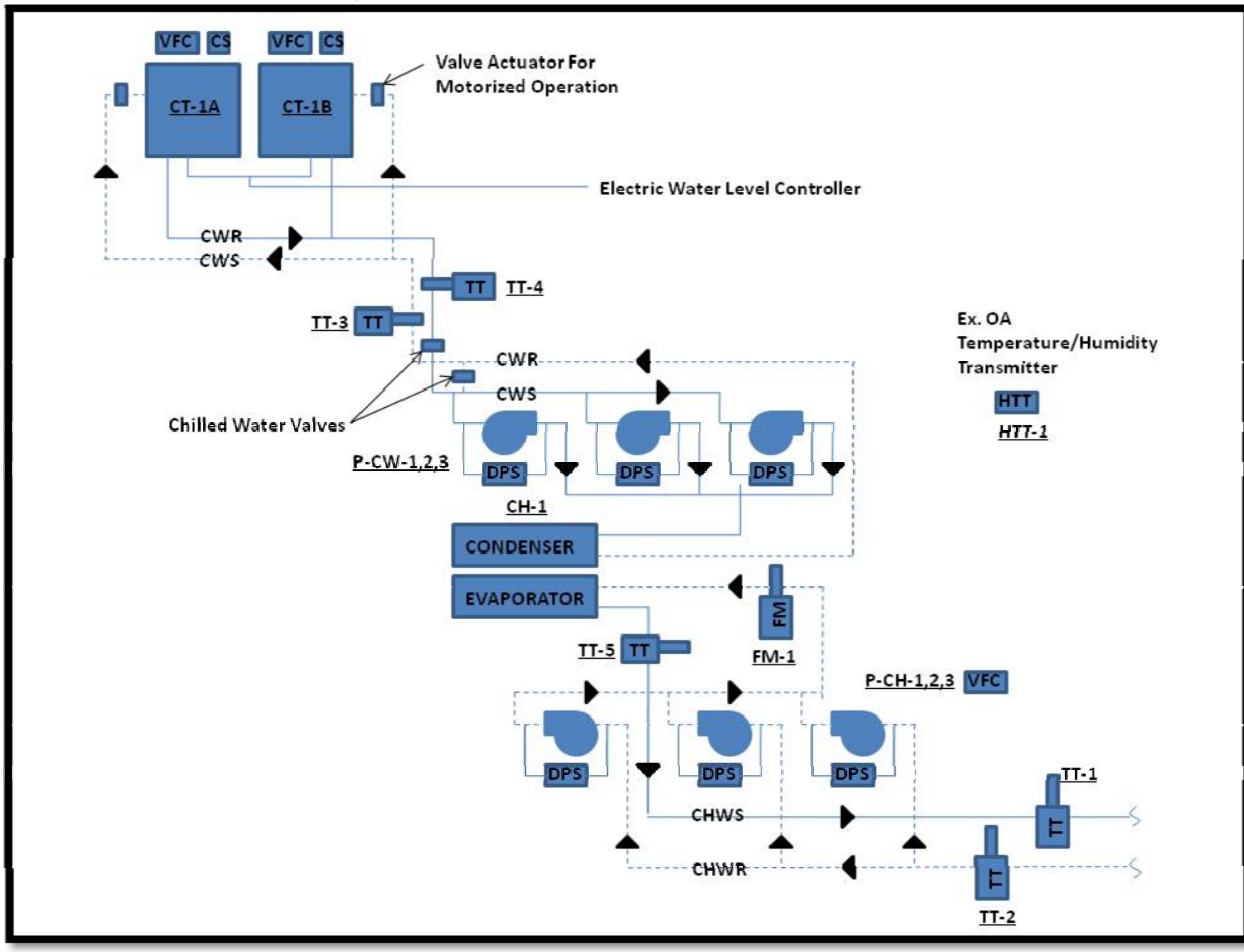

Figure 7

The automatic temperature control for the chilled water distribution in the South Tower Vertical Expansion utilizes the existing Johnson controls network and infrastructure. The control of the system is manually indexed by an operator when the outside air temperature exceeds 50°F. Transmitter HTT-1 (figure 7) prompts the operator when this occurs.

When the chilled water system is energized, the plant begins to operate. This is when the primary chilled water pump, condenser water pump, and cooling tower start. Once flow is proven, demonstrated by the flow meter FM-1, the chiller energizes and the chilled water temperature is monitored by an integral controller. The chilled water valves are then indexed to open.

Temperature transmitters TT-1 and TT-2 (figure 7) provide input to the CCMS system which calculates the distribution loop tonnage.

LEED-NC Rating

SUSTAINABLE SITES

Credit		*Y*	*N*
Prereq	Construction Activity Pollution Prevention	•	
1	Site Selection	•	
2	Development Density & Community Connectivity	•	
3	Brownfield Redevelopment		•
4.1	Alternative Transportation, Public Transportation Access	•	
4.2	Alternative Transportation, Bicycle Storage & Changing Rooms	•	
4.3	Alternative Transportation, Low Emitting & Fuel Efficient Vehicles		•
4.4	Alternative Transportation, Parking Capacity		•
5.1	Site Development, Protect or Restore Habitat		•
5.2	Site Development, Maximize Open Space		•
6.1	Stormwater Design, Quantity Control	•	
6.2	Stormwater Design, Quality Control		•
7.1	Heat Island Effect, Non-Roof	•	
7.2	Heat Island Effect, Roof	•	
8	Light Pollution Reduction		•

WATER EFFICIENCY

Credit		*Y*	*N*
1.1	Water Efficient Landscaping, Reduce by 50%		•
1.2	Water Efficient Landscaping, No Potable Use or No Irrigation		•
2	Innovative Wastewater Technologies		•
3.1	Water Use Reduction, 20% Reduction		•
3.2	Water Use Reduction, 30% Reduction		•

ENERGY & ATMOSPHERE

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

MATERIALS & RESOURCES

Credit		***Y***	***N***
Prereq	Storage & Collection of Recyclables	•	
1.1	Building Reuse, Maintain 75% of Existing Walls, Floors & Roof		•
1.2	Building Reuse, Maintain 95% of Existing Walls, Floors & Roof		•
1.3	Building Reuse, Maintain 50% of Interior Non-Structural Elements		•
2.1	Construction Waste Management, Divert 50% from Disposal		•
2.2	Construction Waste Management, Divert 75% from Disposal		•
3.1	Materials Reuse, 5%		•
3.2	Materials Reuse, 10%		•
4.1	Recycled Content, 10% (post-consumer + 1/2 pre-consumer)		•
4.2	Recycled Content, 20% (post-consumer + 1/2 pre-consumer)		•
5.1	Regional Materials, 10% Extracted, Processed & Manufactured Regionally	•	
5.2	Regional Materials, 20% Extracted, Processed & Manufactured Regionally	•	
6	Rapidly Renewable Materials		•
7	Certified Wood		•

INDOOR ENVIRONMENTAL QUALITY

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

INNOVATION & DESIGN PROCESS

Credit		*Y*	*N*
1.1	Innovation in Design		•
1.2	Innovation in Design		•
1.3	Innovation in Design		•
1.4	Innovation in Design		•
2	LEED Accredited Professional	•	

PROJECT TOTALS:	**20**	**38**

Based on given data and assumptions, the Sinai Hospital South Tower Vertical Expansion would have received 20 points out of a possible 69 points in the LEED – New Construction Rating System. This indicates that the building would not have achieved LEED certification.

Additionally, this conclusion corresponds to the fact that the owner, architects, and engineers agreed not to follow through with LEED accreditation for the project. Consequently, no analyses were performed, resulting in a lack of information in specific areas of the LEED certification process.

Overall Evaluation

The construction cost of the mechanical systems in the Sinai Hospital South Tower Vertical Expansion was a large percentage of the overall project costs. There may be ways to reduce this amount through system design or equipment selection and could possibly be explored in the upcoming proposal. Additionally, the annual operating cost of $2.10 per square foot is relatively high and could be mitigated.

Maintainability of the building's mechanical systems is relatively simple, as a majority of the systems in the expansion required only the extension of capped piping. The only new maintenance on the project was a new chiller plant, two new custom-fabricated air handling units, and associated equipment, piping, and ductwork.

There are no major concerns with environmental control and indoor air quality. Preventative measures have been taken in a hospital environment to isolate airborne contaminants. Set point temperatures are relatively constant, being maintained at around 72°F. However, there is some thermal control available in various spaces such as nurse stations and patient rooms.