TECHNICAL REPORT 3:

Mechanical Systems and Existing Conditions

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INOVA South Patient Tower
Falls Church, VA
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Executive Summary

The South Patient Tower is a 233,000 square foot addition to the INOVA Fairfax Hospital located in Falls Church, VA. The building is currently under construction and is scheduled to be completed in the summer of 2012. The thirteen (13) story tower is designed primarily as a patient bed-tower to add more rooms to the existing hospital.

The primary means of heating and cooling is provided through a constant air volume system with reheat at the terminal boxes. When designing the system, designers selected constant air volume due to the existing building using that same system and the ability to easily maintain appropriate pressurization requirements. Ventilation requirements of ASHRAE 62.1 and ASHRAE 170 state the design should provide 62,700 CFM of outdoor air. The system complies and is shown to be oversized by providing 95,000 CFM of outdoor air at design loads.

After performing a load and energy analysis using Trane TRACE 700 software, it was found that the designers oversized equipment to help with air quality and support of the system as a whole if a piece of equipment was taken off-line due to problems or maintenance. The energy model provided that operation cost of the South Patient Tower mechanical systems is approximately $93,000. The designers did not provide their energy model analysis so no comparison could be made to the actual estimate. The tower is pursuing LEED Silver certification with 11 potential credits being received by the mechanical systems.

The South Patient Tower is fed from a central utility plant and includes three (3) 715 GPM steam to hot water heat changers, four (4) 50,000 CFM air handling units and two (2) smaller air-handling units that serve the kitchen area. The four main air handlers are headered together to provide the entire system with appropriate amounts of supply air. A single return plenum is utilized for the air system that controls return and relief air to each unit. The heating hot water system utilizes a parallel pumping system to serve the building loads. A further description of the building mechanical systems including schematics, as well as a cost breakdown and an overall summary of the mechanical design can be found in the following pages.

Mechanical Summary

Introduction

The South Patient Tower at INOVA Fairfax Hospital serves as an addition to the existing patient tower. With an overall size of 233,000 square feet, the new tower serves as additional patient recovery rooms, a new cafeteria, and a state of the art ultrasound suite located on the ground floor. Mechanical services are mainly located on the fifth floor of the hospital to minimize the need for mechanical penthouses on the roof, so that a new emergency helipad can be located on top of the tower. An interesting two storied atrium lobby exists on the Southwest corner that consists of vast amounts of glazed curtain wall to help draw people to the entrance.

Design Criteria

The main design approach to the South Patient Tower was to create a world-class patient bed-tower to help serve the INOVA Fairfax Hospital and its growth towards 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 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 to help provide better indoor air quality for the patient healing process. 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***. For more detailed weather input information refer to ***Technical Report 2: Appendix A.***

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

Ventilation Requirements

After analyzing the ventilation system of the INOVA South Patient Tower, it has been determined that not all spaces meet the minimum ventilation requirements set by ASHRAE 62.1. The spaces that do not meet the minimum ventilation are storage areas, janitor closets, electrical closets, and equipment rooms. Typically these spaces are not supplied with air, but rather have air transferred from adjoining spaces. Due to this they are not provided with any supply air in the current design.

The South Patient Tower is mainly supplied by AHU-1, 2, 3, and 4, which are coupled together to help serve the loads of the spaces. The maximum Z_p value for the zones served by these air-handlers was found to be 0.99 in the basement. There were other spaces, however over the 0.55 limit of Table 6-3 so even if this zone was not included, the method provided in Appendix A would still need to be exercised. After following the method outlined, it was found that the E_v for AHU-1, 2, 3 and 4 would be 0.77. The uncorrected outdoor airflow for each of these air-handlers was calculated as 9,600 CFM and taking into account the 0.77 efficiency, the adjusted outdoor airflow intake for each was found to be 12,468 CFM. The kitchen is served exclusively by AHU-6. The maximum Z_p value found for the zones that AHU-6 serves was 0.33. From Table 6-3, the efficiency value (E_v) was found to be 0.8. The uncorrected outdoor airflow for AHU-6 was calculated as 2,270 CFM and when the efficiency is taken into account, the adjusted outdoor intake airflow was calculated as 2,838 CFM.

AHU-1, 2, 3, and 4 each are designed to handle a supply of 50,000 CFM with a designed outdoor airflow of 20,000 CFM. The adjusted outdoor airflow minimum of 12,468 CFM is below the design and shows that these air-handlers exceed the standard and thus comply. AHU-6 was selected to handle a supply of 13,000 CFM with an outdoor airflow of 5,000 CFM. The adjusted outdoor airflow minimum of 2,838 CFM is below the design, so AHU-6 complies with Section 6. When combined in viewing the whole building, the designed airflow was found to be 223,000 CFM with a design outdoor airflow of 95,000 CFM. Calculating the minimum outdoor airflow for the building as a whole, it was found that 62,708 CFM was required. This is well below the design value and thus the systems comply with ASHRAE 62.1 Section 6. ***Table 3*** provides a summary of the design supply and outdoor airflow, efficiency, and comparison to the calculated minimums.

Table 3: **Summary Chart of Compliance with ASHRAE 62.1 Section 6**

Unit	Area(s) Served	Supply Airflow	Outdoor Airflow	Uncorrected OA	System Efficiency	Minimum OA	Comply Y/N?
AHU-1	Tower	50,000	20,000	9,600	0.77	12,468	Y
AHU-2	Tower	50,000	20,000	9,600	0.77	12,468	Y
AHU-3	Tower	50,000	20,000	9,600	0.77	12,468	Y
AHU-4	Tower	50,000	20,000	9,600	0.77	12,468	Y
AHU-5	Hood MAU	10,000	10,000	-	-	10,000	Y
AHU-6	Kitchen	13,000	5,000	2,270	0.80	2,838	Y
TOTALS		**223,000**	**95,000**			**62,708**	**Y**

It can be seen that the designer upsized the equipment for the South Patient Tower. They met the minimum required ventilation airflows and, in fact, exceeded them for the systems. This can be attributed to designer's factors of safety in the calculations, as well as the requirement for there to be redundancy in the hospital so that it may operate 24 hours a day. They also designed in excess of the outdoor airflow required to provide the best possible quality of air for the patients that will be occupying the bed tower.

*All supporting calculations can be found in ***Technical Report 1: Appendix B***.

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 on 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 system is transported through the building by three (3) 715 GPM pumps that supply 60 feet of head. These pumps are served with variable frequency drives (VFDs) and can adjust to the appropriate need for heating called for by the system. Additional recirculating pumps are provided for necessary distribution to the reheat coils on each floor. ***Tables 4-8*** provide a breakdown of the mechanical equipment used in the South Patient Tower.

Table 4: Air Handling Unit Schedule

Unit	Service	Supply CFM	Cooling		Heating	
			EAT (DB in F)	LAT (DB in F)	EAT (F)	LAT (F)
AHU-1	Tower	50,000	83.3	50	0	45
AHU-2	Tower	50,000	83.3	50	0	45
AHU-3	Tower	50,000	83.3	50	0	45
AHU-4	Tower	50,000	83.3	50	0	45
AHU-5	Hood-MAU	10,000	95	68.2	0	73.6
AHU-6	Kitchen	13,000	83.3	52.8	45	61.7

Table 5: Air Handling Supply Fan Data

Unit	Service	Supply CFM	Minimum OA CFM	HP	RPM
AHU-1	Tower	50,000	20,000	125	1750
AHU-2	Tower	50,000	20,000	125	1750
AHU-3	Tower	50,000	20,000	125	1750
AHU-4	Tower	50,000	20,000	125	1750
AHU-5	Hood-MAU	10,000	10,000	15	1750
AHU-6	Kitchen	13,000	5,000	25	1750

Table 6: Return and Exhaust Fan Schedule

Designation	Service	CFM	SP INCH WG	HP
RF-1	Return Plenum	30,000	6.0	50
RF-2	Return Plenum	30,000	6.0	50
RF-3	Return Plenum	30,000	6.0	50
RF-4	Return Plenum	30,000	6.0	50
RF-5	Return Plenum	30,000	6.0	50
RF-6	Return Plenum	30,000	6.0	50
RF-6a	Return (AHU-6)	8,000	2.0	7.5
KEF-1	Kitchen Exhaust	6,800	1.75	5
KEF-2	Kitchen Exhaust	2,700	1.25	2
EF-1	Toilet Exhaust	6,300	0.75	5
EF-2	Toilet Exhaust	6,300	0.75	5
EF-3	Toilet Exhaust	3,150	0.9	2
EF-4	Toilet Exhaust	3,150	0.9	2
EF-5	Toilet Exhaust	1,500	0.95	1
EF-6	Trash/Lin Exhaust	890	0.75	0.25
GEF-1	General Exhaust	4,500	-	5
TB-1	General Exhaust	12,600	3.25	15

Table 7: Steam/Heating Water Converter Schedule

Designation	GPM	EWT (F)	LWT (F)	Passes
HX-1	715	160	190	2
HX-2	715	160	190	2
HX-3	715	160	190	2

Table 8: Pump Schedule

Designation	Service	GPM	Head (ft wg)	HP
HWP-1	Heating Water	715	60	15
HWP-2	Heating Water	715	60	15
HWP-3	Heating Water	715	60	15
DWBP-1	Dom. Water Booster Pump (BSMT-4th)	330	196	30
DWBP-2	Dom. Water Booster Pump (BSMT-4th)	330	196	30
DWBP-3	Dom. Water Booster Pump (BSMT-4th)	330	196	30
DWBP-4	Dom. Water Booster Pump (5th-11th)	220	196	25
DWBP-5	Dom. Water Booster Pump (5th-11th)	220	196	25
DWBP-6	Dom. Water Booster Pump (5th-11th)	220	196	25
HWRP-1	Hot Water Recirc. Pump (BSMT-4th)	30	90	3
HWRP-2	Hot Water Recirc. Pump (BSMT-4th)	30	90	3
HWRP-3	Hot Water Recirc. Pump (BSMT-4th)	30	90	3
HWRP-4	Hot Water Recirc. Pump (5th-11th)	30	90	3
HWRP-5	Hot Water Recirc. Pump (5th-11th)	30	90	3
HWRP-6	Hot Water Recirc. Pump (5th-11th)	30	90	3
HWRP-7	Hot Water Recirc. Pump (5th-11th)	30	90	3
CRP-1	Coil Recirc. Pump (AHU-1)	162	20	2
CRP-2	Coil Recirc. Pump (AHU-2)	162	20	2
CRP-3	Coil Recirc. Pump (AHU-3)	162	20	2
CRP-4	Coil Recirc. Pump (AHU-4)	162	20	2
CRP-5	Coil Recirc. Pump (AHU-5)	54	20	0.75
CRP-6	Coil Recirc. Pump (AHU-6)	16	20	1/12

Mechanical First Costs

The following is a breakdown of the first costs associated with the mechanical, plumbing and medical gas systems as reported by the contractor. ***Table 9*** provides a detailed summary of the costs associated with various equipment, installation, material and permitting. It can be seen that the HVAC system (excluding Medical Gas and Plumbing) costs **$9,818,635** and has a cost per square foot of about **$42/SF.**

Including the Plumbing and Medical Gas systems that fall under the Mechanical Contract, the total cost is **$14,918,435** with a cost per square foot of **$63.80/SF**

Table 9: Mechanical Cost Breakdown

Item		Cost		Cost/SF
Mechanical Equipment				
AHU-1,2,3,4	$	894,945.00	$	3.83
Fan Coil Units (20)	$	80,000.00	$	0.34
Terminal Boxes	$	150,000.00	$	0.64
Steam Humidifiers	$	40,000.00	$	0.17
HEPA Filter	$	50,000.00	$	0.21
Steam Condensate Pumps	$	14,000.00	$	0.06
Misc. Heaters	$	30,000.00	$	0.13
Fans/Air Curtain	$	8,000.00	$	0.03
Steam Specialties	$	100,000.00	$	0.43
Variable Frequency Drives	$	100,000.00	$	0.43
Med Gas Equipment	$	397,000.00	$	1.70
TOTAL	*$*	*1,863,945.00*	*$*	*7.97*
Plumbing Equipment				
Domestic Water Heaters	$	215,000.00	$	0.92
Domestic Booster Pumps	$	85,000.00	$	0.36
Pumps, HX, EX Tank	$	68,000.00	$	0.29
TOTAL	*$*	*368,000.00*	*$*	*1.57*
Miscellaneous Material				
Mechanical	$	4,120,653.00	$	17.62
Plumbing	$	1,271,500.00	$	5.44
Med Gas	$	570,000.00	$	2.44
TOTAL	*$*	*5,962,153.00*	*$*	*25.50*
Labor Summary				
Mechanical	$	4,231,037.00	$	18.10
Plumbing	$	867,500.00	$	3.71
Med Gas	$	794,000.00	$	3.40
TOTAL	*$*	*5,892,537.00*	*$*	*25.20*
Project Deliverables/Permits	$	831,800.00	$	3.56
GRAND TOTAL	**$**	**14,918,435.00**	**$**	**63.80**

Lost Usable Space

A summary of the lost usable space due to the mechanical system in the South Patient Tower can be seen in ***Table 10*** below. A majority of the floors only lose space due to shaft penetrations in the northern and south central area of the floor. The basement has 2,013 SF of lost area due to a smaller mechanical room being located here. The fifth floor is the mechanical floor which serves in place of a rooftop mechanical penthouse, thus the entire floor is taken by mechanical space. Finally, the number of shafts increases starting at the third floor due to the exhaust shafts for the bathrooms in the patient rooms.

Table 10: Lost Usable Space

Floor	Area (SF)
Basement	2,013
Ground	332
First	360
Second	332
Third	416
Fourth	416
Fifth	15,057
Sixth	421
Seventh	421
Eighth	421
Ninth	421
Tenth	421
Eleventh	421
TOTAL	**21,452**

System Operation

Air Side Operation

The main four air-handlers that supply the tower with heating, ventilation and air conditioning (AHU-1, 2, 3, 4) are all independent units which are headered together to handle the entire load of the South Patient Tower. All of the units are the same size and have independent supply fans, outdoor air dampers and return dampers. Along with these devices, each air-handler is equipped with a pre-heat coil, cooling coil, low pressure steam humidifiers, pre- and final filters, and separate controls. Variable frequency drives (VFDs) control each of the supply fans to help meet the various loading conditions of the tower and are modulated with static pressure sensors at the outlet of each air handling unit. The return fans are grouped together in a common return air plenum for the whole system. These fans are operated with VFDs to help maintain a constant pressure differential with the supply air. They are designed to modulate with the supply fans as needed to maintain the differential at various loads.

The supply air temperature for each unit is controlled by a temperature sensor located at the outlet of the supply fan and modulates the outdoor air damper, return air damper, pre-heat coil and cooling coil all in sequence. The initial set point for cooling mode is a supply temperature of 55 F and the humidity sensors will control temperature if the relative humidity rises above 60%. Control will be returned to the temperature sensor when relative humidity reaches 55%. During the heating mode, a steam humidifier will be controlled by a relative humidity sensor in the return air in an effort to maintain a minimum relative humidity in the space of 35%. ***Figure 1*** and ***Figure 2*** show schematics of the system in further detail.

AHU-5 is energized when a kitchen hood is activated to provide air for exhausting the grease hoods. The supply fan is located in the unit and controlled by a VFD to meet the various loads of different hoods being engaged at different times. Supply air temperature is maintained by a temperature sensor located at the outlet of the supply fan and modulates the heating/cooling coils to provide appropriate temperatures.

AHU-6 provides heating, ventilation and air conditioning for the kitchen space to meet the loads associated with the space excluding the exhaust hoods. The control is very similar to AHU-1, 2, 3, and 4 except on the return side. The return fan is located within the unit and controlled in conjunction with the supply fan on a VFD. The supply air set point for cooling is 55 F with no specifications on the relative humidity set point.

Steam System Operation

The South Patient Tower heating and humidification is served by a campus steam loop. High pressure steam enters the basement and is diverted to the fifth floor and basement pressure reducing stations. In the basement, the high pressure steam is reduced to medium pressure steam and supplies HX-1, 2, and 3, which is modulated with a control value to produce constant temperature heating hot water supply. It also serves domestic hot water heaters 1 thru 3 (DWH-1, 2, 3) in the basement. On the fifth floor, the steam is again reduced to medium pressure steam to serve domestic hot water heaters 4 thru 7 (DWH-4, 5, 6, 7). It is also reduced to low pressure steam to serve the AHU-1, 2, 3 and 4 humidifiers. Condensate is returned to the sub-basement by gravity to the condensate pump which then pumps it back to the central steam plant.

Water Side Operations

Chilled Water

The building is served from the central utility plant and enters the tower in the basement utility tunnel. It is distributed to the cooling coils for the air-handling units located on the fifth floor and no booster pumps are used in the process. Flow through the coils is controlled via an automatic control value that correlates to the leaving air temperature from the coil and adjusted when needed. After flowing though the coils, the chilled water returns to the central plant to be cooled once again.

Heating Hot Water

The heating hot water is created via a steam to water heat exchanger served by the campus steam loop. After flowing through the heat exchanger, the water then flows through an air separator and expansion tank before reaching the distribution pumps. The heating hot water system is distributed using three (3) pumps controlled with variable frequency drives. The VFDs are regulated by the differential pressure measures taken from the system on the highest floor, and adjust as necessary. Temperature is controlled by temperature sensors on the hot water supply side of the heat exchanger to maintain a constant heating temperature of 190 F. The hot water is distributed from the pumps to the air-handlers on the fifth floor and the multiple reheat coils on each floor. After flowing through the coils it is returned to the heat exchangers in the basement for processing. ***Figure 3*** below shows a schematic of the system.

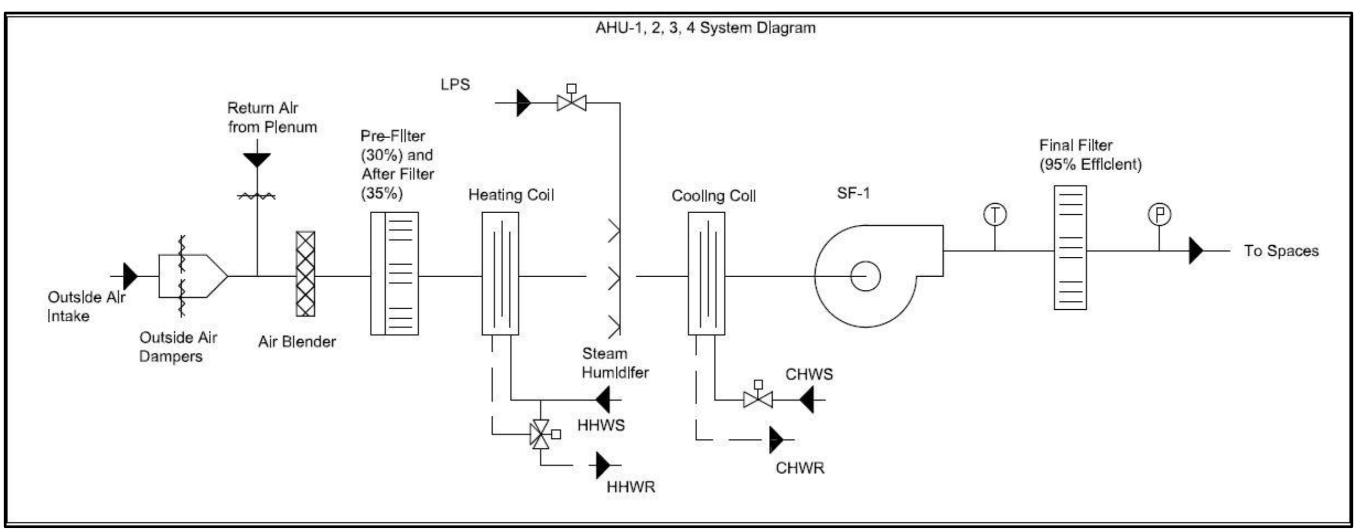

Figure 1: Air Handler Diagram

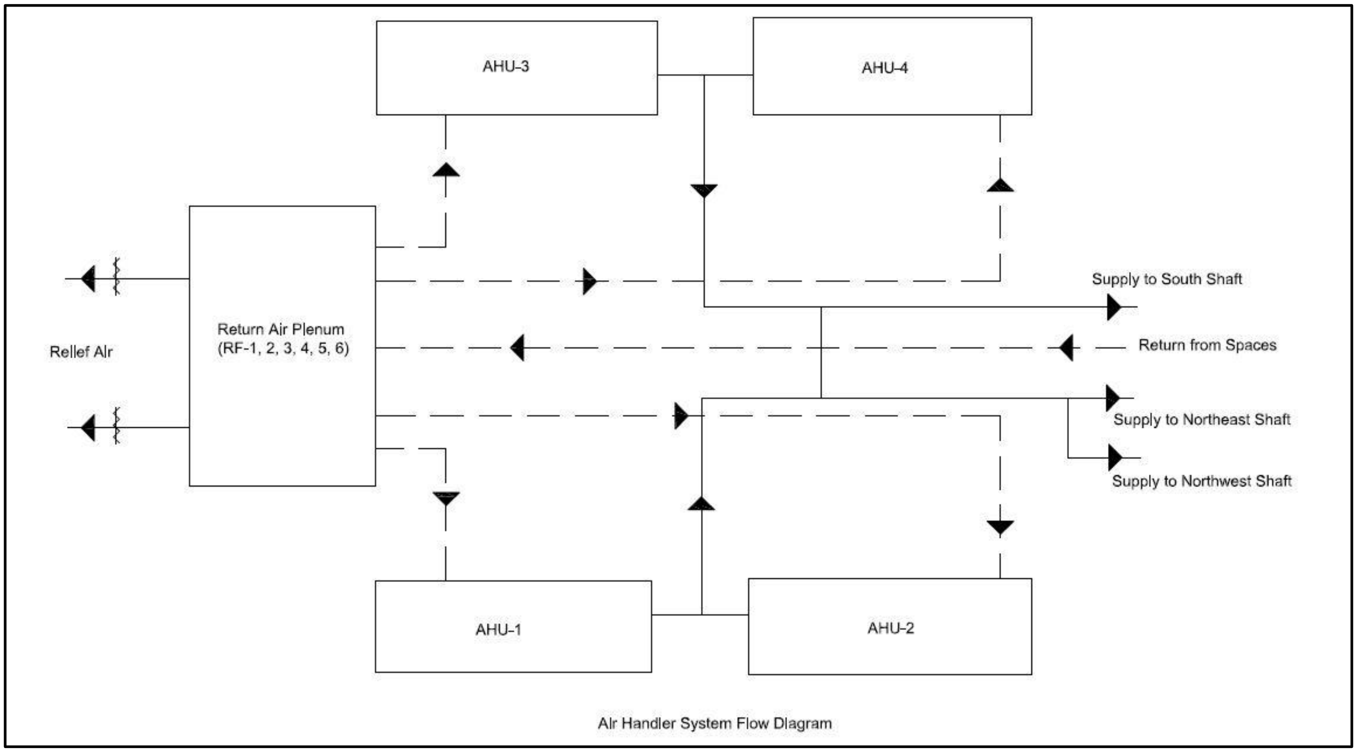

Figure 2: Air-Handling System Diagram

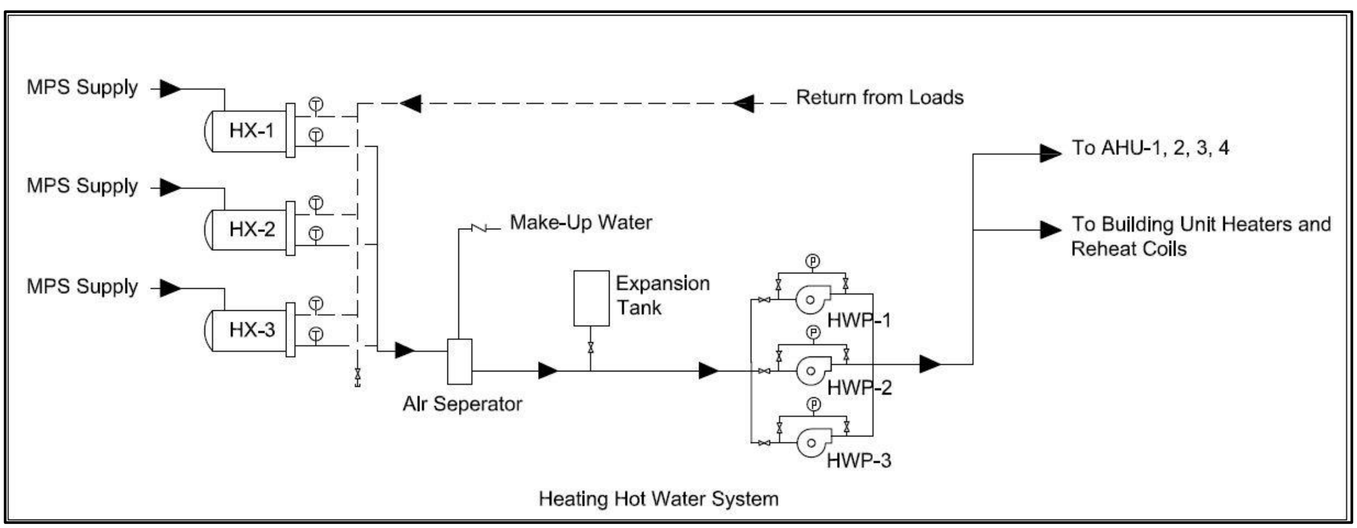

Figure 3: Heating Hot Water Flow Diagram

Building Performance

Thermal Loads

The analyses presented in this portion of the report are results of running the building model in Trane TRACE 700 software. In order to better analysis the building as a whole, a number of assumptions were made for the various room types. Most of the occupancy and airflow data was pulled directly from the original basis of design, while lighting was pulled from ASHRAE Fundamentals 2009 and miscellaneous loads were estimated from prior hospital design experience. For details of the assumptions used refer to **Technical Report 2.**

All loads were calculated by hand by the designer without the use of a program using guidelines suggested by ASHRAE Load Calculation methods. The following presents a comparison of the designers hand calculation and TRACE model results.

Supply Air and Ventilation Comparison

The ventilation rate provided in the documentation was 184,553 cubic feet per minute with 40% outdoor air and a CFM/SF value of 0.95. The TRACE model results in a lower total supply and ventilation rate, but a higher outdoor air percentage. Due to the weather data being the same as what the designer specified in their basis of design, and ventilation being from this documentation also, this can be attributed to inaccurate internal load assumptions in the miscellaneous loads. ***Table 11*** below shows a comparison of the design air-handler and the results of the TRACE model analysis.

Table 11: System Ventilation Comparison

	Design Values	TRACE Values	% Difference
Area (SF)	195,163	200,591	3 %
Total Supply (CFM)	184,553	119,995	-35 %
Outdoor Air (CFM)	73,741	52,778	-28 %
% Outdoor Air	40 %	44 %	10 %
CFM/SF	0.95	0.60	-37 %

Cooling Plant Comparison

Since there was no designer record of plant loads for this building, the results from the TRACE model have been compared to typical cooling load values from the ASHRAE Pocket Guide-2005 Cooling Load Check Figures table. Since the South Patient Tower is primarily patient rooms, the value for a Hospital Patient Room was used from this table. The range in the ASHRAE Pocket Guide-2005 is 275

SF/ton for the lowest to 165 SF/tons for the highest. ***Table 12*** below shows the comparison between the model results and the typical values for this type of building.

Table 12: Cooling SF/ton Comparison

	ASHRAE Typical (Lo)	TRACE Value	% Difference
SF/ton	275	275.8	0.29

The value is slightly higher than the lowest suggested value in the ASHRAE Pocket Guide-2005 but this can be partly attributed to inaccuracies in the miscellaneous loads on the spaces since the lighting and occupancy were taken directly from design documentation.

Energy Consumption

After developing a Trane TRACE model to calculate the various loads on the South Patient Tower, the software was used to determine the buildings total energy consumption. The following section will breakdown the energy usage and associated costs that were determined through the analysis. Although the building is connected to a campus loop, the portion used from that plant was modeled for use in this consumption summary.

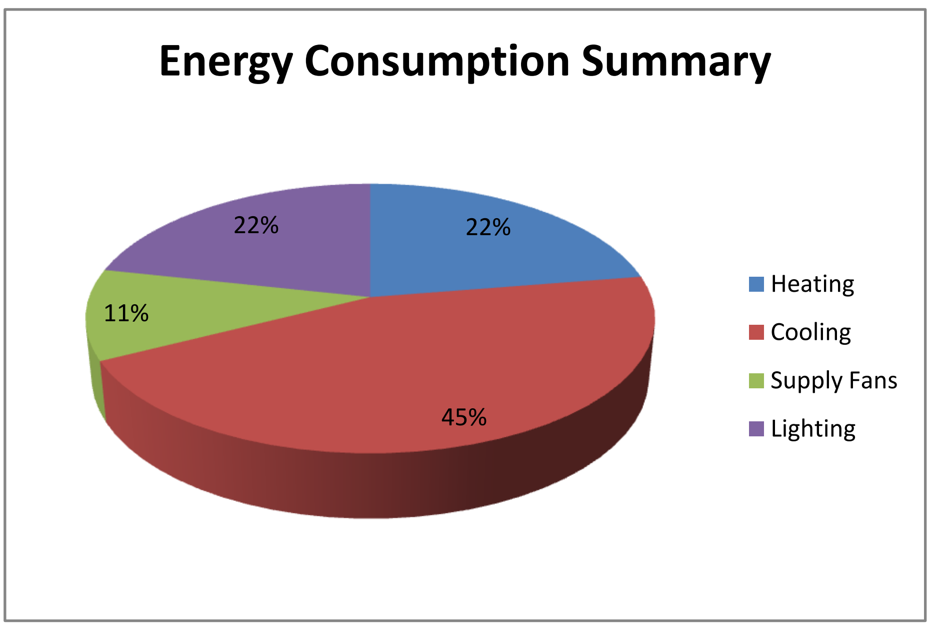

Figure 4: Energy Consumption Summary

As shown previously, ***Figure 4*** breaks down the various consumers of energy in the South Patient Tower. It can be seen that cooling dominates the energy consumption as there are many loads within the hospital that are operating continuously and create heat load. Lighting also seems higher than expected but since the building is under continuous operation, this percentage seems creditable. Further breakdowns can be seen in the following tables and figures. ***Table 13*** shows the Cost/SF of the equipment and includes the water consumption, while ***Figure 5*** shows the monthly utility costs from the analysis. The total Cost/SF for the building seems lower than it should be indicating the inaccurate miscellaneous equipment levels that were previously assumed.

Table 13: Equipment Cost Summary (Includes Water Consumption)

	Energy Usage (kBTU/yr)	Cost ($/yr)	Cost/SF ($/SF)
Heating	2,347,473	$ 10,623	$ 0.05
Cooling	2,917,553	$ 32,451	$ 0.16
Lighting	2,255,491	$ 21,661	$ 0.11
Supply Fans	1,139,462	$ 10,943	$ 0.05
Heat Rejection	1,792,296	$ 17,212	$ 0.09
Other Clg	2,066	$ 19.84	$ 0.00
Totals	**10,454,341**	**$ 92,909**	**$ 0.46**

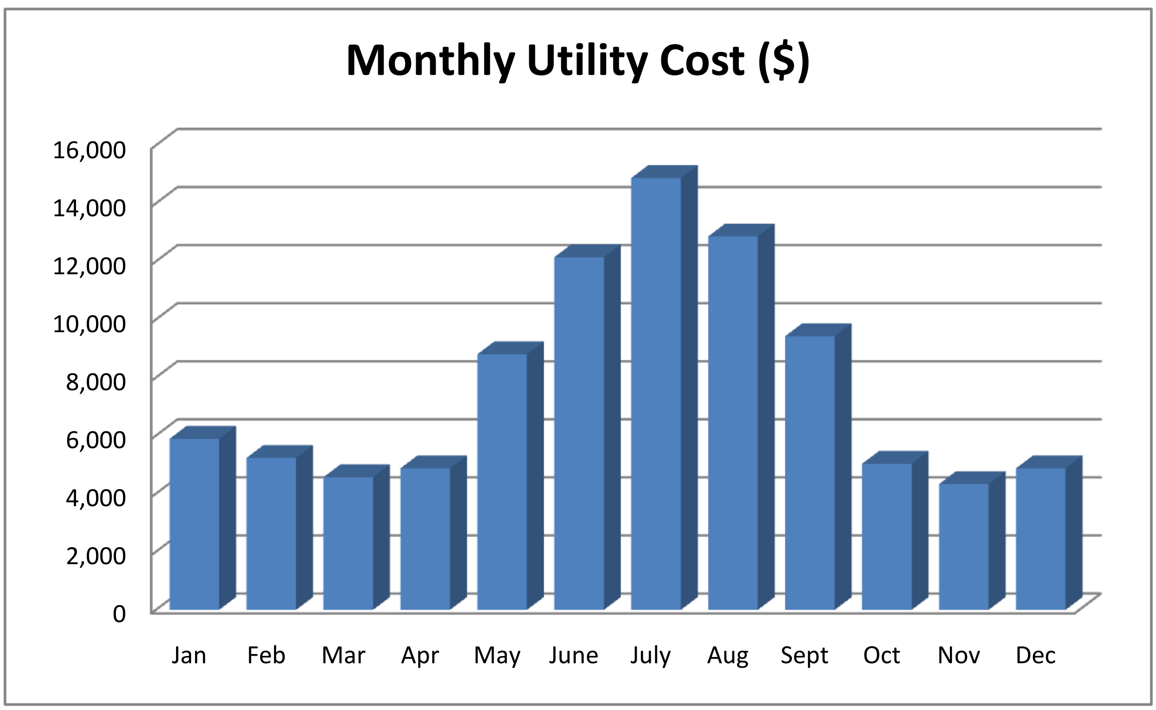

Figure 5: Monthly Utility Costs

An energy analysis was performed by the designers of the South Patient Tower, however this data could not be obtained due to owner request. An overall model is expected to be completed, however, when the Women's Clinic addition is added as part of the next phase of construction for LEED purposes. Also the owner was not willing to release utility data. Due to this there is no way to compare the monthly costs to the TRACE results, and the default utility rates were used.

LEED-NC Analysis

The South Patient Tower was evaluated under LEED-NC v2.2 system, with a goal of obtaining LEED Silver. The following is a summary of the points pertaining to the mechanical systems. These are the points that the designers strived to obtain while creating the South Patient Tower's mechanical systems. If they have been obtained at this point in the construction it has been noted. Other points were obtained or are pending for the project. The full LEED scorecard can be seen in ***Appendix A.***

Energy and Atmosphere

Prerequisite 1: Fundamental Commissioning of Building Energy Systems

Verify that the project's energy-related systems are installed, and calibrated to perform according to the owner's project requirements, basis of design and construction documents. This point is pending on the South Patient Tower until the construction and commissioning is finished but should be achieved upon completion.

Prerequisite 2: Minimum Energy Performance

Establish the minimum level of energy efficiency for the proposed building and systems. The South Patient Tower is designed with ASHRAE 90.1 recommendations for energy usage which makes the design achieve this prerequisite.

Prerequisite 3: Fundamental Refrigerant Management

Reduce ozone depletion by having zero usage of chlorofluorocarbon (CFC) –based refrigerants in the new buildings heating, ventilating, air conditioning and refrigeration systems. The designers have obeyed the requirements for this credit and have achieved this prerequisite.

Credit 1: Optimize Energy Performance

To achieve increasing levels of energy performance above the baseline in the prerequisite standard to reduce environmental and economic impacts associated with excessive energy use. The South Patient Tower designers followed the suggestions of *Option 1 – Whole Building Energy Simulation* and compared to the ASHRAE 90.1 baseline building, the tower achieved a 14% energy reduction and obtained 2 points.

Indoor Environmental Quality

Prerequisite 1: Minimum IAQ Performance

Meet the minimum requirements of Sections 4 through 7 of ASHRAE 62.1-2004, Ventilation for Acceptable Indoor Air Quality. Mechanical ventilation systems shall be designed using the Ventilation Rate Procedure or the applicable local code, whichever is more stringent. The tower complies with the standard and thus receives this prerequisite.

Prerequisite 2: Environmental Tobacco Smoke (ETS) Control

Minimize exposure of building occupants, indoor surfaces, and ventilation air distribution systems to Environmental Tobacco Smoke (ETS). The design achieves this prerequisite by following *Option 1* and prohibiting smoking in the building, and locating any exterior designated smoking area at least 25 feet away from entries, outdoor air intakes and operable windows.

Credit 2: Increased Ventilation

Provide additional outdoor air ventilation to improve indoor air quality for improved occupant comfort, well-being and productivity. Due to the increase in ventilation required by ASHRAE 170 which is above the requirements of ASHRAE 62.1, the South Patient Tower is predicted to obtain 30% more ventilation thus receiving this credit.

Credit 3.1: Construction IAQ Management Plan, During Construction

Reduce indoor air quality problems resulting from the construction/renovation process in order to help sustain the comfort and well-being of construction workers and building occupants. South Patient Tower is implementing the requirements of this credit and the point is pending with high hopes of obtaining it.

Credit 4.1: Low-Emitting Materials, Adhesives and Sealants

Reduce the quantity of indoor air contaminants that are odorous, irritating and/or harmful to the comfort and well-being of installers and occupants. The designers have taken this into account and the point should be achieved at the completion of construction.

Credit 4.2: Low-Emitting Materials, Paints and Coatings

Reduce the quantity of indoor air contaminants that are odorous, irritating and/or harmful to the comfort and well-being of installers and occupants with regards to paints and coatings. The designers have taken this into account and the point should be achieved at the completion of construction.

Credit 4.3: Low-Emitting Materials, Flooring Systems

Reduce the quantity of indoor air contaminants that are odorous, irritating and/or harmful to the comfort and well-being of installers and occupants with regard to the flooring systems especially carpeting. The designers have taken this into account and the point should be achieved at the completion of construction.

Credit 5: Indoor Chemical & Pollutant Source Control

Minimize exposure of building occupants to potentially hazardous particulates and chemical pollutants. The designer has specified filters that are either HEPA or better than MERV 13 for the towers air filtration media, which helps obtain this credit.

Credit 6.2: Controllability of Systems, Thermal Comfort

Provide a high level of thermal comfort system control by individual occupants or by specific groups in multi-occupant spaces to promote productivity, comfort and well-being of building occupants. South Patient Tower employs controls for at least 50% of the building occupants as well as providing comfort system controls for all shared multi-occupant spaces to enable adjustments to suit group needs and preferences, thus obtaining the credit.

Credit 7.1: Thermal Comfort, Design

Provide a comfortable thermal environment that supports the productivity and well-being of building occupants. Since the designer followed the guidelines of ASHRAE Standard 55, the South Patient Tower is awarded this point.

Credit 7.2: Thermal Comfort, Verification

Provide for the assessment of building thermal comfort over time. There was an agreement to implement a thermal comfort survey to the building occupants over a period of 6 to 18 months after occupancy, given the project this credit.

All of the previous credit areas are assumed to be attainable by the design of the South Patient Tower. The mechanical system was able to earn five (5) credits with potential for six (6) more making up 11 of the 43 total points in the overall rating. More credits could have been earned with more energy efficient choices to increase the savings from the baseline.

Overall Evaluation Summary

The constant air volume method of meeting space loads has been used for many years with 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 Trace Energy model estimates an operational cost of **$93,000** or **$0.46/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 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.

Looking forward to a redesign option, the South Patient Tower seems to be a good candidate for a 100% outside air system with an energy recovery wheel on the exhaust stream. Already the hospital is found to be exhausting a large amount of air and no heat recovery exists. With a 100% outdoor air system in place, all return air would be eliminated helping to improve the indoor air quality of the space by exhausting all contaminated air, yet recovering the heat from this air.

Appendix A: LEED Scorecard

Turner Healthcare 9/9/2011

INOVA Fairfax Hospital South Patient Tower LEED-NC v2.2 Overall Scorecard

Project: Inova Fairfax Hospital South Patient Tower
Owner: Inova Health System
Address: 3300 Gallows Road, Falls Church, VA 22042

		Responsible	Points Available	Earned	Anticipated (Design)	Pending
Sustainable Sites						
Prereq 1	Construction Activity Pollution Prevention	Constr	0		Y	
Credit 1	Site Selection	Design	1	1		
Credit 2	Development Density & Community Connectivity	Design	1	1		
Credit 4.1	Alternative Transportation, Public Transportation Access	Design	1	1		
Credit 4.2	Alternative Transportation, Bicycle Storage & Changing Rms	Design	1	1		
Credit 5.2	Site Development, Maximize Open Space	Design	1	1		
Credit 7.2	Heat Island Effect, Roof	Design	1	1		
Water Efficiency						
Credit 1.1	Water Efficient Landscaping, Reduce by 50%	Design	2	2		
Credit 3.1	Water Use Reduction, 20% Reduction, sensors	Design	2	2		
Energy & Atmosphere						
Prereq 1	Fundamental Commissioning of Building Energy Systems	Constr	0			Y
Prereq 2	Minimum Energy Performance	Design	0	Y		
Prereq 3	Fundamental Refrigerant Management	Design	0	Y		
Credit 1	Optimize Energy Performance	Design	10	2		
Photo 3: Gutter buddies installed at storm inlet along South side of Loop Road.						
Materials & Resources						
Prereq 1	Storage & Collection of Recyclables	Design	0	Y		
Credit 2.1	Construction Waste Management	Constr	2			2
Credit 4.1	Recycled Content	Constr	2			2
Credit 5.1	Regional Materials	Constr	2			2
Credit 7	Certified Wood	Constr	1			1
Indoor Environmental Quality						
Prereq 1	Minimum IAQ Performance	Design	0	Y		
Prereq 2	Environmental Tobacco Smoke (ETS) Control	Design	0	Y		
Credit 2	Increased Ventilation	Design	1	0		1
Credit 3.1	Construction IAQ Management Plan, During Construction	Constr	1			1
Credit 3.2	*Construction IAQ Management Plan, Before Occupancy - Maybe*	*Constr*	*1*			*0*
Credit 4.1	Low-Emitting Materials, Adhesives & Sealants	Constr	1			1
Credit 4.2	Low-Emitting Materials, Paints & Coatings	Constr	1			1
Credit 4.3	Low-Emitting Materials, Flooring Systems	Constr	1			1
Credit 4.4	Low-Emitting Materials, Composite Wood & Agrifiber Products	Constr	1			0
Credit 5	Indoor Chemical & Pollutant Source Control	Design	1			1
Credit 6.2	Controllability of Systems, Thermal Comfort	Design	1	1		
Credit 7.1	Thermal Comfort, Design	Design	1	1		
Credit 7.2	Thermal Comfort, Verification	Owner	1	1		
Innovation & Design Process						
Credit 1.1	Innovation in Design: Exempl. Perf.: SS c 5.2 Maximize Open Spa	Design	1	1		
Credit 1.2	Innovation in Design: Exempl. Perf. in Alt Trans SS c 4.1	Design	1	1		
Credit 1.3	*Innovation in Design: Exemplary Performance, Regional/Recycled*	*Constr*	*1*			*1*
Credit 1.4	Innovation in Design: Green Ed/Cleaning, C2C, EPP	Owner	1			0
Credit 2	LEED® Accredited Professional	Constr	1			1
		POINT TOTALS:	43	17	0	15

GOAL	LEED SILVER	33 Points Minimum
	Anticipated LEED Credit Score	32 (Earned + Anticipated + Pending)