11/29

Virtua West Jersey Replacement Hospital

Voorhees NJ

TECHNICAL REPORT THREE

System Overview | Justin Prior | Mechanical

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Executive Summary

The purpose of this report is to discuss the results for the entire mechanical system of the Virtua West Jersey Replacement Hospital. This includes energy analysis, indoor air quality, and weather data from previous reports. New to this report are a LEED analysis, control breakdown, mechanical cost, and schematics for the air side, chilled water, hot water, and steam systems.

While the building was not registered for LEED accreditation, it was able to achieve various LEED points. All of the LEED prerequisites were met, and the building was able to achieve additional credits as well in Indoor Air Quality and Energy & Atmosphere. LEED credits were only counted in this report if they were clearly and absolutely achieved by this building. If any credit was not clearly achieved it was not counted. There is a possibility that more credits could have been achieved, but the information was not substantial enough to give a credit.

A control breakdown was also done for the Air Handling Units, as well as the individual VAV boxes. Included in the control breakdown are the controls for smoke control when a fire alarm is set off. All systems are controlled by a dedicated direct digital controller, and are all tied into a central BAS system.

While the mechanical costs were not made available for this report, an analysis could still be conducted. The mechanical system is a fairly standard VAV system, and should cost around the same. The difference, however, is that this system is larger than that of a conventional system. All pieces of equipment have a fairly large capacity compared to that of normal equipment. Additional costs can also be expected for the larger amount of materials and labor needed since the building is very large as well.

Finally a schematic was drawn for each major system in the hospital. This includes the AHU's, chilled water, hot water, and steam. The schematics were simplified based off of the design documents to show how each system functions throughout the building.

System Overview

The Virtua West Jersey Replacement Hospital is comprised of three main units. They include the hospital bed tower, the ancillary building comprised of offices and surgery rooms, and a central spine that runs through connecting the bed tower and ancillary building. The mechanical system was separated to condition these spaces separately based on the individual needs. The bedroom tower is mainly patient rooms and offices. These do not require the same indoor air quality as the ancillary building does. The ancillary building requires a much higher overall indoor air quality due to the operating and medical rooms.

The hospital consists of three 1,000 ton centrifugal chillers located in the central utility plant behind the ancillary portion of the building. The chiller schedule can be seen in Table 1.1. Located on the roof of the building are three 9,000 gpm high efficiency cooling towers. Table 1.2 shows the cooling tower schedule.

Water Cooled Chiller Schedule				
Tag	Capacity (Tons)	FL KW/Ton	NPLV KW/Ton	Type
CH-1	1000	0.611	0.501	Centrifuge
CH-2	1000	0.611	0.501	Centrifuge
CH-3	1000	0.611	0.501	Centrifuge

Table 1.1 Water Cooled Chiller Schedule

Cooling Tower Schedule				
Tag	Flow	EWT	LWT	Makeup Water
CT-1	9000	95	83	50
CT-2	9000	95	83	50
CT-3	9000	95	83	50

Table 1.2 Cooling Tower Schedule

The hospital utilizes a VAV (Variable Air Volume) system throughout the building. There are three sets of AHU's located on the 7th floor and can be seen in Table 1.3. The first set consists of two AHU's at 50,000 cfm each. This will serve dietary areas and labs. The second set of AHU's also consists of two sets of 50,000 cfm AHU's. These will serve emergency and surgery rooms. The last set consists of six 75,000 cfm units that will serve the 8 story patient bedroom tower. For the computer room there are three computer room air conditioning units (CRAC).

AHU Schedule				
Tag	Supply CFM	Supply Fan	Filter	Manufacturer
AHU-1A	50000	SF1A-1	AF1A-1	Haakon
		SF1A-2		
		SF1A-3		
		SF1A-4		
AHU-1B	50000	SF1B-1	AF1B-1	Haakon
		SF1B-2		
		SF1B-3		
		SF1B-4		
AHU-2A	50000	SF2A-1	AF2A-1	Haakon
		SF2A-2	AF2A-2	
		SF2A-3		
		SF2A-4		
AHU-2B	50000	SF2B-1	AF2B-1	Haakon
		SF2B-2	AF2B-2	
		SF2B-3		
		SF2B-4		
AHU-3A	75000	SF3A-1	AF3A-1	Haakon
		SF3A-2	AF3A-2	
		SF3A-3		
		SF3A-4		
AHU-3B	75000	SF3B-1	AF3B-1	Haakon
		SF3B-2	AF3B-2	
		SF3B-3		
		SF3B-4		
AHU-3C	75000	SF3C-1	AF3C-1	Haakon
		SF3C-2	AF3C-2	
		SF3C-3		
		SF3C-4		
AHU-3D	75000	SF3D-1	AF3D-1	Haakon
		SF3D-2	AF3D-2	
		SF3D-3		
		SF3D-4		
AHU-3E	75000	SF3E-1	AF3E-1	Haakon
		SF3E-2	AF3E-2	
		SF3E-3		
		SF3E-4		
AHU-3F	75000	SF3F-1	AF3F-1	Haakon
		SF3F-2	AF3F-2	
		SF3F-3		
		SF3F-4		

Table 1.3 AHU Schedule

For heating and humidifying the hospital has four steam boilers and six condensing boilers. The boilers schedules can be seen in Tables 1.4 and 1.5. Two of the steam boilers are 40 BHP, while the other two are 287 BHP. All four are located in the central utility plant. Coupled with the boilers are six shell and tube heat exchangers located in various areas around the building used for hot water heating. Table 1.6 shows the heat exchanger schedule.

Steam Boiler Compliance				
Tag	Type	Capicity (BTU/hr)	Fuel	Boiler Efficiency
B-1	MULTI PORT	1,340,000	NG	80
B-2	MULTI PORT	1,340,000	NG	80
B-4	FLEXTUBE	9,614,500	NG	80
B-5	FLEXTUBE	9,614,500	NG	80

Table 1.4 Steam Boiler Compliance

Condensing Boiler Schedule					
Tag	Capacity (HP)	Min Eff.	Design Pressure (PSI)	Max Flow	Manufacturer
B-7	87	87%	70	350	AERCO/GASMASTER
B-8	87	87%	70	350	AERCO/GASMASTER
B-9	87	87%	70	350	AERCO/GASMASTER
B-10	87	87%	70	350	AERCO/GASMASTER
B-11	87	87%	70	350	AERCO/GASMASTER
B-12	87	87%	70	350	AERCO/GASMASTER

Table 1.5 Condensing Boiler Schedule

Heat Exchanger Schedule						
Tag	Type	Capacity (MBH)	Design LMTD (F)	Design PSIG	Flow Rate	Manufacturer
HX-1	Shell & Tube	7200	375	150	325 gpm	B&G
HX-2	Shell & Tube	7200	375	150	325 gpm	B&G
HX-5	Plate & Frame	2512	150	65	500 gpm	Mueller
HX-6	Plate & Frame	7850	22	150	2500 gpm	-
HX-7	Shell & Tube	10041	200	125	10542 lbs/hr	B&G
HX-8	Shell & Tube	10041	200	125	10543 lbs/hr	B&G

Table 1.6 Heat Exchanger Schedule

Since the occupancy of this building is a hospital the filter selection was also important. Table 1.7 shows the filter schedule for the various filters used in the building. As can be seen in the table many of the filters have a high MERV rating due to the areas they serve.

Air Filter Schedule				
Tag	Location	Total CFM	MERV	Manufacturer
AF1A-1	AHU-1A	50000	13	Camfil Farr
AF1B-1	AHU-1B	50000	13	Camfil Farr
AF2A-1	AHU-2A	50000	13	Camfil Farr
AF2A-2		50000	17	Camfil Farr
AF2B-1	AHU-2B	50000	8	Camfil Farr
AF2B-2		50000	17	Camfil Farr
AF3A-1	AHU-3A	75000	8	Camfil Farr
AF3A-2		75000	14	Camfil Farr
AF3B-1	AHU-3B	75000	8	Camfil Farr
AF3B-2		75000	14	Camfil Farr
AF3C-1	AHU-3C	75000	8	Camfil Farr
AF3C-2		75000	14	Camfil Farr
AF3D-1	AHU-3D	75000	8	Camfil Farr
AF3D-2		75000	14	Camfil Farr
AF3E-1	AHU-3E	75000	8	Camfil Farr
AF3E-2		75000	14	Camfil Farr
AF3F-1	AHU-3F	75000	8	Camfil Farr
AF3F-2		75000	14	Camfil Farr

Table 1.7 Air Filter Schedule

Tables 1.8 and 1.9 show the supply fan and return fan schedules. Since air is being moved at high rates over high MERV filters the fans had to be larger than normal to overcome the pressure.

Supply Fan Schedule						
Unit	Service	Max CFM	TSP (In WG)	HP	Type	Manufacturer
SF1A-1	AHU-1A	12500	7	40	Airfoil	Haakon
SF1A-2		12500	7	40	Airfoil	Haakon
SF1A-3		12500	7	40	Airfoil	Haakon
SF1A-4		12500	7	40	Airfoil	Haakon
SF1B-1	AHU-1B	12500	7	40	Airfoil	Haakon
SF1B-2		12500	7	40	Airfoil	Haakon
SF1B-3		12500	7	40	Airfoil	Haakon
SF1B-4		12500	7	40	Airfoil	Haakon
SF2A-1	AHU-2A	12500	7	40	Airfoil	Haakon
SF2A-2		12500	7	40	Airfoil	Haakon
SF2A-3		12500	7	40	Airfoil	Haakon
SF2A-4		12500	7	40	Airfoil	Haakon
SF2B-1	AHU-2B	12500	7	40	Airfoil	Haakon
SF2B-2		12500	7	40	Airfoil	Haakon
SF2B-3		12500	7	40	Airfoil	Haakon
SF2B-4		12500	7	40	Airfoil	Haakon
SF3A-1	AHU-3A	18750	7	50	Airfoil	Haakon
SF3A-2		18750	7	50	Airfoil	Haakon
SF3A-3		18750	7	50	Airfoil	Haakon

SF3A-4		18750	7	50	Airfoil	Haakon
SF3B-1	AHU-3B	18750	7	50	Airfoil	Haakon
SF3B-2		18750	7	50	Airfoil	Haakon
SF3B-3		18750	7	50	Airfoil	Haakon
SF3B-4		18750	7	50	Airfoil	Haakon
SF3C-1	AHU-3C	18750	7	50	Airfoil	Haakon
SF3C-2		18750	7	50	Airfoil	Haakon
SF3C-3		18750	7	50	Airfoil	Haakon
SF3C-4		18750	7	50	Airfoil	Haakon
SF3D-1	AHU-3D	18750	7	50	Airfoil	Haakon
SF3D-2		18750	7	50	Airfoil	Haakon
SF3D-3		18750	7	50	Airfoil	Haakon
SF3D-4		18750	7	50	Airfoil	Haakon
SF3E-1	AHU-3E	18750	7	50	Airfoil	Haakon
SF3E-2		18750	7	50	Airfoil	Haakon
SF3E-3		18750	7	50	Airfoil	Haakon
SF3E-4		18750	7	50	Airfoil	Haakon
SF3F-1	AHU-3F	18750	7	50	Airfoil	Haakon
SF3F-2		18750	7	50	Airfoil	Haakon
SF3F-3		18750	7	50	Airfoil	Haakon
SF3F-4		18750	7	50	Airfoil	Haakon

Table 1.8 Supply Fan Schedule

Return Fan Schedule						
Tag	Service	Max CFM	ESP (in WG)	HP	Type	Manufacturer
RF-1A	BED TOWER	66,660	2	40	Plenum Fan	Greenheck
RF-1B	BED TOWER	66,660	2	40	Plenum Fan	Greenheck
RF-1C	BED TOWER	66,660	2	40	Plenum Fan	Greenheck
RF-1D	BED TOWER	66,660	2	40	Plenum Fan	Greenheck
RF-2A	ANCILLARY	50,000	1.5	25	Mixed Flow	Greenheck
RF-2B	ANCILLARY	50,000	1.5	25	Mixed Flow	Greenheck
RF-3A	ANCILLARY	50,000	1.5	25	Mixed Flow	Greenheck
RF-3B	ANCILLARY	50,000	1.5	25	Mixed Flow	Greenheck
RF-4A	OR/C-SECION	17,590	2	10	Mixed Flow	Greenheck
RF-4B	OR/C-SECION	17,590	2	10	Mixed Flow	Greenheck

Table 1.9 Return Fan Schedule

Design Factors

There were various design factors that had to be taken into account for the overall design of the HVAC for the hospital. The buildings location is in Voorhees NJ. This requires more heating days than cooling days. Additionally, the building is located on a large site with very little surrounding it. This could potentially lead to significant heat loss during the winter due to no wind obstructions. An additional design factor was the large amount of glass being used on the building. The building's exterior consists of over 40% glass. Glass was used that had a U value of at least U-30 to help solve this problem. The orientation of the building is also a factor. The front of the building faces directly north, giving the building a north-south orientation. This is not ideal for an effective solar gain design.

Design Conditions

The outdoor and indoor air conditions for Philadelphia, PA were used. This is because there was no available data for the buildings location in Voorhees NJ. However, Philadelphia is very close, making the weather data an accurate representation for the weather in Voorhees. Values were taken from the 2005 ASHRAE Handbook of Fundamentals. Values used were the .4% and 99.6%. The OA Dry Bulb for the summer is 92.7° F, while the OA Wet Bulb is 75.6° F. The OA Dry Bulb for the winter is 11.6° F. The clearness number was .98 as well.

Appendix A shows the weather data for Philadelphia, PA. It was taken from the 2005 ASHRAE Fundamentals.

Design Ventilation Requirements

It is important to note that the actual highest value of Z_p was not chosen. This is due to the fact that the hospital has specialty rooms that require a large amount of outdoor air. Choosing the absolute highest Z_p would be misleading in terms of figuring out the overall system efficiency. For example, AHU Set 2 has operating rooms that have a 100% Z_p and a 73% Z_p. These are only a couple rooms out of 500, and once again are specialty rooms. The E_v of AHU Set 2 and 3 are both high due to the lower max Z_p values. Both these values were for the patient rooms. Finally the final V_{ot} was calculated for each system.

The design supply air does not include the design outdoor air in the room schedules. When adding the V_{ot} to the supply air for AHU Set 1, the total value was 122,091 cfm. This is important to note because AHU Set 1 can only produce 100,000 cfms, meaning that by AHSRAE standards this system is undersized. This could be because ASHRAE codes were not used in the analysis in this building. Instead IMC 2003 and AIA 2001 were used to determine ventilation rates. AHU Set 2 has the same problem; it is undersized by about 16000 cfm when using ASHRAE standards. AHU Set 3 is actually oversized. It can produce a total of 450,000 cfms; meanwhile only 325,749 cfms are required. There is a reason for this however. Almost all of the hospitals mechanical equipment is designed to have additions in the future. There are plans to add an additional chiller and boilers. The same is being done for additional spaces in the building. AHU Set 3 was designed to be able to handle the additional cooling and heating loads that will occur when new additions are put in place.

Design Thermal Loads and Energy Use

The first section analyzed after the modeling was complete was the three main AHU sets. Tables 5.1, 5.2, and 5.3 show the basic analysis for each AHU set.

AHU-1		
	Cooling	Heating
%OA	36.4	1.2
cfm/ft^2	0.61	9.27
cfm/ton	155.98	
ft^2/ton	257.5	
Occupancy	918	

Table 5.1AHU Set 1 Analysis

AHU-2		
	Cooling	Heating
%OA	34.9	3.7
cfm/ft^2	0.73	2.86
cfm/ton	111.96	
ft^2/ton	152.83	
Occupancy	861	

Table 5.2 AHU Set 2 Analysis

AHU-3		
	Cooling	Heating
%OA	34.4	10.5
cfm/ft^2	0.89	1.7
cfm/ton	177.9	
ft^2/ton	199.5	
Occupancy	3516	

Table 5.3 AHU Set 3 Analysis

As seen in the tables the %OA for each AHU is around 35%. These all seem relatively high, however, when considering the design ventilation rates for the hospital they make sense. Many of the offices in the hospital have a very high %OA, as do the patient rooms. Many of these spaces are conditioned by AHU Set 3. The reason for AHU Set 2s high %OA is because this set conditions many of the medical rooms, including operating, radiation, recovery, and C-section rooms. AHU Set 1 has a high %OA because it also serves offices on the first floor, as well as the large kitchen areas which required a high percentage of outdoor air.

A rule of thumb for a standard building is 400 ft^2/ton. This is for a typical office building however. When looking at the individual AHU sets it is clear that much more energy is used. This makes sense due to the type of building being modeled. A hospital will naturally use much more energy than that of a standard commercial building. According to the DOE (Department of Energy) hospitals can use as much as 2.5 times the amount of energy compared to an office building. When comparing the ft^2/ton for the 3 sets of AHUs it is apparent that they are in the correct range.

Further comparing the ft2/ton for each set to each other also seems to yield accurate results. AHU Set 1 has the highest, at 257.5 ft^2/ton. This is due to the fact that mainly office, lounges, and waiting areas are on this set. It does condition the main kitchen, however, which most likely contributes to it using more energy. The other sets condition spaces that require much more energy. AHU Set 2 uses the most energy, 152 ft^2/ton, since it mainly conditions the operating rooms and medical rooms. AHU Set 3 is in the middle at 199.5 ft^2/ton. Once again, this seems accurate since this supplies most of the patient rooms, and some medical rooms, which require more ventilation than standard offices, such as the ones on AHU Set 1.

Electrical rates were taken directly off of the Atlantic City Electric Company's website. The average value used for the electric rate was $4.50/KW. The rate used for natural gas was $0.50/Therm.

Table 5.4 shows the overall breakdown for the energy consumption by the building annually. The primary heating for the building comprises of mostly natural gas, since the boilers are responsible for this and they run on natural gas. There are several heat exchangers that also operate throughout the building for additional heating that do use electricity, which mainly comprises the "Other" in Table 4.6 under primary heating. The Primary Cooling consists of the various parts of the chillers, and the cooling towers. As seen in the table all of the cooling equipment runs on electricity, with the chiller cooling compressors using the majority of the energy. It is important to note the amount of water used mainly in the cooling towers as well. The supply fans also use a significant amount of electricity as well. This is because they are powerful fans that must push large amounts of air through high MERV rating filters. This equates to a large pressure drop, making it necessary for large, powerful fans to be used.

Energy Consumption Summary						
System		Elec (KWH)	Gas (KBTU)	Water (1000 gal)	Total (KBTU/Yr)	% Total
Primary Heating	Primary Heating	-	292,402,592	-		
	Other	17,721	-	1	292,463	73.70%
Primary Cooling	Cooling Comp.	12,924,327	-	-		
	Tower/Cond Fans	1,859,147	-	88,409		12.70%
	Condenser Pumps	-	-	-	50,455,997	
Auxiliary	Supply Fans	8,851,427	-	-	30,209,902	7.60%
Lighting	Lighting	6,512,327	-	-	22,226,570	6%
Total		**30164949**	**292,402,592**	**88410**	**103,184,932**	**100%**

Table 5.4 Energy Consumption Summary

Mechanical System Cost

Unfortunately information was not made available for the direct costs for the specific pieces of equipment. This includes the chillers and boilers. The equipment for this building is standard since the mechanical system does not utilize many special components. It is a standard VAV system; however, the equipment is much larger than in a normal size building. There will also be a lot more ductwork, and in turn, labor to install the mechanical system. This would assumedly make the cost of the mechanical system slightly larger than that of a comparable building.

An additional cost must also be considered for the space for the mechanical system. All of the mechanical equipment other than the AHU's are located in a central utility plant. This plant serves no purpose other than directly housing all of the equipment.

Mechanical Sustainability Assessment – LEED v2.2

The LEED system is broken down into different sections. Sections analyzed for this report include Energy & Atmosphere, and Indoor Air Quality. LEED was not a significant factor in the design of the building. However, due to the high energy cost for a hospital, an energy efficient design was created to help on reducing the energy costs. This will lead to various LEED credits being obtained.

Energy & Atmosphere

For the Energy & Atmosphere section of LEED, the Virtua Hospital did achieve all three of the required credits. The intent of Prerequisite 1 is to verify that the buildings systems are all installed, calibrated, and perform to the initial design. The commissioning will be performed by the division contractor and will be document by the Commissioning Authority (CxA). The commissioning work will include testing and start up for all mechanical equipment, checklists, providing qualified personnel, and providing overall assistance.

Prerequisite 2 is intended to establish a minimum level of energy efficiency. This requires that the systems comply with ASHRAE Standard 90.1-2004. As studied in Tech 1, the mechanical system does comply with Standard 90.1.

Prerequisite 3 is intended to reduce ozone depletion. This requires that heating, ventilation, air conditioning and refrigeration do not use any chlorofluorocarbon based refrigerants, which the systems installed do not use.

The building does earn 5 out of 10points under EA Credit 1: Optimize Energy Performance. This credit is intended to achieve a high level of energy performance above a certain baseline in the prerequisites standards. The comparable baseline energy consumption used for this analysis was calculated using the Building Performance Rating Method in ASHRAE Standard 90.1-2004.

1 credit is earned in AE Credit 3: Enhanced Commissioning. This is because the CxA is very involved in the commissioning of the building and all of the commissioning will be documented.

1 credit is earned in AE Credit 5: Measurement & Verification. The intent of this credit is to provide an ongoing accountability of the buildings energy consumption over time. A documentation system is in place, and energy usage is recorded. This is especially important due to the occupancy of this building, and energy use is a major expense.

Indoor Air Quality

The hospital does both of the required prerequisites. Prerequisite 1 requires that minimum IAQ performance is achieved. The IAQ must meet the requirements of ASHRAE Standard 62.1-2004. The hospital did comply with this section.

Prerequisite 2 requires that environmental tobacco smoke is controlled. Since no smoking is allowed indoors or anywhere within a certain distance of the building, this requirement is easily met.

1 credit is earned in EQ Credit 1: Outdoor Air Delivery Monitoring. The intent of this credit is to monitor the flow of outdoor air to help sustain occupant comfort and well being. The air handling units are equipped with a monitoring system to ensure proper performance.

5 credits are earned in EQ Credit 4: Low-Emitting Materials. The intent of this credit is to reduce the quantity of indoor air contaminants. An effort was made to use materials

throughout the building that do not release odors or any contaminants into the air. This is especially true in operating areas.

1 credit is earned in EQ Credit 6.1: Controllability of Systems: Lighting. This is intended to provide a system of lighting control. This is achieved in the building in two ways. All patient rooms have two settings for lights. A low light level is used for normal periods when the patient is in the room. When the patient is being examined there is a second setting that increases the light level. For many of the other spaces, including offices, occupancy sensors are installed to help control the lighting.

System Operation

All three AHU Sets are to be controlled using a dedicated direct digital controller. All fans will have a dedicated variable speed drive motor and will be interfaced with the BAS system for all start/stop, speed modulation, and monitoring control to maintain the duct static pressure set point 2/3 the way down the duct. The fans will be operated continuously during occupied hours unless they are manually turned off. Return fan speed shall be controlled to maintain a constant negative pressure. When smoke is detected in the building the outside and exhaust air dampers will modulate to 100% open, meanwhile the return air dampers will be close.

Pre-heating will be accomplished by circulating chilled water at 55° F. The supply air temperature will be maintained at 55° F. There will be a reset based on dehumidification needs and outdoor air temperature. The reset will be between 50° F and 60° F. Overall the system will have three modes of operation: pre-heat, outside air economizer, and mechanical cooling.

There will be two safety devices to be on manual reset. If the freeze stat senses leaving air temperature below set point, all fans will be shut down. A high pressure switch will also be installed after the supply fan. If the discharge pressure exceeds 6" in wg, then the fans will stop running.

All VAV boxes will be controlled by a dedicated direct digital controller. The BAS will modulate the VAV box damper and the reheat coil in sequence to satisfy the space temperature set point. When the system is running at unoccupied operation, the set points for the space will be 80° F and 65° F.

For the chilled water the BAS system will enable the chilled water system when outside air temperature is above a user definable set point. The BAS will determine the “lead” chiller based on the least amount of runtime. It will also indicate the sequence designation of each chiller. When a chiller is started, the chilled water pump shall start first. The lead chillers evaporator isolator valve shall be opened next. The condenser water pump will then open next, followed by the condenser isolation valve. Upon proof of flow the chiller will maintain the chilled water supply temperature set point.

The cooling towers shall also be controlled by the BAS system. When the chilled water system is enabled, the “lead cooling tower will be started, based on least amount of runtime. If the cooling tower is not operational within 15 seconds, than an alarm will be issued and the next cooling tower will replace it in sequence. When the cooling tower is started, condenser water will bypass the towers until the water reaches 60° F. When the temperature exceeds the set point, the lead cooling tower fan will start at minimum speed. All isolation valves will be opened and the BAS will modulate the speed to the fan towards 100% to maintain condenser water set point.

System Schematics

Air Side Schematic

Figure 9.1 shows the airside schematic for all AHU sets. The first set of AHU’s serve the first floor of the patient tower, which comprises of dining areas, offices, and kitchens. AHU Set 2 serves the operating rooms, and any other medical space requiring high indoor air quality. AHU Set 3 serves the entire patient tower, and some of the spaces in the ancillary building as well, such as the offices and lounges.

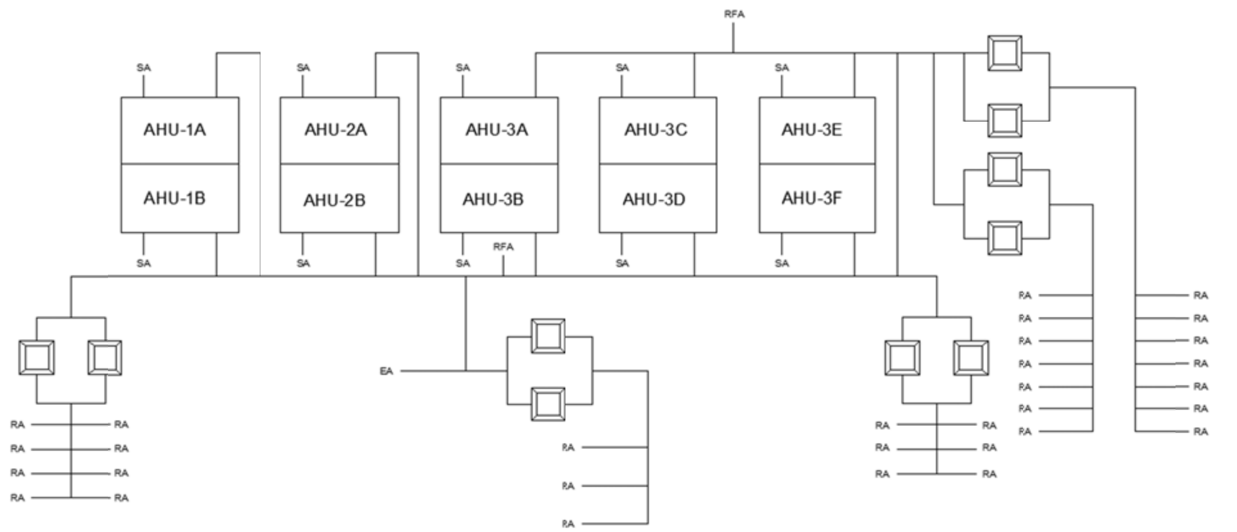

Figure 9.1 Air Side Schematic

Water Side Schematic

Figures 9.2 and 9.3 show the chilled water side schematic. The system includes three chillers that mainly serve the AHU's. Figure 9.2 shows the chilled water leaving the chillers and continuing on to Figure 9.3 where it serves the AHU's.

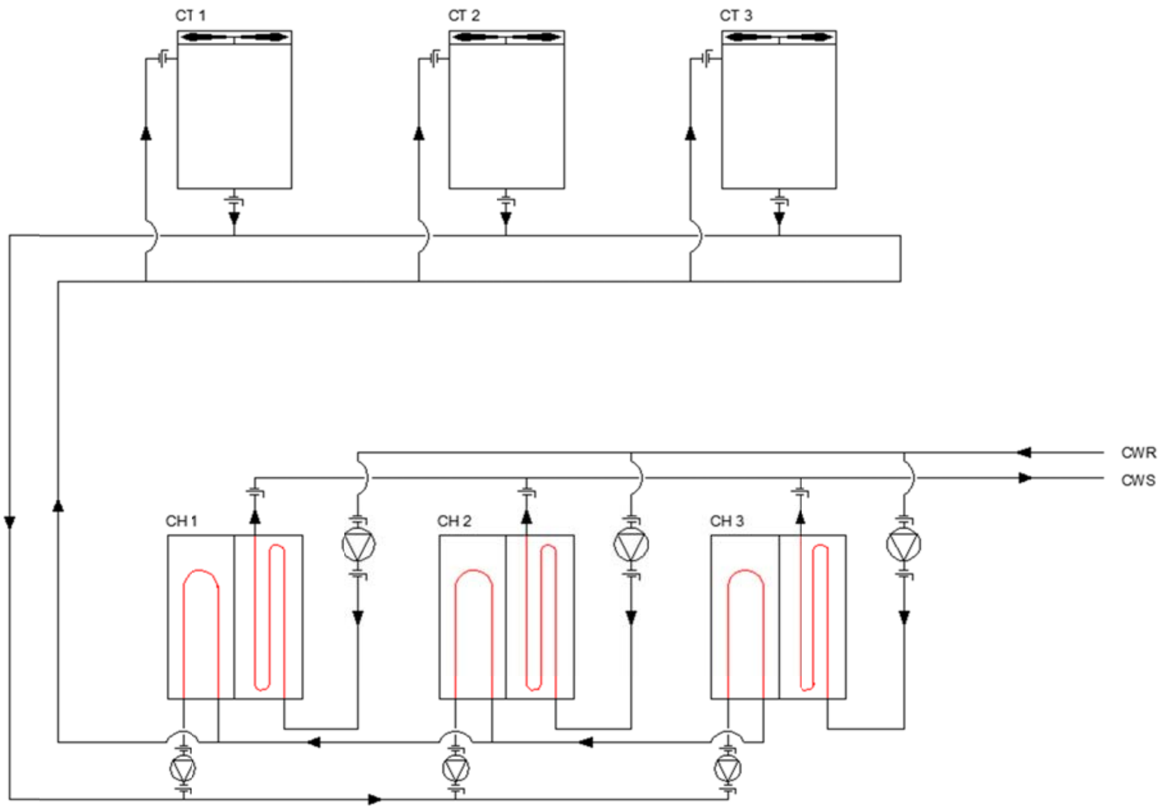

Figure 9.2 Chilled Water Schematic

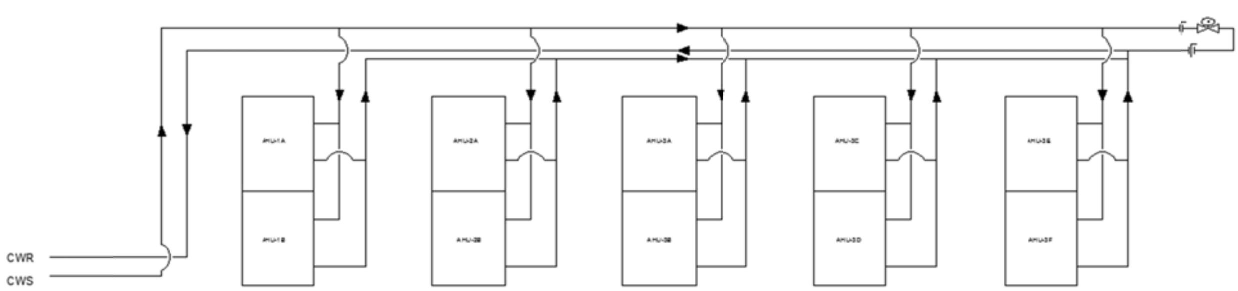

Figure 9.3 Chilled Water Schematic

Figures 9.4, 9.5, and 9.6 show the hot water side schematic. The system includes 6 boilers used for reheat coils in the VAV terminals, as well as utility handlers. Figure 9.4 shows the boiler room schematic. The hot water supply then moves to Figures 9.5 and 9.6, showing the different areas that the hot water is supplied too.

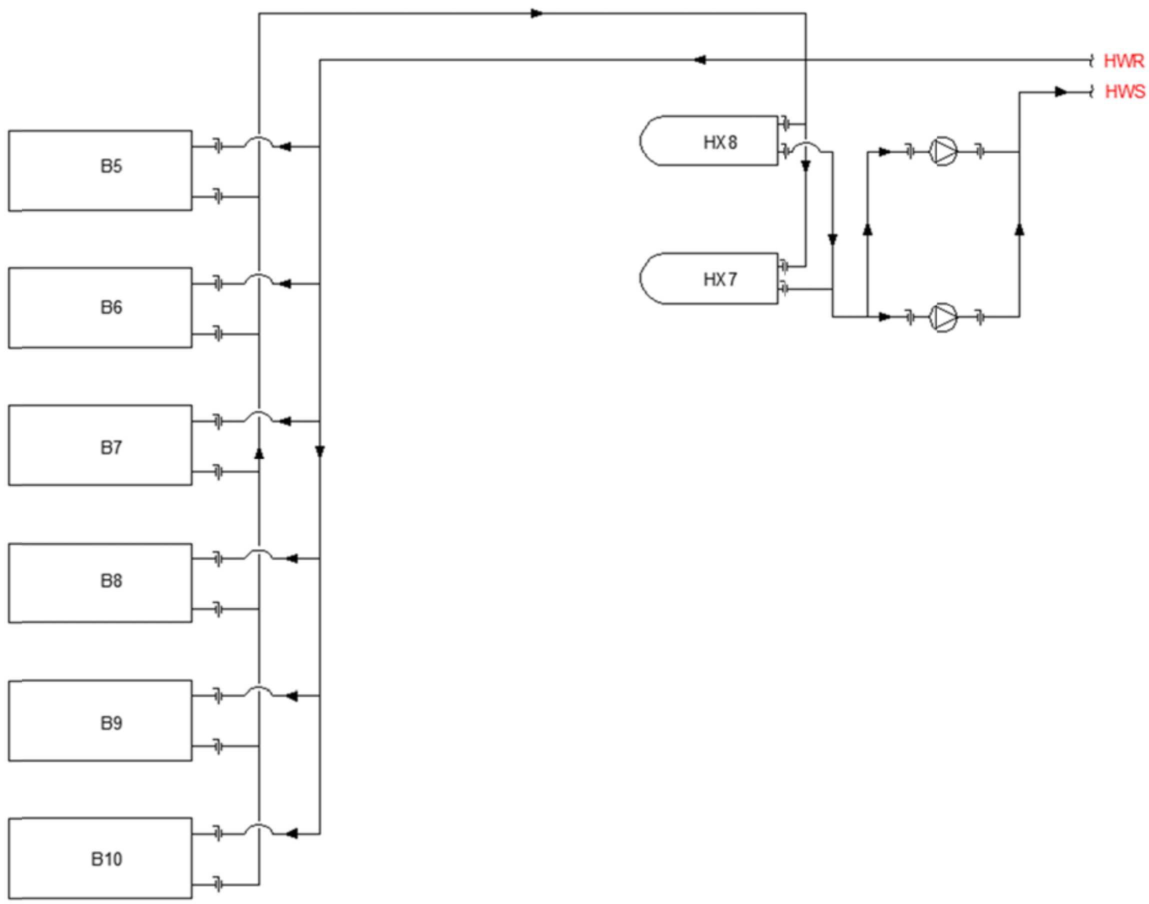

Figure 9.4 Hot Water Schematic

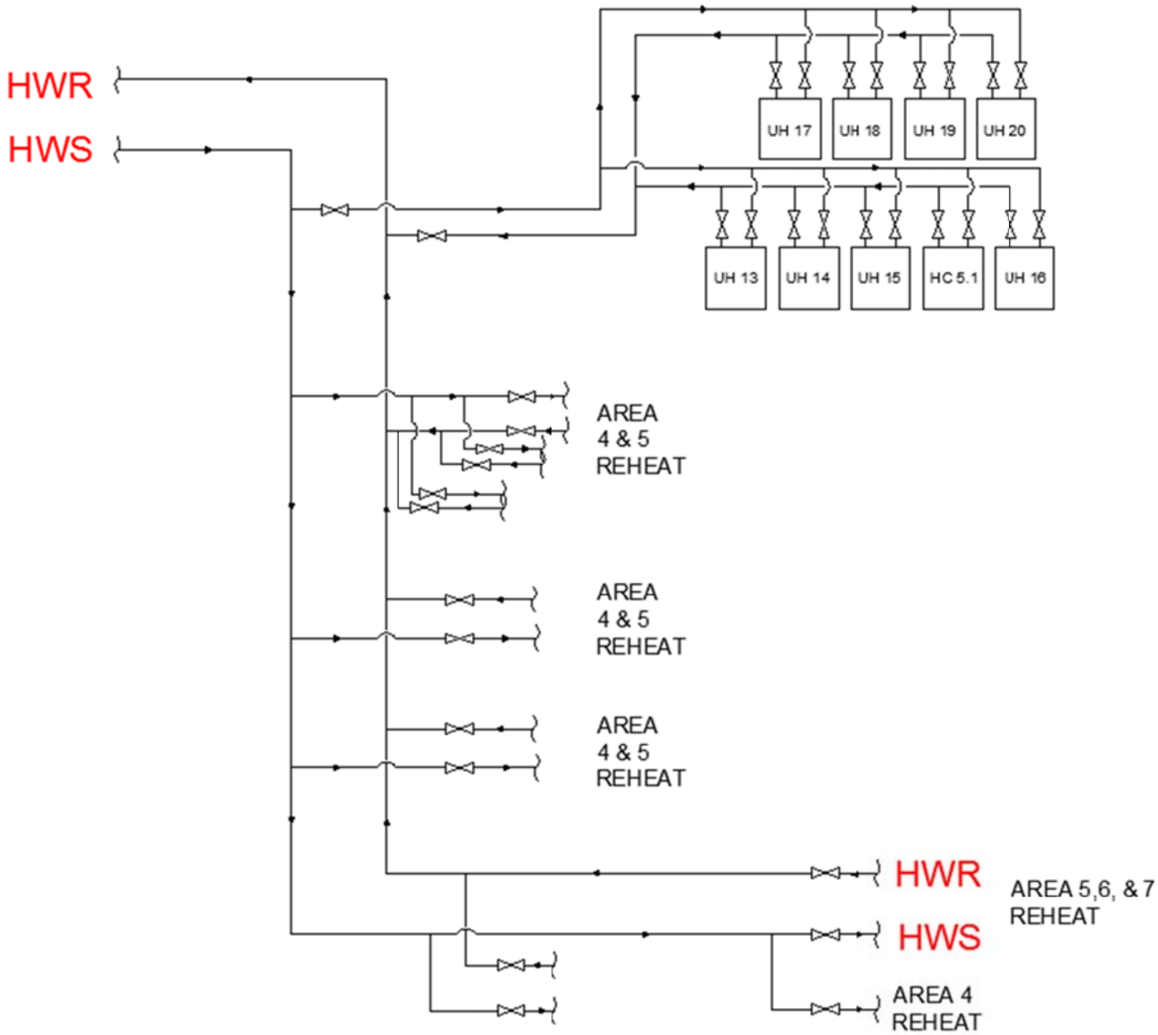

Figure 9.5 Hot Water Schematic

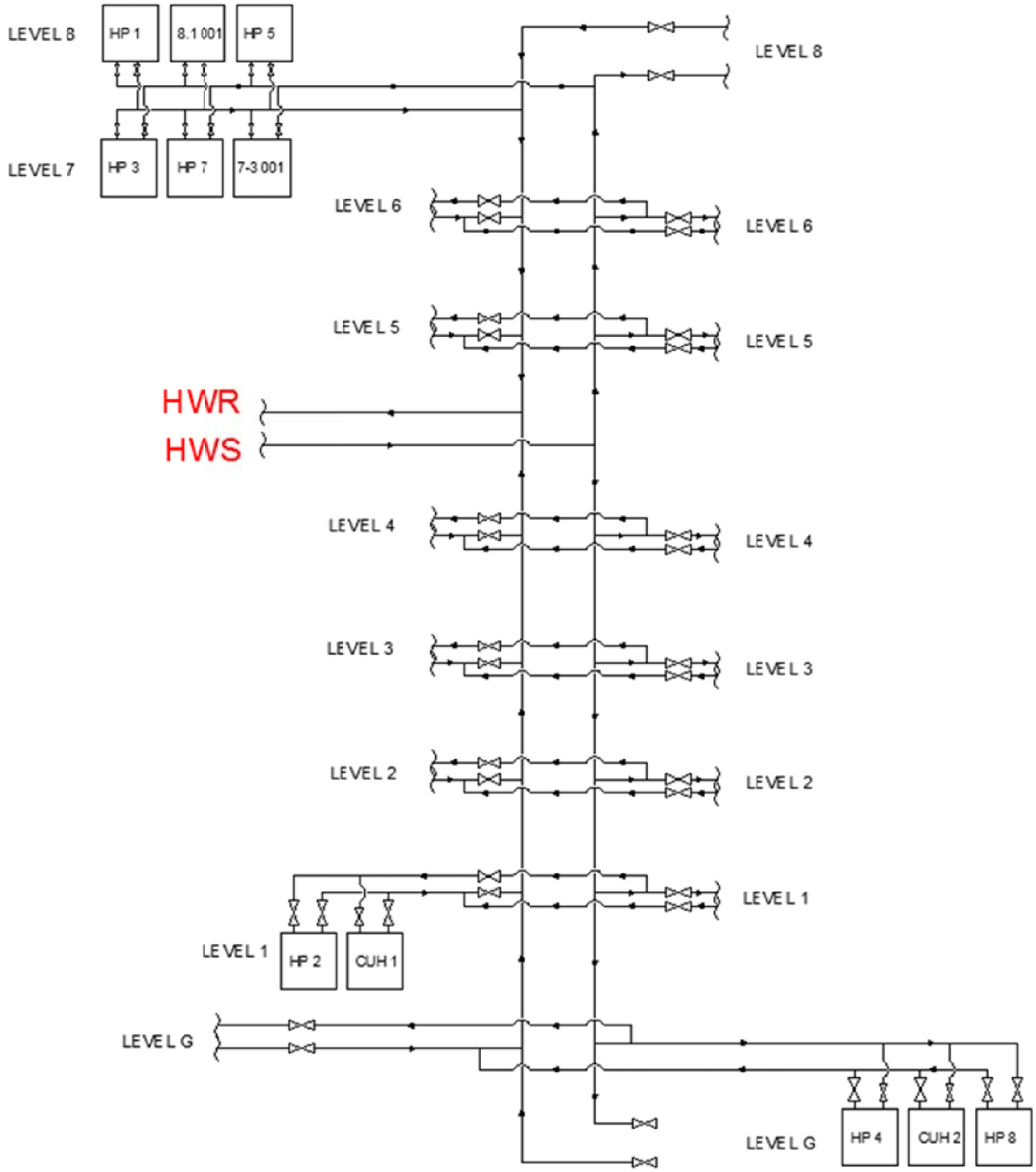

Figure 9.6 Hot Water Schematic

Steam Side Schematic

Figures 9.7 and 9.8 both show the steam schematic for the hospital. Figure 9.7 shows the four steam boilers. They provide both high pressure steam and low pressure steam. The high pressure steam is used for sterilizers located in specific rooms. The low pressure steam is used for the AHU's as well as washing equipment and kettles. This can be seen in Figure 9.8

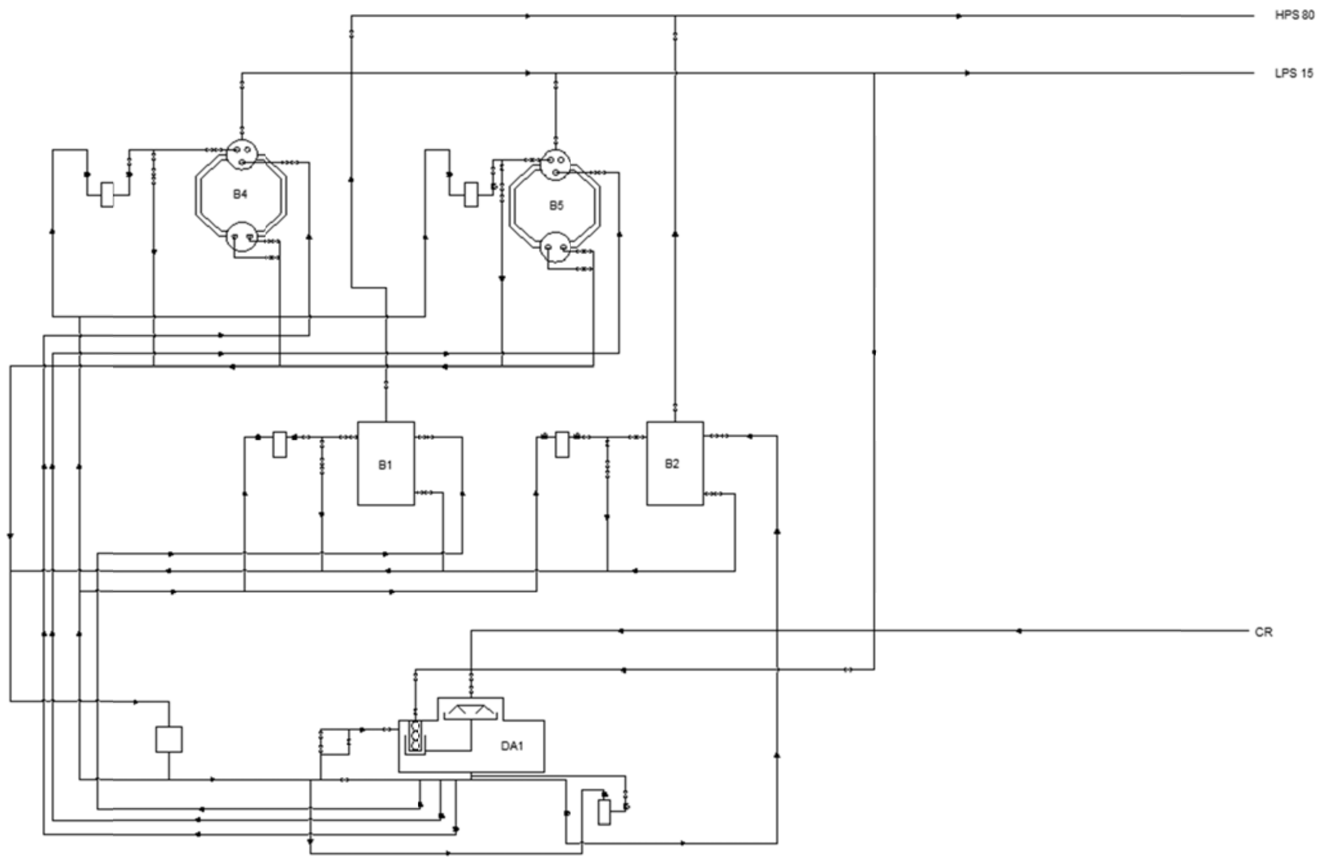

Figure 9.7 Steam Schematic

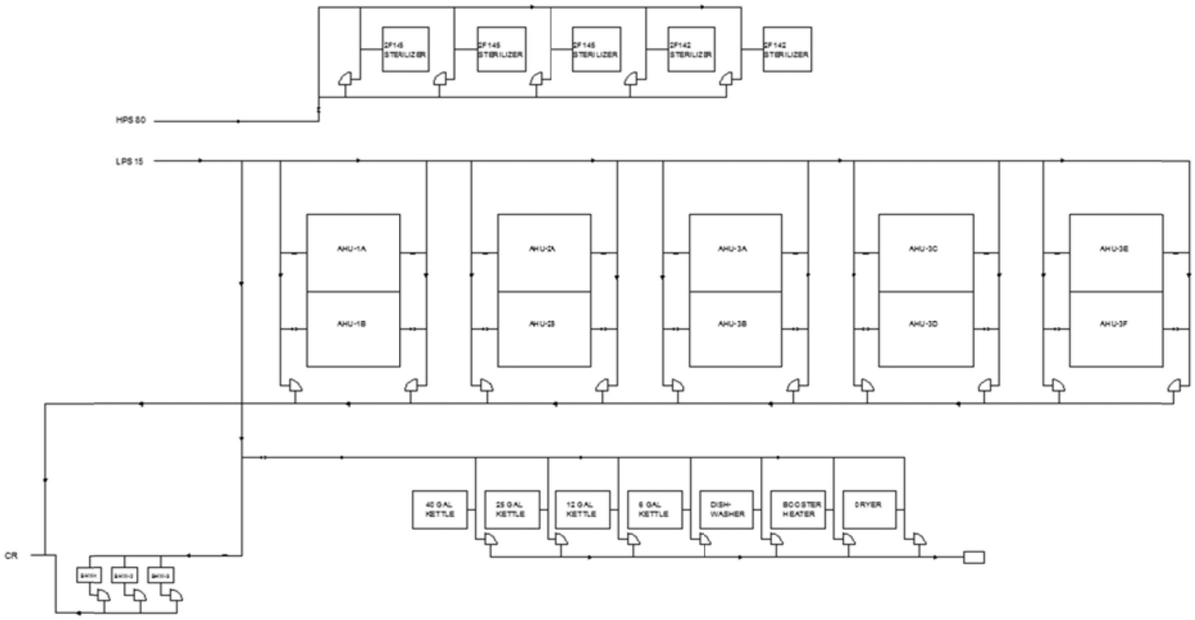

Figure 9.8 Steam Schematic

Final Evaluation

The overall design criterion for the mechanical system in the Virtua West Jersey Replacement Hospital was to create an energy efficient design with exceptional indoor air quality. The mechanical system has to serve two main occupancies. It includes serving office spaces, as well as operating and medical rooms. For obvious reasons the indoor air quality is significantly different for these two spaces. The mechanical system accomplishes this by using three sets of AHU's to serve the individual spaces. The mechanical system mainly uses four steam boilers and three chillers.

Overall I think the system is well designed and is efficient. While this system followed IMC 2003 and AIA 2001, it did comply with ASHRAE Standards 62.1-2004 and 90.1-2004.Tech 1 dealt with the systems indoor air quality. This report showed that the indoor air quality for the building is better than average. The system uses high MERV filters to establish a high indoor air quality. Many of the spaces also have a high outdoor air fraction. Many offices for example are over 50% outdoor air at max supply air.

While the high outdoor air fraction is an absolute necessity for many of these spaces, there are zones that have significantly more outdoor air than required. It seems a waste of energy to have many of the offices to have nearly 100% outdoor air. Since the building is not yet operational, energy costs are not known. According to my Tech Report 2 analysis, the operational cost of the hospital is $2,996,172. While this number is going to be large anyway due to the size and type of building under analysis, I feel it could be less since spaces are over conditioned. There could be an intended reason for this that is not known. For example, a higher outdoor air fraction may have been desired to make the spaces seem more comfortable.

The overall construction cost of the mechanical system was not made available. However, it is a standard VAV system. It will cost more than a standard VAV due to the larger size of the components. The building is very large so the cost of materials and labor will also be greater than a standard hospital.

While the building was not going after any LEED certification, an energy efficient design was desired to help reduce the large operational cost for the hospital. This was done mainly through using energy efficient equipment. All of the boilers and the chillers all have a higher efficiency than required by ASHRAE, and are also above standard equipment efficiencies in general.

The system was also designed to be easily maintained. All of the mechanical equipment is kept in a central utility plant. This plant is quite large and has a lot of space between all the various pieces of equipment. The main piping and ductwork is also exposed in the plant to make for easy maintenance. The AHU's are located in the main spine connecting the patient tower and the ancillary building. The AHU's are stored over 2 levels, making it easy to access them from both the top and the bottom.

Overall the mechanical system for the Virtua Hospital was well designed. Energy efficient equipment was used to help reduce costs, and LEED points could have been obtained if they were to apply for LEED status. While there could be additional energy savings by reducing the outdoor air fraction in spaces such as offices, the rest of the spaces seem to be properly designed in terms of indoor air quality.

References

ASHRAE Standard 62.1-2204

ASHRAE Standard 90.1-2004

ASHRAE Handbook of Fundamentals 2005

Department of Energy

LEED V2.2 Reference Guide

Scott Lindvall – HGA Architects & Engineers

Bill Swanson – Turner Construction Company

Dr. Stephen Treado

APPENDIX A

Design conditions for PHILADELPHIA, PA, USA

Station Information

Station name	WMO#	Lat	Long	Elev	StdP	Hours +/- UTC	Time zone code	Period
1a	1b	1c	1d	1e	1f	1g	1h	1i
PHILADELPHIA	724080	39.87N	75.25W	30	14.680	-5.00	NAE	7201

Annual Heating and Humidification Design Conditions

Coldest month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB	
			99.6%			99%			0.4%		1%			
	99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD
2	3a	3b	4a	4b	4c	4d	4e	4f	5a	5b	5c	5d	6a	6b
1	11.6	15.8	-4.8	4.3	15.0	-0.7	5.3	18.6	28.6	35.2	26.2	34.1	11.9	280

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest month	Hottest month DB range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB	
		0.4%		1%		2%		0.4%		1%		2%			
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
7	8	9a	9b	9c	9d	9e	9f	10a	10b	10c	10d	10e	10f	11a	11b
7	17.1	92.7	76.6	90.1	74.5	87.6	73.0	78.3	88.4	77.0	86.1	75.7	83.8	10.9	240

Dehumidification DP/MCDB and HR									Enthalpy/MCDB					
0.4%			1%			2%			0.4%		1%		2%	
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB
12a	12b	12c	12d	12e	12f	12g	12h	12i	13a	13b	13c	13d	13e	13f
76.5	133.5	83.0	74.3	128.2	81.7	73.1	123.0	80.4	34.0	89.0	32.6	86.0	31.3	83.7

Extreme Annual Design Conditions

Extreme Annual WS			Extreme Max WB	Extreme Annual DB				n-Year Return Period Values of Extreme DB							
				Mean		Standard deviation		n=5 years		n=10 years		n=20 years		n=50 years	
1%	2.5%	5%		Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
14a	14b	14c	15	16a	16b	16c	16d	17a	17b	17c	17d	17e	17f	17g	17h
24.2	20.6	18.5	89.1	97.0	5.6	2.9	6.6	99.1	0.9	100.8	-3.0	102.4	-6.7	104.6	-11.6

Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures

%	Jan		Feb		Mar		Apr		May		Jun	
	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB
	18a	18b	18c	18d	18e	18f	18g	18h	18i	18j	18k	18l
0.4%	63.1	58.5	65.5	53.8	77.1	62.4	88.2	66.1	90.6	71.5	93.9	74.8
1%	60.1	56.5	61.8	54.0	72.9	60.2	81.2	65.2	87.9	70.2	92.1	74.5
2%	56.9	53.4	58.7	52.0	68.3	56.4	78.8	62.0	85.5	69.0	90.3	74.0

%	Jul		Aug		Sep		Oct		Nov		Dec	
	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB
	18m	18n	18o	18p	18q	18r	18s	18t	18u	18v	18w	18x
0.4%	97.3	78.6	95.3	76.7	91.1	76.2	81.5	68.4	73.8	63.8	64.7	59.6
1%	95.2	76.7	93.2	76.3	88.5	73.2	79.2	67.7	70.7	62.5	62.4	57.8
2%	93.3	76.3	91.5	75.9	86.2	72.2	76.7	66.3	68.2	61.3	59.9	55.5

Monthly Design Wet Bulb and Mean Coincident Dry Bulb Temperatures

%	Jan		Feb		Mar		Apr		May		Jun	
	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB
	19a	19b	19c	19d	19e	19f	19g	19h	19i	19j	19k	19l
0.4%	60.2	62.4	58.7	62.2	64.3	74.3	68.1	81.4	74.6	85.5	78.1	89.0
1%	57.3	59.1	56.0	59.3	62.2	70.0	66.5	78.2	73.0	83.5	77.1	87.4
2%	54.1	56.4	53.4	56.8	59.5	66.5	64.6	74.5	71.4	81.6	76.2	86.1

%	Jul		Aug		Sep		Oct		Nov		Dec	
	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB
	19m	19n	19o	19p	19q	19r	19s	19t	19u	19v	19w	19x
0.4%	80.5	92.2	80.0	90.4	77.4	86.2	71.9	76.3	66.6	70.5	61.3	63.7
1%	79.6	90.7	79.0	89.3	76.4	84.2	70.5	75.3	64.9	68.2	58.9	61.2
2%	78.6	89.1	78.0	87.3	75.4	82.3	69.0	74.0	63.4	66.9	56.4	59.4

Monthly Mean Daily Temperature Range

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
20a	20b	20c	20d	20e	20f	20g	20h	20i	20j	20k	20l
14.0	15.3	17.1	19.0	18.8	18.1	17.1	18.6	18.8	17.7	15.9	14.0

WMO#	World Meteorological Organization number	Lat	Latitude, °	Long	Longitude, °
Elev	Elevation, ft	StdP	Standard pressure at station elevation, psi		
DB	Dry bulb temperature, °F	DP	Dew point temperature, °F	WB	Wet bulb temperature, °F
WS	Wind speed, mph	Enth	Enthalpy, Btu/lb	HR	Humidity ratio, grains of moisture per lb of dry air
MCDB	Mean coincident dry bulb temperature, °F	MCDP	Mean coincident dew point temperature, °F	MCWB	Mean coincident wet bulb temperature, °F
MCWS	Mean coincident wind speed, mph	PCWD	Prevailing coincident wind direction, °, 0 = North, 90 = East		