Mechanical Systems Existing Conditions Evaluation:

Technical Assignment #3

Calvert Memorial Hospital
Prince Frederick, MD

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Executive Summary:

This report contains exclusive information about Calvert Memorial Hospital's mechanical systems. Different aspects of the systems such as the design requirements, system configuration, control logic, and operating characteristics were evaluated.

By using data from the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) Handbook of Fundamentals and the building current design conditions, the indoor and outdoor air conditions were determined. They were 72 ^{o}F, 50 % relative humidity with 58.58 grains moisture/lb dry air for the indoor air conditions and 95 ^{o}F Dry Bulb, 79 ^{o}F Wet Bulb, and126 grains moisture/lb dry air for the outdoor air conditions.

The building loads were calculated by the Hourly Analysis Program (HAP) resulting in a total cooling coil load of 40.9 tons. The mechanical cost of $9,404,102 and the building square footage of 184,360 ft^2 created a $51/ft^2 mechanical cost of the hospital.

Schematic diagrams of the Heating Hot Water System, Chilled/Condenser Water System, and the Air Handling Unit #3 – ICU System were drawn and are available in the report appendices. These schematics, along with written explanations illustrate the building's mechanical operations, loads, and controls. Information is also available in tabular format.

The end of the report contains a critique of the hospital system including issues on correct air distribution, indoor air quality and the overall improvement of the efficiency of the systems.

Design Objectives:

In this report, Calvert Memorial Hospital was evaluated based on a number of design objectives and requirements. To determine the crucial values for all calculations in this report, the following resources were used: ASHRAE, The National Electric Code, NFPA, and current data complied from other area hospitals. Along with these criteria, there were other items that were taken into consideration.

The hospital has many plans for new construction. For example, the four-story patient tower is being built to not only accommodate a more efficient hospital, but to compensate for the growing community as well. The hospital design not only has to comply with the appropriate technical code requirements, but also must accommodate the personal interests of the hospital staff, patients, and visitors. Extreme measures must be taken to create an extremely clean, healthy, and comfortable environment. Disease and infection control is relays this aspect of a healthy living environment in the hospital. Critical care areas, operating rooms, and other areas that could produce air that cannot be returned and reused by the air handling units must be exhausted out of the building.

Outdoor and Indoor Design Conditions:

By utilizing data in the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) Handbook of Fundamentals and the building current design conditions, the hospitals outdoor and indoor design conditions can be determined. The following values are the conditions used in this report:

Indoor Design Conditions:	72 ^{o}F
	50 % R.H.
	58.58 grains moisture/lb dry air
Outdoor Design Conditions:	95 ^{o}F Dry Bulb
	79 ^{o}F Wet Bulb
	126 grains moisture/lb dry air

Design Loads:

The load and energy analysis datum were obtained from the ASHRAE standards and the computer program Hourly Analysis Program (HAP). The calculations were based on Calvert Memorial Hospital which is located in Prince Frederick, MD. Weather data for Baltimore, MD was used for this analysis due to it being the closest weather data available by the HAP program. Important values resulting from the HAP calculation include items such as the estimated design heating and cooling loads and outdoor air ventilation rates.

HAP computes these values by implementing individual data for each room. In each space there are many things to consider such as: lighting and equipment loads (watts/sqft), design occupancy for each room, building envelope data, and space height and square footage. These calculations give valuable data about the system heating and cooling loads. The results of the simulation are in the following data table:

Air System Information

Air System Name	CMH 2&3 Flr AHU		Number of zones	35	
Equipment Class	UNDEF		Floor Area	13011.0	ft²
Air System Type	VAV		Location	Baltimore, Maryland	

Sizing Calculation Information

Zone and Space Sizing Method:

Zone CFM	Peak zone sensible load	Calculation Months	Jan to Dec
Space CFM	Individual peak space loads	Sizing Data	Calculated

Central Cooling Coil Sizing Data

Total coil load	40.9	Tons	Load occurs at	Jul 1500	
Total coil load	491.1	MBH	OA DB / WB	95.0 / 79.0	°F
Sensible coil load	378.0	MBH	Entering DB / WB	77.3 / 64.5	°F
Coil CFM at Jul 1500	15809	CFM	Leaving DB / WB	55.0 / 53.9	°F
Max block CFM at Jul 1500	18626	CFM	Coil ADP	52.5	°F
Sum of peak zone CFM	19225	CFM	Bypass Factor	0.100	
Sensible heat ratio	0.770		Resulting RH	49	%
ft²/Ton	317.9		Design supply temp.	55.0	°F
BTU/(hr-ft²)	37.7		Zone T-stat Check	35 of 35	OK
Water flow @ 10.0 °F rise	98.28	gpm	Max zone temperature deviation	0.0	°F

Supply Fan Sizing Data

Actual max CFM at Jul 1500	18626	CFM	Fan motor BHP	0.00	BHP
Standard CFM	18523	CFM	Fan motor kW	0.00	kW
Actual max CFM/ft²	1.43	CFM/ft²	Fan static	0.00	in wg

Outdoor Ventilation Air Data

Design airflow CFM	2598	CFM	CFM/person	22.01	CFM/person
CFM/ft²	0.20	CFM/ft²			

Mechanical First Cost:

The mechanical first cost was determined for Calvert Memorial Hospital in the previous technical assignment, Building Plant and Energy Analysis Report: Technical Assignment #2. The cost figures were taken from all of the mechanical and plumbing equipment located in the hospital. Due to the renovation of many of the interior spaces, removal costs were included in the first cost analysis of the mechanical equipment. Also included in these costs were items such as ductwork, piping, variable frequency controllers, rigging, structural reinforcement, electrical configuration, low pressure steam and condensate, insulation, testing and balancing commissioning, pumps, heat exchangers, and of course all the air handling units, boilers, chillers, generators, and cooling towers. A table of the total costs for the mechanical equipment is illustrated in Appendix 3 – Mechanical Equipment First Cost of the Building Plant and Energy Analysis Report: Technical Assignment #2. By knowing the mechanical cost ($9,404,102) and the square footage of the building (184,360 ft^2), we can determine a $51/$ft^2$ mechanical cost of the hospital.

Schematic Diagrams of Mechanical Systems:

In order to illustrate the sequence of operations for Calvert Memorial Hospital's Heating Hot Water and the Chilled/Condenser Water Systems, schematic diagrams will be used to explain the system operations. In the next three sections of the report the following schematics are present: Hot Water Heating System, Chilled Water / Condenser Water System, and Critical Care Air Handling Unit 3- ICU.

Hot Water Heating System:

The hot water heating system operation and controls will be explained in this section. The boilers are run by a lead-lag Microprocessor Controller system. It is manually energized by the operating personnel by selection made at the controller's keypad display.

First, one of the boilers is indexed as the lead boiler. For example, if boiler B-1 is chosen as the lead boiler, the isolation valve V-HS-1 will open and the primary hot water pump P-13 will run. To ensure this pumping process occurs, there is a secondary or standby pump P-13A. This pump can be manually operated by the engineer if P-13 is insufficient for operation. Boiler B-1 will be energized when the flow switch labeled FS-HS-1 detects the appropriate flow. Once the boiler starts operation, it is controlled by package boiler controls and a temperature transmitter TT-HS-1 that modulates the primary hot water supply temperature to be 160 ^{o}F.

If boiler B-2 is indexed for operation, the isolation valve V-HS-2 will open and begin the pumping process for pump P-14. This system also utilizes the secondary pump P-13A if P-14 is insufficient for operation. Boiler B-2's flow switch FS-HS-2 detects the appropriate flow and sends the boiler into operation. The packaged boiler controls along with the temperature transmitter TT-HS-1, maintain the system operating at a temperature of 180 ^{o}F. Let it be noted that if any of these systems fail, audible alarms will be sounded, alerting the engineers to manually start the secondary standby services.

The lead secondary heating hot water pump P-1 will be run continuously. This will be done manually. Differential pressure transmitters (DPT's) will be used to control the operation of pump P-11. The pump will be controlled by the lower of three available adjustable DPT set points.

The automatic temperature control system will provide the automatic lead-lag controller to the variable speed controller. If the flow is detected to be losing force, pump P-12 will start after an alarm is sounded.

To maintain a supply temperature of 110 ^{o}F and a return temperature of 160 ^{o}F, temperature transmitters and hot water reset valves are used for modulation. The supply air is determined by TT-HS-3/3A and hot water reset valve V-HS-3/3A, while the return air is modulated by TT-HS-7 which will override the control of V-HS-3 to keep the minimum return water temperature. This system operation is illustrated in <u>Appendix 1: Heating Hot Water System Schematic Diagram</u>.

Chilled Water/Condenser Water System:

The hospital chilled water and condenser water systems and controls will be explained in this section. The control of the chilled water plant is through the Siebe-

Prichert DDC Network System. This chilled water system is comprised of four chillers and their associated cooling towers and pumps. The plant's total capacity is 650 tons.

The lead-lag selection method is also used in the operation of the chilled water plant. The chilled water system will automatically be enabled when the outdoor air temperature exceeds 53 ^{o}F. Also, if the outdoor air temperature falls below 50 ^{o}F the system will also be enabled. Chiller CH-4 is the lead chiller when operating in normal mode. The appropriate switches enable the isolation valves to open, allowing the pumps to operate, just as in the heating water scenario. The condenser water isolation valve, V-CHS-4 allows pump P-4 to run, thus allowing the chiller and the cooling tower CT-5 to be energized.

Once the chilled water plant is energized the lead secondary chilled water pump P-9 will be activated. Differential pressure transmitters modulate the pump's speed to maintain their perspective minimum settings. If these settings reach their maximum, pump P-10 (which is in a lead/lab system with P-9) will be started at 30% speed. During this time, the lead pump will decrease its speed to 30% and the two will operate together to reach the minimum requirements of the system.

If chiller CH-4 fails, or a lead/lag selection is made between chillers CH-1, CH-2, or CH-3, the same system of processes as described for CH-4 will occur for all of them. When Chiller CH-1 is indexed on, before the chiller actually starts, the isolation valve V-CHS-1 opens, allowing the pump P-7 to begin. V-CS-1 will then open, and the condenser water pump P-15 will be energized. The existing cooling tower and chiller CH-1 are both in operation when their respective flow switches, FS-CHS-1 and FS-CS-1 detect the proper flows.

Chilled and condenser water flow through CH-2 and the existing cooling tower once the isolation valve V-CHS-2 allows pump P-8 to run, and the condenser water isolation valve V-CS-2 allows pump P-16 to run. Pumps P-8 and P-16 de-energize and valves V-CHS-2 and V-CS-2 will close when the chiller CH-2 de-energizes. Before chiller CH-3 is allowed to start, the water isolation valve V-CHS-3 will be energized. Its end switch allows pump P-18 to be activated when appropriate. The condenser water isolation valve V-CS-3 opens and allows pump P-17 to begin to run. Switches FS-CHS-3 and FS-CS-3 prove that the correct flow is occurring so chiller CH-3 and the existing cooling tower will begin to run. When chiller CH-3 de-energizes, pumps P-18 and P-17 do as well, closing valves V-CHS-3 and V-CS-3. When any of the four chillers are de-energized, each of their respective control panels will maintain a supply air leaving temperature of 40 ^{o}F. See Appendix 2: Chilled/Condenser Water System Schematic for a more visual explanation.

Critical Care Air Handling Unit 3- ICU:

Air handling unit #3 is analyzed in depth to illustrate the main operation of the air handling unit system. The other air handling units run approximately the same way, with the only difference being the airflow capacities. This section will give a detailed explanation of how the air handler is controlled and how it operates.

The air handler is equipped with a DDC Logic Controller. This control creates a "start-stop" function where the controls are in their normal positions in the "stop" mode and are off. In the "start" mode the return fan RF-1 is energized 15 seconds prior to the starting of the supply fans. Smoke isolation dampers (examples SD-1, SD-2, SD-3, and SD-4) shall open with the in the "start" condition. The minimum outside air damper D-1 will open whenever the system is in the "start" position. The minimum outdoor air temperature will be monitored by the air measuring device AMD-3.

The maximum outside air damper D-1A, return air damper D-2, and relief air damper D-3 are set to maintain an adjustable set point of 49 ^{o}F by the DDC logic and enthalpy logic controls. The enthalpy control input shall be from the central outside air humidity/temperature transmitter HTT-2 and return air HHT-1, located within the return air ductwork. The maximum outside and return air dampers shall be controlled through the electronic low limit LL-1, and will close if the maximum outdoor air of 40 ^{o}F is exceeded. The preheat coil circulator pump shall operate continuously when the outside temperature is below 35 ^{o}F.

The system fans (both supply and return) are also controlled by the DDC Controller. The supply and return fan speeds, through their variable frequency controllers are controlled by the system static pressure transmitters SPT-1 and SPT-2 respectively.

The humidifier control system is through the DDC Logic controller system as well. The airflow switch, AFS-1 controls the humidifier valve V-3 to maintain its set point of 40% relative humidity.

Major Equipment Summaries:

As described in the above section, there are many major components involved in such complex mechanical configurations. The following tables will briefly summarize some of the key aspects of Calvert Memorial Hospital's mechanical equipment. Air Handling Unit #3 – ICU information is in a separate, more involved table to illustrate some of the more important design features of the air handling unit system. The other air handling units serving the hospital have similar operating conditions. They only differ in the unit capacities, therefore only AHU #3 –ICU is described in great detail.

	Air Handling Unit #3 - ICU										
		SA Fans				Cooling Coil			Heating Coil		
Service	Total CFM	Airflow - CFM	H.P.	Electrical Data	RPMs	EAT °F db	LAT °F wb	Total / Sens. Cap.	EAT °F db	LAT °F wb	Total Cap.
2nd & 3rd Floor Addition	27,000	13,500	30	460/3/60	1761	80	65.25	1,288 / 904 MBH	180	160	1,666 MBH

Equipment Type:	Label:	Capacity:	EWT: (°F wb)	LWT: (°F wb)	GPM:	Notes:
Air Handling Unit	AHU #1	13,775 CFM	-	-	135	
Air Handling Unit	AHU #2	7,000 CFM	-	-	40	
Air Handling Unit	AHU #3	27,000 CFM	-	-	-	
Air Handling Unit	AHU #4	11,100 CFM	-	-	65	
Air Handling Unit	AHU #8	80,000 CFM	-	-	-	
Air Handling Unit	AHU #11	1,200 CFM	-	-	-	
Air Handling Unit	AHU #13	16,000 CFM	-	-	124	
Air Handling Unit	AHU #14	16,000 CFM	-	-	124	
Air Handling Unit	AHU #15	16,000 CFM	-	-	124	
Air Handling Unit	AHU #16	6,500 CFM	-	-	57	
Air Handling Unit	TO ED	60,000 CFM	-	-	910	
Air Handling Unit	TO ICU	75,000 CFM	-	-	258	
Boiler	B-1	5021 MBH	180	160	-	
Boiler	B-2	5021 MBH	180	160	-	
Chiller	CH-1	110 tons	55	45	-	
Chiller	CH-2	260 tons	55	45	-	
Chiller	CH-3	260 tons	55	45	-	
Chiller	CH-4	650 tons	55	45	-	
Cooling Tower	CT-2	370 tons	-	-	-	Runs for 50°F<OA<53°F
Cooling Tower	CT-3	260 tons	-	-	-	Runs for 50°F<OA<53°F
Cooling Tower	CT-5	650 tons	-	-	-	Runs for 50°F<OA<53°F
Expansion Tank	Expansion Tank	80 gallons	-	-	-	

Critique of the System:

The existing systems of the hospital are in compliance with the accepted practices of construction at that time. However, current design practices have drastically changed, thus instigating the many of the issues to be discussed in this section.

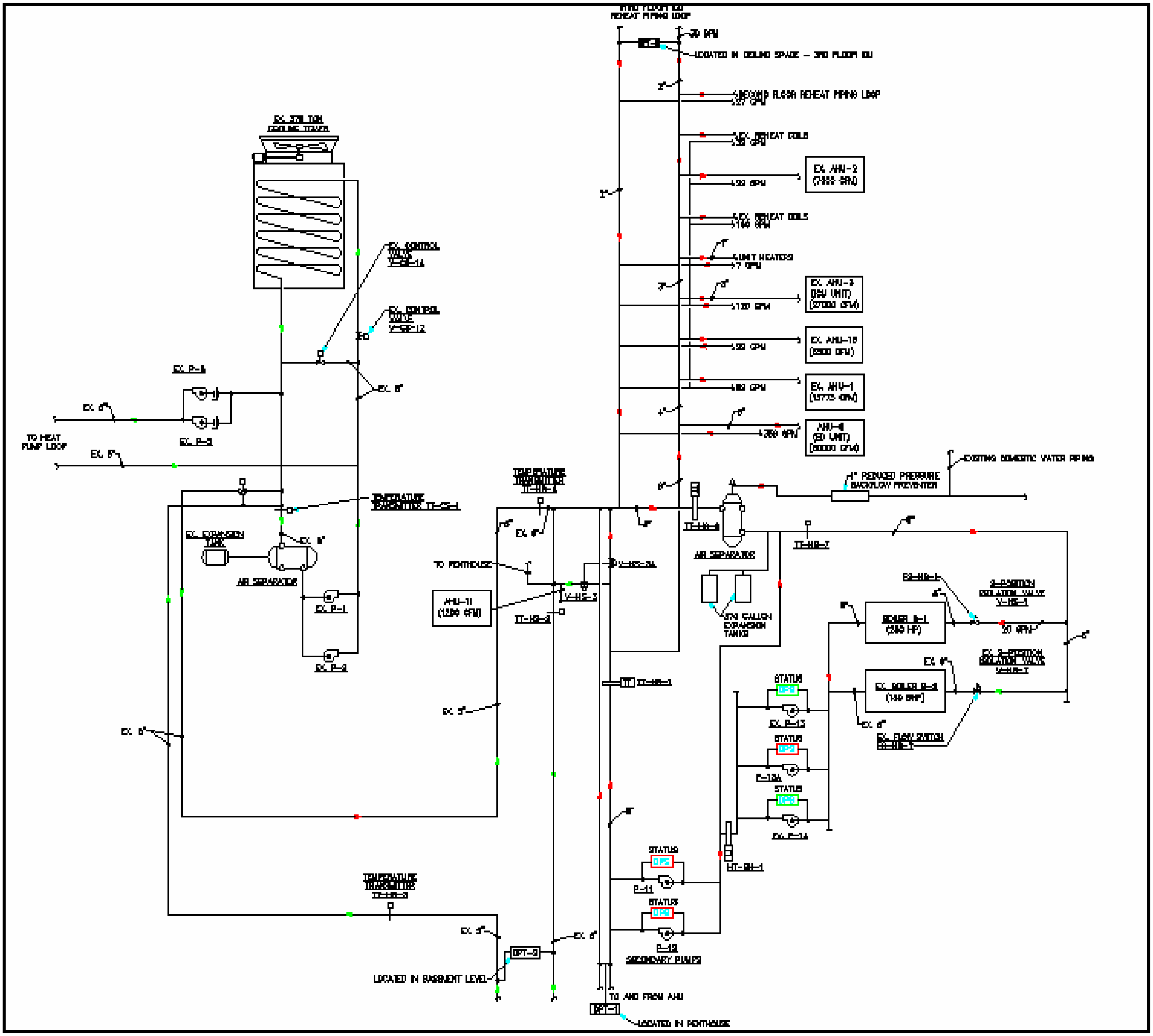
The four-story patient tower, for example, utilizes heat pumps to condition the spaces. These heat pumps have little flexibility in meeting changes in room loads and overall performance enhancements. They also are located directly in the patient rooms. This would not be a problem, but the condensate drip pans in the heat pump systems grow molds and bacteria, thus exposing them to the breathable air. Obviously this is an unacceptable situation for patients to endure. Today, an “all air” system would most likely replace the heat pump system.

The air handling units are also another area that needs improvement. Many of the units are utilizing excessive amounts of outside air and are constant volume systems. This operation is not the most energy efficient. Only five of the sixteen units will be retained for use. The rest of the units will be replaced.

There are also problems with two of the hospital’s cooling towers. Towers No. 1 and No. 4 are both in poor condition and need to be replaced. Also, Tower No. 1 is missing louvers required for the optimal winter operation.

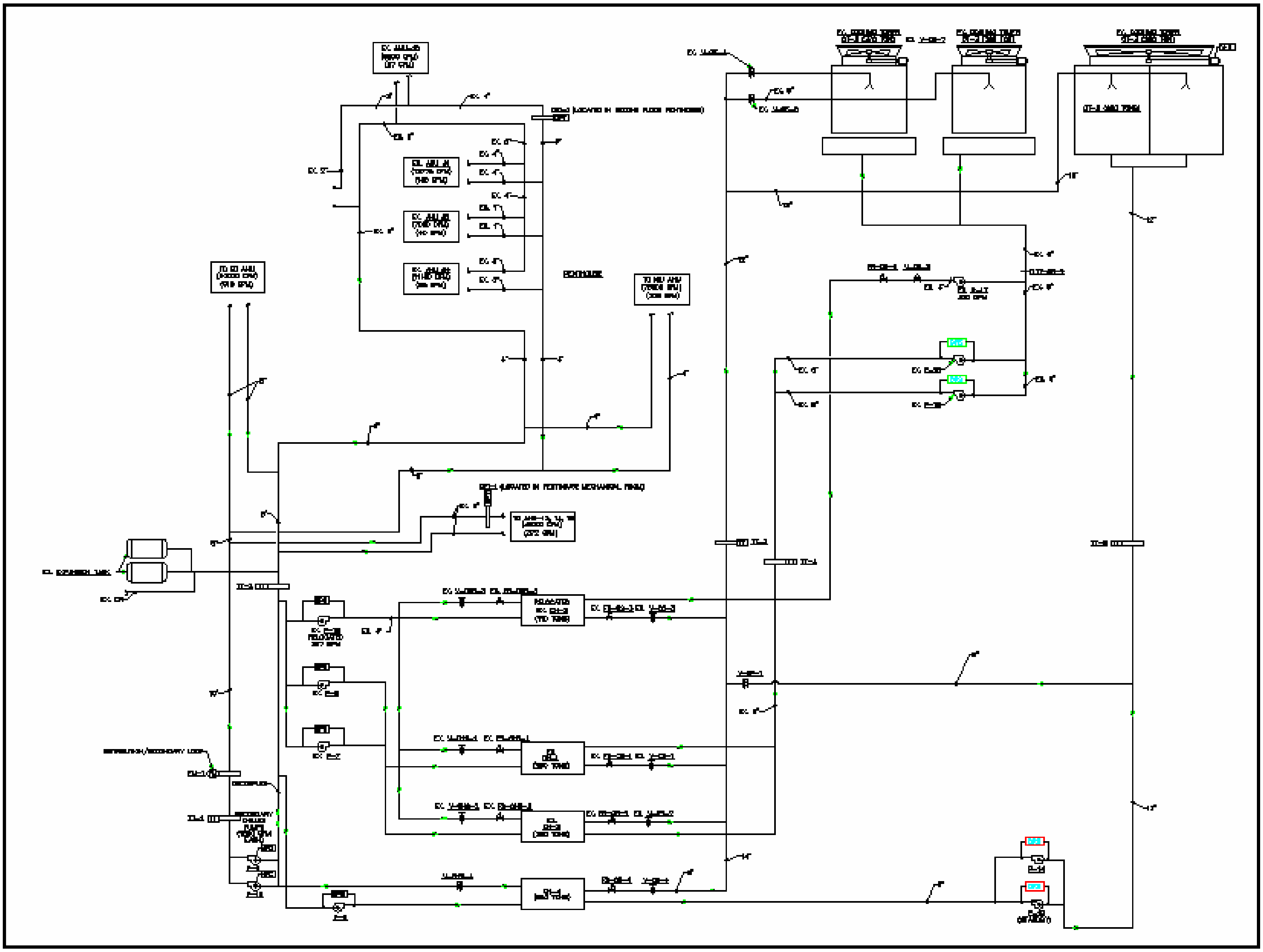
In order to meet the new loads of the hospital expansion, there will need to be a definite expansion to many of the systems including the chilled water system, the boiler plant, and the domestic water system.

Appendix 1: Heating Hot Water System Schematic Diagram:



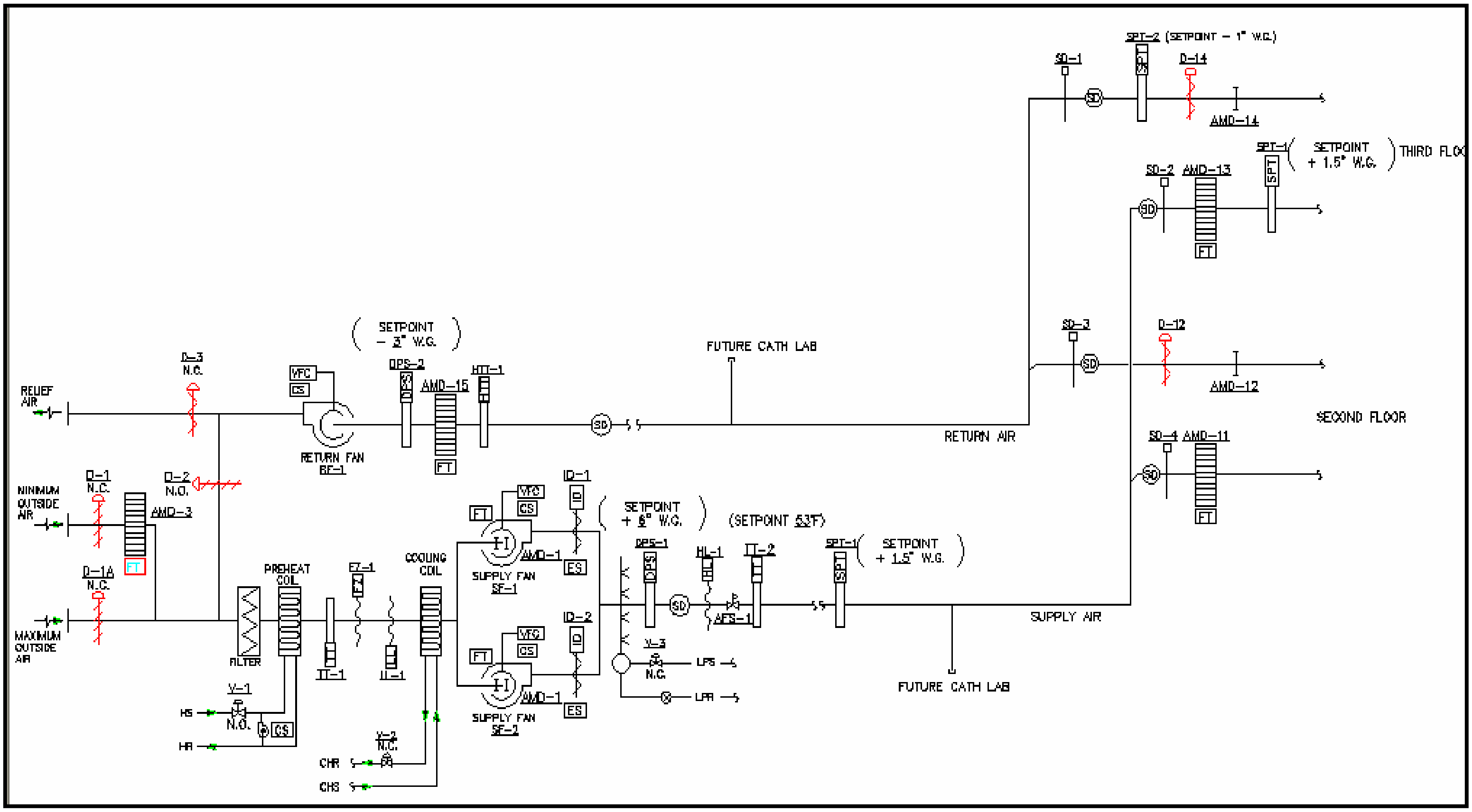
Heating Hot Water System Schematic

Appendix 2: Chilled/Condenser Water System Schematic Diagram:



Condenser Water System Schematic Diagram

Appendix 3: Critical Air Handling Unit 3 – ICU Schematic Diagram:



Critical Air Handling Unit 3 – ICU Schematic Diagram

Bibliography:

ANSI/ASHRAE Standard 62-2001. ASHRAE, Inc., Atlanta, GA. 2001

ASHRAE/IESNA Standard 90.1-2001. ASHRAE Incorporated, Atlanta, GA. 2001.