Mechanical System Existing Condition Evaluation

Technical Assignment 3

CITY HOSPITAL – PHASE I
S.E. Pennsylvania

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Executive Summary

City Hospital – Phase 1 is the first phase of a multiphase development. The entire project will eventually result in the construction of approximately one million square feet of research space, one million square feet of ambulatory care and clinical office space, and one million square feet of parking and support services.

Phase 1 in essence consisted of three buildings, a three-level sub grade vivarium, a three-level sub grade Central Utility Plant (CUP), and a Support Services at street level. The vivarium is chosen for analysis. The mechanical, electrical, and plumbing (MEP) system of the vivarium is supported by the CUP, and its occupants gain access to the street level through Support Services above.

This report looks into the existing mechanical system design for City Hospital – Phase 1. Design objectives and requirements, as well as energy source and their corresponding rates, are studied in order to better understand the design criteria for City Hospital. The design of mechanical system for City Hospital Campus development is based on occupant health, cost, and energy saving criteria.

The mechanical system is found to be adequately designed to deliver a proper indoor air quality. On the other hand, high energy consumption is a result of ensuring occupant health. Several energy and cost saving methods are incorporated into the design. It eventually conveyed the fact that dual fuel boilers and steam turbine/electric centrifugal chiller combination are system of choice. They reduce energy cost and add reliability to the system.

Project Background

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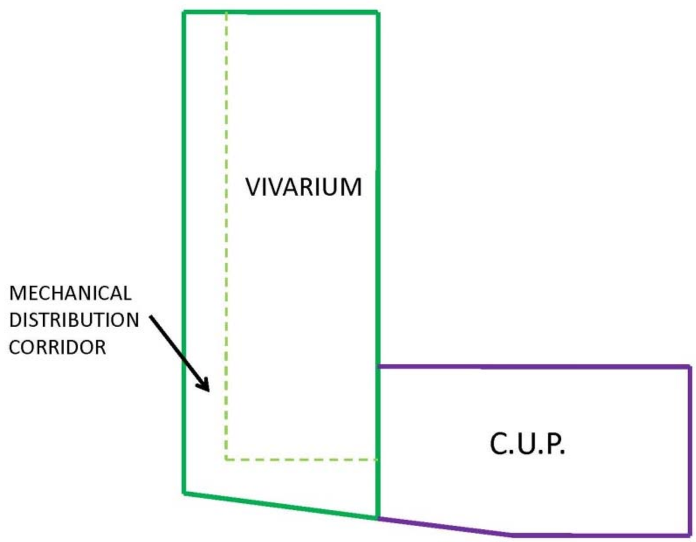


Mechanical System Design Objectives & Requirements

The design of mechanical system for City Hospital Campus development is based on occupant health, cost, and energy saving criteria.

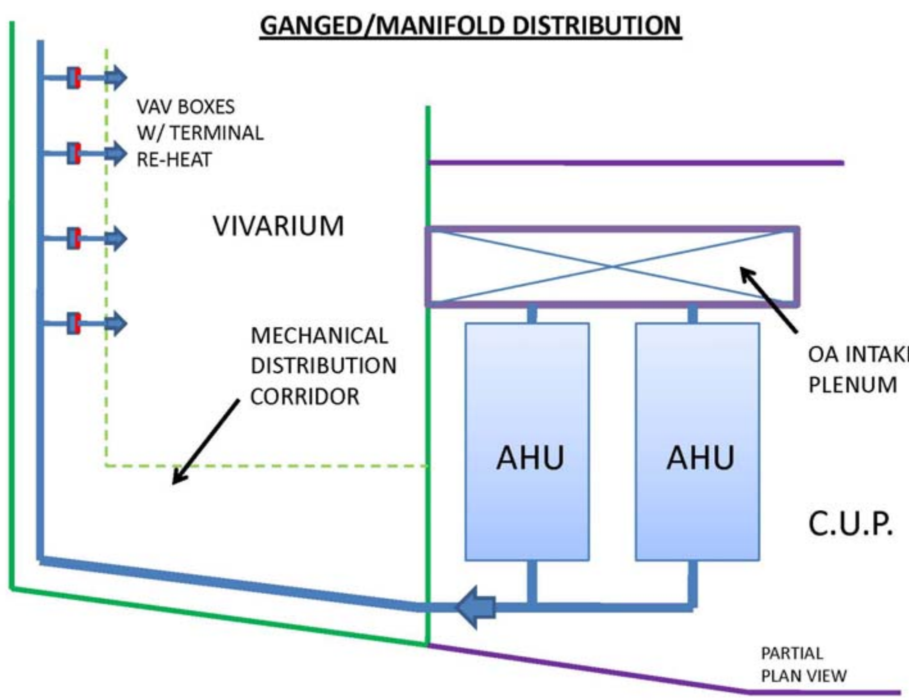
- The mechanical system must design to maintain the proper indoor air quality, deferential pressure and outdoor air exchange rate to minimize the risk of contamination.
- The system will be made as energy efficient as practical in accordance with LEED design principles.
  - Variable volume hydronic pumping and air system are used where possible.
  - Engineering methods to control the building's annual energy expense in recognition of 100% outdoor air and exhaust air requirement.
- Independent air distribution system to provide proper environment for care and handle of laboratory animals.
- The mechanical infrastructure is expected to support Hospital's current activities as well as future programs.

Description of System Operation

Air Side Mechanical System

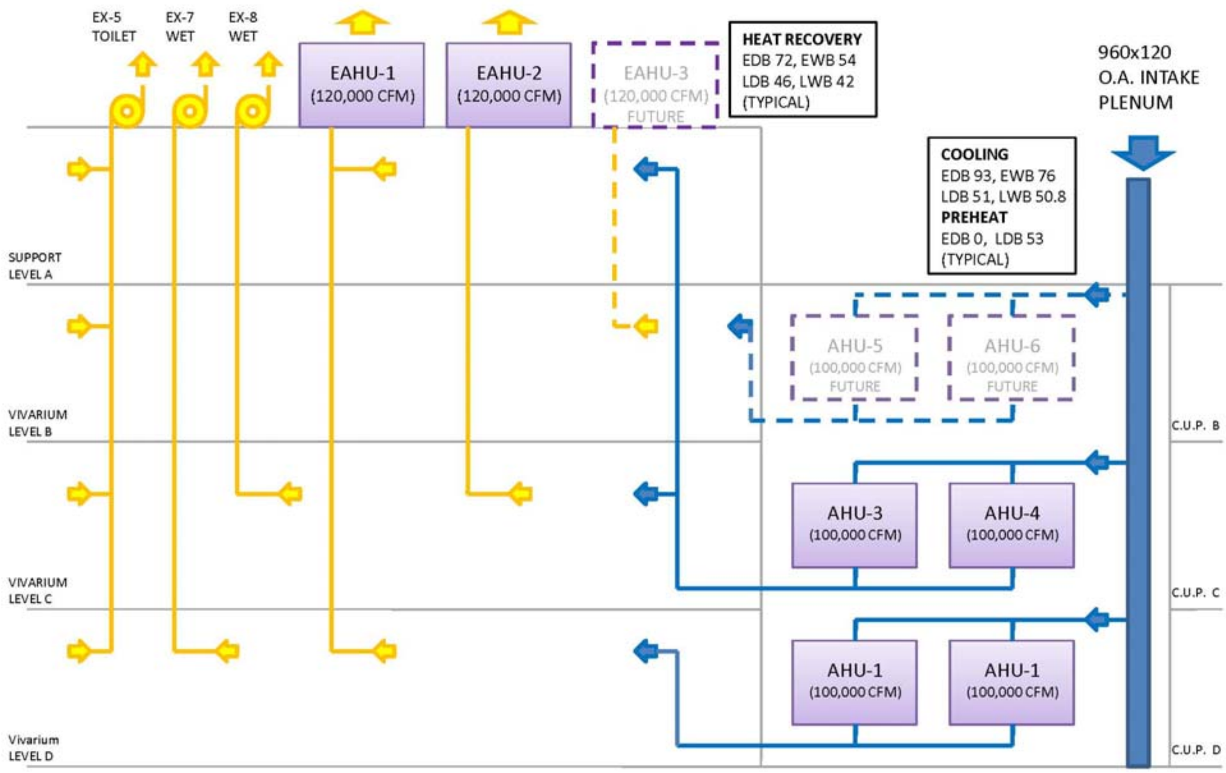
The ventilation system for Phase 1 - vivarium comprised of six (6) 100,000 CFM air handling units (AHU) equipped with variable speed drives (VSD). All six (6) AHUs are demand based, and supply airflow can be reduced to 50% of the design airflow. Each AHU draws outdoor air (OA) from the OA intake plenum. OA then pass through 30% and 95% efficient pre-filter, heat recovery coil, direct injection steam humidifier, chilled water coil bank, a set of sound attenuators before and after the supply fans, and final filter of 99.9% efficient.

Two (2) AHUs are grouped together to deliver 100% outdoor air to each level by the means of variable air volume (VAV) system. Ductworks reach individual zone by ganged/manifold distribution concept through a mechanical distribution corridor on each floor (See Ganged/Manifold Distribution).



Three (3) 120,000 CFM exhaust air handlers (EAHU) with sensible heat recovery remove majority of the indoor air, and preheat OA that become the supply air (SA). Other exhaust systems compensate for the remaining indoor air removal. The Vivarium Air Flow Diagram showed relation of AHUs, EAHUs, and exhaust fans to each space.

VIVARIUM AIR FLOW DIAGRAM

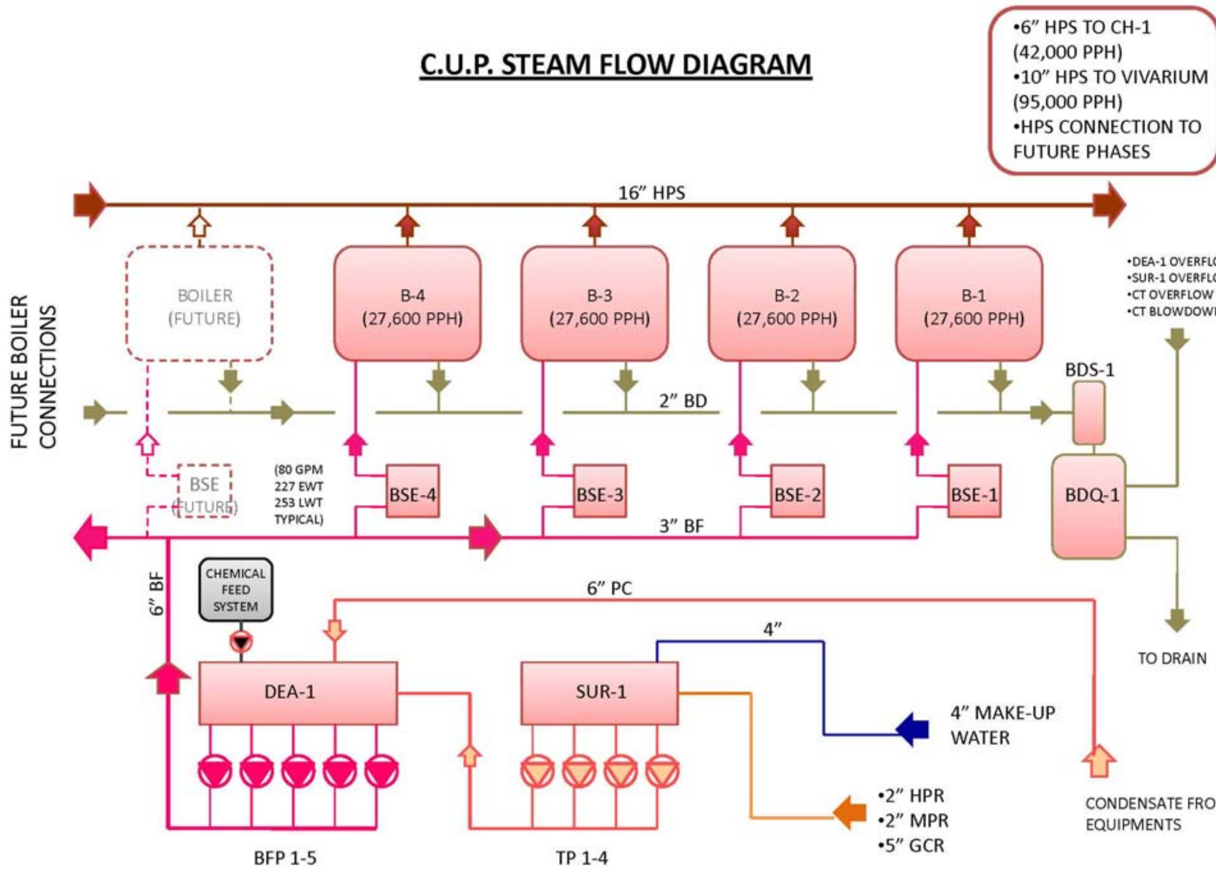


Note: Please refer to Appendix A for mechanical system abbreviations.

Steam System

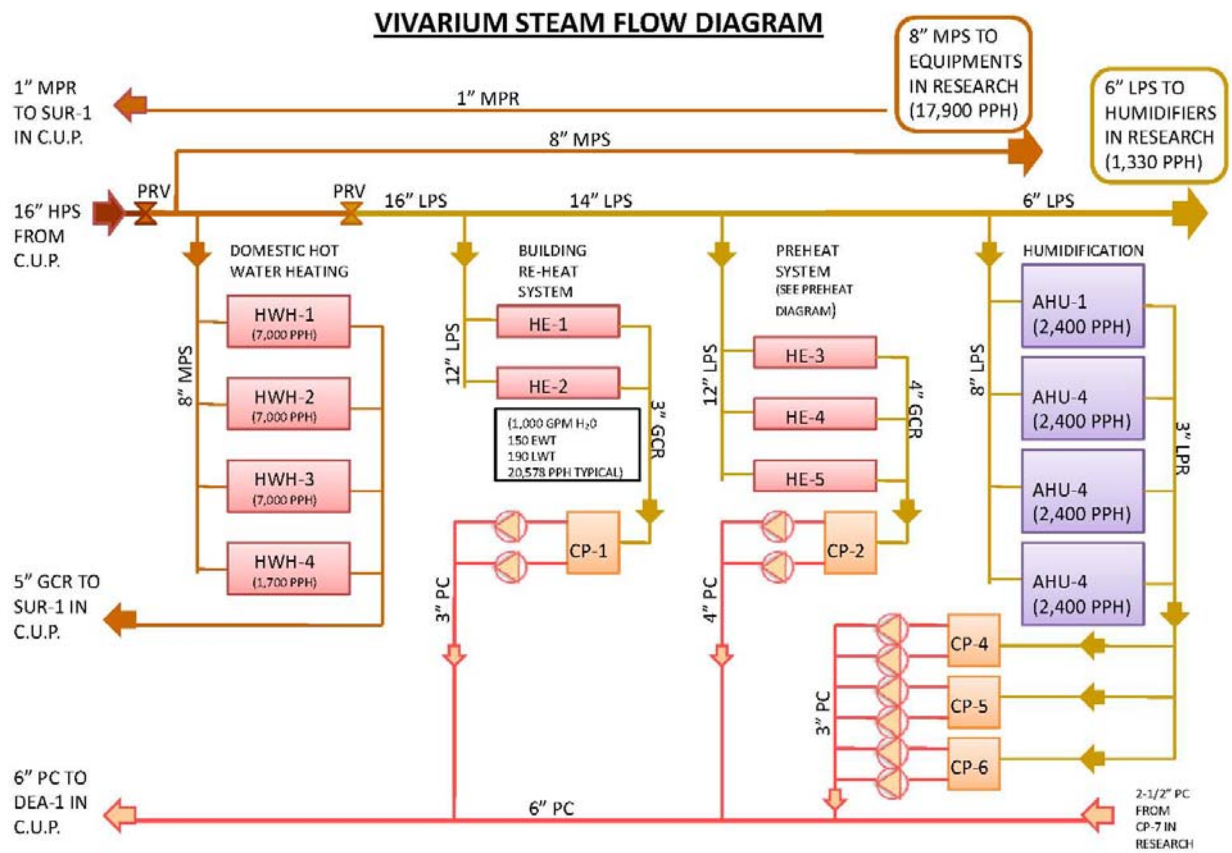
Phase 1 boiler plant included four 800 hp dual fuel boilers with VSD blowers and stack economizer (BSE). These boilers produce high pressure steam at 125 psig for high efficiency distribution, and drive a steam turbine chiller at 120 psig.

Boiler stack economizer pre-heat boiler feed water by recovering heat from flue gas which normally reject to the atmosphere. Each BSE has the capacity to increase boiler efficiency by 3.2%. Two (2) additional boilers will be added in the future phases to increase capacity.



Note: Please refer to Appendix A for mechanical system abbreviations.

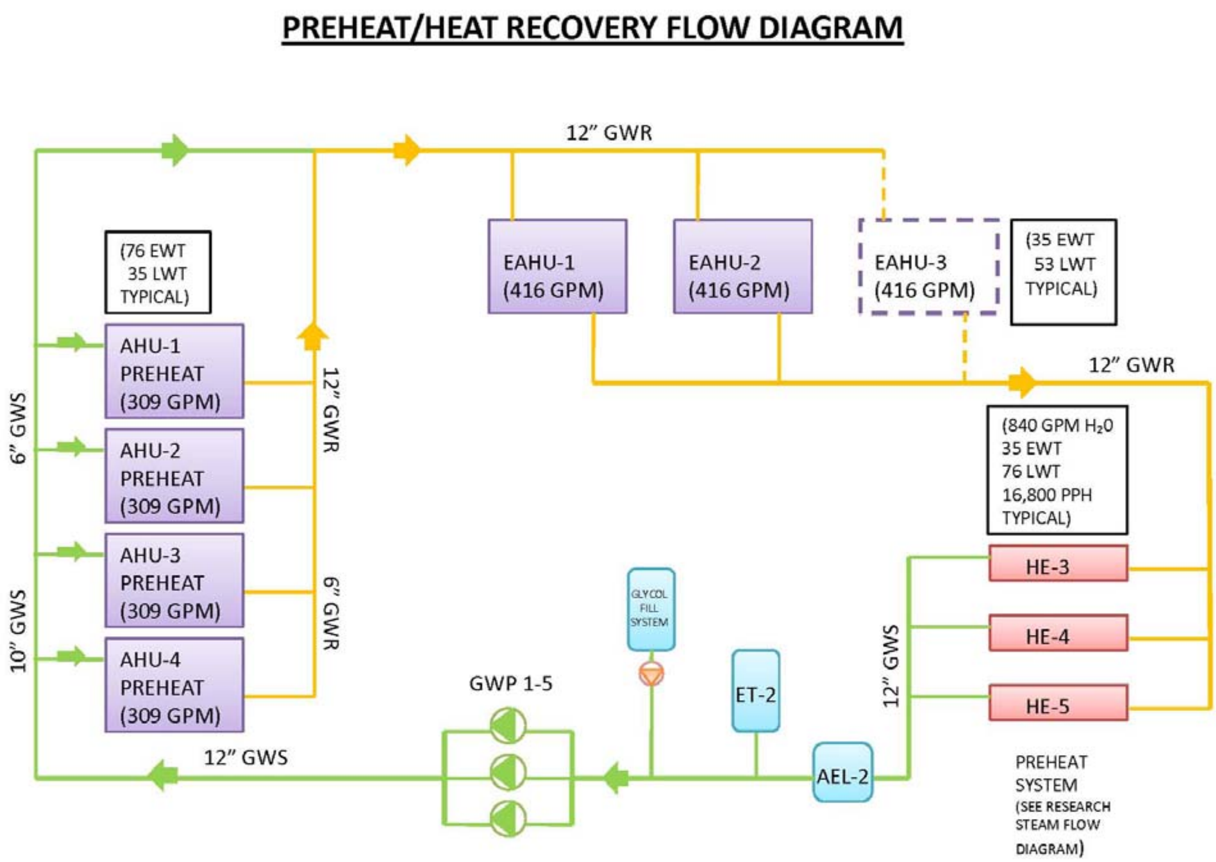
As stated previously, each boiler produces high pressure steam at 125 psig. High pressure steam is reduced to 70 psig medium pressure steam for domestic hot water heating and process equipments on each level. Steam pressure is further reduced to 2 psig low pressure steam for humidification and building hot water loop re-heat.



Note: Please refer to Appendix A for mechanical system abbreviations.

Pre-heat & Heat Recovery System

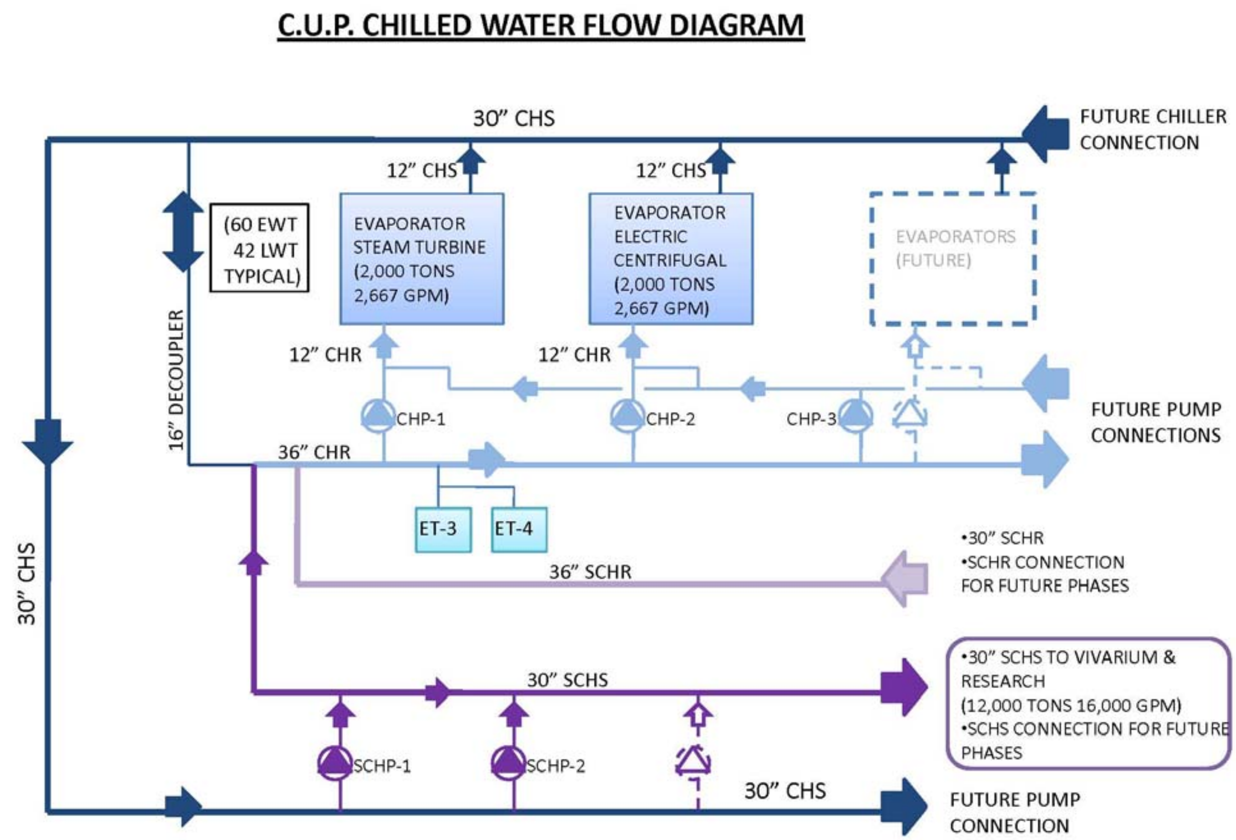
The exhaust air heat recovery system employed a runaround glycol loop, which has an effectiveness of 74%, to recover heat from exhaust air which normally reject to the atmosphere. The heat recovery loop is interconnected with the low pressure steam system through steam-water heat exchangers to pre-heat OA air to 53°F in winter months.



Note: Please refer to Appendix A for mechanical system abbreviations.

Chilled Water System

The chiller plant of Phase 1 consisted of one 2,000 ton steam turbine chiller and one 2,000 ton electric centrifugal chiller that produce 42°F chilled water. These chillers provide chilled water to the AHUs, as well as process chilled water (PCHW) loads. Chilled water is distributed to loads with two (2) variable speed secondary chilled water pumps on a primary/secondary loop. Eight (8) additional 2,000 ton chillers will be added in future phases to meet capacity requirement.

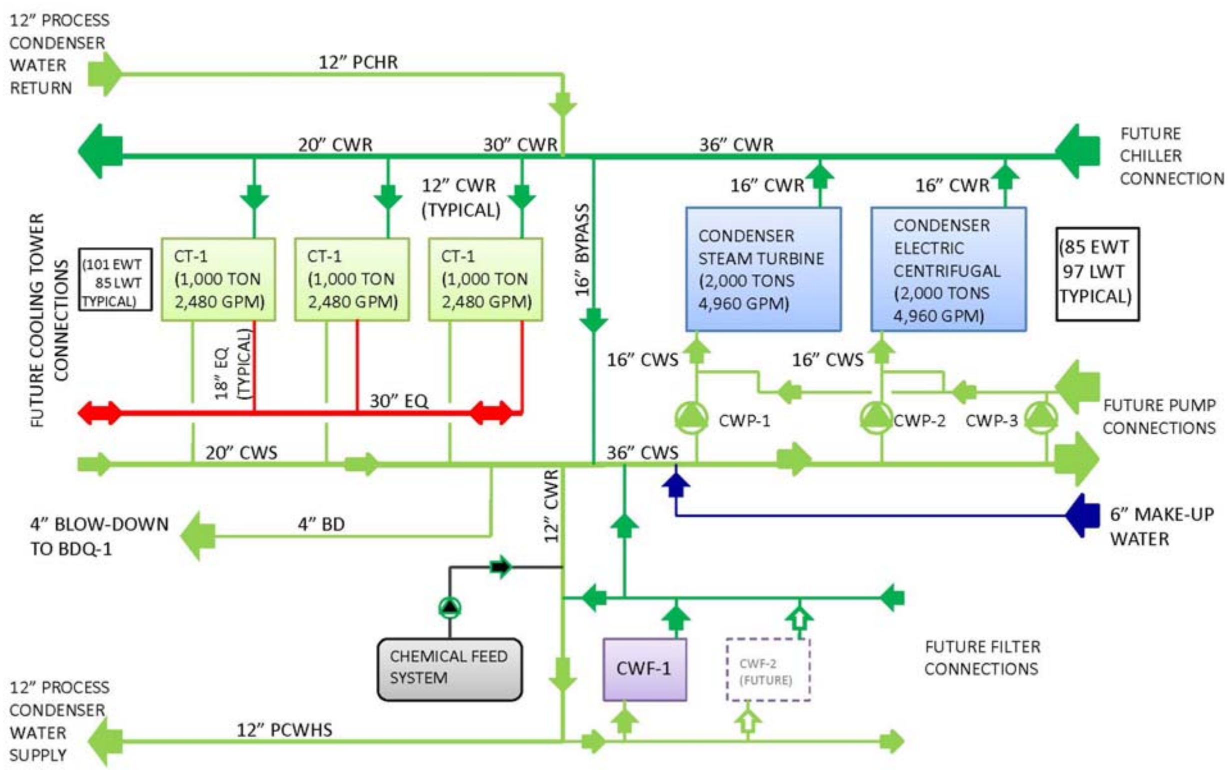


Note: Please refer to Appendix A for mechanical system abbreviations.

Condenser Water System

The condenser water system for the chilled water plant included four (4) 1,000 ton cooling towers with VSDs. These cooling towers serve both chillers and produce process condenser water in winter months. Additional cooling towers will be added in future phases to accommodate future chillers' heat rejection requirement.

C.U.P. CONDENSER WATER FLOW DIAGRAM



Note: Please refer to Appendix A for mechanical system abbreviations.

Energy Source & Rate

City Hospital is located in a dense urban area where electric and natural gas connections are readily available. In addition, City Hospital has onsite fuel oil storage for dual fuel boilers and diesel storage for emergency generators in an event of energy source interruption.

ELECTRIC TARIFF (HT RATE)				
MONTHLY SERVICE	$ 291.43			
		FIRST 150 HR	NEXT 150 HR*	ADDITIONAL
	$/kW	¢/kWh		
DISTRIBUTION SERVICE	$ 1.68	$ 0.91	$ 0.54	$ 0.18
COMPETITIVE TRANSITION	$ 4.68	$ 2.51	$ 1.49	$ 0.48
ENERGY & CAPACITY	$ 7.16	$ 5.49	$ 3.91	$ 2.37
	JUN. - SEP.	OCT. - MAY		
	¢/kWh			
ON-PEAK	$ (0.58)	$ (0.22)		
OFF-PEAK	$ (0.21)	$ (0.21)		

* Maximum 7,500,000 kWh

GAS TARIFF (LARGE BOILER & POWER PLANT RATE)	
MONTHLY SERVICE	$ 75.00
CONSUMPTION ($/Mcf)	$ 14.80

Cost Factors Influencing Design Conditions

Dual fuel steam boiler

- Availability and cost natural gas and fuel oil may vary greatly throughout the year. In addition, local gas provider offered discount for customers that have adequate standby non-natural gas energy and equipment for alternate operation in event of an interruption. A steam boiler system that uses either natural gas or fuel oil added reliability and help reduced energy cost.

Steam turbine / electric centrifugal chiller combination

- Although steam turbine chiller has lower efficiency than electric centrifugal chiller, it helped maintain electric demand constant through the year. It minimized expenditure by avoiding a ratchet charge levy by the local utility provider based on an annual peak-demand level.
- A combination of chiller type allows the chilled water system to operate continually despite failure of one energy source. It added reliability to the system.

Site Factors Influencing Design Conditions

The site for City Hospital is zoned highest density commercial. Because of its high-profile nature, there is a need to minimize the aesthetic effects the mechanical system components would have on the surrounding environment. Majority of mechanical equipments are located in the three-level sub-grade CUP. Cooling towers and boiler stacks are shielded from pedestrian and vehicular traffic by future above ground phases.

Outdoor/Indoor Design Conditions

Weather data is not available for the location of City Hospital. A modified weather data from Philadelphia, Pennsylvania is used for outdoor design conditions.

OUTDOOR DESIGN CONDITION					
	T_{db} °F	T_{wb} °F	LATITUDE	LONGITUDE	ELEVATION
WINTER	0	-	39.9	75.3	30
SUMMER	95	78			

INDOOR DESIGN CONDITIONS				
	SUMMER		WINTER	
SPACE TYPE	MAX TEMP	MAX RH	MIN TEMP	MIN RH
ANIMAL BEDDING	74	50	70	30
ANIMAL HOLDING	66-84	50	66-84	40
ANIMAL PROCEDURE	66-84	50	66-84	40
ANIMAL TESTING	66-84	50	66-84	40
CAGEWASH EQUIPMENT SPACE	85	70	70	30
CLEAN CAGEWASH	78	60	70	30
DIRTY CAGEWASH	78	60	70	30
STERILE CAGEWASH	78	60	70	30
MECHANICAL ROOM	95	-	60	-
ELECTRICAL ROOM	80	-	60	-
ELEVATOR MACHINE ROOM	90	85	60	-
GENERAL STORGE	78	-	70	-
HAZARDOUS STORAGE	78	-	70	-
HOUSEKEEPING CLOSET	78	-	70	-
TEL/DATA ROOM	78	60	70	20
TOILET/LOCKER	75	-	70	-

Major Equipment

Steam System

DUAL FUEL BOILER (W/ VSD BLOWER)									
QUANTITY	BOILER HP	OPER. PRESS.	MBH INPUT	LBS. STEAM 212 °F 0 PSI	GAS THERM/ HR	No. 2 FUEL GPH	NOX PPM (GAS)	BLOWER MOTOR HP	COMP. MOTOR HP
4	800	125	32,656	27,600	336	240	30	75	7.5

BOILER STACK ECONOMIZER									
			TUBE (FEEDWATER)			SHELL (FLUE GAS)			
QUANTITY	NO. OF PASSES	MIN MBH	EWT °F	LWT °F	GPM	EGT	LGT	PPH	BOILER EFF. BOOST
4	3	1043	227	253	80	425	303	31,740	3.20%

STEAM-WATER HEAT EXCHANGER										
			TUBE (WATER SIDE)					SHELL (STEAM SIDE)		
SERVICE	UNIT NO.	NO. OF PASSES	EWT °F	LWT °F	GPM	ΔP FT H_2O	MIN MBH	OPER. PRESS.	PPH	PRESS. RATING
RE-HEAT	HE-1	4	150	190	1,000	2.9	19,544	2	20,578	150
	HE-2 (STANBY)									
GLYCOL PRE-HEAT	HE-3	2	35	76	840	3.2	16,002	2	16,800	150
	HE-4									
	HE-5 (STANDBY)									

Chilled Water System

WATER COOLED CHILLER									
		COMPRESSOR		CONDENSER			EVAPORATOR		
QUANTITY	CAPACITY TON	TYPE	KW/TON	GPM	EWT °F	LWT °F	GPM	EWT °F	LWT °F
1	2,000	STEAM TURBINE	-	4,960	85	97	2,667	60	42
1	2,000	ELECTRIC CENTRIFUGAL	0.598	4,960	85	97	2,667	60	42

COOLING TOWER (W/ VSD FAN)								
						FAN MOTOR		
QUANTITY	NOM TON	EWT °F	LWT °F	EAT °F WB	GPM	BHP	MHP	RPM
4	1,000	101	85	78	2,480	72	75	1,200

Ventilation System

CUSTOM AIR HANDLER UNIT (W/ VSD FANS)										
CASING			SUPPLY FAN							
INSULATION	MIN LEAKAGE CLASS	MIN PRESSURE CLASS	CFM	MIN OA	EXT SP	TOTAL SP	TYPE	QUANTITY	MAX BHP	MIN MHP
4	4	12	100,000	100,000	4	10	VAN AXIAL	2	127	150
COOLING COIL (WATER)										
AIR SIDE							WATER SIDE			
EDB °F	EWB °F	LDB °F	LWB °F	MIN ROW	FIN SPACE FPI	MAX ΔP IN H_2O	GPM	EWT °F	LWT °F	MAX ΔP FT H_2O
93	76	51	50.3	8	10	1	940	42	60	15
PRE-HEAT/HEAT RECOVERY (40% GLYCOL)										
AIR SIDE							WATER SIDE			
EDB °F		LDB °F		MIN ROW	FIN SPACE FPI	MAX ΔP IN H_2O	GPM	EWT °F	LWT °F	MAX ΔP FT H_2O
0		53		8	10	1	309	76	35	15
FILTER									AIR TEMPERATURE	
PREFILTER						FINAL FILTER			LEAVING UNIT (INCLUDED FAN HEAT) °F	
MIN EFF.	PD CLEAN	PD DIRTY	MIN EFF.	PD CLEAN	PD DIRTY	MIN. EFF.	PD CLEAN	PD DIRTY		
30%	0.3	0.6	95%	0.6	1.2	99.9%	1.2	2.4	56	

EXHAUST AIR HANDLER HEAT RECOVERY UNIT (W/ VSD FANS)										
CASING			FAN				FILTER			
INSULATION	MIN LEAKAGE CLASS	MIN PRESSURE CLASS	CFM	EXT SP IN H_2O	TYPE	QUANTITY	MIN EFF.	PD CLEAN	PD DIRTY	
4	4	12	120,000	3	STROBIC	4	30%	0.3	0.6	
HEAT RECOVERY (40% GLYCOL)										
AIR SIDE							WATER SIDE			
EDB °F	EWB °F	LDB °F	LWB °F	MIN ROW	FIN SPACE FPI	MAX ΔP IN H_2O	GPM	EWT °F	LWT °F	MAX ΔP FT H_2O
72	54	46	42	8	10	0.75	416	35	53	15

Circulation System

HOT WATER PUMPS									
SERVICE	UNIT NO.	TYPE	GPM	TOTAL HEAD FT H_2O	MAX NASH FT	MOTOR BHP	MIN MHP	RPM	VSD
VIVARIUM RE-HEAT	HWP-1	END SUCTION	500	100	-	15	20	1,750	YES
	HWP-2 (STANDBY)								
VIVARIUM OA PRE-HEAT	GWP-1	HOR. SPLIT CASE	840	95	-	39	50	1,750	-
	GWP-2								
	GWP-3								
DEAERATOR	TP-1	END SUCTION	110	70	4	-	7.5	3,500	-
	TP-2								
	TP-3								
	TP-4								
BOILER FEED	BFP-1	END SUCTION	85	370	4	-	30	3,500	-
	BFP-2								
	BFP-3		165						
	BFP-4								
	BFP-5								

CHILLED WATER PUMPS										
SERVICE	UNIT NO.	TYPE	GPM	TOTAL HEAD FT H_2O	MAX NASH FT	MOTOR BHP	MIN MHP	RPM	VSD
CHILLED WATER	CHP-1	HOR. SPLIT CASE	2,667	65	-	57	75	1,175	-
	CHP-2								
	CHP-3								
SECONDARY CHILLED WATER	SCHP-1	HOR. SPLIT CASE	5,334	90	-	142	200	1,185	YES
	SCHP-2 (STANDBY)								
	SCHP-2 (STANDBY)								
CONDENSER WATER	CWP-1 (STANDBY)	HOR. SPLIT CASE	4,960	100	-	150	200	1,185	-
	CWP-2								
	CWP-3								

Design & Stimulation Comparisons

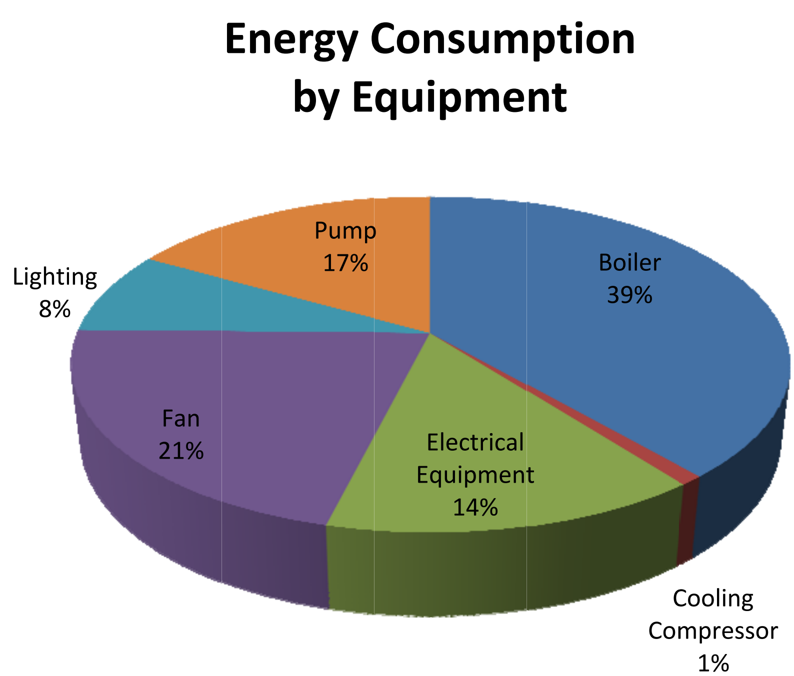
As stated in Technical Assignment #2, Level C is chosen as base of analysis due to partial fit-out on Level D and B, and all three levels shared similar program.

The computed cooling ventilation rate and cooling loads are 70% of design document. The energy simulation program Trace does not have a category for airflow rate through fume hood exhaust. It accounts for approximately 24,000 cfm of exhaust air each floor at maximum capacity, 28% of design flow rate.

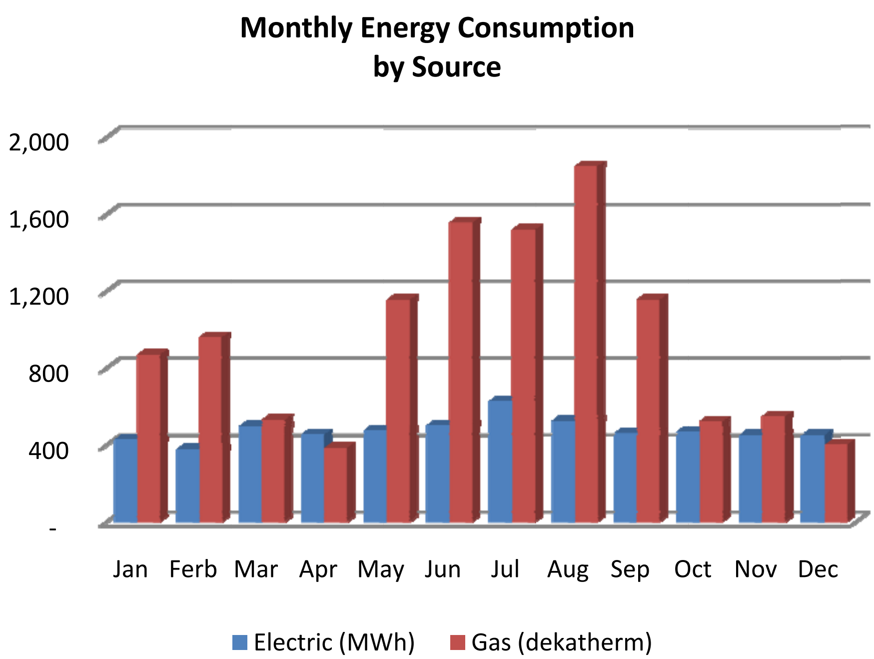
SYSTEM	DESIGN			COMPUTED		
	SUPPLY AIR CFM/SF	**Load** SF/TON	CFM/TON	**Supply Air** CFM/SF	**LOAD** SF/TON	CFM/TON
AHU - C	1.50	74.2	111	1.03	96.9	99.8

Annual Energy Consumption

To calculate energy consumption, computed rather than design ventilation rate and cooling load are used. The Energy Consumption by Equipment pie chart showed the percentage of total energy each major component consumes. HVAC equipments consume 70% of total energy by comparison. Trace assumed the 2,000 ton steam turbine chiller is the primary, and the electric centrifugal chiller as a standby. The electrical centrifugal chiller will operate when additional capacity is required during warm seasons. Hence, only 1% of the total energy consumption is counted toward cooling compressor. Cooling compressor energy consumption should include a portion of the boiler energy consumption since the steam turbine consumes 7,000 MBtu of steam produced by the boiler.



The four 800 hp dual fuel steam boilers use both natural gas and #2 distillate oil. Since natural gas is their primary source of energy, it is used in the for energy consumption simulation. The Monthly Energy Consumption by Source bar chart showed electricity consumption in megawatt-hour, and natural consumption in dekatherm. Electricity consumption remained fairly consistent throughout the year, while gas consumption rate varies. This configuration is a possible operating cost reduction strategy when electric demand charge is minimized.



Operating History

The building is not yet completed at time of this report. Therefore, does not have an operating history.

Critique of System

The mechanical system successfully accomplished all design objectives. The system is adequately designed to meet City Hospital’s current program and has the ability to expand to accommodate future load requirements. To ensure the health and safety of its occupant, a system with the ability to provide 100% OA, and pressure differential is selected. In recognition of 100% OA, methods to control the building’s annual energy expense are top priority. Many energy saving techniques, such as exhaust air heat recovery, boiler stack economizers, and premium motors with VSD, are incorporated into the design. In addition to energy saving methods, the system also exercise cost saving technique such as lowering electric demand by using steam turbine chiller, or obtain lowered energy rate by adding a dual fuel boiler. Although such design require high first cost, owner should see saving in a very short period of time.

Appendix A

MECHANICAL SYSTEM ABBREVIATIONS

AEL	AIE SEPARATOR
AHU	AIR HANDLING UNIT
B	BOILER
BD	BLOW DOWN
BDQ	BLOWDOWN QUENCH TANK
BDS	BLOWDOWN SEPARATOR
BF	BOILER FEED
BFP	BOILER FEED PUMP
BSE	BOILER STACK ECONOMIZER
CC	COOLING COIL
CFM	CUBIC FEET PER MINUTE
CH	CHILLER (STEAM TURBINE)
CHR	CHILLED WATER RETURN
CHS	CHILLED WATER SUPPLY
CP	CONDENSATE PUMP
CT	COOLING TOWER
CUP	CENTRAL UTILITY PLANT
CWF	CONDENSER WATER SIDESTREAM SAND FILTER
CWP	CONDENSER WATER PUMP
CWR	CONDENSER WATER RETURN
CWS	CONDENSER WATER SUPPLY
DEA	DEAERATOR
EA	EXHAUST AIR
EAHU	EXHAUST AIR HANDLER UNIT
EAT	ENTERING AIR TEMPERATURE
EDB	ENTERING DRY BULB TEMPERATURE
EGT	ENTERING GAS TEMPERATURE
EQ	EQUALIZER
ET	EXPANSION TANK
EWB	ENTERING WET BULB TEMPERATURE
EWT	ENTERING WATER TEMPERATURE
FPI	FINE PER INCH
GCR	GRAVITY CONDENSATE RETURN
GPM	GALLON PER MINUTE
GWP	GLYCOL WATER PUMP
GWR	GLYCOL WATER RETURN
GWS	GLYCOL WATER SUPPLY
HPR	HIGH PRESSURE STEAM RETURN
HPS	HIGH PRESSURE STEAM SUPPLY
HWH	DOMESTIC HOT WATER HEAT EXCHANGER
HX	HEAT EXCHANGER
LAT	LEAVING AIR TEMPERATURE
LDB	LEAVING DRY BULB TEMPERATURE
LGT	LEAVING GAS TEMPERATURE
LPR	LOW PRESSURE STEAM RETURN
LPS	LOW PRESSURE STEAM SUPPLY
LWB	LEAVING WET BULB TEMPERATURE
LWT	LEAVNG WATER TEMPERATURE
MPR	MEDIUM PRESSURE STEAM RETURN
MPS	MEDIUM PRESSURE STEAM SUPPLY
OA	OUTDOOR AIR
PC	PUMPED CONDENSATE
PCWHR	PROCESS CONDENSER WATER RETURN
PCWHS	PROCESS CONDENSER WATER SUPPLY
PPH	POUND OF STEAM PER HOUR
PRV	PRESSURE REDUCING VALVE
SA	SUPPLY AIR
SCHR	SECONDARY CHILLED WATER RETURN
SCHS	SECONDARY CHILLED WATER SUPPLY
SUR	SURGE TANK
VAV	VARIABLE AIR VOLUME
VSD	VARIABLE SPEED DRIVE