Mechanical Technical Assignment Three
Mechanical Systems Existing Conditions Evaluation

The Hospital for Special Surgery River Building
New York, New York

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Executive Summary

Mechanical systems have become more integrated and complex as more energy efficient buildings have been built. In order to translate design into construction, commissioning is used. Commissioning assures that the quality and performance specified in design carry over into operation through documentation and assessment. This report will examine the existing mechanical system from its design through to its completion and operation. This report will also provide a critique of the system by cost, energy, and environmental issues.

Cannon Design, an architectural engineering firm provided mechanical designs for the HSS River Building. Through a set of goals, the mechanical engineers at Cannon wanted to provide occupant controllability, energy efficiency, space savings, and reduction in the spread of contaminates in their mechanical design. The HSS River Building contains a heat pump system providing air conditioning for the air handling unit and occupants on each floor. The building has an air distribution system that intakes 100% outdoor air and mixes with return air in each serving zone to provide ventilation. All air in toilets, locker rooms, and gym facilities are exhausted.

Through the analysis of the existing system, the mechanical design drawings, mechanical specifications, Technical Assignment 1 – ASHRAE Standard 62.1-2007 Ventilation Report, and Technical Assignment 2 – Building and Plant Energy Analysis Report were used as references for this report. Mechanical equipments were analyzed and put into schedules, and schematic drawings were developed for the heat pump system to show cooling and heating flow cycles. Equipments that were examined were:

- 14,000 CFM 100% outdoor air unit
- (3) 75 GPM water-to-water heat pumps
- (157) terminal water-to-air heat pumps
- 3,000 MBTU tube and shell heat exchanger
- (2) In-line pressure reducing valves (5,500LBS + 3,000LBS)
- 6,000 MBTU closed loop cooling tower
- (2) sets of centrifugal pumps (1,100 GPM + 225 GPM)

In conclusion, the HSS River Building's mechanical system is found to provide a moderate air distribution system and an effective heat pump system for the building. It was discovered that the system has room for improvement in energy reductions and air distribution techniques.

Building Overview

The HSS River Building is a twelve story 88,245 square feet building located in the Upper East Side of Manhattan. The building is used for acute medical care, containing primarily exam rooms, X-ray rooms, doctor offices, and a rehabilitation gym on the second floor. The HSS River Building is designed to be on top of the FDR Drive highway, overlooking the East River.

Inside the River Building, the project was designed as a core and shell, leaving the interior programming to the client's request. The core and mechanical system were designed to use the least amount of space possible so that the client will be able to rent out the space. This being said, the HSS River Building's mechanical system only takes up 1% of the rentable space available as all equipments are located in the penthouse and concealed in the plenum. **Figure 1** shows each floors rentable space breakdown along with the penthouse area.

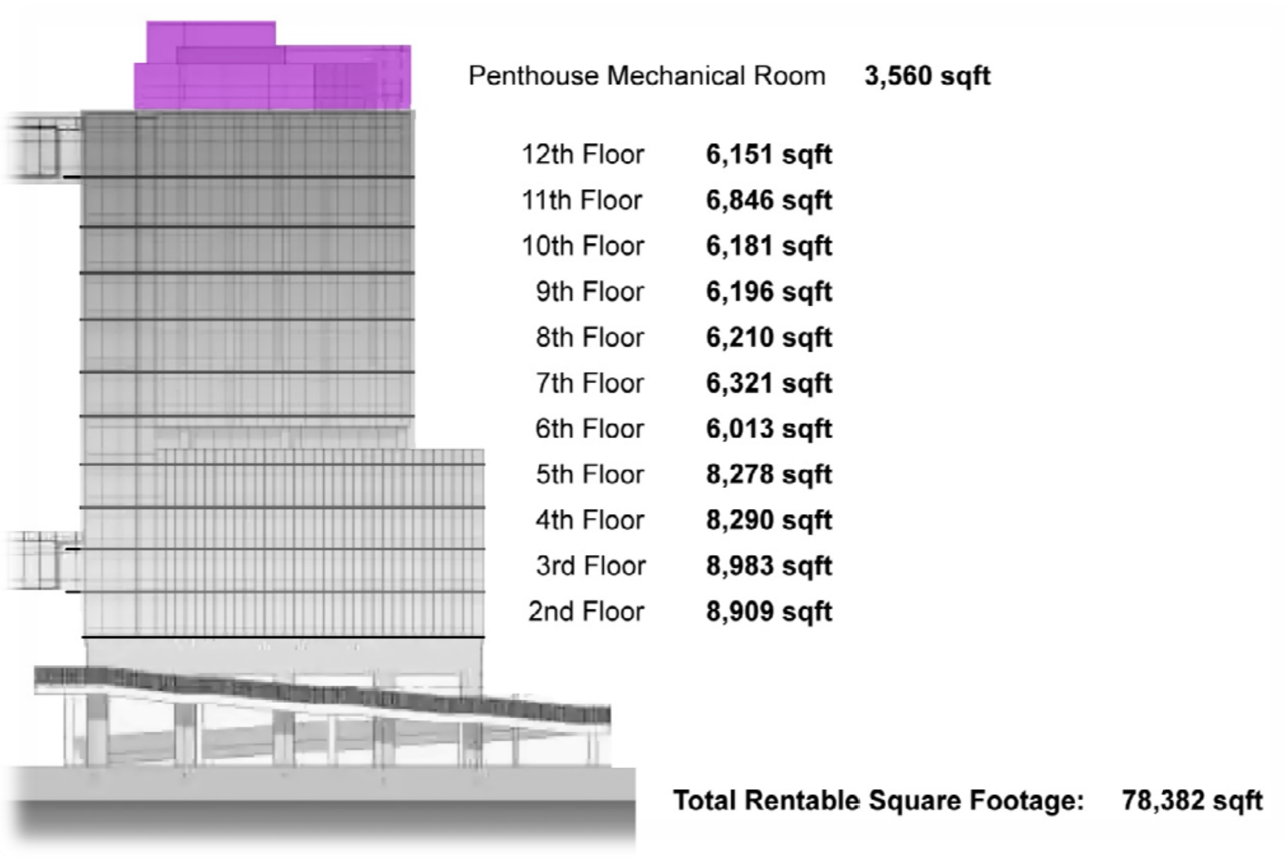


Figure 1 – Rentable Square Footage Breakdown.

Mechanical Design Objectives and Requirements

The mechanical system for the HSS River building is a heat pump system providing cooling and heating for the 100% Outdoor Air Handling Unit. The minimum outdoor air is brought in and mixed with the return air in each terminal heat pump unit serving each area. The main heat pump provides cooling and heating for the AHU is water-to- water system where as the terminal units are water-to-air. The design of the mechanical system for the HSS River Building was developed from the following objectives:

- User-end Controllability
- Energy efficiency
- Space conservation
- Reduce spread of contaminates

With these objectives in mind, the HSS River Building uses multiple terminal heat pumps, providing user-end controllability of temperature for each serving space. To increase energy efficiency, the HSS River Building mechanical system uses a heat pump loop with a 100% air handling unit sized for the minimum outdoor air, reducing energy needed to condition a larger amount of outdoor air. Lastly, by sizing the duct penetrations for the amount of outdoor air only and mixing the recirculation and outdoor air at the terminal end reduces the amount of space needed for the ductwork. By not mixing the return air with the outdoor air in the Air Handling Unit, the system prevents contaminates and air borne diseases to circulate throughout the entire building.

In a heat pump system, there are two sets of temperature ranges for the heat pump to work efficiently. One set is called the load loop temperature and the other is the source loop temperature. In the HSS River Building, a steady temperature range of 90F to 100F is need for the source loop and 46F and 55F for the load loop for cooling. For heating, a range of 60F and 70F is needed for the source loop and 90F and 100F for the load loop. In order to maintain this constant temperature, a cooling tower and heat exchanger is used to reject and supply additional heat to the system.

The HSS River Building was designed to also meet ASHRAE Standard 62.1 Ventilation requirements but did not meet all requirements set forth for ASHRAE Standard 90.1. These results were studied in *Technical Assignment 1 – ASHRAE Standard 62.1-2007 Ventilation Report and Technical Assignment 2 – Building and Plant Energy Analysis Report*.

Mechanical System Design and Operation

All the mechanical components for the HSS River Building are contained inside the penthouse mechanical room except the terminal heat pump units that are concealed in the plenum on each floor. **Figure 2** below shows the layout of the mechanical room. The Cooling Tower is placed strategically outside the mechanical room on the rooftop surrounded by metal panels closing it off to the public's eye. The AHU air intake and cooling tower intake meets ASHRAE Standard 64.1 Section 5 requirements.

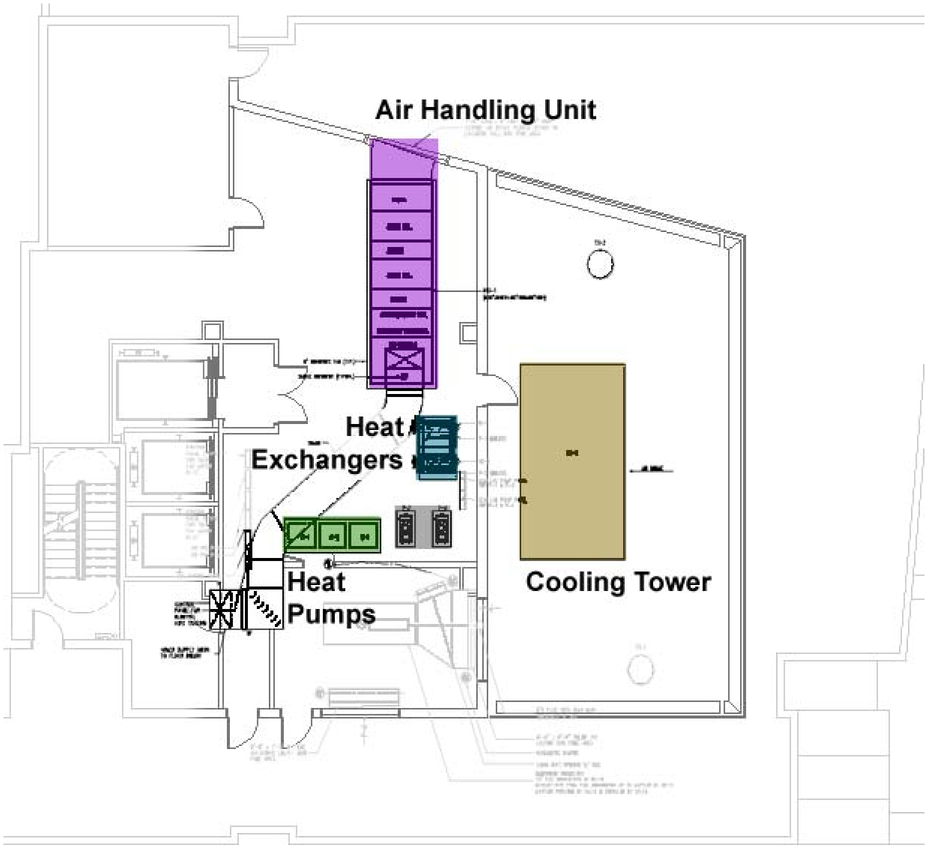


Figure 2 – Mechanical Room Layout.

Air Distribution

The HSS River Building provides 100% minimum outdoor air through the McQuay roof top unit bringing 14,000 CFM into the building. The outdoor air is filtered in two stages, first a 30% efficient throwaway filter at the outdoor air (OA) intake and a final Varicel II cartridge filter of 85% efficiency after the fan. The OA is conditioned by heating and cooling coils and ducted down to each floor. The outdoor air is mixed with the return room air by the terminal heat pump units in the plenum. The supply air is then conditioned again by the terminal heat pump unit. In order to provide thermal comfort, the AHU has an entering and supplying summer temperature of 95F and 57.2F respectively while the entering and supplying winter temperature is 0F and 92.5F respectively. **Table 1** provides additional details for the AHU.

Table 1 - AHU-1 McQuay CAH041-GDAM	
100% OA CFM	14,000
Total Static Pressure	5.39 In. wg
Cooling	
EAT (DB/WB)	95/75
LAT (DB/WB)	57.2/57
EWT/LWT	46.7/55
Flow Rate	225 GPM
Heating	
EAT (DB)	0
LAT (DB)	92.5
EWT/LWT	103/83.2
Flow Rate	225 GPM
Supply Fan	
Motor HP	25
Motor BHP	20.06
RPM	1750
Weight	9500 LBS.

At the terminal end, each terminal heat pump unit cools and heats the supply air mixture of outdoor air and return air. The operating supply air temperature for cooling is 67F and the return and supply mixed air temperature for heating is 105F.

The HSS River Building also contains (6) centrifugal roof up-blast exhaust fans. They are used mainly for exhausting air from toilet rooms and locker rooms. Other exhaust fans are used for exhausting the exercise room on the 2nd floor and also for smoke purging all floors in case of a fire. **Table 2** provides additional details for each exhaust fans.

Table 2- Exhaust Fans – Greenheck Cube-240XP							
Unit No.	Service	CFM	SP IN. WG	RPM	Motor		
					BHP	HP	Electric
SX-1	Smoke Purge	10,000	1.5	875	4.72	5	460/3/60
TX-1	Toilet Exhaust	2,360	1.5	1,601	1.26	1.5	460/3/60
TX-2	Toilet Exhaust	2,755	1.5	1,752	1.62	2	460/3/60
TX-3	Toilet Exhaust	1,784	1.5	1,784	1.7	2	460/3/60
GX-1	General Exhaust	3,240	1.5	627	1.92	3	460/3/60
GX-2	Gym Exhaust	1,250	1.0	1,741	.54	.75	460/3/60

Heat Pump System

The mechanical system contains (3) water-to-water heat pumps to condition the 100% outdoor air and (157) terminal water-to-air heat pump units on all floors to condition each space. The heat pump source and load loop system contains a mixture of water and 35% propylene glycol to prevent the loop from freezing. The (3) water-to-water heat pumps provides the entering water temperature needed for the terminal heat pump units to reject and absorb heat during cooling and heating seasons. This being said, the terminal heat pump units provides their leaving water temperature as the entering water temperature needed for the source loop for the (3) water-to-water heat pumps. This delicate balance is kept in check by a cooling tower and heat exchanger to reject or add more heat to the system to maintain constant temperature differences. **Table 3** provides additional details for the water-to-water heat pumps. **Table 4** provide additional details for (10) different sized water-to-air terminal heat pump units.

Table 3 - Water-to-Water Heat Pump - McQuay WGRW		
	Source	Load
Flow Rate	75 GPM	75 GPM
Water Pressure Drop	21.88	16.68
Cooling		
EWT/LWT	90/100.2	55/46.7
Heat Rejection	382,944 BTUH	
Total Capacity	299,133 BTUH	
Heating		
EWT/LWT	70/60.1	90/103
Heat Absorption	375,685 BTUH	
Total Capacity	464,365 BTUH	

Table 4 - Water-to-Air Terminal Heat Pump Units – McQuay WCMS									
	CFM	EER	COP	Flow Rate (GPM)	WPD (ft)	**Cooling**		**Heating**	
						Total Capacity	Heat Rejection	Total Capacity	Heat Absorption
A	300	11.01	3.23	2	6.06	8,420	11,176	11,792	8,968
B	400	10.69	3.13	2.5	10.47	12,047	16,188	16,895	12,583
C	500	12.49	3.66	3.5	15.37	15,258	19,683	20,168	15,153
D	630	11.86	3.47	4	16.64	19,039	24,907	24,711	18,714
E	800	11.61	3.40	5	6.61	23,683	30,981	29,248	22,201
F	1000	12.35	3.62	7	14.43	31,558	40,759	38,614	29,087
G	1200	12.08	3.54	8	11.17	35,228	45,697	45,645	34,574
H	1400	12.19	3.57	10	13.68	40,952	52,999	52,367	39,330
I	1600	11.60	3.40	11	16.94	46,117	60,387	53,991	40,813
J	2000	11.46	3.36	14	16.98	59,724	78,501	77,619	57,981

Source and Load Loop Cooling Flow Diagram

To understand the heat pump cycle in more detail, **figure 3** below demonstrates the flow path and temperatures of the source and load loops during cooling. Starting with the Load Loop, the heat pump provides 46F water to the cooling coils in the AHU, which returns back to the heat pump by pumps 3 and 4 at 55F. In order for the heat pump to cool 55F water down to 46F, it rejects heat to the Source Loop. The Source Loop absorbs the heat from the Load Loop and heats up the water from 90F to 100F. The 100F water is then by-passed from the floor loads and directed to the cooling tower to reject heat from 100F water down to 90F. The 90F water is then pumped through by pumps 1 and 2 to each floor serving each terminal water-to-air heat pumps. There, the 90F water provides heat rejection for the refrigerant in the heat pump to provide cooling from 80F return air to 67F supply air, returning back again to the cooling tower at 100F water. **Figure 3** shows the cooling flow diagram.

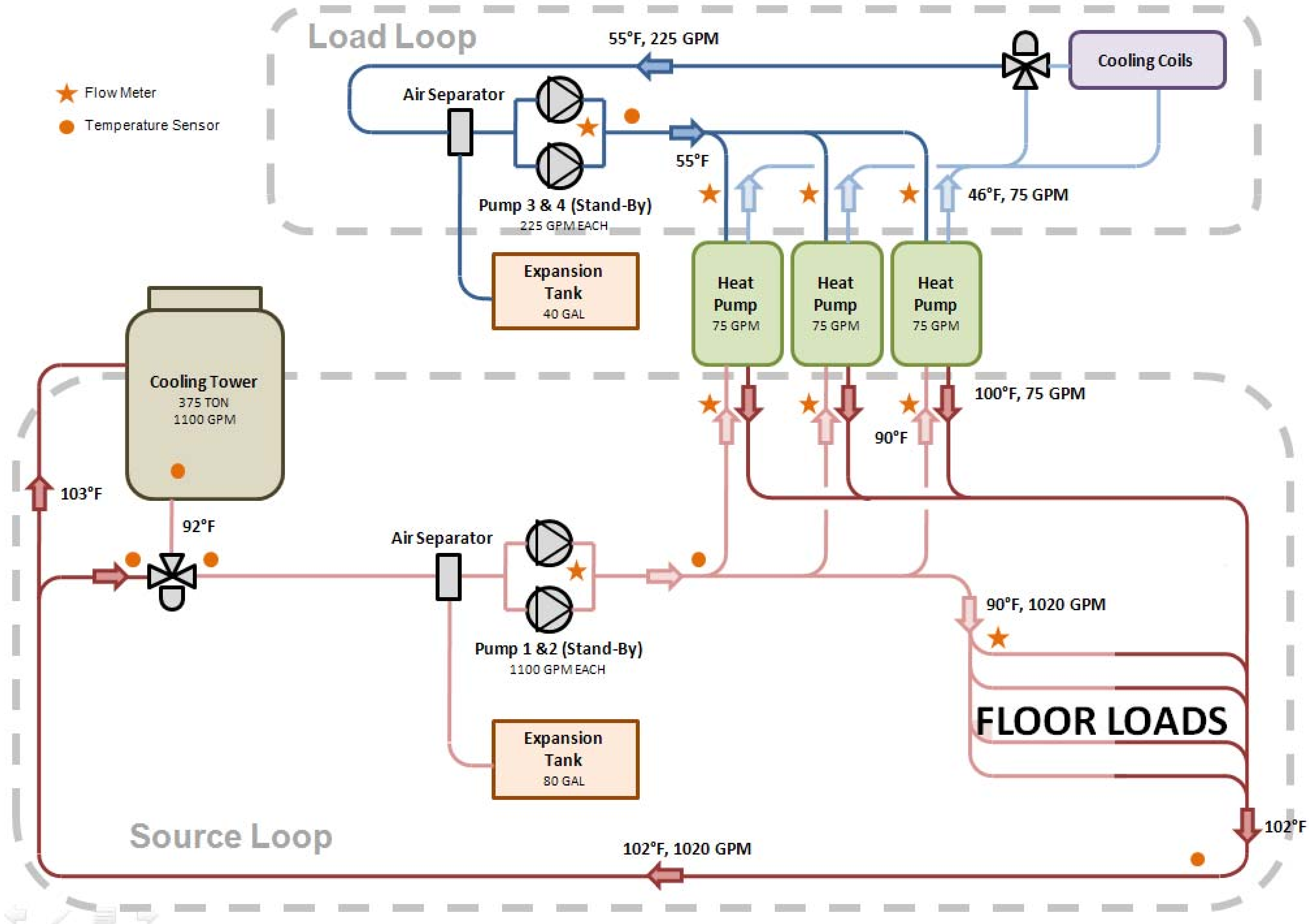


Figure 3 – Heat Pump Cooling Flow Diagram.

Source and Load Loop Heating Flow Diagram

When heating occurs, the Load Loop temperature reverses with the Source Loop in cooling. Starting at the Load Loop, the 103F water serves the heating coils in the AHU and returns back to the heat pumps by pumps 3 and 4 at 90F. In order to produce 103F water again, the heat pump absorbs heat from the Source Loop. The Source Loop rejects the incoming water at 70F to the Load Loop, making the leaving water temperature at 60F. This 60F water is then by-passed from the floor loads and directed to the heat exchangers where the water absorbs heat from the steam and raises the temperature back to 70F. This 70F water is then directed to the terminal water-to-air heat pumps serving each floor by pumps 1 and 2. The 70F water provides heat absorption for the refrigerant in the heat pump to provide heating from 70F return air to 104F supply air, returning back again to the heat exchangers at 60F water. **Figure 4** shows the heating flow diagram.

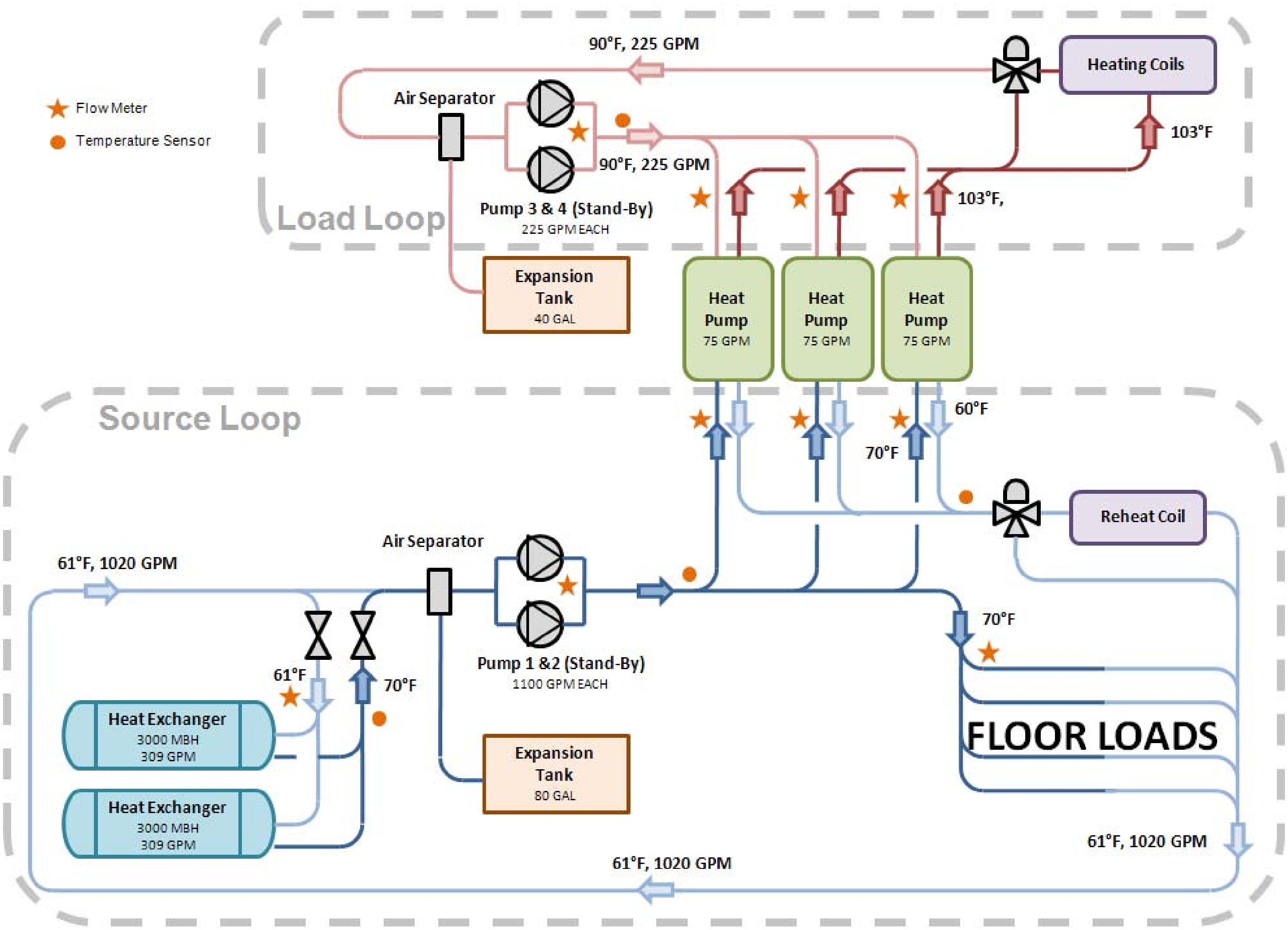


Figure 4 – Heat Pump Heating Flow Diagram.

Heat Absorption - Steam

Con Ed, the utility provider for electricity for the HSS River Building also provides high pressure steam at 160 psi. The steam is stepped down from 160 psi to 80 psi and then down to 15 psi by two sets of Pressure Reducing Valves (PRVs). **Table 5** provides additional details about each PRV station. This low pressure steam (LPS) is then directed to the shell of the heat exchangers to provide heat to the heat pump source loop. The (2) 3,000MBH heat exchangers are controlled by a control valve station with one valve controlling 0-25% at full load and another controlling 0-100% at full load. **Table 6** contains additional details about the tube and shell heat exchangers.

Table 5 – In-Line Pressure Reducing Valves – Leslie		
PRV-1	Pressure Inlet	160 psi
	Pressure Outlet	80 psi
	Capacity	3,000 lbs
PRV-1a	Pressure Inlet	80 psi
	Pressure Outlet	15 psi
	Capacity	3,000 lbs
PRV-2	Pressure Inlet	160
	Pressure Outlet	80psi
	Capacity	5,500 lbs
PRV-2a	Pressure Inlet	80 psi
	Pressure Outlet	15 psi
	Capacity	5,500 lbs

Table 6 - Heat Exchangers – Bell & Gossett Model QSU	
Capacity (Tube side)	3,000 MBH
Capacity (Shell side)	3,124 PPH Steam
Flow Rate	104 GPM
EWT/LWT	70F/130F
Pressure Drop	1.7 Ft Water

Besides serving the (2) heat exchangers, the LPS also serve the cooling tower heater basin to prevent the spray water from freezing and provide the AHU with preheating and emergency heating. **Figure 5** shows the LPS supply and return flow diagram.

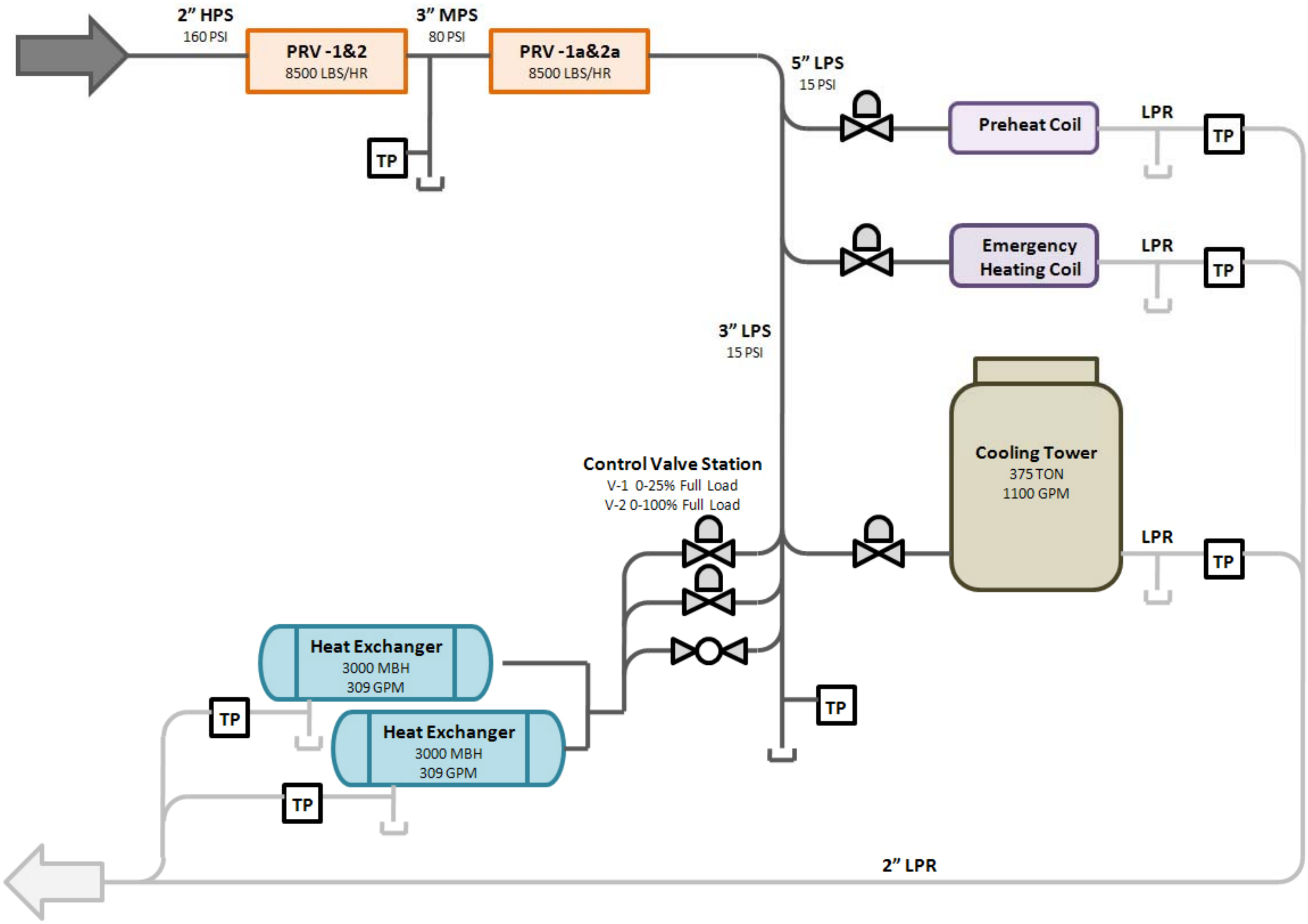


Figure 5 – Low Pressure Steam Supply and Return.

Heat Rejection – Cooling Tower

During the cooling season, the cooling load will fluctuate depending on the outdoor conditions and internal loads in each space. When additional cooling occurs, the heat pump loop load leaving temperature from each terminal heat pump will increase. This increase in temperature is then rejected through the cooling tower to maintain the constant 90F entering temperature for the (3) heat pumps serving the AHU. The Cooling Tower contains two axial fans with variable speed motors at 30HP and 15HP. It is a closed loop system to minimize process fouling and also contains a steam basin heater to prevent spray water from freezing. **Table 6** provides additional details of the Cooling Tower unit**. Figure 5** shows the heat pump loop supply and return flow diagram for cooling.

Table 6 - Cooling Tower – Baltimore FXV-Q661	
Heat Rejection	6,110 MBH at 1095 GPM
Range Temp	102F/90F
Approach Temp	78F
30 HP Motor	917 GPM
15 HP Motor	728 GPM

Pumps

In order to deliver water to and from the source in the heat pump system, two sets of centrifugal pumps are used serving the floor loads and serving the AHU. Both sets of pumps are located in the mechanical penthouse room and both contain a stand-by unit. The floor load pumps are designated as P-1 and P-2, P-2 is a stand-by, each providing 1100 GPM and 120 FT of head. P-1 and P-2 contain variable frequency drives (VFD) that can alter the GPM output by the flow and pressure sensor attached to the pumps. P-3 and P-4 provides circulation for the AHU heating and cooling coils with P-4 as the stand-by, each pumping 225 GPM and 75 FT of head. Both sets of pumps contain a lead-lag panel controlling when each stand-by will be used. **Table 7** provides additional information on the pumps.

Table 7 – Centrifugal Pumps – Bell & Gosset 1510							
	GPM	Head (Ft)	Impeller Size (In)	RPM	HP	VFD	Electric
P-1, P-2	1100	120	12.125	1750	50	Yes	460/3/60
P-3, P-4	225	75	8.875	1750	10	No	460/3/60

Mechanical Design Conditions

Outdoor Design Conditions

The HSS River Building is located at 70^{th} and York Avenue on the Upper Eastside of Manhattan. The nearest data location is located at La Guardia Airport in Queens. **Table 8** provides data from by Trane Trace 700 program that was used was used to design the building and also modeled by the designers at Cannon Design.

Table 8 – Outdoor Design Conditions	
Location	New York La Guardia
Latitude	40.8
Longitude	73.9
Elevation	30 ft
Summer Design DB	92.0F
Summer Coincident WB	74.0F
Summer Daily Range	14.6F
Winter Design DB	13F
Winter Coincident WB	10.4F

Indoor Design Conditions

The indoor conditions used by Cannon Design for the HSS River Building are listed in **Table 9**. These conditions were used for all rooms in the building including exams, offices, conference rooms, locker rooms, and even the gym. These data were inputted into Trane Trace to model the building by the designer.

Table 9 – Indoor Design Conditions	
Cooling Supply DB	78F
Cooling Drift point	90F
Heating Supply DB	72F
Heating Drift point	55F
Relative Humidity	50%

Along with indoor temperature inputs, interior loads were also used to model the building energy use. Interior loads will be discussed later in the **Design Heating and Cooling Loads** section.

Design Ventilation Requirements

The HSS River Building ventilation requirements followed ASHRAE Standard 62.1-2004 Section 6 to provide the amount of minimum outdoor air needed for the occupants. This standard was complied by adding up all the rooms' occupants and function type and working through the Section 6 procedure to find the allowable minimum outdoor air. **Table 10** shows the results from the ASHRAE Standard 62.1-2004 calculations done in *Technical Report One: ASHRAE Standard 62.1-2007 Ventilation Report* and how it compares with the designed outdoor air intake.

Table 10 – ASHRAE Standard 62.1-2004 Ventilation Report.						
Unit	Area Served (Az)	Population (Pz)	Outdoor Air Supply (Vot)	Design Outdoor Air	Max. Zp	Compliance
AHU-1	97,282 sq.ft.	917 ppl	11,631 cfm	14,000 cfm	0.24	Yes

Technical Report One: ASHRAE Standard 62.1-2007 Ventilation Report demonstrated that the HSS River Building was well above compliance by supplying 14,000 CFM of outdoor air into the building.

Design Heating and Cooling Loads

The heating and cooling load calculations for the HSS River Building were done by the help of Trane Trance 700, a building energy modeling software. In *Techanical Assignment 2 – Building and Plant Energy Analysis Report,* a detailed analysis was done by inputting many interior loads such as human, receptacle, and lighting loads and schedules. With all the inputs and with equipment specifications, an estimated heating and cooling load for the whole building was calculated. This estimated load is then compared with the designed load compiled from the project's equipment schedules. **Table 11** compares the calculated load from *Techanical Assignment 2 – Building and Plant Energy Analysis Report*and the designed loads from Cannon Design.

Table 11 – Building Heating and Cooling Load Comparison		
	Computed	Designed
Cooling Load	362 ft2/Ton	415 ft2/Ton
Heating Load	424 ft2/Ton	372 ft2/Ton
Supply Air	0.91 cfm/ft2	1.1 cfm/ft2
Ventilation Supply	0.15 cfm/ft2	0.15 cfm/ft2

Mechanical System Operation

Energy Sources, Rates and Usage

The utility provider for the HSS River building is Consolidated Edison Company (Con Ed). The Hospital for Special Surgery has a contract with Con Ed for a utility rate which is not available for the public. Through Con Edison's website, an estimated on peak demand, on peak consumption, and steam prices are as follows:

- Demand charge – June to September: $15.58/kW
- Demand charge – October to May: $12.04/kW
- Consumption rate: $1.39/kWhr
- Steam – All year: $2.08/therm

By using the Con Edison rates, the annual energy cost can be calculated. **Table 12** shows the energy break down for the HSS River Building, the HVAC equipments use 38% of the total energy while most of it goes to receptacle loads (50%). **Table 13** shows the total annual energy cost along with the cost per square footage.

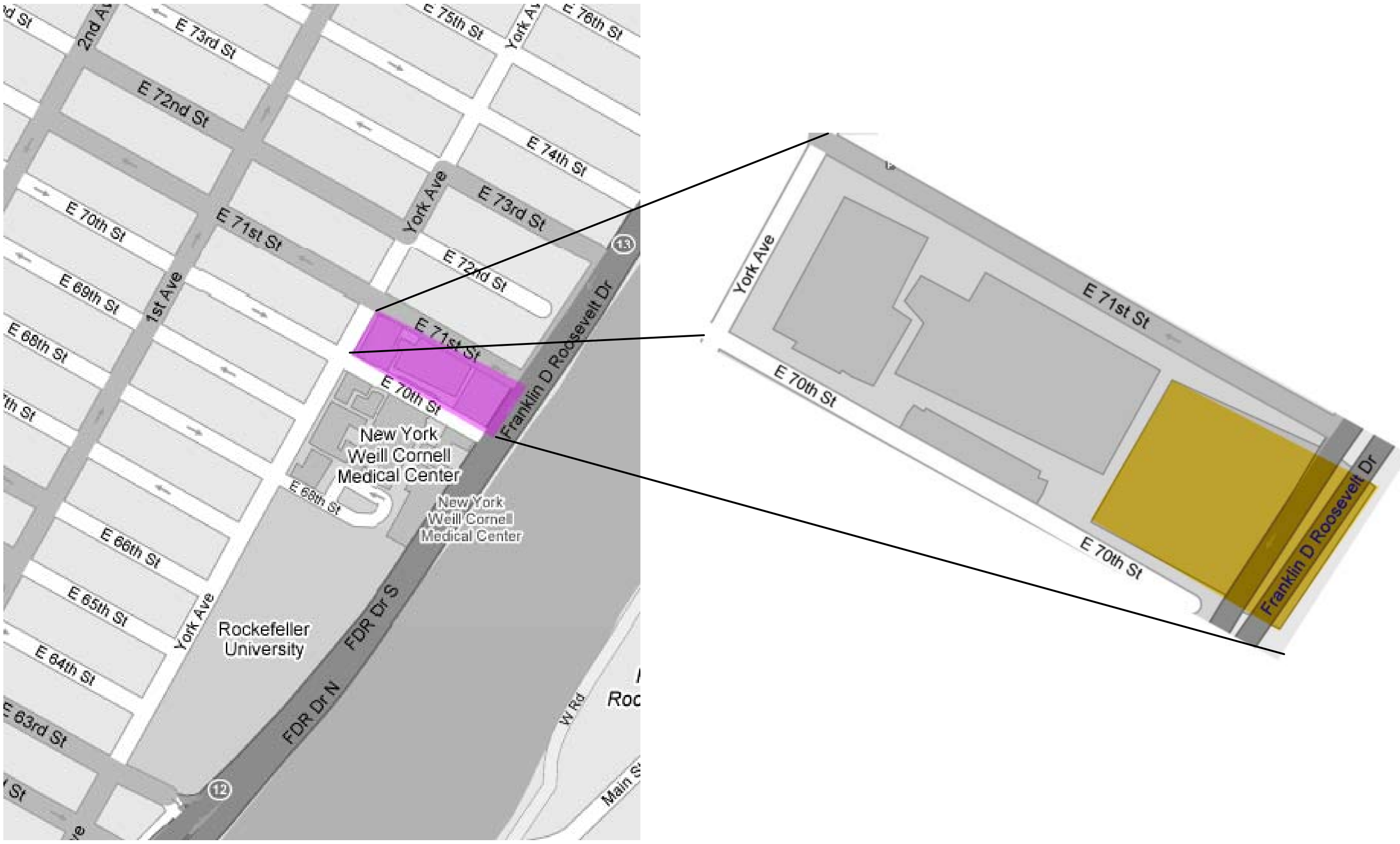
Table 12 - Energy Breakdown		
5.6% Heating	139,709 kWh	$200,200
6.8% Cooling	169,766 kWh	$243,100
16.4% Fans	408,374 kWh	$586,300
9.5% Pumps	236,803 kWh	$339,625
38% HVAC	**954,452 kWh**	**$1,369,225**
50.1% Receptacle	1,278,366 kWh	$1,791,075
10.6% Lighting	265,618 kWh	$378,950
62% Non HVAC	**1,543,984 kWh**	**$2,170,025**

Table 13 – Energy Cost	
Annual Energy Cost	$3,575,000
Energy Cost Per Square Foot	$40.50

Purchased steam from Con Ed is used in the building, but unfortunately there were some technical difficulty specifying the heat exchangers to steam in Trane Trace. For the purpose of this report, steam usage data will not be available.

Site and Cost Factors

The HSS River Building will be built on the Hospital for Special Surgery campus located between 70th and 71st Street and bordered between York Ave and the FDR Drive on the Upper Eastside of Manhattan. The campus is very dense containing (3) buildings within that block.



The HSS River Building is designed to be built as an addition to the Caspary Building to extend over the FDR Drive. The HSS River Building also has more than 50% of the facade containing glass on the north, south and east exposures and also straddles over the busy FDR Drive. With these considerations, the HSS River Building's mechanical system had to be:

- Away from the FDR Drive car exhaust
- Independent from the Caspary Building
- Limited on space usage
- Handle diversity in load in the building from glass exposure

There are no cost factors known at this time.

Operating History

The HSS River Building project was stopped at 100% Bid Documents to be redesigned at the request of the Owner. Therefore, there is no operating history for the mechanical system.

Mechanical System Critique

Air Distribution Critique

The air distribution of the HSS River Building can be seen as a moderate system. The system does not use more space and materials than conventional AHU return systems where either a ducted return or open plenum is required to bring all the return air back to the AHU. The air distribution also does decently at isolating serving zones from each other, which is important in an acute medical procedure building to prevent cross contaminants as each return air is re-circulated in each zone. But on the flipside, the mixture of outdoor air and room air is never exhausted in each serving zone but rather at negative pressure zones such as restrooms, lockers and the rehabilitation gym. This creates a positive pressure for every serving zone, possibly resulting in cross contamination into the negative pressure zones.

Another questionable design is the redundant air conditioning at the AHU and again at the terminal heat pump units. The leaving air temperature at the AHU during cooling contains 100% humidity at 57F while downstream at the terminal heat pump the entering air is drastically higher at 80F even though mixing conditions will probably provide an entering air of around 72F. This causes a significant amount of energy use as the air is getting condition twice even though the first condition does not dehumidify the air. This will have to be investigated further for numerical results.

Heat Pump System Critique

The heat pump system in the HSS River Building is an effective system. The heat pump system requires less space and energy to heat and cool the space. It also allows for simultaneous cooling or heating in different zones of the building at the same time as the terminal heat pump simply reverses its refrigerant flow cycle to allow this. This is a great advantage dealing with the diversity in the building as it contains fully exposed ceiling to floor glass on every floor on the North, East and South side. This is a great feature for providing control for the occupants. Even though the heat pump system is very delicate in its coordination of temperatures with the water-to-water heat pump serving the AHU and the water-to-air heat pumps serving each zone, the balance is maintained through controls and the cooling tower for heat rejection and heat exchangers for additional heat. The downfall of this system is the numerous amounts of terminal heat pumps concealed in the plenum on each floor that would need to be maintained throughout the year. This process will have to be done on premium time on weekends in order not to disturb the doctors and patients on the weekdays.

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