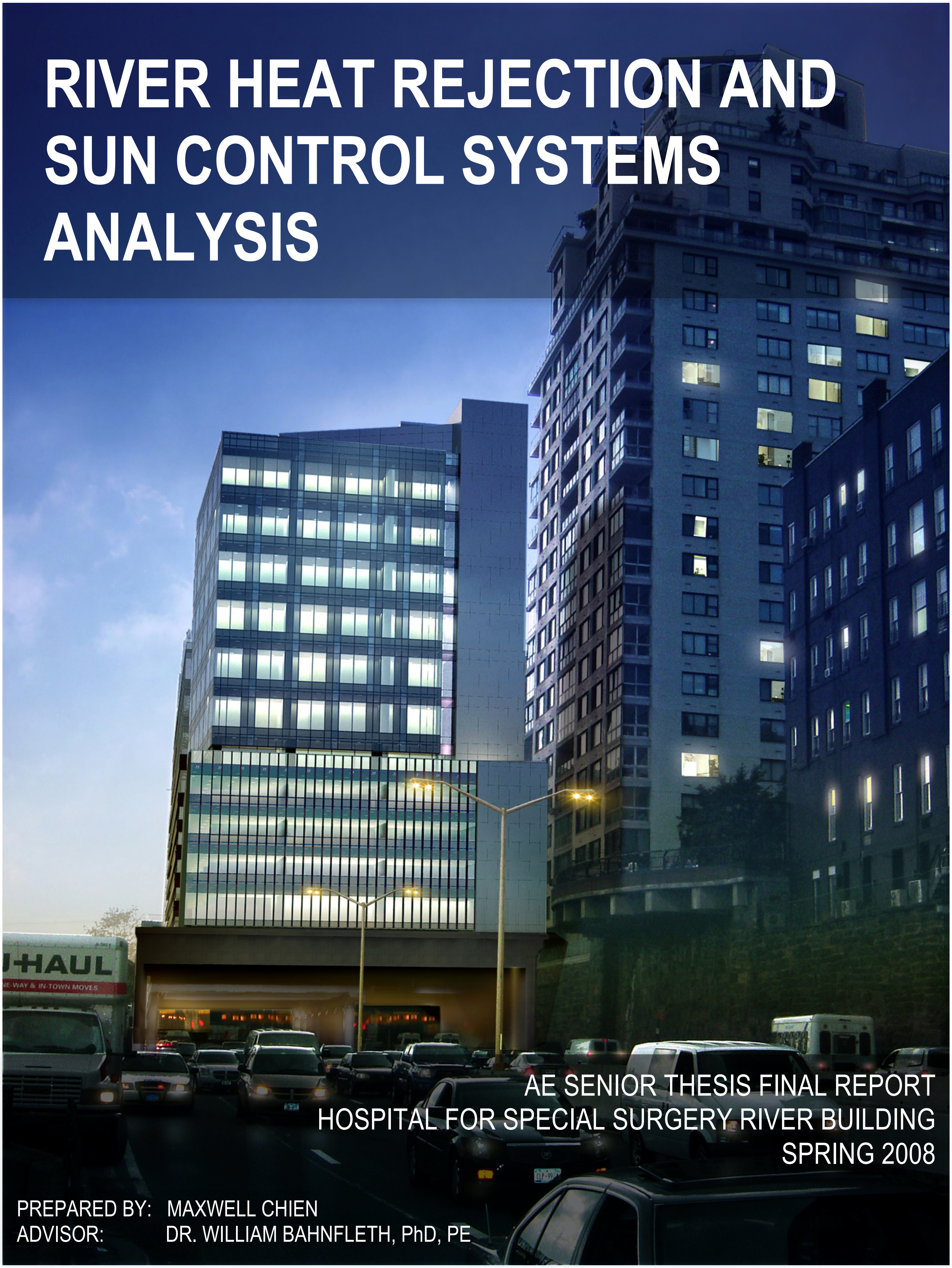
RIVER HEAT REJECTION AND SUN CONTROL SYSTEMS ANALYSIS



AE SENIOR THESIS FINAL REPORT
HOSPITAL FOR SPECIAL SURGERY RIVER BUILDING
SPRING 2008

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EXECUTIVE SUMMARY

The Hospital for Special Surgery River Building is a twelve story, 88,245 square feet building located on the Upper East Side of Manhattan. The building is a medical office building containing many doctor offices and exam rooms while also housing a rehabilitation gym on the second floor.

The existing mechanical system design is great at providing user-end controls, energy efficiency, and space conservation. The HSS River building has three heat pumps conditioning the 100% OA AHU, while the source loop also feeds into the (157) terminal water-to-air heat pumps located on each floor. The heat pump loop rejects and absorbs heat by a 375 ton cooling tower and a steam heat exchanger, with steam provided by Consolidated Edison (Con Ed).

Even though the building is already adequately efficient, the building still can save energy by utilizing the East River as a heat rejection source and reducing the solar gain on its façade of over 50% of fenestration.

This report will analyze the savings equated with developing a system that replaces the cooling tower and uses the East River to cool condensing water. It will also analyze and study the savings that a solar shade system can provide to the building. With these changes, many other aspects of the building will be changed as well. This report will also look into breadth topics of how the new mechanical equipment for the river rejection will affect the structural system on the first floor. Also, this report will analyze the breadth topic of how the solar shade system will impact the architecture façade of the building.

In conclusion, the river rejection system will have an initial cost of $164,000 and will save annually 219,408 kWhr, equaling a savings of $43,881. By removing the cooling tower from the system, the river rejection design will have a simple payback of just 1.8 years, making this system highly recommended. The solar shade system will provide 1,100 linear feet of shading mostly on the western exposure and also at the top of the southern exposure. This system will have an initial cost of $189,750 while saving 20 tons of cooling a year and 189,750kWhr in energy. This system will have a simple payback period of 4 years.

With the addition of these changes, the structural system and architectural façade will be changed. The structural beam under the new mechanical equipments will need to be resized to a W18x130 to replace the W14x90 in order to handle more loads. The architectural façade will also provide a visual the idea of sustainability and attentiveness to the surrounding environment, an idea that many buildings in Upper East Side lack.

EXISTING BUILDING BACKGROUND

BUILDING DESIGN BACKGROUND

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.

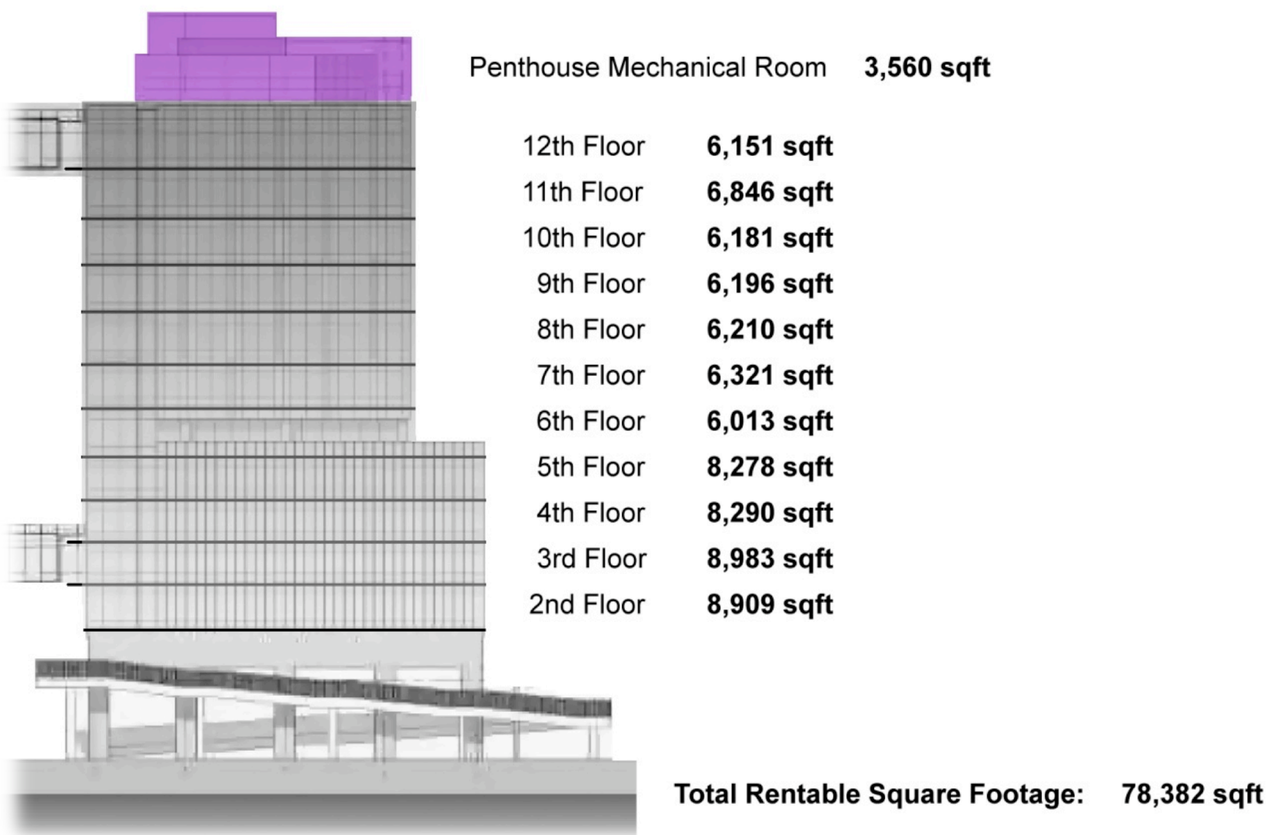

Figure 1 – Rentable Square Footage Breakdown.

STRUCTURAL BACKGROUND

In order to support the HSS River building on top of the FDR Drive, (10) 36 meters deep caissons are anchored to the bedrock below. With this foundation, the building raises twelve stories above ground with the support of six feet by four feet-spread footings on the interior columns. Typical beam sizes are W12x26 spanning 25 feet and spacing at eight feet.

Typical girder sizes for the building are W12x65s and W12x120s spanning 25 feet and spaced at 25 feet also. The building also contains two bridges on the 3rd and 12th story to connect the HSS River Building to the existing hospital. The bridge is built on W8x24 beams with braces that are W8x24 and columns at W14x99. For lateral forces, the building uses chevron brace frames for the 3rd and 12th floors along with a truss system on the 1st and 2nd floors.

MECHANICAL SYSTEM EXISTING CONDITIONS

DESIGN OBJECTIVES AND REQUIREMENTS

The mechanical system for the HSS River building is a heat pump system that provides cooling and heating for the 100% Outdoor Air Handling Unit and also terminal heat pump units that condition each floor space. 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 a water-to- water heat pump where as the terminal units are water-to-air. The design of the mechanical system for the HSS River Building was developed for 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 and return air mixture. 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 AHU, 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 temperature range, a cooling tower and heat exchanger are used to reject and supply additional heat to the system when needed.

The HSS River Building was designed to also meet ASHRAE Standard 62.1-2007 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*.

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.

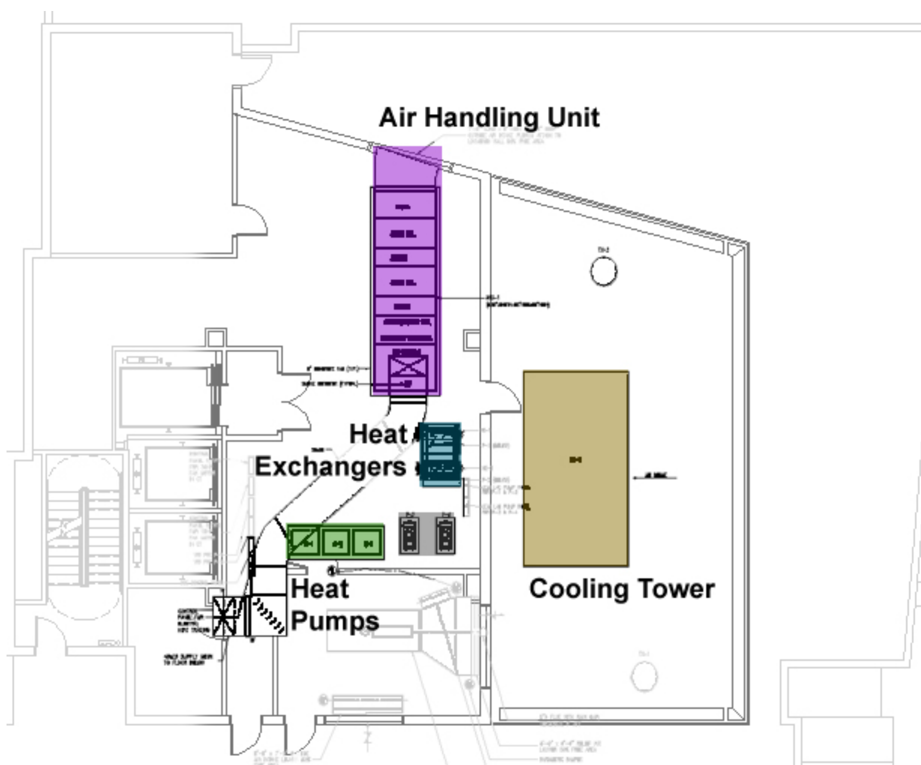

Figure 2 – Mechanical Room Layout.

EXISITING AIR-SIDE MECHANICAL SYSTEM

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 with a MERV 14 rating 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 terminal heat pump unit then conditions the supply air again. **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 bathrooms and locker rooms. Other exhaust fans are used for exhausting the exercise room on the 2^{nd} 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

EXISTING 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 pumps are all connected to a common source loop. 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 provide their leaving condenser water temperature as the entering 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** provides 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 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 pump. 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.

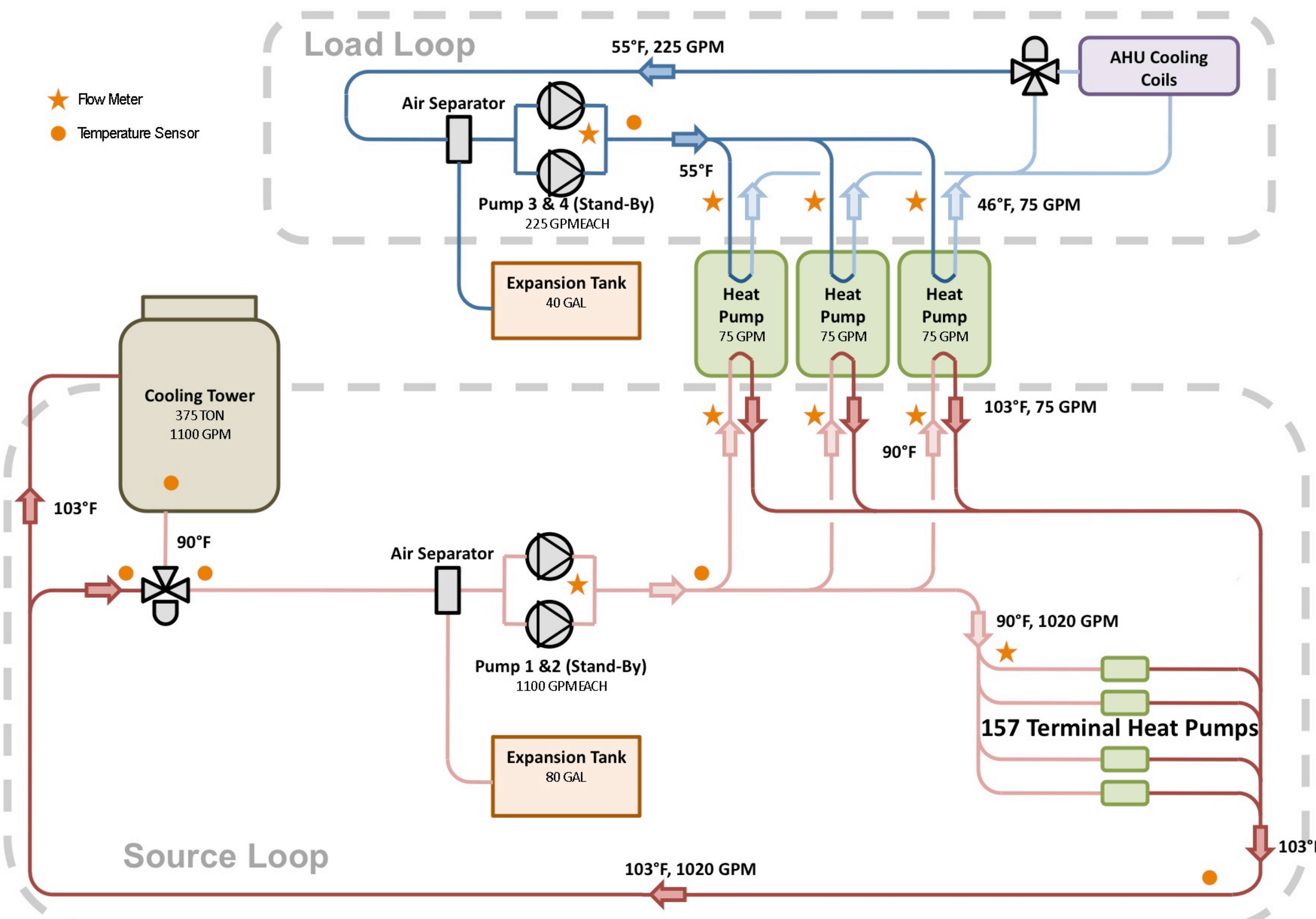

Figure 3 – Heat Pump Cooling Flow Diagram.

SOURCE AND LOAD LOOP HEATING 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. Due to the fact that mechanical redesign will not involve the steam system and heat exchanger, no further details will be provided of the steam system. Please refer to *Technical Report Three: Mechanical Systems Existing Conditions Evaluations* for more information about the heating system of the building.

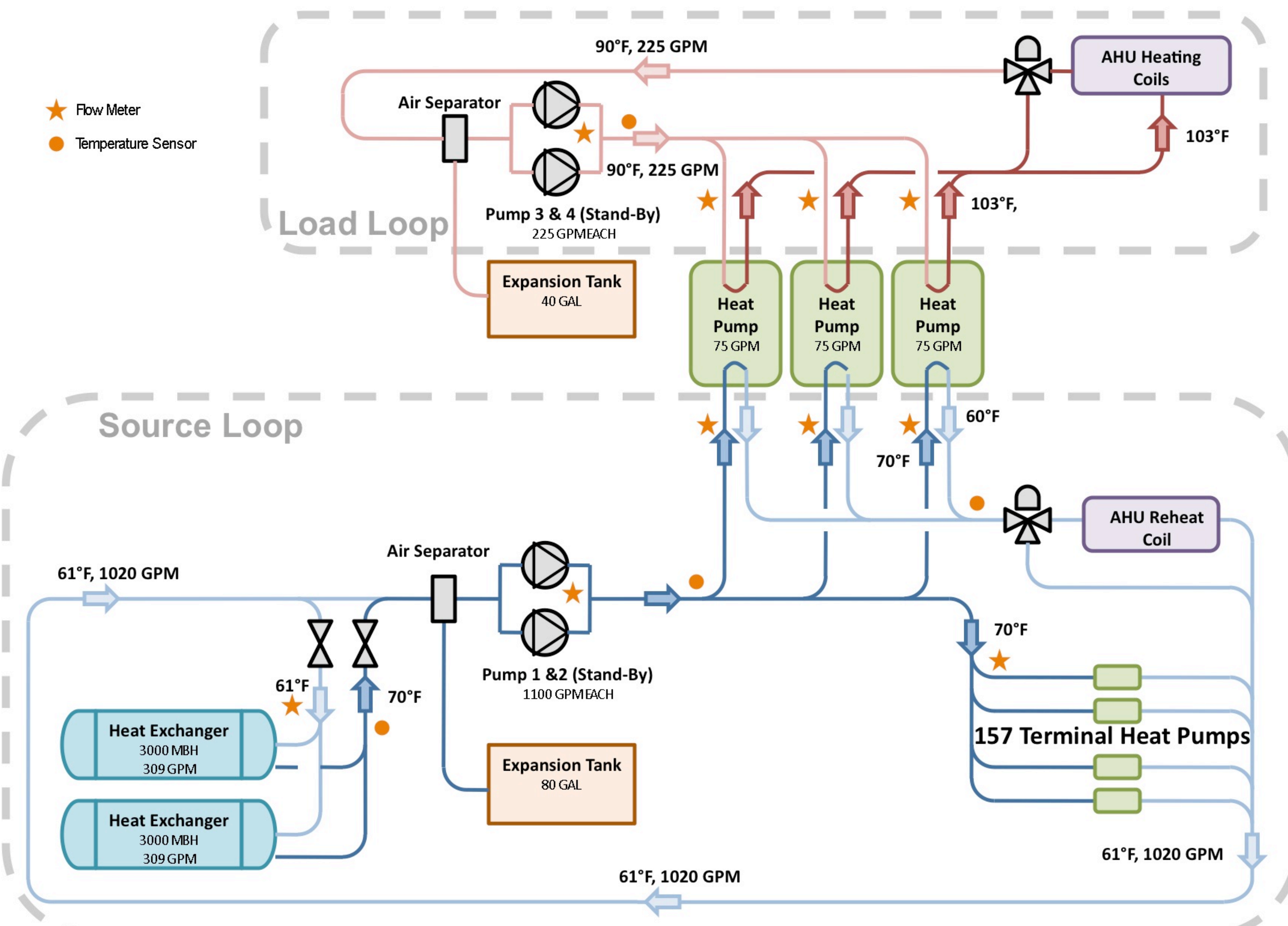

Figure 4 – Heat Pump Heating Flow Diagram.

EXISTING BUILDING LOAD AND COST ANALYSIS

By using Trane Trance 700, a building energy modeling software, the heating and cooling loads were calculated for the HSS River Building. 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 design load compiled from the project's equipment schedules. **Table 5** compares the calculated load from *Techanical Assignment 2 – Building and Plant Energy Analysis Report*and the designed loads from Cannon Design.

Table 5 – Building Heating and Cooling Load Comparison		
	Computed	Designed
Cooling Load	360 ft2/Ton	415 ft2/Ton
Heating Load	423 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

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: $0.20/kWhr
- Steam – All year: $2.08/therm

By using the Con Edison rates, the annual energy cost can be calculated. **Table 6 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 7** shows the total annual energy cost along with the cost per square footage.

Table 6 - Energy Breakdown		
5.5% Heating	147,554 kWh	$86,279
6.8 % Cooling Compressors	174,665 kWh	$106,672
16.1% Fans	870,979 kWh	$252,562
9.4% Pumps	237,145 kWh	$147,459
47% HVAC	**1,430,343 kWh**	**$592,972**
51.7% Receptacle	1,308,240 kWh	$811,024
10.5% Lighting	265,618 kWh	$164,715
53% Non HVAC	**1,573,858 kWh**	**$975,738**

Table 7 – Utility Cost	
Annual Energy Cost	$326,435
Energy Cost Per Square Foot	$3.67

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.

Figure 5 below shows the breakdown of energy usage in for each component of the building.

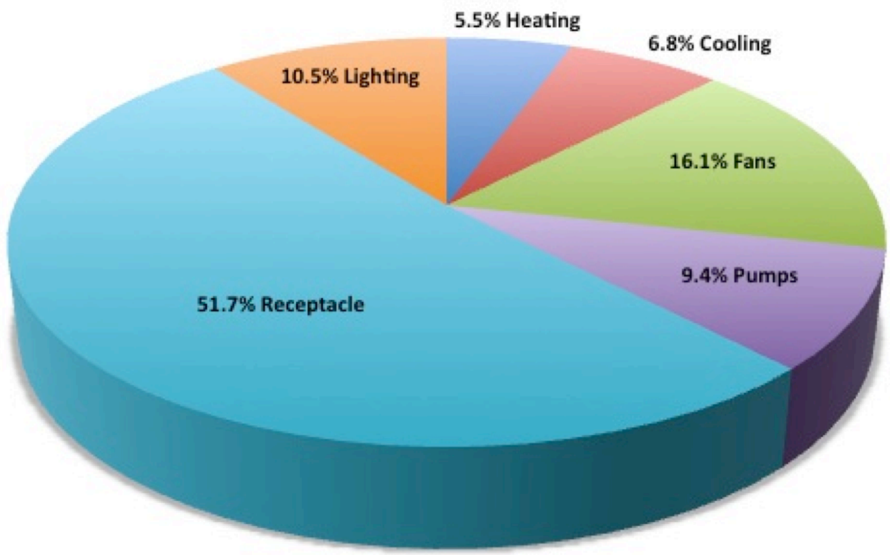

Figure 5. Energy Usage Pie Chart.

The River Building was designed as a Core and Shell project, leaving the floor spaces untouched for the owner to decide what to do. Being so, the mechanical installation did not involve diffusers, balancing and testing, and ductwork leading from the diffuser to the terminal heat pumps. The mechanical equipment and installation cost was a bid package done between the owner and Turner Construction only, making it unavailable to the public. For this report, the estimation came from the 2007 RS Means Mechanical Cost Data book and with the help of Cannon Design HVAC designers through previous jobs with similar mechanical units. Below are the estimated mechanical initial cost and annual maintenance cost:

- Mechanical initial cost: $40/sq. ft.
- Annual mechanical maintenance cost: $14/sq.ft.

The annual mechanical maintenance cost was estimated with the help from Cannon Design HVAC designers to the following breakdown:

- Maintenance for occupied floors, 4 visits a year: $110,000
- Maintenance for mechanical room, 4 visits a year: $20,000
- Cost of repair parts: $20,000

Total annual maintenance cost: $150,000

Figure 6 shows the amount of kWh used per month. As suspected with using a heat pump system, the loads per month are relatively steady and constant. Peaks can be seen during extreme heating and cooling months such as January, December, July and August. While the transitional months of March, September and October also contains relatively higher loads than the other months.

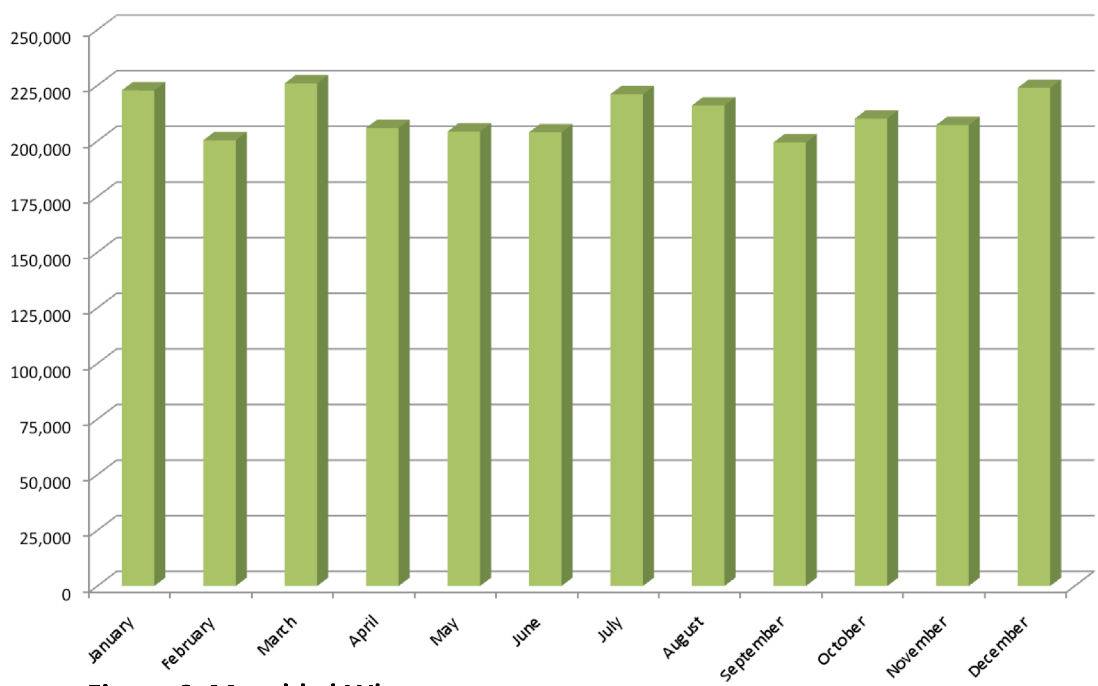

Figure 6. Monthly kWhr usage.

The monthly utility cost as shown in **Figure 7** below presents utility costs for each month for the HSS River Building.

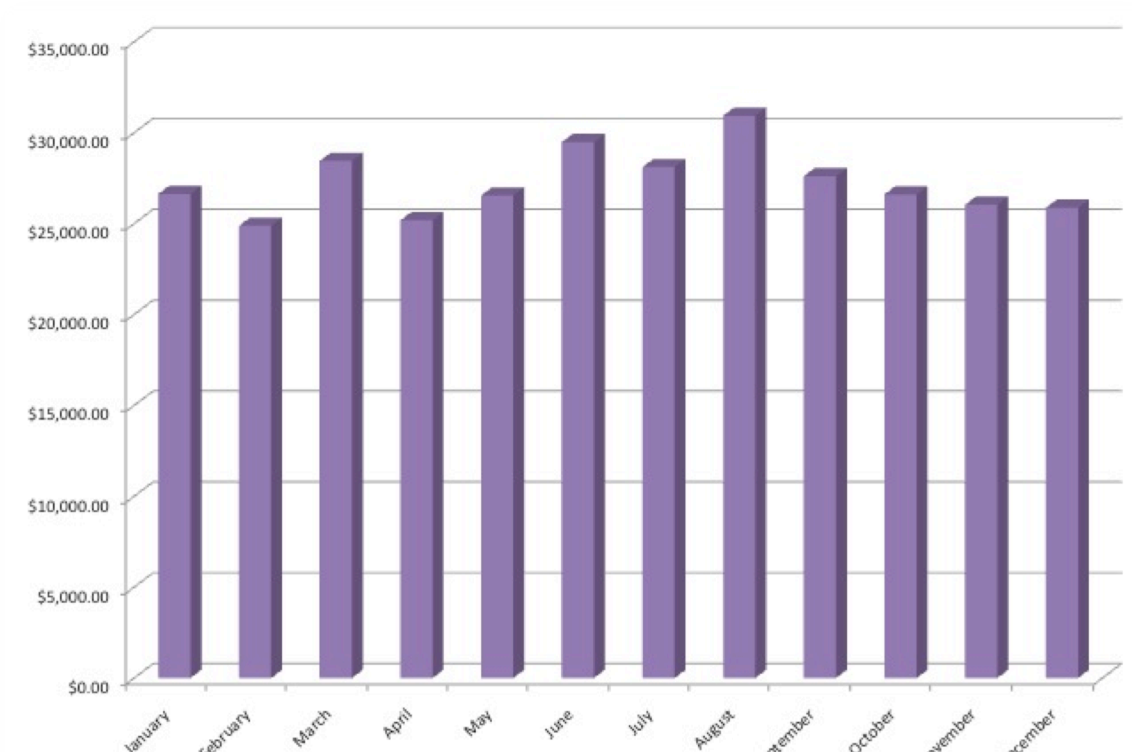

Figure 7. Monthly Utility Cost.

MECHANICAL SYSTEM REDESIGN

The mechanical system for the HSS River Building was designed adequately for its purpose of reducing the spread of contaminates, providing controllability to the user, and reducing energy use. But as with any system, there can be alternative designs for improvement. The following proposal for redesign of the heat rejection and air distribution systems will be studied for the Senior Thesis.

HEAT PUMP SYSTEM REDESIGN

The heat pump system in the HSS River Building provides simultaneous cooling and heating in occupant spaces depending on the needs of the occupant. In order to do so, the heat pump loop maintains a delicate temperature range by rejecting or absorbing heat from a cooling tower and heat exchanger respectively. The current method of heat rejection uses a cooling tower to spray water and to blast air on the loop in order to bring down the temperature. This method requires intense energy use by pumps and fans. As previously calculated, the fan energy is 16% of the total energy used in the building. The River Building is also being built next to the East River, a tidal strait with a semi constant water temperature. This being said, the proposed alternative redesign will take advantage of the site and use the river as a heat rejection source rather than a cooling tower, reducing energy costs and equipment energy.

The system for using natural bodies of constant temperature for heat rejection is common in heat pump systems. Besides rivers, other thermal bodies such as underground soil, lakes, and ponds can be used as a heat rejection and absorption source. This can be achieved as the thermal body acts as a reservoir to supply or absorb the energy coming from the heat pump loop.

SOLAR SHADING DESIGN

The HSS River Building contains over 50% of glass as analyzed in the ASHRAE Standard 90.1-2007 Compliance requirements. This curtain wall system can increase the cooling load of the system dramatically as solar radiation will penetrate through the glass. In order to reduce the amount of solar radiation hitting the glass without dramatically altering the curtain wall façade, solar shades will be installed and calculated for their affects to the internal thermal load of the building.

RIVER HEAT REJECTION DESIGN

EXISTING HEAT REJECTION DESIGN

The HSS River Building existing design provides a cooling tower for the heat pump loop system to reject heat. The cooling tower is located on the roof of the building and 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 8** provides additional details of the Cooling Tower unit**.** The loop water is brought into the cooling tower at 103F and then cooled down to 90F by spraying the loop with water and blowing it with air to increase evaporation rates.

Table 8 - 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
(3) Fans	15 HP each
Spray Pump	7.5 HP

This system of heat rejection is adequate and standard for many buildings in New York. But being that the HSS River Building is located right next to the East River, the cooling tower can be replaced for a more environmentally friendly and energy efficient method of heat rejection.

PROPOSED RIVER HEAT REJECTION DESIGN

The proposed heat rejection system is to allow the heat pump system to rejection its heat by using the relatively constant temperature supplied by the East River through an open loop system with filters and a plate and frame heat exchanger. The East River is actually not a river but a tidal strait, bringing in water from the Atlantic Ocean at the Bronx back into the Atlantic down by the southern tip of Manhattan.

The East River is divided into two sections at Hell Gate as upper and lower portions. The lower section of the channel is where the HSS River Building is located at and is the narrowest and deepest part of the river. The mean depth of the East River is 35 feet but since the topography of the river varies greatly, some sections can be as deep as 99 feet. The mean range of tide at the tip of the river is seven feet while at the midpoint it is 4.5 feet. **Figure 8** shows the map of the East River.

Figure 8. Map of the East River.

Since the East River is actually a tidal strait, it contains salt water from the Atlantic Ocean though some fresh water does mix with the current. The fresh water supply comes from the Harlem River, which creates a salinity mix of 25.2% at Willets Point and 21.4% at the Upper Bay Battery.

The water quality of the East River has increased significantly since the Clean Water Act of 1972. The water now is clearer and contains levels of bacteria that are low enough to sustain fish colonies. This is a result of regulated industrial discharge and improved wastewater treatment plants. Even though the water quality has improved significantly, its sediments from the past still remains at the bottom. The soil below the river contains PCB's, DDT, PAHs, dioxin, and many other heavy metals. These sediments though dormant at the bottom of the river, still enter the food chain of the river as bottom-living animals feed off the soil, which gets eaten by fish of larger sizes in the ecosystem of the river. The temperature of the river varies depending on the season. **Table 9** below shows the average river surface temperature:

Table 9 – Average River Temperature

Month	Temperature (F)
January	36
February	37.5
March	37.3
April	44.5
May	44.5
June	66
July	67.5
August	74.4
September	78
October	71
November	54
December	52

RIVER HEAT REJECTION FLOW DIAGRAM

The proposed river heat rejection system will consist of an open loop system bringing in water from the East river to a plate and frame heat exchanger. The East river water will come in from the inlet mesh screen and be filtered by the centrifugal separators. Then, it will be pumped through the heat exchanger and be discharged back into the river at 15 degrees above its entering temperature. Redundancy will be built into the system to allow the system to run while maintenance is performed. The system will also need a priming vacuum pump in order to allow the water to raise 40 ft above river water levels in order to start driving the pumps. A check valve will be placed in order to not allow backflow to occur during shut down periods. **Figure 9** shows a flow diagram of the system.

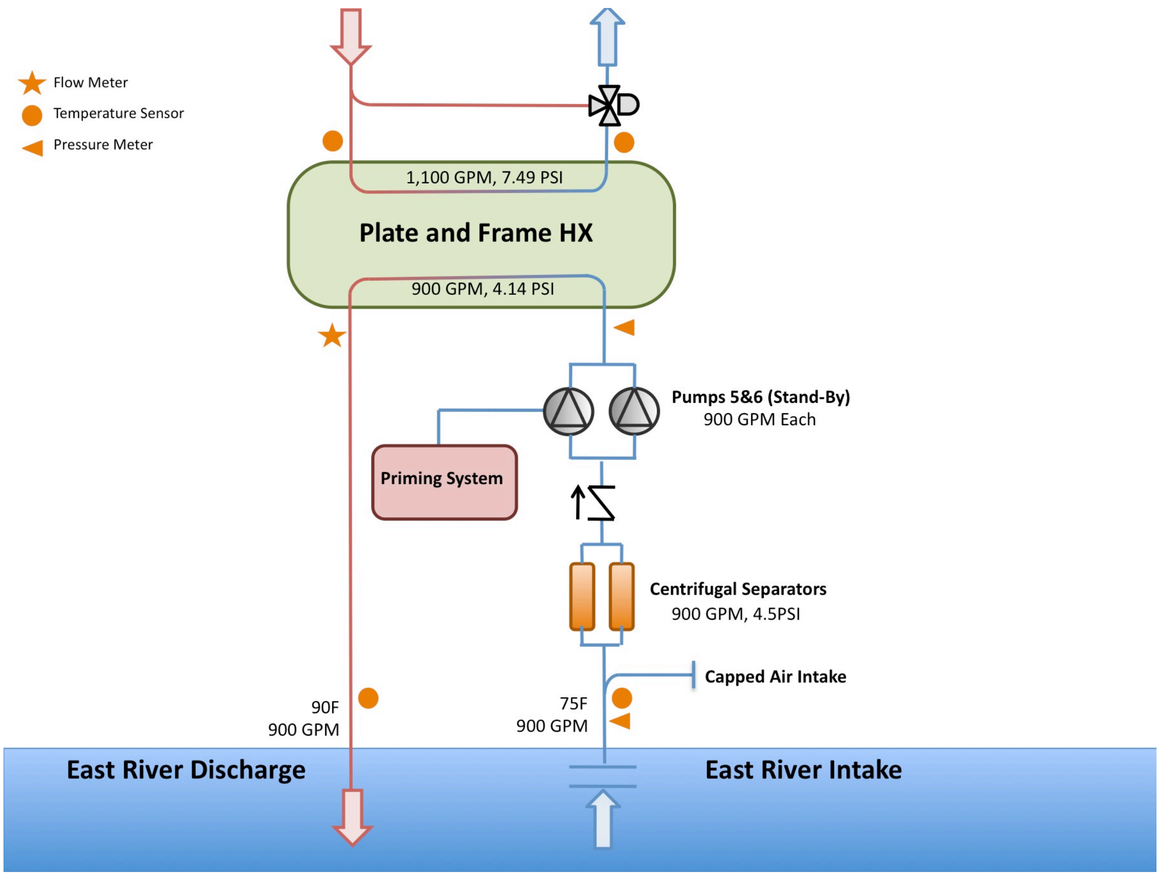

Figure 9. River heat rejection flow diagram.

The system will be placed below the first occupied floor in the building, yet still thirty feet above the FDR Drive. The inlet face will be placed thirty feet below the surface of the river to ensure that it will not be sucking in debris from the top nor the bottom of the river. **Figure 10** shows the elevation diagram.

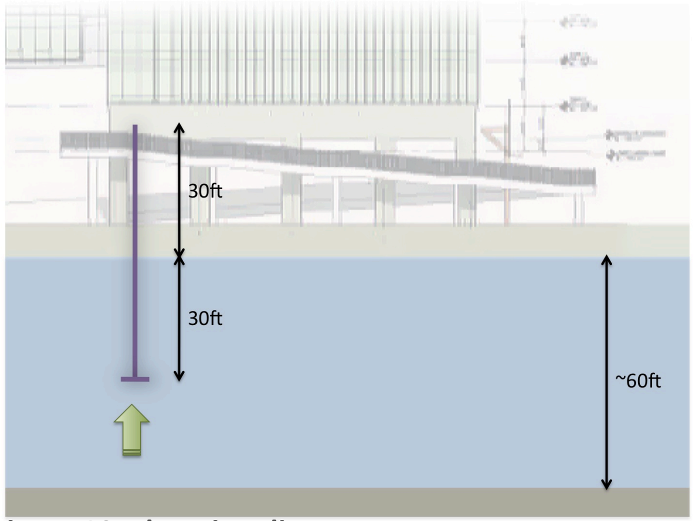

Figure 10. Elevation diagram.

The system provides durability to the harsh waters from the East river. It also provides monitors and simple mechanisms to allow the building engineer to provide simple cleaning aside from the schedule maintenances. The system is also pressurized so that the building heat pump loop has a greater pressure than the river waterside, preventing leakage to enter into the heat pump loop.

CORROSION, MARINE GROWTH AND DEBRIS

In order to design the river heat rejection system: corrosion, marine growth, and debris are three main concerns to address from the beginning. This is because any of those three factors can severely reduce efficiency and even cause the system to fail. To combat corrosion, PVC piping will be used for the system to reduce chemical reactions that metal piping will have with salt water. Also, all the metal equipments will be either of high grades metal such as titanium or 316L stainless steel, or have a specific corrosion resistant coating on them to protect the metal from marine water. Marine growth is also another issue, as the river water will be directly fed into the heat exchangers. To prevent marine growth from occurring, the velocity of the water will need to exceed seven feet per second, though this isn't a magic number to prevent growth, it is high enough so that bio-fouling will not easily occur. Lastly, to prevent debris and fish from the river to enter the system, a number of filtering stages will be put into place. At the inlet, a mesh screen with holes no bigger than ½" preventing big particulates from entering the piping system**. Figure 11** shows an example of the mesh screen used by Clark Nexsen in their river heat rejection project. The second filtration will occur at the centrifugal separators where 98% of all particulates over 75 microns will be separated from the stream. This will basically flush out any particulates big enough to clog the plate and frame heat exchanger and the pump.

Figure 11. Mesh screen intake courtesy of Clark Nexsen.

MAINTENANCE

The proposed river heat rejection system will require a more diligent maintenance than most mechanical systems, as it is an open-loop system, bringing in uncontrolled waters from the river. To provide warnings for clogs and marine growth, sets of pressure meters and flow monitors will be placed before and after the centrifugal separators and pumps to monitor for any pressure build up and flow reduction.

Also, maintenance at the inlet of the pipe in the river will be achieved by simply flushing the system with atmospheric pressure when the pumps are not operating. Adding a capped air vent to the piping will allow atmospheric pressure to push the water back to river levels, dislodging anything stuck on the intake mesh screen. A check valve will be added upstream of the pumps to prevent water to backwash from the pumps and heat exchanger when this maintenance routine occurs.

ENVIRONMENTAL CONSIDERATIONS AND BENEFITS

The heat rejection system has been designed to pay close attention to the environment such as the East River and its ecological system, while also providing a lesser chemical and energy intensive alternative to the cooling tower system. The *Department of Environmental Conservancy of New York* specifies that all thermal discharges shall not:

- Be raised more than four Fahrenheit degrees from October through June nor more than 1.5 Fahrenheit degrees from July through September over that which existed before the addition of heat of artificial origin.
- Be lowered more than four Fahrenheit degrees from October through June nor more than 1.5 Fahrenheit degrees from July through September from that which existed immediately prior to such lowering.

Due to the environmental restrictions, the system is set to release 15F degrees above what the water temperature came in as. This temperature setting will not raise the entire River water surface temperature by 4F or even 1.5F during July through September. This is because the flow of the system is minuscule compared to the river's lowest flow rate of 5 ft/s. Being that the river at that location is 75 ft by 60ft deep, the temperature increase will therefore have little affect at the surface.

Also, by removing the cooling tower, the building eliminates biohazard plumes, chemicals needed for cleaning, and reduces emissions. These eliminations provide a more environmentally friendly method of rejecting the building's heat. In order for the HSS River Building to legally discharge thermally altered water back into the East River, a **SPDES (State Pollutant Discharge Elimination System) NY-2C** form needs to be filed with the *Department of Environmental Conservancy*. The river water rejection system will be filed as a "noncontact cooling water discharge" and can be viewed in **Appendix A**.

METHODOLOGY

Many different types of equipment in the system had to be sized accordingly to the amount of water needed to absorb the heat fully from the building. Such equipments include:

- Plate and Frame Heat Exchangers
- Centrifugal Separators
- Pumps + Priming System
- Pipes
- Controls

PLATE AND FRAME HEAT EXCHANGERS

There are many different types of heat exchangers in the industry, but with the objectives of trying to save space, high efficiency, and less maintenance, the plate and frame heat exchanger was selected as the best choice for the system. The heat exchanger was sized according to the design amount of heat transfer needed for the building to cool down from 103F to 90F. Also, the design only allowed 15F temperature difference for the river water to return back into the river. This allowance was set forth based on the highest river temperature of 75F, allowing the maximum discharge temperature of 90F. **Table 10** displays the information used to size the heat exchanger. **Appendix B** contains manufacturer's cut sheets for this product.

Table 10 – Plate and Frame HX		
	River	HSS
Temperature In	75	103
Temperature Out	90	90
GPM	900	1100
Pressure Loss	4.51 PSI	7.49 PSI
MBTU	6,721	
LMTD	14.15	
Number of Plates	113 at 30mm each	

CENTRIFUGAL SEPARATORS

In order to protect the heat exchanger and pumps from malfunctioning due to clogs and debris, a filter is needed to allow sand and other river water content to separate from the piping flow. This will be done with a centrifugal separator, made out of marine grade 316L stainless steel. The centrifugal separator is able to remove 98% of all particulates over 75 microns, small enough so whatever particulates will pass under 75 microns will not affect the pump nor heat exchanger. There will be two centrifugal separators in the system to allow for streamline maintenance, as one separator can be cleaned out while the other one is running. **Appendix C** contains manufacture's cut sheet for this product.

PIPING

The piping system is designed to withstand marine growth, corrosion and relatively easy maintenance for the building engineers. For the river heat rejection system, an 8"D PVC schedule 80 pipe will be used to provide a sturdy pipe that will not corrode due to the salt water. Also, all fittings will be also made from PVC so that no iron will be present for corrosion to occur. The inlet of the pipe will contain a mesh screen providing a maximum opening of ½" and will be submerged 30 feet below the river surface level. This is to prevent debris floating at the top of the river or debris sinking to the bottom of the river to get caught into the system. The pipe will be brought up along side of a column rising to the HSS River Building from the FDR Drive into the first level of the building, which is not occupied. **Table 11** shows the calculation for pressure drop using the equivalent length method.

Table 11 - PVC Piping Schedule 80 – 8"D			
	Friction Loss	0.07 ft/100ft	
	Equivalent Feet	**Amount**	**Total Feet**
45o Elbow	10.6	10	106
Tee Flow - Run	16.5	2	33
Straight	1	200	200
P+F HX (4.14 PSI)			17
Centrifugal Separators (5 PSI)			11.5
Height			40
Total			**68.74**

PUMPS

After all the equipment has been sized accordingly with all pressure drops measured, the pumps can now be sized to handle the pressure loss of the whole system. The pumps will be located in the mechanical room, 40 feet above the surface of the river. This will require a priming system to bring the water up to the pump station's level in the new mechanical room on the first floor. The pumping station will be coupled with a vacuum pump priming system that will bring the water up 40 ft from the river level to allow the pumps to start pumping water and not air. In order to allow maintenance to occur without shutting down the system, two pumps will be used in the system so that one can be taken down for repairs while the other will be running. **Table 12** shows the information needed to specify the pump. **Appendix D** contains the manufacturer Bell and Gossett cut sheets for this product.

Table 12 – Bell & Gossett 25HP Pump	
Atmospheric Pressure	33.908 ft
Water Pressure	25 ft
Static Vapor Pressure	0.992 ft
Height from inlet to pump	40 ft
Friction loss of pipe	0.51 ft
NPSHA	17.406 ft
Total System Head loss	68.74 ft

CONTROLS

Along with the sized equipments needed for the system to work properly, the controls of the system also needs to be set up to allow the system to maintain pressure, set point cooling temperatures, and provide feedback for clogs and debris. Pressure sensors will be placed at the inlet of the centrifugal separators and also at the end of the pumps to allow monitoring for pressure build-up due to debris. Also, the control valve on the heat pump loop will control the amount of flow going through the heat exchangers depending on the cooling load needed, the same control that the existing system has controlling the cooling tower.

ENERGY ANALYSIS

By designing a system to allow the HSS River Building to reject heat into the East River, the building's cooling tower and its associated chemicals and pumps and fans energy will be replaced. The energy analysis will compare the building using the cooling tower and the building using the river to reject heat. With Trane Trace, the energy use from the existing cooling tower was simulated to be 27% of the overall building energy load. This energy includes the (3) 15HP fans, (2) motors at 30HP and 15HP, and (1) 7.5HP spray pump. **Table 13** shows the energy usage breakdown.

Table 13 – Energy Breakdown	
Cooling Tower	293,850 kWhr/year
River Rejection	74,442 kWhr/year
Savings	**219,408 kWhr/year**

Be replacing all of the cooling tower components with a simple 25HP water pump to reject water, the building will be saving 133,000 kWhr a year. This calculation assumed that the cooling tower and pump would be operating for 3,900 hours a year. A detailed month-by-month analysis of energy use can be seen in the **Appendix E**.

COST ANALYSIS

Consolidated Edison (Con Ed), supplies the HSS River Building with a flat rate for electricity of $0.20/kWhr. With a savings of 219,408 kWhrs a year, the building saves $43,881 a year. This energy saving also reduces the heat rejection component down to just 6% of the total building energy use.

Even though the new system saves the building a lot of energy, the first cost of the new system is greater than the first cost of the cooling tower. The new river rejection system will cost an estimated $150,210, and the existing cooling tower system is estimated at $66,621. The difference in initial cost is an additional $83,589. **Table 14** breaks down the cost of the new design and the existing cooling tower and its associated costs.

Table 14 – Equipment Cost Breakdown			
Unit	Quantity	Price/Ea	Total
Heat Exchanger			
Titanium Plate and Frame	1	$64,000.00	$64,000.00
Centrifugal Separator			
900 GPM	2	$20,000.00	$40,000.00
Pump			
25 HP	2	$3,000.00	$6,000.00
Piping			
PVC 80 - 8"D (&/lf)	160	$150.00	$24,000.00
Copper - 2" & Under ($/lf)	50	$76.01	$3,800.50
Insulation ($/lf)	50	$8.20	$410.00
Misc Equipment			
Priming System	1	$2,000.00	$2,000.00
Vibration Isolation	1	$2,000.00	$2,000.00
Labor			
Q-6 ($/laborhour)	100	$80.00	$8,000.00
		New System Total	**$150,210.50**

Cooling Tower				
	375 Tons	1	$50,000.00	$50,000.00
Piping				
	2" & Under ($/lf)	100	$76.01	$7,601.00
	Insulation ($/lf)	100	$8.20	$820.00
Labor				
	Q-6 ($/laborhour)	40	$80.00	$3,200.00
	Rigging	1	$5,000	$5,000
			Existing System Total	**$66,621.00**
			Total Difference	**$83,589.50**

Having an initial first cost difference of $83,589 and a savings in energy cost of $43,881. The new design for a river heat rejection system will have a simple payback period of just 1.9 years, equaling one year and 11 months.

CONCLUSION

With a payback period of a little under just two years, a chemical and emissions free method of heat rejection, and yearly energy savings of $43,881; the new river rejection design should be implemented as part of the mechanical system. By utilizing the great location of the hospital next to the East River, the building is able to use to river to its potential and cool down the building with it, while also not disturbing the rivers ecological system.

SOLAR SHADING SYSTEM DESIGN

The River Building contains a curtain wall system with over 50% glass. The building's east, north, and south façade are all glass with two different tints ordered to create a checkered pattern. The glass U-values and solar shading coefficients can be found in the *ASHRAE Standard 90.1 Compliance Requirements* section. With over 50% glass coverage, the HSS River Building has no system to shade the windows, reducing the solar heat gain passing through the windows.

This proposal will evaluate the internal heat load reduction by using solar shades on the southern and eastern façades. It will also look at solar shade placements in order to gain maximum energy savings and shadings.

METHODOLOGY

To evaluate solar shade placements and overhang lengths, the location of the HSS River Building needs to be shown in latitude and longitude.

- Latitude: 40'47"
- Longitude: 73'58"

Also, the location of the sun on any given day is also important. By finding the altitude and azimuth angle of the sun position in New York, the HSS River building can know exactly where the sun will be at the given time. The number of clear days given in a month describes the average amount of days that contains clear skies. **Table 15** shows the altitude and azimuth of the sun at noon on the 15th of every month along with the clear days of each month.

Table 15 – Monthly Altitude and Azimuth

Month	Altitude	Azimuth	Clear Days
Jan	28.1	178.7	8
Feb	36.5	177	8
Mar	47.5	178.4	8
Apr	59.3	182.1	8
May	68.3	185.1	7
Jun	72.6	182.8	8
Jul	70.7	178.8	7
Aug	63.1	180	8
Sep	51.9	183.8	10
Oct	40.3	186.1	11
Nov	30.4	185.4	7
Dec	26	182.3	8

Table 15 shows all the azimuth angles at the peak of the day is roughly around 180 degrees, meaning the sun is on the south face of the building at noon at all months.

The shaded area on the southern and western façade can be calculated with the altitude given. **Figure 12** shows the mathematical relationship with the overhang length, shaded length, and altitude.

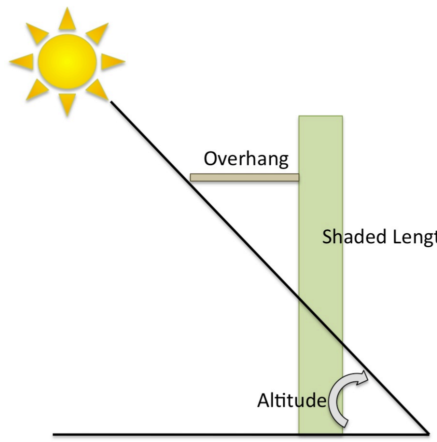

Figure 12. Sun angles with overhang.

The shaded length on the window can be calculated for each month given the geometric relationship of the sun angle and overhang length. To evaluate which overhang length shades the most, an excel sheet was created with an option of three feet, four feet, and five feet overhangs. **Table 16** shows the shaded length at noon for the 15th of each month.

Table 16 – Monthly Shaded Length – South			
	Overhead Length		
	3 feet	4 feet	5 feet
Jan	1.60	2.14	2.67
Feb	2.22	2.96	3.70
Mar	3.27	4.37	5.46
Apr	5.05	6.74	8.42
May	7.54	10.05	12.56
Jun	9.57	12.76	15.96
Jul	8.57	11.42	14.28
Aug	5.91	7.88	9.86
Sep	3.83	5.10	6.38
Oct	2.54	3.39	4.24
Nov	1.76	2.35	2.93
Dec	1.46	1.95	2.44
Average	**4.44**	**5.93**	**7.41**

The equation to find the solar heat gain is given below:

$Solar\ Heat\ Gain(BTU/Hr) = (1-R)(A)(SHGF)$, where

R = shaded area/window area

A= total window area

SHGF= Solar heat gain factor = 64 BTU/Ft^2 for southern exposure

Table 17 shows the amount of solar energy coming through each month by multiplying the solar heat gain by the number of clear days. This case was analyzed for shades at the lengths of three feet, four feet, and five feet. Lastly, a percentage was taken of the difference in BTU savings with the difference in length with no solar shades.

Table 17 – Solar Gain (BTUs) For Each Month				
	3ft Overhang	4ft Overhang	5ft Overhang	No Solar Shade
Jan	40,248,324	38,181,552	36,114,780	46,448,640
Feb	37,856,094	34,991,911	32,127,729	46,448,640
Mar	33,776,191	29,552,041	25,327,892	46,448,640
Apr	26,891,534	20,372,498	13,853,463	46,448,640
May	15,109,999	6,599,146	1,911,708	40,642,560
Jun	9,394,192	2,957,290	15,308,773	46,448,640
Jul	11,628,327	1,956,916	7,714,496	40,642,560
Aug	23,559,822	15,930,216	8,300,610	46,448,640
Sep	39,548,879	33,378,239	27,207,599	58,060,800
Oct	50,326,117	45,812,529	41,298,941	63,866,880
Nov	34,681,348	32,694,277	30,707,207	40,642,560
Dec	40,785,011	38,897,135	37,009,259	46,448,640
Total	**363,805,838**	**301,323,751**	**276,882,456**	**568,995,840**
Percent/Length	**21.31%**	**13.24%**	**9.73%**	

The calculations show that by adding a three feet overhang, the HSS River Building can see a 21% reduction in solar energy per length added. As more length is added to the overhang, the solar energy savings is reduced.

ENERGY ANALYSIS

The calculations demonstrated that by providing a solar shade of three feet, the HSS River building is able to decrease solar energy gain by 21% per length, which is better than the 13% and 10% reduction done by adding a four and five feet overhang respectively. In order to maximize energy savings and minimize cost, the three feet overhang will be used to model our building with external solar shades. By modeling the solar shades in Trane Trace, the HSS River Building saves 189,750 kWh a year in energy. **Table 18** shows the energy breakdown and savings yearly. **Appendix F** shows detail breakdown of energy savings for all system components.

Table 18 – Yearly Energy Breakdown		
	Cooling	Total kWhr
No Solar Shades	245 Tons	3,148,800
Solar Shades – 3ft	225 Tons	3,035,346
Savings	**20 Tons**	**189,750**

The solar shade system will provide enough shading to the building to reduce the cooling load by 20 tons and save as much as 189,750 kWhr a year.

COST ANALYSIS

The cost analysis will analyze the payback for installing and purchasing such a system for the HSS River Building. The solar shades that were selected for this project are made by Construction Specialties, located in Cranford, New Jersey. CS specializes in architectural grilles and solar shades for curtain wall systems. A quote from a CS representative states that:

- Solar Shades: $50/sqft
- Solar Shades weight: 7lb/sqft
- Installation cost: 15% material

The solar shade system being installed on the HSS River Building will have:

- 3 ft – Overhang
- 1,100 linear feet of solar shades

Table 19 provides the break down of the initial cost of the solar shade system and also the cost of removing a 20-ton Heat Pump from the system. This will assume that the reduction in 20 Tons will remove equipments and piping equivalent to a 20-ton Heat Pump.

Table 19 – Solar Shade System Cost Breakdown

	Qty	Price/Ea.	Total
Solar Shades			
6" Airfoils ($/sq.ft.)	3,300	$50	$165,000
Installation			
Labor & Parts (15% Material)	495	$50	$24,750
SOLAR SHADE SYSTEM TOTAL			**$189,750**
Heat Pump			
20 Tons	1	$18,800	$18,800
Installation & Piping			
30% of Total Cost	.3	$18,800	$5,640.0
DIFFERENCE TOTAL			**$165,310**

The solar shade system will have an initial cost of $189,750 but by reducing the cooling load by 20 tons, the analysis assumes that the 20-ton reduction will be the removal of 20-ton heat pump equipment, therefore subtracting that cost from the initial cost to get the difference initial cost of $165,310.

CONCLUSION

In conclusion, the solar shade system will provide amble shading for the curtain wall glass façade of the River Building. By reducing the amount of solar gain from increasing the internal loads, the solar shade system saves 20 tons in cooling load while also saving 189,750 kWhr in energy use a year. Besides from saving energy, the solar shades provide less glare from entering each office along the perimeter of the building, improving work productivity. Also, with a simple payback of 4.3 years, equaling four years and four months, the solar shades are a great system to provide energy and heat reduction while promoting better lighting and productivity.

ARCHITECTURAL BREADTH

The solar shades will add a dramatic impact to the buildings exterior walls. The architectural breadth will study the impact of the solar shades as well as study the optimum placement of solar shades on the building.

METHODOLOGY

The HSS River Building will be built with one side connected to the existing Caspary Building and 30 feet across from the existing Hospital for Special Surgery. With such a tight fit, the building will only require solar shades on the western exposure and minimally on the southern exposure due to its proximity to the hospital. In order to know where the sun will hit the building, sun locations from the azimuth and altitude tables were used. The maximum and minimum height location of the sun will be during June and December respectively. **Figure 13** shows the locations and sunlight spreads during those extremes at noon.

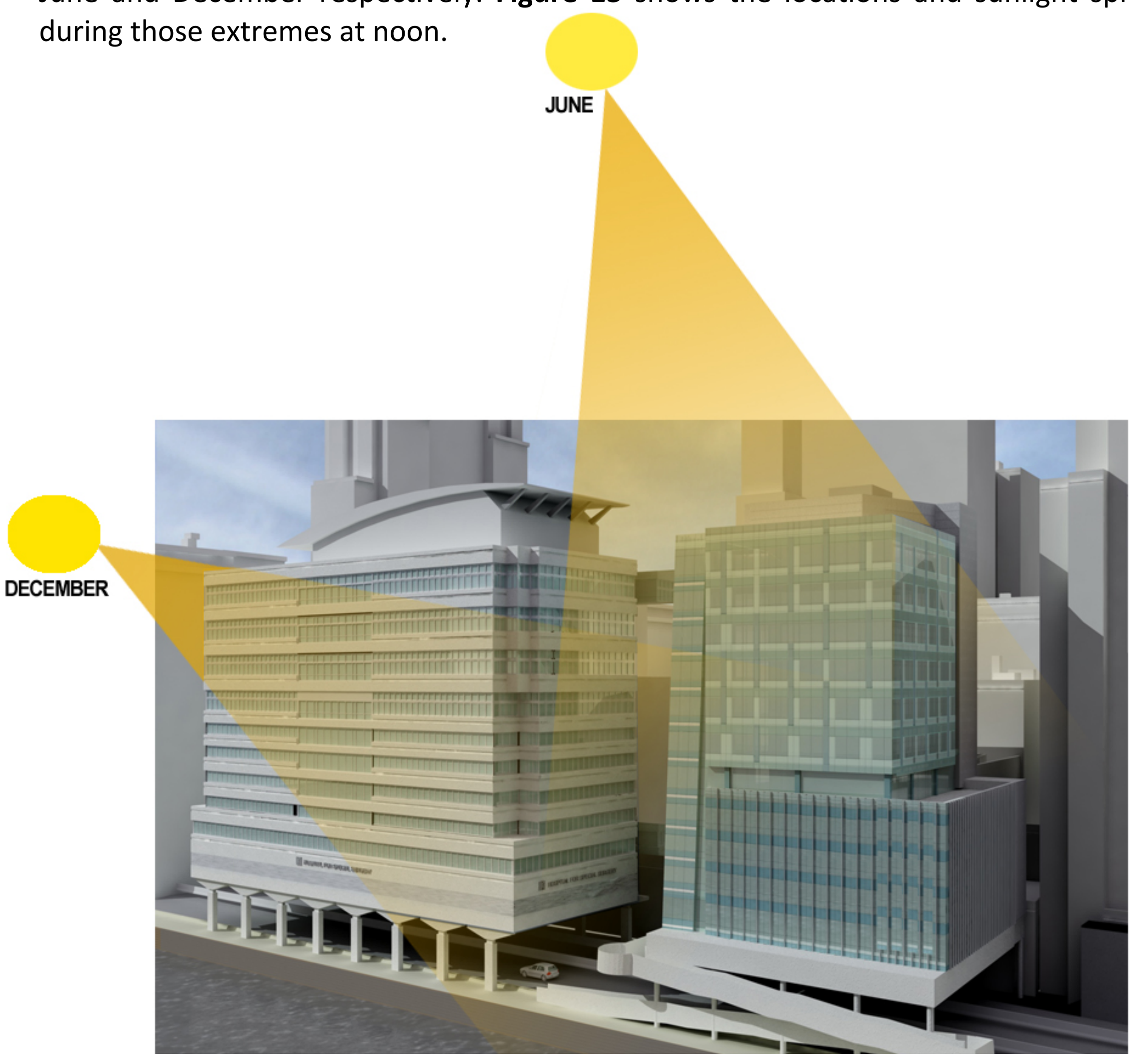

Figure 13. Sun Locations for June and December.

The solar shades will project three feet out, and have a total linear footage of 1,100 feet. The whole western exposure will contain solar shades while only the upper five floors of the southern exposure will have them. This is because the southern exposure will only be exposed to strong sun lighting during the summer months with the sun directly above. The southern exposure will never have direct sun lighting due to its proximity to the Hospital for Special Surgery next door, therefore, eliminating the need for solar shades below a certain height down from the top.

The renderings to show the solar shades were done by Adobe Photoshop. Cannon Design developed the actual renderings through Autodesk Viz for the building and background, while for this thesis; Photoshop was used to create the visual aspects of the shades and shadows.

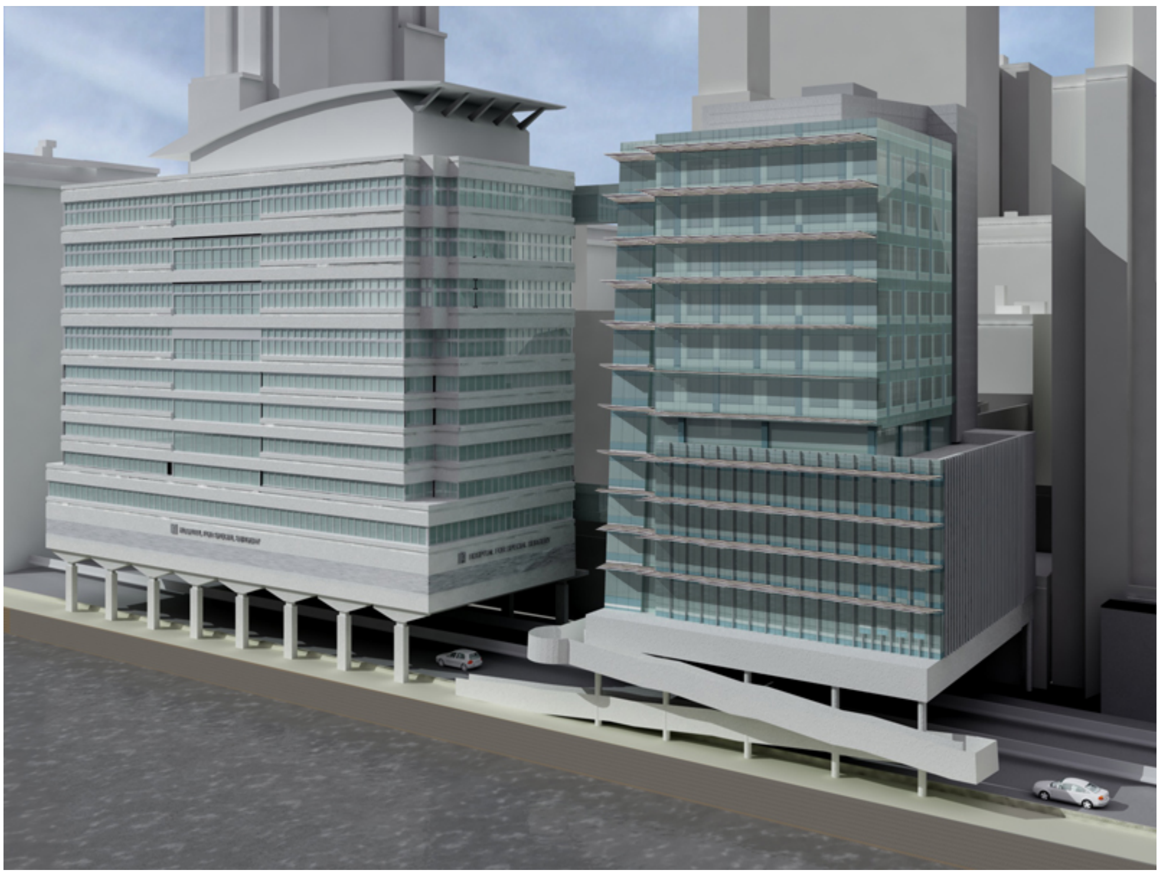

Figure 14. Western exposure solar shading system.

Figure 15. Southern exposure with solar shading system.

Figure 16. Southern exposure looking west to East River.

CONCLUSION

Not only does the solar shading system provide substantial cooling load savings and energy savings, the solar shades also adds a strong visual aspect to the building. The idea of adding solar shades to places where it only needs it provides the people on the street with a visually "smart" solar shading design. It also promotes visually the idea of sustainability and being attentive to the surrounding environment, which many buildings in New York lacks.

STRUCTURAL BREADTH

The new river rejection system to be installed on the unoccupied first floor will contain new equipments and add tremendous new weight to the floor slab. The structural breadth will study and analyze the impact of the equipments on the beam and girder of the first floor.

METHODOLOGY

The first step in analyzing if the floor members can withhold the new mechanical system weight is to compile the square footage area of the required new system and also its weight. **Table 22** shows a breakdown of the weight and amount of space needed for each mechanical equipment. Extra space was given under "Misc Loads" for maintenance paths and walkways.

Table 20 – Mechanical Equipment Weight and Area

	Qty	Lbs/Each	Total Lbs	Area (ft^2)
Heat Exchanger	1	3,582	3,582	12
Pumps	2	660	1,320	24
Centrifugal Separators	2	722	1,444	6
Normal Weight Concrete Pad (lbs/ft^3)	16	150	2,400	0
45ft - 8"D Piping with water (lbs/ft^3)	15.7	62	973	30
Priming System - Vacuum pump	1	900	900	12
Misc Loads (5% Total)	0.05	10,619	531	120
		Total	**11,150**	**204**

To figure out how to load will affect the floor members; the location of the mechanical system needs to be laid out in order to determine which members will be affected. Figure 16 shows the sizes of beams and girders in question and also the space where the mechanical equipments will be placed.

Figure 17. First floor structural plan.

BEAM ANALYSIS

The dead load and the live load of the total area need to be added together to get the distributive load on the W14x90 beam. This is calculated by using the equation:

$$(1.2)(DeadLoad) + (1.6)(LiveLoad) = TotalLoad$$

Table 21 shows the breakdown of how the total load was computed.

Table 21 - Dead and Live Loads			
Dead Load	PSF	Live Load	PSF
2.5" LW Concrete MEP Metal Deck	23.95 5 2	River Rejection System	161.9
Total	**30.95**	**Total**	**161.9**

1.2D+1.6L= 296.18

The total load is calculated to be 296.18PSF. This load needs to be multiplied by the tributary length and divided by 1000 to get kips/linear foot. The load is 7.4 KLF. The next step is to find the ultimate moment of the beam; this will help size the beam that is able to bear the moment the equipments will be applying.

$$Mu = \frac{Wl^2}{8} = \frac{(7.4)(25)^2}{8} = 578kip - ft$$

Using the *AISC Steel Construction Manual*, and using M_n=578 kip-ft and an un-braced length of 25ft, the beam was sized as a W18x130, with an I_x=1,750 in^4.

The next step is to check if this beam is under the depth of the W18x808 girder while also not exceeding the maximum defection. The depth of the W18x808 can be looked up in the dimensions section of the steel manual. The depth for the W18x808 is at 23inches. This means that the new beam W18x130 cannot exceed this depth. The depth of the W18x130 is 18.6inches, which does not exceed the girder and will work.

The last step is to analyze that the actual deflection does not exceed the maximum deflection limit. The equation for this is:

$$\frac{L}{360} > \frac{5Wl^4}{384IE}$$,where

L=25ft, W=7.4Kips/Linear Foot
I= 1750in^4, E= 29,000 KSI

$$.83 > 7.4E^{-4}$$

GIRDER ANALYSIS

The girder is sized at W18x808 and spans 90 feet across the building. The girder also carries the point loads from the beams on the first floor as well as the column loads from the twelve stories above. With such an enormous amount of load being put on the W18x808 girder already, the additional 10kips of mechanical equipment load is minuscule compared to the overall load.

CONCLUSION

In conclusion, the W14x90 will not be able to support the new mechanical system being placed on the unoccupied first floor of the building. Through checking the ultimate moment and the maximum deflection of the new load, a W18x30 is the best option to support the new load. Also, since the new load will affect the girder, an analysis was done to determine whether or not the W14x808 girder could stand up to the newly added 10kips. Being that the girder is already sized to handle the load of the beams of the first floor and also all of the twelve floors above, the 10 kip will not affect much of the girder.

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APPENDIX A – NY-2C FORM

The entire document contains 36 pages of documentation for mostly chemical and pollutant discharge. This appendix will only highlight the important parts of the document highlighting thermal discharge questionnaires.

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Form NY-2C (12/98) - Section II Forms | Page 1

State Pollutant Discharge Elimination System (SPDES)
INDUSTRIAL APPLICATION FORM NY-2C
For New Permits and Permit Modifications to Discharge Industrial Wastewater and Storm Water
Section II - Outfall Information
Please type or print the requested information.

Facility Name:	SPDES Number:

1. Outfall Number and Location

Outfall No.:		
Latitude 40 ° 47 ' "	Longitude 73 ° 58 ' "	Receiving Water East River

2. Type of Discharge and Discharge Rate (List all information applicable to this outfall)

	Volume/Flow	Units MGD	Units GPM	Units Other (specify)		Volume/Flow	Units MGD	Units GPM	Units Other (specify)
a. Process Wastewater					f. Noncontact Cooling Water	900		X	
b. Process Wastewater					g. Remediation System Discharge				
c. Process Wastewater					h. Boiler Blowdown				
d. Process Wastewater					i. Storm Water				
e. Contact Cooling Water					j. Sanitary Wastewater				

4. Expected or Proposed Discharge Flow Rates for this outfall:

a. Total Annual Discharge	b. Daily Minimum Flow	c. Daily Average Flow	d. Daily Maximum Flow	e. Maximum Design flow rate
438 MG	.5 MGD	1.2 MGD	1.2 MGD	1.2 MGD

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Section II - Outfall Information

Facility Name: HSS River Building	**Outfall No.:** SPDES Number:

8. Thermal Discharge Criteria
Is your facility one of the applicable types of facilities listed in the instructions, and does the temperature of this discharge exceed the receiving water temperature by greater than three (3) degrees Fahrenheit?

[X] **YES -** Complete the following table.
[ ] **NO** - Go to Item 9. below.
[ ] **Information on the intake and discharge configuration of this outfall is attached.**

Discharge Temperature, deg. F: Average change in temperature (delta T)	Maximum change in temperature (delta T)	Maximum temperature	Duration of maximum discharge temperature: hours per day	days per year	Dates of maximum discharge temperature: From	To	Maximum flow rate MGD	Discharge configuration (e.g. subsurface, surface, effluent diffuser, diffusion well, etc.)
15	15	90	15	200	Jun	Aug	1.2	Subsurface, 30 feet below river surface

9. **Are any water treament chemicals or additives that are used by your facility subsequently discharged through this outfall?**

[ ] **YES -** Complete the following table and complete pages 1 of 3 and 2 of 3 of Form WTCFX for each water treatment chemical listed.
[X] **NO** - Go to Item 10. below.

APPENDIX B – PLATE AND FRAME HEAT EXCHANGERS

API Heat Transfer

Plate Heat Exchanger

CUSTOMER	: Penn State	QUOTATION NO. :	
REFERENCE	:	DATE :	25-Mar-2008
PROJECT	:		
SERVICE OF UNIT	:		
MODEL	: S66-1500-113		
SURFACE PER UNIT	: 798.12 ft²	NO. OF UNITS:	CONNECTED IN : Single

PERFORMANCE OF UNIT

		COLD SIDE		HOT SIDE	
FLUID CIRCULATED		water		ethylen glycol 35%	
TOTAL FLUID ENTERING		900.0 gpm		1,100.0 gpm	
		448,910.2 lb/h		578,703.7 lb/h	
FLUID TYPE		Liquid	Gas	Liquid	Gas
DENSITY	lb/ft³	63.18	0.0	66.64	0.0
SPECIFIC HEAT	Btu/lb·°F	0.999	0.0	0.875	0.0
THERMAL CONDUCTIVITY	Btu/h·ft·°F	0.354	0.0	0.266	0.0
DYNAMIC VISCOSITY	cP	0.836	0.0	1.863	0.0
LATENT HEAT	Btu/lb				
TEMPERATURE IN / SAT.	°F	**75.0**	→	**103.0**	→
TEMPERATURE OUT	°F	→	**89.67**	→	**90.0**
OPERATING PRESSURE	PSI	150.0		150.0	
NO. OF PASSES / PLATE ARR.		1 / 1 x 8 H . 48 W		1 / 1 x 56 W	
PRESSURE DROP		4.14 PSI		7.49 PSI	
EXCESS SURFACE / FOULING	% / ft²·hr·°F/Btu	2.00 / 0.0000			
HEAT EXCHANGED	Btu/h	6,583,954.0			
LMTD	°F	14.15			

CONSTRUCTION OF SINGLE UNIT

DESIGN PRESSURE	PSI	150.0	
TEST PRESSURE	PSI	195.0	
OPERATING TEMPERATURE	°F	210.0	
PLATE MATERIAL	titanium	GASKET MATERIAL:	NBR
NO. OF PLATES	113	GASKET TYPE:	mechanically Fixed
PLATE THICKNESS (mm)	0.60	TIE RODS:	Zinc Plated
FRAME MATERIAL:	Carbon Steel	SHROUD:	Aluminum

CONNECTIONS

COLD SIDE	pos.	type	HOT SIDE	pos.	type
in	A	6" - 150# Studded Titanium	in	C	6" - 150# Studded Titanium
out	B	6" - 150# Studded Titanium	out	D	6" - 150# Studded Titanium

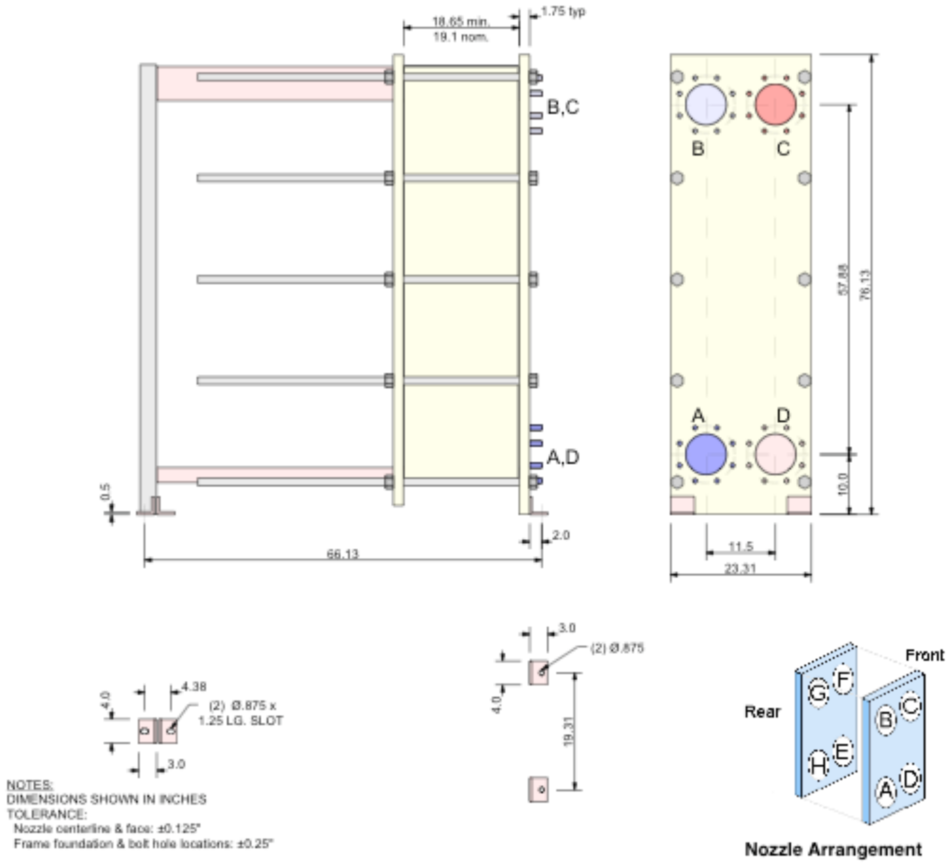
weight (lb):
empty / flooded (H20) / operating 2,984 | 3,559 | 3,582

FLOODED VOLUME (gal) 34.465 / 34.465

CODE REQUIREMENTS:

NOTES:

Version: APIREP 24.0.11 - A



Connections

Fluid	Port	Size	Type	Material
Hot (in)	C	6	150# Studded	Titanium
Hot (out)	D	6	150# Studded	Titanium
Cold (in)	A	6	150# Studded	Titanium
Cold (out)	B	6	150# Studded	Titanium

Design Conditions

	Hot	Cold
Design Pres. (PSIG)	150	150
Test Pres. (PSIG)	195	195
Design Temp. (F)	210	210
Min. Temp. (F)	32	32
Weight Dry/Filled (lb)	2984	3559

Construction

Frame Size	1500
Plate Arr't	1 x 8 H . 48 W 1 x 56 W
No. of Plates	113
Plate Mtl.	titanium / 0.6 mm
Max No. of Plates	147
Gasket Mtl.	NBR - Clip

API Heat Transfer

Job No.			
Part No.	S66-1500-113 Rev.		
Made	Mar 25, 2008	By	Inside Sales
Check	Mar 25, 2008	By	Inside Sales

Version: APIREP 24.0.11

APPENDIX C – CENTRIFUGAL SEPARATORS

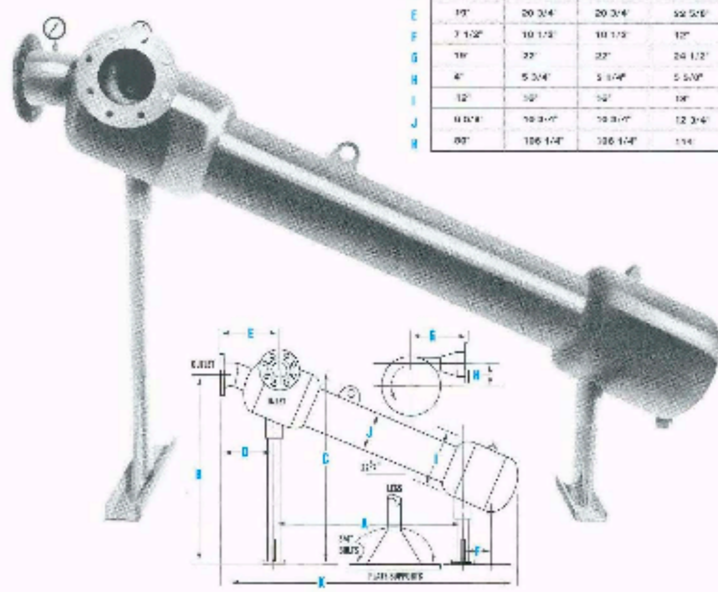
Ag And Industrial Separators

Capacity: 200 to 6200 GPM.
Pressure Rating: 150 lb. standard for long life. For higher ratings, contact factory.
Flow into Separator: Standard counter-clockwise facing outlet. Clockwise rotation is available.
Sand Removal Efficiency: 98% of solids down to 200 mesh.
Pressure Drop: See curves for proper size.
Automatic Purge System: Available at low cost.
Strong: 1/4" carbon steel construction.

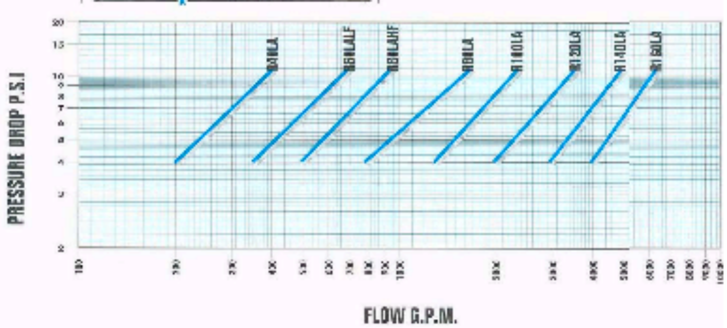
Model	GPM	Flow M3/Hr	Size	Shipping Length	(Lbs.)
R40LA	200-400	[illegible]	4"	87"	200
R60LA LF	365-700	84-161	6"	115 1/2"	403
R60LA HF	500-950	115-219	6"	115 1/2"	453
R80LA	800-1600	182-365	8"	124 3/4"	722
R100LA	1300-2000	[illegible]	10"	138"	940
R120LA	2025-3400	465-782	12"	150"	1400
R140LA	2875-5000	[illegible]	14"	187"	[illegible]
R160LA	4000-6200	920-1426	16"	192"	[illegible]

Dimensions

Inlet Outlet	4"	LF6"	HF6"	8"	10"	12"
A	49 1/2"	63"	63"	71"	78"	102"
B	46 1/2"	85 1/2"	85 1/2"	65"	71"	75 1/4"
C	46 1/2"	60 3/8"	[illegible]	68"	72 3/4"	76 1/2"
D	16"	20 1/2"	20 1/2"	21 3/4"	21"	23 3/4"
E	19"	20 3/4"	20 3/4"	22 5/8"	24 1/2"	26 5/8"
F	7 1/2"	10 1/2"	10 1/2"	12"	13"	14 1/4"
G	18"	22"	22"	24 1/2"	29"	32"
H	4"	5 3/4"	5 1/4"	5 5/8"	7"	8 1/2"
I	12"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
J	8 5/8"	10 3/4"	10 3/4"	12 3/4"	16"	18"
K	80"	106 1/4"	106 1/4"	114"	129 1/2"	139"



Flow and Pressure Drop Chart



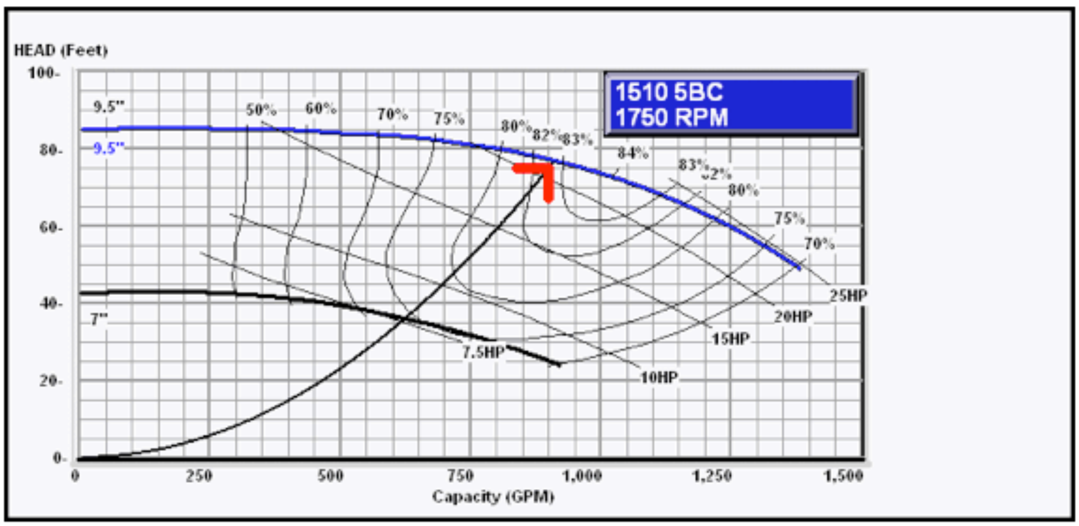
Valve and Filter Corporation • 5270 Marshall Street, Arvada, Colorado • (800) 759-6554 • www.valveandfilter.com

APPENDIX D – PUMPS

BG New Online Pump Selection – Details 3/24/08 6:16 PM

Log Out My Schedule

DETAIL SUMMARY			
Pump Series:	1510	Pump Size:	5BC
Flow Rate: (USGPM)	900	Total Head: (ft.)	75
Pump Speed (RPM)	1750	NPSH req (ft)	11.8
Weight: (lbs)	660	Cost Index:	114
Suction Size: (in)	6	Suction Velocity (fps)	10
Discharge Size: (in)	5	Discharge Velocity: (fps)	14.4
Impeller Diameter: (in)	9.5	Efficiency: (%)	82.49
Max Impeller Dia (in)	9.5		
Max Flow (USGPM)	1382	Duty Flow/Max Flow (%)	0.65
Flow @ BEP (USGPM)	975	Min. Rec. Flow: (USGPM)	250
Motor Power, HP:	25	Frame Size:	284T
Pump Power (BHP)	21.07		
Max Power (BHP)	24.49	Aprox Wt (lbs)	



Another Selection | Generate Submittal | Download CAD | Back To Pumps

http://rcwapp.itt.com/esponline/BG_Details.asp Page 1 of 2

APPENDIX E – DETAILED ENERGY BREAKDOWN OF COOLING TOWER AND RIVER REJECTION SYSTEMS

COOLING TOWER SYSTEM

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	TOTAL
kWhr	5,625	7,500	7,500	15,000	30,000	56,700	56,700	56,700	30,000	15,000	7,500	5,625	**293,850**
kW	75	75	75	75	75	75	75	75	75	75	75	75	
Hr	75	100	100	200	400	756	756	756	400	200	100	75	**3,918**
Cost	$1,125.00	$1,500.00	$1,500.00	$3,000.00	$6,000.00	$11,340.00	$11,340.00	$11,340.00	$6,000.00	$3,000.00	$1,500.00	$1,125.00	**$58,770.00**

RIVER REJECTION SYSTEM

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	TOTAL
kWhr	1,425	1,900	1,900	3,800	7,600	14,364	14,364	14,364	7,600	3,800	1,900	1,425	**74,442**
kw	19	19	19	19	19	19	19	19	19	19	19	19	
Hr	75	100	100	200	400	756	756	756	400	200	100	75	**3918**
Cost	$285.00	$380.00	$380.00	$760.00	$1,520.00	$2,872.80	$2,872.80	$2,872.80	$1,520.00	$760.00	$380.00	$285.00	**$14,888.40**

APPENDIX F – EXISTING AND SOLAR SHADE SYSTEM BUILDING LOADS

EXISTING BUILDING COOLING LOADS

SYSTEM SUMMARY
DESIGN CAPACITY QUANTITIES
By PSUAE

		COOLING				HEATING						
System Description	System Type	Main System Capacity ton	Auxiliary System Capacity ton	Optional Vent Capacity ton	Cooling Totals ton	Main System Capacity Btu/h	Auxiliary System Capacity Btu/h	Preheat Capacity Btu/h	Reheat Capacity Btu/h	Humidification Capacity Btu/h	Optional Vent Capacity Btu/h	Heating Totals Btu/h
12TH FLOOR - 1	Water Source Heat Pump	4	0	1	5	-29,868	0	0	0	0	-20,383	-50,251
12TH FLOOR - 3	Water Source Heat Pump	3	0	0	3	-26,439	0	0	0	0	-5,317	-31,756
12TH FLOOR - 4	Water Source Heat Pump	1	0	0	1	-9,553	0	0	0	0	-886	-10,440
12TH FLOOR - 5	Water Source Heat Pump	2	0	0	2	-16,941	0	0	0	0	-5,317	-22,258
12TH FLOOR - 6	Water Source Heat Pump	2	0	0	2	-14,083	0	0	0	0	-3,545	-17,628
12TH FLOOR - 7	Water Source Heat Pump	1	0	0	1	-12,645	0	0	0	0	-1,772	-14,418
12TH FLOOR - 8	Water Source Heat Pump	1	0	0	1	-8,400	0	0	0	0	-3,545	-11,945
12TH FLOOR - 9	Water Source Heat Pump	1	0	0	1	-9,808	0	0	0	0	-4,431	-14,239
12TH FLOOR - 10	Water Source Heat Pump	1	0	1	2	-10,550	0	0	0	0	-15,243	-25,793
12TH FLOOR - 11	Water Source Heat Pump	0	0	0	0	-1,161	0	0	0	0	-1,772	-2,933
12TH FLOOR - 12	Water Source Heat Pump	1	0	0	2	-8,983	0	0	0	0	-12,496	-21,479
12TH FLOOR - 13	Water Source Heat Pump	1	0	0	1	-9,018	0	0	0	0	-5,317	-14,335
12TH FLOOR - 14	Water Source Heat Pump	1	0	1	1	-6,390	0	0	0	0	-15,243	-21,633
Totals		215	0	29	245	-1,724,110	-55,594	0	0	0	-779,324	-2,559,027

*** The building peaked at hour 15 month 8 with a capacity of 243 tons.**

Project Name: THE HOSPITAL FOR SPECIAL SURGERY RIVER BUILDING
Dataset Name: Y:\Maxwell Thesis\HSSriverloadcalc.TRC

TRACE® 700 v4.1 calculated at 05:40 PM on 03/29/2008
Alternative - 1 Design Capacity Quantities report page 5

EXISTING BUILDING ENERGY SUMMARY

ENERGY CONSUMPTION SUMMARY

By PSUAE

	Elect Cons. (kWh)	Water Cons. (1000 gals)	Percent of Total Energy	Total Source Energy* (kBtu/yr)
Primary heating				
Primary heating	147,554.5		4.7 %	15,109.6
Primary cooling				
Cooling Compressor	174,664.8		5.6 %	17,885.7
Tower/Cond Fans	870,979.6	1,551.3	27.7 %	89,188.5
Condenser Pump	15,211.4		0.5 %	1,557.7
Other CLG Accessories	219.0		0.0 %	22.4
Cooling Subtotal....	1,061,074.8	1,551.3	33.7 %	108,654.3
Auxiliary				
Supply Fans	144,468.8		4.6 %	14,793.6
Circ Pumps	221,934.5		7.1 %	22,726.2
Base Utilities			0.0 %	0.0
Aux Subtotal....	366,403.3		11.6 %	37,519.8
Lighting				
Lighting	265,617.5		8.4 %	27,199.3
Receptacle				
Receptacles	1,308,240.5		41.6 %	133,964.1
Heating plant load				
Base Utilities			0.0 %	0.0
Cogeneration				
Cogeneration			0.0 %	0.0
Totals				
Totals**	3,148,890.5	1,551.3	100.0 %	322,447.1

* Note: Resource Utilization factors are included in the Total Source Energy value.
** Note: This report can display a maximum of 6 utilities. If additional utilities are used, they will be included in the total.

Project Name: THE HOSPITAL FOR SPECIAL SURGERY RIVER BUILDING
Dataset Name: Y:\Maxwell Thesis\HSSriverloadcalc.TRC

TRACE® 700 v4.1 calculated at 05:40 PM on 03/29/2008
Alternative - 1 Energy Consumption Summary report page 1

SOLAR SHADE SYSTEM COOLING LOAD

SYSTEM SUMMARY

DESIGN CAPACITY QUANTITIES

By PSUAE

		COOLING				HEATING						
System Description	System Type	Main System Capacity ton	Auxiliary System Capacity ton	Optional Vent Capacity ton	Cooling Totals ton	Main System Capacity Btu/h	Auxiliary System Capacity Btu/h	Preheat Capacity Btu/h	Reheat Capacity Btu/h	Humidification Capacity Btu/h	Optional Vent Capacity Btu/h	Heating Totals Btu/h
12TH FLOOR - 1	Water Source Heat Pump	3	0	1	4	-26,758	0	0	0	0	-20,383	-47,141
12TH FLOOR - 3	Water Source Heat Pump	2	0	0	3	-22,825	0	0	0	0	-5,317	-28,142
12TH FLOOR - 4	Water Source Heat Pump	1	0	0	1	-7,914	0	0	0	0	-886	-8,800
12TH FLOOR - 5	Water Source Heat Pump	2	0	0	2	-14,816	0	0	0	0	-5,317	-20,133
12TH FLOOR - 6	Water Source Heat Pump	1	0	0	2	-12,099	0	0	0	0	-3,545	-15,644
12TH FLOOR - 7	Water Source Heat Pump	1	0	0	1	-11,032	0	0	0	0	-1,772	-12,804
12TH FLOOR - 8	Water Source Heat Pump	1	0	0	1	-7,790	0	0	0	0	-3,545	-11,335
12TH FLOOR - 9	Water Source Heat Pump	1	0	0	1	-9,160	0	0	0	0	-4,431	-13,591
12TH FLOOR - 10	Water Source Heat Pump	1	0	1	2	-10,550	0	0	0	0	-15,243	-25,793
12TH FLOOR - 11	Water Source Heat Pump	0	0	0	0	-1,161	0	0	0	0	-1,772	-2,933
12TH FLOOR - 12	Water Source Heat Pump	1	0	0	2	-8,983	0	0	0	0	-12,496	-21,479
12TH FLOOR - 13	Water Source Heat Pump	1	0	0	1	-9,018	0	0	0	0	-5,317	-14,335
12TH FLOOR - 14	Water Source Heat Pump	1	0	1	1	-6,390	0	0	0	0	-15,243	-21,633
Totals		196	0	29	225	-1,547,412	0	0	0	0	-776,398	-2,323,810

*** The building peaked at hour 15 month 8 with a capacity of 222 tons.**

Project Name: THE HOSPITAL FOR SPECIAL SURGERY RIVER BUILDING
Dataset Name: Y:\Maxwell Thesis\Solar Shades\SolarshadesSIM.TRC

TRACE® 700 v4.1 calculated at 01:09 AM on 03/31/2008
Alternative - 1 Design Capacity Quantities report page 5

SOLAR SHADE SYSTEM ENERGY SUMMARY

ENERGY CONSUMPTION SUMMARY
By PSUAE

	Elect Cons. (kWh)	Water Cons. (1000 gals)	Percent of Total Energy	Total Source Energy* (kBtu/yr)
Primary heating				
Primary heating	138,958.8		4.6 %	14,229.4
Primary cooling				
Cooling Compressor	161,748.1		5.3 %	16,563.0
Tower/Cond Fans	870,979.6	1,436.6	28.7 %	89,188.5
Condenser Pump	26,625.8		0.9 %	2,726.5
Other CLG Accessories	219.0		0.0 %	22.4
Cooling Subtotal....	1,059,572.6	1,436.6	34.9 %	108,500.5
Auxiliary				
Supply Fans	129,604.4		4.3 %	13,271.5
Circ Pumps	133,352.5		4.4 %	13,655.3
Base Utilities			0.0 %	0.0
Aux Subtotal....	262,956.8		8.7 %	26,926.8
Lighting				
Lighting	265,617.5		8.8 %	27,199.3
Receptacle				
Receptacles	1,308,240.5		43.1 %	133,964.1
Heating plant load				
Base Utilities			0.0 %	0.0
Cogeneration				
Cogeneration			0.0 %	0.0
Totals				
Totals**	3,035,346.3	1,436.6	100.0 %	310,820.2

* Note: Resource Utilization factors are included in the Total Source Energy value.
** Note: This report can display a maximum of 6 utilities. If additional utilities are used, they will be included in the total.

Project Name: THE HOSPITAL FOR SPECIAL SURGERY RIVER BUILDING
Dataset Name: Y:\Maxwell Thesis\Solar Shades\SolarshadesSIM.TRC

TRACE® 700 v4.1 calculated at 01:09 AM on 03/31/2008
Alternative - 1 Energy Consumption Summary report page 1