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.

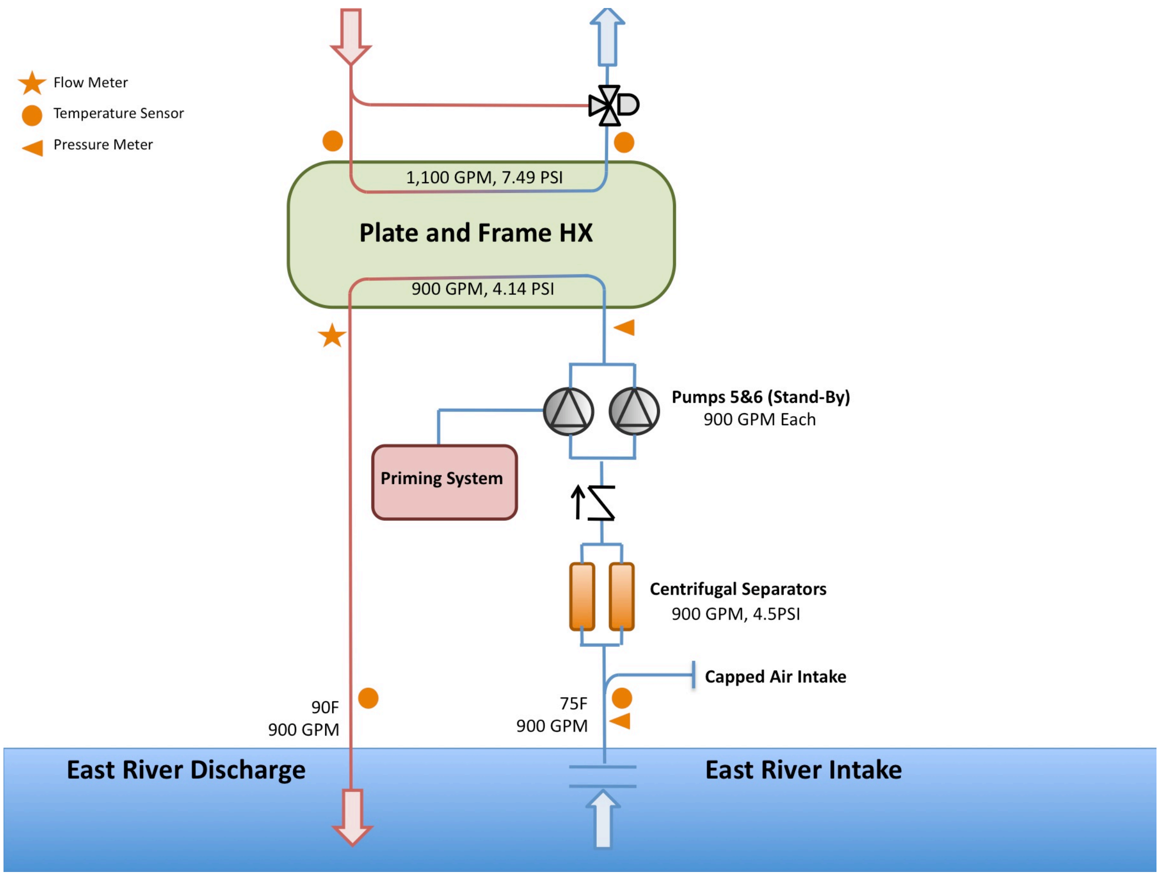

Figure 9. River heat rejection flow diagram.

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.

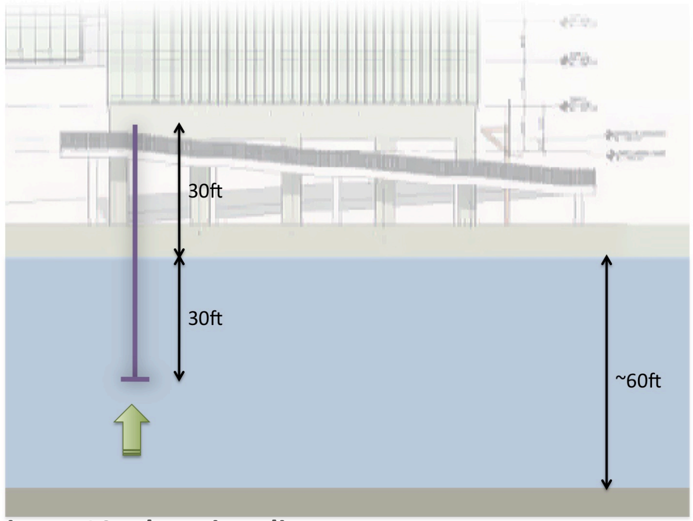

Figure 10. Elevation diagram.

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.