Hunter's Point South

Intermediate School & High School

Long Island City, NY

MECHANICAL OPTION

Revised Thesis Proposal

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Executive Summary

The purpose of the thesis mechanical proposal is to outline the intended design changes for our respective buildings. In the following report, the outline of the mechanical changes, as well as the two breadths of study and master class integration is detailed for Hunter's Point South School. The main focus is the mechanical proposal, in which the three existing VAV AHU's will be removed and replaced with a dedicated outdoor air system. An enthalpy wheel will be included for energy recovery to save costs. The VAV boxes in the school will be removed and the terminal units shall be fan powered induction units. This change will ensure the correct amount of outside are needed is supplied to meet the requirements set up in the NYC Green Schools Guide. Finally, the storm water of Hunter's Point South School shall be collected and used as grey water for toilets. This will improve on the sustainability aspect of the schoolhouse and serve as a learning tool for green design for the students.

The first breadth study shall be an integration of solar photovoltaic panels on the roof. With the implementation of a DOAS system to replace the existing VAV AHU's and some moving around of the CAV AHU's, enough roof space shall be cleared for a solar panel system to be installed. This solar photovoltaic system will generate clean energy year round. Though it will not be big enough to create a substantial dent in the electricity bill, it will payback and lower the carbon footprint of Hunter's Point South School. As with the storm water collection, the solar panel system can also serve as a great learning tool for students.

The second breadth of study will be a structural one analyzing the roof system. With all the moving around and adding of loads on the roof, a look into the structural integrity is in order. If the roof cannot hold the new capacity, one that can will be designed. Also whenever solar photovoltaic panels are added to roofs, a structural analysis must be performed on the roof.

The proposal below also includes a quick background on the existing mechanical systems, alternatives considered, tools needed to complete the analyses, preliminary research, and lastly a work schedule outline. The proposed ideas below were carefully thought out and decided upon to help make Hunter's Point South School more energy efficient and green. Whether or not a substantial cost savings will ensue from these changes, the proposed changes will still move Hunter's Point South School in a more green and sustainable direction.

Building Overview

Hunter's Point South Intermediate School & High School is a public school for grades 5 through 12 serving the PS 287 Queens School district. Hunters Point is a five story school that will house over 1,000 students. It consists of 26 classrooms, 8 special education classrooms, library, gym, assembly space, cafeteria with open terrace seating, kitchen, and support spaces. The building is a part of the Hunter's Point South Project, a redevelopment of the 30 acre Queens area to become a more sustainable, middle income urban community along the waterfront park. This redevelopment in Queens also includes residential housing, apartments, retail space, community/cultural facilities, parking, and a new 11 acre waterfront park.

Mechanical System Overview

Conditioned air is served to Hunter's Point South Intermediate School & High School via the six rooftop air handling units. Units 1, 2, and 3 are variable air volume (VAV) systems that service the classrooms, offices, corridors, and non-public spaces. Units 4, 5, and 6 are constant air volume (CAV) systems that serve the gymnasium, cafeteria/kitchen, and auditorium, respectively. All air handling units have variable frequency drives, wrap around heat pipes for dehumidification, and economizer controls. Preheat coils in the AHU's use a 35% propylene glycol – water mixture while the cooling coil utilizes a 30% propylene glycol – water mixture. This heat-transfer fluid has low toxicity and volatility. It poses little harm to humans in case of a leak.

Four natural gas fired, condensing boilers are used for Hunter's Point South School's heating needs. These boilers are located in the mechanical penthouse's boiler room. Each boiler can produce 1860 MBH worth of 35% propylene glycol – water mixture which is used for the AHU's, perimeter fin tube radiators, unit heaters, and cabinet heaters. All heating hot water and secondary pumps are located in the boiler room along with the hot and chilled water expansion tanks. Two 276 ton air cooled chillers with scroll compressors are also located on the roof. A 30% propylene glycol – water mixture is cooled by the R-410a refrigerant which is used for the AHU's cooling coils.

Cabinet and unit heaters are used to heat the building's entrances, locker rooms/showers, and stairwells. Split heat pumps are utilized in the telecom rooms on each floor, food storage, and elevator machine room. The outdoor section of each heat pump is located on the roof. Fin tubed radiators are used along the perimeter walls to heat the space in conjunction with AHU's. Upblast and mushroom fans are located on the roof where they exhaust air from the science lab's fume hoods and kitchen.

Mechanical Design Objectives

The classrooms house a large number of occupants which consumes a huge amount of energy. Since the classrooms have a fluctuating number of occupants throughout the day, it would be costly and inefficient to run the rooms at full load all day for ventilation and lighting. This was considered in the design so to help reduce energy consumption, VAV boxes were used to vary the flow of conditioned air to the spaces. Occupancy sensors for lighting control were also included to save electricity.

Hazardous chemicals are used in the laboratories and science classrooms. This inherent concern was accounted for in the design phase. Fume hoods with exhaust fans are used to help flush out potentially harmful chemicals while fan powered VAV boxes are used to replenish the exhausted air. Strict standards were imposed on the quality of duct used for the chemical exhaust and the inside of the ducts are negatively pressurized to prevent leakage of the chemical exhaust to surrounding spaces.

The NYC Green Schools Guide requires all new schools, such as Hunter's Point South Intermediate School & High School, to be designed to use above 30% minimum ventilation air calculated in ASHRAE Standard 62.1. This is outlined in Q1.1R Minimum IAQ Performance/Increased Ventilation in the NYC Green Schools Guide.

Overall System Evaluation

The mechanical system for Hunter's Point South School meets the requirements outlined for design. The total mechanical system cost was $7,750,000 which is approximately $50.40 per square foot. Two of the biggest cost factors were the ductwork and custom made air handling units. Operating the mechanical system would cost $294,212 a year or $1.91 a square foot. Space was saved by placing the mechanical equipment on the roof but extensive ductwork was still required. A total of 1,681 square feet were lost to the mechanical system, the most of it being shafts for ducting from floor to floor.

The variable and constant flow AHU's meet the ventilation requirements outlined in ASHRAE Standard 62.1. The VAV terminal boxes further help to save energy costs, however at times of full turndown ventilation requirements may not be met.

The evaluation for maintenance for the mechanical systems is mixed. Huge clearances are given around the AHU's as well as access doors. Chillers are easily reachable on the roof. All proponents of the system are very accessible but no elevator goes up to the mechanical penthouse or roof. Replacement of larger parts would be difficult. The only way to access the chillers, AHU’s, boilers, and generator is by using the stairs.

Fume hoods do an excellent job to remove hazardous chemicals from the laboratories and science classrooms. However this energy is wasted. No heat recovery is used in Hunter’s Point South School for any of the exhaust fans. Recovering exhausted heat can help save building energy costs.

The mechanical system designed for Hunter’s Point South School is very good but not flawless. Heat recovery is not present at all. The use of roof space for mechanical equipment saves usable floor space but the use of a 100% outside air system with hydronic heating and cooling could potentially save more floor space.

Alternatives Considered

Several alternatives were considered to improve the efficiency and operating costs of the mechanical systems in place in Hunter’s Point South School. These alternatives are described more in depth below.

Geothermal Heat Pumps

Geothermal heat pumps use the Earth’s constant temperature for heating or cooling purposes. No combustion is needed and it has a relatively long life. Geothermal is an excellent design idea and once the initial costs are paid off, the costs for heating or cooling is a fraction of the original. The implementation of a geothermal heat pump was a favored topic to use but due to the nature of the site it is not feasible.

Geothermal closed-loop systems require extensive excavating for the piping to be placed. Excavating for Hunter’s Point South School is very costly and the footprint of the building is not big enough to support the number of wells needed. Also, since Hunter’s Point South School is located in the city, sewage lines and electrical wires could run right under the building. Open-loop systems could not be used either because no body of water is located close enough to the schoolhouse.

Reheat Recovery on Fume Hoods

No heat recovery has been used for the fume hoods. Using wrap around heat pipes and using the exhaust to precondition the supply air would be a quick fix and simple solution. This idea was highly considered but ultimately due to the sporadic use of the fume hoods and fear of corrosive properties from the chemicals exhausted, it was abandoned.

Chilled Beam System

Chilled beam systems are an up and coming technology in the U.S. They can be used for both heating and cooling purposes and are traditionally coupled with dedicated outdoor air systems to supply a reduced amount of air to spaces. Chilled beams have the potential to have a huge cost savings when combined with dedicated outdoor air systems. However, the use of chilled beam systems is very limited in the U.S. Owners are skeptical if they run properly. Since chilled beam systems have a cooling coil in the unit, people worry about water condensing on the coil and it “raining” in the space. When properly designed this should not happen but still many owners are skeptical in the U.S. so topic has been avoided.

Cooling Tower

The two chillers located on the roof of Hunter’s Point South School are air-cooled. A possible investigation into whether water cooled chillers would be more efficient would be a great thesis topic. This would include designing a cooling tower and comparing the savings on compressor energy while having to pay for makeup water versus the current air-cooled chillers. This idea alone would not be enough and seems to be a stand-alone consideration. This was considered but a more encompassing idea was preferred.

Mechanical Proposal

Dedicated Outdoor Air System (DOAS)

A dedicated outdoor air system will be used for ventilation air instead of AHU’s 1, 2, and 3. To receive a point in the New York City Green Schools Guide, Hunter’s Point South should supply above 30% outside air according to ASHRAE Standard 62.1. The CAV systems do meet this requirement but the existing VAV system is problematic at times when the VAV boxes are fully turned down. This analysis was performed in technical report one and can be seen in Table 1 below.

	Type	Min OA Intake	Vot	Compliant?	30% Above Vot	Above 30% Compliant?
AHU-1	VAV	14945	12218	Yes	15883	No
AHU-2	VAV	19445	18971	Yes	24662	No
AHU-3	VAV	13210	10954	Yes	14240	No
AHU-4	CAV	13360	7085	Yes	9211	Yes
AHU-5	CAV	11840	6259	Yes	8488	Yes
AHU-6	CAV	6325	2657	Yes	3454	Yes

Table 1 – Air Handling Units' Section 6 Compliance (ASHRAE Std 62.1)

The use of a DOAS is a simple solution to meet the ventilation needs. The air supplied by the DOAS will be constant and sized to 30% of the minimum ventilation standard in ASHRAE Std. 62.1. This will insure that Hunter's Point South will receive the Q1.1R Minimum IAQ Performance/Increased Ventilation credit.

Another goal of using a DOAS, is that it will reduce the amount of ductwork needed in the building. The ductwork was the biggest mechanical cost (excluding emergency generator/fuel oil) and can be seen in Table 2 below. Less ductwork will save on costs and should increase the usable floor space by restricting the size of the floor to floor duct chases and runs.

Mechanical Cost Breakdown		
Type	Cost ($)	Cost per square foot ($/sf)
AHU's	1,190,000	7.74
Chillers	820,000	5.33
Boilers	260,000	1.69
Heat Pumps	49,000	0.32
Fin Tube Radiators	300,000	1.95
Unit/Cabinet Heaters	143,000	0.93
VAV Boxes	216,000	1.40
Fan Powered Boxes	16,000	0.10
HVAC Piping	1,250,000	8.13
Ducts	1,479,500	9.62
HVAC Controls	910,000	5.92
Pumps	32,000	0.21
Convectors	14,000	0.09
Fans	80,000	0.52
Dampers	55,000	0.36
Diffusers/Grills	100,000	0.65
Emergency Generator/Fuel Oil	182,000	1.18
Glycol	35,000	0.23
Miscellaneous	38,500	0.25
Overhead	580,000	3.77
Total	**7,750,000**	**50.40**

Table 2 – Mechanical Cost Breakdown

The AHU's currently used by Hunter's Point South School are the third biggest cost (seen above in Table 1). A single DOAS can replace AHU's 1, 2, and 3. This will result in a smaller system and more roof space. It will also lower the cost of the system and make the operating system much simpler. Since all return air from spaces will be exhausted, the use of an enthalpy wheel would be beneficial so energy is not "thrown away".

Enthalpy Wheel

ASHRAE Standard 90.1 requires any mechanical system that uses 100% outside air to have some form of energy recovery. Currently, no heat recovery is used in the mechanical design for Hunter's Point South School. An enthalpy wheel would be able to transfer sensible and latent properties from the exhausted air of the DOAS to the incoming outdoor air. This will bring the outside air closer to the supply air conditions and would greatly lower energy costs. The dehumidification wrap around coils used in the original VAV AHU's would not be needed in the DOAS because of the wheel. An enthalpy wheel with a purge section would help ensure no cross contamination from the exhaust to the incoming outdoor air. In case there ever is a discharge of chemicals in a lab room to the regular exhaust, this purge section can transfer energy to the incoming outdoor air without spreading contaminants. Below, Figure 1 shows a how a purge section is used in an enthalpy wheel.

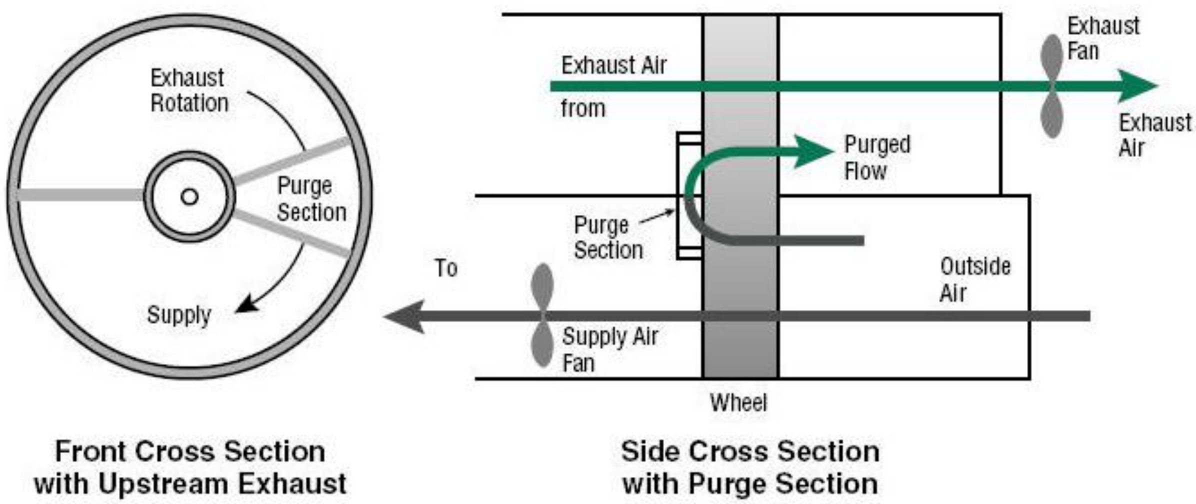

Figure 1 – Enthalpy Wheel with Purge Section

Fan-Powered Induction Units (FPIU)

The classrooms, offices, lab rooms, corridors, and non-public spaces are served by the VAV AHU's 1, 2, and 3 which have VAV boxes as the terminal units. These spaces require the most cost to condition. VAV's systems are well suited to help lower energy costs but as explained before, they are problematic in reaching the minimum ventilation requirements when fully turned down. Using fan-powered induction units would work well in place of the VAV boxes. FPIU's have a dedicated outdoor air supply so minimum ventilation can always be met. Since only minimum outside air is supplied to the rooms, duct sizes will be dramatically reduced. Additional air is recirculated from the room and mixed with the supply air. The FPIU's allow for easy control of temperatures in spaces since both a cooling coil and reheat coil can be placed in the unit. This increases the comfort level for occupants in space and allows for turn down when the space isn't occupied. Each different space is more easily controlled to exactly the thermal needs it has. Though duct sizes may be reduced, piping will have to be provided to the FPIU's for cooling and potentially heating too. This will increase piping costs but hopefully not enough to overcome the savings from the smaller ducts. Using fan-powered induction units will help save on energy costs and increase thermal comfort. Below in Figure 2 is a picture of a FPIU.

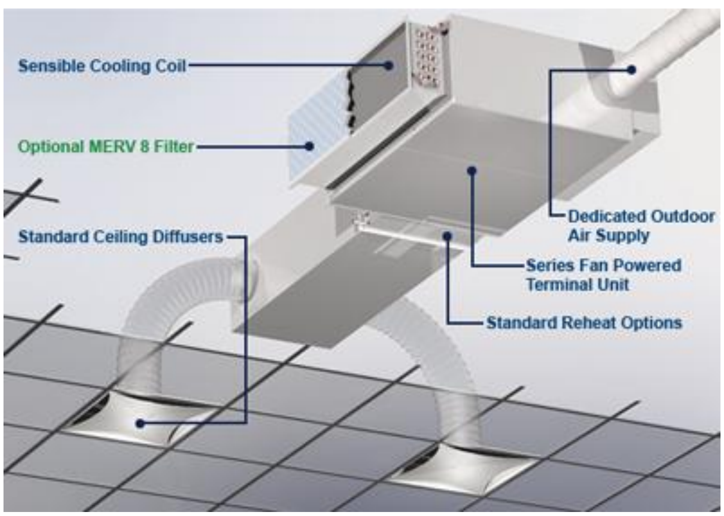

Figure 2 – Fan-Powered Induction Unit

Storm Water Collection

Using a DOAS will reduce the number of air handling units and free up more space on the already mechanically packed roof. Open roof space for Hunter's Point South School could be used to integrate a storm water collection system. This storm water could be used as grey water for toilets. This system would save on water costs and add to sustainable aspects of the school. Further investigation would be necessary, but condensed water from the rooftop air handlers and chillers could also be added to the storm water collection.

Below in Figure 3 is a proposed design for how the roof space could be used. The amount of free space on the roof will be dictated by the size of the DOAS. Exhaust fan outlets could be moved too to free up more space. An addition to the mechanical penthouse could be made to store the tanks and pumps for the collected storm water. Inconjuction with low flow plumbing fixtures, the storm water collection system could potentially supply all the majority water needed for toilets.

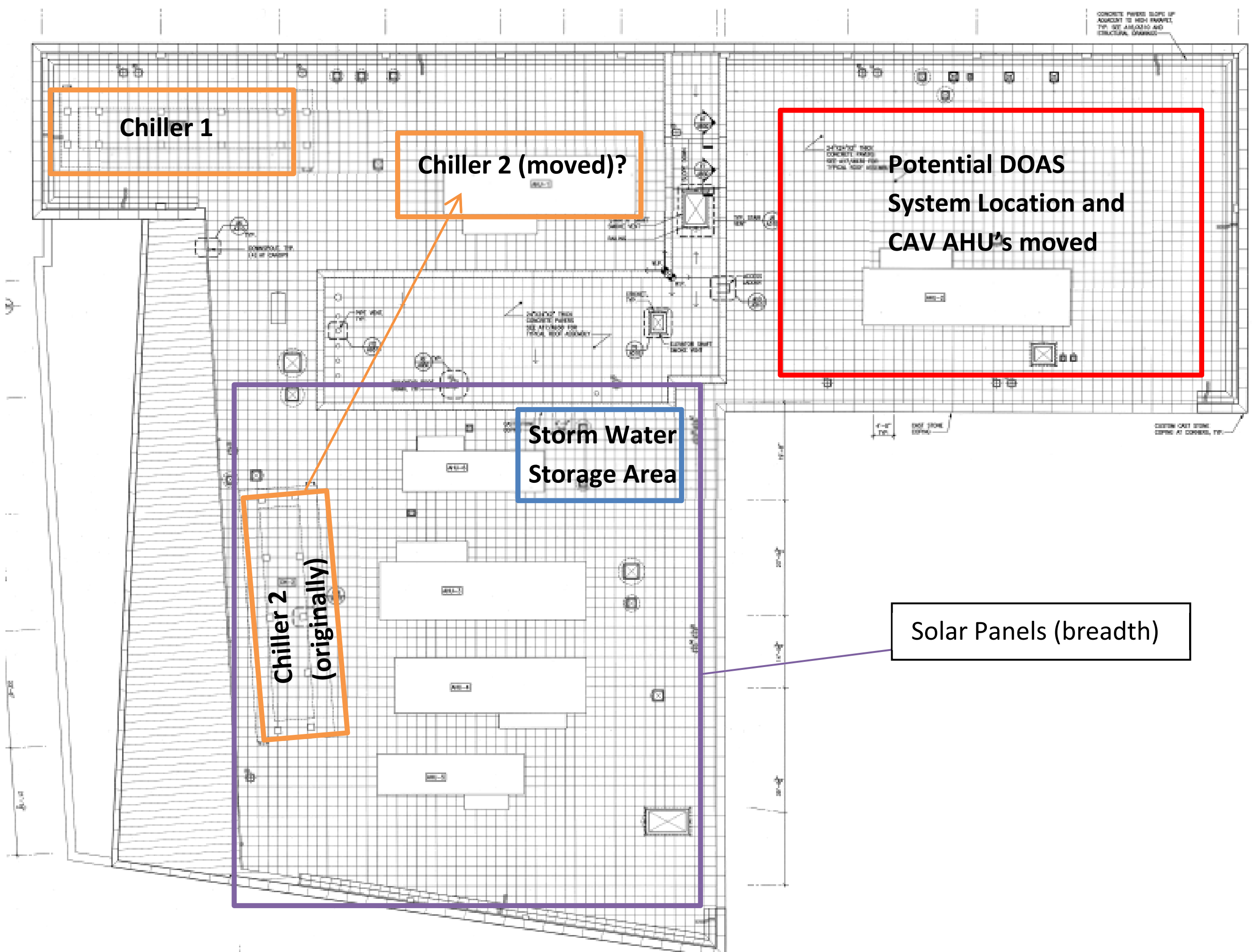

Figure 3 – Proposed Storm Water Collection

Benefits of the Proposed Design

Indoor air quality should be greatly increased through the proposed mechanical redesign. All air used in the spaces is outdoor air (which is presumed healthier than recirculated air) and the air circulation in spaces should increase. Free up of the rooftop space will allow for an area for storm water collection to be built. Free roof space will also allow the electrical breadth study proposed below. The DOAS and FPIU system could potentially be extended to some spaces served by the CAV AHU’s. This will be further investigated if time permits and will allow for more usable roof space. Finally the integration of an enthalpy wheel and FPIU should increase efficiency and lower economic costs.

Breadth Topics

Solar Photovoltaic Panels (Electrical Breadth)

Through all the proposed mechanical changes, extra space will be created on the roof. Figure 3 on page 11 shows the proposed open area. This open area on the roof is south facing, making it a great source for solar power generation. A parapet currently exists all along the roof. The parapet can be reduced in size along the southern walls to allow for sun light to reach the panels. Though the space is not enough to generate a large chunk of Hunter’s Point South School’s electricity needs, solar photovoltaic panels can cut cost and have a reasonable payback time with the current rebates in New York. In the long run, the solar panels will offset enough electricity costs to make money for the school. Energy generated from these panels is also clean and will not pollute the environment. This will further add to the schools sustainable footprint. The design and integration of tying a solar system into the existing electrical system of Hunter’s Point South School shall be included in this breadth. The sizing of the inverter(s) and breaker(s) will be calculated as well as the feeders. An economic analysis on the payback period and energy generated by the panels shall also be performed.

Analysis of the Roof System (Structural Breadth)

With all the moving around of AHU’s, chillers, and adding solar photovoltaic panels, an analysis of the roof of Hunter’s Point South School is in order. Whenever solar photovoltaic panels are installed on a roof, a structural analysis must first be performed. The analysis set up will test whether the existing roof system for the schoolhouse can support all these changes. The roof deck, beams, girders, and columns that have increased loads on them due to the adding/moving around of equipment will be tested. Calculations for strength and deflection will be performed by hand or done using RAM or SAP.

MAE Course Relation

Since FPIU's will be used, heating and cooling will primarily be accomplished at the rooms. When the dedicated outside air is not enough to meet the cooling or heating loads, air from the served space will also be brought in using the FPIU's variable speed motor. Since varied amounts of air at different temperatures will be supplied to the rooms, different air mixing patterns in the rooms will occur. With the information gained in AE 559 Computational Fluid Dynamics, a study may be conducted into how well air is supplied and mixed within the rooms through the FPIU's. This shall show if any dead zones/drafts may exist and give a better picture how thermally comfortable the spaces will be to occupants.

Tools for Analysis

Below is a list of a few programs that shall be used for the integration of the above proposed designs.

Trane TRACE 700

This program will be used to run load calculations on spaces so the FPIU's can be sized properly as well as the DOAS system. An energy analysis will also be performed using TRACE to see the feasibility and life cycle costs of these systems.

Engineering Equation Solver (EES)

EES is an advanced equation solving software. Coupled with excel, problems not easily solved by hand can be made much quicker.

AutoCAD

AutoCAD can be used to take measurements and areas for the different rooms. It is also an excellent tool to use to draw diagrams for the systems and outline proposed piping/duct layouts.

Codes and Standards

Codes and standards for design as well as safe practice will need to be investigated throughout the redesign work. Compliance with the 2007 New York State Mechanical Code, New York City Green Schools Guide, and ASHRAE Standards 62.1 and 90.1 will be checked periodically.

Appendix A - Preliminary Research

1. Mumma, S. "Designing Dedicated Outdoor Air Systems." ASHRAE Journal. (May 2001): 28-31.

This article was found at the following address: http://doas.psu.edu/Journal1.pdf. It discusses the design considerations that go into creating a dedicated outdoor air system.

2. Jeong, Jae-Weon, and Stanley Mumma. "Binary Enthalpy Wheel Humidifcation Control in Dedicated Outdoor Air Systems." *ASHRAE*. (2007): n. page. Print.

This source deals with the control of enthalpy wheels during the heating and intermediates seasons. This article can be found at:
http://doas.psu.edu/Binary_EW_Ctl_LB_07_025_Tech_Paper.pdf

3. New York City School Construction Authority, and New York City Department of Education. "Indoor Environmental Quality." *NYC Green Schools Guide*. (2007): 101-142. Print.

This source lists all the requirements for each New York City Green Schools Guide points. This will be referenced for finding the minimum ventilation requirements needed to size the dedicated outdoor air system to receive the Q1.1R Minimum IAQ Performance credit. A pdf of this document can be found at the below address:

http://source.nycsca.org/pdf/nycgsg-031507.pdf

4. *Krueger Releases DOAS Fan Powered Terminal Unit*. (June, 21 2010): Richardson, Texas. Print.

This press release gave useful information for FPIU's and specification sheets for their different sizes. This is a great jumping off point for determining the right FPIU to use. Below is the address for the source: http://www.krueger-hvac.com/lit/press/klpsdrelease.asp

5. Hargreaves, Steve. "New York City's Solar Power Push." *CNNMoney*. (July 25, 2011). Print.

This article gave the idea for using solar in NYC and some examples of how it's been used efficiently. Link: http://money.cnn.com/2011/07/25/technology/solar-new-york/index.htm

Appendix B – Preliminary Schedule