Section 04: Mechanical System Redesign

4.01: Proposed Goals and Scope

Due to it's primary function as a laboratory and learning space, in addition to the need to employ a 100% outdoor air system, the Hauptman-Woodward Medical Research Institute has an estimated yearly utility bill of $75,136. Laboratory spaces have requirements that naturally increase the operational costs of the building. Since all of the conditioned air is exhausted from these spaces, there is a great deal of energy that is expended into the atmosphere that could be reused.

The primary goal of this report is to modify the existing HVAC system in an effort to reduce energy consumption and yearly utility costs. If these objectives can be achieved, emissions from the building will be decreased as well. In addition to the mechanical redesign, an evaluation of wind power as well as lighting power density requirements will be assessed in the breadth section of this report. While considering the alternatives, it is important to preserve the integrity of the lab and incorporate a design that will not be unfavorable to the program requirements.

The scope of the design process will include the following:

- Model the existing building conditions in Trane Trace to establish base.
- Design and Incorporate a parallel DOAS/ DX VAV System in non-lab critical spaces
- Design and incorporate a parallel DOAS/Hydronic Radiant System with Desiccant Wheel in Lab-critical spaces.
- Model Alternative designs to establish comparison
- Compare existing system to proposed system to determine feasibility

Disclaimer: The remainder of this report provides alternative solutions for the mechanical design at the Hauptman-Woodward Medical Research Institute. These solutions have been put forth for academic purposes only. As such, the modifications described do not suggest flaws in the original design by Cannon Design or others involved on the design or construction of this project.

4.02: Considered Alternatives

Ground Source Heat Pumps

The first consideration for the thesis report was implementing a Ground Source Heat Pump (GSHP) system (Figure XIV). GSHP's use geothermal sources, such as groundwater, surface water or other water mass as a heat source. Most have a reverse refrigeration cycle and either an open or closed geothermal loop. They are preferred over Air-Source Heat Pumps due to the fact that the ground water temperature is nearly constant and shallow depths. Although GSHP's have good response times in terms of allowing a switch between heating and cooling, they require large tracts of land for boring holes into the earth. The Hauptman-Woodward Medical Research Institute does not have a large lot, and there is most likely not enough space to layout the ground loops. In addition, the first costs of drilling boreholes and laying out piping loops would be much higher than the current system that is in place, giving it a very poor payback time. For these reasons, this option will not be considered for the project.

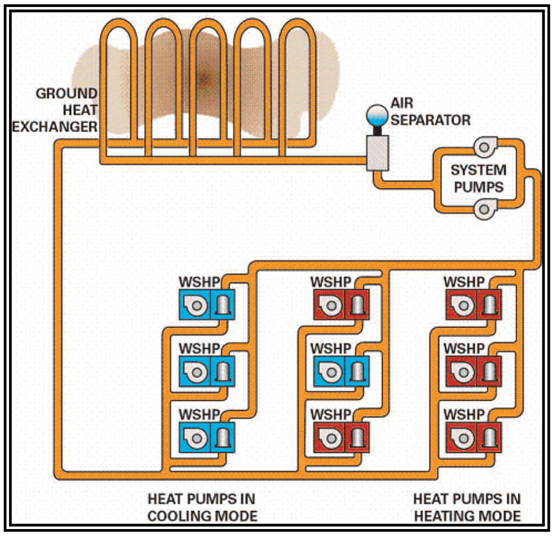


Figure XIV: Typical GSHP Schematic

Latent Energy Storage

High on-peak electric demand charges gave way to the consideration of latent energy storage. Latent storage at first glance seems like a viable option considering the fact that the building occupancy schedule coincides with the on-peak electric demand schedule. After preliminary investigation, this option was discarded to the small building footprint of HWI. There would not be significant space available for ice storage containers. In addition, the structural system of the building would have to be increased a great deal due to the fact that the only location for ice storage would be in the mechanical penthouse. The building was constructed on a slab foundation; therefore there is no basement available to house equipment. This option was disregarded without further review.

4.03: Justification of Proposed Systems

System 1:

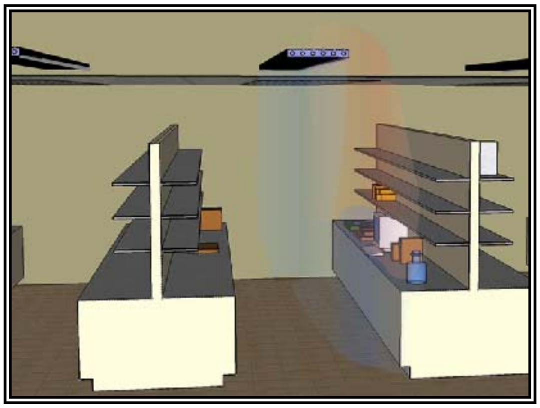


Figure XV: Proposed Chilled Beam Application in Lab

As discussed in section 4.01, this report details the addition of two Dedicated Outdoor Air Systems (DOAS) to the Hauptman-Woodward Medical Research Institute, and comparing them to the current systems. At the present time, Laboratory AHU-1,2 supply 100% outdoor air and utilize a runaround loop to recover some of the energy that is being exhausted. This report will determine whether a DOAS with a parallel chilled beam system (Figure XV) will be an economical alternative to the existing design. The system will utilize a desiccant wheel equipped with a 3Å molecular sieve material. This material that has been developed by SEMCO provides “selective absorption”, unlike other desiccants that cannot provide trap pollutants. Molecular sieves are structurally stable, chemically inert and have a strong affinity for water vapor. This accounts for the high rate of absorption and high latent transfer performance. In addition the unit will be equipped with a purge section to further eliminate possibility of cross contamination. Although this type of application will always bring out worry of such contamination, there have many laboratories that have utilized this type of system. For example, Johns Hopkins University has successfully implemented a 14’ diameter desiccant system at its Ross Research Laboratory, which was completed in 1991. Further tests over the past 15 years have shown no signs of cross contamination. In addition, there are only 8 fume hoods attached to the general exhaust at HWI. The two fume hoods that serve potentially hazardous material are on their own dedicated exhaust, and would never enter the desiccant wheel. Figure XVI shows a cross-sectional view of the desiccant wheel that is proposed for this system.

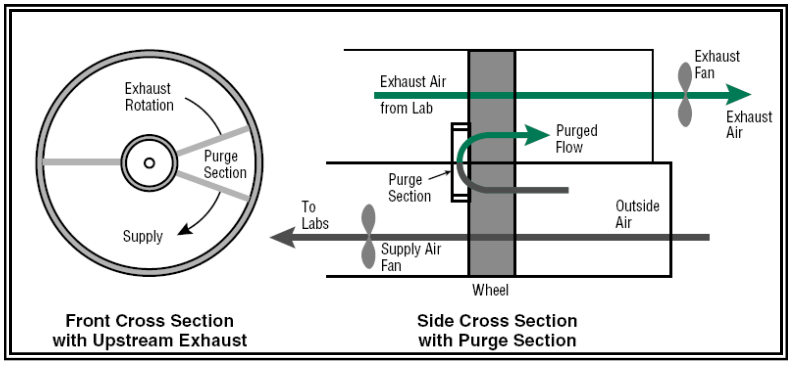


Figure XVI: Cross Sections (Front and Side) of Enthalpy Wheel with Purge Section for Laboratory System (Image Provided by SEMCO, inc.)

System 2:

This existing system consists of two DX rooftop units, RTU-1 and RTU-2, which serve the remainder of the space at HWI. This system supplies outside air and return air to the space, without any further means of heat recovery. Much like the first system, the portions of the building that are not part of the laboratory core will also be served by a dedicated outdoor air system. This proposed redesign shall be set up differently from the first, and shall employ a parallel VAV system to supplement the sensible loads to the space. In this respect, the office will benefit from the improved dehumidification from the DOAS system and space temperature control from VAV boxes in the office areas. In addition, this dedicated outdoor system will employ both latent and sensible wheels (Figure XVII), whereas the laboratory system will only utilize a desiccant wheel that will serve both latent and sensible loads.

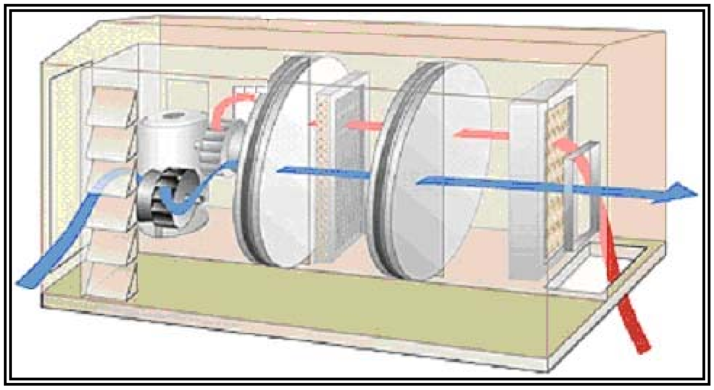


Figure XVII: DOAS System with both Latent and Sensible Wheels for Office-Side
(Image provided by SEMCO, Inc.)

4.04: System 1 Calculations – Laboratory

This section describes the DOAS Unit Selection process using the SEMCO Unit Selection Procedure. Cut sheets from the manufacturer can be found in Appendix C-1.

Design Criteria		Summer	Winter
Supply Air Flow	[cfm]	9400	9400
Return Air Flow	[cfm]	8500	8500
Outdoor Air Conditions			
Temperature	[°F]	86	2
Relative Humidity	[%]	46	10
Moisture Content	[gr/lb]	82	4
Enthalpy	[btu/lb]	34.3	1.1
Return Air Conditions			
Temperature	[°F]	72	70
Relative Humidity	[%]	50	50
Moisture Content	[gr/lb]	55	50
Enthalpy	[btu/lb]	26.6	25.4
Purge Pressure Difference			
ΔP	[in. wg]	3.0	3.0

Table XVIII: Laboratory Design Conditions

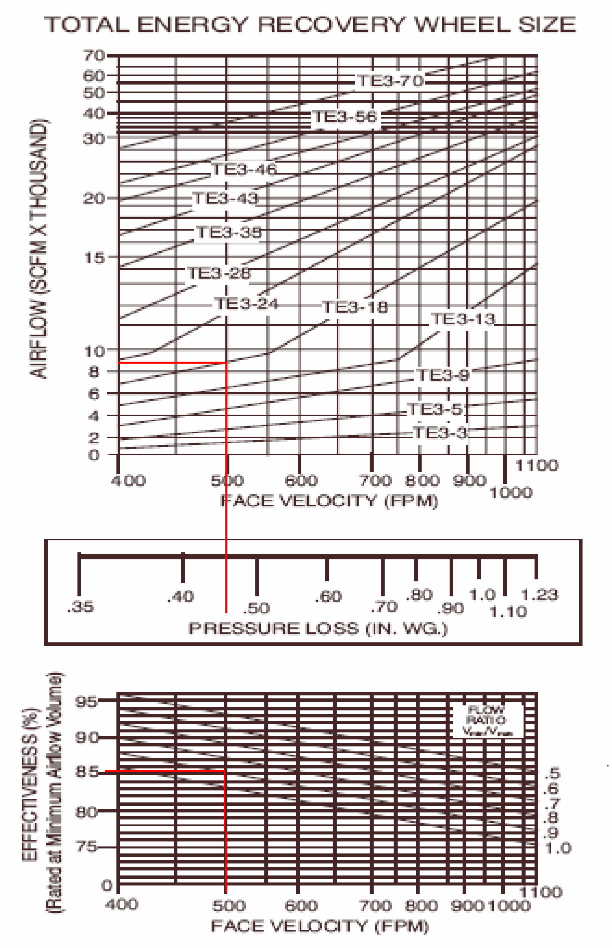


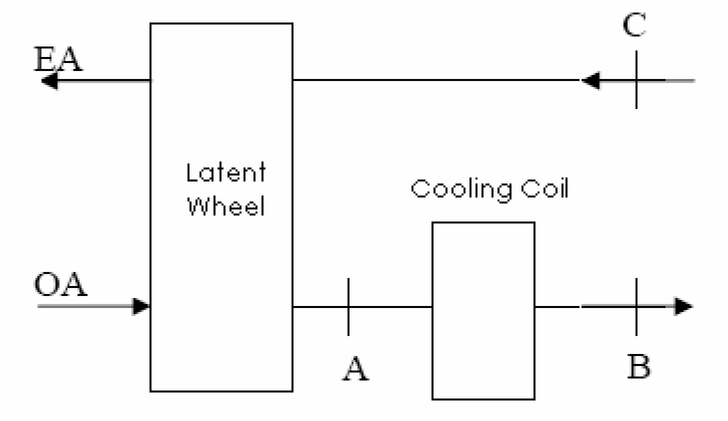
Figure XIX: Enthalpy Wheel Selection
(Chart Provided by SEMCO, Inc.)

Step 1: Enthalpy Wheel Selection, Effectiveness and Pressure Loss

The main component of air-to-air energy recovery in a DOAS system is the enthalpy wheel. The wheel selection is determined based on face velocity and the desired room airflow rate. Based on an airflow rate of 8,500 cfm, the initial wheel size is selected is the **SEMCO TE3-13**. From Figure XIX, we can calculate the Face Velocity, Pressure Loss and Effectiveness of the Wheel. These Values are summarized as Follows:

SEMCO TE3-13 Enthalpy Wheel	
Face Velocity [fpm]	500
Effectiveness	0.85
Pressure Loss [in. w.g.]	0.45

Step 2: Calculate Performance Setpoints



Outside Air Conditions: Cooling (Point A)

DBT

$(\mathrm{Tdb})_2 = 86\,^{\circ}\mathrm{F} - [\epsilon\ (8500\mathrm{cfm} / 9400\ \mathrm{cfm})\ (86\,^{\circ}\mathrm{F} - 72\,^{\circ}\mathrm{F})$

$\mathbf{(Tdb)_2 = 75\,^{\circ}F}$

Humidity Ratio

$W_2 = 82\ \mathrm{gr/lb.} - [\epsilon\ (8500\mathrm{cfm} / 9400\ \mathrm{cfm})\ (82 - 55)$

$\mathbf{W_2 = 60.9\ gr/lb.}$

Enthalpy

$H_2 = 34.3\ \mathrm{Btu/lb} - [\epsilon\ (8500\mathrm{cfm} / 9400\ \mathrm{cfm})\ (34.3 - 26.6)$

$\mathbf{H_2 = 28.3\ Btu/lb}$

Supply Air Conditions: Heating (Point A)

DBT

$(\mathrm{Tdb})_2 = 2\,^{\circ}\mathrm{F} - [\epsilon\ (8500\mathrm{cfm} / 9400\ \mathrm{cfm})\ (2\,^{\circ}\mathrm{F} - 70\,^{\circ}\mathrm{F})$

$\mathbf{(Tdb)_2 = 54.9\,^{\circ}F}$

Humidity Ratio

$W_2 = 4\ \mathrm{gr/lb.} - [\epsilon\ (8500\mathrm{cfm} / 9400\ \mathrm{cfm})\ (4 - 50)$

$\mathbf{W_2 = 39.7\ gr/lb.}$

Enthalpy

$H_2 = 1.1\mathrm{Btu/lb} - [\epsilon\ (8500\mathrm{cfm} / 9400\ \mathrm{cfm})\ (1.1 - 25.4)$

$\mathbf{H_2 = 20.0\ Btu/lb}$

Cooling Coil Load:

$Q_{CC,S} = 1.08 \times \mathrm{CFM} \times (T_{DB,A} - T_{DB,B})$

$Q_{CC,S} = 1.08 \times 8500\mathrm{cfm} \times (75\,^{\circ}\mathrm{F} - 45\,^{\circ}\mathrm{F}) = 275{,}400\ \mathrm{Btu/hr}$

$Q_{CC,L} = 0.68 \times \mathrm{CFM} \times (W_A - W_B)$

$Q_{CC,L} = 0.68 \times 8500\mathrm{cfm} \times (60.9 - 44) = 98{,}260\ \mathrm{Btu/hr}$

$Q_{TOTAL} = Q_{CC,S} + Q_{CC,L}$

$Q_{TOTAL} = 275{,}400\ \mathrm{Btu/hr} + 98{,}260\ \mathrm{Btu/hr} = 373{,}660\ \mathrm{Btu/hr} =$ **31.1 tons**

Step 3: Calculate Chiller and Boiler Reduction Capacity

C= [9,400cfm x 4.5 x (34.3-28.3) Btu/lb] / 12000Btu/ton
C= 22 tons reduced

B= [9,400cfm x 4.5 x (20.0-1.1) Btu/lb] / 33,000 Btu/ bhp
B= 24 bhp reduction

Step 4: Determine Wheel Speed to avoid Frost Formation

Due to the fact that the Hauptman-Woodward Medical Research Institute is located in Buffalo, NY, it is important to take into consideration the possibility of frost formation on the enthalpy wheel and vary the wheel speed accordingly to prevent such occurrences. According to the manufacturer (SEMCO) this procedure will determine the system setpoint for preheat, should it be necessary.

a. Locate Return Air Point on Psychometric Chart
b. Locate Winter OA design condition (stated above in Table XX)
c. Determine Higher DBT at which line intercepts saturation curve
d. Add 2 °F to this temperature and mark as preheat setpoint to avoid freezing.

After completing this method, the psychrometric chart in Figure XX below shows that, the line will never reach saturation. Therefore, there is no need to preheat the Enthalpy Wheel at the Hauptman-Woodward Medical Research Institute.

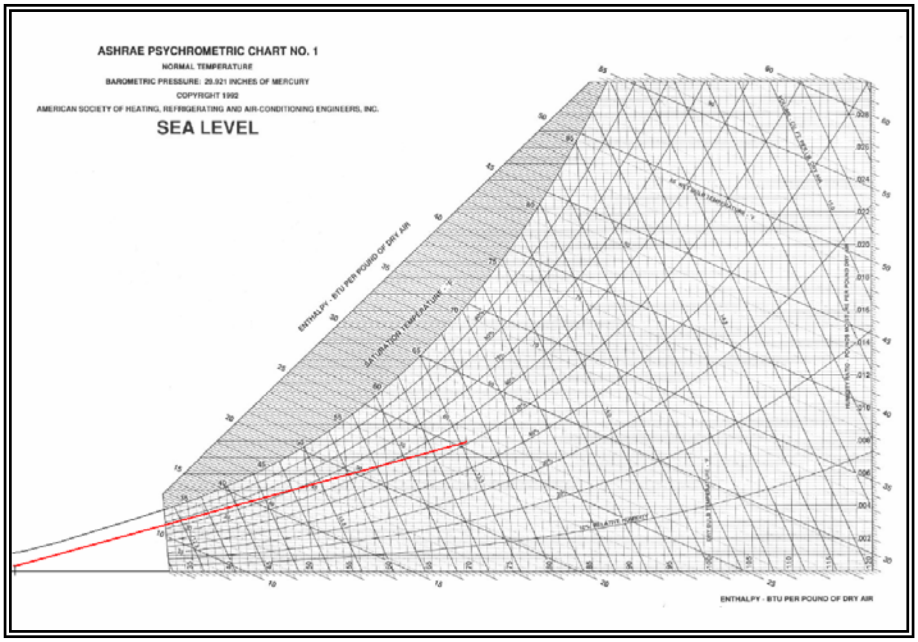
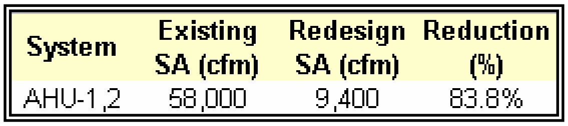


Figure XX: Psychrometric Chart Showing Freeze Precaution Line

Step 5: Resizing the Air-Handling Units

The current configuration at the Hauptman-Woodward Medical Research Institute is the incorporation of two 29,000 cfm air-handling units to meet the 100% outdoor air requirements in the laboratory space. With a Dedicated Outdoor Air System, only the ventilation air will need to be supplied by the air-handling unit. Due to this criterion, only one unit will be necessary and shall be significantly smaller than the existing units. This will hopefully reduce initial cost, and will be determined later in the report.

Based on the design criteria, a comparison of the existing 100% OA System and the designed DOAS system brought about a significant drop in required supply air. When comparing the redesigned laboratory space with the existing system, there is approximately a 83% reduction in supply air, as shown in Table XXI below.



System	Existing SA (cfm)	Redesign SA (cfm)	Reduction (%)
AHU-1,2	58,000	9,400	83.8%

Table XXI: Parallel VAV System Supply Air Reduction

4.05: System 1: Parallel Equipment (Chilled Beam Application)

One of the great things about DOAS systems is the fact that they can significantly reduce the required amount of supply air being sent through the system. The drawback to this scenario is the fact that there must be a supplemental system to remove the additional sensible loads that cannot be removed with the DOAS system. This also holds true in the heating season, when extra heat may be required to satisfy comfort in the building. For these reasons, parallel systems must be employed. As discussed in the redesign scope, the laboratory system will employ chilled beams to accommodate these loads. For the redesign, chilled beams by Halton, Ltd. were used due to their architectural styling and integration to the building design. Specifications are found in table XXII below, however detailed cut sheets can be found in Appendix C-2.

Step 5: Calculate Parallel System Cooling Capacity

DOAS Cooling Capacity:

$Q_{SA} = 1.08 \times CFM_{OA} \times (T_{DB,C} - T_{DB,B})$

$Q_{SA} = 1.08 \times 8500 \text{ cfm} \times (72\,^{\circ}\text{F} - 45\,^{\circ}\text{F}) = 247{,}860 \text{ Btu/hr}$

Parallel System Cooling Capacity

$Q_{PARALLEL} = Q_{SENSIBLE} - Q_{SA}$

$Q_{SENSIBLE} = 743{,}000 \text{ Btu/hr}$

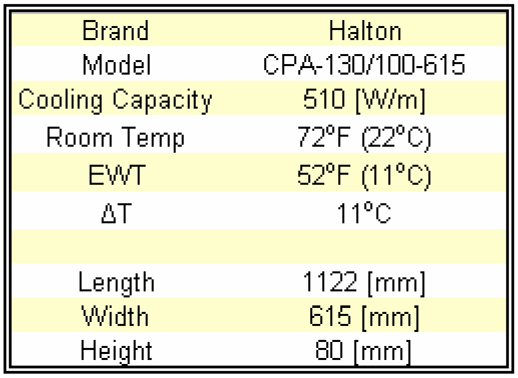
$Q_{PARALLEL} = 743{,}000 - 247{,}860 \text{ Btu/hr} = 495{,}140 \text{ Btu/hr}$

Step 6: Select Equipment + Number of Beams

$Q_{PARALLEL} = 495{,}140 \text{ Btuh} \times 1\text{W}/3.142\text{Btuh}$
$= 145{,}117 \text{ W}$

Area of Beam Coverage: 145,117 W / 510 W/m
= 284.5 m

\# of Beams = Total Coverage Area / Beam Length
=284.5 m / 1.21 m
= 236 Chilled Beams required



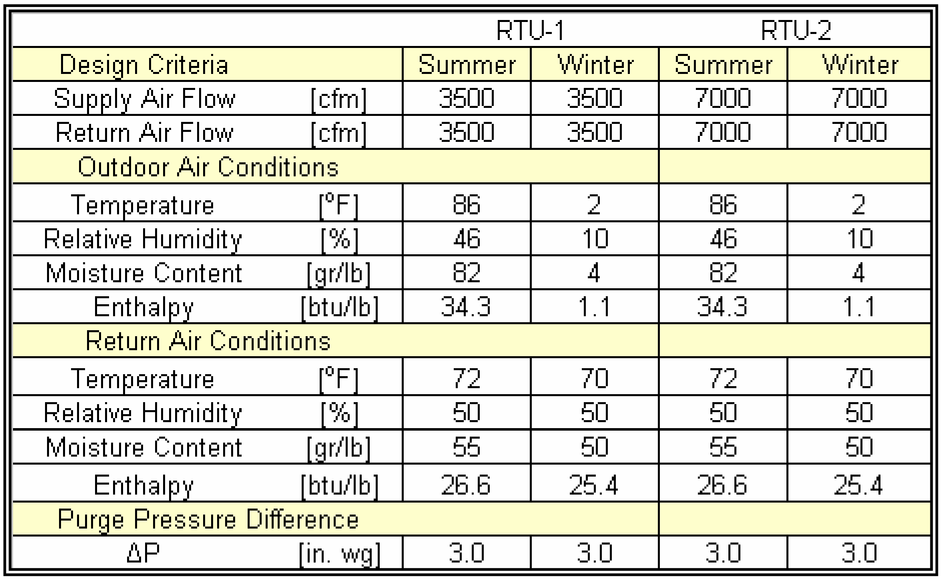
Brand	Halton
Model	CPA-130/100-615
Cooling Capacity	510 [W/m]
Room Temp	72°F (22°C)
EWT	52°F (11°C)
ΔT	11°C
Length	1122 [mm]
Width	615 [mm]
Height	80 [mm]

Table XXII: Chilled Beam Specification

4.06: System 2 Calculations (DOAS w/Parallel VAV)

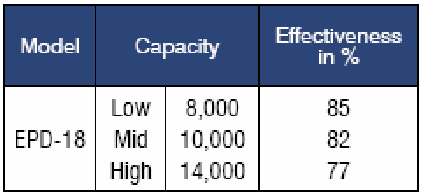
The DOAS system that will be incorporated on the office/learning wings of the building is similar to the previously selected system for the laboratory; however it shall utilize both an enthalpy wheel and a sensible wheel. Manufactured by SEMCO, this unit shall provide an EXCLU-SIEVE energy recovery wheel, a sensible energy wheel, backward-curved supply and exhaust fans, outdoor air and return filtration, and a chilled water cooling coil which will be supplied by the existing chiller. This DOAS unit shall serve the office and support core of the building and will be supplemented by two VAV air-handling units, RTU-1 and RTU-2. The following steps were taken to size the appropriate DOAS Unit by SEMCO, based on space air conditions found in Table XXIII. Cut sheets from the manufacturer can be found in Appendix C-1.

Step 1: Select Unit based on SA quantity:
Total Supply Air Quantity = 10,500 cfm – therefore select SEMCO Model EPD-18



		RTU-1		RTU-2	
Design Criteria		Summer	Winter	Summer	Winter
Supply Air Flow	[cfm]	3500	3500	7000	7000
Return Air Flow	[cfm]	3500	3500	7000	7000
Outdoor Air Conditions					
Temperature	[°F]	86	2	86	2
Relative Humidity	[%]	46	10	46	10
Moisture Content	[gr/lb]	82	4	82	4
Enthalpy	[btu/lb]	34.3	1.1	34.3	1.1
Return Air Conditions					
Temperature	[°F]	72	70	72	70
Relative Humidity	[%]	50	50	50	50
Moisture Content	[gr/lb]	55	50	55	50
Enthalpy	[btu/lb]	26.6	25.4	26.6	25.4
Purge Pressure Difference					
ΔP	[in. wg]	3.0	3.0	3.0	3.0

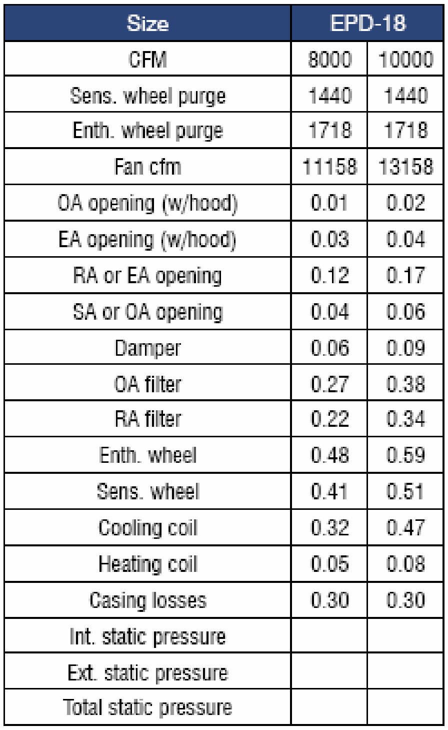
Table XXIII: Office-Side Air Conditions



Model	Capacity		Effectiveness in %
EPD-18	Low	8,000	85
	Mid	10,000	82
	High	14,000	77

Table XXIV: Model Information from SEMCO Selection Guide

Step 2: Determine ISP pressure for the SA side of EPD-18 at 10000 cfm.



Size	EPD-18	
CFM	8000	10000
Sens. wheel purge	1440	1440
Enth. wheel purge	1718	1718
Fan cfm	11158	13158
OA opening (w/hood)	0.01	0.02
EA opening (w/hood)	0.03	0.04
RA or EA opening	0.12	0.17
SA or OA opening	0.04	0.06
Damper	0.06	0.09
OA filter	0.27	0.38
RA filter	0.22	0.34
Enth. wheel	0.48	0.59
Sens. wheel	0.41	0.51
Cooling coil	0.32	0.47
Heating coil	0.05	0.08
Casing losses	0.30	0.30
Int. static pressure		
Ext. static pressure		
Total static pressure		

SA@10,000 CFM		RA@10,000 CFM	
OA Opening	0.02	EA Opening	0.04
SA Opening	0.06	RA Opening	0.17
Damper	0.09	Damper	0.09
OA Filter	0.38	RA Filter	0.34
Enthalpy Wheel	0.59	Enthalpy Wheel	0.59
CHW Coil	0.47	Sensible Wheel	0.51
Sensible Wheel	0.51	Casing	0.30
Casing	0.30		
ISP	**2.42 in. w.g.**	**ISP**	**2.04 in. w.g.**

Table XXV: Model Information from SEMCO Selection Guide (steps 2-4))

Step 3: Determine Total Static Pressure

Formula: **TSP = ISP+ ESP**

ESP [supply] = 1.0 in.w.g
TSP = 2.42 + 1.0 = **3.42 in. w.g.**

ESP [return] = 0.5 in.w.g
TSP = 2.04 + 0.5 = **2.54 in. w.g**

Step 4: Determine Total Supply Air Volume

Using Table XXV above, the sensible wheel purge volume = 1,440 cfm and the enthalpy wheel purge volume = 1,718 cfm

Total Supply Air = 10,000 CFM + 1,440 CFM + 1718 CFM = **13,160 CFM**

Step 5: Determine Motor Horsepower

Supply Fan – Size 13, 9x @ 13.28 HP
Return Fan – Size 9, 5xx , @ 10.55 HP

Step 6: Determine Base Wheel Effectiveness

From Table XXIV on the previous page, the base wheel effectiveness @ 10,000 CFM is 0.82.

Step 7: Determine Summer and Winter Setpoint Conditions:

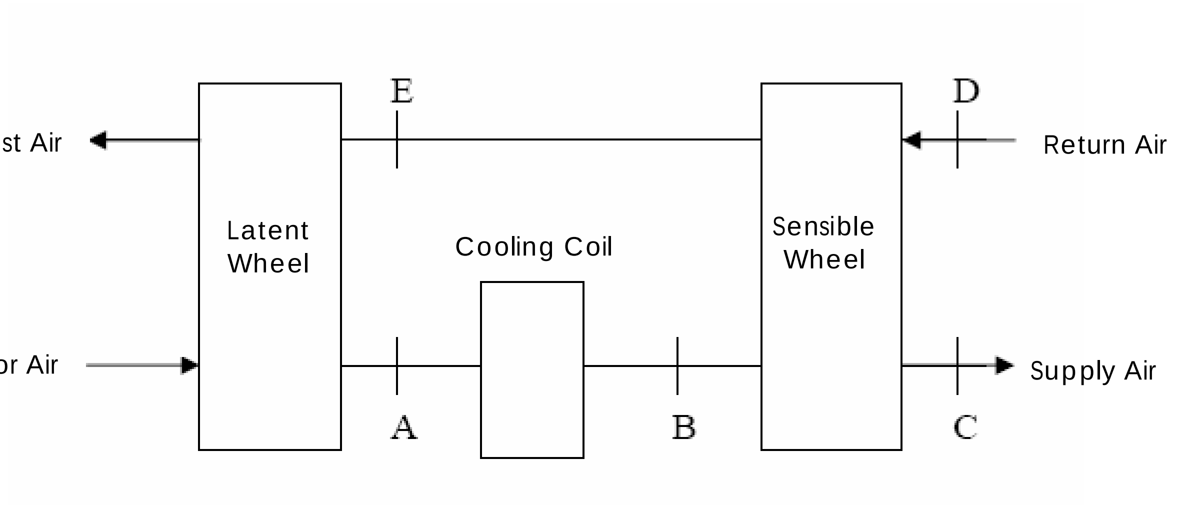


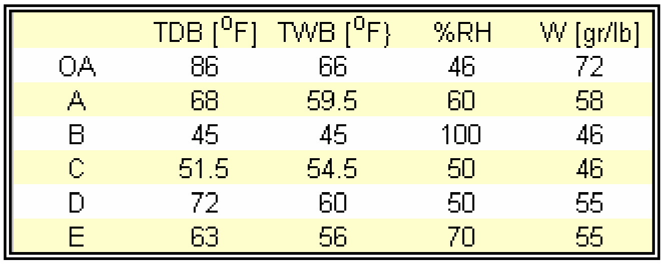
Figure XXVI: Office-Side DOAS

$W_A = W_{OA} – 0.76\ (W_{OA}-W_E)$
$(W_E = W_D)$
$W_A = 72 – 0.76\ (72-55)$
$W_A = 58.57$ gr/lb
$T_A = 68\,^{O}F$

$T_C = T_B – 0.79\ (T_B-T_D)$
$T_C = 45\,^{O}F – 0.76\ (45\,^{O}F- 72\,^{O}F)$
$T_C = 51.48\,^{O}F$

$W_C = W_B = 43$ gr/lb

$T_E = T_D – 0.79\ (T_D - T_B)$
$T_E = 72\,^{O}F – 0.79\ (72\,^{O}F - 45\,^{O}F)$
$T_E =63\,^{O}F$



	TDB [^{o}F]	TWB [^{o}F]	%RH	W [gr/lb]
OA	86	66	46	72
A	68	59.5	60	58
B	45	45	100	46
C	51.5	54.5	50	46
D	72	60	50	55
E	63	56	70	55

Table XXVII: DOAS System 2 Setpoints

Cooling Coil Load:
$Q_{CC,S}$ = 1.08 x CFM x ($T_{DB,A}$ – $T_{DB,B}$)
$Q_{CC,S}$ = 1.08 x 10,500 cfm x (68^{O}F – 45^{O}F) = 260,820 Btu/hr

$Q_{CC,L}$ = 0.68 x CFM x (W_A –W_B)
$Q_{CC,L}$ = 0.68 x 10,500cfm x (58-46) = 85,680 Btu/hr

Q_{TOTAL} = $Q_{CC,S}$ + $Q_{CC,L}$
Q_{TOTAL} = 210,600 Btu/hr + 74,698 Btu/hr = 346,500 Btu/hr = **28.9 tons**

Step 8: Calculate Chiller and Boiler Reduction Capacity

C= [10,500 cfm x 4.5 x (34.3-28.3) Btu/lb] / 12000Btu/ton
C= 23.6 tons reduced

B= [10,500 cfm x 4.5 x (20.0-1.1) Btu/lb] / 33,000 Btu/ bhp
B= 27 bhp reduction

4.07: Sizing Parallel Equipment (Parallel VAV) for System 2

Just like system one, this DOAS system will require a parallel system to make up for additional space loads. The laboratory system employed chilled beams to complete this task; however for the office and laboratory side I will incorporate a parallel VAV system that will closely resemble the existing system. The benefit to this scenario is that the building will definitely be able to accommodate a VAV set-up, since that is what is currently installed. Ducts and VAV boxes will be considerably smaller, however. This would hopefully contribute to cost savings in the initial mechanical design.

Step 9: Calculate Parallel System Cooling Capacity

DOAS Cooling Capacity:

$Q_{SA} = 1.08 \times CFM_{OA} \times (T_{DB,D} - T_{DB,C})$

$Q_{SA} = 1.08 \times 10{,}500\ \text{cfm} \times (72\,^{O}F - 51.5\,^{O}F) = 232{,}470\ \text{Btu/hr}$

Parallel System Cooling Capacity

$Q_{PARALLEL} = Q_{SENSIBLE} - Q_{SA}$

$Q_{SENSIBLE} = 923{,}000\ \text{Btu/hr}$

$Q_{PARALLEL} = 923{,}000 - 232{,}470\ \text{Btu/hr} = \mathbf{690{,}530\ Btu/hr}$

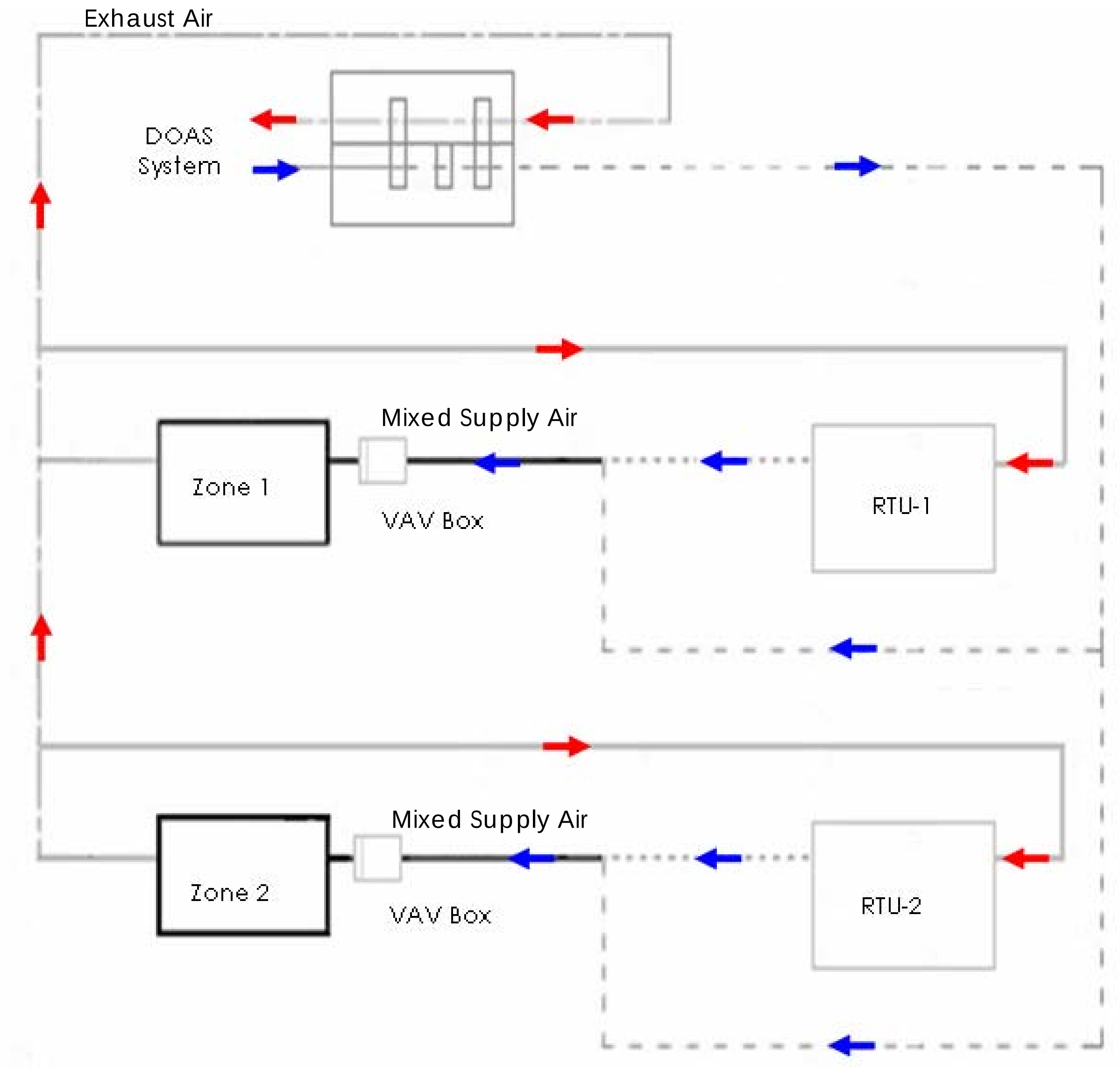


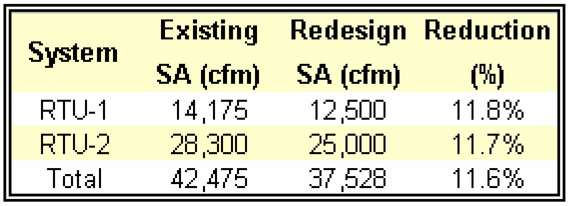
Figure XXVIII: DOAS/Parallel VAV Schematic

Step 10: Calculate Supply Air required for Parallel VAV System

In the previous step, the sensible load that could not be met by the DOAS system was determined to be 690,530 btu/hr. Using the following equation, we can determine the required amount of supply air for the parallel VAV system.

$$CFM_S = \frac{Q_S}{1.08 \times (T_{RA} - T_{SA})} = \frac{690,530 \text{ btu/hr}}{1.08 \times (72^{O}F - 55^{O}F)} = \mathbf{37,528\ cfm}$$

When compared to the existing VAV system, this is approximately a 12% reduction in fan size, as shown in Table XXIX.



System	Existing SA (cfm)	Redesign SA (cfm)	Reduction (%)
RTU-1	14,175	12,500	11.8%
RTU-2	28,300	25,000	11.7%
Total	42,475	37,528	11.6%

Table XXIX: Parallel VAV System Supply Air

Step 11: Calculate the Final Mixed Supply Air Temperature of the System.

As shown in the Figure XXVIII on the previous page, the actual supply air of the DOAS/Parallel VAV System is supplied by air from both the DOAS unit and the VAV Air Handler. For this reason, we must calculate the actual mixed air temperature of the two air streams, using the following equation:

$$T_{S,MIX} = T_{S,VAV} \times \frac{CFM_{VAV}}{CFM_{TOTAL}} + T_{S,DOAS} \times \frac{CFM_{DOAS}}{CFM_{TOTAL}}$$

RTU-1

$T_{S,MIX} = 55^{O}F \times (12,500cfm/16,000cfm) + 45^{O}F \times (3,500cfm/16,000cfm) = \mathbf{52.8^{O}F}$

RTU-2

$T_{S,MIX} = 55^{O}F \times (25,000cfm/32,000cfm) + 45^{O}F \times (7,000cfm/32,000cfm) = \mathbf{52.8^{O}F}$

4.08: Annual Energy and Cost Analysis

Trane TRACE 700 was used extensively for the design load and energy simulation at the Hauptman-Woodward Medical Research Institute. By modeling design criteria into the Trane software, the program is able to estimate Heating and Cooling Loads, Ventilation Rates and Energy Consumption for each space, in addition to emissions and annual operation cost estimates.

Due to the fact that energy consumption data could not be obtained for the existing building, it was crucial that the building be modeled as closely as possible to the actual design in order to establish an appropriate base-case scenario. The following Figure XXX shows the estimated monthly energy and utility costs at the Hauptman-Woodward Medical Research Institute, based on data taken from Trane TRACE 700. A complete set of raw data from the simulation can be found in Appendix D.

	Original Design	**Proposed Design**	**Savings**	**%**
Cost ($/yr)	75,166	55,069	20,097	26.74%
Consumption (kWh/yr)	2,116,058	1,581,585	534,473	25.26%

Figure XXX: Annual Energy and Utility Costs for Base and Proposed Designs

As shown in Figure XXX, the proposed design reduces the annual electricity consumption by approximately 534,473 kWh and saves $20,097 annually on utility costs. This is most likely in part due to reduced chiller and pump sizes, in addition to reduced fan power required by the air-handling units.

4.09: Emissions Analysis

The Hauptman-Woodward Medical Research Institute receives its electricity from National Grid, a global energy generation and distribution company that serve approximately 3.4 million customers across 29,000 square miles in New York, Massachusetts, Rhode Island, and New Hampshire. In New York State, electricity is generated using a mix of technologies including nuclear, fossil fuel power plants, hydro, and others. By 2013, the state will require that 25% of the electricity sold in New York State come from clean renewable resources, such as wind, solar and hydro.

By knowing the amount of electricity and natural gas consumed by the HVAC system, we can determine the emissions that are exhausted by the building. At the present time, National Grid distributes power from the sources found in Figure XXXI. Nuclear and Hydro energy account for approximately 46% of the generated electricity in the area, which is ideal due to the fact that it does not release emissions into the atmosphere. Other sources, such as oil and coal, release NOx, SOx and other particulates due to the fact that these sources must be burned to utilize their energy.

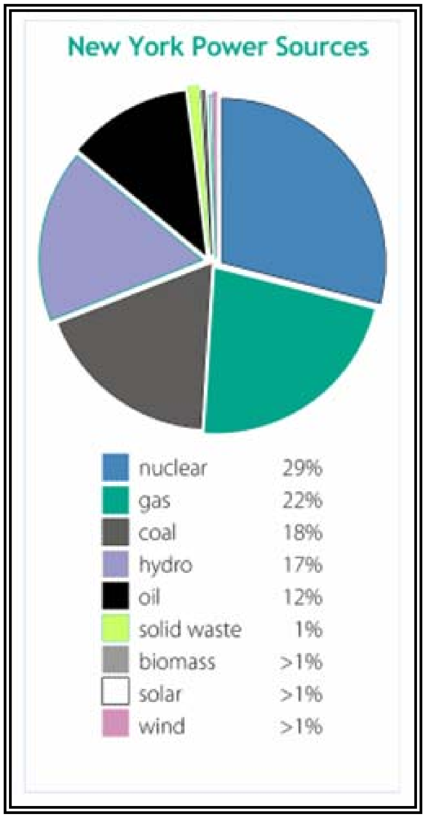


Figure XXXI: National Grid Electricity Generation Sources for New York State

Base Case			**lbm Pollutant /kWh**				**lbm Pollutant**			
Fuel	**% Total**	**kWh**	**Particulates**	**SO_2/kWh**	**NO_x/kWh**	**CO_2/kWh**	**lbm Particulates**	**lbm SO_2**	**lbm Nox**	**lbm CO_2**
Coal	18%	379387	1.80E-02	2.13E-02	1.40E-01	4.15E+01	6828.96	8080.94	53114.17	15736968.61
Oil	12%	252925	2.70E-02	3.80E-01	7.07E-02	3.35E+01	6828.96	96111.35	17886.83	8472974.10
Nat. Gas	22%	463695	0.00E+00	1.35E-03	2.54E-01	1.34E+02	0.00	625.99	117639.45	62158328.16
Nuclear	29%	611234	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydro	17%	358310	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wind	1%	21077	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solar	1%	21077	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	***100%***	***2107705***					***13657.93***	***104818.28***	***188640.44***	***86368270.87***

Figure XXXII: Estimated Emissions for Existing Base Case at

DOAS Redesign			lbm Pollutant /kWh				lbm Pollutant			
Fuel	**% Total**	**kWh**	**Particulates**	**SO_2/kWh**	**NO_x/kWh**	**CO_2/kWh**	**lbm Particulates**	**lbm SO_2**	**lbm Nox**	**lbm CO_2**
Coal	18%	334656	1.80E-02	2.13E-02	1.40E-01	4.15E+01	6023.80	7128.17	46851.81	13881523.41
Oil	12%	223104	2.70E-02	3.80E-01	7.07E-02	3.35E+01	6023.80	84779.47	15777.91	7473979.98
Nat. Gas	22%	409024	0.00E+00	1.35E-03	2.54E-01	1.34E+02	0.00	552.18	103769.33	54829637.71
Nuclear	29%	539168	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydro	17%	316064	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wind	1%	18592	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solar	1%	18592	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	***100%***	***1859199***					***12047.61***	***92459.83***	***166399.05***	***76185141.10***

Figure XXXIII: Estimated Emissions for Redesigned Case at

As shown in the preceding Figures XXXII and XXXIII, the DOAS scenario that has been proposed consumes approximately %25 less electricity as compared to the existing mechanical system at the Hauptman-Woodward Medical Research Institute. Likewise, the emissions were reduced by approximately the same amount as a direct result of this reduction in the building electrical load.

4.10: First Cost Analysis

One of the primary factors in mechanical system design is the first cost of the system. Although customers tend to prefer spending the least amount of money up-front on their mechanical systems, the prospect of saving money in the future on energy costs may entice the owner to spend more money up front. CostWorks was used to analyze the equipment costs of the existing system and the proposed alternative. CostWorks is a program that utilizes the R S Means catalog to determine equipment and labor costs. A summary of the existing system costs versus the proposed system costs is shown below. Based upon the load calculations for the DOAS design with VAV and Chilled Beam Parallel Systems, the chiller capacity is reduced to half the original size. In addition, the amount of supply air required is significantly reduced due to the fact that the dedicated outdoor air units are only supplying the necessary ventilation air to the space. This allowed for a 55% decrease in the size and cost of the air-handling units. Due to these reductions in initial costs, the added cost of the chilled beam parallel system to meet the sensible loads to the space were covered. Other reductions in initial cost that were not considered but would further improve this scenario would be a reduction in a reduced plenum height and a reduced electrical service due to smaller mechanical equipment. A complete breakdown of the initial costs of each alternative is shown in Figure XXXIV.

	Existing System	**Proposed DOAS Systems**
Chiller [tons}	300	150
Boilers [mbh]	10,200	5100
AHU's	$154,500	$72,025
Chiller	$163,500	$97,500
Pumps (Primary)	$10,850	$5,150
Boilers	$21,000	$10,500
Pumps (Boiler)	$30,900	$15,450
Parallel Systems		
VAV	$137,770	$98,070
Chilled Beams		$187,000
Pumps (Parallel)		$5,150
Piping (Parallel)		$7,500
Ductwork	$304,000	$76,000
Totals:	**$822,520**	**$574,345**

Figure XXXIV: Mechanical System First-Cost

4.11: Depth Results and Conclusions

The task of providing an alternative mechanical system at the Hauptman-Woodward Medical Research Institute has been a sensitive one. The existing system is a prime example of a standard laboratory mechanical system with 100% outdoor air handling units which are proven to provide clean air and are trusted by owners whose main concern is indoor air quality. Alternatives must provide identical indoor air quality and there are few options which do so.

The incorporation of a dedicated outdoor air system in this setting has proven to live up to the task of the existing 100% outdoor air system. Based on existing case studies at the Johns Hopkins Ross Research Institute, DOAS systems have proven to be a viable alternative for over 20 years. With the use of SEMCO's desiccant wheel equipped with a 3Å molecular sieve material, "selective absorption" takes place allowing water vapor to pass through without trapping pollutants.

A first-cost analysis done with Costworks shows that the proposed system is approximately 30% cheaper than the existing system. This is in part due to smaller air handling units and supporting equipment based on the nature of a DOAS system. In addition, the energy analysis completed with Trane TRACE 700 has shown a reduction in electricity and as a result a savings of over $20,000 in yearly utility bills.

As a result of the reduced electric and natural gas loads, building emissions were also reduced with the incorporation of the dedicated outdoor air systems. An initiative set forth by the State of New York has mandated that by 2013, twenty-five percent of all electricity must be generated by renewable resources. This will further reduce the building emissions in the coming years.

Based on the results of this report, it is recommended that dedicated outdoor air systems are incorporated into the design at Hauptman-Woodward Medical Research Institute. The provide an energy efficient alternative to the 100% outdoor air systems and DX Rooftop units that are currently serving the space, and drastically reduce energy consumption, first costs, and annual utility costs to the owner.