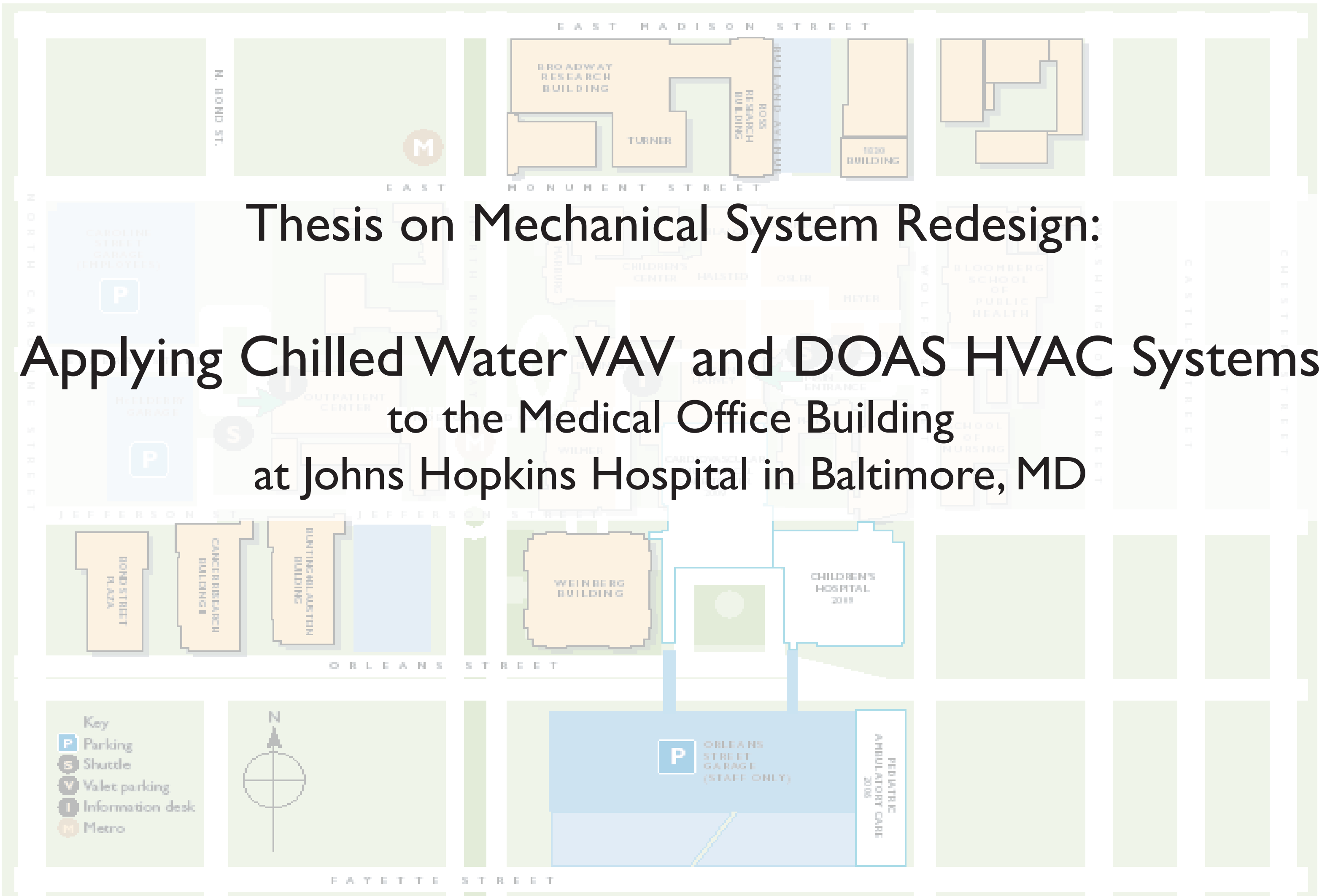
JOHNS HOPKINS
MEDICINE



Thesis on Mechanical System Redesign:

Applying Chilled Water VAV and DOAS HVAC Systems
to the Medical Office Building
at Johns Hopkins Hospital in Baltimore, MD

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Senior Thesis Project Spring 2006
Penn State University Department of Architectural Engineering
Mechanical Emphasis
April 2, 2006

Johns Hopkins Hospital

Baltimore, MD

Medical Office Building

Evan Hughes
Mechanical

Project Team

Architect - ZGF, Washington DC
CM - Atlantic Builders, Baltimore MD
MEP - Leach Wallace Assoc, Baltimore MD
Structural - Columbia Engineering, Columbia MD

Architecture

The MOB is a multi-use medical facility with space for offices, examination rooms, administrative areas and special use areas.

The dedicated areas are used for dialysis, phlebotomy examination, laser treatment, radiology, and infusion.

Site size is 38,600 sq ft
Building size is 88,260 sq ft
Four stories, three above grade
Total projected cost 15.5 million
Dates of Construction June 2005 - March 2006

Mechanical

Six York rooftop dx package units provide 120,000cfm of supply air. for a total of 367.5 tons of cooling.

All heating in the dx rooftop units is performed with electric coils and VAV boxes are also equipped with electric reheat coils.

Hot water is provided by a 225 gallon electric hot water heater.

Oxygen is supplied to the MOB at 55psig via a 1" supply line, tapped off the main oxygen storage facility.

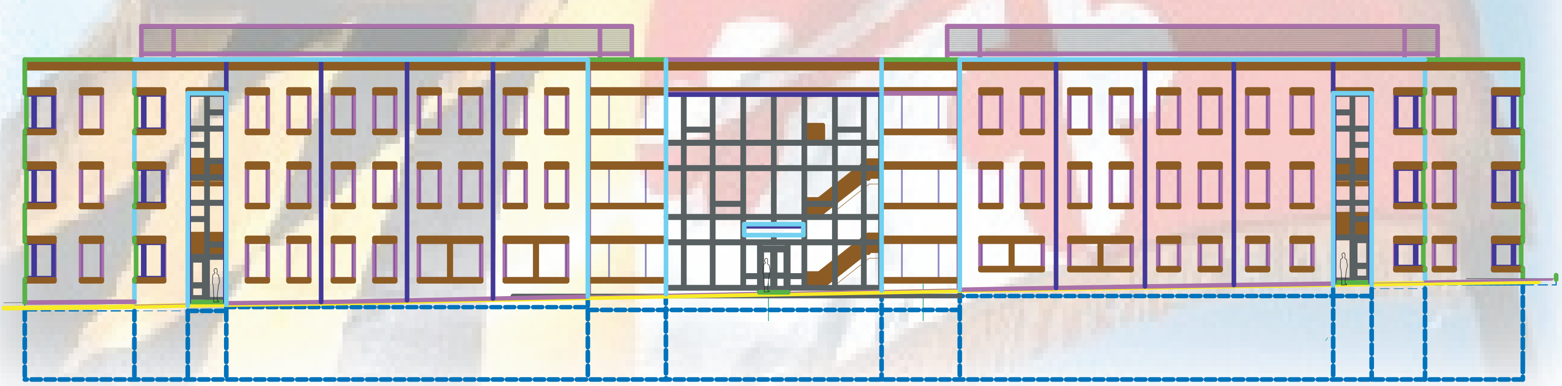
Electrical

The buildings main panel is a 2500KVA panel in the main electrical room in the basement. There are individual panels on each floor fed through a 3000KVA main switchgear.

Emergency power is provided by a generation facility located in the adjacent parking garage.

Structural

The building makes use of a braced steel frame. The columns support wideflange girders which in turn support open web joists.



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Thesis Introduction

The Johns Hopkins Hospital in Baltimore Maryland is currently nearing construction on a new building. The building is a medical office building (abbreviated as MOB in this report) for use as doctors' offices and hospital faculty offices. Currently the building uses a system picked for its low first cost. The system is a VAV system with packaged rooftop DX units, and all electric terminal reheat. The purpose of this thesis is to evaluate the MOB for utilization of a VAV system with chilled water cooling coils as well as the use of a DOAS system paired with active heated/chilled beam parallel system.

After the building details, as well as the existing system ventilation and energy analysis, the operation and merits of both standard VAV systems and DOAS systems is reviewed. The main calculation process for the new mechanical system for the MOB is shown in the equipment selection section. Analysis of the equipment for indoor air quality performance as well as a first cost and operating cost analysis round out the main mechanical depth work.

The report is closed with the breadth work. The first breadth topic is a cost impact study for the reduction in electrical distribution equipment without the DX units and all electric reheat system. The second is a constructability review for connection of the MOB with the remote source chilled water and steam generated on the far side of the block containing the MOB.

Section 1

Building Introduction

1.1 Purpose

The MOB is a new medical office building. The bottom two floors are tenant space consisting of examination rooms, non-invasive care rooms, such as dialysis rooms, blood infusion rooms and various ancillary spaces. The top two floors are mainly faculty space for Johns Hopkins Hospital staff as well as conference rooms.

1.2 Location

Along with the rest of the main Johns Hopkins Hospital campus, the MOB is located in Baltimore Maryland. It's situated along N. Wolfe St. just south of Orleans St. It's newly developed location makes it the new south eastern corner of the JHH campus, and puts it in proximity to a parking garage, a loading dock, the South of Orleans Energy Plant and an abandoned project.

1.3 Size

88,000 sq ft equally divided between four floors, with the basement being below grade.

1.4 Project Team

Architect – ZGF, Zimmer Gunsul Frasca Partnership
CM firm - Atlantic Builders
MEP firm – Leach Wallace Associates, Inc.
Structural – Columbia Engineers

1.5 Dates of Construction

June 2005 – Late March 2006

1.6 Project Delivery Method

Design-Bid-Build

1.7 Cost Information

Approximate project cost is 15.5 million.

Section 2

Existing Ventilation Analysis

2.1 Overview of Assumptions and Analysis

Each of the six existing rooftop units delivers mixed air at a10%OA ratio. The analysis of std. 62-2004 compliance took place at design air delivery values.

Because the MOB is somewhat of a specialized building, it contains many spaces not listed in ASHRAE std. 62-2004 table 6-1. The following table details their approximations as existing ASHRAE defined spaces.

Space Approximation Table

Category Approximated	MOB space name	occ rate/ 1000 sq ft	Rp (cfm/occ)	Ra (cfm/sq ft)
Office	exam, treatment, radiology, infusion, dialysis, files copy, work	5	5	0.06
main entry lobby	Lobby	7	7.5	0.06
corridor	Vest			0.06
pharmacy	Meds	10	5	0.18
reception	Waiting	30	5	0.06
conference	Consult	50	5	0.06
science laboratories	Lab	10	5	0.18

After the analysis in the Air Ventilation Spreadsheet, found in Technical Assignment 1, it was found that the original MOB design met ASHRAE std. 62-2004 guidelines. Below is listed the final conclusions on space ventilation demands from the MOB.

Zone Ventilation Conclusions

	AHU 1-2	AHU 3-4	AHU 5	AHU 6
SUM Vpz	33635	37765	17600	15040
Vpz*.1	**3364**	**3777**	**1760**	**1504**
SUM Vbz	2785	3043	863	972
Zp (max	0.249	0.247	0.236	0.243
Ev	0.9	0.9	0.9	0.9
Vou	**3095**	**3381**	**959**	**1081**
compliance	YES	YES	YES	YES

2.2 Ventilation Conclusions

At design conditions, the MOB satisfies ASHRAE std. 62-2004 requirements. However, one of the design goals of my thesis will be to purposely over ventilate many of the common spaces of the MOB as well as exam rooms. The logic here is that these rooms will often have contaminant generation of pathogenic viruses and germs from ill patients. An updated ventilation summary and comparison will be given later in the report.

Section 3

ASHRAE std. 90.1-2004 Energy Compliance

3.1 Background to ASHRAE std. 90.1-2004

Standard 90.1 is the general energy usage standard for ASHRAE. It is designed to encourage more efficient buildings. The method used to analyze the MOB was the building area method. This is a method whereby the building area is multiplied by an energy usage per unit area number. For the MOB this number was 1.1 W/sqft which is used for office buildings.

3.2 Energy Usage Conclusions

The MOB did not pass the building general electrical usage guidelines set out in ASHRAE std. 90.1-2004. The MOB electrical usage is based strictly on the number of circuits and average loading. The number may seem high, but even with an assumed load of only 8amps per circuit the building still is above compliance with std 90.1. The electrical usage totals also do not reflect the six packaged AHUs on the roof or the many electric reheat VAV boxes in the building.

Building General Energy Usage Chart

Area

Total Building Area	Exempted Area	Adjusted Area
88,260	491	87,769

Allowed Power Use

Allowed power density as per Std 90.1-2004 Table 9.5.1 for Building Area Method

Office Use (W/ft^2)	Adjusted Area	Total Power Allowed
1.1	87,769	**96,546**

Actual Power Use

Circuits	Unit Amperage	Voltage	Power (Watts)
44	15	277	**182,820**

Section 4

DOAS Supply Air Demands
vs.
VAV Supply Air Demands

4.1 VAV Supply Air Demands

The typical office HVAC application is currently a VAV set up. VAV stands for variable air volume. It works on the principal that air is supplied from the central air handling units at medium pressure to localized VAV boxes that regulate the amount of air each zone receives.

Cooling - The air, being at a temperature and humidity level suitable to remove both latent and sensible loads from the spaces based on a cooling application is modulated in accordance with zonal controls that monitor temperature and humidity. In the MOB, the AHUs supply air at 53 F with a wet-bulb temperature of 52 F.

Heating - Any heating needs are typically accomplished via either some sort of heating coils in the individual VAV boxes or in-room sensible heating such as baseboard heaters. The MOB has its heating needs satisfied via the individual VAV boxes which contain electrical resistance heaters.

Ventilation - Ventilation is delivered at design conditions from the supply air which is typically itself a mixture of recycled indoor air and outdoor air. In the MOB, at design conditions, the AHUs pull in 10% outdoor air each for a total of 11,400 cfm of outdoor air.

4.1.1 VAV airside Pros

-Satisfies cooling loads of space with only supply air.
-Relatively high supply cooling supply air temperatures reduce danger of cold drafts.
-With high volumes of supply air and filters installed particle contaminant levels fall quickly within space.

4.1.2 VAV airside Cons

-Supplies entire zone to the needs of the most demanding space within a zone.
-Low outdoor air percentage necessitates large volumes of supply air with high fan costs and increased size of ductwork.

4.2 DOAS Supply Air Demands

DOAS is an acronym for dedicated outdoor air system. Although its initial cost is often higher that standard VAV applications, it can often save both money and energy in the long run while delivering increased amounts of outdoor air to a space. In a DOAS system, the entire volume of supply air is non-recycled outdoor air. Despite this fact is has several critical differences from the 100% outdoor air systems that have been used in hospitals and buildings with sensitive security issues for years. In a 100% outdoor air system the air is supplied at similar parameters as the VAV system where a large volume of air is needed to remove sensible and latent loads from the space. DOAS does not approximate a standard VAV system in its supply air parameters. Supply air in a DOAS system is typically colder and therefore drier than the supply air of a VAV system. This means that the internal latent load demands as well as ventilation requirements are satisfied with a smaller volume of air. Since space sensible loads are still not satisfied with the small amount of air, a parallel cooling system, often chilled radiant panels or chilled beams are used to remove sensible load in excess of the supply airs removal capacity.

Cooling – The primary cooling purpose of DOAS supply air is to remove the entire latent load. It is important that the supply air be able to do this, because if the latent load is not removed it can cause problematic condensation on the parallel cooling equipment. To assure that the entire latent load is removed by the smaller volumes of supply air, the air itself is supplied at lower temperatures. The lower temperature of the supply air means that it is extremely low in moisture content and better able to remove humidity from the space. In the case of the MOB, air will be supplied at 45 degrees. Its moisture content is only 35 grains of moisture per pound of dry air as compared to the standard VAV supply air with 48 grains. This over doubles the supply airs latent removal capacity.

The second part of space cooling in a DOAS application is a parallel cooling system. Because the supply air volume is so low, it typically cannot successfully remove the sensible load. To remove excess sensible load, a parallel system is used within the individual spaces. Often times this parallel system is ceiling mounted chilled radiant panels. These panels approximately split the load removal between radiant heat transfer, which tends to improve thermal comfort, and convective heat transfer.

Parallel cooling in the MOB is achieved through a slightly different system called an active beam. A chilled beam is a device with extended heat transfer surfaces that increase its heat transfer capacity. An active chilled beam is a chilled beam that uses high induction nozzles coupled with the supply air to induce room air to flow past the heat transfer surfaces thereby increasing its convective heat transfer. The particular beams used in the MOB are active chilled and heated beams. They supply air via high velocity, high induction nozzles. The room air induced into the unit by the supply air, enters through a centrally located hydronic cooling or heating coil and then is redistributed to the room from the sides of the unit.

Heating – A secondary heating system is as important to a DOAS system as a parallel cooling system. This is because in a DOAS system the low supply temperatures create a danger of overcooling. Usually the systems used for parallel cooling cannot easily be made to provide heating. Chilled radiant panels and passive beams, if used to provide heat, tend to lead to stratification problems as the units themselves are located on the ceiling. However, in the MOB, the fact that the parallel equipment actively distributes air through induction means that heating can better be accomplished without worry of temperature stratification.

Ventilation – Ventilation in a DOAS system is improved over standard systems for that fact that all of the air supplied is outdoor air. Typically, the amount of supply air needed to remove the entire latent load is greater than the required air for ventilation. Therefore, DOAS systems almost always over ventilate the spaces they serve.

4.2.1 <u>DOAS airside Pros</u>

-Ventilation is greatly improved over standard systems.
-Smaller volume of supply air requires smaller HVAC equipment sizes as well as diminished duct sizes.

4.2.2 <u>VAV airside Cons</u>

-With lower volumes of supply air, some airborne particle contaminants may linger longer than with standard VAV applications.
- Without high induction diffusers, there is a danger of cold drafts in cooling conditions and temperature stratification under heating conditions.
-Parallel cooling system must be employed to meet sensible load requirements.

Section 5

HVAC Equipment Selection

Section 5.1

Current HVAC Equipment

5.1.1 System Basics

The MOB currently is served by six York packaged rooftop units using a DX cooling system. The units are rated at 21,000 cfm and 61 Tons of cooling each. These units were chosen primarily due of their low first cost. The AHUs are supported by a VAV system using fan powered boxes with all electric reheat coils. This system is easy to install since it has no plumbing associated with it and more importantly has a very low first cost compared to the other systems to be analyzed.

Current Design Supply Air – 114,036 cfm

This value determined from an individual fixture count.

Gross Cooling Capacity – 4,414 MBH (LWA specs)
Gross Sensible Capacity – 3,199 MBH (LWA specs)
Gross Latent Capacity – 1,215 MBH
Latent Removal at Design Airflow – 775 MBH

This value is based off of design air supply.
Determined by the following formula:

$$Qs = 0.68 \cdot CFM \cdot (Gra - Gsa)$$

Gra is 58Gr/lbma from the air parameters of 72F and 50%RH
Gsa is 48Gr/lbma from LWA specs
This represents 63% of system capacity for latent removal.

Gross Heating Capacity – 380 kW or 1,296,613 BTU/hr

This value is spread out amongst the 118 fan powered VAV boxes in the building.

5.1.2 Current DX AHU system electricity needs

Total Power

Two of the units are specified at 460V and 207 MCA
The other four units are specified at 460V and 184 MCA
Total Power = 2 * 460V * 207Amps/1.25 + 4 * 460V * 184Amps/1.25
The total maximum demand for all six rooftop units is 423 kW.
Part of this total it the 145.5 kW of the total fan energy

Coolant Circulation Power

Therefore the non-fan power consumption of the six rooftop units is 423kW-145.5kW
Total, non-fan, power consumption of rooftop units is 277.5 kW

Total AHU Electrical Power Use – 423 kW
Fan Power Use – 145.5 kW
Non-Fan Power Use – 277.5 kW
*****These figures do not include the 380 kW maximum heating capacity.

Section 5.2

Alternative #1 Standard VAV System with Water Cooled AHUs

5.2.1 System Basics

The first alternative for the MOB is simply replacing the inefficient packaged DX air handling units on the rooftop with more efficient units that utilize the nearby available chilled water. The powered VAV boxes will also be analyzed for use with hot water heating coils instead of electrical resistance heating coils.

This system will be a standard VAV application just like the current system. For this reason the supply air volume and parameters will remain the same. Just as the original system, Alternative #1 will use 10% outdoor air.

After investigation a York Custom air handling unit was selected that will provide the needed supply air capacity with six units configured in the same way the current system delivers air. The new units have a maximum cfm of 22,500 cfm but equipped with the same fan and total system pressure drop as the original system their capacity is closer to 21,000 cfm.

Supply Air – 114036 cfm
Gross Cooling Capacity – 4,074 MBH

This Value determined from the following equation
Total Cooling = Number of Units * (Sensible Load + Latent Load)
Sensible Load = 1.08 * SCFM * (T mixed air – T coil leaving air)
Latent Load = .68 * SCFM * (G mixed air – G coil leaving air)

$$Qt = 6 \cdot (1.08 \cdot 21000 \cdot (73.9 - 52.9) + 0.68 \cdot 21000 \cdot (62.2 - 48))$$

Gross Sensible Capacity – 2,858 MBH
Gross Latent Capacity – 1,216 MBH

The basic concept behind using a chilled water coil instead of a DX cooling coil is that the cheaper cost of central chilled water versus electricity offsets any losses from additional pumping necessary to deliver the chilled water to the site, through the cooling coils, and back to the central plant.

The electrical needs of the water cooled AHU will consist of fan energy, and pumping cost for circulation of the cooling water. Because the system is essentially the same system as the original DX system, fan power will be assumed to be the exact same. The pumping power for the fan powered box reheat coils will be considered separately.

5.2.2 Chilled Water Pump Selection

Pump selection is a function of the total system head loss as well as the volumetric flow rate of the chilled water.

System Head Loss

Because the same volume of chilled water is supplied and returned to the central plant, all pipe sizes for the AHU cooling water will be the same. The main run from the central plant to the MOB is 432 feet. The vertical rise through the building is 55 feet. The rooftop delivery will be approximated as a 150 foot long pipe which will be long enough to distribute from the southern mechanical chase to the units on the north side of the roof. The following friction factor and flow velocity was found from the flow rate table for Schedule 40 steel piping on page 33.5 of ASHRAE Fundamentals Handbook 1997.
Flowrate = 680 gpm
Pipe Size – 6”
Frictional Loss – 2.8 feet wg per 100 feet of piping
Flow Velocity – 7.2 FPS

The following formula was used to compute overall piping pressure losses.
Supply pressure = total length * frictional loss + vertical rise height
Return pressure = total length * frictional loss – vertical fall height

$$SupplyPressure = (432 + 55 + 150) \cdot \frac{2.8}{100} + 55$$

$$ReturnPressure = (432 + 55 + 150) \cdot \frac{2.8}{100} - 55$$

Total system piping pressure loss = 73 ft – 37 ft = 36 ft wg

The cooling coil head loss is approximated from a similar coils internal pressure drop from Carrier’s AHU builder v.5.42.
Cooling coil pressure loss = 12.3 ft wg.

Total System Head Loss = 36 + 12.3 **= 48.3 ft wg**
Total System Flowrate = 680 gpm
Pump Selected – Bell & Gossett 5x5x9 ¾ 1750RPM with a 9 ¾ “ impeller and a 12 hp motor rated at 72% efficiency

Water Cooled AHU system electricity needs
Pumping Power

Pumping Power is dependant on the total system head loss as well as the volumetric flow rate of the chilled water as shown above.

Pump electrical power = pump horse power *.746/efficiency

Pumping Power = 12.4 kW

Fan Power
The same fan power is used as the original system of 145.5 kW.
Total AHU Electrical Power Use – 158 kW
Fan Power Use – 145.5 kW
Pumping Power Use – 12.4 kW
***** These totals do not include pumping cost and fan cost for fan powered VAV boxes with hot water heating.

5.2.3 <u>Hot Water Pump Selection</u>

Pump selection is a function of the total system head loss as well as the volumetric flow rate of the hot water.

System Head Loss
The pumping distance for hot water will only be from the basement mechanical room where a steam-water heat exchanger will be located, to the various floors of the building, through the distribution to the fan coil units, and then back to the basement.

The following friction factor and flow velocity was found from the flow rate table for Schedule 40 steel piping on page 33.5 of ASHRAE Fundamentals Handbook 1997.
With a flowrate of 216 gpm the following pipe sizes were found.

Riser Pipe Size – 4”
Frictional Loss – 2.7 feet wg per 100 feet of piping
Flow Velocity – 5.5 FPS

Floor Main Branch Pipe Size – 2”
Frictional Loss – 1.3 feet wg per 100 feet of piping
Flow Velocity – <3 FPS

Floor Individual Distribution Pipe Size – 1 ¼ ”
Frictional Loss – 1.7 feet wg per 100 feet of piping
Flow Velocity – <3 FPS

The following formula was used to compute overall piping pressure losses.
Supply pressure = total length * frictional loss + vertical rise height
Return pressure = total length * frictional loss – vertical fall height

$$\text{SupplyPressure} = \frac{80 \cdot 2.7 + 25 \cdot 1.3 + 129 \cdot 1.7}{100} + 50$$

$$\text{ReturnPressure} = \frac{80 \cdot 2.7 + 25 \cdot 1.3 + 129 \cdot 1.7}{100} - 50$$

Water - Air coil Pressure Drop – 8.1 ft wg approximated from Lytron water coil selector.
Steam – Water coil Pressure Drop – 12 ft wg
Total System Head Loss = 54.7ft – 45.3ft + 8.1ft + 12ft = 29.5 **=> 32 ft wg**
Total System Flowrate = 216 gpm
Pump Selected – Bell & Gossett 4x4x9 ¼ L 1150RPM with a 9 3/8 “ impeller with a 2.5 hp motor rated at 73% efficiency

Section 5.3

Alternative #2 DOAS System Paired with Enthalpy Wheel and Parallel Active Heated/Chilled Beams

5.3.1 System Basics

The second alternative for the MOB is again replacement the inefficient packaged DX air handling units on the rooftop with more efficient units that utilize the nearby available chilled water. However this time the units will be serving a DOAS system that requires less supply air. Because the units supply less air in a DOAS application, fewer units will be used. Overall the energy demands as a whole should be diminished because of the lessened amount of supply air needing to be treated. In addition to the air handling units, a parallel system for removal of sensible load and heating will be used.

After investigation, a York Custom air handling unit paired with a Semco enthalpy wheel was selected that will provide the needed supply air capacity with only three units supplying all spaces within the building. The new units have a maximum cfm of 19,000 cfm but are designed to operate at just below 17,000 cfm per unit.

The design method for the DOAS application is shown in the appendix in the Parallel Equipment Sizing Spreadsheet. System set points are based initially off of the larger of the latent load or ventilation requirements of individual spaces. In most cases, the space had excess sensible load not removed by the minimum supply air. To remove the sensible load, either the supply air volume was increased or a chilled beam was introduced to the space. Because the Trox beams can function as either chilled or heated beams, they were only added for heating purposes to spaces that had a heating demand and were not already equipped with a beam for cooling.

Because the chilled beams have recommended air volumes per set cooling capacity, different amounts of supply air are sent through the unit depending on how much cooling capacity is needed from the beam. Beam specifications are given in the parallel system sizing section.

Current Design Supply Air – 49,581 cfm

This value determined from air needed to remove latent load from fixture count method.

Maximum Supply Air – 57,000 cfm
Gross Cooling Capacity – 3,333 MBH
AHU Cooling Capacity – 3,113 MBH
Parallel Design Cooling – 220 MBH
Gross Sensible Capacity – 1,896 MBH
Gross Latent Capacity – 1,217 MBH

Gross Heating Capacity – 884,381 BTU/hr (259 kW)

This value is based off the all of the parallel units being used for maximum heating.

The basic goal of DOAS is that the lowered electrical and thermal loads of supplying lower volumes of air and using parallel cooling and heating systems will save money over the long run versus a relatively inefficient VAV system.

The electrical needs of the DOAS system will consist of fan energy for the AHU, pumping cost for circulation of the cooling water to the AHU, cooling water to the parallel units and heating water to the parallel units.

5.3.2 <u>Chilled Water Pump Selection</u>
Pump selection is a function of the total system head loss as well as the volumetric flow rate of the chilled water.

System Head Loss
Because a lower volume of chilled water is supplied and returned to the central plant versus the Alternative #1, the pipes will be resized using the flow rate table for Schedule 40 steel piping on page 33.5 of ASHRAE Fundamentals Handbook 1997. The main run from the central plant to the MOB is 432 feet. The vertical rise through the building is 55 feet. The rooftop delivery will be approximated as a 110 foot long pipe which will be long enough to distribute from the southern mechanical chase to the unit on the north side of the roof.
The following friction factor and flow velocity was found from the flow rate table for Schedule 40 steel piping on page 33.5 of ASHRAE Fundamentals Handbook 1997.

Flow Rate – 556 gpm
Pipe Size – 6”
Frictional Loss – 1.9 feet wg per 100 feet of piping
Flow Velocity – 6 FPS

The following formula was used to compute overall piping pressure losses.
Supply pressure = total length * frictional loss + vertical rise height
Return pressure = total length * frictional loss – vertical fall height

$$SupplyPressure = (432 + 55 + 110) \cdot \frac{1.9}{100} + 55$$

$$ReturnPressure = (432 + 55 + 110) \cdot \frac{1.9}{100} - 55$$

Total system piping pressure loss = 66.3 ft – 43.7 ft = 22.6 ft wg

The cooling coil head loss is approximated from a similar coils internal pressure drop from Carrier’s AHU builder v.5.42.
Cooling coil pressure loss = 20.4 ft wg.
The increased water pressure drop is due to the large volume of water supplied to the three units.

Total System Head Loss = 22.6 + 20.4 **= 43 ft wg**
Total System Flowrate = 556 gpm
Pump Selected – Bell & Gossett 6x6x9 ¾ 1750RPM with a 7 ¾ “ impeller and a 7.5 hp motor rated at 77% efficiency

Water Cooled AHU system electricity needs
Pumping Power
Pumping Power is dependant on the total system head loss as well as the volumetric flow rate of the chilled water as shown above.

Pump electrical power = pump horse power *.746(kW/hp)/efficiency

Pumping Power = 7.3 kW

Fan Power
The fan power for the DOAS application is found by using the same system static pressure drop of 3.8 inches wg as LWA spec’d for the existing units but lowering the supply volume from the old 21,000 cfm capacity to the new 19,000 cfm capacity.

Using the Greenheck product selection guide a fan speed of 1250RPM and 17hp per unit was found. Assuming an electrical efficiency of .8 the fan electrical power can be calculated in the equation below.

$$\mathrm{Fan}_{\mathrm{Electrical,Power}} = 3 \cdot \mathrm{Fan}_{\mathrm{Horse,Power}} \cdot \frac{0.746}{\mathrm{Efficiency}}$$

Total AHU Electrical Power Use – 54.9 kW
Fan Power Use – 47.6 kW
Pumping Power Use – 7.3 kW
***** These totals do not include pumping costs for the parallel system hot and cold water loops.

Section 5.4

Enthalpy Wheel Selection

5.4.1 Enthalpy Wheel Basics

A crucial part of any DOAS system is some sort of energy recovery system. In any system the outdoor air used may be at an undesirably high or low temperature, as well as being too humid or too dry. In comparison, return air is very close to optimal temperature and humidity parameters. In a standard system, the outdoor air is brought closer to the necessary parameters by simply mixing it with the return air before mechanically treating the air. However, in a DOAS system the outdoor is completely unadulterated by return air. Therefore a different method of removing sensible and latent energy from the air during cooling conditions and adding sensible and latent energy during the heating season is needed.

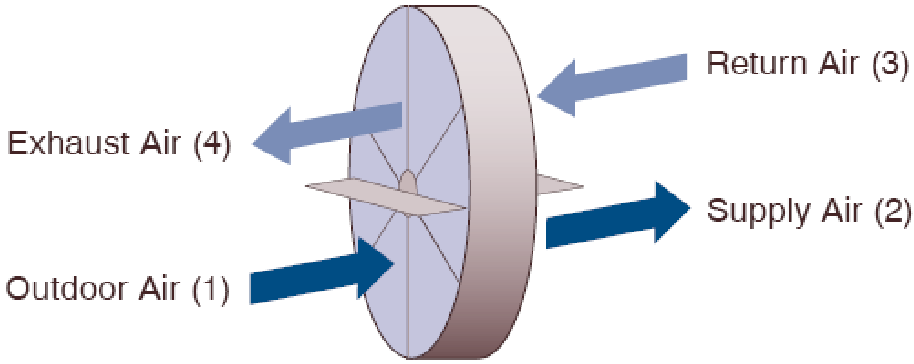
This is where an enthalpy wheel finds its use. An enthalpy wheel uses a single wheel to transfer both sensible and latent energy between airstreams. The sensible load is transferred via the aluminum wheel spokes themselves. The latent energy is transferred by a more sophisticated system. The aluminum spokes are coated in desiccant that is structured with three angstrom holes within itself. For a reference value, this is six times the diameter of an atom of Hydrogen. The holes give the desiccant the quality of being a selective absorption medium, transferring water vapor but not other contaminants, in addition to greatly increasing its surface area and therefore water affinity.

5.4.2 Enthalpy Wheel Sizing

The first step in sizing an enthalpy wheel is determining the amount of supply air needing to be treated. In the case of the MOB, the maximum supply air is 19,000 cfm. Using the Semco sizing chart, TE3-43 wheel was selected. This unit has a maximum flow rate of 21,450 cfm and a resultant face velocity of 500 fpm. The fact that the MOB design value is lower than this means the face velocity will be lower and the efficiency higher than what it's rated for. The efficiency rating for this wheel is 82.5 for transfer for both latent and sensible energy. This efficiency rating represents the percent of difference in either dry bulb temperature or grains of moisture between the return air and the outdoor air able to be transferred. It is represented with the following equation.

$$\text{Efficiency} = \frac{X1 - X2}{X1 - X3}$$

$$X2 = X1 - \text{Efficiency} \cdot (X1 - X3)$$



This Efficiency equation is applied to the outside air to generate the wheeled outside air in the System Sizing Spreadsheet in the appendix.

5.4.3 Enthalpy Wheel Freezing Precaution

Because the wheel will operate at very low outdoor air temperatures during the heating season, it is important to check that it not be in danger of becoming frosted. The procedure from Semco to determine whether this is a danger is as follows.

Step 1

Locate the RA point on the psychometric chart.

Step 2

Locate winter outdoor design condition (ASHRAE Fundamentals 1997 99.6% heating DB) Connect the two points with a straight line.

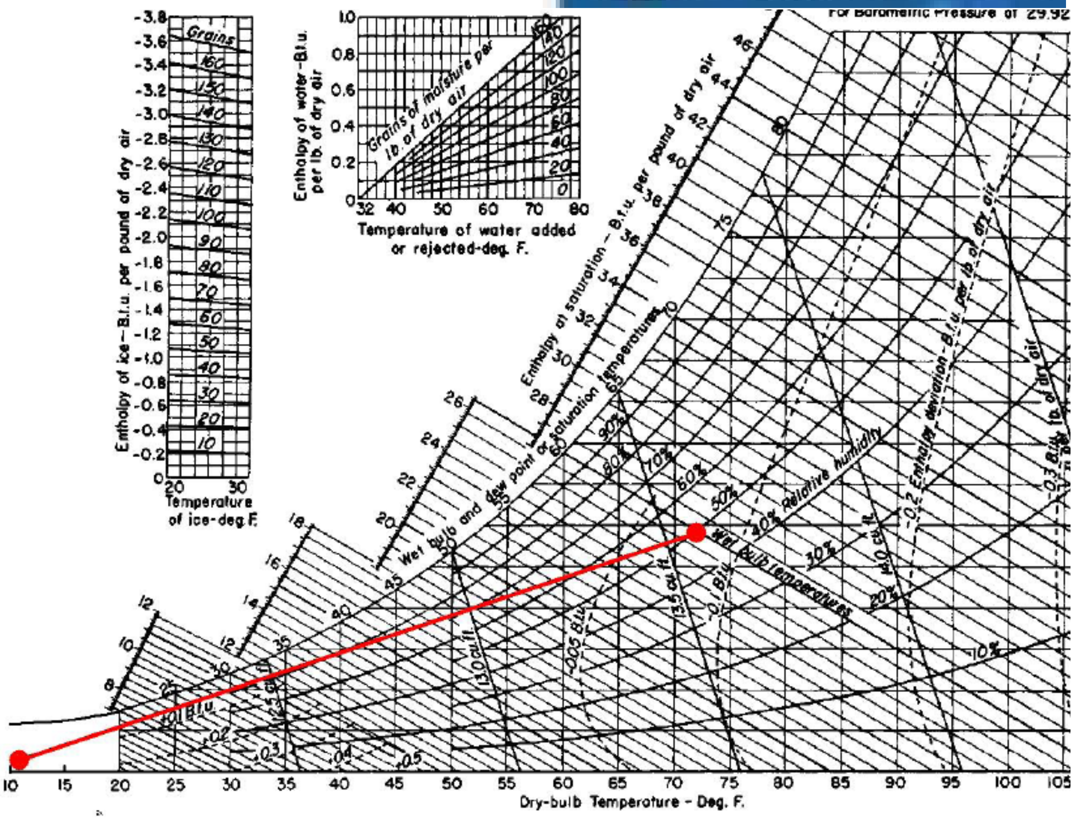
Step 3

Determine the higher dry bulb temperature at which this line intercepts the saturation curve.

Step 4

Add 2 degrees F to this point and make that the system set point for preheating.

In the MOB application the line never reaches the system saturation curve because of Baltimore's relatively mild winter temperatures. This negates the need for preheating. The psychometric chart diagram used for steps one and two is shown below.


For Barometric Pressure of 29.92
Enthalpy of ice – B.t.u. per pound of dry air
Grains
Temperature of ice-deg. F.
Enthalpy of water-B.t.u. per lb. of dry air
Grains of moisture per lb. of dry air
Temperature of water added or rejected-deg. F.
Enthalpy at saturation – B.t.u. per pound of dry air
Wet bulb and dew point or saturation temperatures
Relative humidity
Wet bulb temperatures
Enthalpy deviation-B.t.u. per lb. of dry air
Dry-bulb Temperature - Deg. F.

5.4.5 Wheel Cross Contamination Concerns

One of the main concerns with inclusion of an enthalpy wheel in an all outdoor air system is the contamination of the incoming outdoor air from the wheel that is also in contact with the exhaust air stream.

The following pollutants were independently tested by the Georgia Tech Research Institute. Notice the independently verified water transfer efficiency.

Pollutant Tested	Pollutant Concentration*	Measured Cross-Contamination
Isopropanol	20 ppm	None
Methyl-Isobutyl-Ketone	1840 ppb	None
Xylenes	7100 ppb	None
Carbon Dioxide	500 ppm	None
Propane	82 ppm	None
Sulfur Hexafloride	212 ppm	None
Water Vapor	4000 ppm	80%
*Concentrations selected by GTRI to reflect worst case for typical application		

5.4.6 Wheel Control

Much like an airside economizer, an enthalpy wheel need not operate all of the time at full capacity. There are also times when the outdoor air parameters are closer to the supply air parameters than the return air is. In these cases, the wheel is actually impairing system performance.

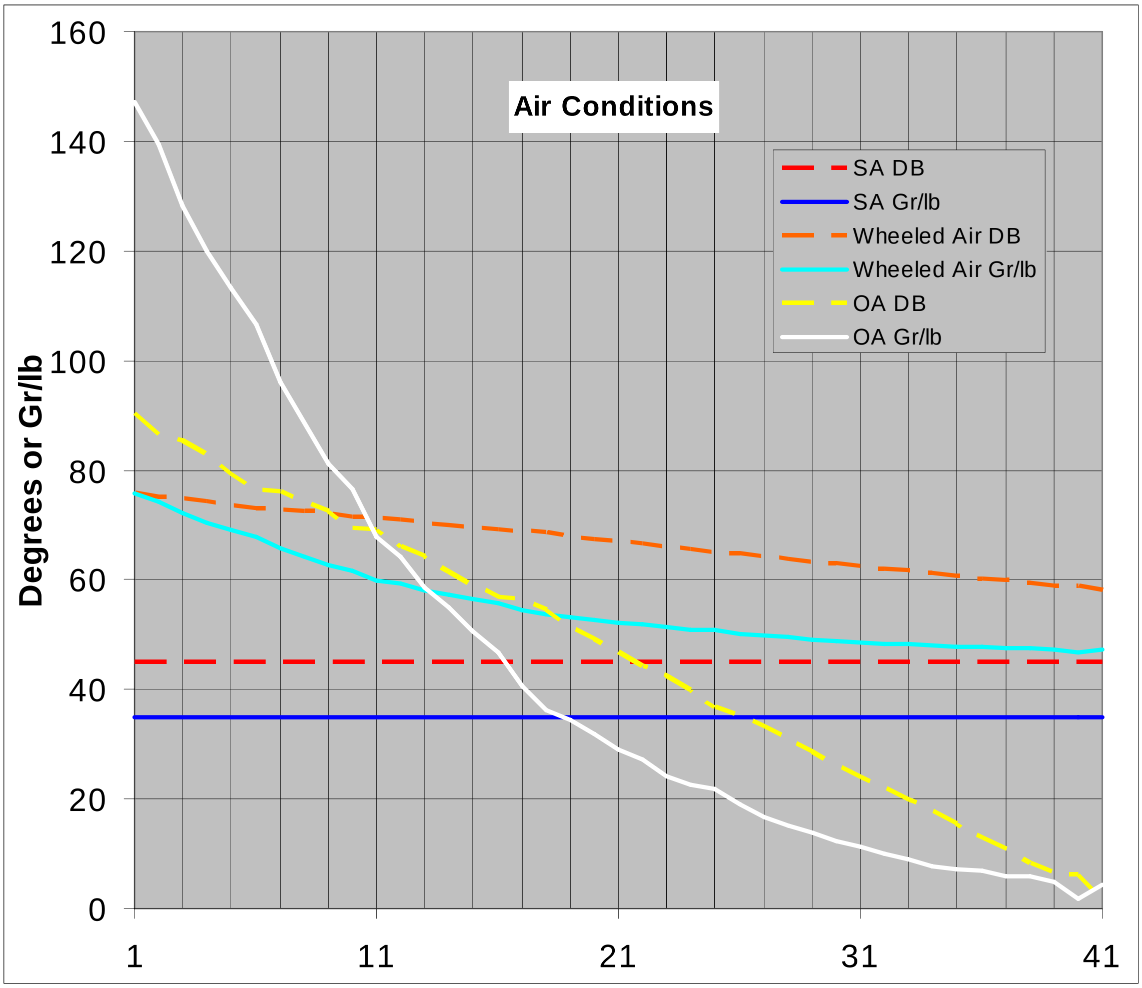
The following graphs were generated by using BIN weather data for Baltimore, MD. The enthalpy wheel is .8, the return air parameters for are 72 degrees F and 58 Gr/lb.

<u>Trial One</u>

Total Cooling Energy with E-Wheel at Full Capacity

The following graph shows the outdoor parameters, return air parameters, and air parameters after being pre-treated by the enthalpy wheel. The three following graphs are based on the values found in the E-Wheel Chart in the appendix. This graph represents the enthalpy wheel operating at full capacity all of the time.

Air Parameters with E-Wheel at Full Capacity



The point in this graph where it would be more economical for sensible performance to use only outside air is where the outside air dry bulb temperature line (dotted yellow) dips below the wheeled air dry bulb temperature (dotted orange). Likewise for latent performance the point is where the white line representing outdoor air water content dips below the light blue line which represents air water content after the enthalpy wheel.

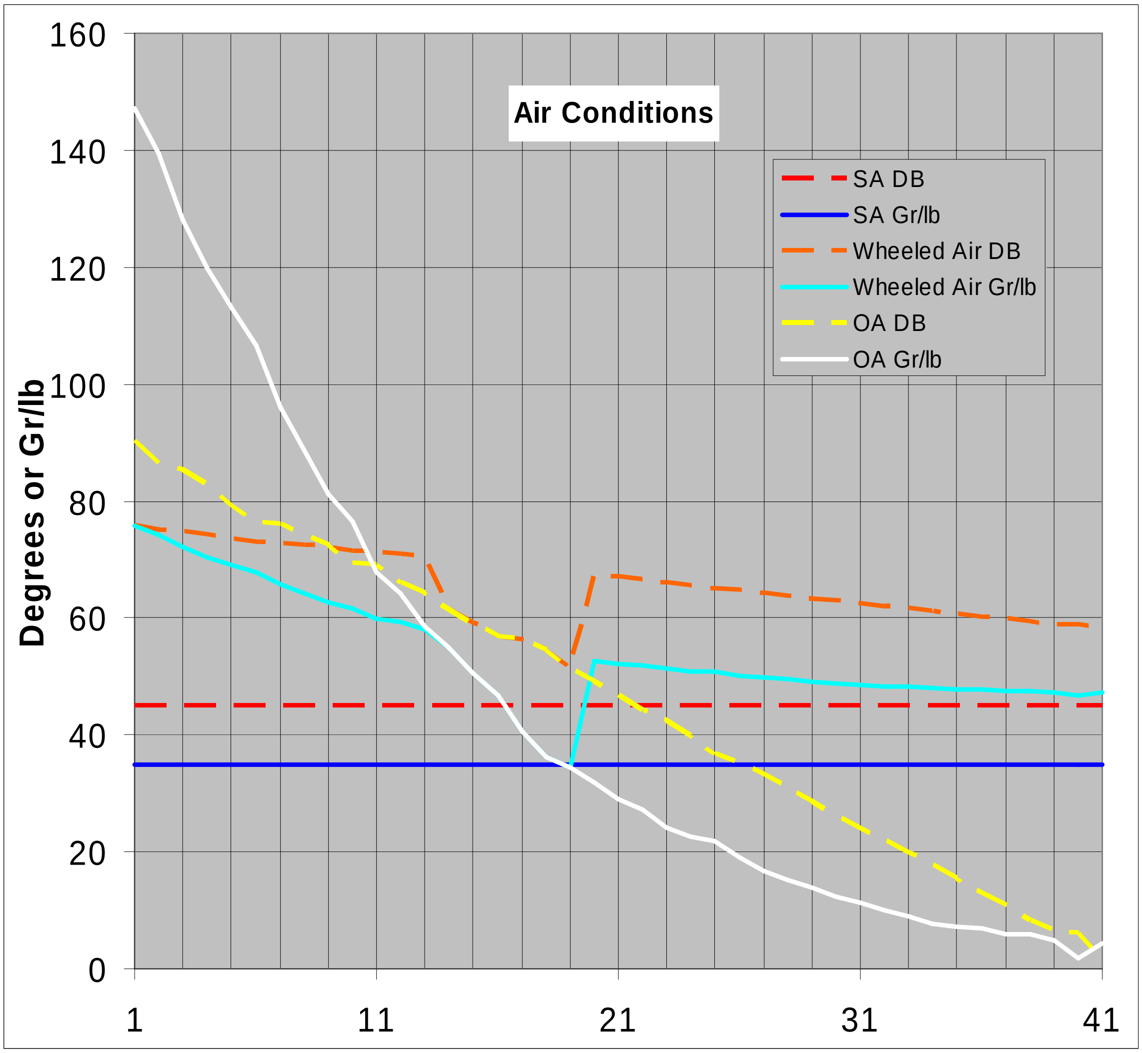
Resultant Total Cooling Energy – 19,532 MMBTU

Trial Two

Total Cooling Energy with Free Cooling when Available

In this trial, the E-Wheel is disused when the latent outdoor latent parameters are between the wheeled air and the minimum supply air latent level. In other, when free cooling is available it is used until overcooling occurs.

Air Parameters with Free Cooling



In this trial, outdoor air is used as soon as the outdoor latent parameters drop below the wheeled air latent parameters as seen at the x-value of thirteen. Once there is an occasion of overcooing as at the x-value of nineteen, the wheel is turned on again to full capacity.

Resultant Total Cooling Energy – 17,861 MMBTU

This value is an 8.5% savings over the E-Wheel being used at full capacity all of the time.

Trial Three

Total Cooling Energy with Free Cooling and Modified E-Wheel use

In this trial, the E-Wheel is disused when the latent outdoor latent parameters are between the wheeled air and the minimum supply air latent level just as before. However, once the outdoor air parameters drop below the desired supply air parameters, the E-Wheel is used at part capacity to warm up the air. The energy transfer capacity of the E-Wheel is assumed to be in a direct linear relationship with the rotation speed of the wheel. This relationship is expressed by the following equation.

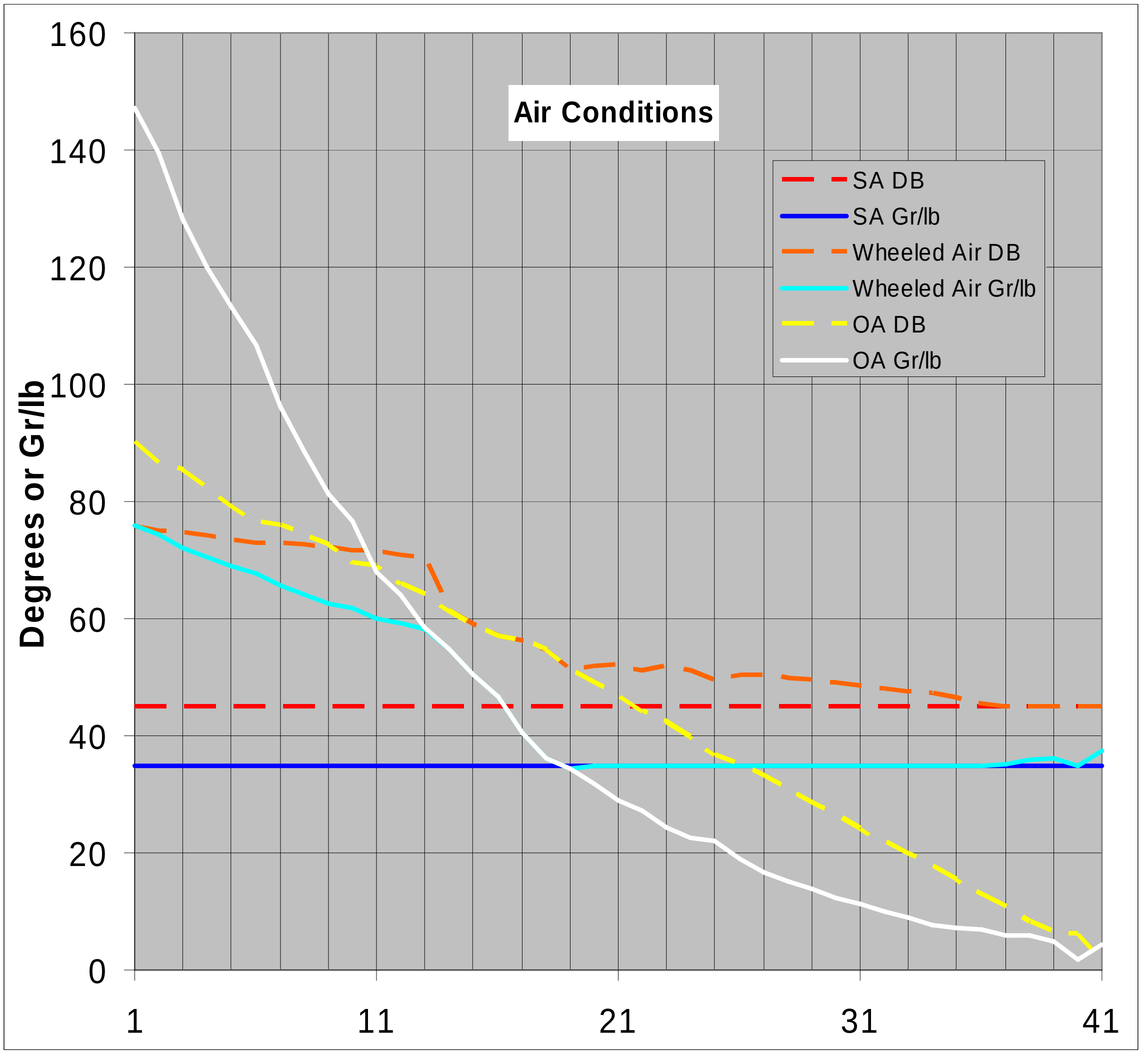
$$Gr = Gr_{oa} - X \cdot 0.8 \cdot (Gr_{oa} - Gr_{ra})$$

This formula simplifies to the formula below, where X equals wheel spin rate as a percentage of full capacity spin rate.

$$X = \frac{Gr_{oa} - 35}{0.8 \cdot (Gr_{oa} - Gr_{ra})}$$

Using this equation the wheel spin rates found in the E-Wheel Chart in the appendix were found. Below is the graph corresponding to this trial.

Air Parameters with Free Cooling and Modified E-Wheel use



In this chart it is evident that latent load was the controlling factor since it exactly matches the desired air parameters from the point when the outside air begins overcooling to the point at the x-coordinate of thirty-seven, where this scheme caused sensible overcooling.

Resultant Total Cooling Energy – 11,134 MMBTU

This value is a 43% savings over the E-Wheel being used at full capacity all of the time. This value is a 38% savings over the E-Wheel with free cooling.

*Note – This savings will not correlate directly to the overall system performance since it does not include parallel system loads. This comparison was conducted simply to evince the savings possible with intelligent E-Wheel control.

Section 5.5

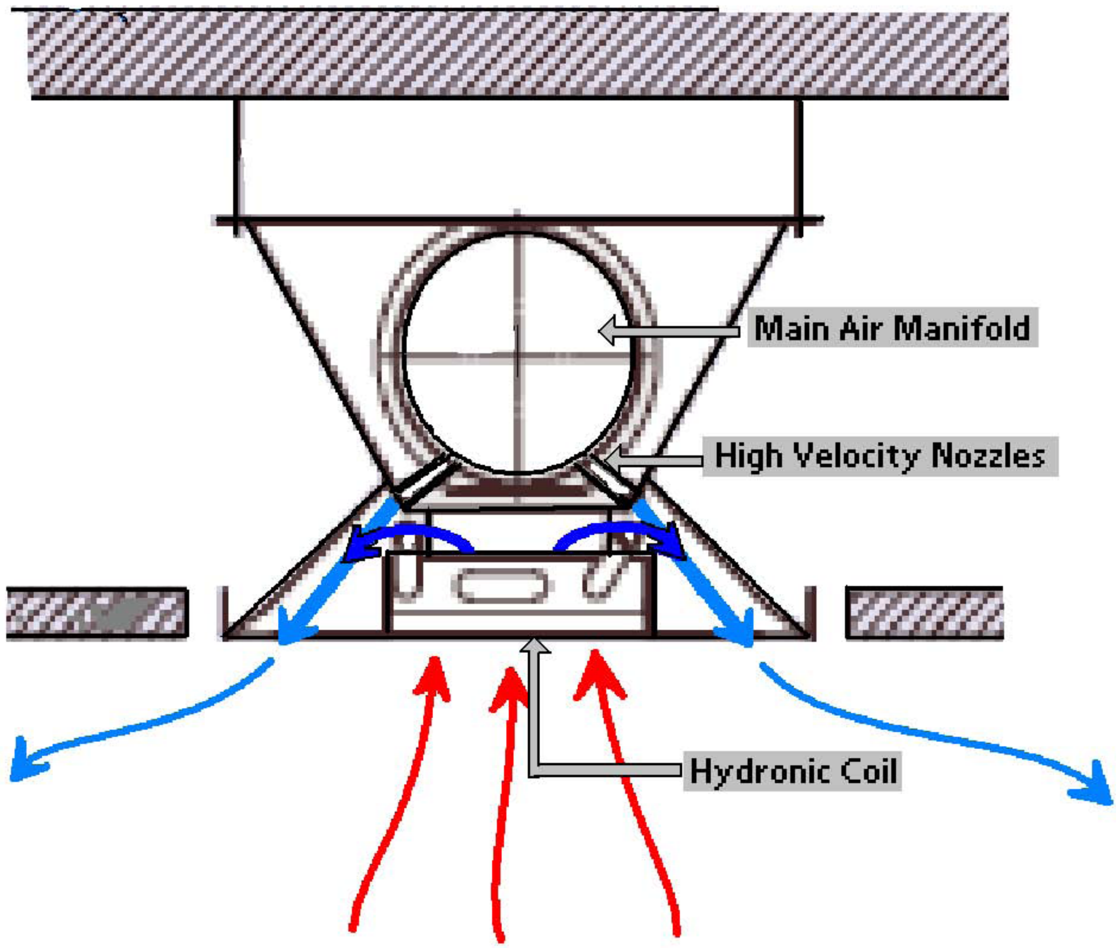
Parallel Equipment Design

5.5.1 Parallel Equipment Basics

Because the supply volumes in a DOAS system are so low, they often cannot remove the entire sensible load in a space. Likewise, if the space has heating needs, they cannot be accommodated by the centrally supplied cold air. For this reason, a parallel system is needed to enable the mechanical system to properly treat the individual spaces.

In the MOB, auxiliary heating and cooling needs will be met by active heated and chilled beams. Active beams are supply terminals that use high velocity, and therefore low pressure, supply air to induce room air through the unit. While passing through the unit, the room air can be either heated or chilled via a centrally located hydronic coil before being mixed with the supply air and delivered to the room. A diagram of the active beam is shown below.

Trox Active Heated/Chilled Beam Section



5.5.2 Parallel System Sizing

The cooling or heating capacities of the beams are determined by the primary airflow and the resulting change in temperature of the water in the hydronic coil. The chilled beams are supplied with water from the main AHU cold water return. This water is mixed with domestic cold water to a temperature of 60 degrees F. The heated beams are supplied hot water from a steam to water heat exchanger in the basement mechanical room. The hot water is at 150 degrees F. The charts below show the unit specific cooling, primary air, water flow rate, temperature change and water pressure drop. These are the values that were used in both the System Sizing Spreadsheet in the appendix.

900mm (2.95ft) long Trox Active beam
Cooling Application

Secondary Air Cooling (BTU/hr)	Needed Primary Air (cfm)	Chilled Water Flowrate (gpm)	Water Temp Rise (degree F)	Water Pressure Drop (ft wg)
427	25	0.59	1.8	0.49
491	32	0.62	1.98	0.49
543	38	0.63	2.16	0.49
587	45	0.63	2.34	0.49
624	51	0.62	2.52	0.49
659	57	0.61	2.7	0.49

1200mm (3.94ft) long Trox Active beam
Cooling Application

Secondary Air Cooling (BTU/hr)	Needed Primary Air (cfm)	Chilled Water Flowrate (gpm)	Water Temp Rise (degree F)	Water Pressure Drop (ft wg)
1174	34	0.61	2.34	0.59
1262	42	0.61	2.7	0.59

900mm (2.95ft) long Trox Active beam
Heating Application

Secondary Air Heating (BTU/hr)	Needed Primary Air (cfm)	Hot Water Flowrate (gpm)	Water Temp Drop (degree F)	Water Pressure Drop (ft wg)
256	21	0.24	2.7	0.1
341	21	0.24	3.6	0.1
444	21	0.25	4.5	0.1
682	25	0.27	6.3	0.1
819	25	0.57	3.6	0.1
918	25	0.28	8.3	0.1
1051	32	0.27	9.7	0.1
1157	38	0.28	10.4	0.1
1320	47	0.28	12.1	0.1

1800mm (5.91ft) long Trox Active beam
Heating Applicaton

Secondary Air Heating (BTU/hr)	Needed Primary Air (cfm)	Hot Water Flowrate (gpm)	Water Temp Drop (degree F)	Water Pressure Drop (ft wg)
2474	106	0.28	22.5	0.1

5.5.3 <u>Parallel Equipment Cold Water Pump Selection</u>
Pump selection is a function of the total system head loss as well as the volumetric flow rate of the hot water.

System Head Loss

The pumping distance for parallel cooling water will be from the basement mechanical room where a tap off the AHU return water will be located, to the various floors of the building, through the distribution to the parallel cooling beams and then back to the basement.

The following friction factor and flow velocity was found from the flow rate table for Schedule 40 steel piping on page 33.5 of ASHRAE Fundamentals Handbook 1997. With a flowrate starting at 277 gpm and diminishing to 20 gpm the following pipe sizes were found.

Flow Rate – 277 gpm
Basement to First Floor Plenum Riser Pipe Size – 4”
Frictional Loss – 4.5 feet wg per 100 feet of piping
Flow Velocity – 7 FPS

Flow Rate – 191 gpm
First Floor Plenum to Third Floor Plenum Riser – 4”
Frictional Loss – 2.2 feet wg per 100 feet of piping
Flow Velocity – 5 FPS

Flow Rate – 50 gpm
Southern Feeder Pipe Size – 2 ½ ”
Frictional Loss – 2 feet wg per 100 feet of piping
Flow Velocity – 3.4 FPS

Flow Rate – 20 gpm
Southern Branch Pipe Size – 1 ½ “
Frictional Loss – 3 feet wg per 100 feet of piping
Flow Velocity – 3.1 FPS

Because this piping service is smaller and more complicated than those previously considered for the rooftop AHUs it will be calculated in the segments above. It will also have elbows and splitters factored into its head pressure loss.
The Equation below accounts for straight pipe losses and fitting losses. The fitting losses are calculated on an equivalent straight pipe length method and modified for the ratio of fluid flow rate in stream of interest to the fluid flow rate in the alternate flow path.

Pressure Drop =2*(length*frictional loss + number of equivalent elbows♦*equivalent length of fitting♦♦)*frictional loss
♦From Figure 4 on page 33.6 of ASHRAE Fundamentals Handbook 1997
♦♦From Table 6 on page 33.6 of ASHRAE Fundamentals Handbook 1997

$$First_{Riser,Head} = 2 \cdot (24 + 0.1 \cdot 13.1 + 0.13 \cdot 10.5) \cdot \frac{4.5}{100}$$

$$Second_{Riser,Head} = 2 \cdot (24 + 0.6 \cdot 10.6 + 4 \cdot 9.5) \cdot \frac{2.2}{100}$$

$$Southern_{Feeder,Head} = 2 \cdot (25 + 6.2 + 5.6) \cdot \frac{2}{100}$$

$$Southern_{Branch,Head} = 2 \cdot (119 + 4.2 + 4.2) \cdot \frac{3}{100}$$

Piping Head Drop = 14.51 ft wg
Water - Air coil Pressure Drop – 0.49 ft wg
This value from equipment manufacturer cut sheet
Total System Head Loss = 14.51 + 0.49 **= 15.0 ft wg**
Total System Flowrate = 277 gpm
Pump Selected – Bell & Gossett 5x5x9 ¾ 1150RPM with a 7 ¾ " impeller and a 1.5 hp motor rated at 74% efficiency

Active Beam Parallel Cooling system electricity needs
Pumping Power
Pumping Power is dependant on the total system head loss as well as the volumetric flow rate of the chilled water as shown above.

$$Fan_{Electrical,Power} = 3 \cdot Fan_{Horse,Power} \cdot \frac{0.746}{Efficiency}$$

Pumping Power = 1.5 kW

5.5.4 Parallel Equipment Hot Water Pump Selection

Pump selection is a function of the total system head loss as well as the volumetric flow rate of the hot water.

System Head Loss
The pumping distance for hot water will only be from the basement mechanical room where a steam-water heat exhchanger will be located to the various floors of the building, through the distribution to the parallel heating beams and then back to the basement.

The following friction factor and flow velocity was found from the flow rate table for Schedule 40 steel piping on page 33.5 of ASHRAE Fundamentals Handbook 1997. With a flowrate starting at 126 gpm and diminishing to 15 gpm the following pipe sizes were found.

Flow Rate – 126 gpm
Basement to First Floor Plenum Riser Pipe Size – 3"
Frictional Loss – 3.5 feet wg per 100 feet of piping
Flow Velocity – 5.3 FPS

Flow Rate – 87 gpm
First Floor Plenum to Third Floor Plenum Riser – 3"
Frictional Loss – 1.8 feet wg per 100 feet of piping
Flow Velocity – 3.8 FPS

Flow Rate – 25 gpm
Southern Feeder Pipe Size – 1 ½ "
Frictional Loss – 4.8 feet wg per 100 feet of piping
Flow Velocity – 3.9 FPS

Flow Rate – 15 gpm
Southern Branch Pipe Size – 1 ¼ "
Frictional Loss – 4 feet wg per 100 feet of piping
Flow Velocity – 4 FPS

Because this piping service is smaller and more complicated than those previously considered for the rooftop AHUs it will be calculated in the segments above. It will also have elbows and splitters factored into its head pressure loss except in the main feeder where the high flow through ratio makes the losses to the main flow path negligible. The Equation below accounts for straight pipe losses and fitting losses. The fitting losses are calculated on an equivalent straight pipe length method.

Pressure Drop =2*(length*frictional loss + equivalent length of fitting♦♦)*frictional loss
♦♦From Table 6 on page 33.6 of ASHRAE Fundamentals Handbook 1997

$$\text{First}_{\text{Riser,Head}} = 2 \cdot 24 \cdot \frac{3.5}{100}$$

$$\text{Second}_{\text{Riser,Head}} = 2 \cdot 24 \cdot \frac{1.8}{100}$$

$$\text{Southern}_{\text{Feeder,Head}} = 2 \cdot (25 + 4 + 4.4) \cdot \frac{4.8}{100}$$

$$\text{Southern}_{\text{Branch,Head}} = 2 \cdot (119 + 3.7 + 3.7) \cdot \frac{4}{100}$$

Piping Head Drop = 15.9 ft wg
Water - Air coil Pressure Drop – 0.1 ft wg
This value from equipment manufacturer cut sheet
Steam – Water coil Pressure Drop – 7 ft wg

Total System Head Loss = 14.51 + 0.49 **= 23 ft wg**
Total System Flowrate = 126 gpm
Pump Selected – Bell & Gossett 4x4x9 ¼ 1150RPM with a 7 3/8 " impeller and a 1.25 hp motor rated at 62% efficiency

Active Beam Parallel Heating system electricity needs
Pumping Power

Pumping Power is dependant on the total system head loss as well as the volumetric flow rate of the chilled water as shown above.

$$Fan_{Electrical,Power} = 3 \cdot Fan_{Horse,Power} \cdot \frac{0.746}{Efficiency}$$

Pumping Power = 1.5 kW

Section 6

Indoor Air Quality Comparison with VAV and DOAS

6.1 Basics on Increased IAQ with DOAS

Aside from energy savings, DOAS has another major advantage over traditional systems. That is the increased level of indoor air quality provided by the 100% outdoor air supply. By not recycling air contaminants too small to be picked up by the filter, DOAS dilutes and removes contaminants much more efficiently than standard systems using mixed air.

Anyone who has been to the doctors' office with a cold of some type, replete with a depressed immune system, can identify with the alarming feeling of being surrounded by people with communicable illnesses. Indoor air quality in a medical office building, although not as critical as facilities with invasive medical procedures or high security risks, is of elevated concern as compared to a normal office building.

6.2 Calculation of Indoor Air Contaminant Levels

In the MOB, contaminant dilution is modeled by using CO2 analysis on a per occupant basis and comparing VAV systems to DOAS systems.

The following formulas are used for determining the current concentration of CO2 in the particular space. The first equation is using a the current VAV system where 90% of the air is re-circulated through the space. The two supply air terms are because of the two sources of supply air; outside air, and return air.

$$C = \frac{Vsa \cdot Camb \cdot 0.1 + Vsa \cdot Cprev \cdot 0.9 - Vra \cdot Cprev}{Volume} + Gocc \cdot Occ \cdot \frac{1000000}{Volume} + Cprev$$

The next equation is for a DOAS application where none of the air is re-circulated. Because none of the air is re-circulated, all of the supply air is outside air, with a low concentration of CO2.

$$C = \frac{Vsa \cdot Camb - Vra \cdot Cprev}{Volume} + Gocc \cdot Occ \cdot \frac{1000000}{Volume} + Cprev$$

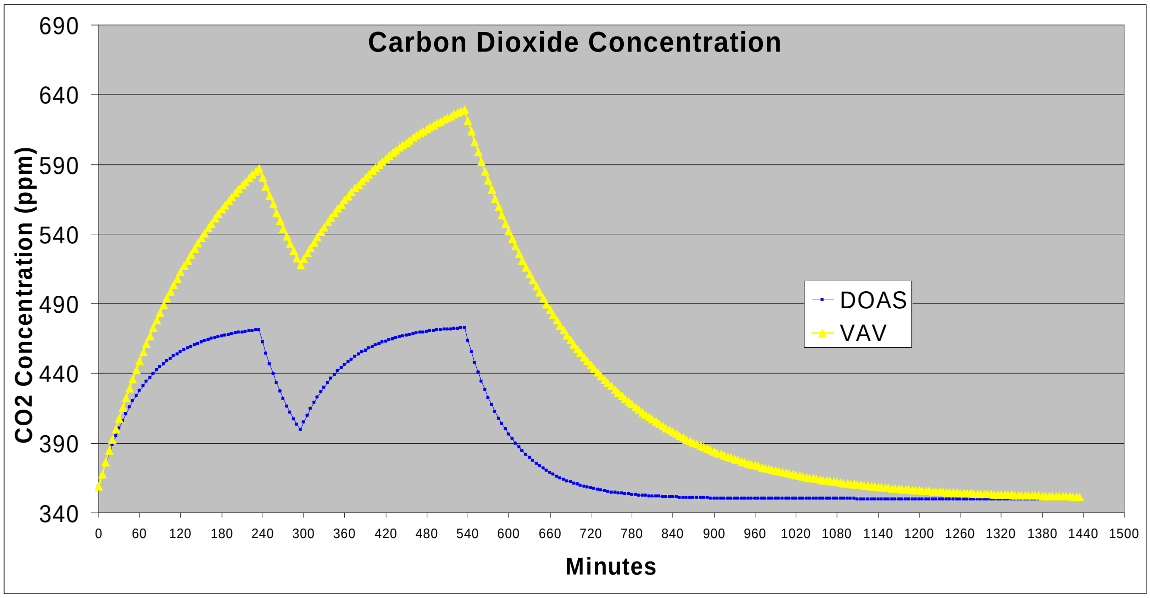
Where C = current concentration (ppm)
Vsa = supply air volume (cfm)
Camb = outside air ambient concentration (ppm)
Cprev = inside air concentration from previous time sample (ppm)
Vra = return air volume (cfm)
Volume = volume of space (ft^3)
Gocc = Generation rate per occupant (cfm)
* 0.31 l/s was used as an occupant generation rate as per ASHRAE std. 62-2004
Occ = number of occupants in space

The Spreadsheet for generation of the following charts is CO2 Diffusion in the appendix.

6.3 Spaces Modeled for Contaminant Levels

When applied to two different rooms in the MOB, the advantage of using DOAS becomes apparent in both lowering of steady state contaminant concentrations and increasing the rate of contaminant dilution. The following graph shows CO2 levels within an office, 3073, on the third floor of the MOB. The yellow line represents the current VAV system and the blue line representing the proposed DOAS system.

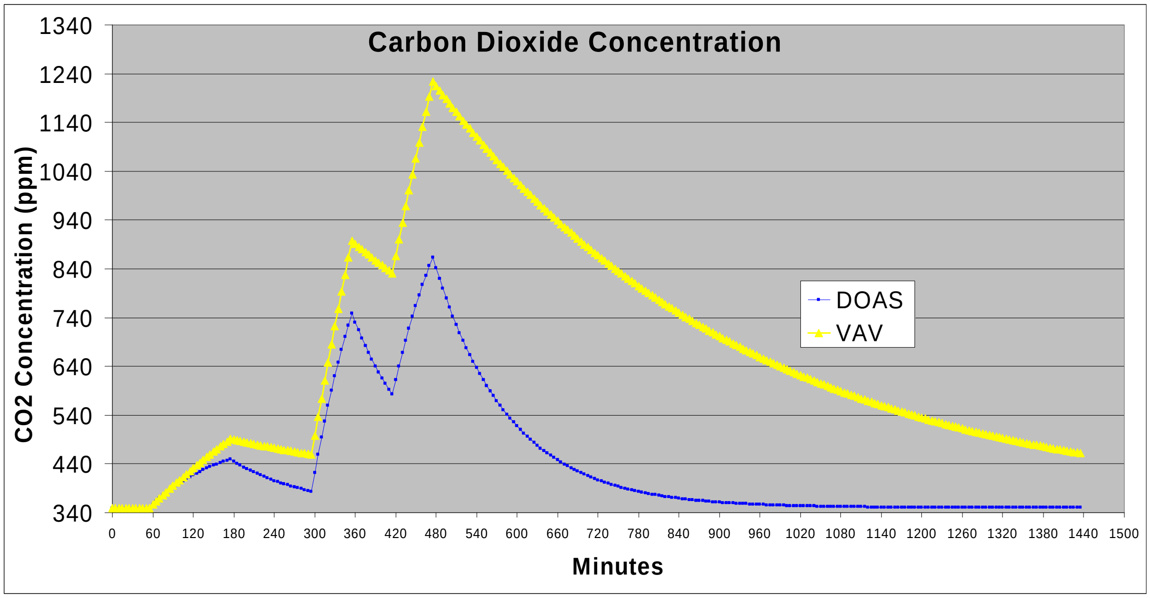
Office 3073, CO2 Dilution



In this graph, the curves represent an eight hour work day with one occupant. The dip beginning at 240 (12:00), and ending at 300 (1:00), represents the lunch hour when the office is unoccupied.

This graph represents a conference room, Room 3080, with intermittent use. Because the room is not constantly occupied and may actually only be occupied a very small percent of the time, a diversity factor is employed in VAV design that reduces the amount of people the space is assumed to be occupied by.

Conference Room 3080, CO2 Dilution



In the morning there are two people using the space for two hours. The shallow dip in levels is the hour before a lunch and the lunch hour, when the conference room is unoccupied. After 300 there is a one hour meeting with twelve people, a one hour break and another one hour meeting, again with twelve people to round out the day. As you can see, because of the diversity factor used in VAV sizing, the ventilation allows a large increase in contaminant concentration when the room is at full occupancy. The DOAS system keeps the contaminant levels significantly lower than that of the currently utilized system.

6.4 <u>Conclusions on DOAS Ventilation</u>

Overall, the DOAS system outperforms the existing VAV arrangement in terms of IAQ. The DOAS system keeps the rooms at a lower contaminant level. It does this because its steady state concentration is lower do to the increased volume of outdoor air. This is evident on the graph of room 3073, where the DOAS system almost reaches steady state concentration while the VAV is clearly not near steady state yet despite its maximum level being over twice as high above ambient concentration as that of the DOAS system.

The DOAS system also reduces the concentration of contaminant faster than the VAV system. This is shown in the graph of room 3080, where the DOAS concentration drops sharply after the first and second meetings as compared to the VAV systems slower decay of contaminant levels.

Section 7

Economic Analysis

7.1 Differing Economic Factors

In any mechanical system there are two main economic considerations the designer takes into account when deciding how to approach the problem. These two factors are the first cost, which covers the initial investment and the operating cost, which includes energy costs and maintenance.

What will the initial price of the buildings systems be? How much will the owner pay up front for the system? Often these questions drive design. This is the case in the MOB. The packaged DX cooling units are pretty much the cheapest option for treating a space. The same can be said about the electric reheat VAV boxes. The individual components of both option #1 and option #2 are higher in first cost.

The operating cost is more of a measure of system efficiency and often comes at a higher premium. The operating cost includes the rate of the driving energy, be it electricity, gas, oil, or other. The operating cost typically also includes maintenance costs. In the MOB the operating cost was of secondary importance to the first cost.

7.2 First Cost Analysis

The first cost of the three systems, Existing, Alternative #1, and Alternative #2 was analyzed in terms of its individual components. Where applicable, Costworks 2005 was used to generate unit costs. Unit quantities for piping were generated from drawing take-offs.

Below is the totaled cost information for the first cost analysis of the MOB. For detailed cost breakdown, reference the First Cost Spreadsheet in the appendix.

First Cost Totals

Assembly Totals	Existing VAV system with DX cooling	242,930.00
	Alt #1 VAV system with chilled water cooling	379,035.00
	Alt #2 DOAS system with chilled water cooling	269,683.20
	Parallel System of Active Heated/Chilled Beams	290,830.30
	Existing VAV box system with electric reheat	109,530.00
	Existing VAV box system with hot water reheat	140,846.40

Combined Totals	Existing system	352,460.00
	Alt #1	519,881.40
	Alt #2	560,513.50

7.2.1 Conclusions on First Cost

The first cost analysis is not surprising. The existing system has a much lower price tag than both Alternative #1, and Alternative #2. Unlike both of those systems, there is no cost for extra piping. The air handling units themselves are also cheaper than the water cooled AHUs used for the two redesigned systems. Much of the increased price for the DOAS system is the cost of the parallel system. The beams themselves, are of English origin and do not have a large market in the US. Also, perhaps they are more economically used in large, open plan office buildings where they will never be used at part capacity as many of the heating beams in the MOB are. However, in the MOB, the danger of overcooling within the many smaller spaces necessitated more units. There were also instances where the inclusion of multiple units where fewer units may have been with a higher volume of supply air per unit. Both of these factors pushed the overall number of beams up. All of this combined to cause the parallel system to negate any of the cost savings of the fewer DOAS AHUs as compared to the other two alternatives.

7.3 Operating Cost Analysis

The operating cost for the existing system and Alternative #1 as applied to the MOB were generated by using Carriers Hourly Analysis Program. HAP did not return a reasonable cost for the DX cooling, other than fan energy cost. For this reason the fan cost from HAP was combined with the annual non-fan energy as per LWA circuit sizing specifications to generate the annual operating cost of the existing DX/VAV system. The electrical system capacities in the System Sizing Spreadsheet in the appendix reflect the LWA supplied sizing. The Values are slightly higher than those determined by Leach Wallace Associates, Inc. However, they are in the same ratio as the costs from LWA and only nine percent higher for the existing system cost and six percent higher for the Alternative #1 cost.

The annual operating cost for Alternative #2, the DOAS system, was not generated using HAP because of its unreliability in evaluating DOAS systems. Instead the DOAS annual operating cost was scaled from the chilled water VAV operating cost by comparing the amount of fan, pumping and chilled water energy used annually. The values for fan energy, chilled water consumption and pumping energy are found in the System Sizing Spreadsheet in the appendix.

Annual Operating Cost Comparison Chart

	Annual Operating Cost (Dollars)	Reference Operating Cost (as per LWA) (Dollars)	Annual Cost Savings vs DX (Dollars)
Existing	165,509	151,399	0
Alternative #1	130,004	122,263	35,505
Alternative #2	106,603		58,906

7.4 Simple Payback Period Analysis

The simple payback period is determined by dividing the difference in cost of two systems by the annual savings.

Alternative #1 vs. Existing System

For alternative #1 as compared to the existing system, the simple payback period is determined as below.
(FC_alt#1 – FC_exist) / (OC_exist – OC_alt#1) = Payback Period
($519,881 - $352,460) / $35,505 per year = **4.7 Years**

Alternative #2 vs. Existing System

For alternative #2 as compared to the existing system, the simple payback period is determined as below.
(FC_alt#2 – FC_exist) / (OC_exist – OC_alt#2) = Payback Period
($560,514 - $352,460) / $58,906 per year = **3.5 Years**

Alternative #2 vs. Alternative #1

For alternative #2 as compared to the existing system, the simple payback period is determined as below.
(FC_alt#2 – FC_alt#1) / (OC_alt#1 – OC_alt#2) = Payback Period
($560,514 - $519,881) / $23,401 per year = **1.7 Years**

7.4.1 Payback Analysis Conclusions

Despite the increased first costs of both the chilled water and steam reheat VAV system, and most notably the DOAS system with parallel active beams, they both showed favorable payback periods. However, in a building that has substantial tenant space, such as the MOB, it is unlikely that either would be selected over the initially cheaper DX system with electric reheat.

Section 8

Breadth Topic #1, Electrical System Resizing for DOAS Application

8.1 Existing Electrical Equipment Supporting Mechanical Systems

The current system is served by eleven separate panel boards. These panel boards were found in the electrical power section of the MOB plans. The breakdown of panel boards is as follows:

Existing Panel Description Chart

Quantity	Amperes	Voltage	MCB/MLO	Service to
1	100	208Y/120	MCB	FCU-1, ACCU-1
1	800	480	MLO	AHU-1,2,5
1	800	480	MLO	AHU-3,4,6
1	300	480Y/277	MLO	FCUs, Hot Water Heater
7	225	480Y/277	MLO	FCUs

With the exception of the 100Amp panel board, all of these panel boards are directly related to the building AHUs and terminal reheat units. The 100Amp panel board is out of the scope of this report because the split DX system it powers is used only for the elevator mechanical room and will not be considered for change.

With the introduction of the DOAS system with parallel beams, the central driver for the system will change from electricity to remotely supplied chilled water and steam. The electrical portion of the overall system will go from a primary role, as in high fan energy, and electrical resistance heating to a supporting role, as pumping energy and reduced fan energy.

-Overall the amount of electrical equipment needed to support the AHUs will be cut in half with the number of units.

-The panel boards serving the heavy loads of the many FCUs with their electric reheat will instead be replaced by a panel board(s) serving pumps to circulate the water to the parallel equipment.

8.2 Alternative #2 Electrical Equipment

The system electrical equipment to be used in Alternative #2 is as follows is listed below. The corresponding amperage of the equipment is determined with the following equation.

$$kW = \sqrt{3} \cdot Voltage \cdot Amperage$$

Three AHU Fan - 15.9kW, 480V, 19Amps
One Main Chilled Water Pump – 7.3kW, 480V, 9Amps
One Parallel System Chilled Water Pump – 1.5kW, 480V, 2Amps
One Parallel System Hot Water Pump – 1.5kW, 480V, 2Amps

Even though the entire system Amperage is only 70Amps, conveniently small enough to be placed on one 100Amp panel board, two 100Amp, 480V panel boards will be used.

8.3 Comparison of Electrical Equipment for Existing Equipment and Alternative #2

Currently the electrical equipment cost for the MOB is valued by Costworks 2005 at $24,380. The exact component designations and RS Means Codes can be found in the First Cost Spreadsheet in the appendix.

The proposed two panel boards are valued at $1,260 each. This value is also found in the First Cost Spreadsheet in the appendix.

This makes the total cost savings in supporting electrical equipment from switching from the existing system to DOAS the following.

Cost Savings - $21,860 = $24380 – 2 * $1,260

Section 9

Constructability Review of Connection of Chilled Water And Steam to the MOB from the S. of Orleans Energy Plant

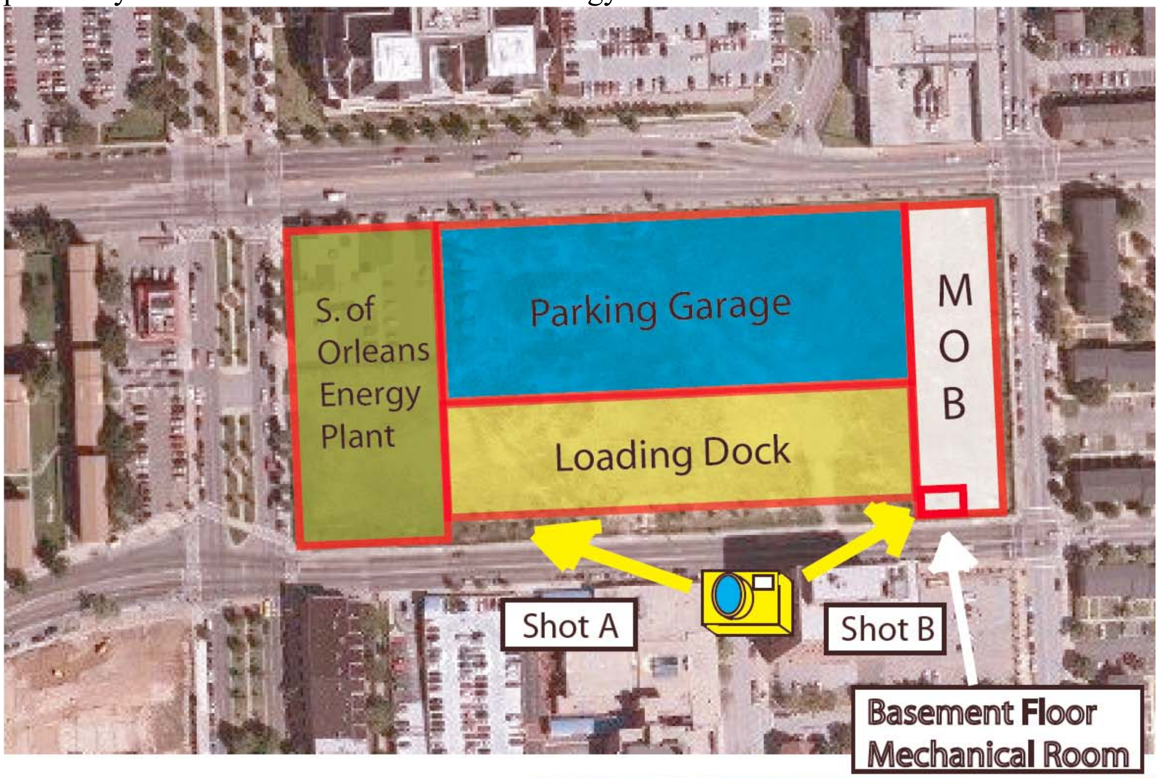
9.1 Overview of Supplying the MOB with Steam and Chilled Water

The central plant from which the MOB will draw its chilled water and steam from in the alternative #1 and #2 schemes is located across the block from the MOB. Between are two new buildings. These buildings are a parking garage on the Orleans St. side and a Loading Dock on the Fayette St. side.

The South of Orleans Energy Plant is approximately 450feet away from the MOB. The easiest way to access the MOB basement mechanical room is through the adjoining loading dock. The photo below shows the area where the MOBs southwestern corner will intersect with the loading dock. In this picture is a decrepit tree, to the left of that and in the background, is a condemned project, and in front of that is a bright yellow excavator. This excavator is approximately where the MOB's Basement main mechanical room is located. This is where the supply and return for the chilled water and steam need to enter and exit the building.

A better overview of the entire block is shown on the next page.

This is the entire block layout with two perspective pictures showing the relative proximity of the South of Orleans Street Energy Plant and the MOB.



9.2 <u>Site Limitations to Installation of Chilled Water and Steam Piping</u>

Installation of the piping raises very few site issues as compared a similar endeavor at a typical job site. This is because the entire block is being developed at the same time. The MOB was planned early enough to facilitate whatever solution was decided upon for the piping route. There are two options for locating the piping for steam and chilled water.

9.2.1 Option One: Buried Pipes

The entire block that the MOB is situated on was developed at the same time and from naught. This made it possible for Johns Hopkins Hospital to bury the steam and chilled water lines in what was at that time, an empty field.

Pros -No impact on planned loading dock.
-The Main Mechanical Room that the pipes need to meet is below grade, so the pipes are closer to their intended destination.
-Pipes are in no danger of damage from equipment in the loading dock.

Cons -Buried utilities may cause schedule delays.
-Access to the pipes will be limited by the overlying concrete slab.

9.2.2 Option Two: Pipes Running Along the Ceiling of the Loading Dock

Because the Loading Dock literally connects points A and B running the pipes, exposed through the loading dock is also an option. Because it an aesthetically unimportant building, to the point of having a barrier wall in front of it, the addition of the pipes would have minimal impact on the building.

Pros -Installation cost may be less expensive without having to deal with excavation.
-Avoids any possible problems with existing underground utilities.
-Pipes will be easily accessible.

Cons -Will necessitate additional fasteners and possibly structural changes to the loading dock.
-Pipes will need to be brought below ground through an area in construction to reach the main mechanical room in the MOB.
- There may be increased risk of damage to the pipes from the equipment activity in the loading dock.

9.3 Schedule Impact of Installation of Chilled Water and Steam Piping

The construction in question is installing piping from the South of Orleans Energy Plant to the MOB. The only length of the piping actually inside the MOB is the few feet entering the mechanical room and supplying the main air handler chilled water pump and the steam-water heat exchanger. For this reason schedule impacts will be limited to those incurred independently of the MOB itself. Such interruptions could include the following:

-With buried pipes, conflicting space demands with existing buried utilizes
-Poor weather impeding excavation of the buried pipe trench.
-Modification of the wall or ceiling structure to the loading dock to accommodate suspended piping.
-Space conflicts with the crew installing the suspended pipe and other tradesmen.

9.4 Conclusion on Constructability of Steam and Chilled Water Piping for the MOB

Overall, the construction of steam and chilled water piping from the South of Orleans Energy Plant to the MOB should be very simple. This is because the entire block has been designed and constructed at the same time, allowing for inclusion of such piping. The area between the MOB and the Energy Plant was originally an empty field able to accommodate buried piping. Suspended piping is also an option because the building between the Energy Plant and the MOB directly connects the two buildings. It is also a purely utilitarian structure and should be well able to accept or be modified to accept the piping.

Thesis Conclusion

In this report the MOB, a medical office building at Johns Hopkins Hospital, was redesigned to use a chilled water VAV system and a DOAS system with parallel active heated/chilled beams.

After the method of design was shown for the MOB both of the systems were evaluated for indoor air quality performance. It was found that the MOB would benefit in terms of indoor air quality from the introduction of a DOAS system, with its high rate of outdoor air supply. The evaluation of the MOB also showed both of the systems to be economically viable options with relatively short payback periods.

The buildings breadth topics analyzed the proposed systems for non-mechanical impact on the MOB. The constructability breadth topics showed that the supply and return piping for the chilled water and steam would not have been a problem to install. Additionally, the electrical supply analysis breadth topic showed that the reduction in electrical support equipment for Alternatives number one and two is significant.

Overall, both the chilled water VAV system and the DOAS application were found to be attractive options for redesign of the Johns Hopkins Hospital MOB.

Oustide Air			Wheeled Outside Air			Inside Air			Mixed Air			Coil Leaving Air			Coil Leaving Air (DOAS)		
ASHRAE Fundamentals 1997 1%DD			Assume .8 efficiency for both latent and sensible			72 F 50% RH			90% RA 10% OA			Same as LWA spec equipment			All values based on 45 F leaving DBT and 90%RH		
DB (F)	WB (F)	Gr	DB (F)	WB (F)	Gr	DB (F)	WB (F)	Gr	DB (F)	WB (F)	Gr	DB (F)	WB (F)	Gr	DB (F)	WB (F)	Gr
91	74	100	75.8	62.8	66.4	72	60	58	73.9	61.4	62.2	52.9	50.4	48	45	41	35

Total Supply Air (from fixture count) **114036 CFM**

Latent Load			
Interior Cooling	Conventional	775,445	(BTU/h)
	DOAS	775,445	(BTU/h)
Coil Latent Load	Conventional	1,101,132	(BTU/h)
	DOAS	1,058,651	(BTU/h)
Conventional	needed CFM	114,036	(cfm)
DOAS	needed CFM	49,581	(cfm)

Sensible Load			
Interior Cooling	Conventional	2,352,335	(BTU/h)
	DOAS	1,445,778	(BTU/h)
Coil Sens Load	Conventional	2,586,336	(BTU/h)
	DOAS	1,649,258	(BTU/h)
Remaining DOAS load for Parallel cooling system		906,556	(BTU/h)

Existing Cooling Systems	CFM cap per unit (CFM)	Units	CFM/unit (6 units) (CFM)	**Total Cooling Cap (BTU/h)**	Latent Cooling Cap (BTU/h)	Sensible Cooling Cap (BTU/h)	Max Elec Use (kW)	Normal Elec Use (kW)	Total Fan Power (hp)	Total Fan Energy (kW)
York DX packaged units	21000	6	19,006	4,074,336	1,216,656	2,857,680	423		156	145.5

Fan electrical power assumes .8 efficiency

Conventional Cooling Systems

	CFM cap per unit (CFM)	Fan cap per unit (CFM)	Units	CFM/unit (6 units) (CFM)	**Total Cooling Cap (BTU/h)**	Latent Cooling Cap (BTU/h)	Sensible Cooling Cap (BTU/h)	Inlet H_2O Temp (F)	Outlet H_2O Temp (F)	Delta T H_2O (F)	Coil Effectivenes (ε)	Chilled H_2O Rate (lb/hr)	**Chilled H_2O Rate (gpm)**	Chilled H20 Heat Gain (BTU/h)	Pumping Power (hp)	Pump Elec Power (kW)	Total Fan Power (hp)	Total Fan Energy (kW)
York Custom AHU with max 45sqft water coil area.	22,500	21,000	6	19,006	**4,074,336**	1,216,656	2,857,680	38	53	15	0.8	339,528.00	**679.33**	5,092,920	12	12.4	156	145.5
				Tons/unit=	**56.6**							gpm/unit=	**113**					

Mdotw*1BTU/(lb*F)*(Tow-Tiw)*ε=1.08*19006*(74-53)+.68*19006*(62.2-48)

Fan Power assumes same ESP and SA volume as LWA specs
Fan electrical power assumes .8 efficiency

Hydronic Heating System

	Box Size (kW)	Box Size (kW)	Box Size (kW)	Box Size (kW)	Box Size (kW)	Box Size (kW)	Box Size (kW)	Box Size (kW)	Box Size (kW)	Box Size (kW)	Box Size (kW)	Box Size (kW)	Box Size (kW)	
Hydronic Heating Coils in Fan Powered VAV Boxes	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	380
Unit Heat Demand (BTU/hr)	5,118	6,824	8,530	10,236	11,942	13,648	15,354	17,060	18,766	20,472	22,178	23,884	25,590	199,602
Incedence	6	16	21	39	5	12	7	3	3	1	2	1	2	118
Hot Water Flowrate (gpm)	5.1	18.2	29.9	66.6	10.0	27.3	17.9	8.5	9.4	3.4	7.4	4.0	8.5	**216.2**
Unit Cost (Dollars)				137.23										

Unit Costs from Lytron Product Selector
Hot Water Flowrate assumes .8 coil efficiency
Hot Water Flowrate assumes 15 degree Delta T

Selected Motor hp =	2.5
Motor Efficiency =	0.73
Input Power (kW) =	2.55

DOAS Cooling Systems

	CFM cap per unit (CFM)	Fan cap per unit (CFM)	Units	CFM/unit (3 units) (CFM	**Total Cooling (BTU/h)**	Latent Cooling (BTU/h)	Sensible Cooling (BTU/h)	Inlet H_2O Temp (F)	**Outlet H_2O Temp (F)**	Delta T H_2O (F)	Coil Effectivenes (ε)	Chilled H_2O Rate (lb/hr)	**Chilled H_2O Rate (gpm)**	Chilled H20 Heat Gain (BTU/h)	Pumping Power (hp)	Pump Elec Power (kW)	Total Fan Power (hp)	Total Fan Energy (kW)
York Custom AHU with max 45sqft water coil area.	22,500	19,000	3	16,527	**3,113,112**	1,217,064	1,896,048	38	**52**	14	0.8	277,956.43	**556.14**	3,891,390	7.5	7.3	51	47.6
				Tons/unit=	**86.5**							gpm/unit=	**185**					

Fan Power assumes same ESP as LWA specs and a SA volume of 19000CFM
Fan electrical power assumes .8 efficiency

Parallel Cooling/Heating Systems

Width of 1' Available Lengths of 3',4',5',6',7',8',9',10'

	Design Cooling capacity (BTU/h)	**Design Heating capacity** (BTU/h)	Maximum Cooling capacity (BTU/h)	Maximum Heating need (BTU/h)	Clg Inlet Water Temp (F)	Htg Inlet Water Temp (F)	Design Chilled H2O Rate (gpm)	**Max Chilled H2O Rate (gpm)**	Design Heated H2O Rate (gpm)	**Max Heated H2O Rate (gpm)**	Design Steam Rating (Therm)	Maximum Steam Need (Therm)	**Parallel Cooling** Pumping Power (hp)	Pump Elec Power (kW)	**Parallel Heating** Pumping Power (hp)	Pump Elec Power (kW)
Trox Active Chilled or Heated Beam	**219,412**	**28,357**			60.8	150.0	245	**277**	10	**126**			1.5	1.5	1.25	1.5

Steam demand assumptions:
ε = .8
Twi = 55

available energy sink=4184J/L*K * (flow rate)L/h * 1h/3600s * (delta Tw)K = 1.162W*h/L*K * (flow rate) * (delta Tw)

	cooling (W)	**delta T (K)**	**Flow Rate (l/h)**	**avail energy (W)**	**effectiveness**	**Floor 0**	**Floor 1**	**Floor 2**	**Floor 3**	**Cooling Water (l/h)**	**Cooling Water (gpm)**	**Total Cooling (BTU/h)**
900 mm	125	1	135	156.87	0.7968	9	28	28	29	12,690	56	40,091
	144	1.1	141	180.23	0.7990	4	8	21	31	9,024	40	31,445
	159	1.2	143	199.40	0.7974	1	20	34	43	14,014	62	53,166
	172	1.3	143	216.02	0.7962		13	34	18	9,295	41	38,146
	183	1.4	141	229.38	0.7978		5	3	15	3,243	14	14,361
	193	1.5	139	242.28	0.7966	21		11	7	5,421	24	25,682
										0		
1800 mm	344	2.7	138	432.96	0.7945	4				552	2	4,695
	361	2.8	139	452.25	0.7982		10			1,390	6	12,317
											245	**219,903**

	heating (W)	**delta T (K)**	**Flow Rate (l/h)**	**avail energy (W)**	**effectiveness**	**Floor 0**	**Floor 1**	**Floor 2**	**Floor 3**	**Heating Water (l/h)**	**Heating Water (gpm)**	**Total Heating (BTU/h)**
900 mm	75	1.5	54	94.12	0.7968	13	1		12	1404	6.182	6,653
	100	2	54	125.50	0.7968	6			2	432	1.902	2,730
	130	2.5	56	162.68	0.7991	3			1	224	0.986	1,774
	200	3.5	62	252.15	0.7932	4		1		310	1.365	3,412
	240	2	130	302.12	0.7944	2	1			390	1.717	2,457
	269	4.6	63	336.75	0.7988	4	9	2	1	1008	4.438	14,685
	308	5.4	62	389.04	0.7917		3		1	248	1.092	4,204
	339	5.8	63	424.59	0.7984		1			63	0.277	1,157
	387	6.7	63	490.48	0.7890		1	2		189	0.832	3,961
										0		
1800 mm	725	12.5	63	915.08	0.7923		1			63	0.277	2,474
											19.1	**43,506**

	Outdoor Air TMY-2* Design Weather Data for Baltimore, MD						VAV			DOAS				
	Total Annual BIN Hours	Mean Coincident Dry Bulb	Wet Bulb BIN Data	BIN Hours Used for Analysis	Enthalpy BTU/LB	Moisture GR./LB.	Mixed Air DB (F)	Mixed Air Gr (Gr/lb)	BTU Usage	Wheel Usage Category	Wheeled Air DB (F)	Wheeled Air Gr (Gr/lb)	BTU Usage	DOAS savings Check
1	15	90.3	81	15	44.82	147.17	73.83	66.92	56,789,999		75.66	75.83	45,660,062	Savings of
2	48	86.6	79	48	41.73	139.38	73.46	66.14	176,639,846		74.92	74.28	141,650,318	Savings of
3	122	85.3	77	122	39.76	128.25	73.33	65.02	436,475,155		74.66	72.05	349,080,074	Savings of
4	197	82.6	75	197	37.89	120.02	73.06	64.20	685,689,726		74.12	70.40	546,920,334	Savings of
5	274	79.3	73	274	36.11	113.35	72.73	63.53	928,378,130	Wheel Use	73.46	69.07	738,485,693	Savings of
6	313	76.3	71	313	34.41	106.71	72.43	62.87	1,032,832,756	at Full	72.86	67.74	819,319,633	Savings of
7	355	76	69	355	32.75	96.16	72.40	61.82	1,141,078,388	Capacity	72.80	65.63	902,649,966	Savings of
8	402	74.2	67	402	31.19	88.54	72.22	61.05	1,259,502,152		72.44	64.11	993,525,667	Savings of
9	375	72.5	65	375	29.69	81.22	72.05	60.32	1,145,760,910		72.10	62.64	901,236,145	Savings of
10	375	69.4	63	375	28.26	76.59	71.74	59.86	1,117,966,482		71.48	61.72	876,862,764	Savings of
11	331	69.1	61	331	26.87	67.83	71.71	58.98	963,104,570		71.42	59.97	753,205,867	Savings of
12	379	65.9	59	379	25.56	64.13	71.39	58.61	1,076,953,807		70.78	59.23	839,794,091	Savings of
13	347	64.1	57	347	24.29	58.53	71.21	58.05	963,270,493		70.42	58.11	748,935,367	Savings of
14	261	61.3	55	261	23.08	54.88	70.93	57.69	708,127,864		61.30	54.88	406,103,487	Savings of
15	271	59.1	53	271	21.91	50.57	70.71	57.26	718,869,020		59.10	50.57	349,798,949	Savings of
16	261	56.8	51	261	20.78	46.72	70.48	56.87	677,160,954	Wheel Not	56.80	46.72	270,326,582	Savings of
17	219	56.2	49	219	19.69	40.45	70.42	56.25	555,925,623	Used	56.20	40.45	173,040,540	Savings of
18	250	54.5	47	250	18.65	36.20	70.25	55.82	621,143,283		54.50	36.20	138,452,607	Savings of
19	313	51.4	45	313	17.64	34.42	69.94	55.64	761,391,328		51.40	34.42	101,961,423	Savings of
20	289	49	43	289	16.67	31.76	69.70	55.38	688,504,707		67.40	52.75	523,996,836	Savings of
21	285	46.8	41	285	15.73	29.00	69.48	55.10	665,159,428		66.96	52.20	504,628,986	Savings of
22	327	44.1	39	327	14.82	27.24	69.21	54.92	747,840,114		66.42	51.85	565,541,008	Savings of
23	332	42.3	37	332	13.94	24.25	69.03	54.62	744,226,445		66.06	51.25	560,992,123	Savings of
24	377	39.8	35	377	13.08	22.55	68.78	54.45	828,516,831		65.56	50.91	622,487,717	Savings of
25	419	36.7	33	419	12.26	21.96	68.47	54.40	902,904,213		64.94	50.79	676,127,207	Savings of
26	414	35.1	31	414	11.45	19.04	68.31	54.10	874,596,731	Wheel Use	64.62	50.21	652,683,921	Savings of
27	264	33.1	29	264	10.67	16.79	68.11	53.88	546,612,812	at Full	64.22	49.76	406,469,555	Savings of
28	179	30.8	27	179	9.91	15.20	67.88	53.72	363,338,161	Capacity	63.76	49.44	269,213,069	Savings of
29	163	28.5	25	163	9.16	13.77	67.65	53.58	324,443,836		63.30	49.15	239,522,011	Savings of
30	158	26.3	23	158	8.44	12.35	67.43	53.44	308,466,471		62.86	48.87	226,891,203	Savings of
31	108	24	21	108	7.73	11.23	67.20	53.32	206,850,656		62.40	48.65	151,582,663	Savings of
32	86	21.9	19	86	7.04	9.93	66.99	53.19	161,622,750		61.98	48.39	117,993,586	Savings of
33	63	19.7	17	63	6.36	8.90	66.77	53.09	116,191,918		61.54	48.18	84,502,559	Savings of
34	74	17.7	15	74	5.70	7.69	66.57	52.97	133,957,627		61.14	47.94	97,045,594	Savings of
35	41	15.3	13	41	5.05	7.19	66.33	52.92	72,851,062		60.66	47.84	52,568,267	Savings of
36	35	12.8	11	35	4.42	6.95	66.08	52.90	61,046,409		60.16	47.79	43,872,577	Savings of
37	17	10.8	9	17	3.79	6.02	65.88	52.80	29,110,062		59.76	47.60	20,835,081	Savings of
38	13	8.3	7	13	3.17	5.95	65.63	52.79	21,852,949		59.26	47.59	15,575,202	Savings of
39	6	6.5	5	6	2.57	4.87	65.45	52.69	9,902,749		58.90	47.37	7,027,880	Savings of
40	1	6.1	3	1	1.99	1.71	65.41	52.37	1,620,999		58.82	46.74	1,145,480	Savings of
41	1	1.9	1	1	1.39	4.45	64.99	52.65	1,590,587		57.98	47.29	1,118,811	Savings of
	4795													
	8760	Operating Hours/Year Used for Analysis		7994					22,838,268,006				17,860,880,025	
													Cooling Savings Percent	

Savings Amount (BTU)
11,129,937
34,989,528
87,395,081
138,769,392
189,892,437
213,513,123
238,428,422
265,976,485
244,524,765
241,103,718
209,898,704
237,159,716
214,335,126
302,024,377
369,070,071
406,834,371
382,885,083
482,690,676
659,429,905
164,507,871
160,530,442
182,299,107
183,234,322
206,029,115
226,777,007
221,912,810
140,143,258
94,125,092
84,921,825
81,575,268
55,267,993
43,629,165
31,689,359
36,912,032
20,282,796
17,173,832
8,274,981
6,277,747
2,874,869
475,519
471,776
4,977,387,981
21.8

	Outdoor Air TMY -2* Design Weather Data for Baltimore, MD						VAV			DOAS							
	Total Annual BIN Hours	Mean Coincident Dry Bulb	Wet Bulb BIN Data	BIN Hours Used for Analysis	Enthalpy BTU/LB	Moisture GR./LB.	Mixed Air DB	Mixed Air Gr	BTU VAV	Wheel Spin Percentage Latent	Wheel Spin Percentage Sensible	Wheel Use Category	Wheeled Air DB (F)	Wheeled Air Gr (Gr/lb)	BTU Usage	Savings Check	Amount of Savings or Loss
1	15	90.3	81	15	44.82	147.17	73.83	66.92	56,789,999				75.66	75.83	45,660,062	Savings of	11,129,937
2	48	86.6	79	48	41.73	139.38	73.46	66.14	176,639,846				74.92	74.28	141,650,318	Savings of	34,989,528
3	122	85.3	77	122	39.76	128.25	73.33	65.02	436,475,155				74.66	72.05	349,080,074	Savings of	87,395,081
4	197	82.6	75	197	37.89	120.02	73.06	64.20	685,689,726				74.12	70.40	546,920,334	Savings of	138,769,392
5	274	79.3	73	274	36.11	113.35	72.73	63.53	928,378,130				73.46	69.07	738,485,693	Savings of	189,892,437
6	313	76.3	71	313	34.41	106.71	72.43	62.87	1,032,832,756			Wheel Use	72.86	67.74	819,319,633	Savings of	213,513,123
7	355	76	69	355	32.75	96.16	72.40	61.82	1,141,078,388			at Full	72.80	65.63	902,649,966	Savings of	238,428,422
8	402	74.2	67	402	31.19	88.54	72.22	61.05	1,259,502,152			Capacity	72.44	64.11	993,525,667	Savings of	265,976,485
9	375	72.5	65	375	29.69	81.22	72.05	60.32	1,145,760,910				72.10	62.64	901,236,145	Savings of	244,524,765
10	375	69.4	63	375	28.26	76.59	71.74	59.86	1,117,966,482				71.48	61.72	876,862,764	Savings of	241,103,718
11	331	69.1	61	331	26.87	67.83	71.71	58.98	963,104,570				71.42	59.97	753,205,867	Savings of	209,898,704
12	379	65.9	59	379	25.56	64.13	71.39	58.61	1,076,953,807				70.78	59.23	839,794,091	Savings of	237,159,716
13	347	64.1	57	347	24.29	58.53	71.21	58.05	963,270,493				70.42	58.11	748,935,367	Savings of	214,335,126
14	261	61.3	55	261	23.08	54.88	70.93	57.69	708,127,864				61.30	54.88	406,103,487	Savings of	302,024,377
15	271	59.1	53	271	21.91	50.57	70.71	57.26	718,869,020				59.10	50.57	349,798,949	Savings of	369,070,071
16	261	56.8	51	261	20.78	46.72	70.48	56.87	677,160,954			Wheel Not	56.80	46.72	270,326,582	Savings of	406,834,371
17	219	56.2	49	219	19.69	40.45	70.42	56.25	555,925,623			in Use	56.20	40.45	173,040,540	Savings of	382,885,083
18	250	54.5	47	250	18.65	36.20	70.25	55.82	621,143,283				54.50	36.20	138,452,607	Savings of	482,690,676
19	313	51.4	45	313	17.64	34.42	69.94	55.64	761,391,328				51.40	34.42	101,961,423	Savings of	659,429,905
20	289	49	43	289	16.67	31.76	69.70	55.38	688,504,707	0.15	-0.22		51.84	35.00	106,797,256	Savings of	581,707,451
21	285	46.8	41	285	15.73	29.00	69.48	55.10	665,159,428	0.26	-0.09		52.02	35.00	107,960,960	Savings of	557,198,468
22	327	44.1	39	327	14.82	27.24	69.21	54.92	747,840,114	0.32	0.04		51.14	35.00	108,444,190	Savings of	639,395,924
23	332	42.3	37	332	13.94	24.25	69.03	54.62	744,226,445	0.40	0.11		51.76	35.00	121,200,695	Savings of	623,025,750
24	377	39.8	35	377	13.08	22.55	68.78	54.45	828,516,831	0.44	0.20		51.11	35.00	124,392,382	Savings of	704,124,450
25	419	36.7	33	419	12.26	21.96	68.47	54.40	902,904,213	0.45	0.29		49.47	35.00	101,229,230	Savings of	801,674,983
26	414	35.1	31	414	11.45	19.04	68.31	54.10	874,596,731	0.51	0.34		50.22	35.00	116,649,772	Savings of	757,946,959
27	264	33.1	29	264	10.67	16.79	68.11	53.88	546,612,812	0.55	0.38		50.29	35.00	75,397,582	Savings of	471,215,231
28	179	30.8	27	179	9.91	15.20	67.88	53.72	363,338,161	0.58	0.43		49.86	35.00	46,986,991	Savings of	316,351,170
29	163	28.5	25	163	9.16	13.77	67.65	53.58	324,443,836	0.60	0.47		49.38	35.00	38,533,282	Savings of	285,910,555
30	158	26.3	23	158	8.44	12.35	67.43	53.44	308,466,471	0.62	0.51		48.97	35.00	33,912,893	Savings of	274,553,578
31	108	24	21	108	7.73	11.23	67.20	53.32	206,850,656	0.64	0.55	Wheel Use	48.40	35.00	19,809,384	Savings of	187,041,272
32	86	21.9	19	86	7.04	9.93	66.99	53.19	161,622,750	0.65	0.58	Capacity	48.03	35.00	14,074,025	Savings of	147,548,726
33	63	19.7	17	63	6.36	8.90	66.77	53.09	116,191,918	0.66	0.60	Modified	47.50	35.00	8,500,860	Savings of	107,691,058
34	74	17.7	15	74	5.70	7.69	66.57	52.97	133,957,627	0.68	0.63		47.18	35.00	8,702,196	Savings of	125,255,431
35	41	15.3	13	41	5.05	7.19	66.33	52.92	72,851,062	0.68	0.65		46.33	35.00	2,949,588	Savings of	69,901,475
36	35	12.8	11	35	4.42	6.95	66.08	52.90	61,046,409	0.69	0.68		45.33	35.00	619,810	Savings of	60,426,599
37	17	10.8	9	17	3.79	6.02	65.88	52.80	29,110,062	0.70	0.70		45.00	35.07	39,738	Savings of	29,070,324
38	13	8.3	7	13	3.17	5.95	65.63	52.79	21,852,949	0.70	0.72		45.00	35.94	414,384	Savings of	21,438,565
39	6	6.5	5	6	2.57	4.87	65.45	52.69	9,902,749	0.71	0.73		45.00	36.10	224,180	Savings of	9,678,569
40	1	6.1	3	1	1.99	1.71	65.41	52.37	1,620,999	0.74	0.74		45.00	34.94	-2,187	Savings of	1,623,187
41	1	1.9	1	1	1.39	4.45	64.99	52.65	1,590,587	0.71	0.77		45.00	37.38	80,792	Savings of	1,509,795
	4795																
	Total Operating Hours/Year Used for Analysis			7994					22,838,268,006						11,133,927,571		11,704,340,435
															Cooling Savings Percent		51.2

space	Sensible Cooling (BTU/hr)	Latent Cooling (BTU/hr)	Heating (BTU/hr)	Latent Removal CFM	Sensible Removal CFM	DOAS application Latent Removal CFM	Minumum OA (Vbz) CFM	Resultant Sensible Removal (BTU/hr)	Remaining Sensible (BTU/hr)	Trox Active Chilled/Heated Beam Estimator Min SA (l/s)	SA via Beam (l/s)	SA w/o Beam l/s	Oversupply Test	Length of Beam (mm)	Beam Qty	Beam Cooling (W)/unit	Beam DeltaTw (K)	Beam Water Flow (l/h)/unit	Heating (W)	Heating Test	Beam Heating (W)/unit	Beam DeltaTw (K)	Beam Water Flow (l/h)/unit	Balance of Qs (overcooling) (W)
BR-B057	12,505		631	0	557	0	30	861	11,644	13.9	135.0	14.0	Oversupply	900	5	193	1.5	110	185					2
B060	801		430	0	36	0	22	630	171	10.2	13.0			900	1				126		130	2.5	56	129
B062	1,068	615	267	53	48	39	10	1,147	79	18.6	18.6			900	1				78		75	1.5	54	52
B064	1,068	615	267	53	48	39	10	1,147	79	18.6	18.6			900	1				78		75	1.5	54	52
B066	218		131	0	10	0	0	0	218	0.0	0.0								38	AddHtg				64
B068	218		131	0	10	0	0	0	218	0.0	0.0								38	AddHtg				64
B070	905	410	267	35	40	26	10	764	141	12.4	15.0			900	1				78		75	1.5	54	69
B072	905	410	267	35	40	26	10	764	141	12.4	15.0			900	1				78		75	1.5	54	69
B074	1,601	1,230	250	106	71	79	9	2,293	692	37.1	37.1			900	1				73		200	3.5	50	(3)
B076	524		315	0	23	0	10	280	244	4.5	8.0			900	1				92		100	2	54	109
B078	1,090	615	267	53	49	39	10	1,147	57	18.6	18.6			900	1				78		75	1.5	54	58
B080	1,090	615	267	53	49	39	10	1,147	57	18.6	18.6			900	1				78		75	1.5	54	58
B082	1,090	615	267	53	49	39	10	1,147	57	18.6	18.6			900	1				78		75	1.5	54	58
B084	1,238	410	444	35	55	26	12	764	474	12.4	13.0			900	1	125	1	110	130					2
MR-B055	792		379	0	35	0	21	624	168	10.1	13.0			900	1				111		100	2	54	97
B056	3,734	1,640		142	166	105	14	3,058	676	49.5	49.5			900	1	193	1.5	110	0					5
B054	1,112	615		53	50	39	11	1,147	35	18.6	18.6								0					(10)
B052	1,112	615		53	50	39	11	1,147	35	18.6	18.6								0					(10)
B061	556			0	25	0	15	437	119	7.1	7.1								0					35
B042	1,207	410		35	54	26	23	764	443	12.4	12.4			900	1	125	1	110	0					5
B039	546	205		18	24	13	7	382	164	6.2	9.0								0					(3)
B040	467			0	21	0	13	367	100	5.9	8.0								0					(8)
B041	1,901	615	528	53	85	39	16	1,147	754	18.6	18.6			900	1	193	1.5	110	155					28
B035	1,068	615		53	48	39	10	1,147	79	18.6	18.6								0					(23)
B033	1,068	615		53	48	39	10	1,147	79	18.6	18.6								0					(23)
B031	2,199	1,640		142	98	105	14	3,058	859	49.5	49.5			900	1				0		269	4.6	50	17
B034	1,068	615		53	48	39	10	1,147	79	18.6	18.6								0					(23)
B032	1,068	615		53	48	39	10	1,147	79	18.6	18.6								0					(23)
B030	1,246	615		53	55	39	13	1,147	99	18.6	18.6								0					29
MES AB	307			0	14	0	8	241	66	3.9	3.9			900	1				0	Units added because of electrical equipmer				19
B051	1,068	615		53	48	39	12	1,147	79	18.6	18.6			900	1				0	Units added because of exterior wall				(23)
B053	1,068	615		53	48	39	12	1,147	79	18.6	18.6			900	1				0	Units added because of exterior wall				(23)
B027	1,090	615		53	49	39	10	1,147	57	18.6	18.6								0					(17)
B025	1,090	615		53	49	39	10	1,147	57	18.6	18.6								0					(17)
B023	1,090	615		53	49	39	10	1,147	57	18.6	18.6								0					(17)
B021	1,090	615		53	49	39	10	1,147	57	18.6	18.6								0					(17)
B026	1,090	615		53	49	39	10	1,147	57	18.6	18.6								0					(17)
B024	1,090	615		53	49	39	10	1,147	57	18.6	18.6								0					(17)
B022	1,090	615		53	49	39	10	1,147	57	18.6	18.6								0					(17)
B020	1,090	615		53	49	39	10	1,147	57	18.6	18.6								0					(17)
B009	2,456	1,080		93	109	69	40	2,014	442	32.6	32.6			900	1	125	1	110	0					5
B019	1,335	615	286	53	59	39	15	1,147	188	18.6	22.0			900	1				84		100	2	54	93
B017	1,112	615	256	53	50	39	11	1,147	35	18.6	18.6			900	1				75		75	1.5	54	65
B015	2,039	1,640	244	142	91	105	11	3,058	1,019	49.5	49.5			900	1				72		269	4.6	50	(30)
B013	2,039	1,640	244	142	91	105	11	3,058	1,019	49.5	49.5			900	1				72		269	4.6	50	(30)
B011	2,039	1,640	244	142	91	105	11	3,058	1,019	49.5	49.5			900	1				72		269	4.6	50	(30)
B000	11,901	4,320		374	530	276	171	8,054	3,847	130.4	130.4	62.0	Oversupply						0					5
CB-4	1,403			0	62	0	28	828	575	13.4	23.0		Oversupply						0					(5)
CB-9,7	1,353			0	60	0	27	798	555	12.9	22.0		Oversupply						0					(2)
CB-3	834			0	37	0	17	491	343	7.9	14.0		Oversupply						0					(9)
CB-1	934			0	42	0	19	551	383	8.9	15.0		Oversupply						0					2
CB-2	703			0	31	0	14	414	289	6.7	11.0		Oversupply						0					7
CB-6	783			0	35	0	16	462	321	7.5	13.0		Oversupply						0					(6)
	83,559	32,050	6,382	2,772	3,720	2,049	851	59,756	23,803															
		115,609			6,492	7,392																		

space	Sensible Cooling (BTU/hr)	Latent Cooling (BTU/hr)	Heating (BTU/hr)	Latent Removal CFM	Sensible Removal CFM	Latent Removal CFM	Minumum OA (Vbz) CFM	Resultant Sensible Removal (BTU/hr)	Remaining Sensible (BTU/hr)	Min SA (l/s)	SA via Beam (l/s)	SA w/o Beam l/s	Oversupply Test	Length of Beam (mm)	Beam Qty	Beam Cooling (W)/unit	Beam DeltaTw (K)	Beam Water Flow (l/h)/unit	Heating (W)	Heating Test	Beam Heating (W)/unit	Beam DeltaTw (K)	Beam Water Flow (l/h)/unit	Balance of Qs (overcooling) (W)
B086	786		457	0	35	0	14	420	366	6.8	12.5		Oversupply	900	1	144	1.1	110	134					(140)
B088	1,616	410	802	35	72	26	11	764	852	12.4	12.4			900	2	125	1	110	235					(0)
B075	905	410		35	40	26	10	764	141	12.4	15.0								0					(6)
B077	905	410		35	40	26	10	764	141	12.4	15.0								0					(6)
B012				0	0	0	0	0	0	0.0	0.0								0					0
B010				0	0	0	0	0	0	0.0	0.0								0					0
B079				0	0	0	0	0	0	0.0	0.0								0					0
B081				0	0	0	0	0	0	0.0	0.0								0					0
B083				0	0	0	0	0	0	0.0	0.0								0					0
B008	369			0	16	0	5	144	225	2.3	6.0								0					(0)
B085	1,191	820		71	53	52	6	1,529	338	24.7	24.7			900	1				0		100	2	50	1
B000	23,290	8,520	2,418	737	1,037	545	332	15,885	7,405	257.1	180.0	121.0	Oversupply	1800	4	344	2.7	110	709					(0)
B087A	905	410		35	40	26	17	764	141	12.4	15.0								0					(6)
B087	1,025	410		35	46	26	13	764	261	12.4	17.0		Oversupply						0					(7)
B089				0	0	0	3	99	99	1.6	12.0		Oversupply	900	1				0		200	3.5	62	(17)
B087B	320			0	14	0	17	483	163	7.8	12.0		Oversupply	900	1				0		130	2.5	50	7
B101	699			0	31	0	9	274	425	4.4	12.0		Oversupply	900	1				0	Unit added for cooling capacity				(12)
B103	1,605	820		71	71	52	16	1,529	76	24.7	26.0			900	1				0	Unit added for cooling capacity				(0)
B150				0	0	0	28	815	815	13.2	13.2			900	1				0		240	2	110	1
B153	2,420	1,080	468	93	108	69	37	2,014	406	32.6	12.0	20.6		900	1	125	1	110	137					(6)
B148	1,605	820		71	71	52	16	1,529	76	24.7	26.0			900	1				0	Unit added for cooling capacity				(0)
B151				0	0	0	5	144	144	2.3	12.0		Oversupply	900	1				0		220	2	110	3
B149	1,143	615	266	53	51	39	11	1,147	4	18.6	18.6			900	1				78		75	1.5	54	74
B147	1,143	615	266	53	51	39	11	1,147	4	18.6	18.6			900	1				78		75	1.5	54	74
B145	1,143	615	266	53	51	39	11	1,147	4	18.6	18.6			900	1				78		75	1.5	54	74
B143	1,143	615	266	53	51	39	11	1,147	4	18.6	18.6			900	1				78		75	1.5	54	74
B141	614		295	0	27	0	17	483	131	7.8	10.0			900	1				86		75	1.5	54	74
B109	1,139	615		53	51	39	11	1,147	8	18.6	18.6								0					(2)
B107	1,139	615		53	51	39	11	1,147	8	18.6	18.6								0					(2)
B105	1,139	615		53	51	39	11	1,147	8	18.6	18.6								0					(2)
B110	10,639	1,640	4,995	142	474	105	81	3,058	7,581	49.5	108.0		Oversupply	900	6	193	1.5	110	1,464					5
B111	1,094	615		53	49	39	10	1,147	53	18.6	23.0		Oversupply	900	1				0		100	2	50	4
B106	1,094	615		53	49	39	10	1,147	53	18.6	23.0		Oversupply	900	1				0		100	2	50	4
B108	1,650	1,230		106	73	79	10	2,293	643	37.1	12.0	25.1		900	1				0		200	3.5	50	12
B113	307			0	14	0	8	241	66	3.9	5.0			900	1				0	Unit added for cooling capacity				(1)
B135	4,015	3,280		284	179	210	54	6,115	2,100	99.0	36.0	62.0		900	3				0		200	3.5	50	2
B137	231			0	10	0	6	181	50	2.9	4.0								0					(5)
B118	10,591	1,640	4,995	142	471	105	81	3,058	7,533	49.5	108.0		Oversupply	900	6	193	1.5	110	1,464					(10)
B115				0	0	0	0	0	0	0.0	0.0								0					0
B134				0	0	0	0	0	0	0.0	0.0								0					0
B117				0	0	0	0	0	0	0.0	0.0								0					0
B119				0	0	0	0	0	0	0.0	0.0								0					0
B132	1,891	615		53	84	39	26	1,147	744	18.6	12.0	8.0		900	1	193	1.5	110	0					(1)
MES BB	303			0	13	0	8	238	65	3.9	12.0		Oversupply	900	1				0		130	2.5	56	2
B123	142			0	6	0	4	112	30	1.8	2.5								0					(4)
B30				0	0	0	0	0	0	0.0	0.0								0					0
B127	3,833	1,680	618	145	171	107	86	3,132	701	50.7	27.0	24.0		900	1	193	1.5	110	181					7
B126A	1,424	205	1,180	18	63	13	9	382	1,042	6.2	15.0		Oversupply	900	2	144	1.1	110	346		second unit added for htg capabil			#VALUE!
B126	1,861	410	1,048	35	83	26	13	764	1,097	12.4	18.0	3.0	Oversupply	900	1	159	1.2	110	307	AddHtg	heating capable			#VALUE!
B124	630	205	197	18	28	13	9	382	248	6.2	10.0			900	1				58		heating capable			#VALUE!
B122	2,912	410	995	35	130	26	11	764	2,148	12.4	31.0		Oversupply	900	2	144	1.1	110	292					4
B120	3,731	410	2,016	35	166	26	11	764	2,967	12.4	40.0		Oversupply	900	3	125	1	110	591					(6)
CB-9,7	1,525			0	68	0	31	899	626	14.6	25.0		Oversupply	900	2				0					(6)
CB-10	1,584		597	0	71	0	32	933	651	15.1	26.0		Oversupply	900	2				175		heating capable			#VALUE!
CB-14	1,584			0	71	0	29	834	750	13.5	26.0		Oversupply						0					(7)
CB-15	540			0	24	0	11	318	222	5.1	9.0								0					(5)
CB-13	768			0	34	0	16	452	316	7.3	13.0		Oversupply						0					(10)
CB-11	279			0	12	0	6	164	115	2.7	5.0								0					(9)
	98,872	31,370	22,145	2,714	4,401	2,006	1,205	58,488	40,384		SA SUI	5,848	Beam Sum	900 mm	82	cold water	(l/h)	4,400	8,360		hot water	(l/h)	1,908	
		130,242			7,115							cfm /\		1800 mm	4		gpm	19	SUM of			gpm	8	
																Clg Cap	(BTU/hr)	25,361	Heating		Htg Cap	(BTU/hr)	16,040	

DOAS application

Trox Active Chilled/Heated Beam Estimator

space	Sensible Cooling (BTU/hr)	Latent Cooling (BTU/hr)	Heating (BTU/hr)	Latent Removal CFM	Sensible Removal CFM	Latent Removal CFM	Minumum OA (Vbz) CFM	Resultant Sensible Removal (BTU/hr)	Remaining Sensible (BTU/hr)	Min SA (l/s)	SA via Beam (l/s)	SA w/o Beam l/s	Oversupply Test	Length of Beam (mm)	Beam Qty	Beam Cooling (W)/unit	Beam DeltaTw (K)	Beam Water Flow (l/h)/unit	Heating (W)	Heating Test	Beam Heating (W)/unit	Beam DeltaTw (K)	Beam Water Flow (l/h)/unit	Balance of Qs (overcooling) (W)
1058	3,008	410	1,095	35	134	26	14	764	2,244	12.4	33.0		Oversupply	900	2	144	1.1	110	321					(4)
1057	5,999	410	1,960	35	267	26	17	764	5,235	12.4	68.0		Oversupply	900	3	172	1.3	110	574					11
1055	4,266	410	1,296	35	190	26	17	764	3,502	12.4	36.0	12	Oversupply	900	3	125	1	110	380					6
1053	4,266	410	1,296	35	190	26	17	764	3,502	12.4	36.0	12	Oversupply	900	3	125	1	110	380					6
1051	6,225	410	2,964	35	277	26	17	764	5,461	12.4	54.0	18	Oversupply	900	3	172	1.3	110	869	Add Htg	htg capable			#VALUE!
1056	1,158	1,025		89	52	66	11	1,911	753	30.9	30.9			900	1				0		220	2	110	(1)
1060	1,217	615	83	53	54	39	11	1,147	70	18.6	20.0			900	1				24	Units added because of exterior wall				#VALUE!
1062	1,090	615		53	49	39	10	1,147	57	18.6	18.6			900	1				0	Units added because of exterior wall				(17)
1064	1,090	615		53	49	39	10	1,147	57	18.6	18.6			900	1				0	Units added because of exterior wall				(17)
1066				0	0	0	0	0	0	0.0	0.0			900	1				0	Units added because of exterior wall				0
1068				0	0	0	0	0	0	0.0	0.0			900	1				0	Units added because of exterior wall				0
1070	1,090	615		53	49	39	10	1,147	57	18.6	18.6			900	1				0	Units added because of exterior wall				(17)
1072	1,090	615		53	49	39	10	1,147	57	18.6	18.6			900	1				0	Units added because of exterior wall				(17)
1074	1,090	615		53	49	39	10	1,147	57	18.6	18.6			900	1				0	Units added because of exterior wall				(17)
1076	1,090	615		53	49	39	10	1,147	57	18.6	18.6			900	1				0	Units added because of exterior wall				(17)
1078	1,090	615		53	49	39	10	1,147	57	18.6	18.6			900	1				0	Units added because of exterior wall				(17)
1080	1,090	615		53	49	39	10	1,147	57	18.6	18.6			900	1				0	Units added because of exterior wall				(17)
1082	1,090	615		53	49	39	28	1,147	57	18.6	18.6			900	1				0	Units added because of exterior wall				(17)
1084	267			0	12	0	7	210	57	3.4	4.0			900	1				0	Units added because of exterior wall				6
1086	1,562	410	990	35	70	26	8	764	798	12.4	15.0	2	Oversupply	900	1	144	1.1	110	290	Add Htg	htg capable			#VALUE!
1061	1,117	615		53	50	39	11	1,147	30	18.6	18.6								0					(9)
1054	1,223	615		53	54	39	13	1,147	76	18.6	20.0								0					(4)
1042	1,170	615		53	52	39	12	1,147	23	18.6	18.6								0					7
1040	1,068	615		53	48	39	10	1,147	79	18.6	18.6								0					(23)
1031	1,094	615		53	49	39	10	1,147	53	18.6	18.6								0					(15)
1035	2,862	1,440		125	127	92	37	2,685	177	43.5	46.0			900	2				0	Units added to increase cooling capacity				6
1035A	507			0	23	0	14	399	108	6.5	6.5								0					32
1063	1,090	615		53	49	39	10	1,147	57	18.6	18.6								0					(17)
1037	1,117	615		53	50	39	11	1,147	30	18.6	18.6								0					(9)
1041	11,366	1,920	4,232	166	506	123	65	3,580	7,786	57.9	127.0		Oversupply	900	6	172	1.3	110	1,240					(0)
1019	1,427	720		62	64	46	18	1,342	85	21.7	23.0								0					2
1019A	3,374	615	1,268	53	150	39	9	1,147	2,227	18.6	37.0		Oversupply	900	2	159	1.2	110	372					1
1017	3,387	615	1,213	53	151	39	10	1,147	2,240	18.6	37.0		Oversupply	900	2	159	1.2	110	355					5
1015	3,420	615	1,228	53	152	39	10	1,147	2,273	18.6	38.0		Oversupply	900	2	159	1.2	110	360					(4)
1013	3,444	615	1,228	53	153	39	11	1,147	2,297	18.6	38.0		Oversupply	900	2	159	1.2	110	360					3
1011	11,017	2,400	3,352	208	490	153	23	4,475	6,542	72.4	128.0		Oversupply	900	5	183	1.4	110	982					(4)
1029	2,196	820	190	71	98	52	24	1,529	667	24.7	18.0	9		900	1	159	1.2	110	56					(4)
1034	1,134	615		53	50	39	11	1,147	13	18.6	18.6								0					(4)
1032	1,108	615		53	49	39	10	1,147	39	18.6	18.6								0					(11)
MES A1	307			0	14	0	8	241	66	3.9	3.9			900	1				0	Units added to increase cooling capacity				19
1027	334			0	15	0	9	262	72	4.2	4.2								0					21
1025	503			0	22	0	14	394	109	6.4	8.0								0					3
1023	360			0	16	0	10	284	76	4.6	6.0								0					(3)
1028	1,117	615		53	50	39	11	1,147	30	18.6	18.6								0					(9)
1026	1,072	615		53	48	39	10	1,147	75	18.6	18.6								0					(22)
1024	1,072	615		53	48	39	10	1,147	75	18.6	18.6								0					(22)
1014	1,072	615		53	48	39	10	1,147	75	18.6	18.6								0					(22)
1075	5,150	1,230	399	106	229	79	246	7,173	2,023	116.1	117.0			900	2				117		308	5.3	50	7
1012				0	0	0	0	0	0	0.0	0.0								0					0
1010				0	0	0	0	0	0	0.0	0.0								0					0
1081				0	0	0	0	0	0	0.0	0.0								0					0
1083				0	0	0	0	0	0	0.0	0.0								0					0
CRI-002	776	410		35	35	26	8	764	12	12.4	12.4			900	1				0	Units added to increase cooling capacity				3
1009	962	410		35	43	26	11	764	198	12.4	16.0			900	1				0	Units added to increase cooling capacity				(8)
1091	2,034	1,640		142	91	105	27	3,058	1,024	49.5	50.0			900	1				0		308	5.3	50	(1)
1093	1,414	615	133	53	63	39	13	1,147	267	18.6	23.0		Oversupply	900	1				39	Units added to increase cooling capacity				(2)
1095	262		66	0	12	0	3	99	163	1.6	5.0			900	1				19	Units added to increase cooling capacity				(14)
1093A	534		133	0	24	0	18	537	3	8.7	12.0			900	1				39		75	1.5	54	14
1098	1,352	615	334	53	60	39	13	1,147	205	18.6	22.0			900	1				98		htg capable			#VALUE!
1001	570			0	25	0	8	224	346	3.6	50.0		Oversupply	1800	1				0		726	12.5	50	(12)
1000	45,819	12,000	10,024	1,038	2,040	767	298	22,373	23,446	362.1	500.0	42	Oversupply	1800	10	361	2.8	110	2,938	Add Htg	htg capable			#VALUE!
C1-5	3,544		1,117	0	158	0	26	751	2,793	12.1	58.0		Oversupply	900	1				327	Add Htg	339	5.8	63	328
C1-6	4,203		1,341	0	187	0	63	1,843	2,360	29.8	68.0		Oversupply	900	1				393	Add Htg	387	6.7	63	388
C1-3	934		86	0	42	0	17	486	448	7.9	15.0		Oversupply						25	Add Htg	htg capable			#VALUE!

space	Sensible Cooling (BTU/hr)	Latent Cooling (BTU/hr)	Heating (BTU/hr)	Latent Removal CFM	Sensible Removal CFM	Latent Removal CFM	Minumum OA (Vbz) CFM	Resultant Sensible Removal (BTU/hr)	Remaining Sensible (BTU/hr)	Min SA (l/s)	SA via Beam (l/s)	SA w/o Beam l/s	Oversupply Test	Length of Beam (mm)	Beam Qty	Beam Cooling (W)/unit	Beam DeltaTw (K)	Beam Water Flow (l/h)/unit	Heating (W)	Heating Test	Beam Heating (W)/unit	Beam DeltaTw (K)	Beam Water Flow (l/h)/unit	Balance of Qs (overcooling) (W)
C1-4	566		182	0	25	0	10	284	282	4.6	9.0		Oversupply	900	1				53		htg capable			#VALUE!
C1-2	534			0	24	0	11	315	219	5.1	9.0								0					(6)
C1-1	1,163			0	52	0	24	686	477	11.1	19.0		Oversupply						0					(3)
C1-10	350			0	16	0	7	206	144	3.3	6.0								0					(6)
A-1				0	0	0	0	0	0	0.0	0.0								0					0
B-1				0	0	0	0	0	0	0.0	0.0								0					0
	166,903	44,310	36,210	3,833	7,430	2,833	1,428	82,614	84,289															48,914
		211,213			11,263	13,505	0	393,796	393,796															0

space	Sensible Cooling (BTU/hr)	Latent Cooling (BTU/hr)	Heating (BTU/hr)	Latent Removal CFM	Sensible Removal CFM	Latent Removal CFM	Minumum OA (Vbz) CFM	Resultant Sensible Removal (BTU/hr)	Remaining Sensible (BTU/hr)	Min SA (l/s)	SA via Beam (l/s)	SA w/o Beam l/s	Oversupply Test	Length of Beam (mm)	Beam Qty	Beam Cooling (W)/unit	Beam DeltaTw (K)	Beam Water Flow (l/h)/unit	Heating (W)	Heating Test	Beam Heating (W)/unit	Beam DeltaTw (K)	Beam Water Flow (l/h)/unit	Balance of Qs (overcooling) (W)
1097	1,157	615		53	52	39	11	1,147	10	18.6	18.6			900	1				0	Unit added to increase cooling capacity				3
1100	1,769	615	1,072	53	79	39	9	1,147	622	18.6	12.0	10		900	1	125	1	110	314	Add Htg				(5)
1102	7,359	2,160	2,929	187	328	138	118	4,027	3,332	65.2	72.0	12	Oversupply	900	4	159	1.2	110	858					(0)
1114	3,237	615	1,209	53	144	39	11	1,147	2,090	18.6	36.0		Oversupply	900	2	144	1.1	110	354					9
1116	1,219	615	269	53	54	39	11	1,147	72	18.6	20.0			900	1				79	unit added because of exterior wall				(5)
1118	1,967	615	1,263	53	88	39	11	1,147	820	18.6	22.0			900	1	172	1.3	110	370	Add Htg				6
1161	1,037	615		53	46	39	9	1,147	110	18.6	18.6								0					(32)
1159	1,090	615		53	49	39	10	1,147	57	18.6	18.6								0					(17)
1157	1,117	615		53	50	39	11	1,147	30	18.6	18.6								0					(9)
1155	3,576	615	1,199	53	159	39	14	1,147	2,429	18.6	40.0		Oversupply	900	2	159	1.2	110	351					6
1153	3,404	615	1,199	53	152	39	10	1,147	2,257	18.6	36.0		Oversupply	900	3	125	1	110	351					(29)
1151	2,666	615	886	53	119	39	10	1,147	1,519	18.6	29.0		Oversupply	900	2	125	1	110	260					6
1149	2,672	615	901	53	119	39	10	1,147	1,525	18.6	29.0		Oversupply	900	2	125	1	110	264					8
1147	2,672	615	901	53	119	39	10	1,147	1,525	18.6	29.0		Oversupply	900	2	125	1	110	264					8
1145	2,672	615	901	53	119	39	10	1,147	1,525	18.6	29.0		Oversupply	900	2	125	1	110	264					8
1144	1,094	615		53	49	39	129	3,774	2,680	61.1	62.0			900	3				0		269	4.6	50	5
1143	2,672	615	901	53	119	39	10	1,147	1,525	18.6	29.0		Oversupply	900	2	125	1	110	264					8
1141	2,672	615	901	53	119	39	10	1,147	1,525	18.6	29.0		Oversupply	900	2	125	1	110	264					8
1101	1,709	820	151	71	76	52	15	1,529	180	24.7	28.0			900	1				44	Unit added to increase cooling capacity				(6)
1158	427			0	19	0	12	336	91	5.4	5.4								0					27
1103	1,775			0	79	0	48	1,396	379	22.6	22.6			900	1	125	1	110	0					(14)
1105	727	410		35	32	26	-69	764	37	12.4	12.4								0					(11)
1148	1,094	615		53	49	39	10	1,147	53	18.6	18.6								0					(15)
1146	1,094	615		53	49	39	10	1,147	53	18.6	18.6								0					(15)
1133	1,094	615		53	49	39	10	1,147	53	18.6	18.6								0					(15)
1135	587			0	26	0	160	4,672	4,085	75.6	60.0	24	Oversupply	900	5				0		269	4.6	50	(4)
1138				0	0	0	0	0	0	0.0	0.0								0					0
1139	402		69	0	18	0	0	0	402	0.0	7.0		Oversupply						20	Add Htg				(9)
1136				0	0	0	0	0	0	0.0	0.0								0					0
1113				0	0	0	0	0	0	0.0	0.0								0					0
1115				0	0	0	0	0	0	0.0	0.0								0					0
1134	1,502	820		71	67	52	14	1,529	27	24.7	24.7			900	2				0	Units added to increase cooling capacity				(8)
1123	601			0	27	0	8	236	365	3.8	10.0		Oversupply						0					(5)
1120	4,527	615	2,441	53	202	39	8	1,147	3,380	18.6	49.0		Oversupply	900	3	144	1.1	110	715					8
1122	1,030	615	203	53	46	39	8	1,147	117	18.6	18.6			900	1				59					(34)
1124	1,808	615	901	53	80	39	10	1,147	661	18.6	12.0	10		900	1	125	1	110	264					7
1126	1,838	615	913	53	82	39	11	1,147	691	18.6	12.0	11	Oversupply	900	1	125	1	110	268					(3)
1128	4,017	615	2,327	53	179	39	15	1,147	2,870	18.6	36.0	8	Oversupply	900	3	125	1	110	682					6
1129	8,728	1,920	3,193	166	389	123	21	3,580	5,148	57.9	90.0	7	Oversupply	900	5	159	1.2	110	936					7
1130				0	0	0	0	0	0	0.0	0.0								0					0
1150	2,146	1,640		142	96	105	46	3,058	912	49.5	12.0	38		900	1				0		269	4.6	50	(7)
C1-8	5,470		2,289	0	244	0	36	1,059	4,411	17.1	89.0		Oversupply	900	4				671	Units added to increase heating capacity				(8)
C1-12	991			0	44	0	20	583	408	9.4	16.0		Oversupply						0					1
C1-11	1,795			0	80	0	36	1,059	736	17.1	29.0		Oversupply						0					1
C1-15	608		72	0	27	0	10	303	305	4.9	10.0		Oversupply						21	Add Htg				(3)
C1-9	605			0	27	0	12	356	249	5.8	10.0		Oversupply						0					(4)
C1-13	627		87	0	28	0	10	303	324	4.9	10.0		Oversupply						25	Add Htg				3
C-1				0	0	0	0	0	0	0.0	0.0													0
	89,254	23,145	27,177	2,002	3,973	1,480	877	43,153	46,101		SA SUM	7,635	Beam Sum	900 mm	122	cold water	(l/h)	9,240	18,577		hot water	(l/h)	940	
		112,399			5,975							cfm /\		1800 mm	11		gpm	41	SUM of			gpm	4	
																Clg Cap	(BTU/hr)	49,791	Heating		Htg Cap	(BTU/hr)	17,374	

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space	Latent Cooling (BTU/hr)	Heating (BTU/hr)	Latent Removal (CFM)	Sensible Removal (CFM)	Latent Removal CFM	Minumum OA (Vbz) CFM	Resultant Sensible Removal (BTU/hr)	Remaining Sensible (BTU/hr)	Min SA (l/s)	SA via Beam (l/s)	SA w/o Beam l/s	Oversupply Test	Length of Beam (mm)	Beam Qty	Beam Cooling (W)/unit	Beam DeltaTw (K)	Beam Water Flow (l/h)/unit	Heating (W)	Heating Test	Beam Heating (W)/unit	Beam DeltaTw (K)	Beam Water Flow (l/h)/unit	Balance of Qs (overcooling) (W)
2055	820	2,536	71	91	52	15	1,529	526	24.7	63.0	5	Oversupply	900	3	172	1.3	110	743					(1,145)
2053	410	1,268	35	91	26	10	764	1,289	12.4	36.0	7	Oversupply	900	3	125	1	110	372					(552)
2051	410	2,399	35	91	26	9	764	1,287	12.4	54.0	7	Oversupply	900	3	159	1.2	110	703					(980)
2056	410	1,519	35	92	26	14	764	1,292	12.4	36.0	4	Oversupply	900	3	125	1	110	445					(497)
2063	410	589	35	92	26	10	764	1,299	12.4	26.0		Oversupply	900	1	183	1.4	110	173					(49)
2061	410		35	92	26	10	764	1,297	12.4	14.0								0					351
2062	410	1,213	35	92	26	10	764	1,298	12.4	21.0		Oversupply	900	1	172	1.3	110	355	Add Htg	htg capable			#VALUE!
2060	410	1,213	35	92	26	10	764	1,296	12.4	21.0		Oversupply	900	1	172	1.2	110	355	Add Htg	htg capable			#VALUE!
2065	410	729	35	92	26	11	764	1,301	12.4	27.0		Oversupply	900	1	193	1.5	110	214					(77)
2064	410	1,005	35	92	26	11	764	1,300	12.4	19.0		Oversupply	900	1	159	1.2	110	295	Add Htg	htg capable			#VALUE!
2054	410		35	91	26	8	764	1,290	12.4	12.4								0					378
2044	410		35	91	26	8	764	1,280	12.4	12.4			900	1				0	Units added to increase cooling capacity				375
2033	410		35	91	26	7	764	1,269	12.4	12.4								0					372
2042	410		35	91	26	8	764	1,278	12.4	12.4			900	1				0	Units added to increase cooling capacity				374
2032	410		35	90	26	10	764	1,268	12.4	14.0								0					342
2030	410		35	90	26	10	764	1,266	12.4	14.0								0					341
2067	410		35	92	26	7	764	1,303	12.4	12.4								0					382
2071	410		35	92	26	7	764	1,307	12.4	12.4								0					383
2075	410	1,096	35	92	26	10	764	1,311	12.4	36.0		Oversupply	900	3	125	1	110	321					(419)
2073	410	1,068	35	92	26	10	764	1,309	12.4	36.0		Oversupply	900	3	125	1	110	313					(419)
2074	410	1,096	35	92	26	10	764	1,310	12.4	20.0		Oversupply	900	1	159	1.2	110	321	Add Htg	htg capable			#VALUE!
2072	410	1,068	35	92	26	10	764	1,308	12.4	20.0		Oversupply	900	1	159	1.2	110	313	Add Htg	htg capable			#VALUE!
2077	410	1,018	35	92	26	11	764	1,313	12.4	36.0		Oversupply	900	2	159	1.2	110	298					(361)
2076	410	990	35	92	26	11	764	1,312	12.4	19.0		Oversupply	900	1	159	1.2	110	290	Add Htg	htg capable			#VALUE!
MES A2			0	#VALUE!	0	8	231	#VALUE!	3.7	3.7			900	1				0	Unit added because of electrical equipmer				#VALUE!
2022	615		53	90	39	11	1,147	875	18.6	18.6								0					257
2018	3,360		291	90	215	134	6,265	4,247	101.4	101.4			900	2	172	1.3	110	0					(1,589)
2026	410		35	90	26	12	764	1,262	12.4	16.0								0					304
2023	410	1,240	35	90	26	9	764	1,259	12.4	30.0	6	Oversupply	900	2	144	1.1	110	363					(347)
2021	410	1,240	35	90	26	9	764	1,257	12.4	30.0	6	Oversupply	900	2	144	1.1	110	363					(348)
2019	820	2,314	71	90	52	12	1,529	490	24.7	60.0	7	Oversupply	900	4	144	1.1	110	678					(1,197)
2017	410	1,240	35	90	26	9	764	1,253	12.4	30.0	6	Oversupply	900	2	144	1.1	110	363					(349)
2015	410	1,435	35	90	26	10	764	1,251	12.4	36.0		Oversupply	900	2	159	1.2	110	421					(379)
2125	615		53	95	39	9	1,147	978	18.6	18.6			900	1				0	Unit added because of exterior wall				287
2127	615	1,848	53	95	39	12	1,147	980	18.6	33.0		Oversupply	900	2	144	1.1	110	542	Add Htg	htg capable			#VALUE!
C2-2			0	#VALUE!	0	6	177	#VALUE!	2.9	2.9								0					#VALUE!
C2-6			0	#VALUE!	0	9	254	#VALUE!	4.1	7.0			900	1				0	Unit added because of exterior wall				#VALUE!
C2-7		1,290	0	#VALUE!	0	38	1,094	#VALUE!	17.7	45.0		Oversupply	900	4				378		387	6.8	63	#VALUE!
C2-4		1,324	0	#VALUE!	0	8	240	#VALUE!	3.9	47.0		Oversupply	900	1				388	Add Htg	387	6.8	63	#VALUE!
C2-5			0	#VALUE!	0	6	183	#VALUE!	3.0	4.0			900	1				0	Unit added because of exterior wall				#VALUE!
C2-8			0	#VALUE!	0	8	231	#VALUE!	3.7	6.0								0					#VALUE!
	18,325	30,738	1,585	0	1,172	543	34,166	34,166															
	18,325			1,585	1,172	0	34,166	34,166															

space	Latent Cooling (BTU/hr)	Heating (BTU/hr)	Latent Removal (CFM)	Sensible Removal (CFM)	Latent Removal CFM	Minumum OA (Vbz) CFM	Resultant Sensible Removal (BTU/hr)	Remaining Sensible (BTU/hr)	Min SA (l/s)	SA via Beam (l/s)	SA w/o Beam l/s	Oversupply Test	Length of Beam (mm)	Beam Qty	Beam Cooling (W)/unit	Beam DeltaTw (K)	Beam Water Flow (l/h)/unit	Heating (W)	Heating Test	Beam Heating (W)/unit	Beam DeltaTw (K)	Beam Water Flow (l/h)/unit	Balance of Qs (overcooling) (W)
2041	1,230	3,851	106	91	79	14	2,293	252	37.1	105.0	1	Oversupply	900	5	172	1.3	110	1,129					(2,181)
2027	410	1,200	35	90	26	8	764	1,263	12.4	30.0	5	Oversupply	900	2	144	1.1	110	352					(328)
2025	410	1,200	35	90	26	8	764	1,261	12.4	30.0	5	Oversupply	900	2	144	1.1	110	352					(328)
2079			0	93	0	0	0	2,079	0.0	0.0								0					609
2013			0	90	0	0	0	2,013	0.0	0.0								0					590
2085	1,230	1,905	106	93	79	17	2,293	208	37.1	72.0	1	Oversupply	900	4	159	1.2	110	558					(1,347)
2083	820	1,096	71	93	52	12	1,529	554	24.7	42.0	4	Oversupply	900	2	172	1.3	110	321					(566)
2086			0	93	0	9	252	1,834	4.1	4.1								0					538
2088	2,460	1,262	213	93	157	32	4,587	2,499	74.2	77.0			900	4				370	Units added to increase cooling capacity				(782)

2082			0	93	0	11	325	1,757	5.3	5.3								0					515
2002	5,400	3,208	467	89	345	195	10,068	8,066	163.0	162.0	5	Oversupply	900	6	193	1.5	110	940					(3,595)
2012	410		35	90	26	10	764	1,248	12.4	14.0								0					336
2081			0	93	0	19	558	1,523	9.0	12.0								0					393
2011	4,100	3,074	355	90	262	55	7,644	5,633	123.7	108.0	22	Oversupply	900	4	193	1.5	110	901					(2,536)
2095	410	1,554	35	93	26	10	764	1,331	12.4	36.0	5	Oversupply	900	2	159	1.2	110	455					(446)
2093	410	1,043	35	93	26	7	764	1,329	12.4	36.0	2	Oversupply	900	2	159	1.2	110	306					(393)
2091	615	1,123	53	93	39	11	1,147	944	18.6	42.0	1	Oversupply	900	2	172	1.3	110	329					(510)
2089	2,870		248	93	184	64	5,351	3,262	86.6	24.0	63		900	2				0		269	4.6	110	(418)
2057	1,230		106	92	79	21	2,293	236	37.1	37.1			900	3				0	Units added to increase cooling capacity				(69)
1094	615	1,549	53	49	39	12	1,147	53	18.6	24.0		Oversupply	900	2	125	1	110	454					(364)
2096	2,050	2,193	177	93	131	20	3,822	1,726	61.9	24.0	39		900	2	125	1	110	643	Add Htg				(776)
2153	615	1,227	53	96	39	10	1,147	1,006	18.6	36.0	2	Oversupply	900	2	159	1.2	110	360					(375)
2151	615	1,215	53	96	39	9	1,147	1,004	18.6	36.0	1	Oversupply	900	2	159	1.2	110	356					(358)
2149	615	1,200	53	96	39	9	1,147	1,002	18.6	36.0	1	Oversupply	900	2	159	1.2	110	352					(358)
2147	615	1,200	53	96	39	9	1,147	1,000	18.6	36.0	1	Oversupply	900	2	159	1.2	110	352					(359)
2145	820	2,238	71	95	52	12	1,529	616	24.7	63.0	7	Oversupply	900	3	172	1.3	110	656					(1,155)
2143	615	1,200	53	95	39	9	1,147	996	18.6	36.0	1	Oversupply	900	2	159	1.2	110	352					(360)
2141	615	1,254	53	95	39	11	1,147	994	18.6	36.0	2	Oversupply	900	2	159	1.2	110	368					(379)
2158	1,230		106	96	79	23	2,293	135	37.1	37.1			900	3				0	Units added to increase cooling capacity				(40)
2158A	205		18	#VALUE!	13	15	434	#VALUE!	7.0	16.0		Oversupply						0					#VALUE!
2148	820		71	96	52	15	1,529	619	24.7	24.7								0					181
2109	615		53	94	39	11	1,147	962	18.6	18.6								0					282
2146	615		53	96	39	11	1,147	999	18.6	18.6								0					293
2144	615		53	95	39	11	1,147	997	18.6	18.6								0					292
2157	615	3,047	53	96	39	21	1,147	1,010	18.6	84.0	9	Oversupply	900	4	172	1.3	110	893					(1,740)
2134			0	95	0	0	0	2,134	0.0	0.0								0					625
2132			0	95	0	0	0	2,132	0.0	0.0								0					625
2030			0	90	0	0	0	2,030	0.0	0.0								0					595
2107	615	1,500	53	94	39	10	1,147	960	18.6	36.0	5	Oversupply	900	3	125	1	110	440					(500)
2105	615	1,069	53	94	39	9	1,147	958	18.6	36.0	3	Oversupply	900	3	125	1	110	313					(464)
2103	615	1,084	53	94	39	11	1,147	956	18.6	42.0		Oversupply	900	2	172	1.3	110	318					(488)
2106	615	1,488	53	94	39	10	1,147	959	18.6	24.0	1	Oversupply	900	1	183	1.4	110	436	Add Htg				(18)
2102	1,230	2,193	106	94	79	20	2,293	191	37.1	42.0	4	Oversupply	900	2	172	1.3	110	643	Add Htg				(561)
2115	615	1,500	53	94	39	10	1,147	968	18.6	42.0	1	Oversupply	900	2	172	1.3	110	440					(503)
2114	615	1,488	53	94	39	10	1,147	967	18.6	21.0	5	Oversupply	900	1	172	1.3	110	436	Add Htg				(23)
2113	615	1,069	53	94	39	9	1,147	966	18.6	36.0	3	Oversupply	900	3	125	1	110	313					(462)
2111	615	1,084	53	94	39	11	1,147	964	18.6	36.0	5	Oversupply	900	3	125	1	110	318					(499)
2112	615		53	94	39	11	1,147	965	18.6	18.6								0					283
MES B2			0	#VALUE!	0	8	223	#VALUE!	3.6	5.0			900	1				0	Units added because of electrical equipme				#VALUE!
2118			0	94	0	5	134	1,984	2.2	2.2								0					581
2120	2,050	4,120	177	94	131	22	3,822	1,702	61.9	84.0	8	Oversupply	900	4	172	1.3	110	1,207	Add Htg				(1,732)
2122			0	94	0	9	252	1,870	4.1	5.0			900	1				0	Units added because of exterior wall				531
2124	615	1,215	53	95	39	11	1,147	977	18.6	24.0	1	Oversupply	900	1	183	1.4	110	356	Add Htg				(13)
2126	615	2,948	53	95	39	11	1,147	979	18.6	54.0	5	Oversupply	900	3	159	1.2	110	864	Add Htg				(922)
C2-19			0	#VALUE!	0	5	157	#VALUE!	2.5	19.0		Oversupply						0					#VALUE!
C2-18			0	#VALUE!	0	24	691	#VALUE!	11.2	12.0	3		900	1				0		200	3.5	50	#VALUE!
C2-2			0	#VALUE!	0	15	432	#VALUE!	7.0	7.0								0					#VALUE!
C2-3			0	#VALUE!	0	7	203	#VALUE!	3.3									0					#VALUE!
C2-1/201(	960		83	#VALUE!	61	53	1,790	#VALUE!	29.0	30.0	4	Oversupply	900	2	144	1.1	110	0					#VALUE!
C2-9A			0	#VALUE!	0	7	218	#VALUE!	3.5	6.0								0					#VALUE!
2000	1,230		106	89	79	82	2,380	380	38.5	45.0	3	Oversupply	900	3	144	1.1	110	0					(715)
C2-11		861	0	#VALUE!	0	39	1,133	#VALUE!	18.3	37.0		Oversupply						252	Add Htg				#VALUE!
C2-12			0	#VALUE!	0	8	219	#VALUE!	3.5	6.0								0					#VALUE!
C2-13			0	#VALUE!	0	7	197	#VALUE!	3.2	5.0								0					#VALUE!
C2-14			0	#VALUE!	0	7	197	#VALUE!	3.2	5.0								0					#VALUE!
C2-15		1,065	0	#VALUE!	0	2	66	#VALUE!	1.1	41.0		Oversupply						312	Add Htg				#VALUE!
C2-16			0	#VALUE!	0	10	283	#VALUE!	4.6	8.0								0					#VALUE!
C2-17			0	#VALUE!	0	2	57	#VALUE!	0.9	2.0								0					#VALUE!
C2-9B			0	#VALUE!	0	8	231	#VALUE!	3.7	6.0								0					#VALUE!
A-2			0	#VALUE!	0	0	0	#VALUE!	0.0	0.0								0					#VALUE!
	46,130	59,523	3,990	0	2,949	1,165	86,007	86,007	SA SUM		7,354	Beam Sum	900 mm	157	cold wate	(l/h)	14,410	26,453		hot water	(l/h)	585	
	46,130			3,990							cfm /\					gpm	63	SUM of			gpm	3	
															Clg Cap	(BTU/hr)	69,775	Heating		Htg Cap	(BTU/hr)	9,120	

DOAS application

Trox Active Chilled/Heated Beam Estimator

space	Sensible Cooling BTU/hr	Latent Cooling BTU/hr	Heating BTU/hr	Latent Removal (CFM)	Sensible Removal (CFM)	Latent Removal CFM	Minumum OA (Vbz) CFM	Resultant Sensible Removal (BTU/hr)	Remaining Sensible (BTU/hr)	Min SA (l/s)	SA via Beam (l/s)	SA w/o Beam l/s	Oversupply Test	Length of Beam (mm)	Beam Qty	Beam Cooling (W)/unit	Beam DeltaTw (K)	Beam Water Flow (l/h)/unit	Heating (W)	Heating Test	Beam Heating (W)/unit	Beam DeltaTw (K)	Beam Water Flow (l/h)/unit	Balance of Qs (overcooling) (W)
3073	3,567	615	1,172	53	159	39	10	1,147	2,420	18.6	36.0	4	Oversupply	900	2	159	1.2	110	343					3
3074	2,163	615	1,172	53	96	39	10	1,147	1,016	18.6	25.0		Oversupply	900	1	183	1.4	110	343	Add Htg	htg capable			#VALUE!
3071	7,667	1,230	2,486	106	341	79	19	2,293	5,374	37.1	72.0	17	Oversupply	900	4	159	1.2	110	729					(0)
3072	2,201	615	1,258	53	98	39	10	1,147	1,054	18.6	24.0	2	Oversupply	900	1	183	1.4	110	369	Add Htg	htg capable			#VALUE!
3070	2,190	615	1,216	53	97	39	10	1,147	1,043	18.6	24.0	1	Oversupply	900	1	183	1.4	110	356	Add Htg	htg capable			#VALUE!
3088	3,675	615	1,179	53	164	39	12	1,147	2,528	18.6	36.0	6	Oversupply	900	2	159	1.2	110	346					(1)
3086	2,947	1,230	450	106	131	79	34	2,293	654	37.1	37.1			900	1	193	1.5	110	132					(1)
3084				0	0	0	9	262	-262	4.2	0.0								0					0
3083	3,873	615	1,279	53	172	39	10	1,147	2,726	18.6	42.0	2	Oversupply	900	2	172	1.3	110	375					(6)
3081	3,830	615	1,228	53	170	39	10	1,147	2,683	18.6	42.0	1	Oversupply	900	2	172	1.3	110	360					(0)
CR3-082	2,078	820	328	71	93	52	17	1,529	549	24.7	21.0	4		900	1	172	1.3	110	96					(16)
3080	4,055	2,050	540	177	181	131	80	3,822	233	61.9	66.0		Oversupply	900	1				158		130	2.5	56	123
3011	10,189	3,280	3,464	284	454	210	55	6,115	4,074	99.0	150.0	1	Oversupply	900	3	125	1	110	1,015	Add Htg	third unit added for htg capacity			#VALUE!
3008	2,714	820	1,323	71	121	52	15	1,529	1,185	24.7	24.7	5	Oversupply	900	2	125	1	110	388					7
3006	2,281	615	1,414	53	102	39	10	1,147	1,134	18.6	27.0		Oversupply	900	1	193	1.5	110	414	Add Htg	htg capable			#VALUE!
3004	2,021	615	1,187	53	90	39	9	1,147	874	18.6	21.0	2	Oversupply	900	1	172	1.3	110	348	Add Htg	htg capable			#VALUE!
3157	8,365	820	3,452	71	372	52	23	1,529	6,836	24.7	90.0	2	Oversupply	900	5	159	1.2	110	1,012					(9)
3109	1,421	615	212	53	63	39	11	1,147	274	18.6	23.0		Oversupply	900	1				62		75	1.5	54	75
3054	7,208	615	3,129	53	321	39	15	1,147	6,061	18.6	75.0	2	Oversupply	900	5	144	1.1	110	917					(2)
3061	2,087	1,230	215	106	93	79	17	2,293	-206	37.1	40.0			900	1				63		100	2	50	(13)
3065	2,935	615	973	53	131	39	10	1,147	1,788	18.6	30.0	2	Oversupply	900	2	144	1.1	110	285					(7)
3064	2,163	615	1,172	53	96	39	10	1,147	1,016	18.6	24.0	1	Oversupply	900	2	183	1.4	110	343		second unit added for htg capaci			#VALUE!
3063	7,066	1,230	2,360	106	315	79	10	2,293	4,773	37.1	72.0	7	Oversupply	900	4	159	1.2	110	692					4
3062	3,838	615	1,258	53	171	39	10	1,147	2,691	18.6	42.0	1	Oversupply	900	2	172	1.3	110	369					2
3060	3,827	615	1,216	53	170	39	10	1,147	2,680	18.6	42.0	1	Oversupply	900	2	172	1.3	110	356					(1)
3050	1,139	615	143	53	51	39	8	1,147	-8	18.6	22.0			900	1				42		75	1.5	54	10
3031	1,139	615	143	53	51	39	8	1,147	-8	18.6	22.0			900	1				42		75	1.5	54	10
3041	6,465	820	3,258	71	288	52	18	1,529	4,936	24.7	72.0	2	Oversupply	900	3	183	1.4	110	955	Add Htg	htg capable			#VALUE!
3032	1,251	615	170	53	56	39	9	1,147	104	18.6	24.0		Oversupply	900	1				50		75	1.5	54	7
3030	1,251	615	170	53	56	39	9	1,147	104	18.6	24.0		Oversupply	900	1				50		75	1.5	54	7
3069	1,670	615	273	53	74	39	14	1,147	523	18.6	12.0	8		900	1	125	10	110	80					2
MES A3	989	615	106	53	44	39	8	1,147	-158	18.6	20.0			900	1				31		75	1.5	54	3
3029	3,382	615	1,326	53	151	39	8	1,147	2,235	18.6	36.0	1	Oversupply	900	2	159	1.2	110	389					3
3027	3,382	615	1,326	53	151	39	8	1,147	2,235	18.6	36.0	1	Oversupply	900	2	159	1.2	110	389					3
3025	3,382	615	1,326	53	151	39	8	1,147	2,235	18.6	36.0	1	Oversupply	900	2	159	1.2	110	389					3
3023	3,412	615	1,349	53	152	39	8	1,147	2,265	18.6	36.0	2	Oversupply	900	2	159	1.2	110	395					(6)
3021	3,382	615	1,326	53	151	39	8	1,147	2,235	18.6	36.0	1	Oversupply	900	2	159	1.2	110	389					3
3019	3,382	615	1,326	53	151	39	8	1,147	2,235	18.6	36.0	1	Oversupply	900	2	159	1.2	110	389					3
3017	3,382	615	1,326	53	151	39	8	1,147	2,235	18.6	36.0	1	Oversupply	900	2	159	1.2	110	389					3
3015	3,421	615	1,460	53	152	39	8	1,147	2,274	18.6	36.0	2	Oversupply	900	2	159	1.2	110	428					(3)
3075	2,772		680	0	123	0	36	1,047	1,725	17.0	30.0		Oversupply	900	2	144	1.1	110	199					(19)
3022	1,539	615	241	53	69	39	13	1,147	392	18.6	12.0	7		900	1	125	1	110	71					(18)
3077	1,428	615	214	53	64	39	11	1,147	281	18.6	23.0		Oversupply	900	1				63		75	1.5	54	77
3018	1,428	615	214	53	64	39	8	1,147	281	18.6	23.0		Oversupply	900	1				63		75	1.5	54	77
3155	3,436	615	1,357	53	153	39	9	1,147	2,289	18.6	30.0	10	Oversupply	900	2	144	1.1	110	398					(5)
3153	3,436	615	1,357	53	153	39	9	1,147	2,289	18.6	30.0	10	Oversupply	900	2	144	1.1	110	398					(5)
3151	6,064	615	3,175	53	270	39	9	1,147	4,917	18.6	60.0	6	Oversupply	900	4	144	1.1	110	930					6
C3-6	4,236	615	1,725	53	189	39	9	1,147	3,089	18.6	48.0		Oversupply	900	2	183	1.4	110	506					6
C3-7	4,448		3,208	0	198	0	31	892	3,556	14.4	48.0		Oversupply	900	4	110	1	110	940					(6)
C3-4	727		403	0	32	0	7	217	510	3.5	12.0		Oversupply	900	1				118		100	2	54	96
C3-5	436		138	0	19	0	5	150	286	2.4	7.0		Oversupply	900	1				40		75	1.5	54	76
C3-8	669		212	0	30	0	8	231	438	3.7	11.0		Oversupply	900	1				62		75	1.5	54	72
C3-3	629		199	0	28	0	7	217	412	3.5	10.0		Oversupply	900	1				58		75	1.5	54	78
C3-2	1,765		560	0	79	0	21	608	1,157	9.8	29.0		Oversupply	900	1				164		150	3	54	142
3009	5,093	2,255	749	195	227	144	98	4,204	889	68.1	24.0	44		900	2	125	1	110	220					11
C3-11	634		201	0	28	0	8	219	415	3.5	10.0		Oversupply	900	1				59					5
B-3				0	0	0	0	0	0	0.0	0.0								0					0
	174,130	37,925	63,344	3,281	7,752	2,425	863																	
		212,055			11,032	13,559	0																	

space	Sensible Cooling BTU/hr	Latent Cooling BTU/hr	Heating BTU/hr	Latent Removal (CFM)	Sensible Removal (CFM)	Latent Removal CFM	Minumum OA (Vbz) CFM	Resultant Sensible Removal (BTU/hr)	Remaining Sensible (BTU/hr)	Min SA (l/s)	SA via Beam (l/s)	SA w/o Beam l/s	Oversupply Test	Length of Beam (mm)	Beam Qty	Beam Cooling (W)/unit	Beam DeltaTw (K)	Beam Water Flow (l/h)/unit	Heating (W)	Heating Test	Beam Heating (W)/unit	Beam DeltaTw (K)	Beam Water Flow (l/h)/unit	Balance of Qs (overcooling) (W)
3057	1,139	615	143	53	51	39	8	1,147	-8	18.6	18.6			900	1				42		75	1.5	54	73
3053	1,415	615		53	63	39	9	1,147	268	18.6	18.6			900	1	80	1	80	0					(1)
3051	1,415	615		53	63	39	17	1,147	268	18.6	18.6			900	1	80	1	80	0					(1)
3146	865		212	0	39	0	16	461	404	7.5	7.5			900	1	125	1	110	62					(7)
3144	1,415	615	211	53	63	39	11	1,147	268	18.6	18.6			900	1	80	1	80	62					(1)
3107	3,891	615	1,590	53	173	39	10	1,147	2,744	18.6	36.0	6	Oversupply	900	3	125	1	110	466					5
3105	3,832	615	1,243	53	171	39	9	1,147	2,685	18.6	36.0	5	Oversupply	900	3	125	1	110	364					6
3103	3,934	615	1,287	53	175	39	11	1,147	2,787	18.6	36.0	7	Oversupply	900	3	125	1	110	377					(1)
3106	2,583	615	1,772	53	115	39	12	1,147	1,436	18.6	24.0	4	Oversupply	900	2	125	1	110	519					0
3102	4,500	1,230	2,552	106	200	79	20	2,293	2,207	37.1	48.0	5	Oversupply	900	2	183	1.4	110	748	Add Htg	htg capable			#VALUE!
3091	3,289	2,050	352	177	146	131	68	3,822	-533	61.9	68.0		Oversupply	900	1				103		269	4.6	50	2
3094	2,535	615	1,652	53	113	39	12	1,147	1,388	18.6	24.0	3	Oversupply	900	2	125	1	110	484					4
3096	5,619	2,460	2,579	213	250	157	74	4,587	1,032	74.2	74.2	3		900	2	125	1	110	756	Add Htg	htg capable			#VALUE!
3097A	1,198	615	158	53	53	39	8	1,147	51	18.6	19.0			900	1				46		htg capable			#VALUE!
3150	2,534	1,230	349	106	113	79	18	2,293	241	37.1	41.0			900	1				102		htg capable			#VALUE!
3101	1,421	615	212	53	63	39	11	1,147	274	18.6	23.0		Oversupply	900	1				62		htg capable			#VALUE!
3148	1,336	615	191	53	59	39	48	1,405	-69	22.7	22.7			900	1				56		htg capable			#VALUE!
3089	3,522	2,460	318	213	157	157	61	4,587	-1,065	74.2	74.2			900	1				93		308	5.3	50	(4)
3095	4,278	615	1,752	53	190	39	10	1,147	3,131	18.6	45.0	4	Oversupply	900	3	125	1	110	513					(8)
3093	7,331	820	2,519	71	326	52	19	1,529	5,802	24.7	75.0	4	Oversupply	900	5	144	1.1	110	738					(2)
3055	1,139	615	143	53	51	39	8	1,147	-8	18.6	18.6			900	1				42		htg capable			#VALUE!
3026	1,460	615	222	53	65	39	12	1,147	313	18.6	24.0		Oversupply	900	1				65		htg capable			#VALUE!
3079				0	0	0	0	0	0	0.0	0.0								0					0
3013				0	0	0	0	0	0	0.0	0.0								0					0
3000	6,225	1,920	844	166	277	123	58	3,580	2,645	57.9	60.0	6	Oversupply	900	5	125	1	110	247					4
3149	3,436	615	1,357	53	153	39	9	1,147	2,289	18.6	36.0	2	Oversupply	900	2	159	1.2	110	398					1
3147	3,412	615	1,349	53	152	39	8	1,147	2,265	18.6	36.0	2	Oversupply	900	2	159	1.2	110	395					(6)
3145	3,412	615	1,349	53	152	39	8	1,147	2,265	18.6	36.0	2	Oversupply	900	2	159	1.2	110	395					(6)
3143	3,436	615	1,357	53	153	39	9	1,147	2,289	18.6	36.0	2	Oversupply	900	2	159	1.2	110	398					1
3141	3,412	615	1,349	53	152	39	8	1,147	2,265	18.6	36.0	2	Oversupply	900	2	159	1.2	110	395					(6)
3115	3,952	615	1,687	53	176	39	10	1,147	2,805	18.6	42.0	3	Oversupply	900	2	172	1.3	110	494					(1)
3113	3,832	615	1,243	53	171	39	9	1,147	2,685	18.6	42.0	1	Oversupply	900	2	172	1.3	110	364					0
3111	3,934	615	1,287	53	175	39	11	1,147	2,787	18.6	42.0	3	Oversupply	900	2	172	1.3	110	377					(6)
3114	2,808	615	1,892	53	125	39	14	1,147	1,661	18.6	30.0		Oversupply	900	2	144	1.1	110	554	Add Htg	htg capable			#VALUE!
3120	8,878	1,640	4,733	142	395	105	31	3,058	5,820	49.5	96.0	7	Oversupply	900	4	183	1.4	110	1,387	Add Htg	htg capable			#VALUE!
MES B3	419		103	0	19	0	8	223	196	3.6	7.0			900	1				30		htg capable			#VALUE!
3118				0	0	0	0	0	0	0.0	0.0								0					0
3134				0	0	0	0	0	0	0.0	0.0								0					0
3132				0	0	0	0	0	0	0.0	0.0								0					0
3130				0	0	0	0	0	0	0.0	0.0								0					0
3124	2,716	820	1,485	71	121	52	12	1,529	1,187	24.7	24.7	5	Oversupply	900	2	125	1	110	435					7
3125	12,310	2,050	6,720	177	548	131	107	3,822	8,488	61.9	135.0	11	Oversupply	900	5	193	1.5	110	1,969	Add Htg	htg capable			#VALUE!
C3-10	548		174	0	24	0	6	188	360	3.0	9.0		Oversupply	900	1				51		htg capable			#VALUE!
C3-12	634		201	0	28	0	8	219	415	3.5	10.0		Oversupply	900	1				59		htg capable			#VALUE!
C3-1	1,749		555	0	78	0	21	604	1,145	9.8	28.0		Oversupply	900	1				163		htg capable			#VALUE!
C3-15	7,439		3,408	0	331	0	33	971	6,468	15.7	75.0	6	Oversupply	900	5	144	1.1	110	999					(6)
C3-20/309	2,053	480	333	42	91	31	12	895	1,158	14.5	21.0	3	Oversupply	900	1	172	1.3	110	98					(5)
C3-19	1,876		595	0	84	0	22	647	1,229	10.5	21.0		Oversupply	900	1	172	1.3	110	174					(2)
C3-18	406		129	0	18	0	5	140	266	2.3	7.0		Oversupply						38	Add Htg				(8)
C3-17	629		199	0	28	0	7	217	412	3.5	10.0		Oversupply						58	Add Htg				3
C3-14	700		222	0	31	0	8	241	459	3.9	11.0		Oversupply						65	Add Htg				6
C3-16	193		61	0	9	0	2	66	127	1.1	3.0								18	Add Htg				2
C3-13	700		222	0	31	0	8	241	459	3.9	11.0		Oversupply						65	Add Htg				6
3009	3,171	840	479	73	141	54	62	1,820	1,351	29.5	30.0	5	Oversupply	900	2	144	1.1	110	140					8
A-3				0	0	0	0	0	0	0.0	0.0								0					0
				0	0	0	0	0	0	0.0	0.0								0					0
	142,931	32,760	52,790	2,834	6,363	2,095	972				SA SUI	8,270	Beam Sum	900 mm	186	cold wate	(l/h)	17,180	34,035		hot water	(l/h)	962	
		175,691			9,197							cfm /\					gpm	76	SUM of			gpm	4	
																Clg Cap	(BTU/hr)	80,970	Heating		Htg Cap	(BTU/hr)	6,677	

Office 3073

space vol assumes 9.5' ceiling

Time (hours)	Time (minutes)	DOAS Entering Air (cfm)	DOAS Leaving Air (cfm)	VAV Entering Air (cfm)	VAV Leaving Air (cfm)	Amb Conc (ppm)	Emission Rate per occupant (cfm)	Occ	Space Vol (ft^3)	DOAS Conc (ppm) 350	VAV Conc (ppm) 350
8:00	0	85	85	335	335	350	0.0106	1	1178	358.998	358.998
	5	85	85	335	335	350	0.0106	1	1178	367.347	367.741
	10	85	85	335	335	350	0.0106	1	1178	375.094	376.235
	15	85	85	335	335	350	0.0106	1	1178	382.282	384.487
	20	85	85	335	335	350	0.0106	1	1178	388.951	392.504
	25	85	85	335	335	350	0.0106	1	1178	395.138	400.294
	30	85	85	335	335	350	0.0106	1	1178	400.880	407.862
	35	85	85	335	335	350	0.0106	1	1178	406.207	415.215
	40	85	85	335	335	350	0.0106	1	1178	411.149	422.358
	45	85	85	335	335	350	0.0106	1	1178	415.735	429.299
	50	85	85	335	335	350	0.0106	1	1178	419.990	436.042
	55	85	85	335	335	350	0.0106	1	1178	423.938	442.594
9:00	60	85	85	335	335	350	0.0106	1	1178	427.602	448.959
	65	85	85	335	335	350	0.0106	1	1178	431.000	455.143
	70	85	85	335	335	350	0.0106	1	1178	434.154	461.151
	75	85	85	335	335	350	0.0106	1	1178	437.080	466.989
	80	85	85	335	335	350	0.0106	1	1178	439.795	472.660
	85	85	85	335	335	350	0.0106	1	1178	442.314	478.170
	90	85	85	335	335	350	0.0106	1	1178	444.651	483.523
	95	85	85	335	335	350	0.0106	1	1178	446.820	488.725
	100	85	85	335	335	350	0.0106	1	1178	448.832	493.778
	105	85	85	335	335	350	0.0106	1	1178	450.699	498.687
	110	85	85	335	335	350	0.0106	1	1178	452.431	503.457
	115	85	85	335	335	350	0.0106	1	1178	454.039	508.092
10:00	120	85	85	335	335	350	0.0106	1	1178	455.530	512.594
	125	85	85	335	335	350	0.0106	1	1178	456.914	516.968
	130	85	85	335	335	350	0.0106	1	1178	458.197	521.219
	135	85	85	335	335	350	0.0106	1	1178	459.389	525.348
	140	85	85	335	335	350	0.0106	1	1178	460.494	529.359
	145	85	85	335	335	350	0.0106	1	1178	461.519	533.257
	150	85	85	335	335	350	0.0106	1	1178	462.471	537.044
	155	85	85	335	335	350	0.0106	1	1178	463.354	540.723
	160	85	85	335	335	350	0.0106	1	1178	464.173	544.298
	165	85	85	335	335	350	0.0106	1	1178	464.933	547.770
	170	85	85	335	335	350	0.0106	1	1178	465.638	551.145
	175	85	85	335	335	350	0.0106	1	1178	466.292	554.423
11:00	180	85	85	335	335	350	0.0106	1	1178	466.899	557.608
	185	85	85	335	335	350	0.0106	1	1178	467.463	560.702
	190	85	85	335	335	350	0.0106	1	1178	467.985	563.708
	195	85	85	335	335	350	0.0106	1	1178	468.470	566.629
	200	85	85	335	335	350	0.0106	1	1178	468.920	569.467
	205	85	85	335	335	350	0.0106	1	1178	469.338	572.224
	210	85	85	335	335	350	0.0106	1	1178	469.725	574.903
	215	85	85	335	335	350	0.0106	1	1178	470.084	577.505
	220	85	85	335	335	350	0.0106	1	1178	470.418	580.034
	225	85	85	335	335	350	0.0106	1	1178	470.727	582.490
	230	85	85	335	335	350	0.0106	1	1178	471.014	584.877
	235	85	85	335	335	350	0.0106	1	1178	471.281	587.196
12:00	240	85	85	335	335	350	0.0106	0	1178	462.530	580.451
L	245	85	85	335	335	350	0.0106	0	1178	454.410	573.897
U	250	85	85	335	335	350	0.0106	0	1178	446.876	567.530
N	255	85	85	335	335	350	0.0106	0	1178	439.886	561.344
C	260	85	85	335	335	350	0.0106	0	1178	433.400	555.334
H	265	85	85	335	335	350	0.0106	0	1178	427.382	549.494
	270	85	85	335	335	350	0.0106	0	1178	421.799	543.821

T	275	85	85	335	335	350	0.0106	0	1178	416.618	538.309
I	280	85	85	335	335	350	0.0106	0	1178	411.811	532.954
M	285	85	85	335	335	350	0.0106	0	1178	407.351	527.751
E	290	85	85	335	335	350	0.0106	0	1178	403.213	522.696
	295	85	85	335	335	350	0.0106	0	1178	399.373	517.785
1:00	300	85	85	335	335	350	0.0106	1	1178	404.809	522.012
	305	85	85	335	335	350	0.0106	1	1178	409.852	526.119
	310	85	85	335	335	350	0.0106	1	1178	414.532	530.108
	315	85	85	335	335	350	0.0106	1	1178	418.874	533.985
	320	85	85	335	335	350	0.0106	1	1178	422.902	537.751
	325	85	85	335	335	350	0.0106	1	1178	426.640	541.410
	330	85	85	335	335	350	0.0106	1	1178	430.109	544.965
	335	85	85	335	335	350	0.0106	1	1178	433.327	548.419
	340	85	85	335	335	350	0.0106	1	1178	436.312	551.774
	345	85	85	335	335	350	0.0106	1	1178	439.083	555.035
	350	85	85	335	335	350	0.0106	1	1178	441.653	558.202
	355	85	85	335	335	350	0.0106	1	1178	444.038	561.280
2:00	360	85	85	335	335	350	0.0106	1	1178	446.251	564.270
	365	85	85	335	335	350	0.0106	1	1178	448.304	567.174
	370	85	85	335	335	350	0.0106	1	1178	450.209	569.997
	375	85	85	335	335	350	0.0106	1	1178	451.977	572.739
	380	85	85	335	335	350	0.0106	1	1178	453.617	575.403
	385	85	85	335	335	350	0.0106	1	1178	455.139	577.991
	390	85	85	335	335	350	0.0106	1	1178	456.550	580.506
	395	85	85	335	335	350	0.0106	1	1178	457.860	582.949
	400	85	85	335	335	350	0.0106	1	1178	459.076	585.323
	405	85	85	335	335	350	0.0106	1	1178	460.204	587.629
	410	85	85	335	335	350	0.0106	1	1178	461.250	589.869
	415	85	85	335	335	350	0.0106	1	1178	462.221	592.046
3:00	420	85	85	335	335	350	0.0106	1	1178	463.122	594.161
	425	85	85	335	335	350	0.0106	1	1178	463.958	596.216
	430	85	85	335	335	350	0.0106	1	1178	464.733	598.213
	435	85	85	335	335	350	0.0106	1	1178	465.453	600.152
	440	85	85	335	335	350	0.0106	1	1178	466.121	602.037
	445	85	85	335	335	350	0.0106	1	1178	466.740	603.868
	450	85	85	335	335	350	0.0106	1	1178	467.315	605.646
	455	85	85	335	335	350	0.0106	1	1178	467.848	607.375
	460	85	85	335	335	350	0.0106	1	1178	468.343	609.054
	465	85	85	335	335	350	0.0106	1	1178	468.802	610.685
	470	85	85	335	335	350	0.0106	1	1178	469.228	612.270
	475	85	85	335	335	350	0.0106	1	1178	469.623	613.810
4:00	480	85	85	335	335	350	0.0106	1	1178	469.990	615.306
	485	85	85	335	335	350	0.0106	1	1178	470.330	616.759
	490	85	85	335	335	350	0.0106	1	1178	470.646	618.172
	495	85	85	335	335	350	0.0106	1	1178	470.939	619.544
	500	85	85	335	335	350	0.0106	1	1178	471.211	620.877
	505	85	85	335	335	350	0.0106	1	1178	471.463	622.172
	510	85	85	335	335	350	0.0106	1	1178	471.697	623.430
	515	85	85	335	335	350	0.0106	1	1178	471.914	624.652
	520	85	85	335	335	350	0.0106	1	1178	472.116	625.840
	525	85	85	335	335	350	0.0106	1	1178	472.302	626.994
	530	85	85	335	335	350	0.0106	1	1178	472.476	628.115
	535	85	85	335	335	350	0.0106	1	1178	472.637	629.205
5:00	540	85	85	335	335	350	0.0106	0	1178	463.788	621.265
G	545	85	85	335	335	350	0.0106	0	1178	455.577	613.550
O	550	85	85	335	335	350	0.0106	0	1178	447.959	606.055
	555	85	85	335	335	350	0.0106	0	1178	440.891	598.774
H	560	85	85	335	335	350	0.0106	0	1178	434.333	591.699
O	565	85	85	335	335	350	0.0106	0	1178	428.247	584.826
M	570	85	85	335	335	350	0.0106	0	1178	422.601	578.148

E	575	85	85	335	335	350	0.0106	0	1178	417.363	571.660
	580	85	85	335	335	350	0.0106	0	1178	412.502	565.356
	585	85	85	335	335	350	0.0106	0	1178	407.992	559.232
	590	85	85	335	335	350	0.0106	0	1178	403.808	553.282
	595	85	85	335	335	350	0.0106	0	1178	399.925	547.501
6:00	600	85	85	335	335	350	0.0106	0	1178	396.323	541.884
	605	85	85	335	335	350	0.0106	0	1178	392.980	536.427
	610	85	85	335	335	350	0.0106	0	1178	389.879	531.126
	615	85	85	335	335	350	0.0106	0	1178	387.001	525.975
	620	85	85	335	335	350	0.0106	0	1178	384.332	520.970
	625	85	85	335	335	350	0.0106	0	1178	381.854	516.108
	630	85	85	335	335	350	0.0106	0	1178	379.556	511.385
	635	85	85	335	335	350	0.0106	0	1178	377.423	506.795
	640	85	85	335	335	350	0.0106	0	1178	375.444	502.336
	645	85	85	335	335	350	0.0106	0	1178	373.608	498.004
	650	85	85	335	335	350	0.0106	0	1178	371.905	493.795
	655	85	85	335	335	350	0.0106	0	1178	370.324	489.706
7:00	660	85	85	335	335	350	0.0106	0	1178	368.858	485.733
	665	85	85	335	335	350	0.0106	0	1178	367.497	481.873
	670	85	85	335	335	350	0.0106	0	1178	366.235	478.123
	675	85	85	335	335	350	0.0106	0	1178	365.063	474.479
	680	85	85	335	335	350	0.0106	0	1178	363.976	470.939
	685	85	85	335	335	350	0.0106	0	1178	362.968	467.500
	690	85	85	335	335	350	0.0106	0	1178	362.032	464.158
	695	85	85	335	335	350	0.0106	0	1178	361.164	460.912
	700	85	85	335	335	350	0.0106	0	1178	360.358	457.758
	705	85	85	335	335	350	0.0106	0	1178	359.611	454.693
	710	85	85	335	335	350	0.0106	0	1178	358.917	451.716
	715	85	85	335	335	350	0.0106	0	1178	358.274	448.824
8:00	720	85	85	335	335	350	0.0106	0	1178	357.677	446.013
	725	85	85	335	335	350	0.0106	0	1178	357.123	443.283
	730	85	85	335	335	350	0.0106	0	1178	356.609	440.630
	735	85	85	335	335	350	0.0106	0	1178	356.132	438.053
	740	85	85	335	335	350	0.0106	0	1178	355.690	435.549
	745	85	85	335	335	350	0.0106	0	1178	355.279	433.116
	750	85	85	335	335	350	0.0106	0	1178	354.898	430.752
	755	85	85	335	335	350	0.0106	0	1178	354.545	428.456
	760	85	85	335	335	350	0.0106	0	1178	354.217	426.225
	765	85	85	335	335	350	0.0106	0	1178	353.913	424.057
	770	85	85	335	335	350	0.0106	0	1178	353.630	421.951
	775	85	85	335	335	350	0.0106	0	1178	353.368	419.905
9:00	780	85	85	335	335	350	0.0106	0	1178	353.125	417.917
	785	85	85	335	335	350	0.0106	0	1178	352.900	415.985
	790	85	85	335	335	350	0.0106	0	1178	352.691	414.109
	795	85	85	335	335	350	0.0106	0	1178	352.496	412.286
	800	85	85	335	335	350	0.0106	0	1178	352.316	410.514
	805	85	85	335	335	350	0.0106	0	1178	352.149	408.794
	810	85	85	335	335	350	0.0106	0	1178	351.994	407.122
	815	85	85	335	335	350	0.0106	0	1178	351.850	405.497
	820	85	85	335	335	350	0.0106	0	1178	351.717	403.919
	825	85	85	335	335	350	0.0106	0	1178	351.593	402.386
	830	85	85	335	335	350	0.0106	0	1178	351.478	400.896
	835	85	85	335	335	350	0.0106	0	1178	351.371	399.448
10:00	840	85	85	335	335	350	0.0106	0	1178	351.272	398.042
	845	85	85	335	335	350	0.0106	0	1178	351.180	396.676
	850	85	85	335	335	350	0.0106	0	1178	351.095	395.349
	855	85	85	335	335	350	0.0106	0	1178	351.016	394.059
	860	85	85	335	335	350	0.0106	0	1178	350.943	392.806
	865	85	85	335	335	350	0.0106	0	1178	350.875	391.589
	870	85	85	335	335	350	0.0106	0	1178	350.812	390.406

	875	85	85	335	335	350	0.0106	0	1178	350.753	389.257
	880	85	85	335	335	350	0.0106	0	1178	350.699	388.141
	885	85	85	335	335	350	0.0106	0	1178	350.648	387.056
	890	85	85	335	335	350	0.0106	0	1178	350.602	386.002
	895	85	85	335	335	350	0.0106	0	1178	350.558	384.978
11:00	900	85	85	335	335	350	0.0106	0	1178	350.518	383.984
	905	85	85	335	335	350	0.0106	0	1178	350.481	383.017
	910	85	85	335	335	350	0.0106	0	1178	350.446	382.078
	915	85	85	335	335	350	0.0106	0	1178	350.414	381.166
	920	85	85	335	335	350	0.0106	0	1178	350.384	380.280
	925	85	85	335	335	350	0.0106	0	1178	350.356	379.419
	930	85	85	335	335	350	0.0106	0	1178	350.330	378.582
	935	85	85	335	335	350	0.0106	0	1178	350.307	377.769
	940	85	85	335	335	350	0.0106	0	1178	350.285	376.979
	945	85	85	335	335	350	0.0106	0	1178	350.264	376.212
	950	85	85	335	335	350	0.0106	0	1178	350.245	375.467
	955	85	85	335	335	350	0.0106	0	1178	350.227	374.743
12:00	960	85	85	335	335	350	0.0106	0	1178	350.211	374.039
	965	85	85	335	335	350	0.0106	0	1178	350.196	373.355
	970	85	85	335	335	350	0.0106	0	1178	350.182	372.691
	975	85	85	335	335	350	0.0106	0	1178	350.168	372.046
	980	85	85	335	335	350	0.0106	0	1178	350.156	371.419
	985	85	85	335	335	350	0.0106	0	1178	350.145	370.810
	990	85	85	335	335	350	0.0106	0	1178	350.135	370.218
	995	85	85	335	335	350	0.0106	0	1178	350.125	369.643
	1000	85	85	335	335	350	0.0106	0	1178	350.116	369.084
	1005	85	85	335	335	350	0.0106	0	1178	350.107	368.542
	1010	85	85	335	335	350	0.0106	0	1178	350.100	368.014
	1015	85	85	335	335	350	0.0106	0	1178	350.093	367.502
1:00	1020	85	85	335	335	350	0.0106	0	1178	350.086	367.004
	1025	85	85	335	335	350	0.0106	0	1178	350.080	366.521
	1030	85	85	335	335	350	0.0106	0	1178	350.074	366.051
	1035	85	85	335	335	350	0.0106	0	1178	350.069	365.595
	1040	85	85	335	335	350	0.0106	0	1178	350.064	365.151
	1045	85	85	335	335	350	0.0106	0	1178	350.059	364.720
	1050	85	85	335	335	350	0.0106	0	1178	350.055	364.302
	1055	85	85	335	335	350	0.0106	0	1178	350.051	363.895
	1060	85	85	335	335	350	0.0106	0	1178	350.047	363.500
	1065	85	85	335	335	350	0.0106	0	1178	350.044	363.116
	1070	85	85	335	335	350	0.0106	0	1178	350.041	362.743
	1075	85	85	335	335	350	0.0106	0	1178	350.038	362.380
2:00	1080	85	85	335	335	350	0.0106	0	1178	350.035	362.028
	1085	85	85	335	335	350	0.0106	0	1178	350.032	361.686
	1090	85	85	335	335	350	0.0106	0	1178	350.030	361.354
	1095	85	85	335	335	350	0.0106	0	1178	350.028	361.031
	1100	85	85	335	335	350	0.0106	0	1178	350.026	360.717
	1105	85	85	335	335	350	0.0106	0	1178	350.024	360.413
	1110	85	85	335	335	350	0.0106	0	1178	350.022	360.117
	1115	85	85	335	335	350	0.0106	0	1178	350.021	359.829
	1120	85	85	335	335	350	0.0106	0	1178	350.019	359.549
	1125	85	85	335	335	350	0.0106	0	1178	350.018	359.278
	1130	85	85	335	335	350	0.0106	0	1178	350.017	359.014
	1135	85	85	335	335	350	0.0106	0	1178	350.015	358.758
3:00	1140	85	85	335	335	350	0.0106	0	1178	350.014	358.509
	1145	85	85	335	335	350	0.0106	0	1178	350.013	358.267
	1150	85	85	335	335	350	0.0106	0	1178	350.012	358.031
	1155	85	85	335	335	350	0.0106	0	1178	350.011	357.803
	1160	85	85	335	335	350	0.0106	0	1178	350.011	357.581
	1165	85	85	335	335	350	0.0106	0	1178	350.010	357.366
	1170	85	85	335	335	350	0.0106	0	1178	350.009	357.156

	1175	85	85	335	335	350	0.0106	0	1178	350.008	356.953
	1180	85	85	335	335	350	0.0106	0	1178	350.008	356.755
	1185	85	85	335	335	350	0.0106	0	1178	350.007	356.563
	1190	85	85	335	335	350	0.0106	0	1178	350.007	356.376
	1195	85	85	335	335	350	0.0106	0	1178	350.006	356.195
4:00	1200	85	85	335	335	350	0.0106	0	1178	350.006	356.019
	1205	85	85	335	335	350	0.0106	0	1178	350.005	355.848
	1210	85	85	335	335	350	0.0106	0	1178	350.005	355.681
	1215	85	85	335	335	350	0.0106	0	1178	350.005	355.520
	1220	85	85	335	335	350	0.0106	0	1178	350.004	355.363
	1225	85	85	335	335	350	0.0106	0	1178	350.004	355.210
	1230	85	85	335	335	350	0.0106	0	1178	350.004	355.062
	1235	85	85	335	335	350	0.0106	0	1178	350.003	354.918
	1240	85	85	335	335	350	0.0106	0	1178	350.003	354.778
	1245	85	85	335	335	350	0.0106	0	1178	350.003	354.642
	1250	85	85	335	335	350	0.0106	0	1178	350.003	354.510
	1255	85	85	335	335	350	0.0106	0	1178	350.003	354.382
5:00	1260	85	85	335	335	350	0.0106	0	1178	350.002	354.257
	1265	85	85	335	335	350	0.0106	0	1178	350.002	354.136
	1270	85	85	335	335	350	0.0106	0	1178	350.002	354.019
	1275	85	85	335	335	350	0.0106	0	1178	350.002	353.904
	1280	85	85	335	335	350	0.0106	0	1178	350.002	353.793
	1285	85	85	335	335	350	0.0106	0	1178	350.002	353.686
	1290	85	85	335	335	350	0.0106	0	1178	350.002	353.581
	1295	85	85	335	335	350	0.0106	0	1178	350.001	353.479
	1300	85	85	335	335	350	0.0106	0	1178	350.001	353.380
	1305	85	85	335	335	350	0.0106	0	1178	350.001	353.284
	1310	85	85	335	335	350	0.0106	0	1178	350.001	353.190
	1315	85	85	335	335	350	0.0106	0	1178	350.001	353.100
6:00	1320	85	85	335	335	350	0.0106	0	1178	350.001	353.012
	1325	85	85	335	335	350	0.0106	0	1178	350.001	352.926
	1330	85	85	335	335	350	0.0106	0	1178	350.001	352.843
	1335	85	85	335	335	350	0.0106	0	1178	350.001	352.762
	1340	85	85	335	335	350	0.0106	0	1178	350.001	352.683
	1345	85	85	335	335	350	0.0106	0	1178	350.001	352.607
	1350	85	85	335	335	350	0.0106	0	1178	350.001	352.533
	1355	85	85	335	335	350	0.0106	0	1178	350.001	352.461
	1360	85	85	335	335	350	0.0106	0	1178	350.001	352.391
	1365	85	85	335	335	350	0.0106	0	1178	350.000	352.323
	1370	85	85	335	335	350	0.0106	0	1178	350.000	352.257
	1375	85	85	335	335	350	0.0106	0	1178	350.000	352.193
7:00	1380	85	85	335	335	350	0.0106	0	1178	350.000	352.130
	1385	85	85	335	335	350	0.0106	0	1178	350.000	352.070
	1390	85	85	335	335	350	0.0106	0	1178	350.000	352.011
	1395	85	85	335	335	350	0.0106	0	1178	350.000	351.954
	1400	85	85	335	335	350	0.0106	0	1178	350.000	351.898
	1405	85	85	335	335	350	0.0106	0	1178	350.000	351.844
	1410	85	85	335	335	350	0.0106	0	1178	350.000	351.792
	1415	85	85	335	335	350	0.0106	0	1178	350.000	351.741
	1420	85	85	335	335	350	0.0106	0	1178	350.000	351.691
	1425	85	85	335	335	350	0.0106	0	1178	350.000	351.643
	1430	85	85	335	335	350	0.0106	0	1178	350.000	351.596
	1435	85	85	335	335	350	0.0106	0	1178	350.000	351.551
8:00											

Conference Room 3080

space vol assumes 9.5' ceiling

Time (hours)	Time (minutes)	DOAS Entering Air (cfm)	DOAS Leaving Air (cfm)	VAV Entering Air (cfm)	VAV Leaving Air (cfm)	Amb Conc (ppm)	Emission Rate per occupant (cfm)	Occ	Space Vol (ft^3)	**DOAS Conc** (ppm) 350	**VAV Conc** (ppm) 350
8:00	0	140	140	340	340	350	0.0106	0	3192	350.000	350.000
	5	140	140	340	340	350	0.0106	0	3192	350.000	350.000
	10	140	140	340	340	350	0.0106	0	3192	350.000	350.000
	15	140	140	340	340	350	0.0106	0	3192	350.000	350.000
	20	140	140	340	340	350	0.0106	0	3192	350.000	350.000
	25	140	140	340	340	350	0.0106	0	3192	350.000	350.000
	30	140	140	340	340	350	0.0106	0	3192	350.000	350.000
	35	140	140	340	340	350	0.0106	0	3192	350.000	350.000
	40	140	140	340	340	350	0.0106	0	3192	350.000	350.000
	45	140	140	340	340	350	0.0106	0	3192	350.000	350.000
	50	140	140	340	340	350	0.0106	0	3192	350.000	350.000
	55	140	140	340	340	350	0.0106	0	3192	350.000	350.000
9:00	60	140	140	340	340	350	0.0106	2	3192	356.642	356.642
	65	140	140	340	340	350	0.0106	2	3192	362.992	363.212
W	70	140	140	340	340	350	0.0106	2	3192	369.064	369.713
O	75	140	140	340	340	350	0.0106	2	3192	374.869	376.145
R	80	140	140	340	340	350	0.0106	2	3192	380.420	382.508
K	85	140	140	340	340	350	0.0106	2	3192	385.727	388.803
	90	140	140	340	340	350	0.0106	2	3192	390.802	395.032
U	95	140	140	340	340	350	0.0106	2	3192	395.654	401.194
S	100	140	140	340	340	350	0.0106	2	3192	400.293	407.290
E	105	140	140	340	340	350	0.0106	2	3192	404.729	413.321
	110	140	140	340	340	350	0.0106	2	3192	408.970	419.288
	115	140	140	340	340	350	0.0106	2	3192	413.025	425.192
10:00	120	140	140	340	340	350	0.0106	2	3192	416.903	431.033
	125	140	140	340	340	350	0.0106	2	3192	420.610	436.811
W	130	140	140	340	340	350	0.0106	2	3192	424.155	442.528
O	135	140	140	340	340	350	0.0106	2	3192	427.544	448.184
R	140	140	140	340	340	350	0.0106	2	3192	430.784	453.780
K	145	140	140	340	340	350	0.0106	2	3192	433.883	459.316
	150	140	140	340	340	350	0.0106	2	3192	436.845	464.793
U	155	140	140	340	340	350	0.0106	2	3192	439.678	470.212
S	160	140	140	340	340	350	0.0106	2	3192	442.386	475.573
E	165	140	140	340	340	350	0.0106	2	3192	444.976	480.877
	170	140	140	340	340	350	0.0106	2	3192	447.452	486.125
	175	140	140	340	340	350	0.0106	2	3192	449.819	491.317
11:00	180	140	140	340	340	350	0.0106	0	3192	445.441	489.811
	185	140	140	340	340	350	0.0106	0	3192	441.255	488.322
	190	140	140	340	340	350	0.0106	0	3192	437.253	486.849
	195	140	140	340	340	350	0.0106	0	3192	433.426	485.391
	200	140	140	340	340	350	0.0106	0	3192	429.767	483.949
	205	140	140	340	340	350	0.0106	0	3192	426.268	482.522
	210	140	140	340	340	350	0.0106	0	3192	422.923	481.111
	215	140	140	340	340	350	0.0106	0	3192	419.725	479.714
	220	140	140	340	340	350	0.0106	0	3192	416.667	478.332
	225	140	140	340	340	350	0.0106	0	3192	413.743	476.965
	230	140	140	340	340	350	0.0106	0	3192	410.947	475.613
	235	140	140	340	340	350	0.0106	0	3192	408.274	474.275
12:00	240	140	140	340	340	350	0.0106	0	3192	405.718	472.951
L	245	140	140	340	340	350	0.0106	0	3192	403.274	471.642
U	250	140	140	340	340	350	0.0106	0	3192	400.938	470.346
N	255	140	140	340	340	350	0.0106	0	3192	398.704	469.064
C	260	140	140	340	340	350	0.0106	0	3192	396.567	467.796
H	265	140	140	340	340	350	0.0106	0	3192	394.525	466.541
	270	140	140	340	340	350	0.0106	0	3192	392.572	465.300

T	275	140	140	340	340	350	0.0106	0	3192	390.705	464.072
I	280	140	140	340	340	350	0.0106	0	3192	388.920	462.857
M	285	140	140	340	340	350	0.0106	0	3192	387.213	461.655
E	290	140	140	340	340	350	0.0106	0	3192	385.581	460.465
	295	140	140	340	340	350	0.0106	0	3192	384.020	459.289
1:00	300	140	140	340	340	350	0.0106	12	3192	422.378	497.974
	305	140	140	340	340	350	0.0106	12	3192	459.053	536.248
	310	140	140	340	340	350	0.0106	12	3192	494.119	574.113
M	315	140	140	340	340	350	0.0106	12	3192	527.648	611.576
E	320	140	140	340	340	350	0.0106	12	3192	559.706	648.639
E	325	140	140	340	340	350	0.0106	12	3192	590.358	685.308
T	330	140	140	340	340	350	0.0106	12	3192	619.666	721.586
I	335	140	140	340	340	350	0.0106	12	3192	647.688	757.478
N	340	140	140	340	340	350	0.0106	12	3192	674.481	792.987
G	345	140	140	340	340	350	0.0106	12	3192	700.099	828.118
	350	140	140	340	340	350	0.0106	12	3192	724.593	862.875
	355	140	140	340	340	350	0.0106	12	3192	748.013	897.262
2:00	360	140	140	340	340	350	0.0106	0	3192	730.557	891.432
	365	140	140	340	340	350	0.0106	0	3192	713.866	885.665
	370	140	140	340	340	350	0.0106	0	3192	697.907	879.959
	375	140	140	340	340	350	0.0106	0	3192	682.648	874.315
	380	140	140	340	340	350	0.0106	0	3192	668.058	868.730
	385	140	140	340	340	350	0.0106	0	3192	654.108	863.204
	390	140	140	340	340	350	0.0106	0	3192	640.770	857.738
	395	140	140	340	340	350	0.0106	0	3192	628.017	852.330
	400	140	140	340	340	350	0.0106	0	3192	615.823	846.979
	405	140	140	340	340	350	0.0106	0	3192	604.164	841.685
	410	140	140	340	340	350	0.0106	0	3192	593.017	836.448
	415	140	140	340	340	350	0.0106	0	3192	582.358	831.267
3:00	420	140	140	340	340	350	0.0106	12	3192	612.016	865.990
	425	140	140	340	340	350	0.0106	12	3192	640.374	900.344
	430	140	140	340	340	350	0.0106	12	3192	667.488	934.331
M	435	140	140	340	340	350	0.0106	12	3192	693.413	967.957
E	440	140	140	340	340	350	0.0106	12	3192	718.200	1001.224
E	445	140	140	340	340	350	0.0106	12	3192	741.901	1034.137
T	450	140	140	340	340	350	0.0106	12	3192	764.562	1066.700
I	455	140	140	340	340	350	0.0106	12	3192	786.229	1098.915
N	460	140	140	340	340	350	0.0106	12	3192	806.946	1130.788
G	465	140	140	340	340	350	0.0106	12	3192	826.754	1162.321
	470	140	140	340	340	350	0.0106	12	3192	845.693	1193.518
	475	140	140	340	340	350	0.0106	12	3192	863.802	1224.382
4:00	480	140	140	340	340	350	0.0106	0	3192	841.267	1215.069
	485	140	140	340	340	350	0.0106	0	3192	819.720	1205.854
	490	140	140	340	340	350	0.0106	0	3192	799.118	1196.738
	495	140	140	340	340	350	0.0106	0	3192	779.420	1187.719
	500	140	140	340	340	350	0.0106	0	3192	760.586	1178.796
	505	140	140	340	340	350	0.0106	0	3192	742.578	1169.968
	510	140	140	340	340	350	0.0106	0	3192	725.359	1161.234
	515	140	140	340	340	350	0.0106	0	3192	708.896	1152.593
	520	140	140	340	340	350	0.0106	0	3192	693.155	1144.044
	525	140	140	340	340	350	0.0106	0	3192	678.104	1135.586
	530	140	140	340	340	350	0.0106	0	3192	663.714	1127.218
	535	140	140	340	340	350	0.0106	0	3192	649.955	1118.940
5:00	540	140	140	340	340	350	0.0106	0	3192	636.799	1110.749
G	545	140	140	340	340	350	0.0106	0	3192	624.220	1102.646
O	550	140	140	340	340	350	0.0106	0	3192	612.193	1094.629
	555	140	140	340	340	350	0.0106	0	3192	600.693	1086.698
H	560	140	140	340	340	350	0.0106	0	3192	589.698	1078.851
O	565	140	140	340	340	350	0.0106	0	3192	579.185	1071.087
M	570	140	140	340	340	350	0.0106	0	3192	569.133	1063.406

E	575	140	140	340	340	350	0.0106	0	3192	559.522	1055.808
	580	140	140	340	340	350	0.0106	0	3192	550.332	1048.290
	585	140	140	340	340	350	0.0106	0	3192	541.545	1040.852
	590	140	140	340	340	350	0.0106	0	3192	533.144	1033.493
	595	140	140	340	340	350	0.0106	0	3192	525.112	1026.213
6:00	600	140	140	340	340	350	0.0106	0	3192	517.431	1019.010
	605	140	140	340	340	350	0.0106	0	3192	510.088	1011.884
	610	140	140	340	340	350	0.0106	0	3192	503.067	1004.834
	615	140	140	340	340	350	0.0106	0	3192	496.353	997.859
	620	140	140	340	340	350	0.0106	0	3192	489.934	990.958
	625	140	140	340	340	350	0.0106	0	3192	483.797	984.131
	630	140	140	340	340	350	0.0106	0	3192	477.928	977.376
	635	140	140	340	340	350	0.0106	0	3192	472.317	970.694
	640	140	140	340	340	350	0.0106	0	3192	466.953	964.082
	645	140	140	340	340	350	0.0106	0	3192	461.823	957.541
	650	140	140	340	340	350	0.0106	0	3192	456.919	951.070
	655	140	140	340	340	350	0.0106	0	3192	452.229	944.667
7:00	660	140	140	340	340	350	0.0106	0	3192	447.745	938.333
	665	140	140	340	340	350	0.0106	0	3192	443.458	932.067
	670	140	140	340	340	350	0.0106	0	3192	439.359	925.867
	675	140	140	340	340	350	0.0106	0	3192	435.440	919.733
	680	140	140	340	340	350	0.0106	0	3192	431.693	913.664
	685	140	140	340	340	350	0.0106	0	3192	428.110	907.660
	690	140	140	340	340	350	0.0106	0	3192	424.684	901.720
	695	140	140	340	340	350	0.0106	0	3192	421.408	895.843
	700	140	140	340	340	350	0.0106	0	3192	418.276	890.029
	705	140	140	340	340	350	0.0106	0	3192	415.282	884.277
	710	140	140	340	340	350	0.0106	0	3192	412.418	878.586
	715	140	140	340	340	350	0.0106	0	3192	409.681	872.956
8:00	720	140	140	340	340	350	0.0106	0	3192	407.063	867.386
	725	140	140	340	340	350	0.0106	0	3192	404.560	861.875
	730	140	140	340	340	350	0.0106	0	3192	402.167	856.422
	735	140	140	340	340	350	0.0106	0	3192	399.879	851.028
	740	140	140	340	340	350	0.0106	0	3192	397.692	845.691
	745	140	140	340	340	350	0.0106	0	3192	395.600	840.411
	750	140	140	340	340	350	0.0106	0	3192	393.600	835.188
	755	140	140	340	340	350	0.0106	0	3192	391.688	830.020
	760	140	140	340	340	350	0.0106	0	3192	389.859	824.907
	765	140	140	340	340	350	0.0106	0	3192	388.111	819.848
	770	140	140	340	340	350	0.0106	0	3192	386.440	814.843
	775	140	140	340	340	350	0.0106	0	3192	384.841	809.892
9:00	780	140	140	340	340	350	0.0106	0	3192	383.313	804.994
	785	140	140	340	340	350	0.0106	0	3192	381.852	800.147
	790	140	140	340	340	350	0.0106	0	3192	380.455	795.352
	795	140	140	340	340	350	0.0106	0	3192	379.119	790.609
	800	140	140	340	340	350	0.0106	0	3192	377.842	785.915
	805	140	140	340	340	350	0.0106	0	3192	376.621	781.272
	810	140	140	340	340	350	0.0106	0	3192	375.453	776.678
	815	140	140	340	340	350	0.0106	0	3192	374.337	772.134
	820	140	140	340	340	350	0.0106	0	3192	373.270	767.637
	825	140	140	340	340	350	0.0106	0	3192	372.249	763.189
	830	140	140	340	340	350	0.0106	0	3192	371.273	758.788
	835	140	140	340	340	350	0.0106	0	3192	370.340	754.433
10:00	840	140	140	340	340	350	0.0106	0	3192	369.448	750.125
	845	140	140	340	340	350	0.0106	0	3192	368.595	745.863
	850	140	140	340	340	350	0.0106	0	3192	367.779	741.647
	855	140	140	340	340	350	0.0106	0	3192	367.000	737.475
	860	140	140	340	340	350	0.0106	0	3192	366.254	733.348
	865	140	140	340	340	350	0.0106	0	3192	365.541	729.265
	870	140	140	340	340	350	0.0106	0	3192	364.860	725.225

	875	140	140	340	340	350	0.0106	0	3192	364.208	721.228
	880	140	140	340	340	350	0.0106	0	3192	363.585	717.274
	885	140	140	340	340	350	0.0106	0	3192	362.989	713.362
	890	140	140	340	340	350	0.0106	0	3192	362.419	709.491
	895	140	140	340	340	350	0.0106	0	3192	361.874	705.662
11:00	900	140	140	340	340	350	0.0106	0	3192	361.354	701.874
	905	140	140	340	340	350	0.0106	0	3192	360.856	698.126
	910	140	140	340	340	350	0.0106	0	3192	360.380	694.418
	915	140	140	340	340	350	0.0106	0	3192	359.924	690.749
	920	140	140	340	340	350	0.0106	0	3192	359.489	687.120
	925	140	140	340	340	350	0.0106	0	3192	359.073	683.529
	930	140	140	340	340	350	0.0106	0	3192	358.675	679.976
	935	140	140	340	340	350	0.0106	0	3192	358.294	676.461
	940	140	140	340	340	350	0.0106	0	3192	357.931	672.984
	945	140	140	340	340	350	0.0106	0	3192	357.583	669.544
	950	140	140	340	340	350	0.0106	0	3192	357.250	666.140
	955	140	140	340	340	350	0.0106	0	3192	356.932	662.773
12:00	960	140	140	340	340	350	0.0106	0	3192	356.628	659.441
	965	140	140	340	340	350	0.0106	0	3192	356.337	656.145
	970	140	140	340	340	350	0.0106	0	3192	356.060	652.884
	975	140	140	340	340	350	0.0106	0	3192	355.794	649.658
	980	140	140	340	340	350	0.0106	0	3192	355.540	646.466
	985	140	140	340	340	350	0.0106	0	3192	355.297	643.308
	990	140	140	340	340	350	0.0106	0	3192	355.064	640.184
	995	140	140	340	340	350	0.0106	0	3192	354.842	637.093
	1000	140	140	340	340	350	0.0106	0	3192	354.630	634.035
	1005	140	140	340	340	350	0.0106	0	3192	354.427	631.010
	1010	140	140	340	340	350	0.0106	0	3192	354.233	628.016
	1015	140	140	340	340	350	0.0106	0	3192	354.047	625.055
1:00	1020	140	140	340	340	350	0.0106	0	3192	353.870	622.125
	1025	140	140	340	340	350	0.0106	0	3192	353.700	619.227
	1030	140	140	340	340	350	0.0106	0	3192	353.538	616.359
	1035	140	140	340	340	350	0.0106	0	3192	353.382	613.522
	1040	140	140	340	340	350	0.0106	0	3192	353.234	610.715
	1045	140	140	340	340	350	0.0106	0	3192	353.092	607.938
	1050	140	140	340	340	350	0.0106	0	3192	352.957	605.190
	1055	140	140	340	340	350	0.0106	0	3192	352.827	602.472
	1060	140	140	340	340	350	0.0106	0	3192	352.703	599.783
	1065	140	140	340	340	350	0.0106	0	3192	352.584	597.122
	1070	140	140	340	340	350	0.0106	0	3192	352.471	594.490
	1075	140	140	340	340	350	0.0106	0	3192	352.363	591.886
2:00	1080	140	140	340	340	350	0.0106	0	3192	352.259	589.309
	1085	140	140	340	340	350	0.0106	0	3192	352.160	586.760
	1090	140	140	340	340	350	0.0106	0	3192	352.065	584.239
	1095	140	140	340	340	350	0.0106	0	3192	351.975	581.743
	1100	140	140	340	340	350	0.0106	0	3192	351.888	579.275
	1105	140	140	340	340	350	0.0106	0	3192	351.805	576.833
	1110	140	140	340	340	350	0.0106	0	3192	351.726	574.417
	1115	140	140	340	340	350	0.0106	0	3192	351.650	572.026
	1120	140	140	340	340	350	0.0106	0	3192	351.578	569.661
	1125	140	140	340	340	350	0.0106	0	3192	351.509	567.322
	1130	140	140	340	340	350	0.0106	0	3192	351.443	565.007
	1135	140	140	340	340	350	0.0106	0	3192	351.379	562.717
3:00	1140	140	140	340	340	350	0.0106	0	3192	351.319	560.451
	1145	140	140	340	340	350	0.0106	0	3192	351.261	558.209
	1150	140	140	340	340	350	0.0106	0	3192	351.206	555.991
	1155	140	140	340	340	350	0.0106	0	3192	351.153	553.797
	1160	140	140	340	340	350	0.0106	0	3192	351.102	551.627
	1165	140	140	340	340	350	0.0106	0	3192	351.054	549.479
	1170	140	140	340	340	350	0.0106	0	3192	351.008	547.354

	1175	140	140	340	340	350	0.0106	0	3192	350.963	545.252
	1180	140	140	340	340	350	0.0106	0	3192	350.921	543.172
	1185	140	140	340	340	350	0.0106	0	3192	350.881	541.115
	1190	140	140	340	340	350	0.0106	0	3192	350.842	539.079
	1195	140	140	340	340	350	0.0106	0	3192	350.805	537.065
4:00	1200	140	140	340	340	350	0.0106	0	3192	350.770	535.072
	1205	140	140	340	340	350	0.0106	0	3192	350.736	533.101
	1210	140	140	340	340	350	0.0106	0	3192	350.704	531.151
	1215	140	140	340	340	350	0.0106	0	3192	350.673	529.221
	1220	140	140	340	340	350	0.0106	0	3192	350.643	527.312
	1225	140	140	340	340	350	0.0106	0	3192	350.615	525.424
	1230	140	140	340	340	350	0.0106	0	3192	350.588	523.555
	1235	140	140	340	340	350	0.0106	0	3192	350.562	521.706
	1240	140	140	340	340	350	0.0106	0	3192	350.538	519.877
	1245	140	140	340	340	350	0.0106	0	3192	350.514	518.068
	1250	140	140	340	340	350	0.0106	0	3192	350.492	516.278
	1255	140	140	340	340	350	0.0106	0	3192	350.470	514.507
5:00	1260	140	140	340	340	350	0.0106	0	3192	350.449	512.754
	1265	140	140	340	340	350	0.0106	0	3192	350.430	511.021
	1270	140	140	340	340	350	0.0106	0	3192	350.411	509.306
	1275	140	140	340	340	350	0.0106	0	3192	350.393	507.609
	1280	140	140	340	340	350	0.0106	0	3192	350.376	505.930
	1285	140	140	340	340	350	0.0106	0	3192	350.359	504.269
	1290	140	140	340	340	350	0.0106	0	3192	350.343	502.626
	1295	140	140	340	340	350	0.0106	0	3192	350.328	501.000
	1300	140	140	340	340	350	0.0106	0	3192	350.314	499.392
	1305	140	140	340	340	350	0.0106	0	3192	350.300	497.800
	1310	140	140	340	340	350	0.0106	0	3192	350.287	496.226
	1315	140	140	340	340	350	0.0106	0	3192	350.274	494.669
6:00	1320	140	140	340	340	350	0.0106	0	3192	350.262	493.128
	1325	140	140	340	340	350	0.0106	0	3192	350.251	491.603
	1330	140	140	340	340	350	0.0106	0	3192	350.240	490.095
	1335	140	140	340	340	350	0.0106	0	3192	350.229	488.603
	1340	140	140	340	340	350	0.0106	0	3192	350.219	487.126
	1345	140	140	340	340	350	0.0106	0	3192	350.210	485.666
	1350	140	140	340	340	350	0.0106	0	3192	350.200	484.221
	1355	140	140	340	340	350	0.0106	0	3192	350.192	482.791
	1360	140	140	340	340	350	0.0106	0	3192	350.183	481.376
	1365	140	140	340	340	350	0.0106	0	3192	350.175	479.977
	1370	140	140	340	340	350	0.0106	0	3192	350.168	478.593
	1375	140	140	340	340	350	0.0106	0	3192	350.160	477.223
7:00	1380	140	140	340	340	350	0.0106	0	3192	350.153	475.868
	1385	140	140	340	340	350	0.0106	0	3192	350.146	474.527
	1390	140	140	340	340	350	0.0106	0	3192	350.140	473.201
	1395	140	140	340	340	350	0.0106	0	3192	350.134	471.888
	1400	140	140	340	340	350	0.0106	0	3192	350.128	470.590
	1405	140	140	340	340	350	0.0106	0	3192	350.122	469.306
	1410	140	140	340	340	350	0.0106	0	3192	350.117	468.035
	1415	140	140	340	340	350	0.0106	0	3192	350.112	466.777
	1420	140	140	340	340	350	0.0106	0	3192	350.107	465.534
	1425	140	140	340	340	350	0.0106	0	3192	350.102	464.303
	1430	140	140	340	340	350	0.0106	0	3192	350.098	463.085
	1435	140	140	340	340	350	0.0106	0	3192	350.094	461.881
8:00											

Item	System	Unit Cost	Unit	Quantity	Cost	RS Means Code	Detail
AHU	Existing	10,300.00	$/AHU	6	61,800.00	300-1080	Central Station AHU "Ducted Evaporative Cooler"
Totals	Alt #1	25,900.00	$/AHU	6	155,400.00	200-2370	Central Station AHU Chilled Water 20000cfm
	Alt #2	25,900.00	$/AHU	3	77,700.00	200-2370	Central Station AHU Chilled Water 20000cfm
Piping	Existing	62.00	$/ft	0	0.00	620-0670	schedule 40 steel pipe
6"	Alt #1	62.00	$/ft	637	39,494.00		
	Alt #2	62.00	$/ft	597	37,014.00		
	Parallel	62.00	$/ft	0	0.00		
	FCU	63.00	$/ft	0	0.00		
	Existing	30.60	$/ft	0	0.00	620-0650	schedule 40 steel pipe
4"	Alt #1	30.60	$/ft	0	0.00		
	Alt #2	30.60	$/ft	0	0.00		
	Parallel	30.60	$/ft	48	1,468.80		
	FCU	31.60	$/ft	48	1,516.80		
	Existing	18.75	$/ft	0	0.00	620-0620	schedule 40 steel pipe
2.5"	Alt #1	18.75	$/ft	0	0.00		
	Alt #2	18.75	$/ft	0	0.00		
	Parallel	18.75	$/ft	260	4,875.00		
	FCU	19.75	$/ft	0	0.00		
	Existing	13.33	$/ft	0	0.00	620-0610	schedule 40 steel pipe
2"	Alt #1	13.33	$/ft	0	0.00		
	Alt #2	13.33	$/ft	0	0.00		
	Parallel	13.33	$/ft	260	3,465.80		
	FCU	14.33	$/ft	520	7,451.60		
	Existing	10.51	$/ft	0	0.00	620-0600	schedule 40 steel pipe
1.5"	Alt #1	10.51	$/ft	0	0.00		
	Alt #2	10.51	$/ft	0	0.00		
	Parallel	10.51	$/ft	1120	11,771.20		
	FCU	11.51	$/ft	0	0.00		
	Existing	9.35	$/ft	0	0.00	620-0590	schedule 40 steel pipe
1.25"	Alt #1	9.35	$/ft	0	0.00		
	Alt #2	9.35	$/ft	0	0.00		
	Parallel	9.35	$/ft	1120	10,472.00		
	FCU	10.35	$/ft	2240	23,184.00		
Piping	Existing				0.00		
Totals	Alt #1				39,494.00		
	Alt #2				37,014.00		
	Parallel				32,052.80		
	FCU				32,152.40		
Pump	Existing	0.00	$/Pump	0	0.00		
Totals	Alt #1	5,576.00	$/Pump	1	5,576.00	Interpolated from RS-Means General Utility Pumps	
	Alt #2	4,869.20	$/Pump	1	4,869.20	same	
	Parallel Clg	3,700.00	$/Pump	1	3,700.00	same	
	Parallel Htg	2,912.50	$/Pump	1	2,912.50	same	
	FCU Htg	3,399.00	$/Pump	1	3,399.00	Interpolated from RS-Means General Utility Pumps	
Duct	Existing	2.00	$/sq. ft	88000	176,000.00	Based on Dr. Mumma's Economic Considerations on	
Totals	Alt #1	2.00	$/sq. ft	88000	176,000.00	doas-radiant.psu.edu assuming baseline of plain DOAS	
	Alt #2	1.00	$/sq. ft	88000	88,000.00	ductwork as VAV boxes will be figured separately	

VAV Box Totals	Electric Heat	112.00	$/box	662.5	74,200.00	700-5640	800cfm VAV box with electric heat
	Hot Water Ht	112.00	$/box	682.5	76,440.00		800cfm VAV box with hot water heat
	Box w/o Heat	48.00	$/box	335	16,080.00		350 cfm VAV box without heat
Beam Totals	Trox					Based on similar system estimate from English manufacturer	
	Series AKV	500.00	$/linear yd	468	234,000.00	halton series CLO	
			kW of System	Resultant Panelboards			
Electrical Support Equipment	Existing	2,565.00	423	2	5,130.00	800-0300	800Amp, 480V, Main distribution panelboard
	Alt #1	2,565.00	157.9	1	2,565.00	800-0300	800Amp, 480V, Main distribution panelboard
	Alt #2	2,100.00	54.9	1	2,100.00	800-0200	600Amp, 480V, Main distribution panelboard
	Parallel	1,260.00	3	1	1,260.00	720-1250	100Amp, 480Y/277, 12 Circuits MLO
	FCU	2,750.00	380	7	19,250.00	720-1350	225Amp, 480Y/277, 12 Circuits MLO
Steam - Water HTX	Parallel	16,905.00	$/unit	1	16,905.00		
	FCU	12,775.00	$/unit	1	12,775.00		
E-Wheel	Semco TE3-4	20,000.00	$/unit	3	60,000.00		

Assembly Totals	Existing VAV system with DX cooling	242,930.00
	Alt #1 VAV system with chilled water cooling	379,035.00
	Alt #2 DOAS system with chilled water cooling	269,683.20
	Parallel System of Active Heated/Chilled Beams	290,830.30
	Existing VAV box system with electric reheat	109,530.00
	Existing VAV box system with hot water reheat	140,846.40

Combined Totals	Existing system	352,460.00
	Alt #1	519,881.40
	Alt #2	560,513.50