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# Final Report

Alternate System Analysis

WESTINGHOUSE ELECTRIC CO. NUCLEAR ENGINEERING HEADQUARTERS CAMPUS

Pittsburgh, PA

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# 1.0 Acknowledgments

The Pennsylvania State University Architectural Engineering Faculty and Staff

Thesis Advisor: William Bahnfleth, Ph.D., PE

Ground Source Heat Pump Instruction: James Freihaut, Ph.D.

Project Sponsor: Turner Construction

Sponsor Contacts: Bob Hennessey, Turner Construction

Ernie Tillman, PE, LLI Engineering

Joel R. Bernard, AIA, NCARB, LEED AP, IKM Inc.

Special Thanks to all of my friends and family for their support!

## 2.0 Executive Summary

Westinghouse Nuclear Engineering Headquarters is comprised of three buildings. The central building, Building 1, is the topic of this report. Building 1 is largely open office with conference rooms, computation laboratories, a Data Center, Fitness Center and cafeteria. The concentration of computer equipment is relatively high compared to a typical low-rise office building.

Of primary importance to the client are adequate thermal comfort and air quality. Both of these variables will allow the occupants to be more productive in the workplace. Also of importance is the cost of operation for the facility in the long-term.

The primary system for Building 1 is a Variable Air Volume (VAV) system supplemented by Computer Room Air Conditioning Units (CRAC Units) where the sensible load is too great for the VAV to handle—specifically in the Data Center. A VAV system was chosen because of its low maintenance costs, easy manageability, and efficiency. The system is supplied with chilled water from three centrifugal chillers and electric re-heat/gas-fired burners from the VAV boxes and AHUs.

In an effort to optimize the systems of Building 1, analyses were performed involving a study of a Dedicated Outdoor Air System with three different systems in the office space. An all Active Chilled Beam configuration, an All DOAS Fan Coil Unit (aka DOAS Fan Powered Terminal Unit) configuration, and a DOAS FCU on Perimeter and ACB in Core configuration were all explored. Once the Plant loads have been reduced with these systems, the three systems will be connected to both a Central Chiller & Boiler Plant and a Hybrid Ground-Source Heat Pump. The Hybrid Ground-Source Heat Pump was explored over a typical non-Hybrid system because of its initial cost savings as well as energy savings. Initially, both a Centralized and a De-Centralized GSHP Plant were explored, however the energy modeling program could not accurately model the De-Centralized Plant—thus only Centralized Plant was extensively analyzed.

Additionally, each of these combinations of system and plant was modeled with and without a Façade Redesign (Architectural Breadth). The intention of this Façade Redesign was to reduce the thermal loads within the space. As part of the Façade Redesign, a Daylighting study was done a south facing office area. The study examined the use of a Light Shelf system to reduce the usage of artificial light in the space as well as reduce the thermal load.

The Dedicated Outdoor Air System with the all DOAS Fan Coil Unit (DOAS Fan Powered Terminal Unit) configuration proved to be the best choice for the Westinghouse Headquarters. The plant analysis showed that the Hybrid Ground-Source Heat Pump Plant option was the most beneficial system, even though it did not have the lowest Initial Cost or Payback Period—the Central Plant had both. The Hybrid GSHP Plant had the lowest emissions, lowest energy use, and lowest Life Cycle Cost. The Façade Redesign had a very beneficial effect upon the Initial Cost, Life Cycle Cost, and Payback Period for all of the systems and plants.

Since the building is owned by a developer, their biggest priority with choosing a system and plant is Initial Cost. This is the reason why the current Mechanical system has a standard VAV system with a Chiller Plant and Electric Resistance. However, according to the results of this report, a Boiler Plant would actually be a lower first cost than the Electric Resistance.

The overall best option for the Westinghouse Headquarters is Dedicated Outdoor Air System with DOAS Fan Coil Unit (DOAS Fan Powered Terminal Box) configuration and a Centralized Hybrid Ground Source Heat Pump Plant.

# **3.0 Existing Conditions**

### 3.1 Introduction

Westinghouse Nuclear Engineering Headquarters is a complex of three buildings of approximately 845,000 square feet, and is being delivered is a Design-Bid-Build project. The complex contains office space with conference rooms as well as a data center, cafeteria and fitness center for employees. With the higher density of computing loads, the receptacle load of the complex will be higher than a typical office building.

For the purpose of this analysis, only Building 1 has been investigated because it contains the largest variety of occupancy types including the cafeteria, atrium/lobby, data center and fitness center along with a largest amount of office space and conference rooms. The complex Site Plan is depicted in the image below.



Image 1: Site Plan (Building 1 is highlighted)

### 3.2 Design Objectives and Requirements

The purpose for any HVAC system is to properly ventilate the building for the specified occupancy while maintaining a comfortable temperature and humidity level for the occupants. The mechanical system for Building 1 is designed to do exactly this. However, since every building is unique, every mechanical system is unique and is designed accordingly to accommodate these unique characteristics.

In the case of Westinghouse's Building 1 of their Nuclear Engineering Complex, the program is largely open office space with conference rooms and computer laboratories. The building also houses a data center, fitness center and cafeteria. This particular program consequently has a relative high concentration of computing equipment. This increase in internal heat load actually benefits the mechanical system because of need for heating for this particular building.

Several similar buildings have had problems maintaining a healthy indoor environment from low relative humidity and poor air filtration. Thus, the owners of the building gave higher priority to a healthier and more productive indoor environment for the workers.

The existing mechanical system was designed with low maintenance as a major influence. A system was designed that provided low maintenance costs, easy manageability, and efficiency. For the owner, this means lower energy bills and less operational costs over the lifetime of the mechanical system.

### 3.3 Equipment Summary

The primary system for Building 1 is a Variable Air Volume system. The system is supported by CRAC (Computer Room Cooling) Units in spaces with higher thermal loads that the VAV system cannot accommodate—specifically the Data Center, and a few computing laboratories. The VAV system was implemented because of it is practicality and lower first costs. VAV systems are widely used in similar buildings and have proven to be adequate systems.

The VAV and CRAC systems are supplied chilled water from the chiller plant located in the Basement of Building 1. The chiller plant includes three chillers with three cooling towers located in the mechanical penthouse. The four main Air Handling Units provide pre-heating through Gas-fired Burners. These main AHU's provide the building with about 40% OA. The VAV Terminal Units have Electric Resistance Re-Heating to provide the heating for the zones. Fan Powered Boxes are used to condition the perimeter spaces.

The Tables 1 through 5 display summaries for the Air Handling Units, Chillers, Cooling Towers, CRAC Units, and Domestic Hot Water Heaters Units respectively.

Air Handling Units					
l lait	System Air Flow Rates		OA Deveenters	Coil Cap Mi	oacities, 3H
Unit	Min OA	System Supply	OA Percentage	Heating	Cooling
AHU-1	22,200	71100	31	2500	3089.4
AHU-2	31,775	63000	50	2500	3084.3
AHU-3	24550	74000	33	2500	3130.8
AHU-4	36350	72500	50	2500	4003.2
AHU-5	800	8000	10	125 kW	280.2
AHU-6	500	5000	10	-	113.7

Table 1.

Chiller Units					
		NDIV	Evaporator	Condenser	
Unit	Capacity	k\//Ton	EWT/LWT	EWT/LWT	
		KVV/TOIT	(°F)	(°F)	
CH-1	450	0.505	58/44	85/94	
CH-2	450	0.505	58/44	85/94	
CH-3	450	0.505	58/44	85/94	

Table 2.

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Cooling Tower Units					
Unit	Water Flow Rate (GPM)		Air Flow Rate (CFM)	Sump Heater	Fan Motor
	Min	Max		(KVV)	(ПР)
CT-1	675	1350	112250	16	25
CT-2	675	1350	112250	16	25
CT-3	675	1350	112250	16	25

Table 3.

### **CRAC Unit Compliance**

Unit	Cooling Capacity	EER
CRAC-1	128000 BTU/hr	8.4
CRAC-2	255000 BTU/hr	8.6
CRAC-3	199000 BTU/hr	7.6

Table 4.

Domestic Hot Water Heater Units (Gas)				
Unit	Delivery Temp °F	Reco GPH	very ΔT	Heat Rate (BTU)
DWH-1	140	327	100	285,000
DWH-2	140	327	100	285,000

Table 5.

All of the mechanical equipment is controlled using a complex-wide BACnet Building Automation System. This will allow the operation and maintenance employees to monitor the building(s) to ensure that the systems continue to run at maximum efficiency. Power is provided to the site through an electric grid connection and a Natural Gas line. The 500kW back-up generator is used only in the event of a power failure.

### 3.4 Mechanical System Schematic Drawings

Schematic Flow Diagrams of the Chilled Water Loop, Condenser Water Loop, and Domestic Hot Water Loop are located on the next three pages.



Evaporator 1 Ŧ --CWP-1 Evaporator 2 -CWP-2 Evaporator 3 -Chilled Water Flow Diagram CWP-3 T CWP-4 Heat Exchanger T --CWP-5 Alr Separator CWP-6 Exp Tank Make-Up Water Ti CWP-7 T AHUs & CRAC Units Fan Coils

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### 3.5 Design Conditions

The outdoor conditions for the energy model are approximated as Pittsburgh, PA and are listed in Table 6 below.

ASHRAE Design Conditions			
Heating Design Temperature	Coc Des Tempe	oling sign erature	
DBT	DBT WBT		
2 °F	86°F	70°F	

Table 6.

### 3.6 System Operation

#### Air side:

For the VAV system, a supply fan runs anytime an AHU is commanded to run. The supply fan VFD speed is modulated to maintain the duct static pressure setpoint. The return fan runs whenever the supply fan runs. The return fan VFD is modulated in unison with the supply fan VFD. The two fans are set to produce a positive pressure in the building.

The cooling coil valve is modulated open whenever the outside air is greater than 60°F and the economizer is disabled or fully open and the supply fan is on and the heat coil is off. The gas pre-heating is enabled whenever the outside air is less than 55°F and the supply fan is on and the cooling coil is off (unless minimum OA requirements cause the mixed air temperature to fall below setpoint). Economizer mode is initiated when the outside air is less than 65°F and the enthalpy is less than 22 Btu/lb. The OA dampers are at a minimum of 20% open whenever the building is occupied. Minimum outside air is controlled by CO2 sensors in the return air.

Fan Coil Boxes (FCB's) run according to an occupancy schedule and run at a minimum when not in occupancy mode. The FCB's maintain the cooling and heating setpoints

within their zones. Variable Air Volume Boxes (VAV's) will modulate flow of supply air such that when cooling is required the VAV Box will increase airflow to the zone. When the space is within range of the setpoint or requires heating, the VAV Box will supply the minimum amount of airflow to the zone.

#### Water side:

The chilled water system shall be enabled to run whenever the cooling set point has been reached and whenever the outside air temperature is greater than 54°F. Each chiller runs from its own internal controls. The three equal sized chillers are staged to run in parallel to meet the cooling demand. The second chiller will stage on when the building load is 400 Tons and the third will stage on at 800 Tons. The three variable speed chilled water pumps operate in a lead/lag fashion. The condenser water pumps operate in the same manner. The chilled water isolation valves open whenever a chiller is called to run or called to run for freeze protection. The isolation valves open prior to the chillers being enabled and close after it is disabled. The condenser water isolation valves work the same.

The cooling towers run whenever a chiller runs or when the free cooling heat exchanger runs. The cooling tower VFD fans maintain a setpoint of 82°F for the rising condenser water supply temperatures.

### 3.7 System Energy Sources

Since Westinghouse's Nuclear Engineering Headquarters is located in the Pittsburgh region, it has the benefit of having relatively low electricity prices. The utility rates used for this project are from Duquesne Light and Columbia Gas. The rates are listed in Table 7 below.

Utility Cost Information					
Electricity Demand (\$/kW)	Elect Consur (\$/k	ricity nption Wh)	Natural Gas (\$/Therm)		
On-Peak	On- Off- Peak Peak		Annual Average		
3.09	0.107	0.507	1.55		

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### 3.8 Mechanical System Initial Cost

The approximate initial costs for the Mechanical system of the project are as follows:

-Chiller Plant: \$4,000,000

-Heating Elements: \$2,000,000

-VAV and FPB Units: \$2,600,000

-AHUs, Plumbing, Controls, and other mechanical items: \$7,400,000

The cost of the Mechanical system totals \$16,000,000 or an estimated 18% of the total hard costs of the building.

# 4.0 Data from Previous Technical Reports

In the required Technical Reports written prior to this report, components of the building systems and performance were analyzed and discussed. These areas include an ASHRAE 62.1-2007 analysis, an ASHRAE 90.1-2007 analysis, a Heating and Cooling Load Analysis, and an Annual Energy Use Analysis.

### 4.1 Ventilation Requirements

To verify that the building air handling system is providing enough ventilation air for the occupancies, an ASHRAE 62.1 Analysis was performed on two of the four Air Handling Units (AHU's). For this analysis the ductwork was followed from the AHU to the diffusers to determine how much outdoor air is being supplied by the design and how much is required by ASHRAE 62.1.

The areas specific to each room were input into the equations specified by ASHRAE 62.1 to determine the amount of ventilation air required for each space. Because the system is a VAV system the ventilation air was given as a fraction of the total maximum supply air to the zone.

On average, the outdoor air fraction was found to be quite high compared to what the design documents prescribed and what most office buildings of this type generally require. The calculated OA% was 75%, which is significantly higher than the designed percentage of about 50%. This difference may be accounted for in the inaccuracies of modeling some of the high computing laboratories. Information on many of these spaces was not permitted as it was sensitive information.

The ability to model a VAV system accurately is very crucial because this outdoor air fraction will be supplied to all of the spaces and so some of the spaces will be receiving more ventilation air than is required. When more outdoor air is supplied than required, more energy must be spent conditioning that air. For this reason it is important to assure that most of the spaces have about the same requirements for outdoor air as they are receiving.

### 4.2 Heating and Cooling Loads

To determine the airflows, design loads on the system, and other energy values, a model was created in the Trane Trace analysis program. Room dimensions, occupancies and window areas were all input into the building simulation. This model was designed only as a block model and all input values have been calculated by hand since a Revit model was not available for this analysis.

The Trace model was also used to calculate the building's total energy use which is approximately 7.36 million kWh per year or about 50,800 BTU/SF-YR. A similar building, according to EIA, consumed about 51,500 BTU/SF-YR. Heating was found to be the largest energy user with about 31% of the total. This can be attributed to the method of primary heating—electric resistance coils in the VAV units. The use of

electric resistance coils mixed with air being the thermal transfer fluid results in a inefficient method to heat a space. Other factors that could have contributed to this high heating demand are the building's location, amount of glazing, orientation and other factors.

Annual Energy Consumption					
Load	Electricity (kWh)	Natural Gas (kWh)	Total Energy (kWh)	Percent of Total (%)	
Heating					
Gas-Fired		49343	49343	0.7	
Electric Resistance	2267004		2267004	30.8	
Cooling					
Chiller	690820		690820	9.4	
Cooling Tower	492072		492072	6.7	
Condenser Pump	543487		543487	7.4	
Auxiliary					
Supply Fans	107267		107267	1.5	
Pumps	401158		401158	5.4	
Lighting					
Lighting	1106314		1106314	15.0	
Miscellaneous					
Receptacle	1711229		1711229	23.2	
		Total	7368694	100	

The following tables and graphs depict the energy usage of Building 1.

Table 8.

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Graph 1. Monthly Electrical Energy Consumption



Graph 2. Monthly Natural Gas Consumption

### 4.3 LEED-NC Evaluation

Information on the LEED-NC evaluation for Building 1's mechanical system has not been available for this report. However, information from the design documents was available and provided a general scope of what LEED points were attained. The building was designed to meet LEED Certified at a minimum under LEED-NC Version2.2. The following LEED credits, that are associated with mechanical systems, are specified in the design documents. Other LEED points are being attained for the project, however they are not listed. These other points are vastly for material and resources.

EQ Prerequisite 1: Minimum Indoor Air Quality PerformanceEstablishminimum indoor air quality (IAQ) performance to enhance indoor air quality inbuildings, thus contributing to the comfort and well-being of the occupants.

Meet the minimum requirements of Sections 4 through 7 of ASHRAE 62.1-2004, Ventilation for Acceptable Indoor Air Quality. Mechanical ventilation systems shall be designed using the Ventilation Rate Procedure or the applicable local code, whichever is more stringent. Naturally ventilated buildings shall comply with ASHRAE 62.1-2004, paragraph 5.1.

#### EQ Prerequisite 2: Environmental Tobacco Smoke Control

Minimize exposure of building occupants, indoor surfaces, and ventilation air distribution systems to Environmental Tobacco Smoke (ETS).

# Credit EQ 3.1: Construction Indoor Air Quality Management Plan: During Construction

Reduce indoor air quality problems resulting from the construction/renovation process in order to help sustain the comfort and well-being of construction workers and building occupants.

### Credit EQ 3.2: Construction Indoor Air Quality Management Plan: Before Occupancy

Reduce indoor air quality problems resulting from the construction/renovation process in order to help sustain the comfort and well-being of construction workers and building occupants. For this project, all ducts were sealed to prevent any material from entering the system.

#### Credit EQ 4.1: Low-Emitting Materials: Adhesives & Sealants

Reduce the quantity of indoor air contaminants that are odorous, irritating and/or harmful to the comfort and well-being of installers and occupants.

#### Credit EQ 4.2: Low-Emitting Materials: Paints & Coatings

Reduce the quantity of indoor air contaminants that are odorous, irritating and/or harmful to the comfort and well-being of installers and occupants.

#### Credit EQ 4.3: Low-Emitting Materials: Carpet Systems

Reduce the quantity of indoor air contaminants that are odorous, irritating and/or harmful to the comfort and well-being of installers and occupants.

#### Credit EQ 4.4: Low-Emitting Materials: Composite Wood & Agrifiber Products

Reduce the quantity of indoor air contaminants that are odorous, irritating and/or harmful to the comfort and well-being of installers and occupants.

#### Credit EQ 6.2: Controllability of Systems: Thermal Comfort

Provide a high level of thermal comfort system control by individual occupants or by specific groups in multi-occupant spaces (i.e. classrooms or conference areas) to promote the productivity, comfort and well-being of building occupants. Provide individual comfort controls for 50% (minimum) of the building occupants to enable adjustments to suit individual task needs and preferences. Operable windows can be used in lieu of comfort controls for occupants of areas that are 20 feet inside of and 10 feet to either side of the operable part of the window. The areas of operable window must meet the requirements of ASHRAE 62.1-2004 paragraph 5.1 Natural Ventilation.

#### AND

Provide comfort system controls for all shared multi-occupant spaces to enable adjustments to suit group needs and preferences. Conditions for thermal comfort are described in ASHRAE Standard 55-2004 to include the primary factors of air

temperature, radiant temperature, air speed and humidity. Comfort system control for the purposes of this credit is defined as the provision of control over at least one of these primary factors in the occupant's local environment.

#### Credit WE 3.1: Water Use Reduction: 20% Reduction

Maximize water efficiency within buildings to reduce the burden on municipal water supply and wastewater systems.

#### EA Prerequisite 1: Fundamental Commissioning of the Building Energy Systems

Verify that the building's energy related systems are installed, calibrated and perform according to the owner's project requirements, basis of design, and construction documents.

#### EA Prerequisite 2: Minimum Energy Performance Required

Establish the minimum level of energy efficiency for the proposed building and systems.

# EA Prerequisite 3: Fundamental Refrigerant Management Reduce ozone depletion.

Zero use of CFC-based refrigerants in new base building HVAC&R systems. When reusing existing base building HVAC equipment, complete a comprehensive CFC phase-out conversion prior to project completion. Phase-out plans extending beyond the project completion date will be considered on their merits.

#### Credit EA 4.0: Enhanced Refrigerant Management

Reduce ozone depletion and support early compliance with the Montreal Protocol while minimizing direct contributions to global warming. No CFC refrigerants use.

### 5.0 Evaluation of Current System

For detailed analysis of the system, Building 1 was closely investigated. The VAV System chosen for Building 1 is typical choice for an office building of this nature. The only information on the first cost for the mechanical system of Building 1 is the bulk system price of \$16 million with an estimated \$4 million for the cooling plant. However, with the VAV system specified and no special equipment, e.g. enthalpy wheel, the cost of the mechanical system should be relatively normal for a building of this type. This building is tenant-occupied and the owners were primarily concerned with low initial costs to return their investments as quickly as possible—thus a typical VAV system was the obvious HVAC solution.

The system should also have a relatively low operational cost. According to the Trane Trace model from Technical Report 2, the operational cost for the HVAC system is estimated to be \$1.30/SF (\$0.73/SF for energy bills and ~\$0.60/SF for maintenance). This is quite similar to a similar to the \$1.40/SF listed in the Energy Information Agency's (EIA) 2003 Commercial Buildings Energy Consumption Survey. The lower cost might be accounted for with the VAV system being relatively low maintenance and relatively efficient as compared to some less common systems. Another major influence is the low utility cost for the Pittsburgh area.

Another cost of a system of this type is that a considerable amount of space is required for routing of ducts. The owner of the Building, Wells REIT II, is leasing the building out to Westinghouse, the higher floor heights and larger shaft areas effect the payback period for the owner significantly—higher floor to floor height, higher capital cost; less rentable square footage, less revenue. By downsizing certain components through alternative strategies, the overall building cost could be decreased. Since air has a relatively small heat capacity, by conditioning the spaces through other means, e.g. chilled beams, the ductwork can be significantly downsized. This idea was implemented in the Data Center with the CRAC Units. These units are connected to the Chilled Water loop and condition the space by re-circulating the air instead of using return air. With a VAV system, Indoor Air Quality can become an issue. This problem comes from the very nature of the system; that the air delivered to the rooms is a combination of ventilation and return air. If designed or installed incorrectly, modulations of supply airflow by the VAV Boxes can occur with no change in the outdoor air fraction-- resulting in a ventilation air deficiency. Also, if filters are not placed in the correct location and maintained, contaminants from inside the building can be re-circulated to all of the spaces in the building.

When designed, each of the Westinghouse Complex buildings was given chiller plants to more easily separate the leasing space into the three buildings. However, from an overall maintenance perspective, this is harder to maintain as the personnel must go from building to building. Also, each building has N+1 redundancy for its chillers, the cost of which could be reduced through a plant strategy. Additionally, when the project was still in design phase, a boiler system and fin tube heating was considered but the owners did not want fin tubes because of the high churn rate of the office.

Overall, the VAV system was a good choice for a variety of reasons. The VAV system will exhibit a low first cost, high ease of construction and maintenance, and can be designed to adequately meet the needs of the building. Other systems may have been ruled out due to higher first costs. However, better economic performance may be achieved from another system. A system with a lower operational cost, more energy savings and low emissions might be a better solution for the owners.

# 6.0 Proposed Alternate Systems

While a VAV system is effective to meet the needs of the owner, other alternatives may be better in the long-term. To determine the best solution for Building 1, the coil loads within the building will be analyzed and options will be studied to determine load reduction relative to a VAV System. Active Chilled Beams (ACB) and Dedicated OA System Fan Powered Terminal Unit (DOAS FCU) will be the two air distribution methods used. Both of these systems will be implemented into a Dedicated Outdoor Air System (DOAS). Then these two air systems will be applied to two different plant options: a Ground-Source Heat Pump (GSHP) System and a Chiller/Boiler (Central Plant) System. Additionally, the architectural and daylighting breadths are intended to lower the external thermal load on the building. With these thermal reductions, each system/plant combination will be reduced further. The results from these studies will be compared with the design case of the VAV system with a Chiller and Electric Re-heat. All system/plant combinations will be compared on several parameters.

### 6.1 Dedicated Outdoor Air System

The best step to making a building efficient is to reduce the loads. In general, this is the most cost-effective method to gain overall efficiency. For example, selecting a very high efficiency chiller might not be the best choice if the loads have not been addressed. In that case, the chiller does not need to be as large as it is to meet loads that are dealt with more efficiently. By meeting the loads with less input energy required, the chiller can be downsized, increasing savings.

Since the building is largely office space, a major proportion of this analysis will focus on reducing the coil loads of these spaces. A Dedicated Outdoor Air System, or DOAS, will be explored to reduce the load on the mechanical system. DOAS is beneficial for several reasons of energy savings, smaller system, and improved indoor air quality. Two sensible cooling methods will be explored: Active Chilled Beams (ACB) and DOAS Fan Powered Terminal Units, commonly referred to as DOAS Fan Coil Units (DOAS FCU). One study will explore the usage of only the Active Chilled Beams throughout the office areas. Another will use only DOAS FCUs throughout the office areas, while a third study will use both systems in tandem—DOAS FCUs for the perimeter and Active Chilled Beams for core office spaces. The tandem system will be explored because of the large amount of heating required for the building and FCUs are much more efficient for heating than ACBs. Other major steps will be taken to reduce external gains to these spaces including solar shading and façade re-design.

By creating an energy model of these systems, a comparison can be made with the existing VAV system with respect to initial cost, total cooling and heating load on the plants, payback period, construction impact, and indoor air quality.

### 6.2 Ground Source Heat Pumps

Once the loads have been reduced or adjusted, the design case of current chiller plant and electric re-heat can be compared to the Ground-Source Heat Pump option. Applying the loads from each of the air systems allows the determination of overall building performance.

With the Westinghouse complex located in the middle of a large piece of property, there is a considerable amount of open land that would be suitable for a ground-source heat pump system. A hybrid heat pump system will be explored using a supplemental Cooling Tower. This strategy will greatly save in initial costs without reducing the efficiency of the plant too much. A back-up Boiler will be implemented; however, the Heat Pump System will be sized appropriately so that the Boiler should not have to handle any excess loads.

The GSHP System will be explored in a two separate methods—a centralized plant and a distributed plant. The centralized plant will be three staged Heat Pumps sharing a condenser loop (ground loop) and conditioning the building with a 4-pipe system. The distributed plant will be smaller Heat Pumps located throughout the building to handle only local loads. And similarly to the centralized plant, these Heat Pumps will share a condenser loop to take advantage diverse loading.

A ground-source heat pump system has a significant initial cost however maintenance costs are generally low and the life of the system will outlast almost any other system. A GSHP system will also have an impact on the construction schedule depending on the depth and number of bores needed to meet the building's load. The GSHP system will be implemented into the Active Chilled Beam system as well as the DOAS Fan Coil Unit design.

### 6.3 Central Plant

Another option for providing heating and cooling to the building is the use of a Chiller and Boiler Plant, or a Central Plant. The existing mechanical system already has a Chiller Plant, but the heating is done with Gas-fired pre-heat in the main AHUs with electric resistance in the terminal units. However, with the addition of a Boiler Plant and a Hydronic System, the spaces will be able to be conditioned much more efficiently with less primary fuel usage. And with the load reduction from the DOAS design, the Chiller Plant will use much less electricity.

This system will be implemented in the Active Chilled Beam system as well as the DOAS Fan Coil Unit system. The two configurations will be compared with the existing plant along with the Ground Source Heat Pump Plant upon initial cost, energy usage, utility costs, and emissions.

### 6.4 Architectural Breadth

The redesign of the façade and overall exterior response of the building will be the focus of this breadth. A study will be done on each of the facades to examine the appropriate response to each of their orientations. The major heat gain/losses on each façade will be tabulated to develop the best strategy of redesign. The concept behind the redesign is to be sensitive to the existing architectural style while still effectively improving the thermal performance of each facade.

### 6.5 Lighting Breadth

In addition to an architectural breadth, a lighting breadth will be done with an overall goal to reduce the lighting requirements for the open office spaces. The current lighting design is already quite energy efficient with the use of low-wattage fixtures; however this breadth will focus on other aspects of lower lighting energy usage. Light shelves will be explored to possibly reduce the need for as much artificial lighting. With the implementation of a Dimmer Control System in addition to the light shelves,

Westinghouse should be able to save a considerable amount on energy. These light shelves can be projected from the building's façade to also act as a solar shade. The implementation of solar shades has an architectural aspect to them as they will be a prominent feature on the building's façade.

Overall, the addition of light shelves may be an inexpensive addition with major impacts to the design of the building's mechanical system.

### 6.6 Integration of Studies

All of the above depth and breadths are integrated in such a way that the overall combination of efforts will be toward a more efficient system. In this manner the architectural and daylighting breadths can be combined with the system and plant analyses to determine the best overall configuration for the building.

### 6.7 Basis of Comparison

When considering options for redesign of a system, it is important to lay the guidelines for determining whether a redesign is an improvement. The following are the criteria used to meter the success of the alternate system analysis:

### 6.7.1 Initial Cost

Sometimes the most critical factor for the Owner is the initial cost. This value, while important from a feasibility standpoint, needs to be balanced with the other associated costs when the building will be operated for a relatively long period of time. The Westinghouse Headquarters will be tenant occupied for at least 15 years, and should be designed to be occupied for at least the next 40 to 50 years.

### 6.7.2 Lifecycle Cost

Lifecycle cost will be computed by using the tabulated utility costs combined with maintenance costs. Figures for maintenance costs are estimated from previous projects

with similar systems. The Lifecycle Cost will more adequately represent the overall cost of one system versus the existing baseline system.

### 6.7.3 Construction Impact

Impact on construction schedule will be rated from least to greatest impact. This will include discussions of the timeframe of each system's installation. Even though this project is being delivered as a Design-Bid-Build, keeping the construction low will lower the overall cost of the project.

### 6.7.4 Indoor Air Quality

Indoor Air Quality of the office air system options will be compared on a qualitative level based upon air supply. The baseline of this comparison will be the VAV system for the office space.

### 6.7.5 Energy Use

The projected Energy Use will be compared using values from an energy model. These values will be obtained while maintaining the same indoor thermal comfort insuring that the systems are capable of providing a comfortable environment.

### 6.7.6 Environmental Impact

Environmental Impact will be assessed quantitatively depending upon the Energy Used. Environmental Impact is moving closer to the forefront when considering system design. Many mandates and incentives exist to limit the negative impacts of humans on the environment and more are planned for the future.

# 7.0 Dedicated Outdoor Air System

Dedicated Outdoor Air Systems can be a very effective method to not only increase a building's overall energy efficiency but can dramatically increase the Indoor Air Quality.

A DOAS system needs to supply much less air than a typical VAV system (rule of thumb is about 20% of a conventional system). This reduction in supply air means a downsizing of ductwork and fans. Additionally, the downsizing of ductwork results in lower floor-to-floor height requirements—saving additional construction costs. With the use of DOAS, the heating and cooling is decoupled from the ventilation air. Since water has a much better heat capacity than air, the energy requirements for the mechanical system will be much less.

With ventilation and space conditioning decoupled, the DOAS Air Handling Unit can accommodate 100% of the space latent loads, 100% of the outdoor air latent loads, and near 30% of the total sensible load with the use of a Total Enthalpy Wheel. With all of these loads handled the Dedicated OA System AHU, it is estimated that only about 40% of the design chiller load must be handled by the parallel sensible only cooling system.

According to Stanley Mumma, compared to a conventional VAV system, which can have issues with properly ventilating all the spaces with enough outdoor air, a Dedicated OA System can place the proper ventilation air quantities into every space. Also, a VAV system generally uses 20-70% more outdoor air than is required in an effort to assure proper ventilation air distribution in all air systems than is required with DOAS. Cooling and dehumidifying the high OA quantities in the summer and humidifying and heating the air in the winter is an energy intensive proposition. Additionally, VAV systems always use more terminal reheat than DOAS at the same air temperature because VAV requires more air.

For this analysis, the Dedicated OA System was modeled using a Total Enthalpy Wheel for latent conditioning. However, due to the parameters available in Trane Trace, the wheel can only be sized to a certain load. This load is selected by the simulation, not by the user. Thus, the simulation included a condensing coil within the unit as well. Even with the inaccuracies, the simulation of the DOAS provided good results within the range of CFM and Cooling tonnage which were described above.

### 7.1 Active Chilled Beam System

Active Chilled Beams are a cutting-edge application of an old technology; the induction unit. They are more sophisticated, but operate on the same premise of buoyancy of air at differing temperatures. By using this property, fan energy can be reduced for the movement of air across the cooling coil. The Active Chilled Beam uses high pressure nozzle to create turbulence and to better mix the re-circulated air. This turbulent mixing allows for warmer water temperatures (55 to 60 deg F) to have the same cooling as a conventional VAV unit (~45 deg F). Active Chilled Beams were selected over a Passive system because of their higher cooling capacity and the Active unit can provide ventilation air as well. Passive chilled beams only induce room air to cool it, ventilation air must be provided by other means. There are some disadvantages of Active Chilled Beams. First, they have difficulty heating a space and with Westinghouse would definitely require supplemental perimeter heating. Secondly, most contractors and commissioners have little experience with them. Also, Active Chilled Beams are condensing water in dangerous location. However, a study was done with Chilled Beams in which the beams were at 14° below the dew point for 8.5 hours with no condensation falling. So the risk of condensation falling on critical equipment does have a flex temperature region—but not recommended. The image below depicts an Active Chilled Beam in cooling mode.



Image 2: Active Chilled Beam in Cooling Mode

### 7.2 DOAS Fan Coil Unit

DOAS Terminal Units or Fan Coil Units (DOAS FCUs) have not had the wide spread popularity as Chilled Beam but still provide several advantages that even Chilled Beams cannot match. DOAS FCUs have a non-condensing cooling coil (and heating coil in this design) in the induction inlet of the box. Because Terminal Units are already common, the installing contractor and maintenance staff will be dealing with known technology. Similarly, this technology results in significantly lower zone cost. Unlike an Active Chilled Beam system, a DOAS FCU system would be a VAV system.

DOAS FCUs can be very useful for spaces that may need heating as well as cooling i.e. perimeter spaces. And with the Westinghouse Headquarters, the demand for heating is quite close to the cooling demand. Thus a single DOAS Fan Coil Unit can both heat and cool, and provide required ventilation air. The FCUs can be ducted to several spaces, unlike a Chilled Beam, as a result one unit can service several enclosed spaces. Likewise, with the DOAS Fan Coil Unit can be located over a corridor where the threat of condensation will not damage the office equipment. The basic concept of a DOAS FCU is very similar to a VAV Terminal Box but with the supply duct be sized only for the zone's ventilation rate. And unlike an Active Chilled Beam, the DOAS FCU does not use a high pressure induction to condition but simply increasing the re-circulated air. The image below depicts a DOAS Fan Coil Unit.





### 7.3 System Modeling

Both systems were modeled using Trane Trace Energy Modeling. Scenario 1 with all Active Chilled Beams in the office spaces was modeled with Active Chilled Beams with Wall Convectors as supplemental heating. For the Dedicated Outdoor Air System, a Total Enthalpy Wheel was modeled. It should be noted that Trane Trace does not allow a user to specify the size of the wheel—only its effectiveness. Thus, the energy model included a condensing coil within the Air Handling Unit to handle the remaining latent load. With the addition of another set of coils in the AHU, the cooling and heating loads increase significantly.

Scenario 2 and 3 were modeled very similarly to Scenario 1 with the DOAS Fan Coil Units being added. Unfortunately, Trane Trace did not have a DOAS FCU prescribe in its library. However, with the assumption that it would work similarly, a 4-pipe Induction Unit was used to model the DOAS FCU. Like the DOAS Fan Coil Unit, the 4-pipe Induction Unit has the ability to heat and cool, has a fan within the terminal, and is served by a primary AHU.

### 7.4 Results

The following table has the total supply air required for each of the systems. As shown, the three re-designs have slightly varying System CFM. This could be explained with small inaccuracies within the Energy Modeling program or inputs. The approximate reduction of the Dedicated OA System was 215,000 CFM or a 73% reduction in total CFM required. In terms of duct size this is going from a 40x25 duct to a 40x10 duct.

System	System CFM	% OA	CFM Reduced
Chilled Beam	80,100	100	213,500
FCU/Chilled Beam	78,700	100	214,900
Fan Coil Unit	77,600	100	216,000
*VAV	293,600	40	-

Table 9: System Size

With these three different air systems, we can see three relatively different results in terms of energy use. The following table shows the energy use in terms of cooling and heating required by the plants. As seen, Scenario 1 with only Active Chilled Beams being used within the Office Space requires the least amount of cooling with about 843 tons. Both the all DOAS Fan Coil Unit and perimeter DOAS FCU layouts actually result in higher cooling than the existing VAV system with 1-7% more cooling required. This higher cooling requirement could be a result of the assumption that the DOAS FCU system could be modeled as a 4-Pipe Induction Unit. The significant improvement over the existing VAV system is seen in the heating load with all three re-designs requiring about 6800 MBH or 28% less than the VAV system.

System	Cooling Tons	Heating MBH
Chilled Beam	842.9	6974.6
FCU/Chilled Beam	938	6803.7
Fan Coil Unit	996.4	6610.3
*VAV	928.9	9407.8

Table 10: Cooling and Heating Load per Air System

The Active Chilled Beams pose a possible problem with its density. Certain applications of ACBs are simply not possible because there is not enough ceiling area. To examine this possibility for Westinghouse, the two layouts that have ACBs were studied to see if the needed ACBs is greater than the area available for them. The below calculation is this study.

Active Chilled Beam = 100.0 W/SF of ceiling area

Core Only = 450.1 Tons x 3500 W/Ton x 1/100 SF/W

Core Only = 15,754 SF required

216,088 SF available

ACBs will use 7.3% of the ceiling in the Core
#### All Office Space = 842.9 Tons x 3500W/Ton x 1/100 SF/W

#### All Office Space = 226,935 SF required

356,076 available

ACBs will use 8.3% of the ceiling in the Office Space

In both scenarios only a small portion of the ceiling space is required to sensibly cool. With these smaller ratios, there should not be any conflicts with lighting layouts or any other ceiling function. In many buildings, the density of cooling required is much higher and ACBs can take up 60 to 80% of the ceiling. In these cases, it would be worth using Integrated Service Beams as well as Active Chilled Beams. The Integrated Service Beams have lighting, cabling, conduits, voice and data services, etc.

Additionally, using Chilled Beams will have a major impact on the aesthetics of the spaces and the architect might have a problem. Also, with a reduction of Acoustic Ceiling Tile, the acoustics of the space should be closely examined to ensure the reverberation time is low enough.

## 7.5 Indoor Air Quality

Indoor Air Quality is a difficult air characteristic to quantify, but a very important one to consider. The Active Chilled Beam system would have a best IAQ over the DOAS FCU and the existing VAV system. This is because the only air supplied to the space is outdoor air which means that there is no chance for a decrease when the load in the space decreases.

With the DOAS FCU, although the ventilation air is 100% outdoor air, the Terminal Unit uses its air dampers to control the conditioning of the space. The chance of the dampers being not set properly is still a threat to the Indoor Air Quality. Thus, if all the DOAS FCUs have their dampers properly set, the IAQ of the DOAS FCUs will be equivalent to the Active Chilled Beam.

This is not the case for the existing VAV system. Similarly to the DOAS FCU, the dampers will adjust when the space load fluctuates to adequately condition the space. And like the DOAS FCU, the existing VAV unit dampers may be incorrectly set and could inadequately supply enough ventilation air. However, unlike the DOAS FCU, the existing air system mixes return air with the ventilation air which lowers the IAQ of the building by re-circulating possible contaminates.

Therefore, in terms of Indoor Air Quality an Active Chilled Beam system would be the preferred system selection. If Active Chilled Beams are not possible, a Dedicated OA System Fan Coil Unit could provide similar IAQ to the Active Chilled Beam but would need closer maintenance.

# 8.0 Ground Source Heat Pump

With approximately 1,598,000 SF (36.7 acres) of the property being covered by asphalt parking, a ground-source heat pump will add no marginal site disturbance. The GSHP system could provide a considerable amount of energy savings because of the near constant temperature of the earth (52°F in the Pittsburgh region).

In this hybrid system, the Ground Loop is sized to handle the peak heating load. It was determined that the peak heating load will be less than the peak cooling load (see demand graph below), thus a Cooling Tower was sized to handle the remainder of the cooling load.

For this project a water-glycol Closed Loop will be used instead of an open loop. The closed loop prevents the need for a heat exchanger which lowers the ground loop's efficiency and increases the plant's maintenance costs. The ground loop uses thermally fused high-density-polyethylene (HDPE) 1 inch U-tubes. Since this will be a ground source and not a water source system, grout is injected into the bored to increase the heat transfer from the tubing to the ground. In terms of efficiency, a typical GSHP system can perform at a COP of 6.0 to 6.5 in cooling mode; whereas an air-cooled chiller has a COP of around 4.1. In heating mode, the COP of the Plant is closer to 4.4.

#### 8.1 Centralized Plant

#### 8.1.1 Characteristics

A central plant is the most expensive ground source heat pump configuration with larger and more extensive piping headers, central control, and added pump capacity. However, a central plant is easiest to integrate with the prescribed hybrid system (parallel with Cooling Tower). Also, this system is easiest to maintain which results in lower maintenance costs.



### 8.1.2 Schematic

Image 4: Centralized Ground Source Heat Pump Plant

#### 8.1.3 Ground Study

With a ground source heat pump system, the geological make-up of the ground can make or break the viability of the system. Certain geology like bedrock can make the initial cost of a ground system not feasible. A ground study for Westinghouse's structural design, it was found the half of the property had bedrock close to the surface. With this, it was assumed that half of the parking area was also over bedrock and therefore only half could be used for a ground source system or about 800,000 square feet.

When installing the vertical bores, it is common practice to allow 20 feet in between each bore or 400 SF per bore. So as a limiting factor, only 2,000 bores can be placed on the site. Typically bores are 200 to 400 feet in depth and result in approximately 1 to 2.5 tons per bore. Therefore, with initial cost being a non-issue a 2,000 ton ground source heat pump system could be implemented.

#### 8.1.4 Energy Use

A ground source heat pump relies on the constant temperature of the ground to use as a heat sink/source. With the ground warm in the winter and cool in the summer, the delta T between the ground and the condensing loop will provide a relatively efficient system. A conventional thermal system relies on Cooling Towers as a heat sink. However, the performance of a Cooling Tower relies on the ambient air dry bulb and wet bulb temperatures. In a rather humid region like Pittsburgh, the performance of a Cooling Tower can be diminished in the summer time.

#### 8.1.5 Ground Source Heat Pump Sizing

Sizing of the GSHP System correctly is essential for the system's energy savings to pay off. The three Heat Pumps were sized so all three could handle the warm season's cooling demand, while sized to also handle the heating and cooling demand in the occupied winter mode with a 2 to 1 configuration. The Heating and Cooling Demand is shown in the graph below. As seen, the cooling demand is higher than the heating for all of the year except January and February. The cooling peaks at 843 Tons and the heating peaks at 6723 MBH. The three heat pump sizes are shown in the table below. The three sizes were chosen to meet the demand curve as best as possible throughout the year. A 600-ton Heat Pump would possibly need to be custom made because the largest size found in literature was 500 tons.



Graph 3: GSHP System Demand

Heat Pump Plant	Size	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
HP-1	600	С	С	Н	С	С	С	С	С	С	С	Н	Н
HP-2	350	Н	Н	С	Н	Н	Н	Н	Н	Н	С	С	С
HP-3	350	Н	Н	С	С	С	С	С	С	С	-	С	С

Table 11: GSHP Plant Configuration

In a hybrid system, the Cooling Tower is sized to handle the peak loading of the cooling. The difference between the peak cooling and peak heating is 270 Tons. Therefore the Cooling Tower will be sized for 270 Tons of Cooling. The use of a Cooling Tower is important for two reasons. First, the initial cost of the GSHP system is reduced significantly. And secondly, it is very important to balance the heat transfer to the ground. If a geothermal system only was used for cooling, the ground temperature would slowly rise. With the temperature rise, the delta T for the heat exchange will be

less, thus lowering the capacity of the system. The addition of a Cooling Tower will not increase the energy usage of the system too dramatically since it is sized for only the peak cooling load which is rarely hit. Actually, according to the Trace results, the Cooling demand only crests 66% of the peak less than 5% of the time.

# 8.1.6 Life Cycle Costs/Maintenance

The following Table compares the Utility Costs for the first 15 years associated with a Hybrid GSHP System to the All GSHP System and Existing Chiller/Electric Resistance.

System	kWh \$	kW \$	Total \$	Utility \$/SF/YR	15 Year Savings \$
Hybrid GSHP Plant	5,881,860	433,335	6,315,195	1.15	4,652,970
GSHP Plant	6,150,000	450,000	6,600,000	1.18	4,368,165
*Existing Plant	9,957,105	1,011,060	10,968,165	2.00	-

Table 12: 15-Year of GSHP Utility Costs

A GSHP system typically requires a maintenance cost of around \$0.20/SF/YR. Compare this to a conventional plant's maintenance cost of around \$0.40/SF/YR. That results in a savings of \$72,000 a year for Westinghouse.

# 8.1.7 Emissions

One of the main reasons a GSHP System was explore is because of its low energy usage. Westinghouse, as a company, is an industry leader in energy system design. And if their headquarters is not an energy efficient building, then that would only hurt their reputation. Likewise, it would be wise of them to set the standard for other buildings and reduce their carbon footprint on the world. A Geothermal system uses so much less energy and results and results in a significant pollution reduction.

#### 8.1.8 Initial Cost

Initial cost for a ground source heat pump system is difficult to calculate without entering into a construction management breadth. However, the initial cost can be estimated from previous projects. It is estimated with the location of the property of the grove of a hill, the bore depth required is approximately 350 feet. And with estimation of 150 ft/ton, each bore should handle about 2.33 tons—to anticipate lower performance, a value of 1.75 tons/bore will be used. Using figures from previous projects, this boring scheme will result in approximately \$4,000/ton for the bore field. For the Heat Pump Plant equipment costs, a similar project ended with an equipment cost of \$7,530/ton. Thus, the initial cost will be approximately \$11,530/ton with the Hybrid GSHP slightly lower and the all GSHP slightly higher.

## 8.2 De-Centralized Plant

### 8.2.1 Characteristics

Like the Centralized Heat Pump plant, the De-centralized plant can take advantage of load diversity since the heat pumps share a common ground loop. A de-centralized system had several advantages-- they are easy to control, can be used in larger buildings, and are relatively inexpensive. Also, in terms of heat pump systems, the decentralized design is the most commonly implemented.

### 8.2.2 Schematic



Image 5: De-Centralized GSHP Plant

# 8.2.3 Energy Modeling Inaccuracies

Unfortunately, Trane Trace Energy Model lacks somewhat in the field of modeling Ground Source Heat Pump Systems. The Centralized Plant was easily modeled as a water-to-water heat pump. However, the distributed GSHPs can only be modeled as water-to-air heat pumps. Also, in order to Trace to run properly, every unitary heat pump requires its own condenser loop, thus does not take into consideration the advantages of load diversity. Other modeling programs like Design Builder have better GSHP modeling capabilities, but were not able to be explored in time for this report.

#### 8.2.4 Life Cycle Costs/Maintenance

The Life Cycle Costs of the De-Centralized system would be slightly less than the Centralized system. This assumption could be made because the distributed systems could be controlled easier and can be kept closer to the full load. Maintenance costs would be higher than the Centralized simply because there are more units to inspect and maintain.

#### 8.2.5 Initial Cost

The Initial Cost should be lower than the Centralized Plant. The small tubing and headers required for the ground loop would neglect the increase in costs for the equipment—the larger heat pumps are cheaper on a per ton basis.

# 9.0 Central Plant

#### 9.1 Chiller Plant

The current Chiller Plant has three staged Centrifugal Chillers. The same chiller plant was used for the Central Plant design with the only difference being the sizing. The current Chillers are quite efficient with a NPLV of 0.505 kW/Ton and a Full Load Efficiency of 0.547. With the redesign of the air system to be a Dedicated OA System, the size of the Chiller Plant dropped by 28% with the Active Chilled Beams.

#### 9.2 Boiler Plant

The existing mechanical system has electric resistance as its primary heating plant. The selection of electric resistance was from it low initial cost since it is easy to install, does not require any specialized contractors and does not require piping which can be very expensive. However, electric resistance has difficulty effectively heating a space. This inefficiency results in much higher energy usage for the building. Heating constituted 32% of the energy usage of the entire building. There are several alternatives to this

heating method that would be more efficient and save the Owner significantly over the course of the building's life.

Using a Boiler Plant would be a viable option for a building like this. The switch to a Natural Gas Boiler Plant has several benefits. First, a commercial Boiler has more than twice the efficiency of delivered electricity. A typical Boiler has an efficiency of about 83%. A typical power plant in the U.S. burns coal at about 40%. After transmission losses, the delivered energy is only about 36%. This inefficiency of the grid leads to much more emissions considering that Natural Gas burns much cleaner than Coal which is in 50% of all U.S. power plants. Secondly, new building construction should be very cautious of relying on the grid's electrical utility rates to remain the same. Deregulation will be taking effect in 2010 and is an almost certainty that electric rates will be raised significantly. On the other hand, Natural gas prices remain quite inexpensive.

#### 9.3 Hydronic System

A hydronic system is a much more efficient heat transfer system than relying on electric resistance and the air system to transfer heat. With the same delta T and same mass flow, water can transport 4 times as much heat. Also, water is 1000 times the density of air. In terms of size, a 1 inch in diameter water pipe could carry the same amount of heat as a 55x55 air duct. This reduction in area usage can dramatically reduce the floor-to-floor height especially with DOAS.

### 9.4 Schematic



**Central Chiller Plant** 



Image 6: Central Boiler Plant

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## 9.5 Energy Use

Since the existing Chiller Plant is quite efficient already and the use of Boiler Plant more than doubles the efficiency of the Heating Plant, the energy usage of the Central Plant should be quite low. Also, in terms of cost/BTU, buying natural gas as opposed to delivered electricity is a much better deal.

# 9.6 Life Cycle Costs/Maintenance

The following Table compares the Utility Costs for the first 15 years associated with a Central Plant to the Existing Chiller/Electric Resistance. As shown, the Initial Cost of the Central Plant is actually less than the existing system. This is due to the energy reduction from the Dedicated OA System. With the VAV system, the cost would be approximately 20-30% more.

System	kWh \$	kW \$	Therm \$	Total \$	Utility \$/SF/YR	15 Year Savings \$	Initial Cost \$	Simple Payback Yrs
Central Plant	5,086,140	382,605	2,836,875	8,305,620	1.51	2,662,545	5,340,000	-0.1
*Existing Plant	9,957,105	1,011,060	-	10,968,165	2.00	-	5,500,000	-

Table 13: 15-Year of Central Plant Utility Costs

A Central Plant typically requires a maintenance cost of around \$0.40/SF/YR. This is a typical maintenance cost for a Plant. When compared to the existing Chiller/Electric Resistance Plants, the Central Plant would have a slightly higher maintenance cost due to the upkeep of the Boiler Plant.

# 9.7 Emissions

One of the main reasons a Central Plant was explore is because of its low energy usage. Westinghouse, as a company, is an industry leader in energy system design. And if their headquarters is not an energy efficient building, then that would only hurt their reputation. Likewise, it would be wise of them to set the standard for other companies and reduce their carbon footprint on the world. A Boiler Plant uses on-site energy as opposed to delivered electrical energy. The use of on-site energy results in less primary fuel used and therefore fewer emissions produces. As discussed previously, natural gas has a quarter of the carbon that coal has. So not only is on-site fuel usage more efficient it is also cleaner.

## 9.8 Initial Cost

The Initial Cost of the Central Plant was based on figures from previous projects and tabulated numbers from R.S. Means. The Chiller Plant will be similar to the Initial Cost of the Existing Chiller Plant with a cost of about \$4,000,000. This number will fluctuate with the three different DOAS configurations with the All Active Chilled Beam layout resulting in the lowest initial cost for the Chiller Plant with \$2,530,000.

The Boiler Plant Initial Cost will be much less than the Chiller Plant Initial Cost. The estimated cost for the Boiler Plant is \$300/MBH or about \$2,000,000. These figures were difficult to find since R.S. Means figures are for the Boiler only and not the piping, pumps, or heating plant accessories.

# **10.0 Architectural Study**

# 10.1 Existing Design

The existing façade treatments are all designed in basically the same manner. It's fairly safe to assume that all the facades were designed relatively the same for the simple reason of symmetry and it's cheaper and simpler to construct. The symmetry was clearly the defining mark of this building. With a multi-billion dollar company like Westinghouse, a symmetrical hierarchal design definitely well represents the sense of order, permanence, ability, and might that Westinghouse has come to exemplify. However, this emphasis on symmetry and order has somewhat neglected the true purpose of a façade—to protect the building.

The only significant design feature that is a response to the orientation is the horizontal fins on the Cafeteria's large glazing faces. The horizontal fins were placed only on the top half of the glazing leaving the bottom 15 feet or so unprotected. The only reasoning behind this is possibly to give the Cafeteria patrons an unobstructed view of the hill behind the property.



#### Image 7: Existing Typical Floor Plan

As seen from the Image above, the program of this building called for mostly open office space. Conference rooms are place near the Cores and on the Northeast and Northwest corners. The shaded regions are the Core spaces with restrooms, stairwells, duct shafts, etc.



Image 8: Existing North Façade Panorama



Image 9: Existing North Façade View

The two images above show the symmetry and hierarchy of the building. The brick juts from the wings are used to reinforce this idea of hierarchy and are abutments to the entrance to further signify it.



Image 10: Existing South Façade Panorama



Image 11: Existing South Façade View

The above two images again show the symmetry of the building. Hierarchy was not as enforced on this side of the building because the main entrance is on the north face and no vehicular traffic can really view this side. The Cafeteria's horizontal fins are seen in these images as well.

### 10.2 New Design

#### 10.2.1 South Façade

The South façade has clearly the largest thermal loads. Its solar transmission contributes about 65-70% of the total cooling load in the building. To shade the building from the harsh summer sun, solar overhang shades were placed on all the south glazing on floors 2, 3, and 4. These overhangs were designed with two purposes—shade and redirect daylight further into the office space.

An earlier design of these overhangs was to have a solid ban of overhangs going the length of the south façade. However, this idea aesthetically did not complement the rest of the façade since all vertical and horizontal entities on the façade were broken up to reduce the apparent mass of the building. Thus, the overhangs were segmented as well. The overhangs were purposefully designed to appear lighter with its narrow profile and thin tension cable suspension to attempt to ease/compliment the heavy, dark masculinity of the rest of the exterior.

With the East and West facades being so narrow compared to the other two, they did not contribute as much thermal loading. However, for the sake of symmetry and increasing the daylighting in the spaces, the same solar shading treatment was applied to the East and West.

No overhangs were placed on the fifth floor because the large 'capital' of the roof overhangs enough to shade during the summer. To save money, the first floor was shaded differently. With the use of deciduous trees, the first floor can be shaded during the summer and shoulder seasons while allowing absorption of winter solar energy. With the cafeteria facing south, this use of heavy shading from trees is most important here. The current cafeteria design has horizontal fins on half of the glazing; however, the cafeteria still has the largest thermal load of any other space in the building. It could also be said that the placement of trees near the building will improve workers' satisfaction of the facility.



Image 12: New Design South Facade Open Office Section



Image 13: New Design South Face Panorama



Image 14: New Design South Face View

#### 10.2.2 North Façade

The North façade is whole different story. The major thermal load is heat loss of the glazing during the winter. To combat this loss, two treatments were implemented.

The first was the lowering of the glazing percentage. Lowering the glazing has several downsides—less daylighting, more worker dissatisfaction (feeling of being in a box), and the loss of the sense of transparency of the building. So to be sensitive to this, the selection of where to lower the glazing was done very carefully. The key was a look at the office layout—the corners of the north office area are occupied with conference rooms. Conference rooms generally spend more time unoccupied and when they are occupied it's quite common that PowerPoint presentations are in use. Thus daylighting is not a priority for this space, and the infrequency of their use means that artificial lighting energy use will not be an issue. Hence, thermal loading can be prioritized, and the glazing in these spaces can be dramatically reduced. And with conferences rooms on both ends of the building, the symmetry of the façade is still pronounced.

The second North façade treatment was the implementation of floor to ceiling partitions creating a buffer space on the abutment wings of the 2<sup>nd</sup>, 3<sup>rd</sup>, and 4<sup>th</sup> floors. The current open office layout has an unused space of approximately 5 feet between the cubicles and exterior wall. By adding an all-glass partition, this space can be treated as a separate unoccupied space instead of office space. This means that the temperature in these buffer zones can be allowed to drift higher and lower than the office space.

This design offers many benefits, first of which is that these partitions are moveable and do not hinder the rearrangement of desks, secondly they are all glass so no loss of daylight, and they reduced the heating demand for the north office spaces. The concept still allows these spaces to be accessed with doors at the end of each aisle of cubicles which would allow workers to use the spaces for private calls, etc.

With these façade treatments, the thermal load in the spaces has been drastically reduced and thus the cooling and heating equipment is reduced in size.



Image 15: New Design North Façade Plan

The shading floor area in the image above is the new Buffer Zone. The conference rooms on the corners had to be rearranged with some of the open office to ensure that no desks would be negatively affected by the lowering of the glazing area.



Image 16: New Design North Façade Conference Room Section



Image 17: New Design North Facade Buffer Zone Section



Image 18: New Design North Façade Panorama



Image 19: New Design North Façade View

As seen from the images above, the lowering of the glazing area did not take away from the architectural style of the façade. With the Conference Room designs, the north glazing was reduced from 40% to 34.5%. In the North Façade View, mullions were added on the abutment wings of the façade to continue the horizontal band pattern and to give continuity to the new scale of the wings.

# 10.3 Effects of Plants

The effects of these architectural designs had a significant impact on the heating and cooling demand on the Mechanical system. The following graphs depict the reduction in the Cooling load and Heating Load respectively. As seen from both graphs, the façade redesigns reduced both the cooling and heating loads. The most notable reduction is the reduced cooling load for the Active Chilled Beams which had a 43% reduction. The other two system layouts also saw reductions of about 20%. The reduction on the Heating Plants was not as significant. All three systems had a heating load reduction of about 12%. This may be attributed to still having 34% glazing on the north face or the

buffer zones needed to have larger drift points—they were set to 65 and 78 degrees Fahrenheit.

Impacts on initial cost, energy use, emissions, utility costs will be discussed in the Conclusions section.



Graph 5: Reduced Cooling Load from Façade Re-Design



Graph 6: Reduced Heating Load from Façade Re-Design

# 11.0 Daylighting Breadth

#### 11.1 Design

With a Dedicated Outdoor Air System, the CFM delivered is cut down to approximately 20% of the VAV system. This reduction results in the largest ducts going from a 44x14 down to a 24x8. This savings in volume is translated into savings on ceiling height of 6 inches. This increases the ceiling height to 10 feet which will definitely improve the effectiveness of the light shelf design.

With the room height at 10 feet, the light shelves are placed at 8 feet. Eight feet was chosen because it's high enough to not effect office traffic, but low enough to allow a decent sized clerestory.

To effectively block low morning and late afternoon glare, the interior shelf would have to protrude into the space 3.5 feet. 3.5 feet is far too large of a shelf and would possibly be perceived as making the space feel cramped and stuffy. Therefore, the interior shelf was designed to only be 2.5 feet deep. The shorter shelf does not block winter glare, however winter in Pennsylvania is almost always cloudy, thus there should be relatively little glare or complaints. The following graph shows the percentage of clear skies during the winter to only be around 10-15%



Graph 7: Cloud Accumulation for Pittsburgh, PA

The exterior light shelf was designed for two purposes—reflect daylight into the space and shade the glazing from direct solar gain. If daylighting was the only function of the exterior shelf, its length would be about 1.5 times the height of the clerestory or about 3 feet. However, since it serves as a glazing shade, the projection was increased to 4.5 feet. To optimize the exterior shelf's daylighting effectiveness, it was tilted inward at a slope of 18 degrees (Latitude – 22 deg.).

A good measurement of the daylight within a space is the Daylight Factor. Daylight Factors that are between 2-5% make the room appear daylit, but artificial light would be needed. Anything over 5% and no artificial light should be needed.

# 11.2 Dimmer Control System

In order to take full advantage of the daylighting system, the first two rows of luminaires from the south wall were placed on separate control system. This control system is a Dimmer System which allows a light sensor to actively control the electric lighting within the space to be additive to the daylight within the zone. The Dimmer System allows for energy savings even with daylighting levels below the minimum intensity.

#### 11.3 Results

The following contour plans depict the results of the DaySim Analysis. The Continuous Daylight Autonomy contours are the fraction of time when the lights do not need to be at 100%. The Daylight Autonomy contours are the fraction of time when the lights can be off. The Useful Daylight Illuminance contours are the fraction of time when daylighting light levels are within the acceptance range of 450-1000 footcandles.

According to the results, the light shelves will actually hinder daylighting by a small amount. This was not the expected result for this breadth. However, the results can be explained rather logically. First, the clerestory is only 2 feet in height and is recessed a foot from the façade surface. Having only 2 feet of clerestory really will only marginally increase the daylighting within the space even in a sunny climate. A second disadvantage was the height to depth ratio of the room—10'/45' or about 0.22. With a

room this deep, a clear story would have to be nearly 10 feet in height to effectively daylight the whole space.

Even though the light shelves were designed appropriately from this building, it would simply not be worth the expense and implementation to attempt to use daylighting. However, the external shading should definitely still be used as a solar shade (see Architectural Effects on Plant). With this information, the external shade should be relocated at the top of the glazing to gain the full shading effect of the shelf.

The dimmer control of the first two rows of lights, however did have a positive impact. The DaySim results concluded that the dimmer controls would save the building approximately 98,000 kWh/year. Without the dimmer control system, the total energy usage of lights in the building was 819,000 kWh/year, therefore the dimmer control system reduces the usage by 12.0%. This translates to about \$10,500/ year in savings.



Image 20: Continuous Daylighting Autonomy (left- with light shelves, right- existing)



Image 21: Daylighting Autonomy (left- with light shelves, right- existing)



Image 22: Useful Daylight Illuminance (left- with light shelves, right- existing)

#### 11.4 Sections and Plans



Image 23: Open Office Daylighting Section

# 12.0 Conclusions and Discussion of Results 12.1 Energy Use

The following two graphs depict the energy usage associated with each Air System and Plant respectively. As seen, the Active Chilled Beam system requires the smallest Cooling Plant. Likewise, the DOAS Fan Coil Unit system requires the least amount of heating. From this graph it can be seen that it is much more beneficial to use an all Active Chilled Beam layout in terms of lowest total energy usage. The use of the Fan Coil Units only marginally reduces the heating load.



Graph 8: Plant Sizing per Air System



Graph 9: Building Energy Usage per Plant

With the implementation of the Façade Redesign, the plant sizing and energy usage was reduced significantly. The following two graphs show the reduction of the plant

sizes. As seen the Active Chilled Beam has the largest cooling reduction while the DOAS Fan Coil Unit has the largest heating reduction.



Graph 10: Reduced Cooling Load from Façade Re-Design



Graph 11: Reduced Heating Load from Façade Re-Design

The following graph shows the reduction in the building's energy usage per plant with the façade redesign. As seen from the graph there is a reduction in the heating and cooling energy use. Both Plant designs had a reduction of 16% in both heating and cooling energy use.



Graph 12: Reduced Building Energy Usage per Plant

#### 12.2 Initial Cost

The Initial Cost of each of the Air Systems is shown below with and without the Façade Redesign. The Façade Redesign reduces the Initial cost of the ACB system 21% and the other two systems 11%. The Active Chilled Beam System is the most expensive at \$3,200,000 with the Façade Redesign. The three designs are significantly higher than the existing air system because of the extra cost of having an Enthalpy Wheel within the DOAS air handling unit. The DOAS air systems would be much higher, but the savings in ductwork and fan sizes reduced the initial cost.



Graph 13: Initial Cost per Air System

The graph below shows the Initial Cost of each Plant both with and without the Façade Redesign. As seen, the most expensive plant would be the All GHSP system, but with the Cooling Tower (Hybrid), the Hybrid GSHP System went down \$1,050,000. The Central Plant was found to be actually less than the Existing Plant. This is the result of the load reduction from the Dedicated OA System. Likewise, all three Plants designs would have significantly higher initial costs if they were used in the existing VAV system. The initial cost of these plants in the existing VAV system would increase by about 10-20%.





#### 12.3 Annual Utility Cost/ Life Cycle Cost

The 15 Year Lifecycle Costs associated with each air system and Mechanical plant are shown below. Operation Costs were taken from similar buildings. As seen, the Architectural redesign of the façade has little impact on the Life Cycle Cost of the air systems with about a 4% reduction for each system. Overall, the all DOAS FCU air system has the smallest Lifecycles cost among the three designs. This is an interesting result considering that the all Active Chilled Beam uses the least amount of energy.

The Plant graph indicates that the Hybrid Ground Source Heat Pump plant has the smallest Lifecycle Cost over the 15 year period. This is directly related to the low maintenance costs and low energy usage of the GSHP plant.



Graph 15: 15 Year Lifecycle Cost per Air System


Graph 16: 15 Year Lifecycle Cost per Plant

With the information from the Initial Cost and Lifecycle Cost, a simple payback period can be calculated for each air system and plant. The table below shows the payback period for each system and plant combination. This payback period is in comparison to the existing VAV system and Chiller/Electric Resistance plant. As seen from the table, the Central Plant with a DOAS FCU only System will have the shortest payback of about 0.9 years. With the Façade Redesign, the payback period for each combination is reduced dramatically by about 60% for the GSHP Plants and about 80% for the Central Plant.

Simple Payback	Withou	ut Façade Re	design	With	Façade Red	esign
Period (Years)	ACB only	ACB/FCU	FCU only	ACB only	ACB/FCU	FCU only
GSHP Plant	21.3	18.9	18.3	8.4	8.9	7.1
Hybrid GSHP Plant	18.0	15.6	13.4	5.4	7.2	5.5
Central Plant	12.6	9.6	5.6	2.7	2.4	0.9

Table 14: Simple Payback Period per System/Plant Combination

# 12.4 Indoor Air Quality

Indoor Air Quality is a difficult air characteristic to quantify, but a very important one to consider. The Active Chilled Beam system would have a best IAQ over the DOAS FCU and the existing VAV system. This is because the only air supplied to the space is outdoor air which means that there is no chance for a decrease when the load in the space decreases.

With the DOAS FCU, although the ventilation air is 100% outdoor air, the Terminal Unit uses its air dampers to control the conditioning of the space. The chance of the dampers being not set properly is still a threat to the Indoor Air Quality. Thus, if all the DOAS FCUs have their dampers properly set, the IAQ of the DOAS FCUs will be equivalent to the Active Chilled Beam.

This is not the case for the existing VAV system. Similarly to the DOAS FCU, the dampers will adjust when the space load fluctuates to adequately condition the space. And like the DOAS FCU, the existing VAV unit dampers may be incorrectly set and could inadequately supply enough ventilation air. However, unlike the DOAS FCU, the existing air system mixes return air with the ventilation air which lowers the IAQ of the building by re-circulating possible contaminates.

Therefore, in terms of Indoor Air Quality an Active Chilled Beam system would be the preferred system selection. If Active Chilled Beams are not possible, a Dedicated OA System Fan Coil Unit could provide similar IAQ to the Active Chilled Beam but would need closer maintenance.

# 12.5 Environmental Impact

The following graphs show the emissions related to each Plant. The second graph shows the emissions with the new façade design. As seen from both graphs, the existing plant creates much more emissions than either new plant. This is due to the VAV system in the existing building and the existing mechanical plant's reliance on delivered electricity. Switching to a Central Plant is equivalent to taking 316 cars off the



road and switching to a Hybrid GSHP Plant is equivalent to 386 cars. With the Façade Redesign, the emissions is reduces slightly by about 6% or an extra 30 cars.

Graph 17: Emissions per Plant without Façade Redesign



Graph 18: Emissions per Plant with Façade Redesign

## 12.6 Operation and Maintenance

The Dedicated Outdoor Air Unit needed a standard amount of maintenance as does any air handling unit. The Enthalpy Wheel in the unit typically needs to be replaced every 20 years or so with good maintenance. The replacement of the wheel adds about \$500,000 on to the 15 year Lifecycle Cost.

The Active Chilled Beams are a very good system in terms of maintenance. ACBs do not have any moving parts, thus regular inspection is not needed. This low maintenance also leads to long lives as well. Most maintenance costs with an Active Chilled Beam system will come from the mechanical plant or the air handling unit.

The DOAS Fan Coil Units have relatively the same amount of maintenance needed as a conventional VAV unit. The biggest maintenance to the system will be the replacement of the filters on the units. Since the DOAS FCU has a fan in the unit, the life span will be lower than the Active Chilled Beam unit.

The Ground Source Heat Pump Plant will need minimal maintenance. Additionally, the life span of the ground loop is in the vicinity of 50 years and the Heat Pump's life span is around 25 years. However, GSHPs are not as common in the United States, thus the maintenance staff will have to be trained for operating the equipment.

A Central Plant would have a nominal amount of maintenance required. A Central chiller and boiler plant are very common in commercial buildings today and maintenance staff should be able to operate it with relative ease. The chiller plant should have a life span of about 20 to 30 years. The boiler plant has an estimated life of about 20 years.

# 12.7 Construction Impact

Even though this project is being delivered as a Design-Bid-Build, the construction impact can definitely effect the decision of an owner as to what system they want. The best air system for a construction standpoint is the existing VAV system, with the all

DOAS FCU second, the ACB/DOAS FCU layout third, and the all ACB last. The Active Chilled Beams would require a specialized contractor to install them.

For the plants, the existing Chiller/Electric Resistance would have the least impact on the construction since there is no heating plant to install. Second would be the Central Plant, third would be the Hybrid GSHP Plant and last would be the non-Hybrid GSHP Plant. The Hybrid plant would require less bores drilled thus less time spent. Also, drilling of the bores in the middle of the parking lot area will delay the paving as well as hinder construction site traffic.

## 12.8 Conclusions

After completing multiple analyses, the best mechanical plant for this application is the Hybrid Ground Source Heat Pump Plant. While the Central Plant had the shortest Payback Period, the other criteria for a successful plant swayed more toward the Hybrid GSHP. However, A Central Plant would probably be the choice of the Owner. The Initial Cost would be the biggest factor in terms of their decision. They are leasing this building to Westinghouse, so their biggest priority is a return on their investment.

From the standpoint of Westinghouse, I would suggest the Hybrid GSHP Plant. Westinghouse is the United States most prominent company for the energy industry. They would be poorly marketing themselves if they did not opt for the more efficient plant. The Hybrid GSHP Plant uses the least amount of energy, has the lowest Lifecycle Cost, and produces the least amount of emissions. These facts would be very beneficial for the marketing of Westinghouse.

The best air system for the Westinghouse Headquarters is the all Dedicated Outdoor Air System Fan Coil Unit layout. From the Owner's standpoint, they would again elect for the least expensive Initial Cost in the existing VAV system. However, when considering the benefits that come with DOAS e.g. smaller plant size, smaller lifecycle cost, smaller operation and maintenance costs, and the huge benefit of improve indoor air quality, it would be absurd not to consider DOAS. Several studies have been done on a comparison to a 100% OA ventilation to a conventional 30% OA ventilation. The results were a dramatic increase in worker productivity and fewer sick days.

Thus, from this analysis the best option is the Hybrid Ground Source Heat Pump Plant combined with the all DOAS Fan Coil Unit System. The following tables are summaries of the comparisons for the air systems and mechanical plants.

1- Best,		Air	Systems	
4- 000150	ACB only	ACB/FCU	FCU only	Existing VAV
Plant Size	1	2	3	4
Initial Cost	4	3	2	1
Life Cycle	3	2	1	4
Payback Period	2	3	1	-
IAQ	1	2	3	4
Op. and Maint.	1	2	3	4
Construction	4	3	2	1
Average Value	2.3	2.4	2.1	3.0

Table 15: Summary of Comparison of Air System Options

1- Best A- Worst		Mechan	ical Plant	
1- Dest, 4- Worst	Hybrid GSHP	GSHP	Central Plant	Existing Plant
Energy Use	1	2	3	4
Initial Cost	3	4	1	2
Life Cycle Cost	1	2	3	4
Payback Period	2	3	1	-
Environmental Impact	1	2	3	4
Op. and Maint.	2	3	1	4
Construction	3	4	2	1
Average Value	1.9	2.9	2.0	3.2

Table 16: Summary of Comparison of Plant Options

# References

1. Int-Hout, Chief Engineer, Dan. "A Reasonable Alternative to Chilled Beams- The DOAS Fan Powered Terminal Unit." May 2009. Krueger HVAC. 8 Dec. 2009

<http://doas.psu.edu>

This article discusses the benefits of a DOAS Fan Powered Box over the popular Chilled Beam. The article explains the uses of each terminal unit and how they can work in tandem.

 Kavanaugh, PhD, Steve. "Ground Source Heat Pumps." ASHRAE Journal 40.10 (1998): 31-36.

This article discusses in some detail the cost of a GSHP system for different construction methods and tubing used. It also includes design suggestions, potential outputs for various GSHP systems. The article illustrates its point with a thorough example of a GSHP in a small commercial building.

 Kavanaugh, PhD, Steve. "Ground Source Heat Pumps for Commercial Buildings." September 2008. HPAC Engineering. 8 Dec. 2009

<http:///hpac.com>

This web article discusses some of the key points of how a Ground Source Heat Pump System operates. It compares a GSHP system to other standard commercial systems. Additionally, it lists the benefits and disadvantages of three different types of GSHP.

 Minea, PhD, Vasile. "Ground Source Heat Pumps." ASHRAE Journal 48 (2006): 28-35.

This article discusses a comparison of a vertical to a horizontal Ground Source Heat Pump System in Canadian Schools. The article includes discussions on system descriptions, construction costs, soil temperatures, energy consumption and operating experiences.  Mumma, PhD, PE, Stanley. "Dedicated Outdoor Air Systems." February 2001. The Pennsylvania State University DOAS. 14 Dec. 2009

<http://doas.psu.edu>

This webpage discusses the advantages of a Dedicated OA System over a conventional system—namely VAV. It also explains the basic concept of how DOAS is implemented into a building.

 Mumma, PhD, PE, Stanley. "Designing Dedicated Outdoor Air Systems." ASHRAE Journal 43.5 (2001): 28-31.

This article discusses in some detail the working parameters of DOAS. The article includes a comparison of a VAV system to three different configurations of DOAS.

 Rafferty, PE, Kevin. "A Capital Cost Comparison of Commercial Ground-Source Heat Pump Systems." Geo-Heat Center, Oregon Institute of Technology.

# Appendix A: Trane Trace Results

	COOLING COIL PEAK Peaked at Time: Mo/Hr: 7/15 Outside Air: OADB/WB/HR: 86/71/9				c	LG SPACE	PEAK			HEATING	COIL PEAK		TEMP	ERATURE	s	
Pea	ked at T Outside	ime: Alr:	OADB/WB/	/Hr: 7/15 HR: 86/71/9	15	Mo/Hr: OADB:	9/12 73			Mo/Hr. OADB:	Heating Design 5		SADB Ra Planum	Cooling 56.4 72.9	Heat 8	ing 3.8
	Sen	Space 8. + Lat	Plenum Sens. + Lat	Net	Percent	Sensible	Percent			Space Peak	Coll Peak	Percent	Return	72.8	6	6.1 6.1
	1000	Btu/h	Btu/h	Btu/h	(56)	Btulh	(%)			Btu/h	Btu/h	1961	En MtrTD	0.0		0.0
Envelope Loads					1.41		1.41	Envelope Lo	ada			1-4	Fn BldTD	0.1		0.0
Skyllte Solar		0	0	0	0:	0	0	Skylte So	lar	0	0	0.00	Fn Frict	0.3	3	0.0
Skylite Cond		0	0	0	0:	0	0	Skylte Co	brid	0	0	0.00	100 M	4393	5	885
Roof Cond		0	53.330	53,330	0!	0	0	Roof Con	d	0	-129.452	1.76				
Glass Solar	3.	568,087	0	3,568,087	32	5,176,271	72	Glass Sol	ar	0	0	0.00	AI	RFLOWS		
Glass/Door Con	d	359,316	0	359,316	3:	-181,781	-3	Glass/Dor	or Cond	-2.383.476	-2.383.476	32.33		Ocellan		
Wall Cond		270,352	451,903	722,256	6	217,212	3	Wall Cond	1	-381,292	-1,022,116	13.86		Cooling	nea	ung
Partition/Door		315		315	0	7.294	0	Partition/D	Door	-209.586	-209.586	2.84	Diffuser	433,771	263	,277
Floor		0		0	0;	0	0	Floor		-19,001	-19,001	0.26	Terminal	433,771	263	,277
Adjacent Floor		0	0	0	0;	0	0	Adjacent	Floor	0	0	0	Main Fan	433,771	130	1,131
Inflitration		590,347		590,347	5	49.367	1	Infiltration		-1,198,576	-1,198.576	16.26	Sec Fan	0	133	,145
Sub Tota/ ==>	4,	788,418	505,234	5,293,651	47	5,268,363	73	Sub Total	==>	-4,191,930	-4,962,206	67.31	Nom Vent	54,007		0
Internal Loads								Internal Loa	ds				Infil	17,824	17	,824
Lights		145,970	583,880	729,850	7	152,093	2	Lights		0	0	0.00	MinStop/Rh	130,131	130	1,131
People	2,	104,188	0	2,104,188	191	1,097,766	15	People		0	0	0.00	Return	451,596	147	,955
Misc		567,814	0	567,814	5	587,978	8	Misc		178,595	178,595	-2.42	Exhaust	71,831		351
Sub Total ==>	2,	817,971	583,880	3,401,851	31	1,837,836	25	Sub Total	==>	178,595	178,595	-2.42	Rm Exh Auxillary	0		0
Celling Load		97.311	-97.311	0	0	82 680	1	Celling Load	1	-212,180	0	0.00	Leakage Dwn	0		0
Ventilation Load		0	0	2,316,983	21	0	0	Ventilation I	oad	0	0	0.00	Leakage Ups	0		0
Adl Air Trans Hea	at	a		0	0	0	0	Adl Air Tran	s Heat	0	0	0				-
Dehumid Ov Sizi	na	100				10.73	- 20	Owllindr Siz	ing	0	0	0.00	-			
Ovil Indr Sizing		0		0		28 595	0	Exhaust Her	*		ŏ	0.00	ENGIN		ke	
Exhaust Heat		-	-71.596	-71.596	-11	20,000		OA Preheat	DIT		-2.588 523	35.11	ENGIN	EERINGC	1.3	
Sup, Fan Heat				205,642	2			RA Preheat	DIT		0	0.00		Cooling	Heat	Ing
Ret Fan Heat			3	3	0			Additional R	teheat		0	0.00	% OA	13.6	-	0.0
Duct Heat Pkup			-462.997	0	0:		2		1200		5		cfm/ft <sup>=</sup>	1.22	0	.37
Underfir Sup Ht F	kup		100000000000000000000000000000000000000	0	0;			Underfir Su	D Ht Pkup		0	0.00	cfm/ton	466.98		
Supply Air Leaka	de l		0	0	0			Supply Air I	eakage		0	0.00	ft9ton	383.34		
	-										-		Btufur.ff=	31.30	-26	42
Grand Total ==>	7,	703,700	457,212	11,146,534	100.00	7,217,474	100.00	Grand Total	=>	-4,225,515	-7,372,134	100.00	No. People	4,597	56	12-1
	8	63	COOLING	COIL SEL	ECTION			00	-	AREAS		HE	ATING COIL	SELECTIO	N	-
	Total C ton	MBh	Sens Cap. MBh	Coll Airflow cfm	F F	gr/lb	Leave "F	"F gr/lb		Gross Total	Glass ft <sup>2</sup> (%)		Capacity MBh	Coll Airflow	Ent "F	Lvg *F
Main Cig 9	28.9 1	11,146.5	8,484.9	433,771	74.7 61.6	64.8	55.0 52	2.6 58.0	Floor	356,076	3.85 B	Main Htg	-6,527.5	263,277	60.6	83.8
Aux cig	0.0	0.0	0.0	0	0.0 0.0	0.0	U.0 0	0.0 0.0	Part	26,736	1	Aux Htg	0.0	0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0 0.0	0.0	0.0 0	0.0 0.0	Int Door	0		Preheat	-2,880.4	54,007	5.0	55.0
									ExFIr	1,508						
Total	28.9 1	11,146.5							Roof	69,901	0 0	Humidif	0.0	0	0.0	0.0
									Wall	93,535 4	5,032 48	Opt Vent	0.0	0	0.0	0.0
									Ext Door	0	0 0	Total	-9,407.8			

System Checksums

The Existing System Checksum (Cooling 928.9 Tons, Heating 9,407.9 MBH)

Main System	1					833							A	ctive Chilled	d Bea	ms
	COOLING COIL PEAK leaked at Time: Mo/Hr: 9 / 12 Outside Air: OADB/WB/HR: 73 / 61 / 63					CLG SPACE	E PEAK			HEATING	COIL PEAK		TEM	PERATURE	s	
P	eaked a Outs	at Time: side Air:	OADB/WB/	/Hr: 9/12 HR: 73/61/6	52	Mo/Hr: OADB:	11/12 54			Mo/Hr.	Heating Design 5		SADB Ra Diapum	Cooling 55.0 73.9	Heal 7	ting 72.0
		Space Sens. + Lat.	Plenum Sens. + Lat	Net Total	Percent Of Total	Space Sensible	Percent Of Total			Space Peak Space Sens	Coll Peal Tot Sens	Percent Of Total	Return Ret/OA	73.9 73.9	00	55.8
Envelope Load	ls i	Bturn	Btu/h	Btu/h	(%)	Bturn	(%)	Envelope Lo	oada	Bturn	Btur	1 (%)	Fn MtrTD Fn BidTD	0.0		0.0
Skyllte Solar		0	0	0	0:	0	0	Skylte So	olar	0		0.00	Fn Frict	0.0		0.0
Skylite Cond		0	0	0	0	0	0	Skylite Co	ond	0	(	0.00		100	_	_
Roof Cond		0	-12,165	-12,165	0;	0	0	Roof Con	d	0	-128,674	1.32				
Glass Solar		3,812,379	0	3,812,379	84:	4,351,275	85	Glass Sol	lar	0	and and a second	00.00	A	IRFLOWS		
Glass/Door Ca	ond	-5,717	0	-5,717	0:	-666,664	-13	Glass/Do	or Cond	-2,383,476	-2,383,476	5 24.40		Cooling	He	ating
Wall Cond		183,147	311,731	494,877	11	98,917	2	Wall Con	đ	-381,292	-1,018,267	10.42	Diffusor	30 416	11	3 252
Partition/Door		-38,910		-38,910	-1	-95,238	-2	Partition/I	Door	-209,586	-209,586	2.15	Transland	20,416		3,202
Floor		0		0	0	0	0	Floor		-19,001	-19,001	0.19	Terminal	30,410	11	3,252
Adjacent Floo	r	0	0	0	0	0	0	Adjacent	Floor	0		0 0	Main Fan	30,416	115	5,252
Infiltration		43,283		43,283	1:	-334,838	-7	Infiltration	1	-1,198,576	-1,198,576	5 12.27	Sec Fan	0		0
Sub Tota/ ==>	-	3,994,182	299,566	4,293,747	94;	3,353,452	66	Sub Total	/==>	-4,191,930	-4,957,579	50.74	Nom Vent	96,419	82	2,345
K1000 100 000 000					1								AHU Vent	96,419	82	2,345
Internal Loads					1		1	Internal Loa	ds				Infil	17,824	17	7,824
Linhts		155 853	627 451	784 314	17	156 863	3	Lights		0		0.00	MinStop/Rh	113,252	113	3,252
People		1 939 581	021,401	1 939 581	43	1 053 340	21	People		ő		0.00	Return	144 659	213	3,421
Misc		599.069	0	599 069	13	599 069	12	Misc		178 595	178 595	-1.83	Exhaust	114 243	100	0.169
Dub Tatal an		0 505 513		2 200 064		1 840 070		Cub Tata		170,000	170,000	4.00	Rm Exh	0		0
SUD 10(a)>	5	2,090,010	027,451	3,322,904	10;	1,019,272	30	SUD TOtal		170,595	1/0,390	-1.00	Auxiliany	658 370		
Colling Load		000 000	000.020			1 47 105		Calling Load		-253 605		0.00	Lookono Dun	000,010		ŏ
Ventilation Los	art i	1 147 550	-209,232	1 142 660	25	147,190	2	Ventilation	bed	-1 405 208	-1 //06 206	14 30	Loakayo Dwit			
Adl Air Tropp H	laat	-1,140,005		-1,140,005	-20	-200,000		Adl Air Tran	In Heat	1,400,200	1,000,000		reavage ope	U		0
Auj Ali Tians r	10di	0		U		0	U	AujAn man	is rieat							_
Denumia. OV S	izing			579,899	13			Owunar siz	ang	C C	0.00.000	0.00				_
Ov/Undr Sizing	1	-2,266,144		-2,266,144	-50	0	0	Exhaust He	at		240,290	-2.46	ENGI	NEERING C	KS	
Exhaust Heat			-226,133	-226,133	-0-		3	OA Preneat	DIII.		-2,062,722	2 21.11		Cooling	Heat	ting
Sup. Fan Heat			22				2	KA Preneat	DIT.			0.00	8.04	317.0	1100	72.7
Ret Fan Heat	5.		1	1	0:		3	Additional F	teneat		-1,762,595	9 18.04	of miles	0.00		1 20
Duct Heat Pkur	P		U	0	0.								CITIVIL	0.09	- 2	1.32
Undernr sup H	т Ркир		-	0	0;		1	Undernr su	рнтркир		1	0.00	cmvton	99.98		
Supply Air Lea	kage		0	0	0;		8	Supply AIr I	Leakage		(	00.00	ft-rton	1,170.43		
1.200		100000000	02004285	010 000 000 F	- charles	19070300	- and -	1. 16 1		100000000000000000000000000000000000000	1000000	s waard	Btu/hr-ft*	10.25	-12	2.81
Grand Total ==	2	3,489,125	491,652	4,560,676	100.00	5,114,089	100.00	Grand Total	(=>	-5,673,238	-9,770,310	100.00	No. People	4,597		
	- 8	125	COOLING	COIL SEL	ECTION					AREAS	6	H	EATING COIL	SELECTIO	N	1
	ton	al Capacity MBh	Sens Cap. MBh	Coll Airflow cfm	Enter De	BAWB/HR F gr/lb	Leave F	"F gr/lb		Gross Total	Glass ft= (%)		Capacity MBh	Coll Almow	Ent "F	Lvg "F
Main Cig	0.0	0.0	0.0	0	0.0 0.	0.0 0.0	0.0	0.0 0.0	Floor	356,076	1.20	Main Htg	-2,500.2	113,252	51.3	72.0
Aux Cig	380.1	4,560.7	4,560.7	658,379	72.0 59.	9 61.2	65.5 5	7.5 61.2	Part	26,736		Aux Htg	-4,377.6	0	0.0	0.0
Opt Vent	304.2	3,650 7	1,892.3	96.419	71.5 65	1 86.8	53.1 5	2.4 60.0	Int Door	D		Preheat	0.0	0	0.0	00
State States						10 10 10 10	0750	20 (03.5%)	ExElr	1.508		Reheat	-2 500 2	113,252	51.3	72.0
Total	684.3	82114							Roof	69 901	0 0	Humidif	0.0	0	0.0	0.0
									Wall	93 535	5 032 48	Opt Vent	-2 052 7	96.419	50.0	70.0
									E-d D	50,000 4	40	Treat	-R 0.40 F	20,415	00.0	10.0
									Ext Door	0	U O	IOTAL	-0,940.5			_

### System Checksums

By PENN STATE UNIVERSITY

Central Plant w/ All ACB (Cooling 684.3 Tons, Heating 8,940.5 MBH)

Main System														A	ctive Chille	d Bea	ams
	COOLING COIL PEAK Peaked at Time: Mo/Hr: 9/12 Orticulde Alr: QADB/WB/HB: 73/61//				1	CLG SPACE	PEAK			HEATING	COIL	PEAK		TEM	PERATURE	S	÷
Pe	eaked a Outsi	t Time: Ide Alr:	Mo OADB/WB/	Hr: 9/12 HR: 73/61/6	52	Mo/Hr: OADB:	11 / 12 54			Mo/Hr OADB	Heatin 5	ng Design		SADB Ra Dienum	Cooling 55.0 74.1	Hea	ating 70.0
	s	Space ens. + Lat.	Plenum Sens. + Lat	Net Total	Percent Of Total	Space Sensible	Percent Of Total			Space Peak Space Sens	K B	Coll Peak Tot Sens	Percent Of Total	Return	74.1 74.1		65.8 65.8
Excelence resources		Btu/h	Btu/h	Btu/h	(%)	Btu/h	(%)	Connerson	JOSN .	Btu/h	1	Btu/h	(%)	Fn MtrTD	0.0		0.0
Envelope Loads	8							Envelope Lo	ada				0.00	Fn Bidtb	0.0		0.0
Skylle Cond		0	0	0	0:	0	0.	Skylte Cr	and and			0	0.00	FR FRC	0.0	÷	0.0
Boof Cond		ő	-12 525	-12 626	0	0	0	Boof Con	d.			-128 704	1.55				î
Glass Solar		3,812,379	0	3.812.379	59	4,351,275	85	Glass Sol	ar	č	5	0	0.00	A	IRFLOWS		
Glass/Door Cor	nd	-5,717	D	-5,717	D;	-666,664	-13 ;	Glass/Doc	or Cond	-2,383,476	5	-2,383,476	28.76	· · · · · · · · · · · · · · · · · · ·	Cooling	H	nation
Wali Cond		183,147	312,779	495,926	8;	98,917	2 :	Wall Cond	1	-381,292	2	-1,018,413	12.29	Diffusor	87 788		4 252
Partition/Door		-38,910		-38,910	-1	-95,238	-2 :	Partition/E	Door	-209,586	5	-209,586	2.53	Tanalast	97 700		4,303
Floor		0		0	0	0	0	Floor	-	-19,001	1	-19,001	0.23	Main Ean	87 788		4,353
Adjacent Floor		0	0	150.010	0	224 220		Adjacent	FIDOF	4 400 570		4 400 575		main r an	01,100		
Innitration		159,240	300 453	159,240	2	-334,636	-1	Sub Total		-1,196,576	2	-1,198,576	14,40	Sec Fan	07.207		
SUD TOTAT ==>		4,110,139	300,155	4,410,295	09	3,303,402	00	Sup rola	100	-4,151,551	( ) ( )	-4,501,100	05.02	Nom vent	97,307		53,313
Internal Loads								Internal Loa	da					And vent	17 924		17 824
Liebte		100 000	507 4F4	704 344		155 053	. 1	Linhia					0.00	MinSton/Rh	17,024		0
Dennie		1 939 581	027,451	1 030 581	30	1 063 340	21	Deonle			5	0	0.00	Return	202 005	21	15 490
Misc		599.069	0	599.069	9	599.069	12	Misc		178,595	5	178,595	-2.16	Exhaust	115.211	10	01,137
Sub Total ==>		2 695 513	627 451	3 322 964	52	1 819 272	35	Sub Total		178 595	5	178 595	-2 15	Rm Exh	0	)	0
Con rear		2,000,010	021,401	0,022,004		1,010,212	~	out retai	807E	110,000		110,050		Auxiliary	664,700	1	0
Celling Load		233,770	-233,770	0	0	166,994	3	Celling Load	1	-252,030	3	0	0.00	Leakage Dwn		)	0
Ventilation Load	1	-1,050,408	0	-1,050,408	-16	-207,895	-4 ;	Ventilation L	Load	-1,422,826	5	-1,422,827	17.17	Leakage Ups	0	)	0
Adj Air Trans He	eat	0		D	0:	0	0:	Adj Alr Tran	s Heat	0	2	0	0	A SAME A PRINT PARTY.			502
Dehumid. Ov Siz	zing			0	0			Ow/Undr Siz	Ing	-244,102	2	-244,102	2.95				
Ov/Undr Sizing		-1,166		-1,166	0;	-1,166	0 ;	Exhaust Hea	at			241,103	-2.91	ENGI	NEERING C	KS	
Exhaust Heat			-254,791	-254,791	-4			OA Preneat	DIIIT.			-2,082,351	25.13	1000	Cooling	Her	ating
Sup. Fan Heat				1			1	Additional F	Diff.			0	0.00	% OA	110.9		72.9
Duct Heat Dian			-80 333	ò	0:			Automatin	of loar				0.00	cfm/ft°	0.25		0.32
Underfir Sup Ht	Pkup		100000000	0	0:		1	Underfir Su	D Ht Pkup			0	0.00	cfm/ton	191.22		1000000
Supply Air Leak	age		0	0	0		1	Supply Air L	eakage			0	0.00	ft%ton	775.59		
	-						2020200000						(1992)	Btu/hr-ft*	15.47		7.30
Grand Total ==>	5	5,987,849	358,711	6,426,894	100.00 '	5,130,658	100.00 '	Grand Total	=>	-5,932,293	3	-8,287,336	100.00	No. People	4,597		101504678 2
			COOLING	COIL SEL	ECTION				8	AREA	s		HE	ATING COIL	SELECTIC	N	
	Tota	MBh	Sens Cap. MBh	Coll Airflow cfm	Enter DE	B/WB/HR F gr/lb	Leave	F grib	0	Gross Total	Gla	88 (%)		Capacity MBh	Coll Airflow	Ent "F	Lvg
Main Cig	151.8	18219	229.4	75 262	74.1 60	6 612	54 0 52	0 57.0	Floor	356 076		22222	Main Hto	-516.7	114 353	65.8	70.0
Aux Clg	383.8	4,605.0	4,605.0	664,700	72.0 59.	9 61.2	65.5 57	5 61.2	Part	26,736			Aux Htg	-4,375.6	0	0.0	0.0
Opt Vent	307.3	3.687.4	1,911,3	97.387	71.5 65.	1 86.8	53.1 52	4 60.0	Int Door	0			Preheat	0.0	0	0.0	0.0
	10000		1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.		X.3-0.92	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	500 B 100 B	And Addit	ExFIr	1,508			State Street	2004	12	21100	
Total	842.9	10,114.3							Roof	69,901	0	0	Humidif	0.0	0	0.0	0.0
									Wall	93,535	45,032	48	Opt Vent	-2,082.4	97,387	50.0	70.0
									Ext Door	0	0	0	Total	-6,974.6	0.000	25.55	- unstag

#### System Checksums By PENN STATE UNIVERSITY

Hybrid GSHP Plant w/ All ACB (Cooling 842.9 Tons, Heating 8,940.5 MBH)

Main System																	4-pipe li	nduc	tion
-	COOLING COIL PEAK Peaked at Time: MolHr: 7 / Outside Air: OADB/WB/HR: 86 /					C	LG SPACE	PEAK				HEATING	G COI	PEAK		TEM	PERATURE	s	
P	eaked at Outsi	t Time: ide Alr:	OADB/WB	0/Hr: 7/15 /HR: 86/71/9	95	1	Mo/Hr: OADB:	7 / 15 86				Mo/H	r: Heat 3: 5	ing Design		SADB	Cooling 55.0	He	ating 124.6
	s	Space ens. + Lat.	Plenum Sens. + Lat	Net Total	Percent Of Total		Space Sensible	Percent Of Tota	t			Space Pea Space Sen	k 8	Coll Peak Tot Sens	Percent Of Total	Return Ret/OA	75.1		64.7 64.7
Envelope Loads	8	Btulh	Btu/h	Btu/h	(%)	1	Btuh	(%)	Er	velope Lo	ada	Btu/	h	Btu/h	(%)	Fn MtrTD Fn BidTD	0.0		0.0
Skylle Solar Skylle Cond		0	0	0	0		0	-		Skylte So Skylte Co	ar		0	0	0.00	Fn Frict	0.0	i,	0.0
Roof Cond Glass Solar		2,791,252	69,105 D	69,105 2,791,252	1	1	2,182,626	51		Roof Cond Glass Sola	l Ar		0	-126,461	1.95	A	IRFLOWS		
Glass/Door Co Wall Cond	ond	426,838 263,761	415,692	426,838 679,454	6	5	481,181 235,258	11	5	Glass/Doc Wall Cond	r Cond	-2,383,47	5	-2,383,476	36.77 15.54	Diffuser	Cooling 49.577	H	eating
Floor Adjacent Floor		20,278	D	20,278	0		25,612	-		Floor Adlacent F	loor	-209,58 -19,00	1	-209,586 -19,001	0.29	Terminal Main Fan	49,577 49,577		49,577
Infiltration Sub Total ==>		602,298 4,104,426	484,797	602,298 4,589,223	9	9	226,794 3,151,471	73		Infiltration Sub Total	==>	-1,198,57	6	-1,198,576	18.49 76.27	Sec Fan Nom Vent	55,071	)   .	0 40,997
Internal Loads									In	ternal Loa	ts .					AHU Vent Infli	55,071 17,824		40,997
Lights People Mise		139,357 1,762,929	557,426 0	696,783 1,762,929	10 26	5	133,951 913,631	21		Lights People		178 50	0	178 505	0.00	MinStop/Rh Return	122,472 72,895	1	08,398 58,821
Sub Total ==>		2,458,304	557,426	3,015,730	45	5	1,601,021	37		Sub Total	==>	178,59	5	178,595	-2.75	Rm Exh Auxilliary	389,250	3	0
Ceiling Load Ventilation Load	d	349,862 -860,276	-349,862 0	-860,276	-13	3	353,206 -944,716	-22		elling Load entilation L	oad	-371,50 -700,14	5	-700,144	0.00	Leakage Dwn Leakage Ups	0	1	0
Adj Alr Trans H Dehumid. Ov Si	ieat Izing	0		0	0		0	c	A	dj Air Tran: v/Undr Sizi	s Heat ng		3	0	0.00	2.2.0 <del>-</del>			_
Ov/Undr Sizing Exhaust Heat		157,547	-231,848	157,547	-3	3	157,547	4	DO	A Preheat	t Diff.			206,705	-3.19	ENGI	Cooling	KS	ating
Ret Fan Heat Duct Heat Pkup	,		-52,918	1	0				A	dditional R	eheat			o	0.00	% OA cfm/ift°	111.1 0.14		82.7 0.14
Underfir Sup Ht Supply Air Leal	t Pkup kage		D	0	0				SI	nderfir Sup upply Air L	eakage			0	0.00	cfm/ton ft%ton	155.50 1,116.87		
Grand Total ==	>	6,209,863	407,597	6,670,377	100.00	,	4,318,528	100.00	G	rand Total	=>	-5,084,98	1	-6,482,854	100.00	Btu/hr-ft* No. People	4,597	-	12.33
2)	Tota	al Canacity		COIL SEL	ECTION	DBM	RIHR	len	/e DR	BWB/HR			S	999	HE	EATING COIL	SELECTIC	En	t Ive
271.000	ton	MBh	MBh	cfm	*F	*F	gr/lb	*F	'F	gr/lb		sides rotai	ft	· (%)		MBh	cfm	*F	· ·F
Main Cig Aux Cig	127.4 677.6	1,528.4 8,131.1	1,125.6 6,920.9	49,577 389,250	75.1	61.0 59.9	61.2 61.2	54.0 55.2	49.8 52.4	48.9 56.9	Floor Part	356,076 26,736			Main Htg Aux Htg	-3,167.6	49,577 389,250	64.7 68.0	124.6 73.3
Opt Vent	191.5	2,297.4	1,265.9	55,071	74.6	66.2	87.5	53.1	52.3	60.0	Int Door ExFlr	1,508			Preheat	0.0	0	0.0	0.0
rotar	990.4	11,956.9									Wall Ext Door	93,535	45,032 0	48	Opt Vent Total	-1,223.6 -6,610.3	55,071	49.2	70.0

#### System Checksums

By PENN STATE UNIVERSITY

Central Plant w/ All DOAS FCU (Cooling 996.4 Tons, Heating 6,610.3 MBH)

Main Systen	n														4-pipe Ir	nduc	tion
~	COOLING COIL PEAK Peaked at Time: Mo/Hr: 7 / 15 Outside Air: OADBIWB/HR: 66 / 71 / /					CLG SPACE	PEAK	_		HEATING	G COIL	PEAK		TEM	PERATURE	S	
F	Peaked a Outs	at Time: side Air:	Mo OADB/WB/	/Hr: 7/15 HR: 86/71/9	15	Mo/Hr: OADB:	7 / 15 86	•		Mo/H OADE	ir: Heatir B: 5	ng Design		SADB Ra Plenum	Cooling 55.0 75.1	Hea 1	ating 24.6 64.7
	5	Space Sens. + Lat.	Plenum Sens. + Lat	Net Total	Percent Of Total	Space Sensible	Percent Of Total			Space Pea Space Ser	ak IS	Coll Peak Tot Sens	Percent Of Total	Return Ret/OA	75.1 75.3		64.7 64.7
2 2 2 3		Btu/h	Btu/h	Btu/h	(%)	Btu/h	(%)	2 2 7 3	195	Btu	h	Btu/h	(%)	Fn MtrTD	0.0		0.0
Envelope Load	38							Envelope Lo	ada		0		0.00	Fil Bidity	0.0		0.0
Skylite Cond		ŏ	0			0		Skylte Cr	nai		0	0	0.00	FILFINGE	0.0		0.0
Roof Cond		ő	69,105	69,105	1	0	0	Roof Con	d		õ	-126.461	1.95				
Glass Solar		2,791,252	0	2,791,252	42	2,182,626	51	Glass Sol	ar		ō	0	0.00	A	RFLOWS		
Glass/Door C	ond	426,838	0	426,838	6;	481,181	11	Glass/Do	or Cond	-2,383,47	6	-2,383,476	36.77	200	Cooling	He	nation
Wall Cond		263,761	415,692	679,454	10 !	235,258	5	Wall Cont	1	-381,29	2	-1,007,311	15.54	Diffusor	49 577		0 577
Partition/Door	r i	20,278		20,278	0	25,612	1	Partition/E	0001	-209,58	16	-209,586	3.23	Tampleat	40 577		10,011
FIDOF	2	0		0	0	0	0	FIOOF	Flate	-19,00	1	-19,001	0.29	Main Fan	49.577	2	9.577
Adjacent Floo	ar -	602 208	U	600.000		225 704	0	Adjacent	FIDOF	1 100 57	0	1 109 575	19.40	Roo Ean			0
Full Tatal and		4 104 425	484 707	4 580 223	60	3 151 471	73	Sub Total	==>	-4 191 93	0	-1,190,570	76.27	Sec Fall	55 071		0.007
300 Total	*	4,104,420	404,737	4,005,220	00	3,131,471	13	000 1000		4,121,22			10.21	AHII Vent	55 071	1	0,997
Internal Loads					1		2	Internal Loa	dis					Infil	17 824		7 824
Lights		120 257	557 495	606 793	10	133.051	2	Linhie			0	0	0.00	MinSton/Rh	0		0
People		1,762,929	007,420	1,762,929	26	913.631	21	People			ō	ő	0.00	Return	122.472	10	8,398
MISC		556.018	ō	556.018	8:	553,438	13	MISC		178.59	15	178.595	-2.75	Exhaust	72,895	5	8,821
Sub Total ==:	>	2 458 304	557 426	3.015.730	45	1.601.021	37	Sub Total	==>	178.59	5	178 595	-2.75	Rm Exh	0	1	0
														Auxiliary	389,250	38	9,250
Celling Load	100	349,862	-349,862	D	0	353,206	8	Celling Load	1	-371,50	15	0	0.00	Leakage Dwn	0		0
Ventilation Los	ad	-860,276	0	-860,276	-13	-944,716	-22	Ventilation	Load	-700,14	15	-700,144	10.80	Leakage Ups	0	(	0
Adj Air Trans H	Heat	0		0	0:	0	0	Adj Alr Tran	s Heat		0	0	0				
Dehumid. Ov s	Sizing			0	0:			Ov/Undr Siz	ing		3	000 700	0.00	2407924 Q	C	20.743	
Ov/Undr Sizing	9	157,547	024 040	157,547	2	157,547	4	Exhaust He	30			1 200,700	-3.19	ENGIN	IEERING C	KS	
Sun Fon Heat			-231,040	-231,040	6			RA Preheat	Diff.			-1,223,005	0.00	200.000	Cooling	Hea	ating
Ret Fan Heat			1	1	0		1	Additional F	teheat			o	0.00	% OA	111.1		82.7
Duct Heat Pku	P		-52,918	Ó	0:									cfm/ft <sup>a</sup>	0.14		0.14
Underfir Sup H	it Pkup			D	0			Underfir Su	p Ht Pkup			0	0.00	cm/ton	155.50		
Supply Air Lea	akage		0	0	0		3	Supply Air I	eakage			0	0.00	ft%ton	1,116.87		2222
Grand Total ==	-	6,209,863	407,597	6,670,377	100.00	4,318,528	100.00	Grand Total	=>	-5,084,98	1	-6,482,854	100.00	Btu/hr-ft <sup>a</sup> No. People	10.74 4,597	-1	2.33
	1050		COOLING	COIL SEL	ECTION		200.300		<u> </u>	AREA	s		H	ATING COIL	SELECTIO	N	
	Tot	al Capacity MBh	Sens Cap. MBh	Coll Airflow	Enter De	BAWB/HR 'F gr/lb	*F	F gr/lb	0	Gross Total	Gla ft <sup>z</sup>	88 (%)		Capacity MBh	Coll Airflow	Ent *F	Lvg
Main Cig	127.4	1,528.4	1,125.6	49,577	75.1 61.	.0 61.2	54.0 49	9.8 48.9	Floor	356,076			Main Htg	-3,167.6	49,577	64.7	124.6
Aux Cig	677.6	8,131.1	6,920.9	389,250	72.0 59	.9 61.2	55.2 5	2.4 56.9	Part	26,736			Aux Htg	-2,219.2	389,250	68.0	73.3
Opt Vent	191.5	2,297.4	1,265.9	55,071	74.6 66.	2 87.5	53.1 5	2.3 60.0	Int Door	0			Preheat	0.0	0	0.0	0.0
Summer .									ExFIr	1,508		0205	an march		1.2		
Total	996.4	11,956.9							Roof	69,901	0	0	Humidif	0.0	0	0.0	0.0
									Wall	93,535	45,032	48	opt vent	-1,223.6	55,071	49.2	70.0
									Ext Door	0	0	0	Total	-6,610.3			

### System Checksums

By PENN STATE UNIVERSITY

Hybrid GSHP w/ All DOAS FCU (Cooling 996.4 Tons, Heating 6,610.3 MBH)

Core							-,									A	ctive Chille	d Bea	ams
	c	OOLING	OIL PEAK			с	LG SPACE	PEAK	5			HEATIN	GCC	IL PEAK		TEM	PERATURE	s	
	Peaked Out	at Time: side Air:	M OADB/WE	o/Hr: 9 / 11 VHR: 70 / 59 / 1	52	1	Mo/Hr: OADB:	11/12 54				Mo/F OAD	Hr: He B: 5	ating Design		SADB Ra Planum	Cooling 55.0 74.2	Hea	68.0
		Space Sens. + Lat.	Plenum Sens. + Lat	Net Total	Percent Of Tota		Space Sensible	Percent Of Total				Space Per Space Ser	ak ns	Coll Peak Tot Sens	Percent Of Total	Return Ret/OA	74.2		66.8
Envelope Loa	artis	Dium	Bium	Blum	(%	9	Dium	(%)	En	velope L	ada	DUU	l/n	Dium	(%)	Fn BidTD	0.0		0.0
Skylite Solar	r	0	0	0	0		0	0		Skyllte Sc	lar		0	0	0.00	En Frict	0.0		0.0
Skyllte Cond	1	0	0	0	0	1	0	0	1 2	Skyllte Co	nd		0	0	0.00		2237		1.5
Roof Cond		0	-10,635	-10,635		3	0	0	F	Roof Con	d		0	-87,567	2.82	774	Station Stores		
Glass Solar		1,692,315	0	1,692,315	47	7	2,066,419	65	6	Glass Sol	ar		0	0	0.00	A	IRFLOWS		
Glass/Door 0	Cond	-46,233	D	-46,233	-1	11	-210,801	-7		Glass/Do	or Cond	-739,25	51	-739,251	23.78		Cooling	a He	aatino
Wall Cond		39,015	50,860	89,876		2	35,506	1	10	Wall Cont	1	-101,57	76	-225,284	7.25	Diffusor	54 146	-	P 01
Partition/Doo	or	-13,359		-13,359	0		-32,630	-1		Partition/E	Door	-71,6	18	-71,618	2.30	Childoon			0,013
Floor		0		0	1		0	0	्राष्ट्	Floor		-5,14	41	-5,141	0.17	Terminal	54,140	2 2	/8,013
Adjacent Flo	or	0	0	0		2	0	0	1 2	Adjacent	Floor		0	0	0	Main Fan			0,010
Infiltration		-38,246	10000000	-38,246	-1		-206,388	-7	1.1	nfiltration	100 m	-745,94	44	-745,944	24.00	Sec Fan			
Sub Total ==	=>	1,633,491	40,225	1,673,717	46		1,650,106	52	-	SUD IOtal	==>	-1,663,54	30	-1,8/4,804	60.31	Nom Vent	46,983	3 2	9,155
						3			1		123					AHU Vent	46,983	3 2	9,155
Internal Loads	8					1			inte	ernal Loa	CI8					Infil	11,093	5 1	1,093
Lights		93,995	375,981	469,977	13	3	95,225	3	1	lights			D	0	0.00	MinStop/Rh	0	1	0
People		1,955,224	0	1,965,224	54	4	911,679	29	F	People			D	0	0.00	Return	112,222	2 9	8,261
Misc		468,932	0	468,932	13	3	472,256	15	1.1	Misc		178,59	95	178,595	-5.74	Exhaust	58,076	5 4	0,248
Sub Total ==	=>	2,528,152	375,981	2,904,133	80		1,479,160	47	1 1	Sub Total	==>	178,59	95	178,595	-5.74	Rm Exh	C	1	0
						1			1.13							Auxillary	336,953	5	0
Celling Load		147,685	-147,685	0		3	135,183	4	Cel	ling Load	1	-83,44	48	0.000	0.00	Leakage Dwn	C	1	0
Ventilation Lo	bad	-821,140	0	-821,140	-23	3	-100,296	-3	Ver	ntilation I	oad	-497,93	26	-497,925	16.02	Leakage Ups	0	2	0
Adj Alr Trans	Heat	0		0	0	1	0	0	Ad	Air Tran	s Heat		0	0	0	100			
Dehumid. Ov	Sizing			0					OW	Undr Siz	Ing		0	0	0.00	-			
Ov/Undr Sizin	ng	-403		-403	0		-403	0	Ext	haust He	st			52,340	-1.68	ENGI	NEERING C	KS	
Exhaust Heat	1		-133,707	-133,707	-4	4			OA	Preheat	Diff.			-966,923	31.10				
Sup. Fan Heat	it .			0		0			RA	Preheat	DIT.			0	0.00		Cooling	неа	ung
Ret Fan Heat	t.		1	1	0				Ade	ditional F	teheat			0	0.00	% OA	86.8		50.3
Duct Heat Pku	up		0	0					1		949 Barri					сптуп-	0.25	£ 1	0.27
Underfir Sup I	Ht Pkup			0	0	2			Un	derfir Su	p Ht Pkup			0	0.00	cfm/ton	211.97		
Supply Air Le	akage		0	0		2			Su	ppiy Air i	.eakage			0	0.00	ft=/ton	845.92		
Grand Total =		3,487,785	134,816	3,622,602	100.00	,	3,163,751	100.00	Gra	and Total	⇒	-2,066,30	08	-3,108,716	100.00	Btu/hr-ft <sup>a</sup> No. People	14.19 3,901	1	4.82
			COOLIN	G COIL SEL	ECTION							AREA	AS	Class	н	EATING COIL	SELECTIC	N	
	ton	MBh	MBh	côn Allilów cîm	*F	"F	gr/ib	*F	*F	gr/lb		sides rotai		ft <sup>z</sup> (%)	200400040	MBh	côn Annow cîm	"F	LV
Main Cig	107.2	1,285.4	332.5	43,383	74.2	60.7	61.2	55.0 4	9.9	47.6	Floor	216,088			Main Htg	-75.4	58,013	66.8	68.
Aux Cig	194.7	2,336.2	2,336.2	336,953	72.0	59.9	61.2	65.5 5	7.5	61.2	Part	9,136			Aux Htg	-1,726.7	0	0.0	0.
Opt Vent	148.2	1,778.9	922.1	46,983	71.5	65.1	86.8	53.1 5	2.4	60.0	Int Door	0			Preheat	0.0	0	0.0	0.
1000										1000000	ExFIr	408		- 1894	12-22.2				
Total	450.1	5,401.5									Roof	46,777		0 0	Humidif	0.0	0	0.0	Ο.
											Wall	28,531	13,70	03 48	Opt Vent	-966.9	46,983	50.7	70.
											Ext Door	n		0 0	Toral	-2769.0			

System Checksums By PENN STATE UNIVERSITY

Core of Central Plant w/ ACB/DOAS FCU (Cooling 450.1 Tons, Heating 2,769.0 MBH)

Perimeter							2.27.10.21212		2299-2119-2120					4-pipe l	nduc	tion
	C	COOLING COIL PEAK ied at Time: Mo/Hr: 7 / 15 Outside Air: OADB/WB/HR: 86 / 71 /			CLG SP/	ACE PEAK			HEATING	G COIL PEAK		TEM	PERATURE	S		
F	Peaked Out	at Time: Iside Air:		o/Hr: 7 / 15 VHR: 86 / 71 / 1	95	Mo OA	/Hr: 7 / 15 DB: 86			Mo/H OADE	ir: Heating Design 3: 5		SADB Ro Disputto	Cooling 55.0 75.4	Hea 1	ating 124.4
		Space Sens. + Lat.	Plenum Sens. + Lat	Net	Percent Of Total	Spa Sensi	ble Of Tota	t		Space Pea Space Sen	ak Coll Peal Is Tot Sens	k Percent B Of Total	Return Ret/OA	75.6		63.5
Envelope Load	da	Bturn	Bturn	Bturn	(%)	BI	un (%	Envelope L	oads	Etu	n stur	n (%)	Fn BidTD	0.0		0.0
Skylite Solar Skylite Cond		0	0	0	0		0 0	Skylite S Skylite C	olar ond			0.00	Fn Frict	0.0		0.0
Roof Cond Glass Solar		0 1,948,689	21,382 0	21,382 1,948,689	1 59	1,338,6	0 0	Roof Cor Glass So	lar		0 -40,998 0 0	8 1.01 0 0.00	A	IRFLOWS		
Glass/Door C Wall Cond Partition/Door	Cond	277,748 196,300 14,716	341,095	277,748 537,395 14,715	8 16 0	333,4 167,8 16,7	185 16 125 ( 144 1	5 Glass/Do B Wall Con I Partition/	or Cond d Door	-1,644,22 -279,71 -137,95	4 -1,644,224 6 -776,054 8 -137,968	4 40.33 4 19.03 8 3.38	Diffuser	Cooling 34,492	g He 2 7	eating 34,492
Floor Adjacent Floor	or	0	0	0	0		0 0	Floor Adlacent	Floor	-13,86	0 -13,860	0 0.34	Terminal Main Fan	34,492 34,492	2 3	34,492 34,492
Infiltration Sub Total ==	>	208,661 2,646,115	362,478	208,661 3,008,592	6 92	83, 1 1,939,9	95 4 08 92	Infiltration	n i/ ==>	-452,63 -2,528,40	2 -452,630	2 11.10 5 75.19	Sec Fan Nom Vent	25,687	1	0 29,441
Internal Loads								Internal Los	ada				AHU Vent	25,687	2	29,441 6,731
Lights People		54,809 278,117	219,236 0	274,045 278,117	8	52,1 161,2	56 2 46 8	2 Lights People			0 0	0.00	MinStop/Rh Return	66,911 32,410		0 70,664
Sub Total ==	*	450,014	219,236	669,250	20	330,7	76 16	5 Sub Tota	/==>		0 0	0.00	Rm Exh	180.280	1 11	0
Celling Load Ventilation Lo	ad	149,575	-149,575 D	0 -382,082	-12	149,5	27 7 142 -20	Celling Loa Ventilation	d Load	-198,98 -502,79	2 ( 7 -502,797	0.00	Leakage Dwn Leakage Ups	00,205	j	0
Adj Air Trans i Dehumid. Ov \$	Heat Sizing	0		0	0		0 0	Ow/Undr St	ns Heat zing		1	0 0			2	- 48
Ov/Undr Sizing Exhaust Heat	9	107,815	-126,767	107,815	340	107,8	15 5	5 Exhaust He OA Preheat	at Diff.		173,200	2 -4.25 7 16.72	ENGI		KS	ating
Ret. Fan Heat Duct Heat Pku	ID		-36,816	0	0			Additional	Reheat			0.00	% OA cfm/ft=	74.5		85.4 0.25
Underfir Sup I Supply Air Lea	Ht Pkup akage		O	0	0			Underfir Su Supply Air	ip Ht Pkup Leakage		0	0.00	cfm/ton ft=/ton	188.00 763.02	13	
Grand Total ==	-	2,971,437	268,556	3,276,809	100.00	2,105,7	84 100.00	Grand Tota	l=>	-3,230,17	8 -4,077,237	7 100.00	Btuhr-ft <sup>a</sup> No. People	15.73	-2	0.88
	To	tel Canaalhy	COOLIN		ECTION		(			AREA	S	H	EATING COIL	SELECTIC	N	
	ton	MBh	MBh	cfm	°F	*F gr/lb	*F	"F gr/lb		31065 10(21	ft° (%)		MBh	cfm	*F	F
Main Cig Aux Cig	81.1 304.5	973.4 3,653.3	836.2 3,323.6	34,492 180,289	75.6 6 72.0 5	1.2 61.2 9.9 61.2	54.0 55.1	51.1 53.6 52.6 57.9	Floor Part	139,988 17,600		Main Htg Aux Htg	-2,240.9	34,492 180,289	63.5 68.0	124.4 73.8
Opt Vent	102.4	1,228.2	676.8	29,441	74.6 6	6.2 87.5	53.1	52.3 60.0	Int Door ExFir	1,100		Preheat	0.0	0	0.0	0.0
Total	487.9	5,854.9							Roof Wall	23,124 65,004	0 0 31,330 48	Humidif Opt Vent	0.0 -681.9 -4 034 7	0 29,441	0.0 48.3	0.0 70.0

#### System Checksums By PENN STATE UNIVERSITY

Perimeter of Central Plant w/ ACB/DOAS FCU (Cooling 487.9 Tons, Heating 4034.7

MB)

Perimeter													4-pipe li	nduc	tion
92 	COOLING COIL PEAK eaked at Time: Morh Ourfaide Air OADBIWB/HI				CLG SPACE	PEAK	_		HEATING	COIL PEAK		TEM	PERATURE	s	
Pea	aked at Time: Outside Air:	OADB/WB	o/Hr: 7 / 15 VHR: 86 / 71 /	95	Mo/Hr: OADB:	7/15 86	•		Mo/Hr: OADB:	Heating Design 5		SADB	Cooling 55.0	Hea 1	ating 24.4
	Sens. + Lat.	Plenum Sens. + Lat	Net Total Stub	Percent Of Total	Space Sensible Sturb	Percent Of Total			Space Peak Space Sens	Coll Peak Tot Sens	Percent Of Total	Return Ret/OA	75.6 75.6		63.5 63.5 63.5
Envelope Loads Skylite Solar	0	0	0	0	0	(%)	Envelope Li Skylite So	blar	0	0	0.00	Fn BidTD Fn Frict	0.0		0.0
Roof Cond Glass Solar	0 1,948,689	21,382 0	21,382 1,948,689	1 59	1,338,658	0 64	Roof Con Glass So	d lar	0	~40,998 0	1.01	A	IRFLOWS		
Glass/Door Con Wall Cond Partition/Door Floor	d 277,748 196,300 14,716 0	0 341,095	277,748 537,396 14,716 0	8 16 0	333,485 167,825 16,744 0	16 8 1 0	Glass/Do Wall Con Partition/I Floor	or Cond d Door	-1,644,224 -279,716 -137,968 -13,860	-1,644,224 -776,054 -137,968 -13,860	40.33 19.03 3.38 0.34	Diffuser Terminal Main Fan	Cooling 34,492 34,492 34,492	He 3	ating 4,492 4,492
Infiltration Sub Total ==>	208,661 2,646,115	362,478	208,661 3,008,592	6 92	83,195 1,939,908	4 92	Inflitration Sub Tota	    ==>	-452,632 -2,528,400	-452,632 -3,065,736	11.10 75.19	Sec Fan Nom Vent AHU Vent	25,687 25,687	2	0 19,441
Internal Loads				1			Internal Loa	ds				Infil	6,731		6,731
Lights People Misc	54,809 278,117 117,088	219,235	274,045 278,117 117,088	8	52,156 161,246 117,374	2 8 6	Lights People Misc		0	0	0.00	MinStop/Rh Return Exhaust	66,911 32,419	7	0,664
Sub Total ==>	450,014	219,236	669,250	20	330,776	16	Sub Tota	(==>	o	0	0.00	Rm Exh Auxiliary	180,289	18	0
Celling Load Ventilation Load	149,575 -382,082	-149,575 D	-382,082	-12	149,527	-20	Celling Loa Ventilation	d Load Heat	-198,982 -502,797	-502,797	0.00	Leakage Dwn Leakage Ups	0	)	0
Dehumid. Ov Sizi Ov/Undr Sizing Exhaust Heat Sup. Fan Heat Ret. Fan Heat	ing 107,815	-126,767 D	0 107,815 -126,767 0	0 0 3 4 0 0	107,815	5	Ow/Undr Stz Exhaust He OA Preheat RA Preheat Additional	at Diff. Diff. Reheat	1	1 173,202 -681,907 0	0.00 -4.25 16.72 0.00 0.00	ENGI	NEERING C Cooling 74.5	KS Hea	ating 85.4
Duct Heat Pkup Underfir Sup Ht F Supply Air Leaks	9kup ge	-36,816 D	0000	0			Underfir Su Supply Air I	p Ht Pkup Leakage		0	0.00	cfm/ft= cfm/ton ft=/ton	0.25 188.00 763.02		0.25
Grand Total ==>	2,971,437	268,555	3,276,809	100.00	2,105,784	100.00	Grand Tota	=>	-3,230,178	-4,077,237	100.00	No. People	15.73	-2	0.88
	Total Capacity ton MBh	COOLIN Sens Cap. MBh	G COIL SEL Coll Almow	ECTION Enter D "F	B/WB/HR *F gr/lb	Leave *F	• DB/WB/HR *F gr/lb		AREAS Gross Total	Glass ft <sup>z</sup> (%)	HE	EATING COIL Capacity MBh	SELECTIC Coll Airflow	Ent F	Lvg
Main Cig Aux Cig	81.1 973.4 304.5 3,653.3	836.2 3,323.6	34,492 180,289	75.6 61 72.0 59	1.2 61.2 3.9 61.2	54.0 5 55.1 5	1.1 53.6 2.6 57.9	Floor Part	139,988 17,600		Main Htg Aux Htg	-2,240.9 -1,111.9	34,492 180,289	63.5 68.0	124.4 73.8
Opt Vent	102.4 1,228.2	676.8	29,441	74.6 66	5.2 87.5	53.1 5	2.3 60.0	Int Door ExFir	1,100		Preheat	0.0	0	0.0	0.0
rotar	101.9 5,854.9							Wall Ext Door	23,124 65,004 3	1,330 48 0 0	Opt Vent Total	-681.9 -4,034.7	29,441	48.3	70.0

### System Checksums

By PENN STATE UNIVERSITY

Perimeter of Hybrid GSHP w/ ACB/DOAS FCU (Cooling 487.9 Tons, Heating 4034.7

MB)

Core		COOLING COIL PEAK										A	tive Chilled	Beams	5	
	co	COOLING COIL PEAK ked at Time: Mo/Hr: 9/11 Outside Air: OADB///BB//B: 70/59/62				CLG SPACE	E PEAK			HEATING	COIL PEAK		TEM	PERATURE	s	_
Pe	aked at Outsi	Time: de Air:	OADB/WB/	/Hr: 9/11 HR: 70/59/(	52	Mo/Hr: OADB:	11/12 54			Mo/Hr: OADB:	Heating Design 5		SADB Ba Plenum	Cooling 55.0 74.2	Heating 68.0	
	Se	Space ens. + Lat.	Plenum Sens. + Lat	Net Total	Percent Of Total	Space Sensible	Percent Of Total			Space Peak Space Sens	Coll Peak Tot Sens	Percent Of Total	Return Ret/OA	74.2 74.2	66.8 66.8	8
Emplone Londe		Dun	Dium	Dium	(%)	Dium	(%)	Envolution	ada	Buurn	Dium	(%)	En BidTD	0.0	0.0	ń
Skylite Solar		0	0	0	0	0	0	Skylte Sc	slar	0	0	0.00	En Erict	0.0	0.0	6
Skylite Cond		0	ō	ō	0	O O	0	Skylte Co	bnd	0	ō	0.00	THITING			<u> </u>
Roof Cond		ō	-10.635	-10.635	0	ō	0 :	Roof Con	d	0	-87.567	2.82	1 853	and the second second		
Glass Solar		1,692,315	0	1,692,315	47	2,066,419	65	Glass Sol	ar	0	0	0.00	A	RFLOWS		- 1
Glass/Door Cor	nd	-46,233	0	-46,233	-1	-210,801	-7	Glass/Dor	or Cond	-739,251	-739,251	23.78		Cooling	Heatin	-
Wall Cond		39,015	50,860	89,876	2:	35,506	1;	Wall Cont	1	-101,576	-225,284	7.25	Difference	54 145	50.04	19
Partition/Door		-13,359		-13,359	0:	-32,630	-1	Partition/D	Door	-71,618	-71,618	2.30	Dilluser	54,140	30,01	10
Floor		0		0	0.	0	0	Floor		-5,141	-5,141	0.17	Terminal	54,146	58,01	13
Adjacent Floor		0	0	0	0	0	0	Adjacent	Floor	0	0	0	Main Fan	34,140	30,01	10
Infiltration		-38,246	2000000	-38,246	-1;	-206,388	-7	Infiltration	la la	-745,944	-745,944	24.00	Sec Fan	0		0
Sub Total ==>		1,633,491	40,225	1,673,717	46	1,650,106	52	SUD Total	==>	-1,663,530	-1,874,804	60.31	Nom Vent AHU Vent	46,983 46,983	29,15 29,15	55 55
Internal Loads								internal Loa	08				Infli	11,093	11,09	33
Lights		93,995	375,981	469,977	13	95,225	3	Lights		0	0	0.00	MinStop/Rh	0	2,222,022	0
People		1,965,224	0	1,965,224	54	911,679	29	People		0	0	0.00	Return	112,222	98,26	51
MISC		468,932	D	468,932	13	472,256	15	Misc		178,595	178,595	-5.74	Exhaust	58,076	40,24	48
Sub Total ==>		2,528,152	375,981	2,904,133	80	1,479,160	47	Sub Total	==>	178,595	178,595	-5.74	Rm Exh	0		0
					2			auters (all)			07.50.03	1226	Auxillary	336,953		0
Celling Load	1	147,685	-147,685	0	0:	135,183	4 ;	Celling Load	1	-83,448	0	0.00	Leakage Dwn	0		0
ventilation Load	1	-821,140	0	-821,140	-23	-100,296	-3	ventilation	Dag	-497,926	-497,925	16.02	Leakage Ups	0		0
Adj Air Trans He	at	0		0	0.	0	0	Adj Air Tran	s Heat	0	0	0				
Dehumid. Ov Sla	zing	8555		0	0	1 10000	1.1	Ow/Undr Siz	Ing	0	0	0.00	1 10-10-10		88	-
Ov/Undr Sizing		-403		-403	0	-403	0	Exhaust He	BI.		52,340	-1.68	ENGI	EERING CI	KS	
Exhaust Heat			-133,707	-133,707	-4		7	OA Preneat	DIT.		-966,923	31.10		Cooling	Heating	
Sup. Fan Heat								RA Preneat	DITT.		0	0.00	% 04	85.8	50.3	
Ret Fall Reat								Auditional P	teneat		U	0.00	cfm/ff=	0.25	0.27	, 1
Underfit Sun Ht	Diam			0			1	Underfir Su	n Ht Pkun			0.00	ofmiton	211.97		
Supply Air Leak	ane		0	ő	0			Supply Air I	eakage		0	0.00	fition	845.92		- 1
and build out a sound	990			1.5	S			a abbil our a	a anna ga			0.00	Bhuthr.#	14 19	-4.82	,
Grand Total ==>		3,487,785	134,816	3,622,602	100.00	3,163,751	100.00	Grand Total	=>	-2,066,308	-3,108,716	100.00	No. People	3,901		
	1350/		COOLING	COIL SEL	ECTION		2335/02		50	AREAS	;	H	EATING COIL	SELECTIO	N	
	ton	Capacity MBh	Sens Cap. MBh	Coll Airflow	Enter D "F	B/WB/HR *F gr/lb	*F	F gr/lb		Gross Total	Glass 11 <sup>2</sup> (%)		Capacity MBh	Coll Airflow	"F	•F
Main Cig	107.2	1,286.4	332.5	43,383	74.2 60	1.7 61.2	55.0 49	47.6	Floor	216,088		Main Htg	-75.4	58,013	66.8 68	8.0
Add Cig	194.7	2,330.2	2,000.2	330,933	72.0 39	01.2	00.0 5/	01.2	Part	9,130		Hux nug	-1,720.7	U	0.0 0	0.0
optivent	148.2	1,/78.9	922.1	46,983	/1.5 65	5.1 85.8	53.1 52	4 60.0	Int Door	0		Preneat	0.0	0	0.0 0	0.0
Toral	450.4	-							EXFI	408		Neneat	0.0	0	0.0 0	0.0
TUCAT	430.1	0,401.0							Mail	40,777	2 702 49	Opt Vont	0.0	46.093	0.0 0	0.0
									Trail	20,001 1	0,100 40	opt vent	900.9	40,903	199.1 TL	0.0
									EXT DOOL	0	0 0	rotar	-2,109.0			

#### System Checksums

By PENN STATE UNIVERSITY

Core of Hybrid GSHP w/ ACB/DOAS FCU (Cooling 450.1 Tons, Heating 2,769.0 MBH)

Perimeter													63		4-pipe li	nduc	tion
	с	OOLING C	OIL PEAK			CLG SPACE	SPACE PEAK HEATING COIL PEAK						TEMPERATURES				
Pe	eaked a Outs	t Time: Ide Alr:	Mo OADB/WB/	Hr: 7/15 HR: 85/71/9	95	Mo/Hr: OADB:	7 / 15 86			Mo/H OADE	ir: Heatir B: 5	ng Design		SADB Ra Dianum	Cooling 55.0	Hea 1	24.0
	S	Space iens. + Lat.	Plenum Sens. + Lat	Net Total	Percent Of Total	Space Sensible	Percent Of Total			Space Pea Space Sen	ik IS	Coll Peak Tot Sens	Percent Of Total	Return Ret/OA	76.3 76.3		64.0 64.0
-		Btu'h	Btu/h	Btu/h	(%)	Btu/h	(%)	-		Btu	ħ	Btu/h	(%)	Fn MtrTD	0.0		0.0
Skylite Solar	8	0	0	0		0	0	Skylite Sc	lar		0	0	0.00	En Erlet	0.0		0.0
Skylite Cond		ō	Ū.	ő	0;	0	ō	Skylte Cr	nd		ō	ő	0.00	ritringe	0.0		0.0
Roof Cond		õ	12.654	12.654	1	0	0	Roof Con	d		õ	-25.917	0.89	1000	100000000000000000000000000000000000000		
Glass Solar		613,061	0	613,061	40	575,849	50	Glass Sol	ar		0	0	0.00	AI	RFLOWS		
Glass/Door Co	nd	183,168	0	183,168	12;	235,150	21	Glass/Do	or Cond	-1,158,65	8	-1,158,658	39.82		Cooling	H	nation
Wall Cond		154,818	250,270	405,088	26 ;	127,802	11	Wall Con	1	-200,89	0	-522,060	17.94	Diffusor	25 275	110	aung
Partition/Door		13,490		13,490	1	16,744	1	Partition/I	Door	-137,96	8	-137,968	4.74	Dilluser	25,275		0,210
Floor		0		0		0	0	Floor		-13,86	0	-13,860	0.48	Terminal Main Ean	25,275	2	5,275
Adjacent Floor	5	0	0	0	01	0	0	Adjacent	Floor		0	0	0	main ran	20,210	1	0,210
Innitration		150,031		150,031	10	61,726	5	Innitration		-353,90	9	-353,909	12.16	sec Fan	10.000	1 74	
Sub Total ==>		1,114,567	262,924	1,377,492	90	1,017,272	99	SUD TOLA		-1,000,20	4	-2,212,311	10.05	Nom Vent	16,470	2	20,224
					1			Internal Los	da					AHU Vent	16,470	2	0,224
Internal Loads					8 <b>1 8</b> 8			internal coa	00					Infil	5,263		5,263
Lights		40,752	163,007	203,759	13	37,900	3	Lights			0	0	0.00	MinStop/Rh	0		0
People		156,664	0	156,664	10	96,578	8	People			0	0	0.00	Return	47,008	-	10,762
MISC		57,440	0	57,440	4	60,066	5	MISC			0	0	0.00	Exnauat	21,733	-	.5,407
Sub Tota/ ==>		254,856	163,007	417,863	27	194,544	17	Sub Total	==>		0	0	0.00	Rm Exh		100	
Colline Land										470.70			0.00	Auxiliary	83,744		3,144
Ventilation Load	d	129,299	-129,299	035 040	0	127,498	11	Ventilation	bed	-132,39	2	-345 385	11.87	Leakage Dwn			0
Adl Air Trans H	inat	-230,242	U	-230,242	-10	-2/1,420	-24	Adl Air Tran	e Heat	-040,00	0	-040,000	11.07	Leakage ups	0		0
Auj All Halls H	Bal	U		0	2:	U	0	Auj An Tran	is near				0.00	and the second			_
Outlinds Clains	izing	79 002		79 003	2	78 022	7	Exhaust Ha	nig		1	107 708	-3.70	FUOIN	CEDING O	100	-
Exhaust Heat		10,923	-100 235	-100 235	.7:	70,923		OA Preheat	DIFF			-460 059	15.81	ENGIN	EERING C	KS	
Sup Fan Heat			100,200	0	0			RA Preheat	Dett			400,000	0.00		Cooling	Hea	ating
Ret Fan Heat			0	0	0			Additional F	teheat			0	0.00	% OA	65.2		80.08
Duct Heat Pkup			0	0	0:									cfm/ft <sup>=</sup>	0.24		0.24
Underfir Sup Ht	Pkup			0	0;			Underfir Su	p Ht Pkup			0	0.00	cfm/ton	199.45		
Supply Air Leak	kage		0	0	0			Supply Air I	eakage			0	0.00	nt%ton	832.07		
	-								-					Btu/hr-ft*	14.42	-1	9.71
Grand Total ==	>	1,341,404	196,398	1,537,801	100.00 '	1,146,809	100.00	Grand Total	=>	-2,343,06	0	-2,910,016	100.00	No. People	426		
	222	803 - 83X	COOLING	COIL SEL	ECTION	535203	- 23	00000000		AREA	S		н	EATING COIL	SELECTIO	N	1988
	ton	al Capacity MBh	Sens Cap. MBh	Coll Airflow	Enter D	B/WB/HR F gr/lb	*F	F gr/lb	G	FOSS Total	Gla ft=	88 (%)		Capacity MBh	coll Airflow	Ent "F	Lvg •F
Main Cig	56.4	677.0	577.2	25,275	76.3 61	.4 61.2	55.0 5	1.9 55.1	Floor	105,444		10.18	Main Htg	-1,618.3	25,275	64.0	124.0
Aux Cig	158.8	1,905.6	1,552.7	83,744	/2.0 59	.9 61.2	55.0 5	1.7 54.4	Part	17,600			AUX Htg	-786.5	83,744	68.0	76.8
Opt Vent	70.3	843.7	464.9	20,224	74.6 66	.2 87.5	53.1 5	2.3 60.0	Int Door	0			Preheat	0.0	0	0.0	0.0
								- the storesty by	ExFIr	1,100							
rotar	285.5	3,426.3							NOOT	14,488	0	0	numian	0.0	0	0.0	0.0
									wall	47,308	23,445	50	opt vent	-400.1	20,224	40.7	70.0
									Ext Door	0	0	0	Total	-2,864.8			

### System Checksums

By PENN STATE UNIVERSITY

#### Perimeter of Hybrid GSHP w/ ACB/DOAS FCU w/ Façade Redesign

(Cooling 285.5 Tons, Heating 2864.8 MBH)

COOLING COIL PEAK         CLG SPACE PEAK         HEATING COIL PEAK         TEMP           Peaked at Time: Outside Air: Outside Aired Outside Outside A	PERATURES Cooling Heating 55.0 68.0 74.1 66.2 74.1 66.2 74.1 66.2 74.1 66.2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
Peaked at Time: Outside Air:         MoHr: 9/15 OADB://S1/51         MoHr: 11/12 OADB:/S4         MoHr: Heating Design OADB:/S         SaDB SaDB           Space Sens. Lat.         Plenum Sens. Lat.         Net Percent Sens. Lat.         Percent Total         Space Proteint Sens. Lat.         Percent Sens. Lat.         Space Sens. Lat.         Coll Peak Percent Sens. Lat.         Space Sens. Lat.         Coll Peak Sens. Lat.         Space Sens. Lat.         Space Sens. State Sens.         Coll Peak Sens. Coll Peak Sens. Dor Cond         Coll Peak Sens. Coll Peak Sens. Coll Peak Sens. Dor Cond         Space Sens. Soll Cond         Coll Peak Sens. Coll Peak Sens. Cond Cond         Space Sens. Sens. Cond Cond         Coll Peak Sens. Cond Cond         Space Sens. Sens. Cond Cond         Space Sens. Soll Cond         Space Sens. Sens. Cond Cond         Space Sens. S	Cooling 55.0         Heating 68.0           74.1         66.2           74.1         66.2           74.1         66.2           0.0         0.0           0.0         0.0           0.0         0.0           0.0         0.0           100         0.0           101         0.0           102         0.0           103         0.0           104         0.0           105         0.0           105         0.222           102.752         32.924           102.752         32.924           102.752         32.924
Space Sens. + Lat. Sens. + Lat. Se	74.1         66.2           74.1         66.2           0.0         0.0           0.0         0.0           0.0         0.0           100         0.0           100         0.0           100         0.0           100         0.0           100         0.0           100         0.0           100         0.0           100         0.0           100         0.0           100         0.0           100         0.0           100         0.0
Bhuh         Bhuh         Bhuh         Bhuh         Bhuh         Bhuh         Bhuh         Bhuh         Pin MirTD           Skylite Solar         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0 </td <td>0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 IRFLOWS Cooling Heating 49,222 60,275 49,222 60,275 49,222 60,275 0 0 50,752 32,924 50,752 32,924 12,778 42,778</td>	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 IRFLOWS Cooling Heating 49,222 60,275 49,222 60,275 49,222 60,275 0 0 50,752 32,924 50,752 32,924 12,778 42,778
Envelope Loads         Envelope Loads         Fine Blatto           Skylite Solar         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0 <td< td=""><td>0.0 0.0 0.0 0.0 IRFLOWS Cooling Heating 49,222 60,275 49,222 60,275 49,222 60,275 0 0 50,752 32,924 50,752 32,924 12,778 42,788</td></td<>	0.0 0.0 0.0 0.0 IRFLOWS Cooling Heating 49,222 60,275 49,222 60,275 49,222 60,275 0 0 50,752 32,924 50,752 32,924 12,778 42,788
Skylite Solar         0         0         0         0         0         0         Skylite Solar         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0 <td>0.0 0.0 IRFLOWS Cooling Heating 49,222 60,275 49,222 60,275 49,222 60,275 0 0 50,752 32,924 50,752 32,924 12,778 42,788</td>	0.0 0.0 IRFLOWS Cooling Heating 49,222 60,275 49,222 60,275 49,222 60,275 0 0 50,752 32,924 50,752 32,924 12,778 42,788
Skyline Cond         0         0         0         0         0         0         Skyline Cond         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0	IRFLOWS Cooling Heating 49,222 60,275 49,222 60,275 49,222 60,275 0 0 50,752 32,924 50,752 32,924 12,778 42,778
Proof Cond         0         10(J39         10(J39         10(J39         0         Non Cond         0         -104,300         2.76         AIF           Glass Solar         1,344,573         0         1,344,573         0         1,344,573         0.00         0.00         Glass Solar         0         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         -716,18         -716,18         -716,18         1.96,41         0.14         0.00         0         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00 <td>IRFLOWS Cooling Heating 49,222 60,275 49,222 60,275 0 0 50,752 32,924 50,752 32,924 12,778 42,788</td>	IRFLOWS Cooling Heating 49,222 60,275 49,222 60,275 0 0 50,752 32,924 50,752 32,924 12,778 42,788
Glass/Door Cond         1,344,513         0         1,244,513         0         1,715,550         C         Glass/Door Cond         -946,169         -946,169         25,01           Wail Cond         107,459         130,139         237,598         6         19,637         1         Wail Cond         -196,415         -436,169         -946,169         25,01           Partfiton/Door         10,643         0         0         0         0         71,618         1.98         1.98         1.98,323         2.2500         -1         Partfiton/Door         -71,618         1.98         1.98         1.98         1.98         1.98,323         0         32,630         -1         Partfiton/Door         -51,614         -71,618         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98         1.98	Cooling Heating 49,222 60,275 49,222 60,275 49,222 60,275 0 0 50,752 32,924 50,752 32,924 12,78 42,78
Glassibility         Glassibility         Constraints	Cooling Heating 49,222 60,275 49,222 60,275 49,222 60,275 0 0 0 50,752 32,924 50,752 32,924
Internal Loads         101,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,643         -100,644         -20,673,686         -24,418,733         63,944         Mom Went         Mom Went         Nom Went <td>49,222 60,275 49,222 60,275 49,222 60,275 0 0 50,752 32,924 50,752 32,924</td>	49,222 60,275 49,222 60,275 49,222 60,275 0 0 50,752 32,924 50,752 32,924
Pail         Procession         Procession <td>49,222 60,275 49,222 60,275 0 0 50,752 32,924 50,752 32,924 12,778 42,778</td>	49,222 60,275 49,222 60,275 0 0 50,752 32,924 50,752 32,924 12,778 42,778
Adjacent Floor         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0	49,222 60,275 0 0 50,752 32,924 50,752 32,924 12,708 12,708
Infitration         121,979         121,979         3         -238,727         -8         Infitration         -854,544         -854,544         22.59         See Fan           Sub Total ==>         1,645,760         140,179         1,780,939         48         1,256,414         44         Sub Total ==>         -2,073,886         -2,418,733         63.94         Nom Vent           Internal Loads         internal Loads         internal Loads         internal Loads         0         0         0.000           Misc         504,811         0         1,936,618         0         1,936,618         0         0.000           Misc         504,811         0         504,811         14         533,699         19         Misc or 178,595         178,595         178,595         4.72         Exhaust heat         0.000           Ventiliation Load         -252,285         -562,285         -562,285         -4.72         Auxiliary	0 C 50,752 32,924 50,752 32,924 12,708 12,708
Sub Total ==>         1,648,760         140,179         1,788,939         48         1,256,414         44         Sub Total ==>         -2,073,886         -2,418,733         63.94         Nom Vent           Internal Loads         Lights         103,451         413,804         517,254         14         112,019         4         Lights         0         0.000         0         0.000           Misc         504,811         0         1,336,618         52         969,864         34         People         0         0         0.000         Return           Sub Total ==>         2,544,879         413,804         2,958,683         80         1,615,581         56         Sub Total ==>         178,595         178,595         4.72         Rm Exhaust           Celling Load         170,078         -170,078         0         0         0.000         Lights         0         0.000           Ventilation Load         -882,068         0         115,325         4         Celling Load         -143,445         0.000         Liakage Dwn           Ventilation Load         -882,068         0         0         0         0         0         0         0         0         0         0         0         0	50,752 32,924 50,752 32,924 12,708 42,708
Internal Loads         Internal Loads         Internal Loads         Infli         Infli           Lights         103,451         413,804         517,254         14         112,019         4         Lights         0         0.000         Minstop/Rh           People         1,936,618         0         139,6618         52         969,864         34         People         0         0.000         Minstop/Rh           Misc         504,811         0         504,611         14         533,699         19         Misc         178,595         178,595         4.72         Amultary           Sub 70tal ==>         2,544,879         413,804         2,958,683         80         1,615,581         65         Sub 70tal ==>         178,595         178,595         4.72         Rm Exh           Celling Load         170,078         -170,078         0         0         141,525         4         Celling Load         -162,245         -562,265         1.06         Laakage Upe           Ventilation Load         -882,068         0         -382,068         -24         -102,341         -4         Ventilation Load         -562,255         1.66         0         0         0         0         0         0         0	12 708 12 708
Lights         103,451         413,804         517,254         14         112,019         4         Lights         0         0         0.00         MinStop/Rh           People         1,936,618         0         1,336,618         52         969,864         34         People         0         0         0.00         Return           Misc         504,811         0         504,811         0         504,811         0         0         178,995         178,995         4.72         Khaut           Sub Tota/ ==>         2,544,879         413,804         2,958,683         80         1,615,581         56         Sub Tota/ ==>         178,995         178,995         4.72         Rm Exhaut           Celling Load         170,078         -170,078         0         0         115,325         4         Celling Load         -143,445         0         0.00           Ventilation Load         -882,068         0         -882,068         -24         -108,341         -4         Ventilation Load         -562,285         14.65         Ligakage Dwn           Leakage         0         0         0         0         0         0         0         0         0         0         0         0	12,700 12,700
Péople         1,936,518         0         1,936,518         52         969,864         34         Péople         0         0.00         D         Return           Misc         504,811         0         504,811         14         533,699         19         Misc         178,595         178,595         178,595         4.72         Mich         Misc         178,595         178,595         4.72         Mich         Mich         18,595         4.72         Mich         Mich         18,595         4.72         Mich         Mich         18,595         4.72         Mich         Mich         18,395         4.72         Mich         Mick         18,395         4.72         Mick         Mick         18,395         4.72         Mick         Mick         18,395         4.72         Mick         Mick         19,395         4.72         Mick         Mick         10,00         0.00         0.00         0.00         0.00         0.00	0 0
Misc         504,811         0         504,811         0         504,811         0         504,811         14         533,699         19         Misc         178,595         178,595         -4.72         Exhaust           Sub Total ==>         2,544,879         413,604         2,958,683         80         1,615,581         56         Sub Total ==>         178,595         178,595         -4.72         Rm Exh           Ceiling Load         170,078         -170,078         0         0         115,325         4         Ceiling Load         -143,445         0         0.00           Ventilation Load         -852,068         0         -852,068         -24         -106,341         -4         Ventilation Load         -562,255         14.86         Leakage Upe           Adj Air Trans Heat         0         0         0         O/VUndr Stzing         0         0         0         0           Ov/Undr Stzing         -1,169         0         -1,169         0         -1,169         0         24,11         -1,067,053         28,21         ENG/NI	112,681 105,906
Sub Total ==>         2,544,879         413,804         2,958,683         80         1,615,581         56         Sub Total ==>         178,595         178,595         4.72         Rm Exh Auxiliary Laxage Dwn Leakage Dwn           Celling Load         170,078         -170,078         0         0         115,325         4         Celling Load         -143,445         0         0.000           Ventilation Load         -882,068         0         -882,068         -24         -108,341         -4         Ventilation Load         -562,285         -562,285         14.86           Ad JAir Trans Heat         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0	63,459 45,632
Celling Load         170,078         -170,078         0         0         115,325         4         Celling Load         -143,445         0         0.00           Ventilation Load         -882,068         0         -882,068         -24         -108,341         -4         Ventilation Load         -562,265         14.86         Leakage Dwn         Leakage Dwn         Leakage Dwn         Leakage Upe         Leakage Upe         Delumid. Ov Sizing         0         0         0         0         0         0         Delumid. Ov Sizing         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0 <td< td=""><td>0 0</td></td<>	0 0
Ceiling Load         170,078         -170,078         0         0         115,325         4         Ceiling Load         -143,445         0         0.00         Leakage Dwn           Ventilation Load         -882,068         0         -882,068         0         -24         -108,341         -4         Ventilation Load         -562,285         -562,285         14.86           Adj Air Trans Heat         0         0         0         0         0/d Air Trans Heat         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0	350,198 0
Adj Air Trans Heat         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0	0 0
Dehumid. Ov Stzing         0         0         Ov/Undr Stzing         0         0         0.0           Ov/Undr Stzing         -1,169         0         -1,169         0         Exhaust Heat         86,753         -2.29         ENGINE           Exhaust Heat         -143,092         -143,092         -4         0.0 Preheat DMR.         -1,067,053         28.21	
Ov/Undr sizing -1,169 -1,169 0 -1,169 0 Exhaust Heat 86,763 -2.29 ENGINE Exhaust Heat -143,092 -143,092 -4 0A Preheat Diff1,067,053 28.21	
Exhaust Heat -143,092 -143,092 -4 OA Preheat Diff1,057,053 28.21	NEERING CKS
Sup. Fan Heat 0 0 RA Preheat Diff. 0 0.00	Cooling Heating
Ret Fan Heat 1 1 0; : Additional Reheat 0 0.00 % OA	103.1 54.6
Duct Heat Pkup -43,347 0 0:	0.19 0.24
Underfit Sup Ht Pkup 0 0.00 cfm/tion	183.68
Supply Air Leakage 0 0.00 Supply Air Leakage 0 0.00 R4ton	948.19
Grand Total ==> 3,480,480 197,465 3,721,293 100.00 2,877,810 100.00 Grand Total => -2,601,021 -3,782,712 100.00 No. People	12.66 -4.65 4,167
COOLING COIL SELECTION AREAS HEATING COIL	SELECTION
Total Capacity Sens Cap. Coll Airflow Enter DB/WB/HR Leave DB/WB/HR Gross Total Glass Capacity C ton MBh MBh cfm 'F 'F grilb 'F 'F grilb ft' (%) MBh	coll Airflow Ent Lv
Main Clo 107.8 1.294.0 279.5 40.611 74.1 60.7 61.2 54.0 49.0 45.8 Floor 254.088 Main Hto -114.6	60.275 66.2 68
Aux Clg 202.3 2.427.3 2.427.3 350.198 72.0 59.9 61.2 65.5 57.5 61.2 Part 9.136 Aux Htg -2.194.3	0 0.0 0.
Opt Vent 160.1 1,921.6 996.0 50,752 71.5 65.1 86.8 53.1 52.4 60.0 Int Door 0 Preheat 0.0	0 0.0 0.1
Total 470.2 5,642.9 Roof 56,277 0 0 Humidif 0.0	0 0.0 0.0
Wall         39,731         17,063         43         Opt Vent         -1,067.1           Ext Door         0         0         1         7         -3,375.9	50,752 50.3 70.0

#### System Checksums

By PENN STATE UNIVERSITY

Core of Hybrid GSHP w/ ACB/DOAS FCU w/ Façade Redesign

(Cooling 470.2 Tons, Heating 3375.9 MBH)

COOLING COIL PEAK         CLG SPACE PEAK         HEATING COIL PEAK           Peaked at Time: Outside Arr.         MoHr: 7/15 OADB/WBIHR: 66/71/95 Sens. + Lat. Sens Lat Sens. + Lat. Sens Lat. + Lat Sens. + Lat Sens. + Lat Sens. + Lat. + Sens Lat. + Lat. + Sens Lat. + Lat. + Sens. + Lat. + Sen	ieating 72.0 65.8 65.8 65.8 0.0 0.0 0.0
Pasked at Time: Outside Arr.         MoHrt: 7/15 OADB/SH         MoHrt: 1/1/2 OADB: 54         MoHrt: Heating Design         Cooling ADB: 54           Space Sens. + Lat.         Sens. + Lat. Sens. + Lat.         Total Sens. + Lat.         Of Total Sens. + Lat.         MoHrt: 7/1 / 55         MoHrt: 7/1 / 55         Space Space         Percent Space         Space Sens. Space         Coll Peak Space         Percent Sens. + Lat.         South Sens. + Lat.         South Sens. + Lat.         South Stuth         Of Total Space         Space Percent Space         Space Sens. Space         Coll Peak South Stuth         Percent South         Space Space         Percent South         Space Space         Percent South         Space Space         Coll Peak South         Percent South         Space Space         Percent South         Space Space         Percent South         Space Space         Coll Peak South         Percent South         Space Space         Percent South         Space Space         Percent South         Space Space         Percent South         Space Space         Percent South         Space Space         Coll Peak South         Percent South         Space Space         Percent South         Space Space         Percent South         Space Space         Percent South         Space Space         Space Space         Percent Space         Space Space         Percent Space         Space Space         Space Space         Sp	feating 72.0 65.8 65.8 65.8 0.0 0.0 0.0
space         Pierum         Het         Percent         Space         Percent         Space Peak         Coll Peak Percent         Return         Tots or Total           Stink - Lat.         Sens. + Lat.         Sens.	65.8 65.8 0.0 0.0 0.0
Bluh         Bluh         Bluh         Bluh         (%)         Bluh         (%)         Bluh         (%)         Fn MtrTD         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0	0.0 0.0 0.0
Envelope Loade         Envelope Loade         Envelope Loade         Image: Condition of the source of th	0.0
Skylite Solar         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0	0.0
Skylite Cond         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         <	
Roof Cond         0         48,876         48,876         44,876         0         0         Roof Cond         0         -128,779         1.69           Glass Solar         1,336,398         12,35,398         124,875         2,583,084         71         Glass Solar         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0	_
Glass/Dor Cond (Glass/Dor Cond Partflor/Dor Partflor/Dor 1,959       1,336,395       0       1,336,395       0       1,336,395       0       1,336,395       0       1,336,395       0       1,336,395       0       1,028,256       -1,928,256       -1,928,256       -2,525       -2,525       2,525       2,525       -1,928,256       -2,525       -2,525       -2,525       -2,525       -2,525       -2,525       -2,525       -2,525       -2,525       -2,525       -2,525       -2,525       -2,525       -1,928,256       -2,525       -2,525       -2,525       -2,525       -2,525       -2,525       -2,525       -2,525       -2,525       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25       -2,551,25<	
Glass/bor Cond         39/811         0         389/811         0         389/811         0         389/811         0         389/811         0         389/811         0         389/811         0         389/811         0         389/811         0         389/811         0         389/811         0         389/811         0         389/811         0         389/811         0         389/811         0         389/811         0         389/811         0         389/811         0         389/811         0         389/811         0         389/811         0         389/811         0         389/811         10.3         39/811         10.3         39/811         10.3         39/811         10.3         39/811         10.3         39/811         10.3         39/811         10.3         39/811         11.451         39/811         11.451         39/811         11.451         39/811         11.451         39/811         10.3         39/811         10.3         39/811         10.3         39/811         10.3         39/811         10.3         39/811         10.3         39/811         10.3         39/811         10.3         39/811         10.3         39/811         10.3         30/812         10.3         39	
Instruction         203,856         307,005         510,844         407,617         113,125         3         Mail Colling         -322,825         -796,214         0.23,855         274         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0	Heating
Paramination       Price	82,210
Adjacent Floor         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0	82 210
Initiation         668,039         668,039         668,039         668,039         7334,838         -9         Initiation         -1,198,576         -1,198,576         15.70         Sec Fan         0           Sub Total ==>         2,595,925         355,884         2,951,809         270,421         1,724,664         48         Sub Total ==>         -3,678,043         -4,280,411         56.05         Nom Vent         65.040           Internal Loads         Internal Loads         Internal Loads         Internal Loads         0         0.000         0.000           Misc         564,731         0         564,731         517,76         599,069         17         Misc         178,595         178,595         2.24         MinstoprRh         82,864           Sub Total ==>         2,821,755         580,493         3,402,251         311,667         1,819,272         50         Sub Total ==>         178,595         178,595         -2.34         MinstoprRh         82,864           Sub Total ==>         2,83,802         -293,802         0         0         2         24,543         4         Ventilation Load         -670,411         11.40           Adj Air Trane Heat         0         0         0         0         0         0	82,210
Internal Loads         Coolumn	0
Sub 7(a)         23.0         200,24         2.00,24         2.00,24         2.00,24         2.00,24         2.00,24         2.00,24         2.00,24         2.00,24         2.00,24         2.00,24         2.00,24         2.00,24         2.00,24         1.02,04         2.00,24         2.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0.00,24         0	en nee
Internal Loads         Internal Loads         Internal Loads         Internal Loads         Internal Loads           Lights         145,123         580,493         725,617         66,475         156,863         4         Lights         0         0         0.00         MinstopRh         82,210           People         2,111,904         0         2,111,904         193,476         1,063,340         29         People         0         0         0.00         Return         100,285         178,595         -2.34         MinstopRh         82,210         Return         100,285         186,20         100,00         100,00         100,00         100,00         100,00         100,00         100,00	50,900
Inimit Data         145,123         580,493         725,617         66,475         156,863         4         Lights         0         0         0.00           People         2,111,904         0         2,111,904         133,476         1,053,340         29         People         0         0         0.00         Return         100,345           Sub Tota/==>         2,821,758         580,493         3,402,251         311,667         1,819,272         50         Sub Tota/==>         178,595         178,595         -2.34         Rm Exh         0         0         0         0         0         0.000         Naxiliation Load         -248,039         0         0.000         0         AdJ Air Trans Heat         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0	17,900
Lights       145,123       \$50,433       725,517       66,475       156,683       4       Lights       0       0       0.000       Minscoprich       62,210         Misc       564,731       0       564,731       51,736       599,059       17       Misc       178,595       178,595       -2.34       Refurm       100,245         Sub Total ==>       2,821,758       580,493       3,402,251       311,667       1,819,272       50       Sub Total ==>       178,595       178,595       -2.34       Rm Exh       82,064         Celling Load       293,802       -293,802       0       0       222,454       6       Celling Load       -246,039       0       0.00       Rm Exh       82,064       Rm Exh       40,017       114,00       -211       14,00       -0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0 <td>92,210</td>	92,210
People       2,111,904       0       2,111,904       10,05,340       24       People       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0	151 000
Misc         54,731         0         564,731         51,736         599,069         7         Misc         178,995         178,595         -2.34         Enduat         Current           Sub Total ==>         2,621,756         580,493         3,402,251         311,667         1,819,272         50         Sub Total ==>         178,995         178,595         -2.34         Fm Eth         0         Auxiliary         478,044         Leakage Upe         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0	59 700
Sub Total ==>         2,621,758         580,493         3,402,251         311,667         1,819,272         50         Sub Total ==>         178,595         178,595         -2.34         Rm Em         0           Ceiling Load         233,802         -93,802         0         0         222,454         6         Ceiling Load         -240,039         0         0.00         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0	00,790
Celling Load         293,802         -293,802         -293,802         0         222,454         6         Celling Load         -248,039         0         0.00           Ventilation Load         -1,012,213         0         -1,012,213         -92,731         -138,843         -4         Ventilation Load         -870,411         11,40         11,40         Leakage Dyn         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         <	
Certify Code         233,802         -293,802         -293,802         -293,802         -224,254         6         Certify Code         -240,035         0         0         Delandge Dwit         0           Adj Air Trans Heat         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0	
Verification Load         -1,012,213         0         -1,012,213         -1,05,043         -2,04         -1,012,112         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -1,05,043         -2,016         ENGINEERING CW         ENGINEERING CW         ENGINEERING CW         -0,00         -1,045,055         18,02         -1,05,043         -2,01,012,013         -2,013,012,013         -2,013,012,013         -2,013,012,013         -2,013,012,013         -2,013,012,013         -2,013,012,013         -2,013,012,013         -2,013,012,013         -2,013,012,013         -2,01,012,013         -2,01,012,013,013	
Adj art rans heat         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0	0
Definition         Ov/Und         Stand         Cov/Und         C	
Ovinition sizing         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -5,650,612         -	
Exitation from         -230,310         -230,310         -230,310         -21,100         OR Premissi Diff.         -1,306,616         10.19         Cooling           Sup, Fan Heat         0         0         R4 Premissi Diff.         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00	Con 1
Supp. rail neat         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0	leating
Instrument         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O         O	62.0
Duck right Pkup         0         0         0         Underfit Sup Ht Pkup         0         0.00         cfm/ton         85.18           Supply Air Leakage         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0<	0.23
Supply Air Leakage         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0         0	
Grand Total => -1,151,539 412,257 1,092 100.00 3,627,547 100.00 Grand Total => -4,617,898 -7,636,557 100.00 No. People 4,597	
Grand Total ⇒ -1,151,539 412,257 1,092 100.00 3,627,547 100.00 Grand Total ⇒ -4,617,898 -7,636,557 100.00 0.00 People 4,557	-9.45
	3.40
COOLING COIL SELECTION AREAS HEATING COIL SELECTION	1.5
Total Capacity Sens Cap. Coll Airflow Enter DB/WB/HR Leave DB/WB/HR Gross Total Glass Capacity Coll Airflow	int Lvg
ton Men Men ctm + + grio + r+ grio π- (%) Men ctm	·F ·F
Main Cig 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.	4 72.0
Aux Clg 275.9 3,310.6 3,310.6 478,044 72.0 59.9 61.2 65.5 57.5 61.2 Part 26,736 Aux Htg -3,871.8 0 (	0.0
Opt Vent 205.2 2,462.6 1,276.4 65,040 71.5 65.1 86.8 53.1 52.4 60.0 Int Door 0 Preheat 0.0 0 0	0.0
ExFir 1,508 Reheat -1,981.2 82,210 4	4 72.0
Total 481.1 5,773.2 Roof 69,901 0 0 Humidif 0.0 0 1	0.0
Wall 77,855 37,640 48 Opt Vent -1,388.9 65,040 5	0 70.0
Ext Door 0 0 Total -7,241.8	

#### System Checksums

By PENN STATE UNIVERSITY

Central Plant w/ All Active Chilled Beam w/ Façade Redesign

(Cooling 481.1 Tons, Heating 7241.8 MBH)

Active Chilled Beams

Pea	ked at Ti	COOLING COIL PEAK									Sole i La ut		TEMPERATURES			
	Outside	Air:	OADB/WB/	Hr: 7/15 HR: 86/71/9	6	Mo/Hr: OADB:	11/12 54			Mo/Hr: OADB:	Heating Design 5	_	SADB Ra Dianum	Cooling 55.0 74.6	Heating 72.0	
	Sen	Space 8. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)			Space Peak Space Sens Btwh	Coll Peak Tot Sens Btu'h	Percent Of Total (%)	Return Ret/OA Fn MtrTD	74.6 74.6 0.0	65.8 65.8 0.0	
Envelope Loads Skylite Solar Skylite Cond		0	0	0	0	0	0	Envelope Lo Skylite So Skylite Co	ada lar nd	0	0	0.00	Fn BidTD Fn Frict	0.0 0.0	0.0	
Roof Cond Glass Solar	1,	336,398	48,876	48,876	4,478 122,430	2,583,064	71	Glass Sol	d ar	0	-128,779	1.69	A	RFLOWS		
Glass/Door Con Wall Cond Partition/Door Floor	d	389,811 203,636 -1,959 0	0 307,008	389,811 510,644 -1,959 0	35,711 46,781 -179 0	-541,452 113,128 -95,238 0	-15 3 -3 0	Glass/Doo Wall Cons Partition/E Floor	r Cond I Ioor	-1,928,256 -322,625 -209,586 -19,001	-1,928,256 -796,214 -209,586 -19,001	25.25 10.43 2.74 0.25	Diffuser Terminal Main Fan	Cooling 17,481 17,481 17,481	Heating 82,210 82,210 82,210 82,210	
Adjacent Floor Infiltration Sub Total ==>	2,5	568,039 595,925	355,884	668,039 2,951,809	61,200 270,421	-334,838 1,724,664	-9 48	Adjacent Infiltration Sub Total	==>	-1,198,576 -3,678,043	-1,198,576 -4,280,411	15.70 56.05	Sec Fan Nom Vent AHU Vent	0 65,040 65,040	0 50,966 50,966	
Internal Loads								internal Loa	dis				Infil	17,824	17,824	
Lights People Misc	2,	145,123 111,904 564,731	580,493 0 0	725,617 2,111,904 564,731	66,475 193,476 51,736	156,863 1,063,340 599,069	4 29 17	Lights People Misc		0 178,595	0 0 178,595	0.00 0.00 -2.34	MinStop/Rh Return Exhaust	82,210 100,345 82,864	82,210 151,000 68,790	
Sub Total ==>	2,8	821,758	580,493	3,402,251	311,687	1,819,272	50	Sub Total	==>	178,595	178,595	-2.34	Rm Exh Auxillary	478.044	0	
Ceiling Load Ventilation Load	-1,0	293,802 012,213	-293,802 0	-1,012,213	-92,731	222,454 -138,843	64	Celling Load	l .oad	-248,039 -870,412	-870,411	0.00	Leakage Dwn Leakage Ups	0	0	
Dehumid. Ov Sizi Ov/Undr Sizing	ing -5,8	0 850,812		740,373 -5,850,812	67,827 -536,005	0	0	Ov/Undr Siz Exhaust Hea	ing t	0	0 161,400	0.00	ENGIN	EERING C	KS	
Exhaust Heat Sup. Fan Heat Ret. Fan Heat Duct Heat Pkup			-230,318 0 0	-230,318 0 0 0	-21,100			OA Preheat RA Preheat Additional R	Diπ. Diπ. Jeheat		-1,388,876 0 -1,436,855	18.19 0.00 18.82	% OA cfm/ft=	Cooling 372.1 0.05	Heating 62.0 0.23	
Underfir Sup Ht F Supply Air Leaks	eknb Be		0	0	0			Underfir Su Supply Air L	eakage		0	0.00	cfm/ton ft9ton	85.18 1,735.11	.0.45	
Grand Total ==>	-1,	151,539	412,257	1,092	100.00	3,627,547	100.00	Grand Total	->	-4,617,898	-7,636,557	100.00	No. People	4,597	-3.40	
	Total C	apacity	COOLING Sens Cap.	COIL SELI	ECTION Enter De	B/WB/HR	Leave	DBWB/HR	G	AREAS Gross Total	Glass	HE	EATING COIL Capacity	SELECTIO Coll Airflow	N Ent Lvg	
Main Cin	ton	MBh	MBh	cfm	-F -	F gr/b	*F	F gr/b	Floor	355.075	π. (%)	Main Hte	MBh	cfm 82.210	"F "F	
Aux Clg	275.9	3,310.6	3,310.6	478,044	72.0 59	9 61.2	65.5 5	7.5 61.2	Part	26,736		Aux Htg	-3,871.8	02,210	0.0 0.0	
Total	205.2 481.1	2,462.6 5,773.2	1,276.4	65,040	71.5 65.	.1 86.8	53.1 5	2.4 60.0	ExFIr Roof Wall	0 1,508 69,901 77,855 37	0 0 ,640 48	Preneat Reheat Humidif Opt Vent	0.0 -1,981.2 0.0 -1,388.9	0 82,210 0 65,040	0.0 0.0 49.4 72.0 0.0 0.0 50.0 70.0	

#### System Checksums

By PENN STATE UNIVERSITY

Main System

Hybrid GSHP w/ All Active Chilled Beam w/ Façade Redesign

(Cooling 481.1 Tons, Heating 7241.8 MBH)

Main System	m											3	<u></u>	4-pipe Ir	nduction
	(	COOLING	OIL PEAK			CLG SPACE	E PEAK			HEATING	COIL PEAK		TEM	PERATURE	s
1	Peaked Out	at Time: Iside Air:	MC OADB/WB/	/Hr: 7/15 HR: 86/71/9	15	Mo/Hr: OADB:	7 / 15 86			Mo/Hr: OADB:	Heating Design 5		SADB Ba Plenum	Cooling 55.0 75.2	Heating 123.7 65.2
		Space Sens. + Lat.	Plenum Sens. + Lat	Net Total	Percent Of Total	Space Sensible	Percent Of Total			Space Peak Space Sens	Coll Peak Tot Sens	Percent Of Total	Return Ret/OA	75.2 75.4	65.2 65.2
		Btu/h	Btu/h	Btu/h	(56);	Btu/h	(%)			Btu/h	Btu/h	(%)	Fn MtrTD	0.0	0.0
Envelope Loa	dis							Envelope Lo	BDBC			0.00	FR BIOID	0.0	0.0
Skylle Cond							0	Skylte Cr	nai	0	0	0.00	FR FRCt	0.0	0.0
Boof Cond			70 508	70 508	1	0		Boof Con	d d	0	-127 470	2.30	17		
Glass Solar		1,419,288	0,000	1,419,288	27	1,366,137	39	Glass Sol	ar	õ	0	0.00	A	IRFLOWS	
Glass/Door C	Cond	331,570	0	331,570	6	388,249	11	Glass/Do	or Cond	-1,928,256	-1,928,256	34.81		Cooling	Hasting
Wall Cond		246,552	356,137	602,689	12	217,814	6	Wall Con	1	-322,625	-791,399	14.29	Diff.	41 602	neaung
Partition/Doo	NT .	20,284		20,284	0;	25,612	1	Partition/I	Door	-209,586	-209,586	3.78	Dinuser	41,052	41,092
Floor		0		0	0	0	0	Floor		-19,001	-19,001	0.34	Terminal	41,692	41,692
Adjacent Floo	OF	0	0	0	0;	0	0	Adjacent	Floor	0	0	0	Main Fan	41,032	41,052
Infiltration		593,555		593,555	11	225,717	6	Infitration	Carlos and	-1,198,576	-1,198,576	21.64	Sec Fan		i anno
Sub Total ==	>	2,611,250	426,645	3,037,894	58	2,223,528	64	SUD TOTAL	>	-3,070,043	-4,2/4,200	11.11	Nom Vent	47,185	33,111
					1			Internal Los	de				AHU Vent	47,185	33,111
Internal Loads	8				100			incontar Loa	40			8202	Infil	17,824	17,824
Lights		140,578	562,313	702,891	13	134,274	4	Lights		0	0	0.00	MinStop/Rh	0	00.007
People		1,753,763	0	1,753,763	-33	912,856	26	People		0	0	0.00	Keturn	106,701	50,025
MISC		562,367	U	562,367	11	554,533	10	MISC		1/8,595	1/8,595	-3.22	Exhaust	00,009	50,955
Sub Total ==	>	2,456,708	562,313	3,019,021	58	1,601,663	46	Sub Total	==>	178,595	178,595	-3.22	Auxillana	202 896	003 005
Celling Load		250 517	250 517			761 014	10	Calling Loss		-317 770	0	0.00	Leskage Dwg	253,000	250,000
Ventilation Lo	her	-735 617	-359,617	-735 617	-14	-817 756	-23	Ventilation	beo	-565 474	-565 475	10.21	Lookage Une		
Adl Air Trans	Heat	-100,017				-017,700		Adl Air Tran	s Heat	0	0	0	reawage ope		
Dehumid Ov	Sizing							Owlindr Siz	ing	3	3	0.00			
Ovil Indr Sizin	a	124 836		124 835	2	124,836	4	Exhaust He	at a	, in the second s	153 106	-2.76	ENCH		Ke.
Exhaust Heat	.9		-209,221	-209,221	-4	124,000	- 7	OA Preheat	DITT.		-1,030,648	18.61	ENGI	EERING C	1.3
Sup. Fan Heat	t			0	0			<b>RA Preheat</b>	DIT.		0	0.00		Cooling	Heating
<b>Ret Fan Heat</b>			1	1	0:			Additional F	teheat		0	0.00	% OA	113.2	79.4
Duct Heat Pku	qu		-44,501	0	0:								cfm/ft°	0.12	0.12
Underfir Sup H	Ht Pkup			0	0			Underfir Su	p Ht Pkup		0	0.00	cfm/ton	151.26	
Supply AIr Lea	akage		0	0	0;			Supply Air I	.eakage		0	0.00	ft=/ton	1,291.85	
Grand Total =	-	4,816,794	375,619	5,236,914	100.00	3,493,284	100.00	Grand Total	=>	- <mark>4</mark> ,382,698	-5,538,705	100.00	Btu/hr-ft* No. People	9.29 4,597	-10.21
	821	2365 - 527	COOLING	COIL SEL	ECTION	1012010	1000	acamana.	8	AREAS		н	EATING COIL	SELECTIO	N
	tor	tal Capacity MBh	Sens Cap. MBh	Coll Airflow cfm	Enter D "F	B/WB/HR *F gr/lb	Leave "F	F gr/lb		Gross Total	Glass ft <sup>z</sup> (%)		Capacity MBh	Coll Airflow	F T
Main Cig	111.6	1,339.2	941.5	41,692	75.2 61	1.0 61.2	54.0 4	9.3 47.1	Floor	356,076		Main Htg Aux Htg	-2,604.8	41,692	65.2 123. 68.0 74
Ont Vent	154.0	1 968.4	1 084 7	47 185	74.6 66	2 87.5	53 1 5	23 60.0	Int Door	0	1	Preheat	0.0	0	00 0
operate			.,004.7						ExFir	1.508			0.0		u.u. u.
Total	810.4	9,724.6							Roof	69,901	0 0	Humidif	0.0	0	0.0 0.
									Wall	77,855 37	7,640 48	Opt Vent	-1,030.7	47,185	49.5 70.
									Ext Door		0 0	Toral	-5.701.6		

#### System Checksums

By PENN STATE UNIVERSITY

Central Plant w/ All DOAS Fan Coil Units w/ Façade Redesign

(Cooling 810.4 Tons, Heating 5701.6 MBH)

Main System													4-pipe Ir	nduction	
	COOLING COIL PEAK Peaked at Time: MoiHr: 7 / 1 Outside Air: OADB/WB/HR: 66 /				CLG SPACE	PACE PEAK			HEATING	COIL PEAK		TEMPERATURES			
Pea	ked at Time: Outside Air:	OADB/WE	lo/Hr: 7 / 15 3/HR: 86 / 71 / 1	95	Mo/Hr: OADB:	7/15 86			Mo/Hr. OADB:	Heating Design 5		SADB Ra Diapum	Cooling 55.0 75.2	Heating 123.7 65.2	
	Space Sens. + La	e Pienum t. Sens. + Lat	Net Total	Percent Of Total	Space Sensible	Percent Of Total			Space Peak Space Sens	Coll Peak Tot Sens	Percent Of Total	Return Ret/OA	75.2 75.4	65.2 65.2	
	Btu	h Btu/h	Btu/h	(%);	Btw/h	(%)			Btu/h	Btu/h	(%)	Fn MtrTD	0.0	0.0	
Envelope Loads							Envelope Lo	bada	-			FNBIOTD	0.0	0.0	
Skylle Solar		0 0	0		0	0	Skylte St	Jiai	0		0.00	FILFINCE	0.0	0.0	
Boof Cond		0 70 509	70 500	1			Boof Con	d	0	107 470	0.00				
Class Solar	1 419 28	8 0	1 / 10,000	27	1 366 137	30	Class Sol		0	-127,470	0.00	<u>م</u>	IRELOWS		
Glass/Door Con	1 331 57	0 0	331 570		388 249	11	Glass/Do	or Cond	-1 928 256	-1 928 255	34.81	<sup>^</sup>	and como	10072070	
Wall Cond	246.55	2 355 137	602 689	12	217 814	6	Wall Con	1	-322 625	-791 399	14.29		Cooling	Heating	
Partition/Door	20.28	4	20.284	0	25.612	1	Partition/I	Door	-209 586	-209 586	3.78	Diffuser	41,692	41,692	
Floor		0	0	ŏ.	0	Ó	Floor		-19.001	-19.001	0.34	Terminal	41,692	41,692	
Adjacent Floor		0 0	0	0	0	0	Adjacent	Floor	0	0	0	Main Fan	41,692	41,692	
Inflitration	593.55	5	593,555	11	225,717	6	Infiltration		-1,198,576	-1,198.576	21.64	Sec Fan	0	0	
Sub Total ==>	2.611.25	0 426.645	3.037.894	58	2.223.528	64	Sub Total	==>	-3,678,043	-4,274,288	77.17	Nom Vent	47,185	33 111	
		15 C.			100019403519						10000	AHU Vent	47,185	33 111	
Internal Loads				:			Internal Loa	ds				Infil	17 824	17 824	
Linhis	140 57	8 552 313	702 801	13	134 274		Linhic				0.00	MinStop/Rh	0	0	
People	1 753 76	3 0	1 753 763	33	912 855	26	People		ő	0	0.00	Return	105 701	92.627	
Misc	562.36	7 0	562 367	11	554 533	16	Misc		178,595	178,595	-3.22	Exhauat	65,009	50,935	
Sub Total ==>	2 455 70	R 660 343	3 0 10 021		1 601 663	45	Sub Total		179 505	179 505	3 22	Rm Exh	0	0	
300 10001	2,400,70	0 302,313	3,015,021		1,001,005	40	300 7008		170,050	170,350	-0.22	Auxillary	293 886	293.885	
Celling Load	359.61	7 -359 617	0	0	361 014	10	Celling Loa	d	-317,779	0	0.00	Leakage Dwn	0	0	
Ventilation Load	-735.61	7 0	-735.617	-14	-817,756	-23	Ventilation I	Load	-565,474	-565.475	10.21	Leskage Line	0	0	
Adl Air Trans Hea	at	0	0	0	0	0	Adi Air Tran	s Heat	0	0	0	Trange obe	-	-	
Dehumid Ov Sizi	na	ē	0				Owillindr Siz	Inc	3	3	0.00	-			
Ovil Indr Sizing	124 83	6	124 835	2	124 836	4	Exhaust He	at		153,106	-2.76	ENGI		K.C.	
Exhaust Heat		-209,221	-209,221	-4	100.000		OA Preheat	DIT.		-1,030,648	18.61	LINOI	ILLINING C	113	
Sup. Fan Heat			0	0			<b>RA Preheat</b>	DIT.		0	0.00		Cooling	Heating	
Ret Fan Heat		1	1	0:			Additional F	teheat		0	0.00	% OA	113.2	79.4	
Duct Heat Pkup		-44,501	0	0:							126	cfm/ft <sup>=</sup>	0.12	0.12	
Underfir Sup Ht F	kup		0	0			Underfir Su	p Ht Pkup		0	0.00	cfm/ton	151.26		
Supply Air Leaka	ge	0	0	0			Supply Air I	Leakage		0	0.00	ft%ton	1,291.85		
							Leave and the second				1111100	Btu/hr-ftº	9.29	-10.21	
Grand Total ==>	4,816,79	4 375,619	5,236,914	100.00*	3,493,284	100.00	Grand Total	(=>	-4,382,698	-5,538,705	100.00	No. People	4,597		
	STREET, NR	COOLIN	G COIL SEL	ECTION	Rateros	-31	1000000000		AREAS	;	H	EATING COIL	SELECTIO	N	
	Total Capacit ton ME	h Sens Cap. MBh	Coll Airflow cfm	Enter D	B/WB/HR "F gr/lb	*F	F gn/b		Gross Total	Glass ft <sup>2</sup> (%)		Capacity MBh	Coll Alrilow	F T	
Main Cia	11.6 1.220	2 0/15	41 500	75.2 54	0 512	54.0 4	03 474	Floor	355 075	1.1	Main Hte	2 604 9	41 500	EE 2 192 -	
Aux Cig	34.8 6,417	0 5 057 0	293 885	72.0 59	9 61.2	55.1 5	20 55.6	Part	26,736		Aux Hto	-2,004.0	293.885	68.0 74.6	
OntVient	EAD 1050	4 1.0247	47 105	746 66	2 975	62.1 6	2.2 60.0	Int Door	20,100		Drohoat	0.000.2	230,000	0.0 0.0	
optivent	04.0 1,908.	- 1,064.7	47,185	14.0 00	.2 01.0	55.1 5	2.3 00.0	Ever	1 500		FIGURAL	0.0	U	0.0 0.0	
Toral	104 0794	6						Roof	69 901	0 0	Humidif	0.0		00 00	
rotar C	10.4 3,124	×.						Wall	77 855 3	7 640 48	Ont Vent	-10307	47 185	49.5 70.0	
							I	Ext Dress			Toral	-5 701 5	41,100	19.9	
								EXLOOOI	<b>U</b>	0 0	ruidi .	-0,101.0			

# System Checksums By PENN STATE UNIVERSITY

Hybrid GSHP w/ All DOAS Fan Coil Units w/ Façade Redesign

(Cooling 810.4 Tons, Heating 5701.6 MBH)

Core						0.00000		00000000				Ad	tive Chilled	l Bear	ns
	COOLING	COIL PEAK		c	LG SPACE	PEAK			HEATING	G COIL PEAK	TEMPERATURES				
Pea	ted at Time: Outside Air:	Mo OADB/WB/	/Hr: 9/15 HR: 79/63/1	57	Mo/Hr: OADB:	11 / 12 54			Mo/H OADE	ir: Heating Design B: 5		SADB	Cooling 55.0	Heating 68	ng 8.0
	Space Sens. + Lat.	Plenum Sens. + Lat	Net Total	Percent Of Total	Space Sensible	Percent Of Total			Space Pea Space Sen	ak Coll Peak Is Tot Sens	Percent Of Total	Return Ret/OA	74.1	66	5.2
Envelope Loads	Biun	Bturn	Bturn	(%)	Bturn	(%)	Envelope Lo	oada	Bou	n stun	(%)	Fn BidTD	0.0	ġ	0.0
Skylite Cond	0	0	0	0	0	0	Skylte Co	and		0 0	0.00	FN FNCt	0.0		1.0
Glass Solar	1,344,573	10,039	1,344,573	36	1,775,850	62	Glass Sol	ar ar		0 -104,390	0.00	A	RFLOWS		~
Glass/Door Cond Wall Cond Partition/Door	107,459	130,139	237,598	6	-267,716 19,637 -32,630	-9 1	Wall Cont Radition/	or Cond 1	-946,16 -195,41	9 -946,169 5 -436,872 8 -71,618	11.55	Diffuser	Cooling 49,222	Hea 60,	ting ,275
Floor Adjacent Floor	0	0	0	0	02,000	0	Floor	Floor	-5,14	1 -5,141	0.14	Terminal Main Fan	49,222 49,222	60, 60,	275
Inflitration Sub Total ==>	121,979 1,648,760	140,179	121,979 1,788,939	3 48	-238,727 1,256,414	-8 44	Infiltration Sub Total	==>	-854,54 -2,073,88	4 -854,544 6 -2,418,733	22.59 63.94	Sec Fan Nom Vent	0 50,752	32,	0 ,924
Internal Loads							Internal Loa	ds				AHU Vent Infil	50,752	32,	,924 ,708
Lights People	103,451 1,936,618	413,804 0	517,254 1,936,618	14 52	112,019 969,864	4 34	Lights People			0 0	0.00	MinStop/Rh Return	112,681	105,	906
Sub Total ==>	2,544,879	413,804	2,958,683	80	1,615,581	56	Sub Total	==>	178,59	176,595	-4.72	Rm Exh Auxiliary	00,409	40,	0
Celling Load Ventilation Load	170,078 -882,068	-170,078 0	0 -882,068	0 -24	115,325 -108,341	44	Celling Load	d Load	-143,44 -562,28	5 0 5 -562,285	0.00	Leakage Dwn Leakage Ups	0		0
Adj Alr Trans Hea Dehumid, Ov Sizi	t 0 19		0	0	0	0	Adj Air Tran Ov/Undr Siz	s Heat Ing		0 0 0	0.00			10	_
Exhaust Heat Sup. Fan Heat Ret. Fan Heat	-1,109	-143,092	-143,092	400	-1,109	Ŭ	OA Preheat RA Preheat Additional F	Diff. Diff. teheat		-1,067,053	28.21 0.00 0.00	% OA	Cooling 103.1	Heating 54	ng 4.6
Duct Heat Pkup Underfir Sup Ht P Supply Air Leaka	kup 19	-43,347 0	0	0			Underfir Su Supply Air I	p Ht Pkup Jeakage		0	0.00	cfm/ft <sup>=</sup> cfm/ton ft=/ton	0.19 183.68 948.19	0.	.24
Grand Total ==>	3,480,480	197,465	3,721,293	100.00	2,877,810	100.00	Grand Total	=>	-2,601,02	1 -3,782,712	100.00	Btuihr-ftª No. People	12.66 4,167	-4.	65
	Total Capacity ton MBh	COOLING Sens Cap. MBh	Coll SEL Coll Airflow cfm	ECTION Enter DB/ "F "F	WB/HR	Leave *F	DB/WB/HR *F gr/b	6	AREA Gross Total	AS Glass ft <sup>2</sup> (%)	HE	EATING COIL Capacity MBh	SELECTIO Coll Airflow cfm	N Ent 'F	Lvg
Main Cig 1 Aux Cig 2	07.8 1,294.0 02.3 2,427.3	279.5 2,427.3	40,611	74.1 60.7 72.0 59.9	61.2 61.2	54.0 4 65.5 5	9.0 45.8	Floor	254,088 9,136		Main Htg Aux Htg	-114.6 -2,194.3	60,275	66.2 0.0	68.0 0.0
Opt Vent 1	50.1 1,921.6	996.0	50,752	71.5 65.1	86.8	53.1 5	2.4 60.0	Int Door ExFir	408		Preheat	0.0	o	0.0	0.0
Total 4	70.2 5,642.9							Roof Wall Ext Door	56,277 39,731 0	0 0 17,053 43 0 0	Humidif Opt Vent Total	0.0 -1,067.1 -3,375.9	0 50,752	0.0	0.0 70.0

#### System Checksums

By PENN STATE UNIVERSITY

Core of Central Plant w/ ACB/DOAS FCU w/ Façade Redesign

(Cooling 470.2 Tons, Heating 3375.9 MBH)

Perimeter														4-pipe Ir	ducti	on
	C	DOLING C	OIL PEAK			CLG SPACE	PEAK			HEATING	COIL PEAK		TEM	PERATURE	s	
Pe	aked at Outsi	t Time: de Alr:	OADB/WB/	(Hr: 7 / 15 HR: 86 / 71 / 1	95	Mo/Hr: OADB:	7/15 86			Mo/Hr. OADB:	Heating Design 5		SADB	Cooling 55.0	Heatil 124	ing 4.0
	S	Space ens. + Lat. Btw'h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)			Space Peak Space Sens Btu/h	Coll Peak Tot Sens Btu/h	Percent Of Total (%)	Ra Plenum Ret/OA Fn MtrTD	76.3 76.3 0.0	66	4.0
Envelope Loads Skylite Solar Skylite Cond		0	0	0	0	0	0	Envelope Lo Skylite So Skylite Co	bada Ilar Ind	0	0	0.00	Fn BloTD Fn Frict	0.0	c r	0.0
Roof Cond Glass Solar		613,061	12,654	12,654 613,061	40	575,849	0 50	Roof Con Glass Sol	d ar	0	-25,917 0	0.89	A	RFLOWS		
Glass/Door Cor Wail Cond Partition/Door Floor Adjacent Floor Inflitration Sub Tota/ ==>	nd	183,168 154,818 13,490 0 150,031 1,114,567	0 250,270 0 262,924	183,168 405,088 13,490 0 150,031 1,377,492	12 26 1 0 10 90	235,150 127,802 16,744 0 61,726 1,017,272	21 11 0 5 89	Glass/Do Wall Con Partition/I Floor Adjacent Infitration Sub Total	or Cond d Door Floor	-1,158,658 -200,890 -137,968 -13,860 0 -353,909 -1,865,284	-1,158,658 -522,060 -137,968 -13,860 0 -353,909 -2,212,371	39.82 17.94 4.74 0.48 0 12.16 76.03	Diffuser Terminal Main Fan Sec Fan Nom Vent	Cooling 25,275 25,275 25,275 0 16,470 16,470	Hea 25, 25, 25, 20	ting ,275 ,275 ,275 ,275 0 ,224
Internal Loads								Internal Loa	da				Infli	5,263	5	263
Lights People		40,752	163,007 0	203,759 156,664	13 10	37,900 96,578	3	Lights People		0	0	0.00	MinStop/Rh Return	47,008 21,733	50,	0 762 487
Sub Total ==>		254,856	163,007	417,863	27	194,544	17	Sub Total	==>	0	ő	0.00	Rm Exh Auxillary	0 83.744	83	0
Celling Load Ventilation Load	1	129,299	-129,299 0	-236,242	-15	127,498 -271,428	11 -24	Celling Load	l Load	-132,392 -345,385	-345,385	0.00	Leakage Dwn Leakage Ups	0		0
Adj Air Trans He Dehumid. Ov Siz Ov/Undr Sizing	at zing	0 78.923		0 78.923	0	0 78,923	0	Adj Air Tran Ov/Undr Siz Exhaust He	s Heat ing at	0	0 1 107,798	0 0.00 -3.70	ENGI		KC	
Exhaust Heat Sup. Fan Heat Ret. Fan Heat			-100,235	-100,235 0 0	-7			OA Preheat RA Preheat Additional F	Diff. Diff. teheat		-460,059 0 0	15.81 0.00 0.00	% OA	Cooling 65.2	Heati	ng 0.0 24
Underfir Sup Ht Supply Air Leak	Pkup age		0	0	0			Underfir Su Supply Air I	p Ht Pkup Jeakage		0	0.00	cfm/ton ft=/ton Bhumr.ft=	199.45 832.07 14.42	-19	71
Grand Total ==>		1,341,404	196,398	1,537,801	100.00	1,146,809	100.00	Grand Total	=>	-2,343,060	-2,910,016	100.00	No. People	426		
	Tota ton	al Capacity MBh	COOLING Sens Cap. MBh	COIL SEL Coll Airflow cfm	ECTION Enter De	B/WB/HR 'F gr/lb	Leave *F	DB/WB/HR 'F gr/b	G	AREAS Gross Total	Glass ft <sup>z</sup> (%)	HE	EATING COIL Capacity MBh	SELECTIO Coll Airflow cfm	N Ent F	Lvg
Main Cig Aux Cig	56.4 158.8	677.0 1,905.6	577.2 1,552.7	25,275 83,744	76.3 61. 72.0 59.	.4 61.2 .9 61.2	55.0 51 55.0 51	.9 55.1 .7 54.4	Floor Part	105,444	100	Main Htg Aux Htg	-1,618.3 -786.5	25,275 83,744	64.0 1 68.0	124.0
Opt Vent	70.3	843.7	464.9	20,224	74.6 66.	.2 87.5	53.1 52	.3 60.0	Int Door ExFir	1,100		Preheat	0.0	0	0.0	0.0
Total	285.5	3,426.3							Roof Wall Ext Door	14,488 47,308 2 0	0 0 3,445 50 0 0	Humidif Opt Vent Total	0.0 -460.1 -2,864.8	0 20,224	0.0 48.7	0.0

#### System Checksums By PENN STATE UNIVERSITY

Perimeter of Central Plant w/ ACB/DOAS FCU w/ Façade Redesign

(Cooling 285.5 Tons, Heating 2864.8 MBH)