Tech Report 2: Building and Plant Energy Analysis Report

PHARM CORP.

Pills, Delaware

Advisor: Dr. Bahnfleth

Option: Mechanical

Ryan Schulok

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EXECUTIVE SUMMARY

Technical Report 2 analyzes the energy consumed by the building and plant annually for Pharm Corp, located in Delaware. The information from this report was gathered from the mechanical and architectural drawings provided by both AKF Group, and Granum A/I.

With the use of Trane Trace 700, the building was modeled and analyzed for energy consumption, peak design load and operating cost throughout a year. All of the assumptions and schedules were either provided by AKF Group, such as occupancy and ventilation rates, or based on general office operating schedules selected in Trane Trace 700. ASHRAE 62.1 was used for ventilation rates. ASHRAE 90.1 was used for lighting power density values through office space, atrium space and dining areas.

The cooling plant modeled is a closed-circuit cooling tower providing condensate to a water-cooled DX AHU. Heating is provided by the air-side economizer at the unit, with additional electric reheat coils in the VAV terminal unit boxes. Perimeter heating is at all the curtain walls and windows.

The cooling load calculated by Trane Trace 700 is 627.4 SF/ton compared to the design documents value of 505.2 SF/ton. The cooling load has a relationship with electric demand, along with the temperature fluctuation. Both cooling and electric demand increase as a function of temperature, as found from Trane Trace.

Heating loads are low, being 9.0 BTUh/SF from Trace and 7.9 BTUh/SF from the design documents. Minimal values are concluded to be due to economizer usage, along with possible overestimation of lighting and equipment loads. Outdoor air ventilation in Trane Trace is 14%, which was the designed outdoor air intake for the mechanical equipment in the design documents.

Mechanical energy consumption within the building, from Trace, was 19% for Heating Plant, 32% for Cooling, 28% for Lighting and 11% for both Fans and Receptacles. The entire cost for the mechanical system, including maintenance, electricity and water, the total operating cost is $1.70/SF. The overall electric load demand of 1.7 kWh creates the byproduct CO_2 of over 2.7 million lb/year.

BUILDING OVERVIEW

The entire building is being evaluated within this report. Two wings are mirrored across a symmetric line of 22.5° reference line from the horizontal shown in blue, in Figure 1. The dashed black lines indicate the separation between the West wing, the central core, and the East wing. This general footprint is repeated in the upper floors, with slight modifications and offsets to create sustainable external green roof terraces, along with an architectural change in the façade.

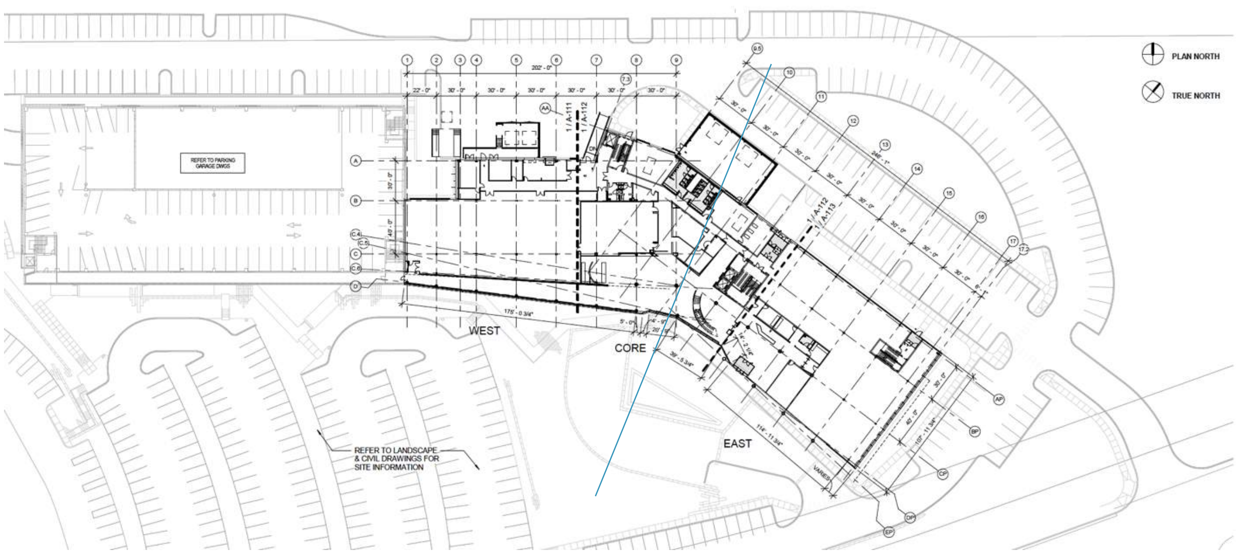

Figure 1. Site plan of building, illustrating West, Core and East, with mirror line of 22.5°.

The angled in elevation faces the South elevation of the site, reducing the length of exposed building envelope from the southern heat gain through the glass. The lengthier elevation is on the North façade, encouraging natural light to enter the space. Shown in the schematic in Figure 2 is the south façade, which features a 4-story atrium faced with glass.

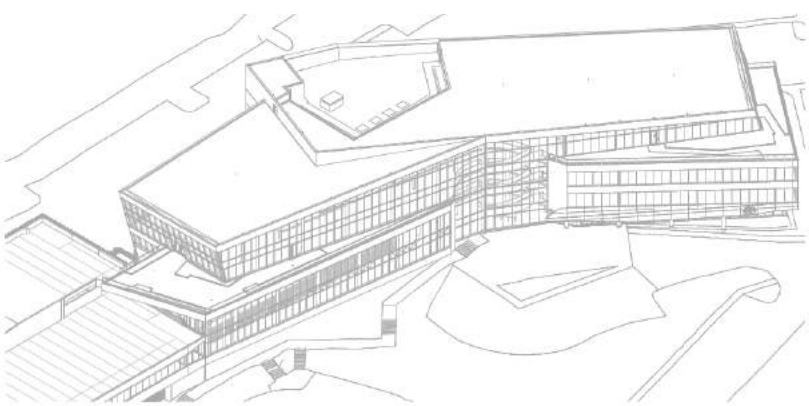

Figure 2. Angled South façade, showing exposure of glass for atrium.

Optimizing entry of light in the morning to initially heat up the space, while rejecting heat gain from the sun in the afternoon is a strategy that was taken in this building. East facing curtain wall glass was angled inward, gathering the maximum amount of heat gain from the space. The West curtain wall façade, leaning outward, fights internal heat gain from the sun in the afternoons.

As far as the interior of the building, it is composed of mostly office space, with an atrium on the South façade extending the 4-story vertical length, and a 2-story dining area on the third floor. The third floor is also where a fully functioning 10,000 kitchen exists. Figure 3 emphasizing the view one would have form the second floor looking at the 4-story atrium that contains a glass-railing curved staircase and a floor-to-ceiling curtain wall.

Figure 3. Atrium view from second floor office space.

MECHANICAL OVERVIEW

Each floor in this building contains two mechanical rooms: one serving the West wing and Core areas and one serving the East wing. The mechanical rooms house one air-handling unit (AHU), which contains an air-side economizer with enthalpy control. The perimeter mechanical room brings in outdoor air through a louver. Figure 4 is an example of the typical AHU set up that resides in each mechanical room.

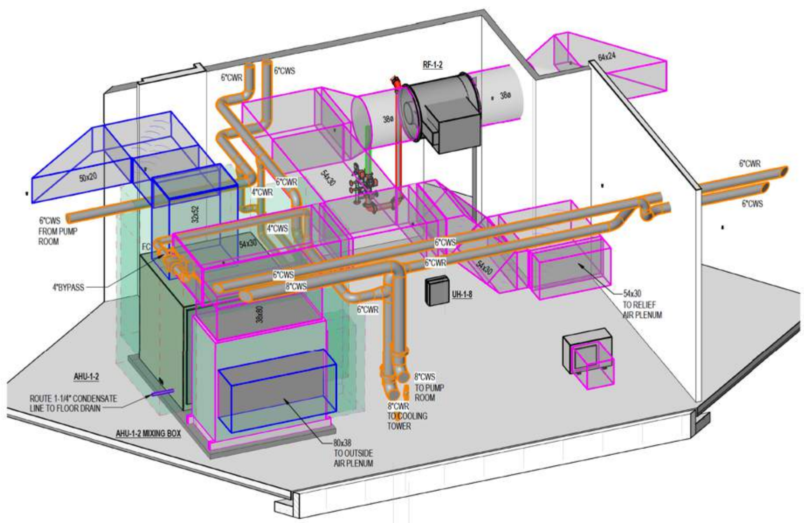

Figure 4. Typical isometric mechanical room layout.

The air is drawn through by the return air fan, shown in gray. Air then is controlled by the economizer, detecting the temperature and enthalpy of the room air and comparing it to the air entering from the outdoors. If the outdoor air can handle the load, the outdoor air damper opens and reduces the amount of recirculated air.

The return air is then sent through the relief air plenum and out of the building. If the outdoor air conditions are insufficient for the space, then the minimum outdoor air is brought in, and the remaining return air is recirculated, mixed with the outdoor air and sent through the air handling unit to be conditioned. States were the economizer can be utilized partially, the outdoor air damper allows the correct amount of air the enter, determined by the economizer, and the remaining airflow is taken from the recirculated return air, mixed and conditioned in the AHU. The two paths of the return air are shown in pink in Figure 4 above.

Depending on the season, the air is either cooled or heated. The mixed air combination entered a filter of MERV-8 to remove particulate from the air that may be dangerous to inhale. If the system is cooling, the load is determined in the space and the cooling coil valve reacts. Once the desired temperature, VAV terminal boxes control how much air is sent to satisfy the load. Ceiling diffusers disperse the air within the space. For part load conditions where the cooling coil cannot be reduced anymore, electric reheat coils are placed in the VAV boxes to increase the supply air temperature.

For a heating condition, similar steps are taken in the beginning. The air is filtered, but the heating valve opens to heat the air. However, for heating in this building, there are two conditions that take place. For perimeter zones, the minimum amount of outdoor air is heated and sent to the space. The remainder of the load is served by electric baseboard heating, usually placed underneath windows or curtain wall glass. Figure 5 shows where baseboard heating is located on the first floor. For interior spaces, the space is strictly heated from the AHU and supplied from the VAV boxes. The economizer, when utilized, recirculated return air, offsetting the heating energy that has to be used.

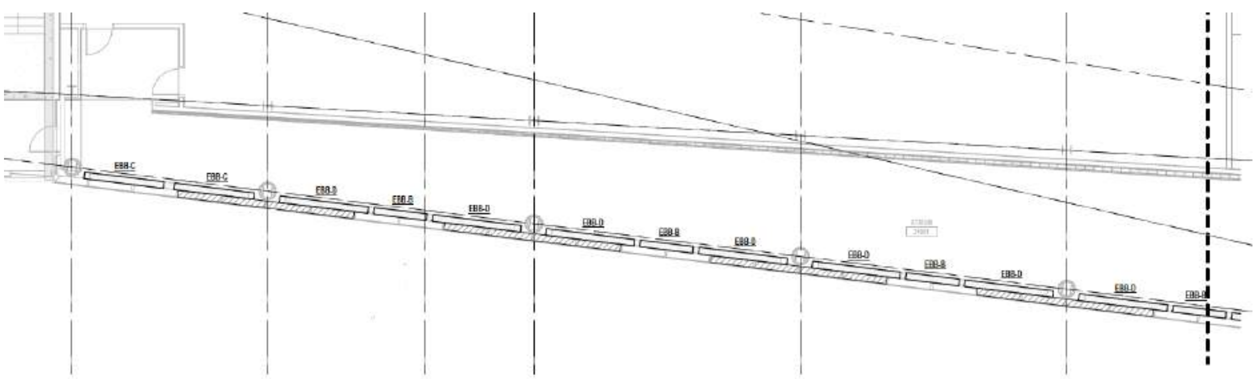

Figure 5. Electric baseboard locations in atrium.

LOAD ESTIMATIONS

Design Conditions

Location

The site of Pharm Corp. is located in Delaware, classifying it as a 4A zone, indicating it is a warm, moist area. A temperature range model was constructed for the average high and low temperatures throughout the year. Figure 6 displays the variation in temperatures, with the average high peaking at 86°F for the cooling season and the average low dropping to 25°F during the heating season. Rainfall at this site is consistent annually, ranging approximately 3”-4” per month, totaling an annual approximation of 43”-48”.

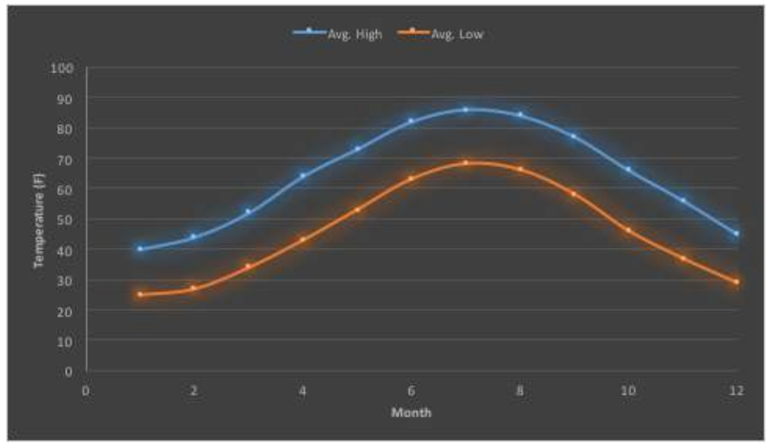

Figure 6. Annual average temperature fluctuation.

From the ASHRAE Handbook of Fundamentals 2009, the outdoor air design temperatures were selected at the 99.6% and 0.4% conditions for winter and summer, respectively. The table to the right shows what ASHRAE states as the design conditions are for Delaware.

Table 1. Pharm Corp. outdoor air design conditions.

Conditions	Temperature	
	DB	WB
Summer (0.4%)	91.9	75.1
Winter (99.6%)	11.7	-

Building Construction

Upon entering this building, one walks into a 4-story atrium faced with a floor-to-ceiling curtain wall, housing a curvature staircase. This continuous system is Wall Type 1, which is strictly a curtain wall glass system design. Continuing through the building, to either the West or East of the atrium resides office space with an envelope wall assembly of Wall Type 2, which is a combination of a metal wall panel assembly and a curtain wall glass system. Curtain wall percentages fluctuate between 25-30%, depending on the elevation of the building, so the U-value used was the 30% glass. The final wall assembly, Wall Type 3, is strictly a metal wall panel construction. Location of this wall type is on the North side of the building where the mechanical rooms, restrooms and any facilities are located.

Table 1 and Figure 7 below show the wall construction U-values along with their location in the building.

Table 2. Building construction wall assemblies with thermal U-values.

Assembly Name	Description	U-Value
Roof	Occupied terrace roof area, insulation above deck	0.03
Wall Type 1	Curtain wall glass system ONLY	0.46
Wall Type 2	30% Curtain wall / 70% Metal wall panel	0.1695
Wall Type 3	Metal wall panel ONLY	0.045

Figure 7. Different wall type locations.

Angled glass on the East side leans inward, curtain wall system A, allowing the light to enter the space. Some of the East side glass, curtain wall system B, is vertical, allowing sunlight to enter during all seasons. These are heating strategies in the winter to get early natural heat from the sun to heat the space. Curtain wall system C on the West face prevents sun from entering in the summer, to easily maintain the design set point, while some sunlight can enter during the low azimuth sun level in the winter. The different sloping glass walls can be seen in the Figure 8 below.

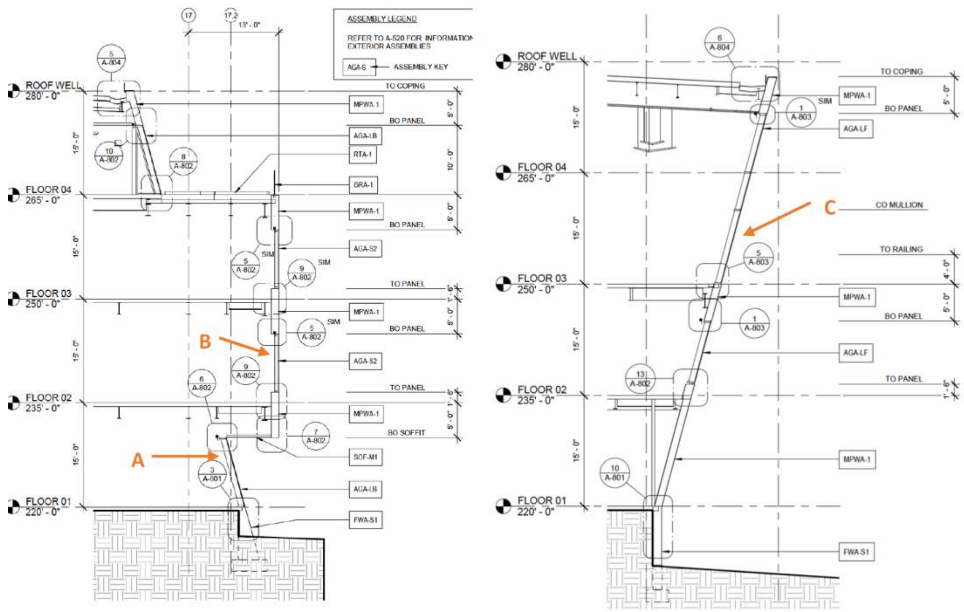

Figure 8. Curtain wall systems.

*Note: AGA=angled glass assembly, MWPA=metal wall panel assembly

Load Assumptions

Occupancy and Ventilation

Occupancy densities were selected by Pharm Corp. There are three types of occupancies in this building that needed to be determined. For an office zone, the design criteria is143 SF per person, which results in 7 people per 1000 SF. ASHRAE has an occupancy density value of 5 people per 1000 SF, so the default value is less than the desired number of employees per 1000 SF.

For the dining area, it was designed to fit up to 300 people on a regular occupancy schedule, but can accommodate 700 people during a town hall meeting, taking place four times a year in the space. The adjacent kitchen will also have a designed number of workers in it, which was chosen to be 30 people. All of these densities were entered into Trane Trace 700 to calculate the appropriate ventilation rates needed.

Thermostat Set Points

The MEP engineers, AKF Group, selected the indoor air design conditions for Pharm Corp. The cooling season condition changes between the space types, while the heating condition remains the same. Appendix A contains a psychrometric chart of the procedure that the air goes through in the cooling case for the typical office.

Table 3. Design constraints for each space type.

Space Type	AHU Equipment	Design Constraints			
		Occupied		Lighting	Equipment
		Heating	Cooling	[W/SF]	[W/SF]
Food Prep/Dining	AHU-3-1	72°F	80°F / 50% RH	1.2	25
Atrium	All Others	72°F	74°F / 50% RH	0.6	0.5
General Office Space	All Others	72°F	74°F / 50% RH	1.0	2

Lighting and Equipment

The allowance for the lighting load was also selected AKF Group. Table 3 shows the interior lighting heat rejection allowances that may add to the load of the space. These values are in accordance to Table 9.6.1 of ASHRAE Standard 90.1-2010. The lights selected provided 80% of its heat rejection into the space, with 20% of the heat going into the plenum.

The equipment heat rejection allowance for the atrium and general office space was determined by Trane Trace 700. With the office space not being assigned a specific usage, the upper end of 2 W/SF was used for the office equipment load. The kitchen contains many pieces of equipment constantly being used, so the threshold for equipment heat rejection is 25 W/SF. This correlates to a higher designed cooling condition as shown in Thermostat Set Points. This is also the reason that the heating condition did not change for this space, since the equipment is going to be generating heat into the space.

Schedules

Determining the schedule for a headquarters of a company was assumed to be fully operational between the normal working hours of 8 am – 5 pm, Monday through Friday. Although the headquarters can operate past these general operating office hours, the slightly overestimated W/SF for the office space allows for it. All of the schedules were designed the same way – lighting and equipment usage.

The schedule that was difficult to design for is the four-times a year town hall meeting that will take place in the dining area and would be operating outside of the normal business hours. For simplicity and reasonable economic numbers, this was not accounted for.

Zoning

For the block load that was computed, the perimeter zone and interior zones had to be separated consistently to provide accurate data. Perimeter zones were designed with 15 feet depth into the space from the exterior exposed wall. If the perimeter zone had a wall that was located near the perimeter zone that separated the interior and perimeter zone, then that length was taken for those areas. This can be especially seen in Figure 9 for the left image. 1W Atrium zone is slanted due to the interior wall.

The figures below illustrate some of the zones that were designed to show the approach taken. The nomenclature remained the same throughout all of the floors to provide consistency when reading the zone loads. Appendix B contains all of the system checksums with their heating and cooling loads, along with the required airflow needed. The take on the same nomenclature system as in Figure 9.

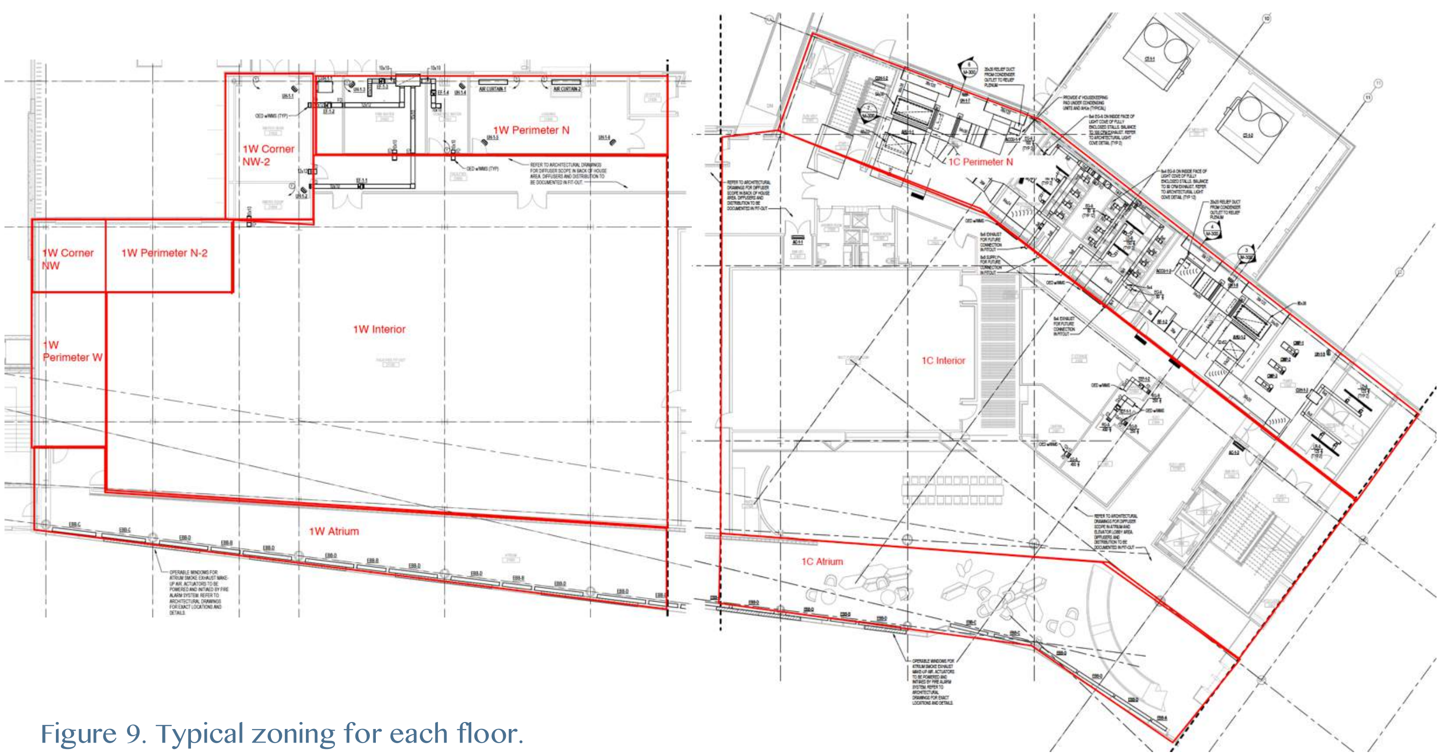

Figure 9. Typical zoning for each floor.

System Equipment

Air-side Equipment

The air-side equipment that is used within this building are air-handling units to VAV terminal unit boxes that provide cooling to all of the spaces. Two 270-ton closed circuit cooling towers are used to provide condenser water to the air-handling units in the mechanical room. Each air-handling unit fluctuates on its demanded load, which will be visible in the next section. The heating system has electric reheat coils in the VAV boxes for interior zones. All the perimeter zones have their heating demand satisfied by the electric perimeter baseboard heaters. Both the heating and cooling air-side equipment utilize an economizer, when ambient temperatures allow for it, to offset the cooling and heating load.

Overall Heating and Cooling Loads

With all of the load assumptions and air-side equipment being input into Trane Trace 700, the cooling load, heating load, and airflow amounts were determined for the block load. Table 4 is a breakdown of all the calculated amounts, and are compared to the design documents that were provided.

Table 4. Comparison between computed loads and design document loads.

Design Method	Cooling		Heating		Airflow	
	Peak Load [tons]	Per SF [SF/ton]	Peak Load [MBH]	Per SF [BTUh/SF]	Total Supply Air [cfm/SF]	Total Ventilation Air [cfm/SF]
Trane Trace 700 Computed Loads	239.1	627.4	1355	9.0	0.60	0.14
Design Document Computations	296.9	505.2	1187	7.9	0.98	0.19

Comparing the values from Table 4, the cooling load is not as great. Trace provides the ventilation needed to satisfy the capacity based on the load assumptions stated above. For a block load, the assumed occupancy for the desired schedule that was selected may differ from the design document values that were calculated by the MEP engineer. The air change rate may have been adjusted in the design documents, decreasing the amount of square footage that a ton of cooling could satisfy.

Relating the heating values, they are within 12% of each other when comparing the BTUh per SF. The values seem relatively low compared to what one would expect, but the reasoning is that a majority of the heating that is provided is not from the units; rather it is from the perimeter baseboard heating. Other interior heating loads are small due to the occupancy density, lighting loads and equipment loads. Those small loads can be partially met from the air-side economizer, mixing the maximum recirculated air with the minimum outdoor air ventilation rate value.

With the computed tonnage from Trane Trace being less than the design documents, it also decreased the amount of air that is being supplied per SF of the building, and the percentage of outdoor air per SF that is being supplied. The MEP engineer designed the system to have a value of approximately 1 CFM/SF, which is their general design guideline for an office building. They also designed their AHUs to have a minimum of 20% outdoor air, which is the lowest threshold that the air-side economizer was designed for.

The units that were selected originally were designed for 15% outdoor air, and then later increased to 20% for the economizer. So as for the outdoor air rate that was calculated by Trace, the value is accurate to the initial design.

Load Source Description

The three main load sources are envelope load, internal load and ventilation load. For the cooling case, the main areas that add load to the space are through glass solar, lighting, people, miscellaneous equipment, and ventilation. The internal load is 43% of the total load, followed by envelope load of 27% and then ventilation with 25%. These three are the majority of the load, summing to 95% of the created load.

As for cooling, the same three main load sources are envelope, internal and ventilation loads. The percentages responsible for the increase in demand heating are different, however. The ventilation load is responsible for creating 49% of the load, above the envelope load at 36% and surpassing the return air reconditioning of 16%.

Conclusion

The main driving force behind the computed values from Trane Trace 700 refers back to the load assumptions that were designed for. The occupancy density increases the amount of load radiated from individuals, and the schedule for the occupants will reflect on how much full-load cooling will be brought to the space. Increasing the occupancy schedule will correlate to an increased lighting schedule and equipment schedule.

The other variable would be the zoning that was selected. The perimeter depth into the space will affect how much floor area Trace registers as being influenced from heat transfer through the envelope. The more area influenced by the heat transfer results in larger cooling loads, increased amounts of airflow and decreased square footage per ton.

ANNUAL ENERGY CONSUMPTION

Fuel Consumption

Pharm Corp. was designed with mechanical equipment that only operated by electricity. The pie graph on the right shows the ratios of energy per each category that uses electricity within the building. The largest consumption is for the lighting load, with the majority of the building being 9-hour office space. The categories that were compared are: Heating Equipment, Cooling Equipment, Auxiliary Fans, Lights, and Receptacle Loads.

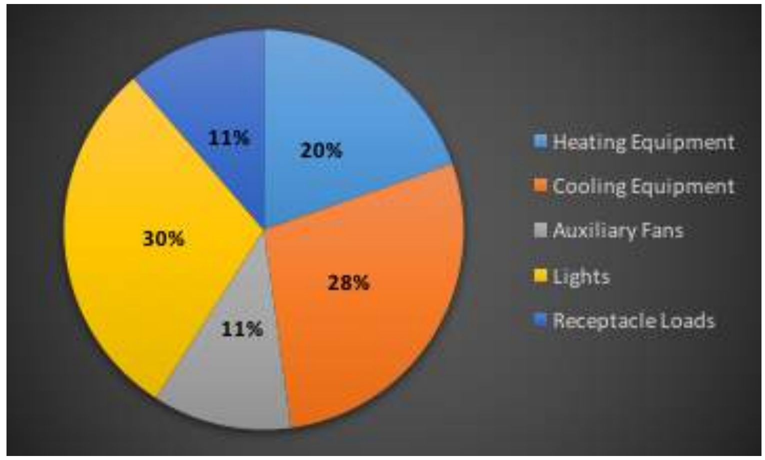

Figure 10. Ratios of electric usage.

Delaware has approximately the same heating and cooling seasons, with cooling edging out heating due to the internal heat gain from lights, equipment and people. The receptacle load is the lowest of the categories due to not all of them being used at once. This is from the 50% diversity factor when calculating receptacle loads. The equation below shows how a receptacle load is computed:

$$Rec. Load = 100\% * (1st\ 10{,}000\ kWh) + 50\% * (any\ additional\ receptable\ kWh)$$

Investigating the electricity consumption when looking at the cooling load profile, there is a strong relationship. As the cooling load increases, the electricity demand needed also increases, generally in the same shape. This correlation can be viewed in the right figure.

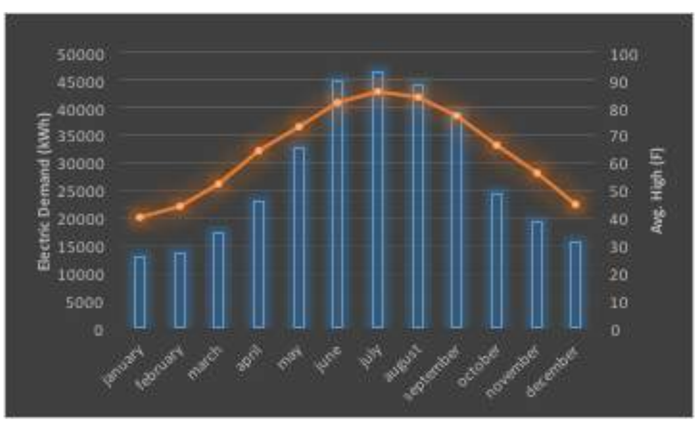

Figure 11. Cooling load profile v. electric demand.

A monthly breakdown of each electric consuming category is located in the cluster bar graph in Figure 12. There are two main takeaways from this figure that are helpful. The lighting electric demand and the fan electric demand are approximately consistent throughout all of the months. This is equivalent to a "baseload" demand. They do not change so they are easy to approximate. The other loads, cooling and heating, are "dynamic" loads. They are influenced throughout the year from the temperature difference. Besides January, most of the months are approximately the same. As the cooling loads decrease, the heating load for that month increases.

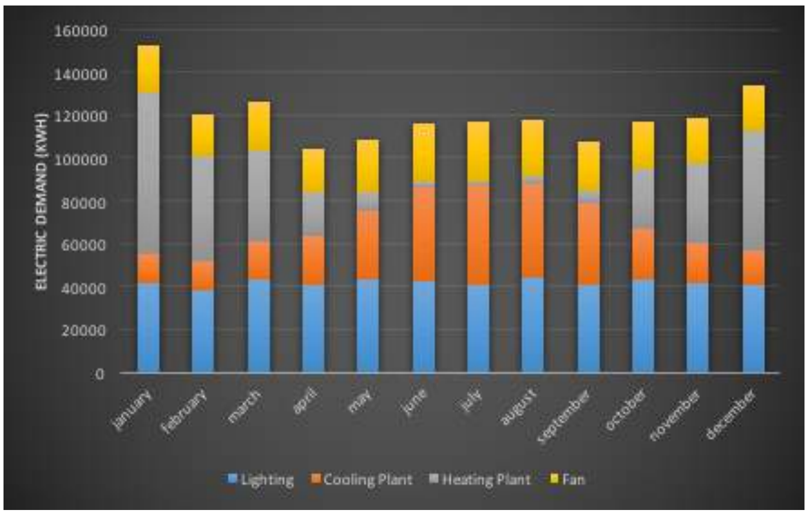

Figure 12. Monthly electric demand breakdown.

Water Consumption

Water usage in the mechanical system is for the two 270-ton closed-circuit cooling towers. The tower uses three 810 GPM condensate pumps to provide condensate to the water-cooled DX air handling unit. The water consumption is graphed below. Analyzing this graph, it takes on the same profile as the average high temperature profile for the site. This demonstrates the dependence of condensate water needed to meet the cooling demand load as temperature fluctuates.

The peak amount of water used is in July, being 312,000 gallons, with the annual amount of water being approximately 2.1 million gallons.

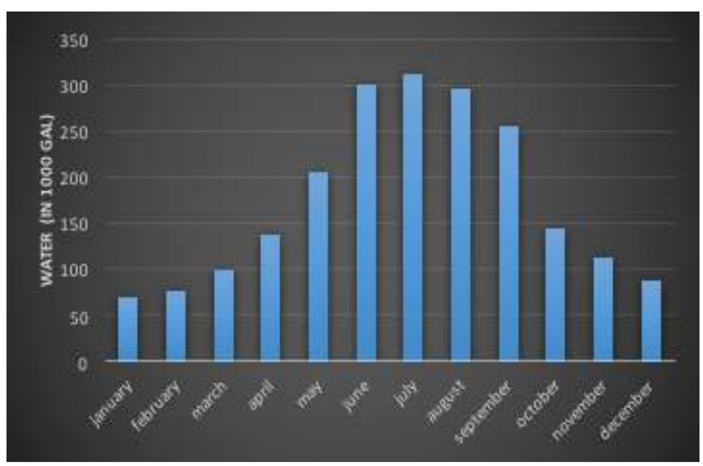

Figure 13. Monthly water demand.

Existing Energy Model

AKF Group performed an energy model analysis of Pharm Corp. The analysis was based on protocol of ASHRAE 90.1-2010 Section 11 Energy Cost Budget (ECB) method. The design proposed cost cannot exceed the energy cost budget for the building. eQUEST v3-64 was the program used. Courtesy of AKF Group, figures of the design schedule are provided below, in Figure 14.

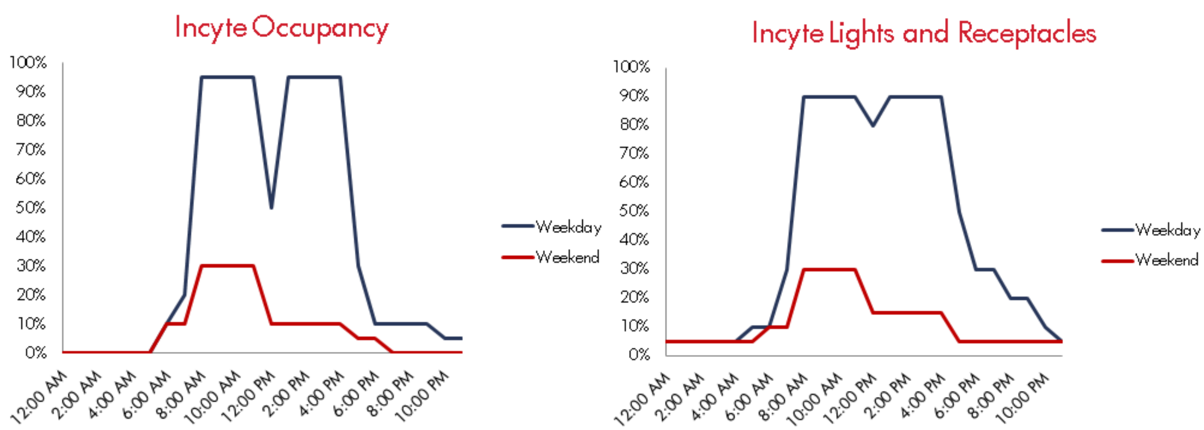

Figure 14. Schedules created by AKF Group in eQUEST.

Comparing these results to the schedule described in the Load Assumptions section, the approximations are the same for the weekdays, with the weekends being different from the general office operating hours. The lighting profile is assumed to be 90% operative throughout the main operating hours.

Lighting power density values were taken from Table 9.6.1 from ASHRAE 90.1-2010, which is the same table as the assumptions prompted above. Their annual energy consumption values are in Figure 15.

The blue bars are the proposed design while the gray bars are the energy cost budget model, which cannot be exceeded. The space heating energy exceeds the proposed design, which concludes that it may be necessary to re-evaluate the heating method that was proposed within the building.

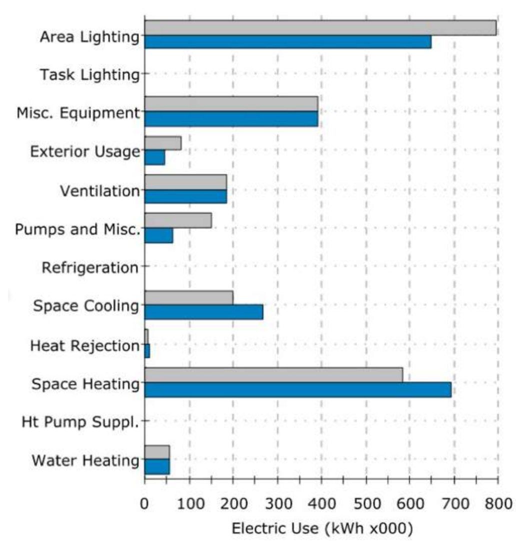

Figure 15. Conducted energy model analysis.

Annual Consumption Results

Using the same schedules as in the Load Assumptions section, which are occupancy being from 8 am – 5 pm, lighting and equipment operating the same hours as occupants are there, the values for annual water consumption and air rates were calculated. The air rates to the space are affected by the load that needs to be met. The increasing load has a strong relationship with the electric demand for the building. As the rate of cool air to the space decreases, there is an increase in the warmer air that is being distributed.

Electric is the only fuel-type that is used within the building, which is the most efficient energy source on-site, while it is the least efficient source off-site, since it is 33% efficient during it generation, transportation and distribution (GTD). The result that stands out the most is the electric use for all of the heating for the space, which includes both VAV heating and baseboard heating. The baseboard heating is nearly the entire demand for the space heating, since the VAV heating that is used, being 9 MBH/SF, is also accommodated by the air-side economizer, reducing the electric demand for the coils. This would be the area to investigate more to become more energy efficient and reduce the electric demand in the building.

ANNUAL OPERATION COSTS

Building Energy Costs

The three main factors that were taken into account for building cost due to mechanical equipment were the cost of the fuel, cost of the water for the equipment, and maintenance cost to keep the equipment running properly. The unit cost for maintenance was taken from Trane Trace 700, being $0.50/(SF*yr). Electric costs and water costs were taken from the utility cost for the site in Delaware, being $0.1008/kWH and $4.88/ 1000 gal, respectively.

Referring to Table 5, the cost breakdown is provided for the overall energy categories. As expected, the electricity cost on site accumulates for nearly $170,000 per year, approximately 67% of the mechanical consumed energy.

Table 5. Operating cost per system in building.

Category	Maintenance Cost [$/(SF*yr)]	Electricity [$/kWh	Water [$/1000 gal]	Total Operating Cost [$]
Unit Cost	0.50	0.1008	4.88	
Multiplier	150,000 SF	1683206 kWh	2,100,000 gal	
Cost [$]	$ 75,000.00	$ 169,667.16	$ 10,248.00	$ 254,915.16

Subsystem Energy Costs

Breaking down the analysis further, the electric usage was divided into each subsystem that was evaluated: Cooling Plant, Heating Plant, Lighting, Auxiliary Fans and Receptacle Loads. The water cost was added to the cooling plant condition, since the cooling towers use the water to provide condensate temperatures to the chiller. The cost breakdowns are in Table 6, with Figure 16 supplementing it.

Table 6. Subsystem cost breakdown.

Energy Consumer	Electricity	Water	Total Cost	Percentage of Total Cost	Area Cost [$/(SF*yr)]
Heating Plant	$ 33,304.92	-	$ 33,304.92	19%	$ 0.22
Cooling Plant	$ 47,827.68	$ 10,248.00	$ 58,075.68	32%	$ 0.39
Auxiliary Fans	$ 19,108.96	-	$ 19,108.96	11%	$ 0.13
Lighting	$ 50,259.18	-	$ 50,259.18	28%	$ 0.34
Receptacle Loads	$ 19,166.40	-	$ 19,166.40	11%	$ 0.13

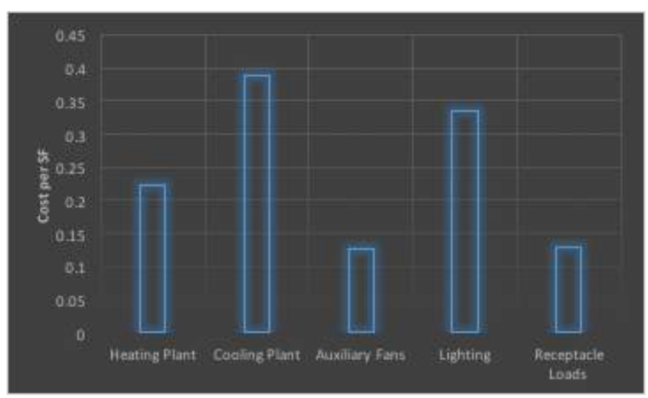

Figure 16. Cost per square foot per subsystem.

Correlating the numerical values to the graphed bars in Figure 16, the cooling plant is the highest cost per SF of energy. Electricity cost is 80% of that total, with water completing the other 20% of the cost. Lights are the annual largest consumer of the electricity in the building, with the receptacle loads and fans being the smallest at $0.13/SF per year. The conducted energy model by AKF Group uses much more energy than that calculated by Trace. The difference between eQUEST and Trane Trace 700 may allow different user control for load assumptions, schedules and level of detail. Recommendations for reducing energy can still be made.

Emissions

Pollutant Emissions

Electric is the only energy source used on site, so evaluating the emission rates for the pollutants of concern, CO_2, NO_x and SO_x were taken from the total emission factors for grid delivered electricity, displayed in Figure 17. Breaking down the process for electricity, it has to go through three phases until it gets into the building for use. It has to be generated at the power plant, it has to be transported to the site which may be far from the power plant, and then has to be distributed throughout the building to all of the needed electric demands. Once this process is complete, the efficiency for the electric is reduced to 33%. Once the electricity is in the building and running equipment, lights and assisting in demand loads, the efficiency is 100%. The overall efficiency then is 33% for electric.

Table 7. Emission pollutant per year.

Pollutant	Electricity Demand	Emissions [lb/year]
CO2	1683206	2760458
NOx	1683206	5050
SOx	1683206	14425

Pollutant (lb)	National	Eastern	Western	ERCOT	Alaska	Hawaii
CO_{2e}	1.67E+00	1.74E+00	1.31E+00	1.84E+00	1.71E+00	1.91E+00
CO_2	1.57E+00	1.64E+00	1.22E+00	1.71E+00	1.55E+00	1.83E+00
CH_4	3.71E-03	3.59E-03	3.51E-03	5.30E-03	6.28E-03	2.96E-03
N_2O	3.73E-05	3.87E-05	2.97E-05	4.02E-05	3.05E-05	2.00E-05
NO_x	2.76E-03	3.00E-03	1.95E-03	2.20E-03	1.95E-03	4.32E-03
SO_x	8.36E-03	8.57E-03	6.82E-03	9.70E-03	1.12E-02	8.36E-03
CO	8.05E-04	8.54E-04	5.46E-04	9.07E-04	2.05E-03	7.43E-03
TNMOC	7.13E-05	7.26E-05	6.45E-05	7.44E-05	8.40E-05	1.15E-04
Lead	1.31E-07	1.39E-07	8.95E-08	1.42E-07	6.30E-08	1.32E-07
Mercury	3.05E-08	3.36E-08	1.86E-08	2.79E-08	3.80E-08	1.72E-07
PM10	9.16E-05	9.26E-05	6.99E-05	1.30E-04	1.09E-04	1.79E-04
Solid Waste	1.90E-01	2.05E-01	1.39E-01	1.66E-01	7.89E-02	7.44E-02

Table 17. Total emission factors from delivered electric, in lb/yr.

This low efficiency generates a lot of pollutants, in pounds per delivered kWh. Table 7 is the calculated emission rates for the building for CO_2, NO_x and SO_x. Carbon dioxide is the largest pollutants, followed by SO_x and finally NO_x. With operating costs superseding environmental effects of the chosen energy source, the emission rates result in extreme values.

Overall, the emissions can be reduced if a different fuel source was used for heating space loads, which is worth looking into.

REFERENCES

ANSI/ASHRAE. (2010). Standard 62.1-2010, Ventilation for Acceptable Indoor Air Quality. Atlanta, GA: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

ANSI/ASHRAE. (2010). Standard 90.1-2010, Energy Standard for Buildings Except Low Rise Residential Buildings. Atlanta, GA: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

ASHRAE (2009). 2009 ASHRAE Handbook - Fundamentals. Atlanta, GA: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

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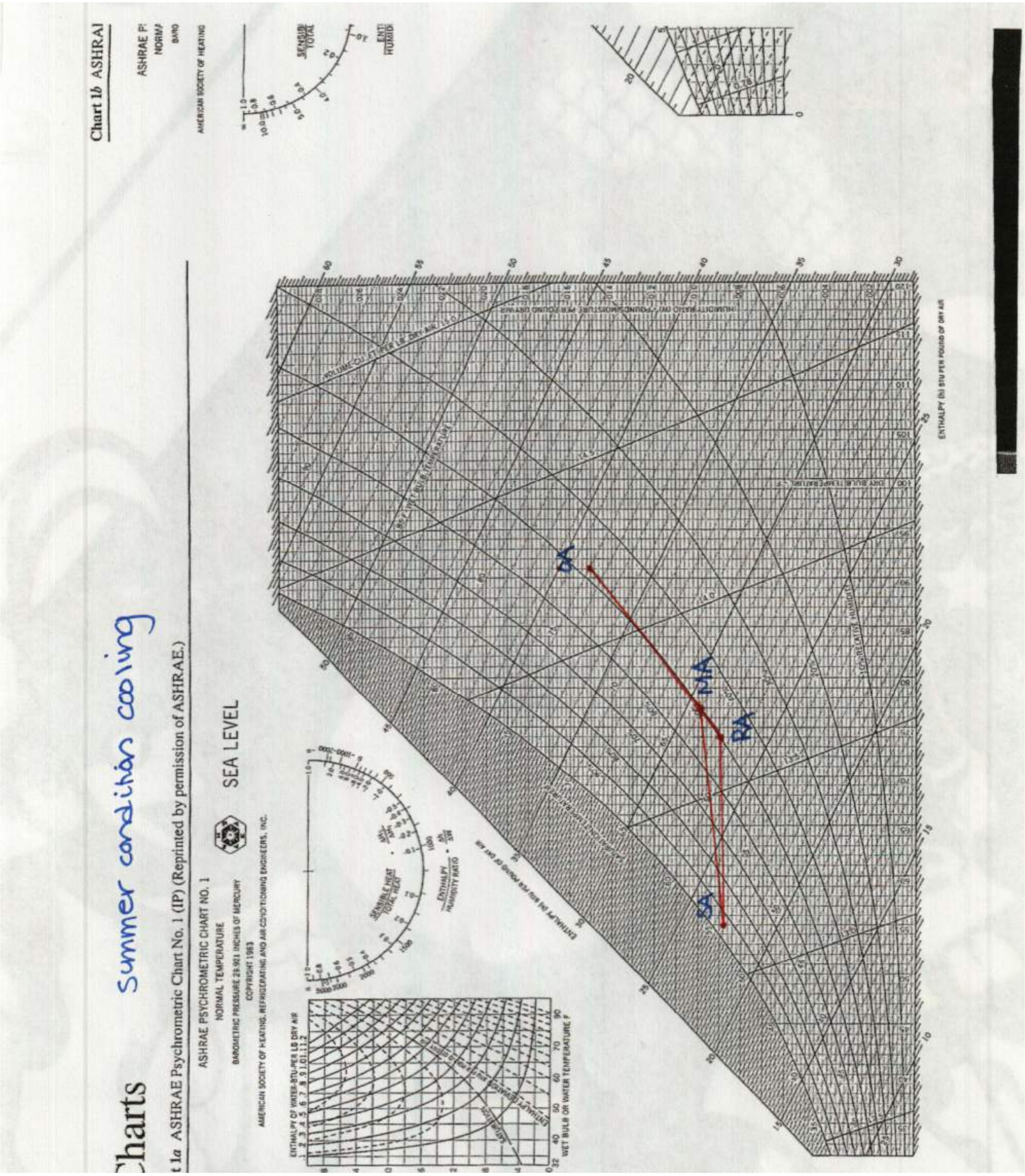
APPENDIX A

Cooling Case Psychrometric Chart



APPENDIX B

System Checksums

By ACADEMIC

ACADEMIC USE ONLY

AHU-1-1 — **Variable Volume Reheat (30% Min Flow Default)**

COOLING COIL PEAK / CLG SPACE PEAK

Cooling coil peak: Peaked at Time: Mo/Hr: 7 / 15; Outside Air: OADB/WB/HR: 92 / 76 / 108

Clg space peak: Mo/Hr: 7 / 15; OADB: 92

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	62,956	0	62,956	14	62,956	25
Glass/Door Cond	20,785	0	20,785	5	20,785	8
Wall Cond	3,193	5,010	8,203	2	3,193	1
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	26,943		26,943	6	10,600	4
Sub Total ==>	113,877	5,010	118,887	26	97,535	39
Internal Loads						
Lights	61,143	15,286	76,429	17	61,143	24
People	61,861	0	61,861	14	34,367	14
Misc	50,949	0	50,949	11	50,949	20
Sub Total ==>	173,953	15,286	189,239	42	146,459	58
Ceiling Load	7,611	-7,611	0	0	7,611	3
Ventilation Load	0	0	121,660	27	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-5,294	-5,294	-1		
Sup. Fan Heat			14,539	3		
Ret. Fan Heat		11,367	11,367	3		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	295,442	18,758	450,399	100.00	251,605	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 14

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	-69,283	-69,283	22.93
Wall Cond	-3,272	-9,284	3.07
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-33,730	-33,730	11.16
Sub Total ==>	-106,284	-112,297	37.16
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-3,717	0	0.00
Ventilation Load	0	-152,307	50.41
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		1,340	-0.44
OA Preheat Diff.		0	0.00
RA Preheat Diff.		-38,893	12.87
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-110,001	-302,157	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.6	94.5
Ra Plenum	74.9	71.6
Return	75.7	71.6
Ret/OA	78.8	40.7
Fn MtrTD	0.1	0.0
Fn BldTD	0.2	0.0
Fn Frict	0.7	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	12,267	4,396
Terminal	12,267	4,396
Main Fan	12,267	4,396
Sec Fan	0	0
Nom Vent	2,349	2,349
AHU Vent	2,349	2,349
Infil	520	520
MinStop/Rh	4,396	4,396
Return	12,788	4,916
Exhaust	2,869	2,869
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	19.1	53.4
cfm/ft²	0.44	0.16
cfm/ton	326.84	
ft²/ton	745.79	
Btu/hr·ft²	16.09	-10.79
No. People	137	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	37.5	450.4	332.8	12,267	78.8	65.2	71.4	54.5	53.0	57.8
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	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
Total	37.5	450.4								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	27,992		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	5,203	2,531	49
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-195.6	4,396	54.5	94.5
Aux Htg	0.0	0	0.0	0.0
Preheat	-106.6	2,349	13.8	54.5
Reheat	-85.6	4,396	54.5	72.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-302.2			

Project Name:

Dataset Name: Thesis Loads.trc

TRACE® 700 v6.3.2 calculated at 05:40 PM on 10/13/2016

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System Checksums

By ACADEMIC

ACADEMIC USE ONLY

AHU-1-2 — **Variable Volume Reheat (30% Min Flow Default)**

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 15; Outside Air: OADB/WB/HR: 92 / 76 / 108

Clg Space Peak — Mo/Hr: 9 / 15; OADB: 86

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	38,878	0	38,878	14	48,986	32
Glass/Door Cond	8,788	0	8,788	3	5,572	4
Wall Cond	3,848	3,366	7,214	3	3,860	2
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	18,956		18,956	7	4,750	3
Sub Total ==>	70,471	3,366	73,838	27	63,168	41
Internal Loads						
Lights	30,362	7,591	37,953	14	30,362	20
People	43,741	0	43,741	16	24,301	16
Misc	33,175	0	33,175	12	33,175	21
Sub Total ==>	107,279	7,591	114,869	43	87,838	57
Ceiling Load	3,698	-3,698	0	0	3,638	2
Ventilation Load	0	0	68,368	25	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-3,076	-3,076	-1		
Sup. Fan Heat			8,752	3		
Ret. Fan Heat		6,889	6,889	3		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	181,448	11,072	269,640	100.00	154,644	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 14

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	-29,294	-29,294	16.72
Wall Cond	-4,783	-9,005	5.14
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-23,729	-23,729	13.54
Sub Total ==>	-57,806	-62,027	35.40
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-2,329	0	0.00
Ventilation Load	0	-85,581	48.84
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		993	-0.57
OA Preheat Diff.		0	0.00
RA Preheat Diff.		-28,624	16.33
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-60,135	-175,239	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.7	91.0
Ra Plenum	74.8	71.5
Return	75.6	71.5
Ret/OA	78.6	44.7
Fn MtrTD	0.1	0.0
Fn BldTD	0.2	0.0
Fn Frict	0.7	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	7,587	2,847
Terminal	7,587	2,847
Main Fan	7,587	2,847
Sec Fan	0	0
Nom Vent	1,320	1,320
AHU Vent	1,320	1,320
Infil	366	366
MinStop/Rh	2,847	2,847
Return	7,953	3,213
Exhaust	1,686	1,686
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	17.4	46.4
cfm/ft²	0.55	0.20
cfm/ton	337.65	
ft²/ton	618.60	
Btu/hr·ft²	19.40	-12.61
No. People	97	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	22.5	269.6	197.2	7,384	78.6	65.0	70.8	54.6	52.9	57.0
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	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
Total	22.5	269.6								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	13,900		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	3,660	1,070	29
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-115.2	2,847	54.6	91.0
Aux Htg	0.0	0	0.0	0.0
Preheat	-60.1	1,320	13.8	54.6
Reheat	-55.1	2,847	54.6	72.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-175.2			

System Checksums

By ACADEMIC

AHU-2-1 — **Variable Volume Reheat (30% Min Flow Default)**

ACADEMIC USE ONLY

	COOLING COIL PEAK				CLG SPACE PEAK		HEATING COIL PEAK			
Peaked at Time:	Mo/Hr: 7 / 15				Mo/Hr: 7 / 15			Mo/Hr: Heating Design		
Outside Air:	OADB/WB/HR: 92 / 76 / 108				OADB: 92			OADB: 14		
	Space Sens. + Lat.	Plenum Sens. + Lat	Net Total	Percent Of Total	Space Sensible	Percent Of Total		Space Peak Space Sens	Coil Peak Tot Sens	Percent Of Total
	Btu/h	Btu/h	Btu/h	(%)	Btu/h	(%)		Btu/h	Btu/h	(%)
Envelope Loads							**Envelope Loads**			
Skylite Solar	0	0	0	0	0	0	Skylite Solar	0	0	0.00
Skylite Cond	0	0	0	0	0	0	Skylite Cond	0	0	0.00
Roof Cond	0	0	0	0	0	0	Roof Cond	0	0	0.00
Glass Solar	62,956	0	62,956	14	62,956	25	Glass Solar	0	0	0.00
Glass/Door Cond	20,785	0	20,785	5	20,785	8	Glass/Door Cond	-69,283	-69,283	22.93
Wall Cond	3,193	5,010	8,203	2	3,193	1	Wall Cond	-3,272	-9,284	3.07
Partition/Door	0		0	0	0	0	Partition/Door	0	0	0.00
Floor	0		0	0	0	0	Floor	0	0	0.00
Adjacent Floor	0	0	0	0	0	0	Adjacent Floor	0	0	0
Infiltration	26,943		26,943	6	10,600	4	Infiltration	-33,730	-33,730	11.16
Sub Total ==>	113,877	5,010	118,887	26	97,535	39	*Sub Total ==>*	-106,284	-112,297	37.16
Internal Loads							**Internal Loads**			
Lights	61,143	15,286	76,429	17	61,143	24	Lights	0	0	0.00
People	61,861	0	61,861	14	34,367	14	People	0	0	0.00
Misc	50,949	0	50,949	11	50,949	20	Misc	0	0	0.00
Sub Total ==>	173,953	15,286	189,239	42	146,459	58	*Sub Total ==>*	0	0	0.00
Ceiling Load	7,611	-7,611	0	0	7,611	3	**Ceiling Load**	-3,717	0	0.00
Ventilation Load	0	0	121,660	27	0	0	**Ventilation Load**	0	-152,307	50.41
Adj Air Trans Heat	0		0	0	0	0	**Adj Air Trans Heat**	0	0	0
Dehumid. Ov Sizing			0	0			**Ov/Undr Sizing**	0	0	0.00
Ov/Undr Sizing	0		0	0	0	0	**Exhaust Heat**		1,340	-0.44
Exhaust Heat		-5,294	-5,294	-1			**OA Preheat Diff.**		0	0.00
Sup. Fan Heat			14,539	3			**RA Preheat Diff.**		-38,893	12.87
Ret. Fan Heat		11,367	11,367	3			**Additional Reheat**		0	0.00
Duct Heat Pkup		0	0	0						
Underflr Sup Ht Pkup			0	0			**Underflr Sup Ht Pkup**		0	0.00
Supply Air Leakage		0	0	0			**Supply Air Leakage**		0	0.00
Grand Total ==>	295,442	18,758	450,399	100.00	251,605	100.00	***Grand Total ==>***	-110,001	-302,157	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.6	94.5
Ra Plenum	74.9	71.6
Return	75.7	71.6
Ret/OA	78.8	40.7
Fn MtrTD	0.1	0.0
Fn BldTD	0.2	0.0
Fn Frict	0.7	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	12,267	4,396
Terminal	12,267	4,396
Main Fan	12,267	4,396
Sec Fan	0	0
Nom Vent	2,349	2,349
AHU Vent	2,349	2,349
Infil	520	520
MinStop/Rh	4,396	4,396
Return	12,788	4,916
Exhaust	2,869	2,869
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	19.1	53.4
cfm/ft²	0.44	0.16
cfm/ton	326.84	
ft²/ton	745.79	
Btu/hr·ft²	16.09	-10.79
No. People	137	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	37.5	450.4	332.8	12,267	78.8	65.2	71.4	54.5	53.0	57.8
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	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
Total	37.5	450.4								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	27,992		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	5,203	2,531	49
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-195.6	4,396	54.5	94.5
Aux Htg	0.0	0	0.0	0.0
Preheat	-106.6	2,349	13.8	54.5
Reheat	-85.6	4,396	54.5	72.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-302.2			

Project Name:
Dataset Name: Thesis Loads.trc

TRACE® 700 v6.3.2 calculated at 05:40 PM on 10/13/2016
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System Checksums

By ACADEMIC

AHU-2-2 — **Variable Volume Reheat (30% Min Flow Default)**

ACADEMIC USE ONLY

COOLING COIL PEAK / CLG SPACE PEAK

	Cooling Coil Peak: Space Sens. + Lat. (Btu/h)	Plenum Sens. + Lat (Btu/h)	Net Total (Btu/h)	Percent Of Total (%)	CLG Space Peak: Space Sensible (Btu/h)	Percent Of Total (%)
Peaked at Time:	Mo/Hr: 7 / 15				Mo/Hr: 9 / 15	
Outside Air:	OADB/WB/HR: 92 / 76 / 108				OADB: 86	
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	38,878	0	38,878	14	48,986	32
Glass/Door Cond	8,788	0	8,788	3	5,572	4
Wall Cond	3,848	3,366	7,214	3	3,860	2
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	18,956		18,956	7	4,750	3
Sub Total ==>	70,471	3,366	73,838	27	63,168	41
Internal Loads						
Lights	30,362	7,591	37,953	14	30,362	20
People	43,741	0	43,741	16	24,301	16
Misc	33,175	0	33,175	12	33,175	21
Sub Total ==>	107,279	7,591	114,869	43	87,838	57
Ceiling Load	3,698	-3,698	0	0	3,638	2
Ventilation Load	0	0	68,368	25	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-3,076	-3,076	-1		
Sup. Fan Heat			8,752	3		
Ret. Fan Heat		6,889	6,889	3		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	181,448	11,072	269,640	100.00	154,644	100.00

HEATING COIL PEAK

	Space Peak Space Sens (Btu/h)	Coil Peak Tot Sens (Btu/h)	Percent Of Total (%)
Mo/Hr:	Heating Design		
OADB:	14		
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	-29,294	-29,294	16.72
Wall Cond	-4,783	-9,005	5.14
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-23,729	-23,729	13.54
Sub Total ==>	-57,806	-62,027	35.40
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-2,329	0	0.00
Ventilation Load	0	-85,581	48.84
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		993	-0.57
OA Preheat Diff.		0	0.00
RA Preheat Diff.		-28,624	16.33
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-60,135	-175,239	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.7	91.0
Ra Plenum	74.8	71.5
Return	75.6	71.5
Ret/OA	78.6	44.7
Fn MtrTD	0.1	0.0
Fn BldTD	0.2	0.0
Fn Frict	0.7	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	7,587	2,847
Terminal	7,587	2,847
Main Fan	7,587	2,847
Sec Fan	0	0
Nom Vent	1,320	1,320
AHU Vent	1,320	1,320
Infil	366	366
MinStop/Rh	2,847	2,847
Return	7,953	3,213
Exhaust	1,686	1,686
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	17.4	46.4
cfm/ft²	0.55	0.20
cfm/ton	337.65	
ft²/ton	618.60	
Btu/hr·ft²	19.40	-12.61
No. People	97	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	22.5	269.6	197.2	7,384	78.6	65.0	70.8	54.6	52.9	57.0
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	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
Total	22.5	269.6								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	13,900		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	3,660	1,070	29
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-115.2	2,847	54.6	91.0
Aux Htg	0.0	0	0.0	0.0
Preheat	-60.1	1,320	13.8	54.6
Reheat	-55.1	2,847	54.6	72.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-175.2			

Project Name:
Dataset Name: Thesis Loads.trc

TRACE® 700 v6.3.2 calculated at 05:40 PM on 10/13/2016
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System Checksums

By ACADEMIC

AHU-3-1 **Variable Volume Reheat (30% Min Flow Default)**

ACADEMIC USE ONLY

	COOLING COIL PEAK				CLG SPACE PEAK		HEATING COIL PEAK			
Peaked at Time:	Mo/Hr: 7 / 18				Mo/Hr: 6 / 8			Mo/Hr: Heating Design		
Outside Air:	OADB/WB/HR: 89 / 73 / 96				OADB: 75			OADB: 14		
	Space Sens. + Lat.	Plenum Sens. + Lat	Net Total	Percent Of Total	Space Sensible	Percent Of Total		Space Peak Space Sens	Coil Peak Tot Sens	Percent Of Total
	Btu/h	Btu/h	Btu/h	(%)	Btu/h	(%)		Btu/h	Btu/h	(%)
Envelope Loads							**Envelope Loads**			
Skylite Solar	0	0	0	0	0	0	Skylite Solar	0	0	0.00
Skylite Cond	0	0	0	0	0	0	Skylite Cond	0	0	0.00
Roof Cond	0	0	0	0	0	0	Roof Cond	0	0	0.00
Glass Solar	46,887	0	46,887	6	73,924	16	Glass Solar	0	0	0.00
Glass/Door Cond	17,422	0	17,422	2	158	0	Glass/Door Cond	-68,537	-68,537	12.21
Wall Cond	3,110	4,292	7,402	1	623	0	Wall Cond	-4,153	-10,562	1.88
Partition/Door	0		0	0	0	0	Partition/Door	0	0	0.00
Floor	0		0	0	0	0	Floor	0	0	0.00
Adjacent Floor	0	0	0	0	0	0	Adjacent Floor	0	0	0
Infiltration	22,295		22,295	3	376	0	Infiltration	-35,918	-35,918	6.40
Sub Total ==>	89,714	4,292	94,006	11	75,081	16	*Sub Total ==>*	-108,607	-115,017	20.49
Internal Loads							**Internal Loads**			
Lights	43,430	10,858	54,288	6	46,519	10	Lights	0	0	0.00
People	175,285	0	175,285	21	104,230	22	People	0	0	0.00
Misc	234,055	0	234,055	28	234,492	51	Misc	0	0	0.00
Sub Total ==>	452,770	10,858	463,627	55	385,242	83	*Sub Total ==>*	0	0	0.00
Ceiling Load	3,639	-3,639	0	0	3,106	1	**Ceiling Load**	-2,855	0	0.00
Ventilation Load	0	0	253,627	30	0	0	**Ventilation Load**	0	-298,737	53.23
Adj Air Trans Heat	0		0	0	0	0	**Adj Air Trans Heat**	0	0	0
Dehumid. Ov Sizing			0	0			**Ov/Undr Sizing**	0	0	0.00
Ov/Undr Sizing	0		0	0	0	0	**Exhaust Heat**		2,026	-0.36
Exhaust Heat		-9,524	-9,524	-1			**OA Preheat Diff.**		-78,152	13.92
Sup. Fan Heat			25,758	3			**RA Preheat Diff.**		-71,370	12.72
Ret. Fan Heat		19,811	19,811	2			**Additional Reheat**		0	0.00
Duct Heat Pkup		0	0	0						
Underflr Sup Ht Pkup			0	0			**Underflr Sup Ht Pkup**		0	0.00
Supply Air Leakage		0	0	0			**Supply Air Leakage**		0	0.00
Grand Total ==>	546,124	21,797	847,305	100.00	463,428	100.00	***Grand Total ==>***	-111,462	-561,251	100.00

TEMPERATURES

	Cooling	Heating
SADB	56.3	83.8
Ra Plenum	74.5	71.7
Return	75.3	71.7
Ret/OA	79.2	40.3
Fn MtrTD	0.1	0.0
Fn BldTD	0.2	0.0
Fn Frict	0.7	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	23,461	8,504
Terminal	23,461	8,504
Main Fan	23,461	8,504
Sec Fan	0	0
Nom Vent	6,302	4,608
AHU Vent	6,302	4,608
Infil	554	554
MinStop/Rh	8,504	8,504
Return	24,015	9,058
Exhaust	6,856	5,162
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	26.9	54.2
cfm/ft²	0.92	0.33
cfm/ton	332.27	
ft²/ton	362.24	
Btu/hr·ft²	33.13	-21.94
No. People	646	

COOLING COIL SELECTION

	Total Capacity		Sens Cap.	Coil Airflow	Enter DB/WB/HR			Leave DB/WB/HR		
	ton	MBh	MBh	cfm	°F	°F	gr/lb	°F	°F	gr/lb
Main Clg	70.6	847.3	581.0	21,733	79.2	65.5	72.3	55.2	52.6	55.0
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	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
Total	70.6	847.3								

AREAS

	Gross Total	Glass ft²	(%)
Floor	25,577		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	5,540	2,504	45
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-270.6	8,504	55.2	83.8
Aux Htg	0.0	0	0.0	0.0
Preheat	-290.7	6,302	13.8	55.2
Reheat	-159.1	8,504	55.2	72.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-561.3			

Project Name:

Dataset Name: Thesis Loads.trc

TRACE® 700 v6.3.2 calculated at 05:40 PM on 10/13/2016

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System Checksums

By ACADEMIC

ACADEMIC USE ONLY

AHU-3-2 **Variable Volume Reheat (30% Min Flow Default)**

	COOLING COIL PEAK				CLG SPACE PEAK	
Peaked at Time:	Mo/Hr: 7 / 15				Mo/Hr: 9 / 15	
Outside Air:	OADB/WB/HR: 92 / 76 / 108				OADB: 86	
	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	38,878	0	38,878	14	48,986	32
Glass/Door Cond	8,788	0	8,788	3	5,572	4
Wall Cond	3,848	3,366	7,214	3	3,860	2
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	18,956		18,956	7	4,750	3
Sub Total ==>	70,471	3,366	73,838	27	63,168	41
Internal Loads						
Lights	30,362	7,591	37,953	14	30,362	20
People	43,741	0	43,741	16	24,301	16
Misc	33,175	0	33,175	12	33,175	21
Sub Total ==>	107,279	7,591	114,869	43	87,838	57
Ceiling Load	3,698	-3,698	0	0	3,638	2
Ventilation Load	0	0	68,368	25	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-3,076	-3,076	-1		
Sup. Fan Heat			8,752	3		
Ret. Fan Heat		6,889	6,889	3		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	181,448	11,072	269,640	100.00	154,644	100.00

	HEATING COIL PEAK		
	Mo/Hr: Heating Design		
	OADB: 14		
	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	-29,294	-29,294	16.72
Wall Cond	-4,783	-9,005	5.14
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-23,729	-23,729	13.54
Sub Total ==>	-57,806	-62,027	35.40
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-2,329	0	0.00
Ventilation Load	0	-85,581	48.84
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		993	-0.57
OA Preheat Diff.		0	0.00
RA Preheat Diff.		-28,624	16.33
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-60,135	-175,239	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.7	91.0
Ra Plenum	74.8	71.5
Return	75.6	71.5
Ret/OA	78.6	44.7
Fn MtrTD	0.1	0.0
Fn BldTD	0.2	0.0
Fn Frict	0.7	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	7,587	2,847
Terminal	7,587	2,847
Main Fan	7,587	2,847
Sec Fan	0	0
Nom Vent	1,320	1,320
AHU Vent	1,320	1,320
Infil	366	366
MinStop/Rh	2,847	2,847
Return	7,953	3,213
Exhaust	1,686	1,686
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	17.4	46.4
cfm/ft²	0.55	0.20
cfm/ton	337.65	
ft²/ton	618.60	
Btu/hr·ft²	19.40	-12.61
No. People	97	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB/WB/HR °F	°F	gr/lb	Leave DB/WB/HR °F	°F	gr/lb
Main Clg	22.5	269.6	197.2	7,384	78.6	65.0	70.8	54.6	52.9	57.0
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	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
Total	22.5	269.6								

AREAS

	Gross Total	Glass ft²	(%)
Floor	13,900		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	3,660	1,070	29
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-115.2	2,847	54.6	91.0
Aux Htg	0.0	0	0.0	0.0
Preheat	-60.1	1,320	13.8	54.6
Reheat	-55.1	2,847	54.6	72.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-175.2			

System Checksums

By ACADEMIC

AHU-4-1 — **Variable Volume Reheat (30% Min Flow Default)**

ACADEMIC USE ONLY

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 15; Outside Air: OADB/WB/HR: 92 / 76 / 108

Clg Space Peak — Mo/Hr: 9 / 15; OADB: 86

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	25,137	25,137	4	0	0
Glass Solar	69,248	0	69,248	12	86,444	36
Glass/Door Cond	20,876	0	20,876	4	13,236	5
Wall Cond	4,205	5,600	9,805	2	4,882	2
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	29,136		29,136	5	7,268	3
Sub Total ==>	123,466	30,737	154,203	27	111,830	46
Internal Loads						
Lights	48,702	12,175	60,877	11	48,702	20
People	45,352	0	45,352	8	25,196	10
Misc	40,612	0	40,612	7	40,612	17
Sub Total ==>	134,666	12,175	146,842	26	114,510	48
Ceiling Load	17,428	-17,428	0	0	14,529	6
Ventilation Load	0	0	261,358	46	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-16,009	-16,009	-3		
Sup. Fan Heat			13,511	2		
Ret. Fan Heat		10,631	10,631	2		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	275,561	20,106	570,535	100.00	240,869	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 14

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-23,742	5.18
Glass Solar	0	0	0.00
Glass/Door Cond	-69,588	-69,588	15.17
Wall Cond	-4,158	-10,470	2.28
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-36,307	-36,307	7.92
Sub Total ==>	-110,053	-140,107	30.55
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-18,093	0	0.00
Ventilation Load	0	-221,623	48.33
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		8,171	-1.78
OA Preheat Diff.		-72,267	15.76
RA Preheat Diff.		-32,763	7.14
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-128,146	-458,589	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.3	93.9
Ra Plenum	75.8	70.2
Return	76.6	70.2
Ret/OA	83.5	33.6
Fn MtrTD	0.1	0.0
Fn BldTD	0.2	0.0
Fn Frict	0.7	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	11,553	5,264
Terminal	11,553	5,264
Main Fan	11,553	5,264
Sec Fan	0	0
Nom Vent	5,023	3,418
AHU Vent	5,023	3,418
Infil	560	560
MinStop/Rh	5,264	5,264
Return	12,113	5,824
Exhaust	5,583	3,978
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	43.5	64.9
cfm/ft²	0.37	0.17
cfm/ton	242.98	
ft²/ton	651.43	
Btu/hr·ft²	18.42	-14.81
No. People	573	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	47.5	570.5	373.6	11,399	83.5	68.8	82.4	54.2	52.9	57.9
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	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
Total	47.5	570.5								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	30,972		
Part	0		
Int Door	0		
ExFlr	0		
Roof	14,043	0	0
Wall	5,600	2,542	45
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-232.4	5,264	54.2	93.9
Aux Htg	0.0	0	0.0	0.0
Preheat	-226.2	5,023	13.8	54.2
Reheat	-104.3	5,264	54.2	72.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-458.6			

System Checksums

By ACADEMIC

AHU-4-2 — **Variable Volume Reheat (30% Min Flow Default)**

ACADEMIC USE ONLY

COOLING COIL PEAK / CLG SPACE PEAK

	COOLING COIL PEAK				CLG SPACE PEAK	
Peaked at Time:	Mo/Hr: 7 / 15				Mo/Hr: 9 / 15	
Outside Air:	OADB/WB/HR: 92 / 76 / 108				OADB: 86	
	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	38,878	0	38,878	14	48,986	32
Glass/Door Cond	8,788	0	8,788	3	5,572	4
Wall Cond	3,848	3,366	7,214	3	3,860	2
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	18,956		18,956	7	4,750	3
Sub Total ==>	70,471	3,366	73,838	27	63,168	41
Internal Loads						
Lights	30,362	7,591	37,953	14	30,362	20
People	43,741	0	43,741	16	24,301	16
Misc	33,175	0	33,175	12	33,175	21
Sub Total ==>	107,279	7,591	114,869	43	87,838	57
Ceiling Load	3,698	-3,698	0	0	3,638	2
Ventilation Load	0	0	68,368	25	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		-3,076	-3,076	-1		
Sup. Fan Heat			8,752	3		
Ret. Fan Heat		6,889	6,889	3		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	181,448	11,072	269,640	100.00	154,644	100.00

HEATING COIL PEAK

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Mo/Hr: Heating Design			
OADB: 14			
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	-29,294	-29,294	16.72
Wall Cond	-4,783	-9,005	5.14
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-23,729	-23,729	13.54
Sub Total ==>	-57,806	-62,027	35.40
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-2,329	0	0.00
Ventilation Load	0	-85,581	48.84
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		993	-0.57
OA Preheat Diff.		0	0.00
RA Preheat Diff.		-28,624	16.33
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-60,135	-175,239	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.7	91.0
Ra Plenum	74.8	71.5
Return	75.6	71.5
Ret/OA	78.6	44.7
Fn MtrTD	0.1	0.0
Fn BldTD	0.2	0.0
Fn Frict	0.7	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	7,587	2,847
Terminal	7,587	2,847
Main Fan	7,587	2,847
Sec Fan	0	0
Nom Vent	1,320	1,320
AHU Vent	1,320	1,320
Infil	366	366
MinStop/Rh	2,847	2,847
Return	7,953	3,213
Exhaust	1,686	1,686
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	17.4	46.4
cfm/ft²	0.55	0.20
cfm/ton	337.65	
ft²/ton	618.60	
Btu/hr·ft²	19.40	-12.61
No. People	97	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	22.5	269.6	197.2	7,384	78.6	65.0	70.8	54.6	52.9	57.0
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	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
Total	22.5	269.6								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	13,900		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	3,660	1,070	29
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-115.2	2,847	54.6	91.0
Aux Htg	0.0	0	0.0	0.0
Preheat	-60.1	1,320	13.8	54.6
Reheat	-55.1	2,847	54.6	72.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-175.2			