Tech Report 2: Building and Plant Energy Analysis Report

PHARM CORP.



Pills, Delaware

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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 CO₂ 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.

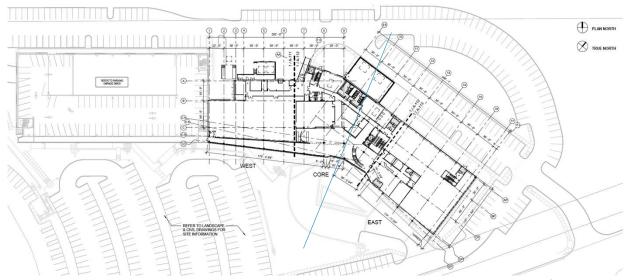


Figure 1. Site plan of building, illustrating West, Core and East, with mirror line of 22.5°.

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.

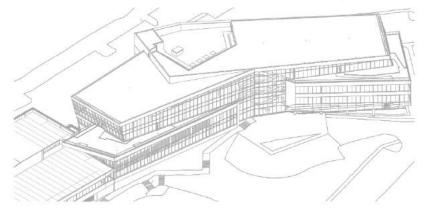


Figure 2. Angled South façade, showing exposure of glass for atrium.

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.

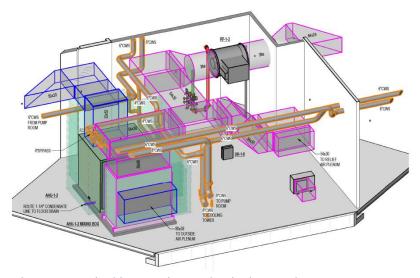


Figure 4. Typical isometric mechanical room layout.

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.

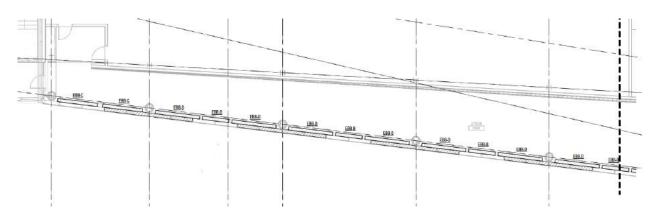


Figure 5. Electric baseboard locations in atrium.

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".

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

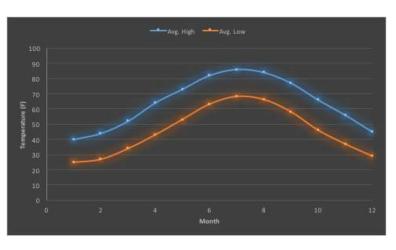


Figure 6. Annual average temperature fluctuation.

Table 1. Pharm Corp. outdoor air design conditions.

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

what ASHRAE states as the design conditions are for Delaware.

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

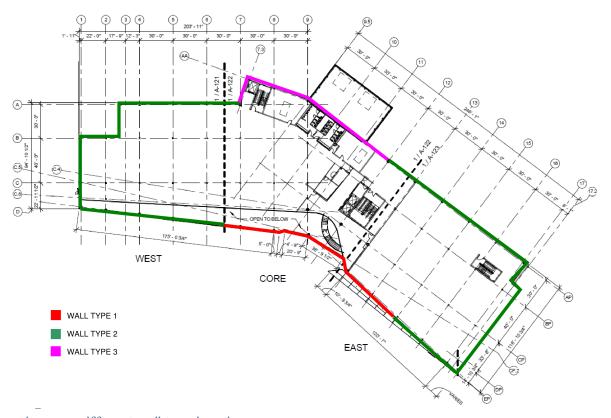


Figure 7. Different wall type locations.

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.

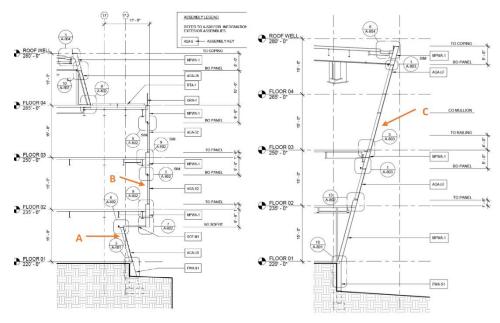


Figure 8. Curtain wall systems.

*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 is 143 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.

	AHU	Design Constraints			
Space Type	Equipment	Occupied		Lighting	Equipment
	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

Table 3. Design constraints for each space type.

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

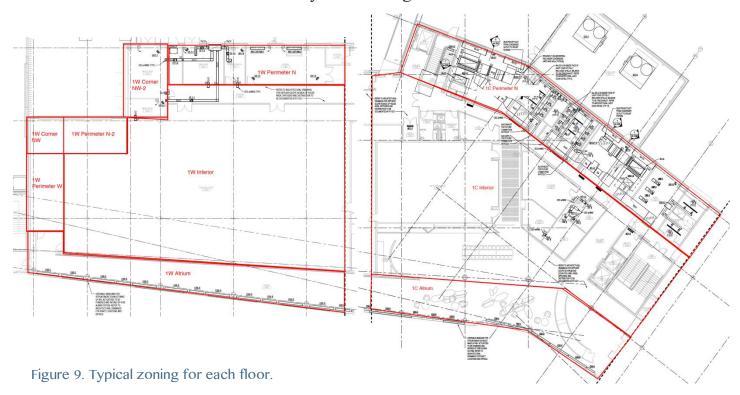
Determining the schedule for a headquarters of a company was assumed to be fully operational between the normal working hours of 8 am – 5 pm, Monday through Friday. Although the headquarters can operate past these general operating office hours, the slightly overestimated W/SF for the office space allows 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.



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.

Cooli		ing	Hea	ting	Airflow		
Design Method	Peak Load [tons]	Per SF [SF/ton]		Per SF [BTUh/SF]	131 141 141 141	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	

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

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.

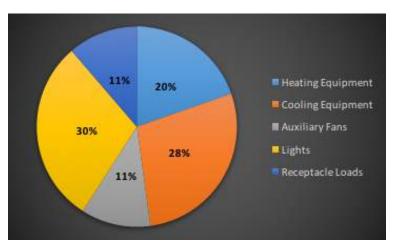


Figure 10. Ratios of electric usage.

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.

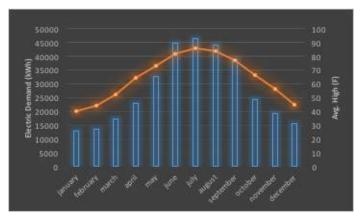


Figure 11. Cooling load profile v. electric demand.

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.

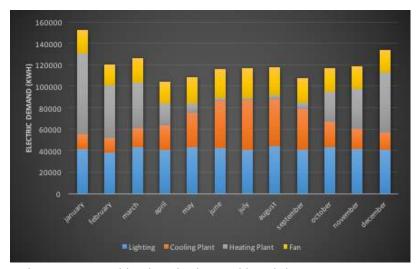


Figure 12. Monthly electric demand breakdown.

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.

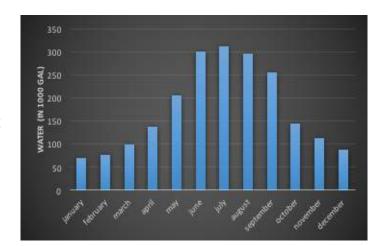


Figure 13. Monthly water demand.

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.

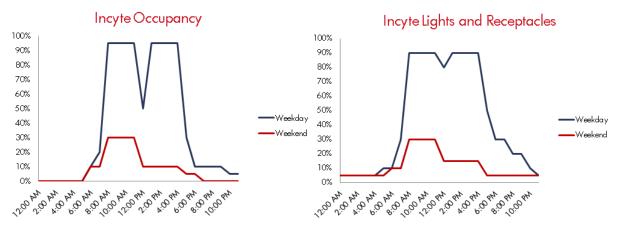


Figure 14. Schedules created by AKF Group in eQUEST.

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.

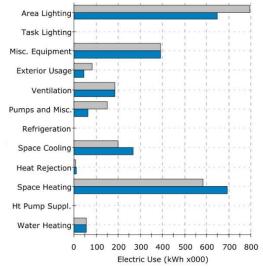


Figure 15. Conducted energy model analysis.

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.

Maintenance Category Cost [\$/(SF*yr)]		Electricity [\$/kWh		
Unit Cost	0.50	0.1008	4.88	
Multiplier	150,000 SI	1683206 kWh	2,100,000 ga	1
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

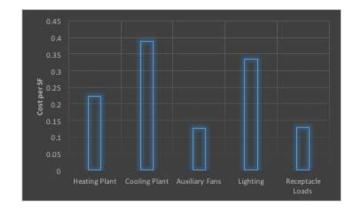


Figure 16. Cost per square foot per subsystem.

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 ₈	3.71E-03	3.59E-03	3.51E-03	5.30E-03	6.28E-03	2.96E-03
N:O	3.73E-05	3.87E-05	2.97E-05	4.02E-05	3.05E-05	2.00E-05
NOx	2.76E-03	3.00E-03	1.95E-03	2.20E-03	1.95E-03	4.32E-03
SOx	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

This low efficiency generates a lot of pollutants, in pounds per delivered kWh. Table 7 is the calculated emission rates for the building for CO₂, 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.

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

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.

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

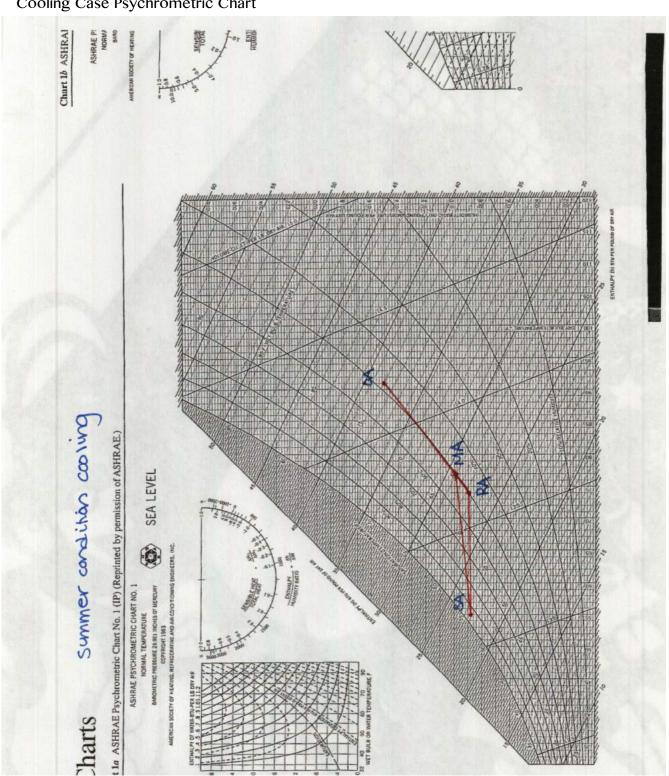
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APPENDIX A

Cooling Case Psychrometric Chart



APPENDIX B

System Checksums By ACADEMIC

			4	-1
А	п	u	- 1	-1

Variable Volume Reheat (30% Min Flow Default)

	COOLING C	OIL PEAK			CLG SPACE	PEAK		HEATING COIL	- PEAK		TEMP	ERATURE:	S
Peake	d at Time:	Mo/H	łr: 7 / 15		Mo/Hr:	7 / 15		Mo/Hr: Heat	ing Design			Cooling	Heating
0	utside Air:	OADB/WB/HF	R: 92 / 76 / 1	08	OADB:	92		OADB: 14			SADB	55.6	94.5
											Ra Plenum	74.9	71.6
	Space	Plenum	Net			Percent		Space Peak	Coil Peak		Return	75.7	71.6
	Sens. + Lat.	Sens. + Lat	Total	Of Total	Sensible		:	Space Sens	Tot Sens		Ret/OA	78.8	40.7
	Btu/h	Btu/h	Btu/h	(%)	Btu/h	(%)		Btu/h	Btu/h	(%)	Fn MtrTD	0.1 0.2	0.0
Envelope Loads Skylite Solar	0		0	0	0	_	Envelope Loads Skylite Solar	0	0	0.00	Fn BldTD Fn Frict	0.2	0.0
Skylite Cond	0	0	0	0	0	0	Skylite Cond	0	0	0.00	FII FIICT	0.7	0.0
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	AIR	RFLOWS	
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		Cooling	Heating
Partition/Door	0		0	0	0	0	Partition/Door	0	0	0.00	Diffuser	12,267	4,396
Floor	0		0	0	0	0	Floor	0	0	0.00	Terminal	12,267	4,396
Adjacent Floor	0	0	0	0	0	0	Adjacent Floor	0	0	0	Main Fan	12,267	4,396
Infiltration	26,943		26,943	6 :	10,600	4	Infiltration	-33,730	-33,730	11.16	Sec Fan	0	
Sub Total ==>	113,877	5,010	118,887	26	97,535	39	Sub Total ==>	-106,284	-112,297	37.16	Nom Vent	2,349	2,349
							latement to and				AHU Vent	2,349	2,349
Internal Loads							Internal Loads				Infil	520	520
Lights	61,143	15,286	76,429	17		24	Lights	0	0	0.00	MinStop/Rh	4,396	4,396
People	61,861	0	61,861	14		14	People	0	0	0.00	Return	12,788	4,916
Misc	50,949	0	50,949	11 ;		20	Misc	0	0	0.00	Exhaust	2,869	2,869
Sub Total ==>	173,953	15,286	189,239	42	146,459	58	Sub Total ==>	0	0	0.00	Rm Exh	0	(
								-3.717	0	0.00	Auxiliary	0	(
Ceiling Load Ventilation Load	7,611	-7,611	0	0	7,611	3	Ceiling Load Ventilation Load	-3,717	-152,307	50.41	Leakage Dwn	•	(
Account Account	0	0	121,660	27	0	0		0	-132,307	0	Leakage Ups	0	C
Adj Air Trans Heat	0		0	0	0	0	Adj Air Trans Heat Ov/Undr Sizing	0	0	0.00			
Dehumid. Ov Sizing Ov/Undr Sizing	0		0	0	0	_	Exhaust Heat	0	1,340	-0.44	ENGINE		'
Exhaust Heat	Ü	-5.294	-5.294	0 : -1 :	0	0	OA Preheat Diff.		1,340	0.00	ENGINE	EERING CH	KS
Sup. Fan Heat		-0,204	14.539	3			RA Preheat Diff.		-38,893	12.87		Cooling	Heating
Ret. Fan Heat		11,367	11,367	3			Additional Reheat		0	0.00	% OA	19.1	53.4
Duct Heat Pkup		0	0	0					_		cfm/ft²	0.44	0.16
Underfir Sup Ht Pku	р		0	0 :			Underfir Sup Ht Pkup		0	0.00	cfm/ton	326.84	
Supply Air Leakage		0	0	0			Supply Air Leakage		0	0.00	ft²/ton	745.79	
											Btu/hr·ft²	16.09	-10.79
Grand Total ==>	295,442	18,758	450,399	100.00	251,605	100.00	Grand Total ==>	-110,001	-302,157	100.00	No. People	137	

			COOLING	COIL SEL	ECTIC	N				
		Capacity	Sens Cap.	Coil Airflow		er DB/W				WB/HR
	ton	MBh	MBh	cfm	°F	°F	gr/lb	°F	°F	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								

	AREA	\S	
G	ross Total	Glass	- 1
		ft²	(%)
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

HEA	ATING COIL	SELECTION	ON	
	Capacity	Coil Airflow	Ent	Lvg
	MBh	cfm	°F	°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 Opt Vent	0.0 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 Alternative - 1 System Checksums Report Page 1 of 8

AHU-1-2

Variable Volume Reheat (30% Min Flow Default)

	COOL	ING C	OIL PEAK			CLG SPACE	PEAK		HI	EATING CO	L PEAK		TEM	PERATURE	S
Pea	iked at Tim Outside A		Mo/H OADB/WB/HF	r: 7 / 15 R: 92 / 76 / 1	08	Mo/Hr: OADB:				Mo/Hr: Hea OADB: 14	ating Design		SADB Ra Plenum	Cooling 55.7 74.8	Heating 91.0 71.5
		Space + Lat.	Plenum Sens. + Lat	Net Total	Percent Of Total					pace Peak pace Sens	Coil Peak Tot Sens	Percent Of Total	Return Ret/OA	75.6 78.6	71.5 44.7
Envelope Loads Skylite Solar		Btu/h	Btu/h	Btu/h	(%)	Btu/h	(%)	Envelope Loads		Btu/h	Btu/h	0.00	Fn MtrTD Fn BldTD Fn Frict	0.1 0.2 0.7	0.0 0.0 0.0
Skylite Cond Roof Cond Glass Solar		0 0 38.878	0 0	0 0 38.878	0 0 14	0 0	0 0 32	Roof Cond	# (0	0	0.00 0.00 0.00	AI	RFLOWS	
Glass/Door Con Wall Cond		8,788 3,848	3,366	8,788 7,214	3	5,572	4	Glass/Door Co	ind	-29,294 -4,783	-29,294 -9,005	16.72 5.14		Cooling	Heating
Partition/Door Floor		0 0 0	0	0 0 0	0	0	0	Floor		0 0 0	0	0.00	Diffuser Terminal Main Fan	7,587 7,587 7,587	2,847 2,847 2,847
Adjacent Floor Infiltration Sub Total ==>		18,956 70,471	0 3.366	18,956 73.838	0 7 27	4,750	0 3 41	Infiltration		-23,729 -57,806	0 -23,729 -62,027	13.54 35.40	Sec Fan Nom Vent	1,320	
Internal Loads								Internal Loads					AHU Vent Infil	1,320 366	1,320 366
Lights People	4	30,362 43,741 33,175	7,591 0 0	37,953 43,741 33,175	14 16 12	24,301	20 16	People		0	0	0.00 0.00 0.00	MinStop/Rh Return Exhaust	2,847 7,953 1,686	2,847 3,213 1,686
Misc Sub Total ==>		07,279	7,591	114,869	43	87,838	21 57			0	0	0.00	Rm Exh Auxiliary	0	0
Ceiling Load Ventilation Load	₩.	3,698	-3,698 0	0 68,368	0 25	0	2 0	Total Assessment		-2,329 0	-85,581	0.00 48.84	Leakage Dwn Leakage Ups	0	0
Adj Air Trans Hea Dehumid. Ov Siz Ov/Undr Sizing	100	0		0 0	0 0			Adj Air Trans He Ov/Undr Sizing Exhaust Heat	at	0	0 0 993	0.00 -0.57	FNOI	IEEDING O	
Exhaust Heat Sup. Fan Heat		U	-3,076	-3,076 8,752	-1 3		0	OA Preheat Diff. RA Preheat Diff.			0 -28,624	0.00 16.33		Cooling	Heating
Ret. Fan Heat Duct Heat Pkup Underfir Sup Ht F	Pkup		6,889 0	6,889 0 0	3 0 0	:		Additional Rehea			0	0.00	% OA cfm/ft² cfm/ton	17.4 0.55 337.65	46.4 0.20
Supply Air Leaka	•		0	0	0			Supply Air Leak	•		0	0.00	ft²/ton Btu/hr·ft²	618.60 19.40	-12.61
Grand Total ==>	18	31,448	11,072	269,640	100.00	154,644	100.00	Grand Total ==>		-60,135	-175,239	100.00	No. People	97	
	Total Ca			oil Airflow	Enter	DB/WB/HR		e DB/WB/HR	Gross		ilass	HE		Coil Airflow	Ent Lvg
Main Clg	ton 22.5	MBh 269.6	MBh 197.2	cfm 7,384		°F gr/lb	°F 54.6			13,900		Main Htg	MBh -115.2		°F °F 54.6 91.0
Aux Clg	0.0	0.0	0.0	0	0.0	0.0 0.0	0.0	0.0 0.0 P	art	0		Aux Htg	0.0	0	0.0 0.0

0.0

0.0 0.0

0.0

Int Door

0

0

3,660 1,070

0

29

ExFlr

Roof

Wall

Ext Door

Project Name:

Opt Vent

Total

Dataset Name: Thesis Loads.trc

0.0

22.5

0.0

269.6

0.0

0 0.0 0.0

> TRACE® 700 v6.3.2 calculated at 05:40 PM on 10/13/2016 Alternative - 1 System Checksums Report Page 2 of 8

-60.1 -55.1

0.0

0.0

-175.2

Preheat

Reheat Humidif Opt Vent

Total

0.0

54.6 72.0 0.0 0.0

1,320 13.8 2,847 54.6 0 0.0 0 0.0

AHU-2-1

Variable Volume Reheat (30% Min Flow Default)

	C	OOLING C	OIL PEAK			CLG SPAC	E PEAK			HEATING (COIL PEAK		ТЕМ	PERATURE	S	
ı	Peaked a Outsi	t Time: ide Air:		/Hr: 7 / 15 HR: 92 / 76 / 1	08	Mo/Hr: OADB				Mo/Hr: OADB:	Heating Design 14		SADB Ra Plenum	Cooling 55.6 74.9		ting 94.5 71.6
		Space	Plenum	Net	Percent	Space	Percen	t		Space Peak	Coil Peak	Percent	Return	75.7		71.6
	S	ens. + Lat.	Sens. + Lat	Total	Of Tota	Sensible	Of Tota	ıl :		Space Sens	Tot Sens	Of Total	Ret/OA	78.8	4	40.7
,		Btu/h	Btu/h	Btu/h	(%)	Btu/h	(%			Btu/h	Btu/h	1 (%)	Fn MtrTD	0.1		0.0
Envelope Loa								Envelope I					Fn BldTD	0.2		0.0
Skylite Solar		0	0	0	9	ACCORDING TO THE REAL PROPERTY AND ADDRESS OF THE PARTY AND ADDRESS OF		Skylite S		0	C	0.00	Fn Frict	0.7		0.0
Skylite Cond Roof Cond		0	0	0				O Skylite O		0	C					_
Glass Solar		62,956	0	62.956	14	The second second	2			0				IRFLOWS		
Glass/Door C	Cond	20,785	0	20,785	1-				oor Cond	-69.283	-69.283		^			
Wall Cond	Jona	3,193	5,010	8,203		3,193		1: Wall Co		-3,272	-9,284			Cooling		ating
Partition/Doo	r	0	0,0.0	0): 0		0 : Partition		0	0,20		Diffuser	12,267		4,396
Floor		0		0	(): 0		0 : Floor		0	C	0.00	Terminal	12,267		4,396
Adjacent Floo	or	0	0	0	(0		0 Adjacen	t Floor	0	C	0	Main Fan	12,267		4,396
Infiltration		26,943		26,943	6	10,600		4 : Infiltratio	n	-33,730	-33,730		Sec Fan	0)	0
Sub Total ==	>	113,877	5,010	118,887	26	97,535	3	9 : Sub Tota	a/ ==>	-106,284	-112,297	37.16	Nom Vent	2,349) ;	2,349
						:		i					AHU Vent	2,349) :	2,349
Internal Loads	5							Internal Lo	ads				Infil	520		520
Lights		61,143	15,286	76,429	17	61,143	2	4 Lights		0	C	0.00	MinStop/Rh	4,396		4,396
People		61,861	0	61,861	14		1			0	C		Return	12,788		4,916
Misc		50,949	0	50,949	11	50,949	2	0 : Misc		0	C	0.00	Exhaust	2,869		2,869
Sub Total ==	>	173,953	15,286	189,239	42	146,459	5	B Sub Tota	a/ ==>	0	C	0.00	Rm Exh	0		0
		7 (60)			- 4				V	0.747			Auxiliary	0		0
Ceiling Load		7,611	-7,611	0	(1000000	3 Ceiling Lo		-3,717 0	-152,307		Leakage Dwn	•		0
Ventilation Lo	Account	0	0	121,660	27	L' ANNOUNT AND	1000	Ventilation		0	-152,307		Leakage Ups	0)	0
Adj Air Trans I		0		0	(CONTRACTOR OF THE PARTY OF THE		Adj Air Tra		0	-	-				
Dehumid. Ov S Ov/Undr Sizin		0		0	9			Ov/Undr S Exhaust H		- 0	1,340					
Exhaust Heat	y	U	-5.294	-5.294	(-1			OA Prehea			1,540		ENGII	NEERING C	KS	
Sup. Fan Heat	•		-0,204	14,539		3:		: RA Prehea			-38,893			Cooling	Hea	ting
Ret. Fan Heat			11.367	11,367		3:		Additional			00,000		% OA	19.1	5	53.4
Duct Heat Pku	ıp		0	0	():		:					cfm/ft²	0.44	(0.16
Underfir Sup I	Ht Pkup			0	() :		Underfir S	up Ht Pkup		C	0.00	cfm/ton	326.84		
Supply Air Lea	akage		0	0	() :		Supply Air	Leakage		C	0.00	ft²/ton	745.79		
						:		:					Btu/hr·ft²	16.09	-10	0.79
Grand Total =	=>	295,442	18,758	450,399	100.00	251,605	100.0	O Grand Total	a/ ==>	-110,001	-302,157	100.00	No. People	137		
			COOLING	COIL SELI	ECTION]				AREAS		Н	EATING COIL	SELECTIO	N	
	Tota ton	I l Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter °F	DB/WB/HR °F gr/lb	Lea °F	ve DB/WB/HR °F gr/lb		Gross Total	Glass ft² (%)		Capacity MBh	Coil Airflow cfm	Ent °F	Lv
Main Clg	37.5	450.4	332.8	12,267		65.2 71.4	54.5		Floor	27,992		Main Htg	-195.6		54.5	94.
Aux Clg	0.0	0.0	0.0	0	0.0	0.0 0.0	0.0	0.0 0.0	Part	0		Aux Htg	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	Int Doo			Preheat	-106.6		13.8	54.
T-4-1	07.5	450 4							ExFlr	0		Reheat	-85.6	,	54.5	72.
Total	37.5	450.4							Roof	0 5.203 2	0 0 2.531 49	Humidif	0.0 0.0	0	0.0	0. 0.
									Wall	-,	,	Opt Vent		Ü	0.0	0.0
									Ext Do	or 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 Alternative - 1 System Checksums Report Page 3 of 8

AHU-2-2

Variable Volume Reheat (30% Min Flow Default)

	cc	OOLING C	OIL PEAK			CLC	G SPACE	PEA	(HEATING (COIL PEA	ĸ		TEM	PERATURE	S	
	Peaked at Outside	: Time: de Air:		/Hr: 7 / 15 HR: 92 / 76 / 1	108	:	Mo/Hr: OADB:		:			Mo/Hr: OADB:	Heating De 14	sign		SADB Ra Plenum	Cooling 55.7 74.8		ting 91.0 71.5
	Se	Space ens. + Lat.	Plenum Sens. + Lat	Net Total	Percen Of Tota	ıl :	Space Sensible	Percei Of Tot	al∵			Space Peak Space Sens	Tot	Sens	Percent Of Total	Return Ret/OA Fn MtrTD	75.6 78.6 0.1	7	71.5 44.7 0.0
Envelope Loa Skylite Solar	ır	Btu/h	Btu/h	Btu/h		0	Btu/h		0 En	velope Lo Skylite Sc	olar	Btu/h		Btu/h 0	0.00	Fn BldTD Fn Frict	0.2		0.0
Skylite Cond Roof Cond Glass Solar		0 0 38,878	0 0 0	0 0 38,878		0 0 4	0 0 48,986		0 1	Skylite Co Roof Con Glass Sol	d	0 0		0 0 0	0.00 0.00 0.00	Α	IRFLOWS		
Glass/Door	Cond	8,788	0	8,788		3:	5,572			Glass/Do		-29,294		9,294	16.72		Cooling	ı He	ating
Wall Cond		3,848	3,366	7,214		3:	3,860			Wall Cond		-4,783	-	9,005	5.14	Diffuser	7,587		2,847
Partition/Doo	or	0		0		0 : 0 :	0			Partition/[Floor	Joor	0		0	0.00	Terminal	7,587		2,847
Adjacent Flo	oor	0	0	0		0:	0			Adjacent	Floor	0		0	0.00	Main Fan	7,587		2,847
Infiltration		18,956		18,956		7	4,750			Infiltration		-23,729	-2	3,729	13.54	Sec Fan	C)	0
Sub Total ==	=>	70,471	3,366	73,838	2	7:	63,168	4	и: 🔻	Sub Total	==>	-57,806	-6	2,027	35.40	Nom Vent	1,320) .	1,320
						:			i							AHU Vent	1,320) .	1,320
Internal Load	ds								,	ernal Loa	ids					Infil	366		366
Lights		30,362	7,591	37,953	14		30,362			Lights		0		0	0.00	MinStop/Rh	2,847		2,847
People Misc		43,741	0	43,741	11		24,301 —33,175			People		0		0	0.00	Return Exhaust	7,953 1.686		3,213 1,686
		33,175 107,279	The second second	33,175	1:					Misc	V. 1	0	*			Rm Exh	1,000		0,000
Sub Total ==		107,279	7,591	114,869	4:	3	87,838		7	Sub Total	==>	0		0	0.00	Auxiliary	C		0
Ceiling Load		3.698	-3,698	0		0	3,638		2 Cei	iling Load	d	-2,329		0	0.00	Leakage Dwn	č		0
Ventilation Lo	oad	0	0	68,368	2		0	W 76	0 Ver	ntilation l	Load	0	-8	5,581	48.84	Leakage Ups	C)	0
Adj Air Trans	Heat	0		0		0	0	/ 1	0 Adj	j Air Tran	s Heat	0		0	0				
Dehumid. Ov				0		0.				Undr Siz		0		0	0.00				
Ov/Undr Sizir		0	0.070	0		0 :	0			naust Hea				993 0	-0.57	ENGI	NEERING C	KS	
Exhaust Heat Sup. Fan Hea			-3,076	-3,076 8,752		1 ; 3 :				Preheat Preheat			-2	ں 8,624	0.00 16.33		Cooling	Hea	tina
Ret. Fan Heat			6.889	6,889		3:				ditional F			-2	0,024	0.00	% OA	17.4		46.4
Duct Heat Pk			0	0		0:					torrout				0.00	cfm/ft²	0.55	(0.20
Underfir Sup				0		0 :			Un	derflr Su	p Ht Pkup			0	0.00	cfm/ton	337.65		
Supply Air Le	eakage		0	0		0 :			Su	pply Air l	_eakage			0	0.00	ft²/ton	618.60		
Grand Total =	==>	181,448	11,072	269,640	100.0	0 :	154,644	100.0	00 Gra	and Total	==>	-60,135	-17	5,239	100.00	Btu/hr·ft² No. People	19.40 97	-12	2.61
	Tata	l Camaaitu		COIL SELI			/UD		DB	/WB/HR		AREAS Gross Total	Class		HE	EATING COIL			
	ton	I Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	°F	r DB/WB °F	gr/lb	°F	°F	gr/lb			Glass ft² (%	6)		MBh	Coil Airflow cfm	Ent °F	°F
Main Clg	22.5	269.6	197.2	7,384	78.6	65.0	70.8		52.9	57.0	Floor	13,900			Main Htg	-115.2	_,	54.6	91.0
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	Part	0		- 11	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	Int Door	0			Preheat	-60.1		13.8	54.6
Total	22.5	269.6									ExFlr Roof Wall	0 0 3,660 1		o	Reheat Humidif Opt Vent	-55.1 0.0 0.0	2,847 0 0	54.6 0.0 0.0	72.0 0.0 0.0

Project Name:

Dataset Name: Thesis Loads.trc TRACE® 700 v6.3.2 calculated at 05:40 PM on 10/13/2016 Alternative - 1 System Checksums Report Page 4 of 8

Ext Door

0 Total

AHU-3-1

Variable Volume Reheat (30% Min Flow Default)

	COOLING C	OIL PEAK			CLG SPACE	PEAK		HEATING COIL	PEAK		TEMP	ERATURE	S
Peake	d at Time:	Mo/H	Hr: 7 / 18		Mo/Hr:	6/8	!	Mo/Hr: Heat	ng Design			Cooling	Heating
0	utside Air:	OADB/WB/HI	R: 89 / 73 / 9	96	OADB:	75		OADB: 14			SADB	56.3	83.8
				:							Ra Plenum	74.5	71.7
	Space	Plenum	Net	Percent	Space	Percent		Space Peak	Coil Peak	Percent	Return	75.3	71.7
	Sens. + Lat.	Sens. + Lat	Total	Of Total	Sensible	Of Total		Space Sens	Tot Sens	Of Total	Ret/OA	79.2	40.3
	Btu/h	Btu/h	Btu/h	(%)	Btu/h	(%)		Btu/h	Btu/h	(%)	Fn MtrTD	0.1	0.0
Envelope Loads							Envelope Loads				Fn BldTD	0.2	0.0
Skylite Solar	0	0	0	0	0	0	Skylite Solar	0	0	0.00	Fn Frict	0.7	0.0
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		251 0140	
Glass Solar Glass/Door Cond	46,887	0	46,887 17,422	6	73,924 158	16	Glass Solar Glass/Door Cond	0	0	0.00	All	RFLOWS	
Wall Cond	17,422 3.110	4,292	7,422	2:		0	,	-68,537 -4,153	-68,537 -10,562	12.21 1.88		Cooling	Heating
Partition/Door	3,110	4,292	7,402	0:	023	0	: Partition/Door	-4,155 0	-10,562	0.00	Diffuser	23,461	8,504
Floor	0		0	0:	0	0	Floor	0	0	0.00	Terminal	23,461	8.504
Adjacent Floor	0	0	0	0:	0	0	Adjacent Floor	0	0	0.00	Main Fan	23,461	8,504
Infiltration	22,295	· ·	22,295	3	376	0	Infiltration	-35,918	-35,918	6.40	Sec Fan	0	0
Sub Total ==>	89.714	4.292	94.006	11	75,081	16	Sub Total ==>	-108,607	-115,017	20.49	Nom Vent	6.302	4,608
Sub Total>	03,714	4,232	34,000	- '':	73,001	10	, Gub rotar	100,001	,	20.10	AHU Vent	6,302	4,608
Internal Loads							Internal Loads				Infil	554	554
Lights	43,430	10.858	54,288	6	46,519	10	Lights	0	0	0.00	MinStop/Rh	8,504	8,504
People	175,285	10,656	175,285	21	104,230	22	People	0	0	0.00	Return	24,015	9.058
Misc	234,055	0	234.055	28	234,492	51	Misc		0	0.00	Exhaust	6,856	5,162
	452,770		463.627		385,242	83			0	0.00	Rm Exh	0,000	0,102
Sub Total ==>	452,770	10,858	463,627	55	385,242	83	Sub Total ==>		U	0.00	Auxiliary	0	0
Ceiling Load	3.639	-3.639	0	0	3,106	1	Ceiling Load	-2.855	0	0.00	Leakage Dwn	0	0
Ventilation Load	3,039	-5,059	253,627	30	3,100	0	Ventilation Load	0	-298,737	53.23	Leakage Ups	0	0
Adj Air Trans Heat	0		0	0	0	0	Adj Air Trans Heat	0	0	0	Leakage Opa	0	Ü
Dehumid. Ov Sizing			0	0	U		Ov/Undr Sizing	0	0	0.00			
Ov/Undr Sizing	0		0	0	0	_	Exhaust Heat		2.026	-0.36	ENCIN	EERING CH	/ C
Exhaust Heat	U	-9,524	-9,524	-1	U	U	OA Preheat Diff.		-78,152	13.92	ENGIN	EERING C	13
Sup. Fan Heat		0,021	25.758	3			RA Preheat Diff.		-71,370	12.72		Cooling	Heating
Ret. Fan Heat		19,811	19,811	2			Additional Reheat		0	0.00	% OA	26.9	54.2
Duct Heat Pkup		0	0	0 :							cfm/ft²	0.92	0.33
Underfir Sup Ht Pku	ıp		0	0 :			Underfir Sup Ht Pkup		0	0.00	cfm/ton	332.27	
Supply Air Leakage		0	0	0			Supply Air Leakage		0	0.00	ft²/ton	362.24	
											Btu/hr·ft²	33.13	-21.94
Grand Total ==>	546,124	21,797	847,305	100.00	463,428	100.00	Grand Total ==>	-111,462	-561,251	100.00	No. People	646	
		COOLING	COIL SELE	ECTION				AREAS		HE	EATING COIL	SELECTION	N

			COOLING	COIL SEL	ECTIC	N				
	Total	Capacity	Sens Cap.	Coil Airflow	Ent	er DB/W	B/HR	Lea	ve 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								

	AREA	AS		HEA	ATING
G	ross Total	Gla ft²	(%)		C
Floor Part	25,577 0			Main Htg Aux Htg	-
Int Door ExFir	0			Preheat Reheat	-
Roof Wall	0 5,540	0 2,504	0 45	Humidif Opt Vent	
Ext Door	0	0	0	Total	-

HEATING COIL SELECTION										
	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F						
Main Htg Aux Htg	-270.6 0.0	8,504 0	55.2 0.0	83.8						
Preheat	-290.7		13.8	55.2						
Reheat Humidif	-159.1 0.0	8,504 0	55.2 0.0	72.0 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 Alternative - 1 System Checksums Report Page 5 of 8

AHU-3-2

Variable Volume Reheat (30% Min Flow Default)

	CC	OLING C	OIL PEAK			CI	LG SPACE	PEA	‹			HEATING	COIL P	EAK		TEM	PERATURE	S	
P	eaked at Outsid			/Hr: 7 / 15 HR: 92 / 76 / 1	108	:	Mo/Hr: OADB:		:			Mo/Hr: OADB:	: Heating	Design		SADB	Cooling 55.7	Hea	ting 91.0
						- :										Ra Plenum	74.8		71.5
		Space	Plenum	Net	Percei	nt:	Space	Perce	nt :			Space Peak		oil Peak	Percent	Return	75.6	7	71.5
	Se	ens. + Lat.	Sens. + Lat	Total	Of Tot	al :	Sensible	Of Tot				Space Sens		Tot Sens	Of Total	Ret/OA	78.6	4	44.7
		Btu/h	Btu/h	Btu/h	(%		Btu/h	(%	6)	- 4		Btu/h		Btu/h	(%)	Fn MtrTD	0.1		0.0
Envelope Loads	s		TO							velope L	oads				(,	Fn BldTD	0.2		0.0
Skylite Solar		0	0	0		0	0		0	Skylite S	olar	0		0	0.00	Fn Frict	0.7		0.0
Skylite Cond		0	0	0		0	0			Skylite C		0		0	0.00				
Roof Cond		0	0	0		0	0	/		Roof Cor		0		0	0.00				
Glass Solar		38,878	0	38,878	1	4	48,986			Glass So		0		0	0.00	A	IRFLOWS		
Glass/Door Co	ond	8,788	0	8,788		3:	5,572			Glass/Do		-29,294		-29,294	16.72		Cooling	l He	ating
Wall Cond		3,848 0	3,366	7,214 0		3: 0:	3,860 0			Wall Con		-4,783 0		-9,005 0	5.14 0.00	Diffuser	7,587	,	2,847
Partition/Door Floor		0		0		0:	0		-	Partition/ Floor	Door	0		0	0.00	Terminal	7,587		2.847
Adjacent Floor		0	0	0		0:	0		٠.	Adjacent	Floor	0		0	0.00	Main Fan	7,587		2,847
Infiltration		18,956	U	18,956		7	4,750		٠,	Infiltration		-23,729		-23,729	13.54	Sec Fan	,		0
Sub Total ==>		70,471	3,366	73.838		7 :	63,168	,		Sub Tota		-57.806		-62,027	35.40	Nom Vent	1,320		1,320
Sub Iolai>		70,471	3,300	73,030	-	· ' :	03,100	•	* 1	oub rota		-01,000		-02,021	00.40	AHU Vent	1,320		1,320
Internal Loads									Int	ternal Loa	ads					Infil	366		366
		00.000	7.504	07.050		.:	00.000	,							0.00		2,847		2,847
Lights		30,362 43,741	7,591 0	37,953 43,741		4	30,362 24,301			Lights		0		0	0.00	MinStop/Rh Return	7.953		3.213
People Misc		33,175	0	33,175		6 : 2 :	33,175			People Misc				0	0.00	Exhaust	1.686		1.686
						- 10000			- 1 40	10007 /00				0		Rm Exh	1,000		0
Sub Total ==>		107,279	7,591	114,869	,	3	87,838		57	Sub Tota	/==>)	0	0.00	Auxiliary	(0
Ceiling Load		3.698	-3.698	0	- 4	0	3,638		2 Ce	iling Loa	d	-2.329)	0	0.00	Leakage Dwn	(0
Ventilation Load	d	3,030	-3,098	68,368	-	25	3,030			ntilation		2,020		-85,581	48.84	Leakage Ups	(0
Adj Air Trans H	Acceptance	0		00,000	-	0	0	V V		i Air Trar		0)	0	0	Leakage Ops	,	,	U
Dehumid. Ov Si		0		0		0		/ 1		/Undr Siz		0		0	0.00				
Ov/Undr Sizing	izilig	0		0		0:	0			haust He				993	-0.57	ENGI	NEERING C	ĸe	
Exhaust Heat		Ü	-3.076	-3.076		.1 ·	Ü			A Preheat				0	0.00	ENGI	NEEKING C	NO	
Sup. Fan Heat			-,	8,752		3:			: RA	A Preheat	Diff.			-28,624	16.33		Cooling	Hea	
Ret. Fan Heat			6,889	6,889		3:			: Ac	ditional l	Reheat			0	0.00	% OA	17.4		46.4
Duct Heat Pkup)		0	0		0:			:							cfm/ft²	0.55	(0.20
Underfir Sup Hi	Pkup			0		0 :			Uı	nderfir Su	ıp Ht Pkup			0	0.00	cfm/ton	337.65		
Supply Air Leak	kage		0	0		0 :			Şι	ipply Air	Leakage			0	0.00	ft²/ton	618.60		
						:			:							Btu/hr·ft²	19.40	-12	2.61
Grand Total ==:	>	181,448	11,072	269,640	100.0	00 '	154,644	100.0	00 ' G r	rand Tota	/ ==>	-60,135	5	-175,239	100.00	No. People	97		
			COOLING	COIL SEL	ECTIO	N						AREAS	S		НЕ	ATING COIL	SELECTIO	N	
		I Capacity		Coil Airflow		r DB/W				3/WB/HR		Gross Total	Glass				Coil Airflow	Ent	
	ton	MBh	MBh	cfm	°F	°F	gr/lb	°F	°F	gr/lb			ft²	(%)		MBh	cfm	°F	°F
Main Clg	22.5	269.6	197.2	7,384	78.6	65.0	70.8	54.6	52.9	57.0	Floor	13,900		1 1	Main Htg	-115.2	2.847	54.6	91.0
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0		0.0	Part	0		1.1	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	Int Door	0		1	Preheat	-60.1	1,320	13.8	54.6
	0.0	0.0	5.0	o o	0.0	0.0	0.0	0.0	0.0	0.0	ExFir	Ö			Reheat	-55.1	2.847	54.6	72.0
Total	22.5	269.6									Roof	Ö	0		Humidif	0.0	0	0.0	0.0
											Wall	3,660	1,070	29	Opt Vent	0.0	0	0.0	0.0
											1			1.1	-				

Project Name:

Dataset Name: Thesis Loads.trc TRACE® 700 v6.3.2 calculated at 05:40 PM on 10/13/2016 Alternative - 1 System Checksums Report Page 6 of 8

Ext Door

Total

AHU-4-1

Variable Volume Reheat (30% Min Flow Default)

AHU-4-1									variab	ie volum	e Reneat (30%	Min Flow	Detauit)
	COOLING	COIL PEAK			CLG SPACE PEAK HEATING COIL PEAK TEMPER							ERATURE	S
	ed at Time: Outside Air:	Mo/ł OADB/WB/H	Hr: 7 / 15 IR: 92 / 76 / 1	108	Mo/Hr: OADB:			Mo/Hr: Hea	ating Design		SADB	Cooling 55.3	Heating 93.9
											Ra Plenum	75.8	70.2
	Space	Plenum	Net	Percent :	Space	Percent	:	Space Peak	Coil Peak	Percent	Return	76.6	70.2
	Sens. + Lat.	Sens. + Lat	Total	Of Total	Sensible	Of Total	:	Space Sens	Tot Sens	Of Total	Ret/OA	83.5	33.6
	Btu/h	Btu/h	Btu/h	(%)	Btu/h	(%)		Btu/h	Btu/h	(%)	Fn MtrTD	0.1	0.0
Envelope Loads		~ 4					Envelope Loads		l .	` '	Fn BldTD	0.2	0.0
Skylite Solar	0	0	0	0	0	0	Skylite Solar	0	0	0.00	Fn Frict	0.7	0.0
Skylite Cond	0	0	0	0	0	0	Skylite Cond	0	0	0.00			
Roof Cond	0	25,137	25,137	4	0	0	Roof Cond	0	-23,742	5.18			
Glass Solar	69,248	0	69,248	12	86,444	36	Glass Solar	0	0	0.00	AIR	FLOWS	
Glass/Door Cond	20,876	0	20,876	4 :	13,236	- 5	Glass/Door Cond	-69,588	-69,588	15.17		Cooling	Heatir
Wall Cond	4,205	5,600	9,805	2:	4,882	2	: Wall Cond	-4,158	-10,470	2.28	D:#	11,553	
Partition/Door	0		0	0:	0	0	Partition/Door	0	0	0.00	Diffuser		5,20
Floor	0		0	0	0	0	Floor	0	0	0.00	Terminal	11,553	5,20
Adjacent Floor	0	0	0	0	0	0	Adjacent Floor	0	0	0	Main Fan	11,553	5,2
Infiltration	29,136		29,136	5 :	7,268	3	Infiltration	-36,307	-36,307	7.92	Sec Fan	0	
Sub Total ==>	123,466	30,737	154,203	27 :	111,830	46	Sub Total ==>	-110,053	-140,107	30.55	Nom Vent	5,023	3,4
				:			:				AHU Vent	5,023	3,4
Internal Loads							Internal Loads				Infil	560	56
Lights	48,702	12,175	60,877	11	48,702	20	Lights	0	0	0.00	MinStop/Rh	5,264	5,26
People	45,352	12,170	45,352	8	25,196	10	People	0	0	0.00	Return	12,113	
Misc	40,612	0	40,612	7:	40,612	17			0	0.00	Exhaust	5,583	
Sub Total ==>	134,666	12,175	146.842	26	114,510	48	Sub Total ==>	0	0	0.00	Rm Exh	0,000	
Sub Total ==>	134,000	12,175	140,042	26	114,510	40	Sub Total ==>	0	U	0.00	Auxiliary	0	
Ceiling Load	17,428	-17,428	0	0	14.529	6	Ceiling Load	-18.093	0	0.00	Leakage Dwn	0	
Ventilation Load	17,428	-17,420	261,358	46	14,529	0	Ventilation Load	0	-221,623	48.33	Leakage Ups	0	
Adj Air Trans Heat	STATE OF THE PARTY		,		Accept the	0	Adj Air Trans Heat	0	0	0.00	Leakage Ups	U	
***************************************	0		0	0	0	0			0	-			
Dehumid. Ov Sizing	,		0	0.	_		Ov/Undr Sizing	0	8,171	0.00 -1.78			
Ov/Undr Sizing Exhaust Heat	0	-16,009	-16,009	0 : -3 :	0	0	Exhaust Heat OA Preheat Diff.		-72,267	15.76	ENGINE	ERING CH	KS
		-16,009	13,511	2:					-72,267	7.14		Cooling	Heating
Sup. Fan Heat		10.631	10,631	2:			RA Preheat Diff. Additional Reheat		-32,763	0.00	% OA	43.5	64.9
Ret. Fan Heat Duct Heat Pkup		0,631	10,031	0:			Additional Reneat		U	0.00	cfm/ft²	0.37	0.17
Duct ก่อสเ คนบุ Underfir Sup Ht Pkเ	ın	U	0	0:			Underfir Sup Ht Pkup		0	0.00	cfm/ton	242.98	0.11
Supply Air Leakage		0	0	0:			Supply Air Leakage		0	0.00	ft²/ton	651.43	
oupply All Leakage		0	U	0			Supply All Leakage		U	0.00	Btu/hr·ft²	18.42	-14.81
Grand Total ==>	275,561	20,106	570,535	100.00	240,869	100.00	Grand Total ==>	-128,146	-458,589	100.00	No. People	573	-14.01
		00011110	0011 05:	FOTION				ADEAC				FI FOTIS	
	Total Capacity	COOLING Sens Cap.			B/WB/HR	Loove	DB/WB/HR	AREAS Gross Total G	ilass	н	EATING COIL S Capacity C		
	on MBh	Sens Cap. (cfm		°F ar/lb	°F			112 (%)		MBh	cfm	Ent L °F

			COOLING	COIL SEL	ECTIC	N				
	Total	Capacity		Coil Airflow		er DB/W				WB/HR
	ton	MBh	MBh	cfm	°F	°F	gr/lb	°F	°F	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								

	AREA	AS		
	Gross Total	Glas ft²	s (%)	
Floor	30,972 0			M
Part Int Door	0			P
ExFlr	0			R
Roof	14,043	0	0	н
Wall	5,600	2,542	45	0
Ext Doo	r 0	0	0	7

HEATING COIL SELECTION														
	Capacity	Coil Airflow	Ent	Lvg										
	MBh	cfm	°F	°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 Opt Vent	0.0 0.0	0	0.0	0.0										
Total	-458.6													

Project Name:

Dataset Name: Thesis Loads.trc TRACE® 700 v6.3.2 calculated at 05:40 PM on 10/13/2016 Alternative - 1 System Checksums Report Page 7 of 8

AHU-4-2

Variable Volume Reheat (30% Min Flow Default)

	COOLI	NG C	OIL PEAK			CLG SPACE	PEAK			HEATING (COIL PEAK			TEM	PERATURE	S
Pea	ked at Time Outside Air		Mo/H OADB/WB/HI	Hr: 7 / 15 R: 92 / 76 / 1	08	Mo/Hr: OADB:				Mo/Hr: OADB:	Heating Design	gn		SADB Ra Plenum	Cooling 55.7 74.8	Heating 91.0 71.5
	S _l Sens. +	pace Lat.	Plenum Sens. + Lat	Net Total	Percent Of Total	Space Sensible	Percent Of Total			Space Peak Space Sens		eak Per		Return Ret/OA	75.6 78.6	71.5 44.7
	E	Stu/h	Btu/h	Btu/h	(%)	Btu/h	(%)			Btu/h		u/h	(%)	Fn MtrTD	0.1	0.0
Envelope Loads			~				1.17	Envelope L	pads				``	Fn BldTD	0.2	0.0
Skylite Solar		0	0	0	0	0	0	Skylite S	olar	0			0.00	Fn Frict	0.7	0.0
Skylite Cond		0	0	0	0	0	0	Skylite C	ond	0		0	0.00			
Roof Cond		0	0	0	0	0	0	Roof Cor		0			0.00			
Glass Solar		,878	0	38,878	14		32	Glass So		0			0.00	A	IRFLOWS	
Glass/Door Cond		,788	0	8,788	3		4	: Glass/Do		-29,294	-29,2		6.72		Cooling	Heatin
Wall Cond	3	,848	3,366	7,214	3		2			-4,783	-9,0		5.14	Diffuser	7,587	
Partition/Door		0		0	0		0		Door	0			0.00		7,587	,
Floor		0	_	0	0		0	Floor		0			0.00	Terminal Main Fan	7,587	
Adjacent Floor		0	0	0	0		0	Adjacent		0		0	0			
Infiltration		,956		18,956	7		3	Infiltration		-23,729	-23,		3.54	Sec Fan	0	
Sub Total ==>	70	,471	3,366	73,838	27	63,168	41	: Sub Tota	==>	-57,806	-62,0)27 3	5.40	Nom Vent	1,320	
									_					AHU Vent	1,320	1,32
Internal Loads								Internal Loa	ids					Infil	366	36
Lights	30	,362	7,591	37,953	14	30,362	20	Lights		0		0	0.00	MinStop/Rh	2,847	2,8
People	43	,741	0	43,741	16	24,301	16	People		0		0	0.00	Return	7,953	3,2
Misc	33	,175	0	33,175	12	33,175	21	Misc		0	,	0	0.00	Exhaust	1,686	1,68
Sub Total ==>	107	.279	7,591	114,869	43	87,838	57	Sub Tota	==>	0		0	0.00	Rm Exh	0	
				,					/			-		Auxiliary	0	
Ceiling Load	3	,698	-3,698	0	0	3,638	2	Ceiling Loa	d \	-2,329		0	0.00	Leakage Dwn	0	
Ventilation Load	_	0	0	68,368	25	0	0	Ventilation	Load	0	-85,	581 4	8.84	Leakage Ups	0	
Adj Air Trans Hea	t	0		0	0	0	0	Adj Air Tran	s Heat	0		0	0	•		
Dehumid. Ov Sizi	ng			0	0			Ov/Undr Siz	ing	0		0	0.00			
Ov/Undr Sizing	J	0		0	0	. 0	0	Exhaust He	at		9	993 -	0.57	FNGIN	IEERING C	KS
Exhaust Heat			-3,076	-3,076	-1			OA Preheat	Diff.			0	0.00			
Sup. Fan Heat				8,752	3	:		RA Preheat	Diff.		-28,	524 1	6.33		Cooling	Heating
Ret. Fan Heat			6,889	6,889	3	:		Additional	Reheat			0	0.00	% OA	17.4	46.4
Duct Heat Pkup			0	0	0			:						cfm/ft²	0.55	0.20
Jnderflr Sup Ht P	kup			0	0			Underfir Su	p Ht Pkup				0.00	cfm/ton	337.65	
Supply Air Leakag	ge		0	0	0			Supply Air	_eakage			0	0.00	ft²/ton	618.60	
Grand Total ==>	181	,448	11,072	269,640	100.00	154,644	100.00	Grand Tota	==>	-60,135	-175,2	239 10	00.00	Btu/hr·ft² No. People	19.40 97	-12.61
			COOLING							AREAS		7	НЕ	EATING COIL		
	Total Capa ton	acity MBh	Sens Cap. (MBh	Coil Airflow cfm	Enter I °F	DB/WB/HR °F gr/lb	Leave °F	°F gr/lb	G	Fross Total	Glass ft² (%)			Capacity MBh	Coil Airflow cfm	Ent l °F
Main Clg	22.5 2	69.6	197.2	7,384	78.6	5.0 70.8	54.6 5	2.9 57.0	Floor	13,900		Main	Htg	-115.2	2,847	54.6 9
Aux Clg	0.0	0.0	0.0	0		0.0 0.0		0.0 0.0	Part	0		Aux I		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	Int Door	0		Prehe	eat	-60.1	1,320	13.8 5
	0	0.0	0.0	Ü	0.0		0.0		ExFir	0		Rehe		-55.1		54.6 7
Total	22.5 2	69.6							Roof	0	0 0	Humi		0.0	2,017	0.0
									Wall		,070 29	Opt V		0.0	0	0.0
									Fort Door	0,000	0 0	Total		175.0		

Ext Door

Project Name:

Dataset Name: Thesis Loads.trc TRACE® 700 v6.3.2 calculated at 05:40 PM on 10/13/2016 Alternative - 1 System Checksums Report Page 8 of 8

-175.2

Total