The Joe and Rika Mansueto Library

HVAC Design Calculations

2012 ASHRAE Student Design Competition

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EA Innovation In Ventilation

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Chapter 1

Executive Summary

Our responsibility for this project was to analyze the Joe and Rika Mansueto Library at the University of Chicago and gather all pertinent information regarding its environment. Once all necessary information was gathered, we were to determine the load calculations necessary to maintain the requirements of the library. These data were placed into Trane's Trace 700$^{\mathrm{TM}}$ software in order to estimate loading specifications. Knowing the requirements, we were tasked to design an HVAC system which would effectively fulfill the requirements in an energy- efficient and cost-efficient manner.

This document is a report on all of the information that we have gathered – including all research regarding the building itself, the conditions of the surrounding air, possible systems to implement, and our selection and implementation of our designed system.

Chapter 2

Design Considerations

This project is unique from many others because of its genuine practicality. Amid all of the 'true engineering' tasks like stress testing or element analysis, it is easy to get caught up in the billboard projects: vehicle design, missile design. These types of jobs tend to grab the spotlight for many in the field. Indeed, they are very important in their own right! There is much to be excited about when you consider these applications. But, it is not over-stepping things to say that such ventures are 'specialty projects' – that is, they are for specific contexts and not universal. This is where our project shows its value.

Sometimes without even noticing it, a large percentage of the world lives life relatively unaware of air. Until there is a problem with it, that is. Once an issue arises with temperature or quality, then we move quickly to make a change. Nevertheless, for the most part, we tend to take for granted that if it is cold outside, we will be warm once we enter a building. This is a logical thought-process. But there is a reason behind that warmth. And therein is our task.

The purpose of our project is to design an HVAC system for a building. The two main goals are thermal comfort and acceptable air quality. Since our project is based on a competition, our first major task was to establish project requirements as laid out by ASHRAE. Most of these were gathered from the ASHRAE website. However, when it came to specific environment assumptions, we had a few choices to make.

2.1 Environmental Conditions

As stated before, the library is located at the University of Chicago in downtown Chicago. Trace 700^{TM} has compiled weather data for multiple regions within the United States. Unfortunately, it does not have one for our specific location. Therefore, we assumed a location of Chicago's Midway Airport, which is located approximately 9 miles west of the library. We find this to be a suitable assumption because both of the locations lie along the same longitudinal line – meaning that their weather patterns stay fairly constant within that short distance.

2.2 Building Design

The Joe and Rika Mansueto Library (Figure 2.2) is a breathtaking example of architectural prowess and technological advancement. Constructed in May 2011, it serves as a prime model of modernization in educational buildings.

Figure 2.1: Map showing the relative location of the library site and weather gathering station.

Figure 2.2: Photograph of the glass dome covering the Joe and Rika Mansueto Library.

This dome's surface is made completely out of glass and is fully transparent, allowing for uninhibited visibility between the inside and outside of the library. The glass that is used for the dome is a high-performance class, specifically effective in combining solar heat rejection with ambient light admittance. This provides an incredible amount of tinted light into the library while keeping firm control of the heat that is being permitted, allowing for a very comfortable workspace for those inside. Still, it poses an interesting challenge of maintaining that environment.

The glass dome covering the ground floor of the library is the most significant single load on the HVAC system. The dome is approximately 240 feet long, 120 feet wide and 35 feet tall. The glass higher than 18 feet above the ground is fritted while all lower glass is clear. Since exact drawings were not available it was assumed that the dome is an ellipsoid with a constant curvature in the lateral direction. The total area was calculated using this assumption.

In general, the library has three major subsections with environment requirements to maintain. Each subsection of the library will be covered in detail in this report. At this point, however, we will simply state the three prominent sections and their desired environment conditions:

Figure 2.3: Rendered representations of the library.

- **The Grand Reading Room** — The performance target to be maintained in the ground floor Reading Room is 75 °F and 50% relative humidity (55 °F dew point) in the summer and 72 °F and 30% relative humidity (38.9 °F dew point) in the winter.
- **Archival Storage / Automated Storage and Retrieval System** — The specifications of this area, as laid out by the client, are 68 °F (±2 °F) and 30% relative humidity (29 °F dew point) and a space condition of 80 °F and 60% relative humidity.
- **Conservation Laboratories** — The performance target of this area must be maintained at 75 °F and 45% relative humidity (52.2 °F dew point) in the summer and 72 °F and 45% relative humidity (49.6 °F dew point) in the winter.

These are the three major systems that have been our focal point. Each of them has their own specific needs, and all of these specifications are absolutely crucial for the entire library to function effectively.

Another set of information that we needed to consider was specific requests from the library's owner. Early on in the project, the client requested that heat pumps be used to generate the hot and chilled water; another request of the client was that we employ Variable- Air-Volume (VAV) boxes wherever possible; these boxes help to control and vary flow for specific zones. These requests were considered, and we have explored cost-effective HVAC systems and designs that would provide thermal comfort, indoor air quality, and energy conservation.

Chapter 3

Load Calculations

By a large margin, the pivotal point of this project revolved around obtaining acceptable load estimations. As stated before, we incorporated the program Trane Trace 700^{TM} in order to fabricate our load requirements. This entailed a large amount of research into specific loadings given within the building. People, lights, miscellaneous electronics, ventilations, and of course the roof were all given respective estimations. These numbers were then placed into our Trace 700^{TM} model for analysis.

3.1 Building Envelope

The unique shape of the library represented one of the greatest difficulties to work through. Since an ellipsoid is not a valid shape for input into TRACE^{TM} 700, an approximate model was created with a sweep between three octagons as shown in Figure 3.1.

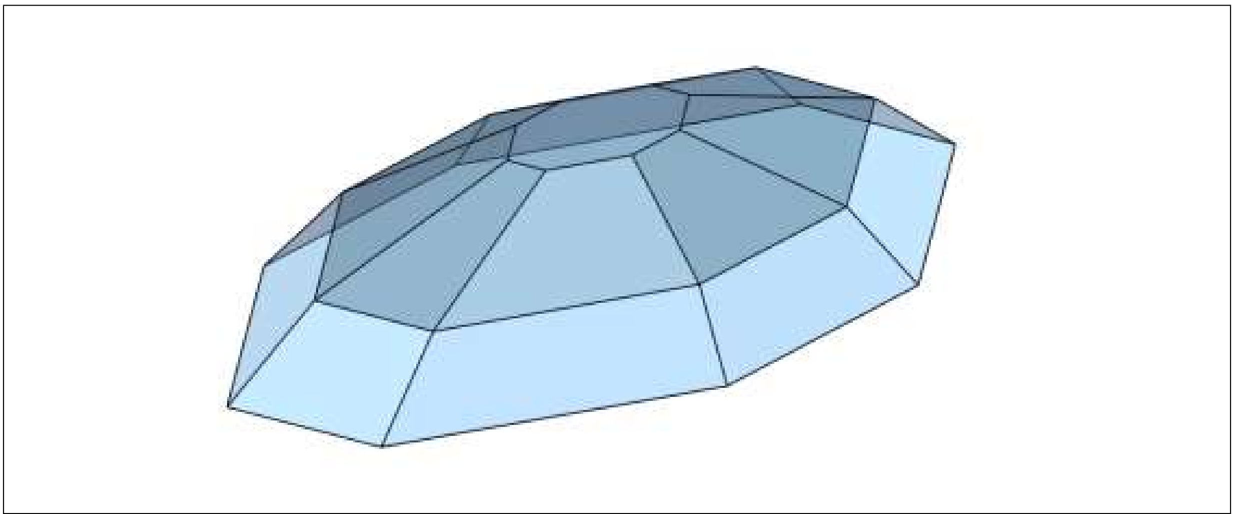

Figure 3.1: Mathematic representation to approximate the heat transfer of the dome.

This model was designed to have essentially the same total length, width, height, and surface area as the ellipsoid model. The middle octagon was placed at a height of 18 feet to distinguish between the fritted and clear glass areas.

Procurement of an acceptable model for the building envelope was absolutely essential for our loading cases. As can be expected (and will graphically be shown later), the library roof proved to be our largest load case to take into account. Therefore, it was vital to have a good estimation of its load potential.

3.2 Building Layout

Earlier we mentioned each specific area and it specifications. Now we will discuss how we went about inputting loading data for each portion.

- **The Grand Reading Room** — The 8,000-square-foot room must provide comfortable seating for faculty, students and visiting scholars. It will be constantly filled with people, giving off latent heat to the environment. Additionally, many of those in the room will be toting laptops and other electronic devices, which account for sensible heat moving into the room—not to mention the Circulation Service Center, which will also house computers. We have taken these various heat sources into account in our analysis. Also, the amount of people in the room necessitates constant cycling of the air in the room for filtration purposes. Furthermore, as far as people numbers, we assumed there to be maximum occupancy at all times. This number was given in the project requirements as 180 persons in the Reading Room. Maintaining this environment is crucial because it is a place of study. It would be a sad ordeal if individuals could not study effectively because they are made uncomfortable by the atmosphere. Indeed, that is why the specifications are so tight. They are standards for a system which maintains a healthy and comfortable environment, so those in the room can achieve optimal focus.

- **Conservation Labs** — The Library houses a state-of-the-art conservation and digital technology laboratory that will be used to preserve manuscripts and other rare materials in their original form or through digitization. One lab contains a 700-cfm fume hood. Accordingly, we modeled that hood as an extra ventilation consideration. These labs must be strictly maintained so as to provide a suitable environment for the work of conserving documents. This process can be incredibly sensitive; as a result, much time and effort will be spent on coming up with an HVAC system which will not only be suitable, but will actually serve to advance and enhance the work in the labs.

- **Archive Storage / Automated Storage and Retrieval System (ASRS)** — Because this area acts as storage for the books, it also necessitates a strict maintenance of the surrounding air. Although the amount of latent heat will be much less substantial than that of the Grand Reading Room, there are other factors to consider. We needed to calculate moisture loads from a variety of sources, such as ventilation, people, and door openings. Furthermore, we necessarily took into account any heat that is generated by the machines and cranes that are used to retrieve the books. The mechanical arms which maintain this operation are each fitted with a 10-horsepower motor. This we modeled as an internal load within the basement. The overarching goal is to minimize natural aging of books, mechanical damage, mold risk, and metal corrosion. In every aspect of this analysis, therefore, we made these points of major emphasis. We want to maximize the amount of time that these books can be on the shelf.

3.3 Zoning

Trace allows the user to set zones for heating and cooling maintenance purposes. This aids specifically in our case because it allows us to separate areas with unique performance specifications – easing the process of determining necessary equipment loads as well.

For our design, we chose the basement as its own zone. Because its requirements for humidity and temperature control were much more stringent than those of the ground floor, we wanted a high rate of manipulability within this area.

On the ground floor, we decided to split the region into five zones, as shown in Figure 3.2.

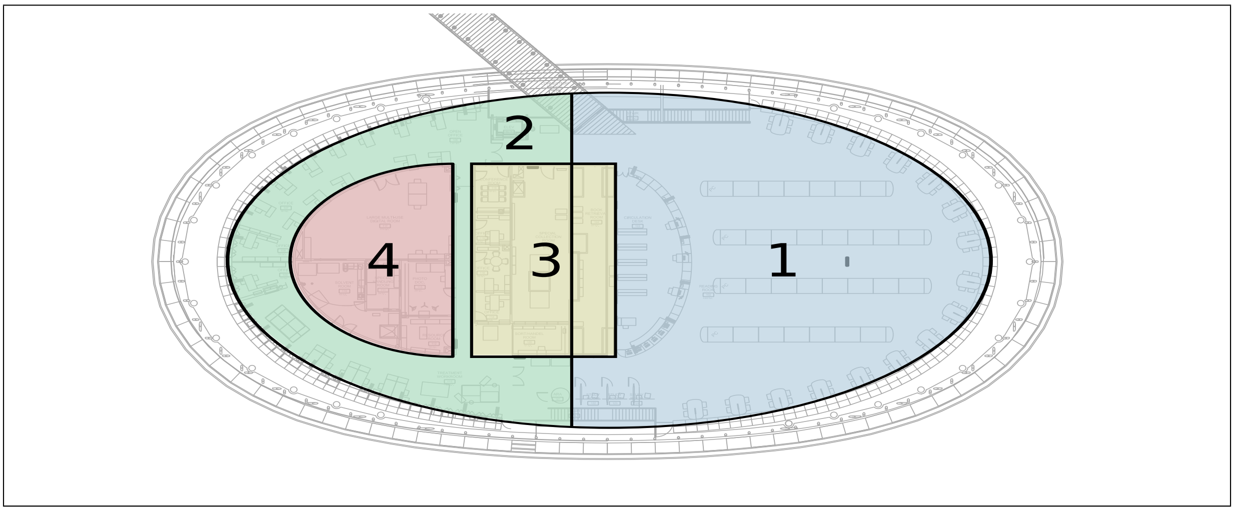

Figure 3.2: Layout of the zones chosen for the HVAC system design.

Again, dividing into zones gives more freedom to control specific regions – since there are differing environments within the building. As can be seen in the figure, the Reading Room (including the Circulation Desk) is its own zone (1). Also, the Offices have their own designated space (3), along with the Laboratories (4), and the Preservation Area (2).

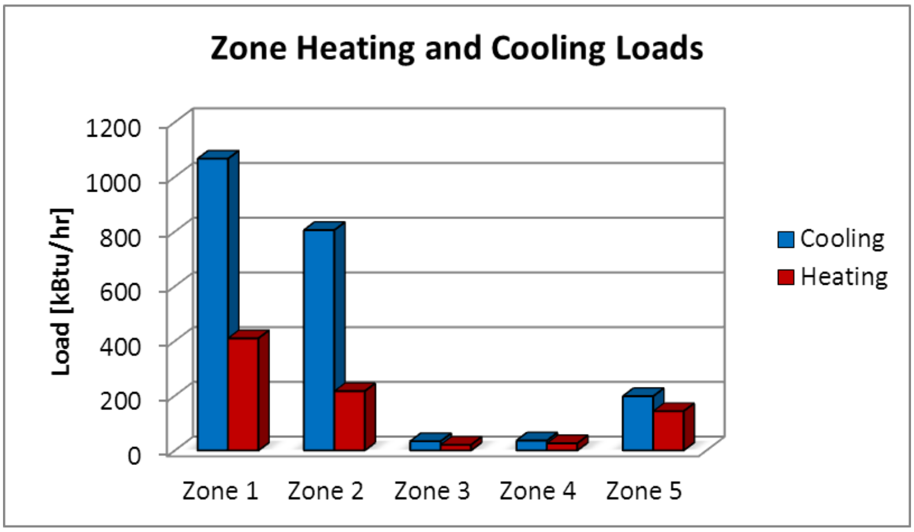

Figure 3.3: Graph of the loads on each zone.

In our analysis, we assumed that Zones 1 and 2 carried the roof load, while Zones 3 and 4 were assumed to be thermally insulated – meaning no roof load would be applied. Using the TRACE^{TM} modeling software, we were then able to define the theoretical peak loads which our proposed HVAC system would be called on to maintain. These loads are shown in Figure 3.3.

By looking at this graph, it is obvious just how much the roof load affects the overall building load. The significant cooling load is directly resulting from the heat obtained through the roof's solar gain. Not only that, but the significant load for heating within those same zones makes sense as well. During colder months, heat is lost by conduction through the roof – meaning that the system would have to work harder in those zones to maintain the required specifications.

In fullness, Zones 3 and 4 should carry a very small load because of their size and relative insulation. Zones 1 and 2, both holding a share of the roof load, should be significantly higher than all of the other sections. And Zone 5 – being the basement – should carry a good load because of its size, yet still be reasonable.

To emphasize the overall significance of that roof load, we compiled a graph which compared its numbers to all of the other factors which we considered.

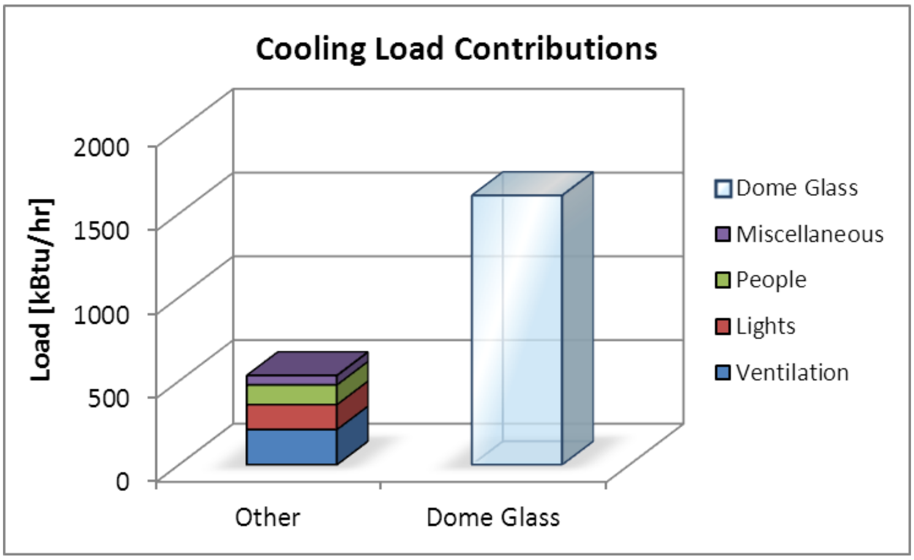

Figure 3.4: Graph of the loads created by various factors.

Figure 3.4 does a perfect job of clarifying just how much the overall load is affected by the roof. All told, the roof comprised roughly 75% of the total necessary load requirements. Truly, the library sacrifices a lot of utility efficiency for the sake of aesthetics.

Chapter 4

HVAC System Design

4.1 Waterside

After justifying the choice of a ground-source heat pump, it was then our responsibility to design a viable water-side piping diagram. This layout is meant to show how water is sent through the ground-loop and coils of the heat pump. Our design is shown in Figure 4.1.

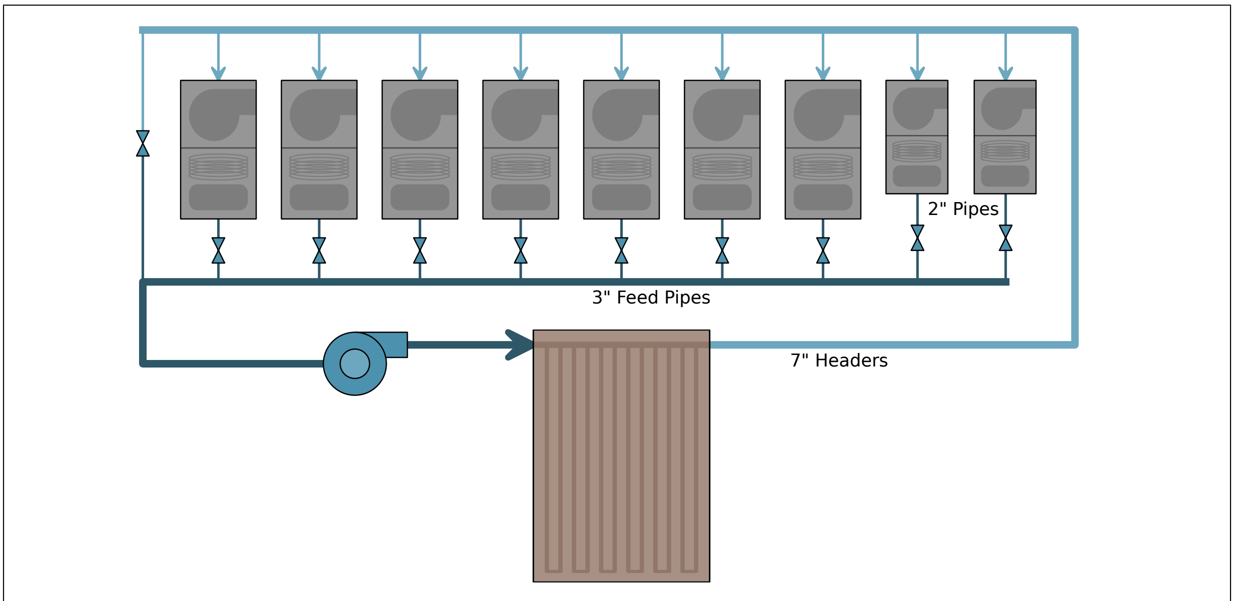

Figure 4.1: Schematic of the waterside system.

As can be seen in the graph, our loads require nine separate heat pumps along one loop. The size of the pumps is dependent on the required load in each zone. Once we discerned the loads in each of the zones, we were then able to make selections regarding equipment to employ in each zone. Based on the loads, we determined that Zone 1 would necessitate four heat pumps; Zone 2, a little smaller, requires three heat pumps. Zones 3 and 4 actually have small enough loads that they can be combined into one smaller heat pump. Finally, Zone 5 will require its own heat pump as well.

4.2 Airside

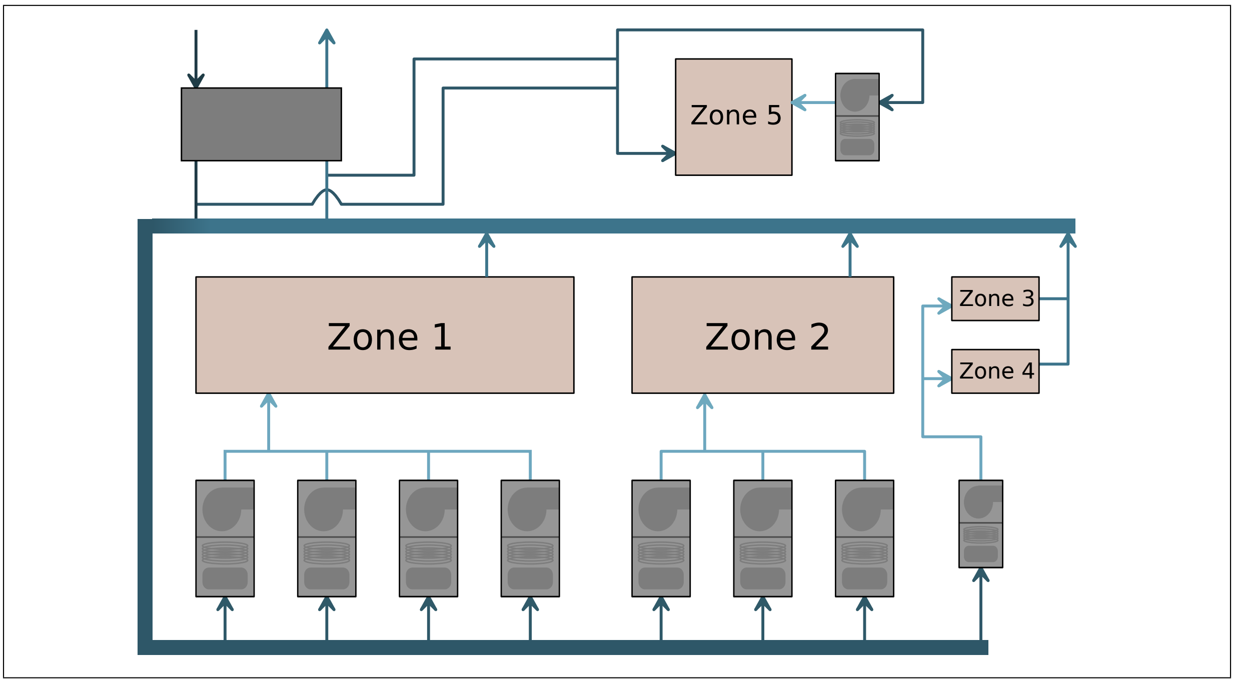

Figure 4.2: Schematic of the airside system.

Figure 4.2 shows a schematic of the airside system design. Zones 1-4 share a return air plenum which routes the air back to the supply side after exhausting air and mixing outside air from the heat recovery unit. Zone 5, covering the basement area uses the same heat recovery unit but does not mix the return air with that of other zones. This is because of the very different requirements within the basement area.

Chapter 5

ASHRAE Standards and Guidelines

This project requires that the design meet ASHRAE Standards 55, 62.1 and 90.1 along with any local regulations which are applicable to the University of Chicago where the building is located. Thus all of these standards must be considered throughout various stages of system design. The basic purpose and function of each of the three ASHRAE standards are summarized below.

ASHRAE Standard 55 - Thermal Environmental Conditions for Human Occupancy - sets forth the guidelines for designing a system which the inhabitants will find thermally acceptable. The standard outlines the combinations of indoor thermal environmental factors and personal factors that will produce a thermal environmental condition that is acceptable by a majority of occupants. The standard includes consideration of the outdoor environment, the people inside the conditioned space and how the space is used. It identifies six factors that must be defined when establishing conditions for thermal comfort which are metabolic rate, clothing insulation, air temperature, radiant temperature, air speed and humidity. Section 5.2 goes through the method for determining acceptable thermal conditions in occupied spaces. To comply with the standard, a system must keep the temperature of the conditioned space within the comfort zone defined by the methods outlined in the standard.

ASHRAE Standard 62.1 - Ventilation for Acceptable Indoor Air Quality - specifies minimum ventilation rates and indoor air quality that will be acceptable to the inhabitants and minimize potential adverse health effects. Ventilation will be designed for air balancing where each space is provided with its required minimum ventilation airflow. Relative humidity will be designed either at the peak outdoor dew-point design conditions and at the peak indoor design latent load or at the lowest space sensible heat ratio expected to occur and the concurrent outdoor condition.

Under Standard 62.1, air is categorized into four different classes. Since the building is a library and does not contain restrooms we will only encounter Class 1 and Class 2 airs. Class 1 air is defined as air with low contaminant concentration, low sensory irritation intensity and inoffensive odor. Class 2 air is defined as air with moderate contaminant concentration, mild sensory irritation and mildly offensive odor. Class 1 air can be recirculated to any space. Class 2 air can be recirculated within itself or within classes 3 and 4 but may not be recirculated into class 1 air.

Two types of procedures exist when it comes to design of a ventilation system, Ventilation Rate Procedure (VRP) and Indoor Air Quality Procedure (IAQ). In VRP, outdoor air intake rates are determined based on space type/application, occupancy level and floor area. In IAQ, the outdoor air intake rates and other system design parameters are based on analysis of containment sources and containment concentration targets. IAQ is also used when the design is intended to attain specific target contaminant concentrations or levels of acceptability of perceived indoor air quality. Both IAQ and VRP yield good results for any context; however IAQ is dependent on case studies which we cannot have since we do not have the building close. Therefore, for our purposes, we will be using the VRP because results from VRP can be attained using tabulated data.

Zone parameters are determined by applying zone parameters in Sections 6.2.2.1 through 6.2.2.3 of ASHRAE Standard 62.1-2004. Systems should be capable of providing the required ventilation rates in breathing zone whenever the zone is occupied. Air ducts should be designed to provide easy accessibility for repair and maintenance. Our final Standard that we had to abide by was ASHRAE 90.1. The local regulations of the City of Chicago calls for all HVAC work to be within the regulations of this code. ASHRAE 90.1 is a compilation of tables and charts which contain standardized values for variables that one encounters while constructing a low-rise building. We used these standards largely for sanity checks and referencing.

Lastly, ASHRAE has an entire array of handbooks that they send out systematically with huge amounts of information on different components that can be applied in scenarios, as well as conventional HVAC methods for specific building types – including one chapter on libraries. This chapter we have used extensively for reference regarding different air classes to keep in mind, what kinds of contaminants to be aware of, as well as information on suitable systems to apply for our future analysis.

Chapter 6

Summary and Conclusions

The goal of this year-long project was to design an HVAC system for the Joe and Rika Mansueto Library which would satisfy ASHRAE Standards 55, 62.1 and 90.1 for thermal comfort, indoor air quality, and energy efficiency, respectively. The task involves proper modeling and calculation of building loads according to ASHRAE's guidelines as well as design and sizing of appropriate equipment to meet all imposed requirements.

Significant study of the relevant standards has been made to help direct the design process and resulting solutions. Sections of all three standards provided for compliance that pertain to the library have been carefully read and compiled for reference throughout the entire project. Local conditions and codes have also been examined so that all requirements for the design may be fully understood and adequately met.

Various equipment and system components have been researched so that informed decisions were made throughout the process. A generic system was initially selected as a baseline model for calculation. Following that analysis, we ran three alternatives against the same loads in order to make a justified selection of a ground-source heat pump.

For the glass dome, which dominated the above-ground loads, an appropriate model was created and implemented with TRACE^{TM} 700 to allow for accurate calculations of the open area of the ground floor. The rest of the building was also broken down and described within TRACE^{TM} 700 to allow for accurate load calculation throughout the building.

The final system design utilized 9 different water source heat pumps to heat and cool the 5 building zones with a ground loop acting as a heat source and sink. A single water pump was used to serve the entire system and adaquately move the water through the ground loop. A heat recovery unit was also design into the system in order to reduce overall ventilation expenses.

Appendix A

System Checksums

Zone Checksums

By UNIVERSITY OF TEXAS AT ARLINGTON

Zone - 1

	COOLING COIL PEAK				CLG SPACE PEAK			HEATING COIL PEAK		
Peaked at Time:	Mo/Hr: 7 / 14				Mo/Hr: 6 / 14			Mo/Hr: Heating Design		
Outside Air:	OADB/WB/HR: 90 / 73 / 99				OADB: 85			OADB: 0		
	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	822,382	0	822,382	77	822,382	89	Skylite Solar	0	0	0.00
Skylite Cond	0	35,706	35,706	3	0	0	Skylite Cond	0	-274,436	65.15
Roof Cond	0	0	0	0	0	0	Roof Cond	0	0	0.00
Glass Solar	0	0	0	0	0	0	Glass Solar	0	0	0.00
Glass/Door Cond	0	0	0	0	0	0	Glass/Door Cond	0	0	0.00
Wall Cond	0	0	0	0	0	0	Wall Cond	0	0	0.00
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	0.00
Infiltration	0		0	0	0	0	Infiltration	0	0	0.00
Sub Total ==>	822,382	35,706	858,088	80	822,382	89	*Sub Total ==>*	0	-274,436	65.15
Internal Loads							**Internal Loads**			
Lights	39,543	0	39,543	4	39,543	4	Lights	0	0	0.00
People	76,050	0	76,050	7	46,350	5	People	0	0	0.00
Misc	15,205	0	15,205	1	15,205	2	Misc	0	0	0.00
Sub Total ==>	130,798	0	130,798	12	101,098	11	*Sub Total ==>*	0	0	0.00
Ceiling Load	0	0	0	0	0	0	**Ceiling Load**	-2	0	0.00
Ventilation Load	0	0	77,322	7	0	0	**Ventilation Load**	0	-160,286	38.05
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**		13,507	-3.21
Exhaust Heat		0	0	0			**OA Preheat Diff.**		0	0.00
Sup. Fan Heat			0	0			**RA Preheat Diff.**		0	0.00
Ret. Fan Heat		0	0	0			**Additional Reheat**		0	0.00
Duct Heat Pkup		0	0	0			**System Plenum Heat**		0	0.00
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 ==>	953,180	35,706	1,066,208	100.00	923,480	100.00	***Grand Total ==>***	-2	-421,214	100.00

TEMPERATURES

	Cooling	Heating
SADB	54.6	72.0
Ra Plenum	75.8	65.9
Return	75.7	66.5
Ret/OA	76.4	62.7
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	41,522	41,522
Terminal	41,522	41,522
Main Fan	41,522	41,522
Sec Fan	0	0
Nom Vent	2,044	2,044
AHU Vent	2,044	2,044
Infil	0	0
MinStop/Rh	0	0
Return	41,522	41,522
Exhaust	2,044	2,044
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	4.9	4.9
cfm/ft²	4.30	4.30
cfm/ton	467.32	
ft²/ton	108.68	
Btu/hr·ft²	110.42	-42.44
No. People	189	

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	88.9	1,066.2	994.8	41,522	76.5	58.2	45.1	54.6	48.5	42.3
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	88.9	1,066.2								

AREAS

	Gross Total	Glass ft²	(%)
Floor	9,656		
Part	0		
Int Door	0		
ExFlr	0		
Roof	16,190	16,190	100
Wall	0	0	0
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-409.8	41,522	62.9	72.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-409.8			

Project Name: TRACE® 700 v6.2.6.5 calculated at 01:00 PM on 04/26/2012

Dataset Name: Library-42612.trc Alternative - 1 System Checksums Report Page 1 of 51

Zone Checksums

By UNIVERSITY OF TEXAS AT ARLINGTON

Zone - 2

	COOLING COIL PEAK				CLG SPACE PEAK	
Peaked at Time:	Mo/Hr: 8 / 12				Mo/Hr: 3 / 12	
Outside Air:	OADB/WB/HR: 85 / 70 / 87				OADB: 44	
	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	717,788	0	717,788	89	739,819	95
Skylite Cond	0	31,458	31,458	4	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	0	0	0	0	0	0
Glass/Door Cond	0	0	0	0	0	0
Wall Cond	0	0	0	0	0	0
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	0		0	0	0	0
Sub Total ==>	717,788	31,458	749,246	93	739,819	95
Internal Loads						
Lights	14,077	0	14,077	2	14,077	2
People	12,600	0	12,600	2	7,000	1
Misc	14,744	0	14,744	2	14,744	2
Sub Total ==>	41,421	0	41,421	5	35,821	5
Ceiling Load	0	0	0	0	-1	0
Ventilation Load	0	0	14,615	2	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		0	0	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	759,209	31,458	805,282	100.00	775,639	100.00

	HEATING COIL PEAK		
	Mo/Hr: Heating Design		
	OADB: 0		
	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	-197,378	88.67
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	0	0	0.00
Wall Cond	0	0	0.00
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	0	0	0.00
Sub Total ==>	0	-197,378	88.67
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	0	0.00
Ventilation Load	0	-27,155	12.20
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		1,931	-0.87
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-1	-222,601	100.00

TEMPERATURES

	Cooling	Heating
SADB	54.9	72.0
Ra Plenum	75.8	66.9
Return	75.8	67.1
Ret/OA	75.9	66.2
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	35,392	35,392
Terminal	35,392	35,392
Main Fan	35,392	35,392
Sec Fan	0	0
Nom Vent	346	346
AHU Vent	346	346
Infil	0	0
MinStop/Rh	0	0
Return	35,392	35,392
Exhaust	346	346
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	1.0	1.0
cfm/ft²	10.29	10.29
cfm/ton	527.39	
ft²/ton	51.23	
Btu/hr·ft²	234.23	-62.98
No. People	28	

COOLING COIL SELECTION

	Total Capacity ton	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	67.1	805.3	791.1	35,392	75.9	59.9	53.3	54.9	51.7	53.3
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	67.1	805.3								

AREAS

	Gross Total	Glass ft²	(%)
Floor	3,438		
Part	0		
Int Door	0		
ExFlr	0		
Roof	11,479	11,479	100
Wall	0	0	0
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-216.5	35,392	66.4	72.0
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-216.5			

Project Name: TRACE® 700 v6.2.6.5 calculated at 01:00 PM on 04/26/2012

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Zone Checksums

By UNIVERSITY OF TEXAS AT
ARLINGTON

Zone - 3

COOLING COIL PEAK / CLG SPACE PEAK

Peaked at Time: Mo/Hr: 7 / 15 — CLG Space Peak Mo/Hr: 7 / 15
Outside Air: OADB/WB/HR: 91 / 73 / 96 — OADB: 91

	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	0	0	0	0	0	0
Glass/Door Cond	0	0	0	0	0	0
Wall Cond	0	0	0	0	0	0
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	0		0	0	0	0
Sub Total ==>	0	0	0	0	0	0
Internal Loads						
Lights	7,479	0	7,479	22	7,479	45
People	13,500	0	13,500	40	7,500	45
Misc	1,816	0	1,816	5	1,816	11
Sub Total ==>	22,794	0	22,794	68	16,794	100
Ceiling Load	0	0	0	0	0	0
Ventilation Load	0	0	10,693	32	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		0	0	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	22,794	0	33,487	100.00	16,794	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 0

	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	0	0	0.00
Wall Cond	0	0	0.00
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	0	0	0.00
Sub Total ==>	0	0	0.00
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	0	0	0.00
Ventilation Load	0	-20,358	78.18
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	1	1	0.00
Exhaust Heat		0	0.00
OA Preheat Diff.		-3,581	13.75
RA Preheat Diff.		-2,102	8.07
Additional Reheat		0	0.00
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	1	-26,041	100.00

TEMPERATURES

	Cooling	Heating
SADB	45.4	72.0
Ra Plenum	75.0	72.0
Return	75.0	72.0
Ret/OA	83.0	36.1
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	520	520
Terminal	520	520
Main Fan	520	520
Sec Fan	0	0
Nom Vent	260	260
AHU Vent	260	260
Infil	0	0
MinStop/Rh	0	0
Return	520	520
Exhaust	260	260
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	49.9	49.9
cfm/ft²	0.28	0.28
cfm/ton	186.46	
ft²/ton	654.33	
Btu/hr·ft²	18.34	-11.15
No. People	30	

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	2.8	33.5	21.3	520	83.0	67.6	78.9	45.4	45.1	45.1
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	2.8	33.5								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	1,826		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	0	0	0
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-20.4	520	36.1	72.0
Aux Htg	0.0	0	0.0	0.0
Preheat	-5.3	520	36.1	45.4
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-20.4			

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Zone Checksums

By UNIVERSITY OF TEXAS AT
ARLINGTON

Zone - 4

	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: 91 / 73 / 96				OADB: 91			OADB: 0		
	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	0	0	0	0	0	0	Glass Solar	0	0	0.00
Glass/Door Cond	0	0	0	0	0	0	Glass/Door Cond	0	0	0.00
Wall Cond	0	0	0	0	0	0	Wall Cond	0	0	0.00
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	0.00
Infiltration	0		0	0	0	0	Infiltration	0	0	0.00
Sub Total ==>	0	0	0	0	0	0	*Sub Total ==>*	0	0	0.00
Internal Loads							**Internal Loads**			
Lights	4,943	0	4,943	14	4,943	28	Lights	0	0	0.00
People	10,350	0	10,350	29	5,750	33	People	0	0	0.00
Misc	6,860	0	6,860	19	6,860	39	Misc	0	0	0.00
Sub Total ==>	22,154	0	22,154	61	17,554	100	*Sub Total ==>*	0	0	0.00
Ceiling Load	0	0	0	0	0	0	**Ceiling Load**	0	0	0.00
Ventilation Load	0	0	14,016	39	0	0	**Ventilation Load**	0	-26,041	100.00
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**		0	0.00
Exhaust Heat		0	0	0			**OA Preheat Diff.**		0	0.00
Sup. Fan Heat			0	0			**RA Preheat Diff.**		0	0.00
Ret. Fan Heat		0	0	0			**Additional Reheat**		0	0.00
Duct Heat Pkup		0	0	0			**System Plenum Heat**		0	0.00
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 ==>	22,154	0	36,169	100.00	17,554	100.00	***Grand Total ==>***	0	-26,041	100.00

TEMPERATURES

	Cooling	Heating
SADB	47.8	72.0
Ra Plenum	75.0	72.0
Return	75.0	72.0
Ret/OA	84.0	31.7
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	593	593
Terminal	593	593
Main Fan	593	593
Sec Fan	0	0
Nom Vent	332	332
AHU Vent	332	332
Infil	0	0
MinStop/Rh	0	0
Return	465	593
Exhaust	205	332
Rm Exh	127	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	56.0	56.0
cfm/ft²	0.49	0.49
cfm/ton	196.70	
ft²/ton	400.45	
Btu/hr·ft²	29.97	-21.58
No. People	23	

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	3.0	36.2	23.3	593	84.0	68.1	80.0	47.8	47.3	48.7
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	3.0	36.2								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	1,207		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	0	0	0
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity	Coil Airflow	Ent	Lvg
	MBh	cfm	°F	°F
Main Htg	-26.0	593	31.7	72.0
Aux Htg	0.0	0	0.0	0.0
Preheat	-10.4	593	31.7	47.8
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-26.0			

Project Name:
Dataset Name: Library-42612.trc

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Zone Checksums

By UNIVERSITY OF TEXAS AT ARLINGTON

Zone - 5

	COOLING COIL PEAK				CLG SPACE PEAK	
Peaked at Time:	Mo/Hr: 7 / 14				Mo/Hr: 7 / 15	
Outside Air:	OADB/WB/HR: 90 / 73 / 99				OADB: 91	
	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	0	0	0	0	0	0
Glass/Door Cond	0	0	0	0	0	0
Wall Cond	0	0	0	0	0	0
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	0		0	0	0	0
Sub Total ==>	0	0	0	0	0	0
Internal Loads						
Lights	83,284	0	83,284	42	83,284	81
People	5,000	0	5,000	3	2,500	2
Misc	16,967	0	16,967	9	16,967	17
Sub Total ==>	105,251	0	105,251	53	102,751	100
Ceiling Load	0	0	0	0	0	0
Ventilation Load	0	0	92,857	47	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		0	0	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	105,251	0	198,108	100.00	102,751	100.00

	HEATING COIL PEAK		
	Mo/Hr: Heating Design		
	OADB: 0		
	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	0	0	0.00
Wall Cond	0	0	0.00
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	0	0	0.00
Sub Total ==>	0	0	0.00
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	0	0	0.00
Ventilation Load	0	-133,954	120.09
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		-9,413	8.44
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
System Plenum Heat		31,824	-28.53
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	0	-111,543	100.00

TEMPERATURES	Cooling	Heating
SADB	41.7	69.8
Ra Plenum	80.0	80.0
Return	70.1	70.1
Ret/OA	80.5	39.1
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS	Cooling	Heating
Diffuser	3,360	3,360
Terminal	3,360	3,360
Main Fan	3,360	3,360
Sec Fan	0	0
Nom Vent	1,720	1,720
AHU Vent	1,720	1,720
Infil	0	0
MinStop/Rh	0	0
Return	2,860	2,860
Exhaust	1,220	1,220
Rm Exh	500	500
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS	Cooling	Heating
% OA	51.2	51.2
cfm/ft²	0.16	0.16
cfm/ton	203.53	
ft²/ton	1,237.81	
Btu/hr·ft²	9.69	-6.56
No. People	10	

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	16.5	198.1	138.2	3,360	79.5	63.8	65.8	41.7	41.6	39.6
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	16.5	198.1								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	20,435		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	0	0	0
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-134.0	3,360	33.2	69.8
Aux Htg	0.0	0	0.0	0.0
Preheat	-27.4	3,360	34.2	41.7
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-134.0			

Project Name: TRACE® 700 v6.2.6.5 calculated at 01:00 PM on 04/26/2012

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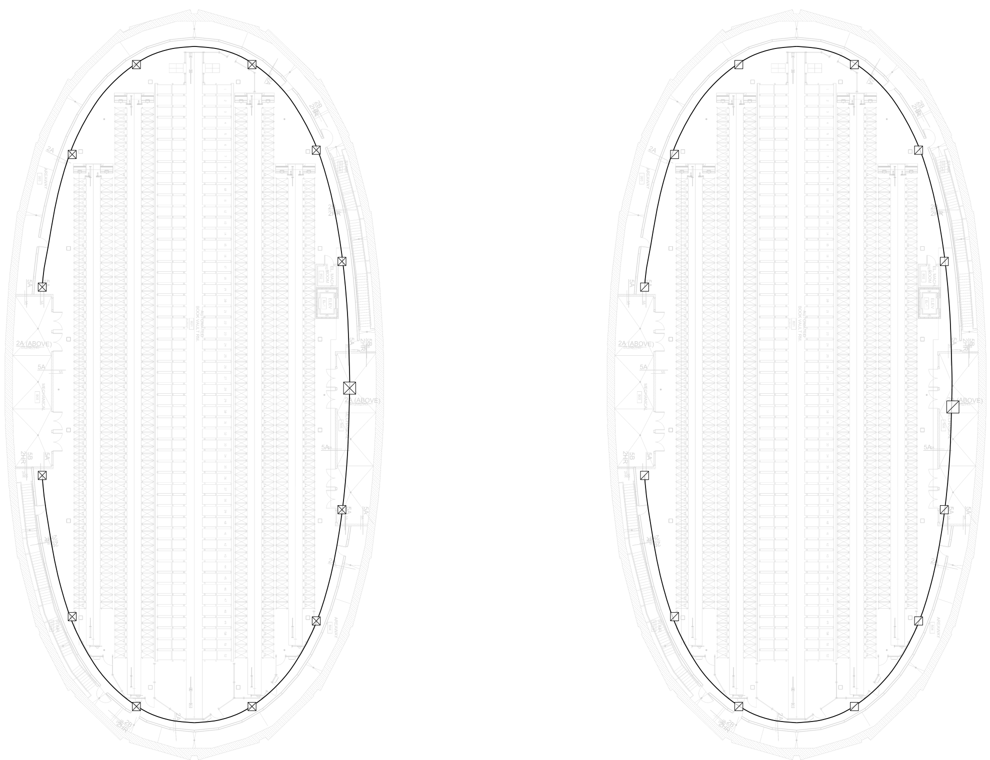
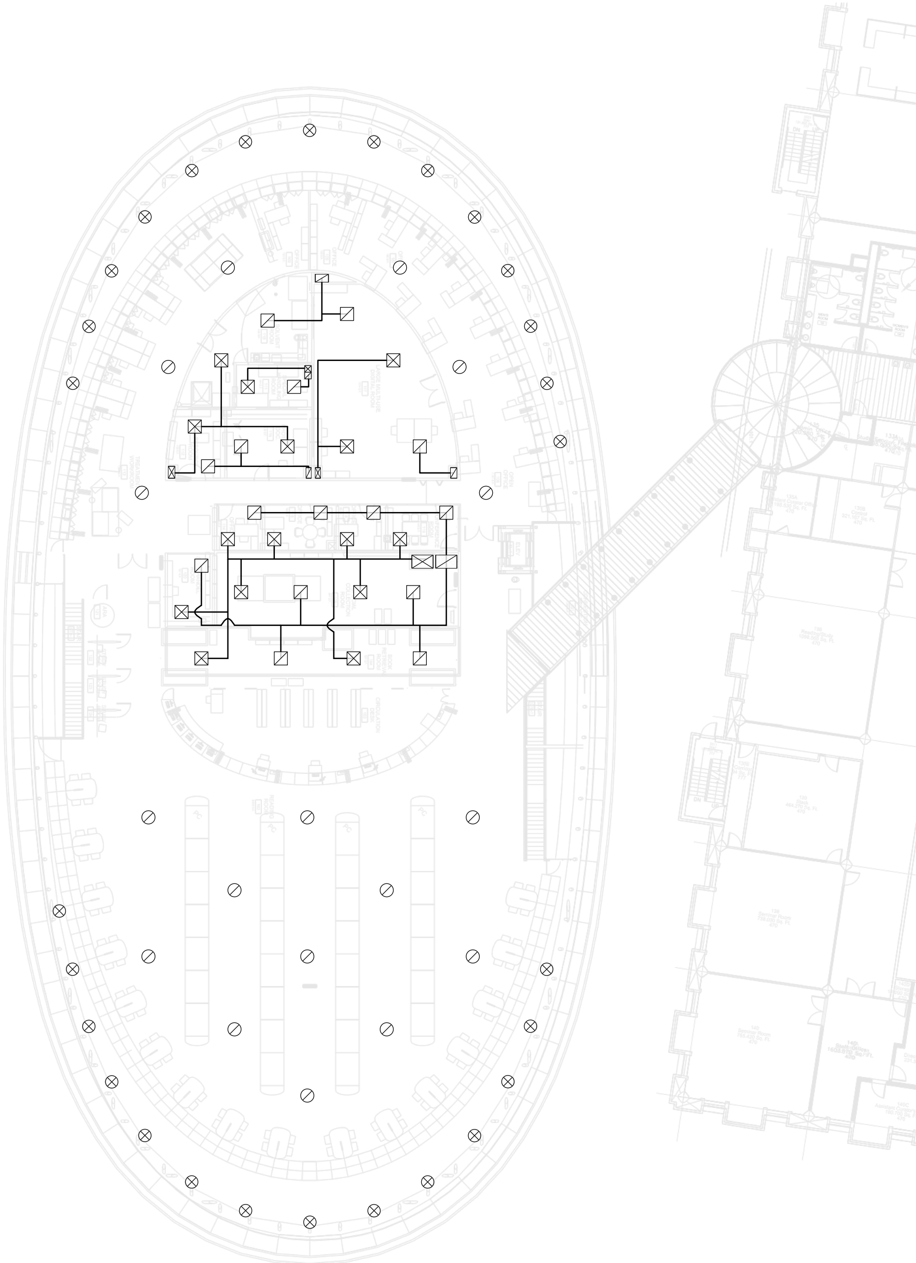
Appendix B

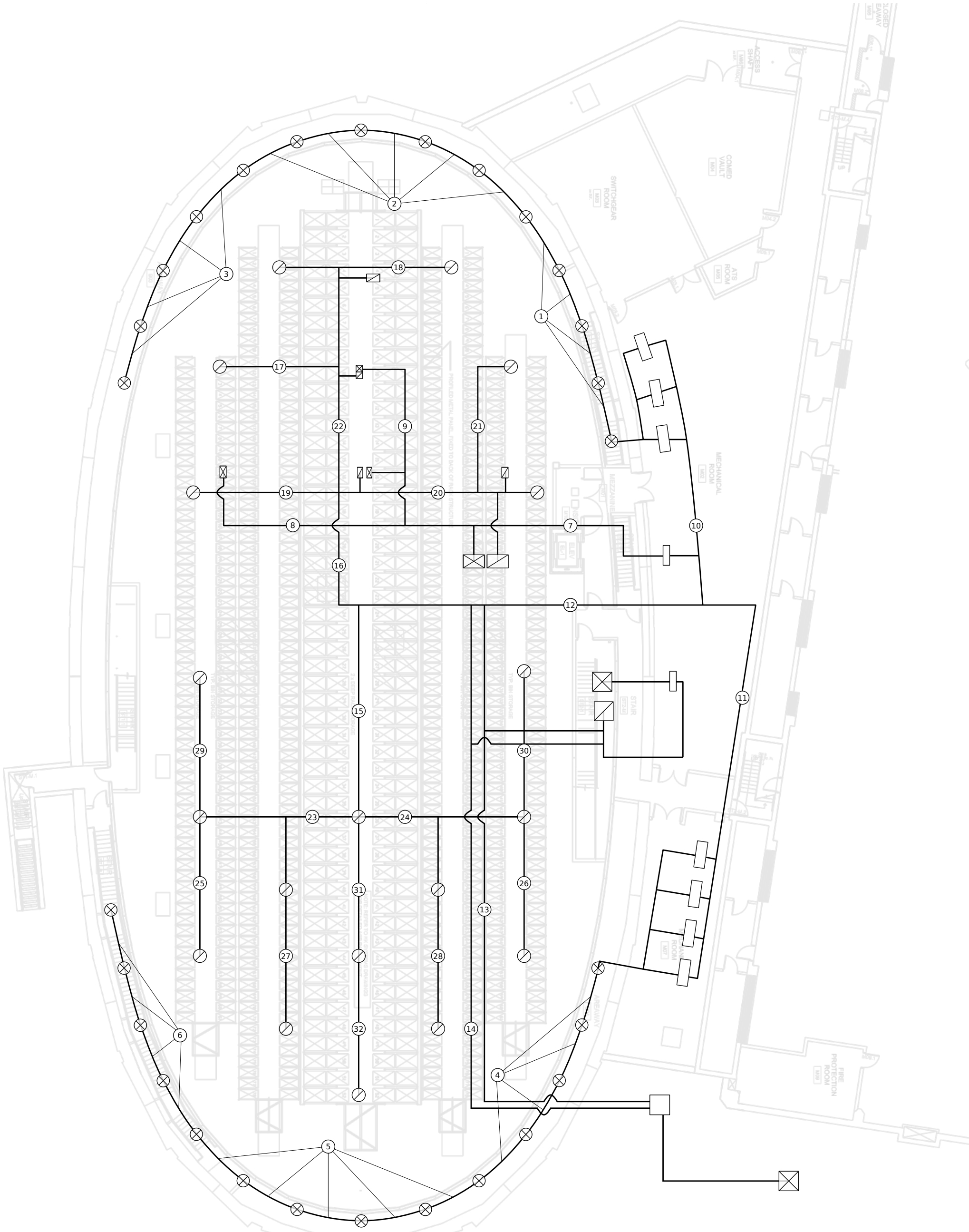
Duct Layouts



Supply level is 40’ above floor; return level is 10’ above floor.



All duct sizes are 8" x 12" on the ground floor.



Duct	A	x	B
1	24	x	52
2	24	x	38
3	18	x	30
4	30	x	46
5	24	x	42
6	18	x	34
7	12	x	8
8	12	x	8
9	12	x	8
10	24	x	52
11	30	x	46
12	36	x	62
13	12	x	24
14	12	x	24
15	24	x	60
16	30	x	40
17	16	x	20
18	16	x	20
19	16	x	20
20	16	x	22
21	16	x	20
22	24	x	30
23	24	x	28
24	24	x	28
25	12	x	18
26	12	x	18
27	12	x	18
28	12	x	18
29	12	x	18
30	12	x	18
31	18	x	20
32	12	x	18

Appendix C

Equipment Schedules

McQuay Efinity Vertical Water Source Heat Pump	
Quantity	7
Model	LVW-290
Capacity [BTU/h]	290000

McQuay Efinity Vertical Water Source Heat Pump	
Quantity	1
Model	LVW-072
Capacity [BTU/h]	72000

McQuay Efinity Vertical Water Source Heat Pump	
Quantity	1
Model	LVW-215
Capacity [BTU/h]	215000

Taco Single Stage Double Suction Horizontal Split Case Pump	
Quantity	1
Model	TA 1229
RPM	1760
Power [BHP]	25
Head (feet)	75-125
Flow (GPM)	700-1050
Max operation pressure	300 psi

Carrier Packaged Energy-Recovery Ventilator			
Quantity	1		
Model	62EHG		
Pressure drop	.93 in		
Nominal capacity	5500 cfm		
	Sensible	Latent	Total
100% Airflow Heating Condition:	68%	60%	65%
75% Airflow Heating Condition:	73%	67%	71%
100% Airflow Cooling Condition:	68%	60%	63%
75% Airflow Cooling Condition:	73%	67%	70%