Table of Contents

Executive Summary

The purpose of technical report is to evaluate and analyze the 123 Alpha Drive Renovation in terms of its energy consumption and building load data. The analysis was conducted by using Carrier HAP 4.0, a common software tool used by smaller MEP firms across the nation. Six packaged rooftop units, which covered 6 zones collectively, were analyzed under a block load simulation. The block load procedure was selected due to time constraints, and although the process is relatively simple, the results produced are satisfactory enough to resemble an accurate energy model for the building. Carrier HAP was used to calculate annual energy costs, airflows, and peak heating and cooling coil loads for the rooftop units. An analysis of the warehouse spaces, which primarily utilize electric resistant heat, was also conducted.

The building was found to have an estimated peak heating load of 71.5 tons and a peak cooling load of 111.6 tons. These capacities were compared with the mechanical equipment designed for the building, and were found to be relatively accurate. The cooling load was found to be higher than the peak heating load, which was not surprising, although the disparity between the two was certainly a bit peculiar.

An annual energy consumption estimation was conducted using Carrier HAP. The utility rates for natural gas and electricity were found using several references for local utility rates in the Pittsburgh area. These utility costs for the HVAC system were estimated to be $24,925, while the entire building cost per year is expected to be $144,500. 123 Alpha Drive was found to consume 329,608 kWh of electricity for the HVAC system and 2,384 therms of Natural Gas.

Building Overview

123 Alpha Drive is an 80,000 square foot, office and warehouse building located on the campus of the Regional Industrial Development Corporation (RIDC) in Pittsburgh, PA. 123 Alpha Drive is a one story structure designed in order to manage various warehouse shipments and offer sufficient office space. Obtained by THAR Geothermal Incorporation in early 2011, the now serves as THAR's corporate headquarters and storage facility. The building is large enough to achieve adequate, storage and office space, while providing additional space purpose requirements such as laboratory areas and conference rooms. The façade of the structure is composed of primarily concrete masonry and brick sections, occasionally separated by large, retractable warehouse doors and typical 3'x5' rectangular window. The building was designed to achieve a high thermal mass within the walls of the building in order to compensate for the poor thermal resistivity properties of the large warehouse doors.

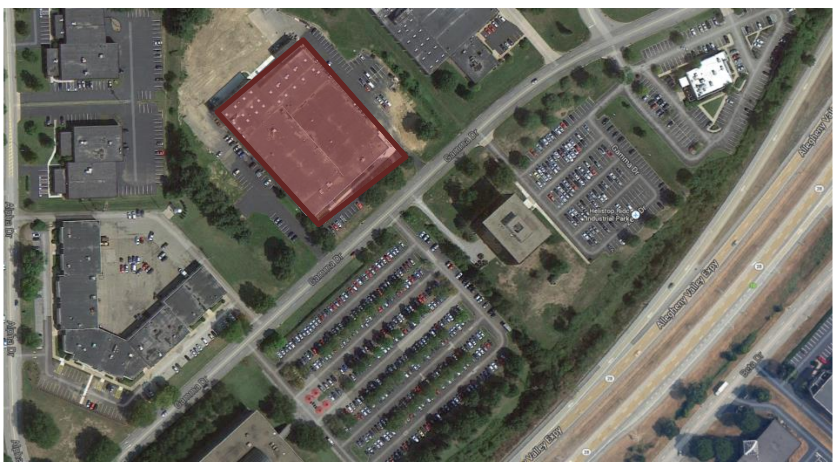


Figure 1: 123 Alpha Drive Location in RIDC Park and Allegheny County

Mechanical System Overview

Ventilation

123 Alpha Drive is ventilated using six small rooftop units (RTUs) and ten large horizontal air handling units. Figure 2, below, indicates the appropriate AHU zoning for the building. Four of the six rooftop units are existing to remain, but the newly installed RTU's have been selected in order to incorporate an outside air carbon dioxide preconditioned heating and cooling cycle, a technique utilized in the airline business. The liquid CO2 preconditioning coil will be located in the outside air stream of the two units. The goal of this preconditioning is to achieve a lower 'delta T' at the final cooling and heating coils, saving considerable energy throughout the unit's lifetime. Equipped with a full economizer each, the RTUs will provide efficient ventilation in the building, along with a considerable reduction in energy

consumption. The units utilize gas heating and electric cooling. The following figure shows which air handling units and rooftop units service different areas of the building.

Lab and Contaminant Exhaust

Various warehouse and dry lab spaces within the building require lab air and contaminant exhaust. Ten small down-blast, roof-mounted exhaust fans with motorized dampers were installed to handle the exhaust air requirements. The air will be replenished by a 4-ton, existing to remain, make-up rooftop unit.

Radiant Floor Slab Cooling and Heating

In addition to the rooftop units supplying fresh air to the office and lab spaces, a hydronic radiant floor cooling and heating system has been implemented through "dry installation", in which the tubing is attached under the finished floor or subfloor. Utilizing an efficient fluid such as liquid carbon dioxide, the radiant floor slabs achieve a more efficient heating and cooling process than a ducted system, as no duct losses exist in a radiant system. A standard gas boiler is used as an energy source to heat the liquid within the tubes. Condensation is a considerable concern with radiant floor cooling, and will be explored throughout the course of this study.

Figure 2: Rooftop Unit Zoning Maps

Load Calculation

The 123 Alpha Drive energy model and building load simulation was produced with the assistance of Carrier HAP 4.7. As previously mentioned, Carrier HAP is used by smaller MEP consulting firms in the country, and although it does not contain the most sophisticated and/or complex analysis procedure, it provides a good baseline for the design of simple building with common heating and cooling applications. Hap 4.7 produced heating and cooling loads, ventilation loads, and an annual energy cost simulation for the entirety of the building. Areas such as restrooms and stairways were accounted for in order to develop an accurate ventilation rate and load. Different spaces within the building required different load considerations. The various spaces throughout the building included office space, warehouse space, dry and wet storage rooms, break rooms, corridors, and conference rooms. A breakdown of the locations of these space types is available in figure 3 below.

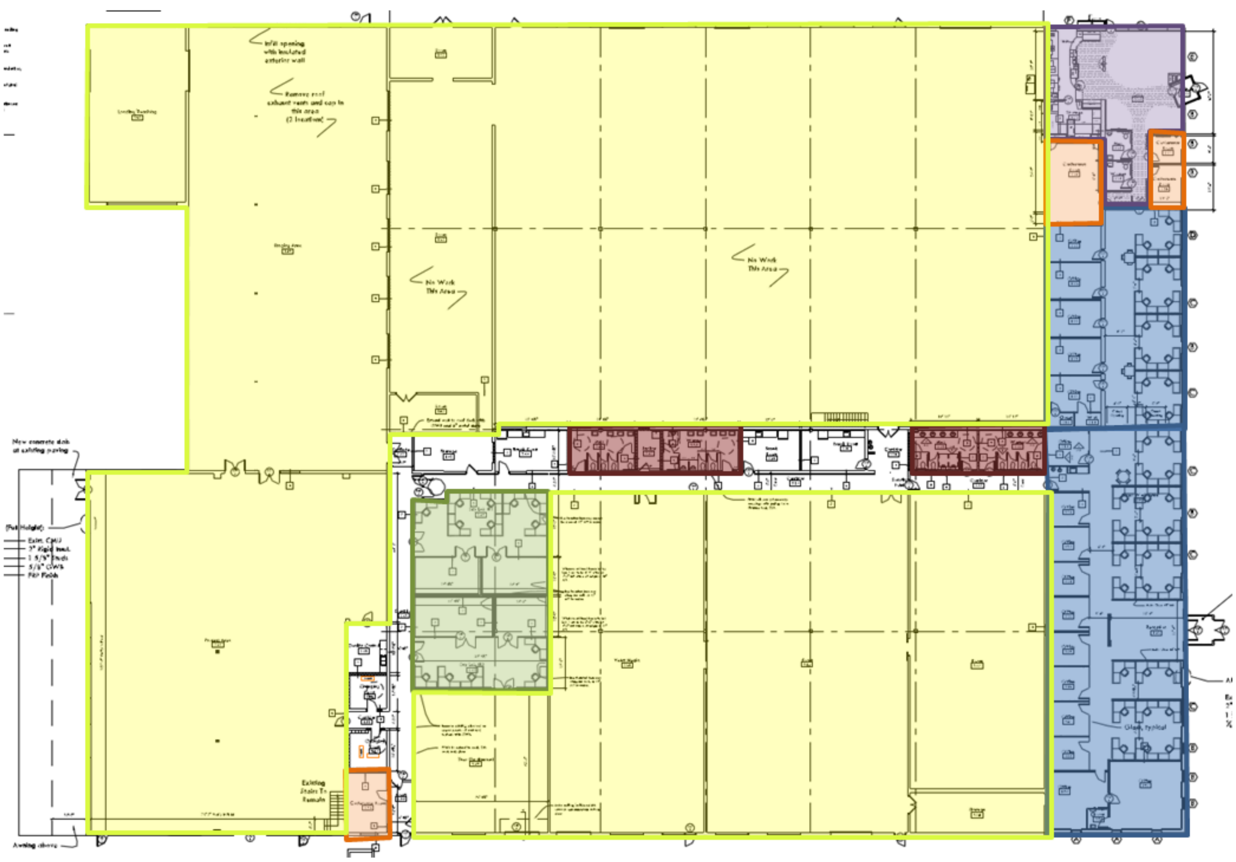


Figure 3: Space Type Layout

KEY

- Office Space
- Warehouse
- Dry Lab
- Restrooms
- Conference Rooms
- Café Space

Design Conditions

123 Alpha Drive is located 9 miles east of Pittsburgh, Pennsylvania. Carrier HAP contains hundreds of locations that can be used to model buildings across the nation and in Canada. Conveniently, a design template for Pittsburgh is available in version 4.7 of Carrier HAP. The measurements were recorded at the Pittsburgh International Airport, which is located several miles southwest of Pittsburgh. There is a possibility that the design conditions at 123 Alpha Drive may not be perfectly modeled by the Pittsburgh IAP, but if such differences existed, they would be minimal. Figures 4 and 5, below, show the weather conditions information provided in Carrier HAP.

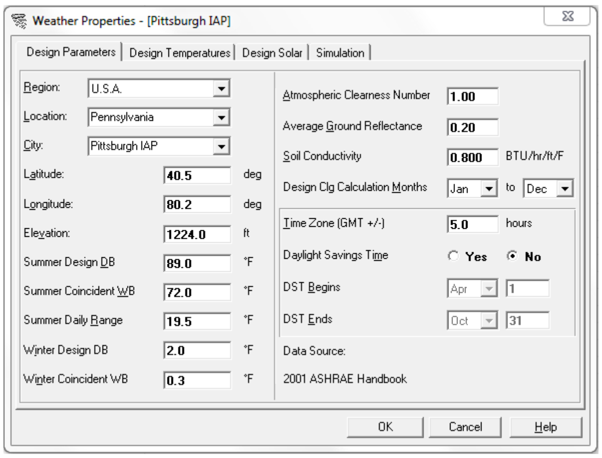


Figure 4: Pittsburgh Design Parameters

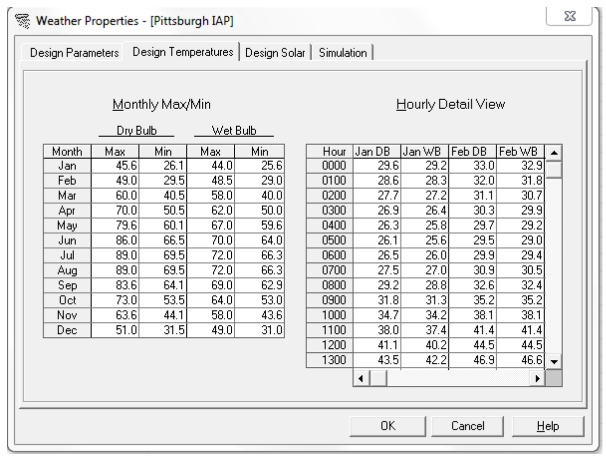


Figure 5: Pittsburgh Design Temperatures

Internal Loads

The internal loads for the building were dependent on the type of space in question. For office space and conference rooms, the lighting power density and electrical equipment load was 2.0 W/sq. ft. and 1.0 W/sq. ft., respectively. Warehouse areas were modeled to have a lighting power density of 2.5 W/sq.ft. and an electrical equipment load of 1.0 W/sq. ft. Corridor and restroom spaces were modeled as 1.0 W/sq. ft. for both internal loads. Areas such as office spaces, conference rooms, and lab spaces were designated as spaces containing people undergoing "office work", which determined their sensible people loads. People in warehouse areas were designated as "medium work" individuals, which created a larger sensible people load.

Schedules

Thermostat schedules were designed for normal work hours, plus two extra hours in the morning for workers in the warehouse space. These occupancy schedules were responsible for modeling the lighting, electrical equipment, miscellaneous, and people loads for the building.

Construction

123 Alpha Drive was designed with the same exterior wall construction around the entire perimeter of the building. The flat roof was equipped with steel studs, asphalt layers, and a vapor retardant membrane across the roof footprint. This building was constructed with significant insulation, providing R-values that were far above the suggested R-values contained within ASHRAE 62.1 and 90.1. Figures 6 and 7 indicate a breakdown of the wall and roof construction types.

Wall Assembly			
Component	Thickness	R-value	U-value
Gypsum Board	0.625	0.56	
Air Space	0	0.91	
R-11 Batt Insulation	3.5	11.22	
8 in HW concrete block	8	1.11	
4-in face brick	4	0.4329	
		15.2509	0.0655699

Figure 6: Typical Exterior Wall Assembly

Roof Assembly			
Component	Thickness	R-value	U-value
Steel Deck	0.034	0.00011	
R-28 Batt Insulation	8	26.55	
Built-up Roofing	0.376	0.332	
		27.90011	0.03584215

Figure 7: Typical Roof Assembly

Calculated Load versus Design Load

In order to determine whether the load calculations established by Carrier HAP 4.7 were accurate, they would need to be analyzed and compared against the design load found in the construction documents of 123 Alpha Drive. Using the previously described internal loads, design conditions, construction values, and system types, a system report was created for each packaged, single zone CAV rooftop unit, which can be found in Appendix A of this report. The design and calculated loads were compared by the variable of airflow, in cubic feet per minute (CFM). A standard percentage error calculation was conducted to determine if the two sets of data contain a correlation and similarity. Figure 8, as seen below, indicates which calculations were deemed accurate and which require a further investigation as to the disparity between the two. The rooftop units that indicate a large difference between calculated and design airflows can be explained by several additional design techniques that were not able to be accounted for during the Carrier HAP design. For instance, all rooftop units modeling the café and office space areas are complimented with a radiant floor cooling and heating loops system, which would reduce a significant amount of the airflow and load needed by the air handling units. For rooftop units which condition bathrooms, the design loads for each restroom were significantly different from the calculated airflow by nearly 300%. This accounts for the high disparity between some units' design and calculated loads. Also, the internal lighting loads used may not be accurate with the actual lighting loads used in the original project, which could explain a difference in required airflow.

Design vs Calculated Airflow (CFM)			
Unit	Design CFM	Calculated CFM	Percent Error
RTU-1	2600	2931	12.73076923
RTU-2	3000	2507	-16.43333333
RTU-3	3000	3732	24.4
RTU-4	3000	2926	-2.466666667
RTU-5	2800	3094	10.5
RTU-6	1800	2492	38.44444444

Figure 8: Design v. Calculated Airflow for 123 Alpha Drive

Design vs Calculated Capacities			
Heating		Cooling	
Calculated (MBH)	323.7	Calculated (MBH)	437.2
Design (MBH)	314.9	Design (MBH)	421.6
Error (%)	-2.79	Error (%)	-3.70

Figure 9: Design v. Calculated Capacities for 123 Alpha Drive

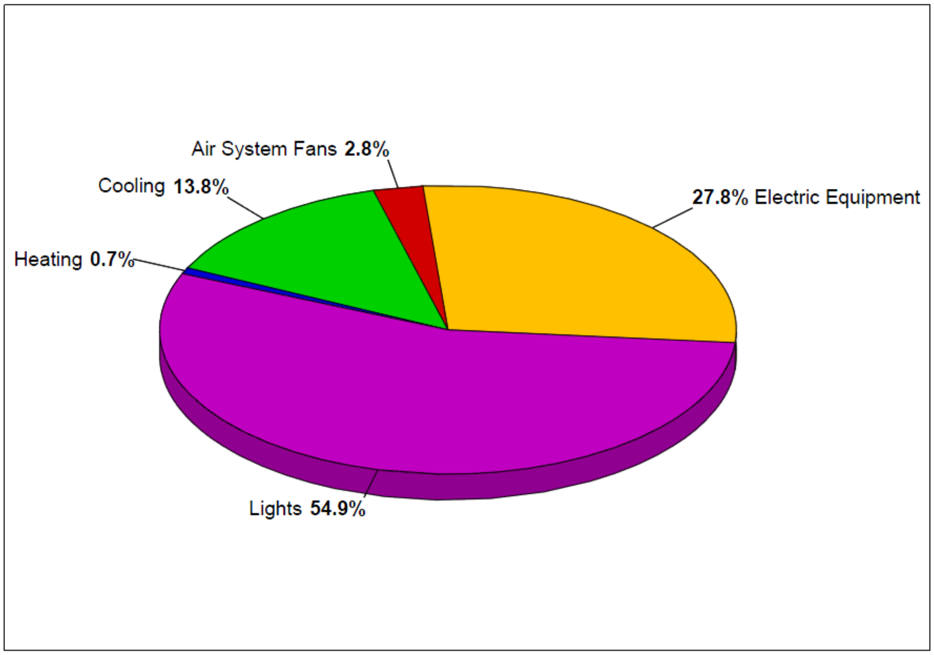
Energy Cost and Consumption

The annual energy consumption simulation was created through Carrier HAP version 4.7. The simulation created a detailed report of energy usage, energy costs, and a breakdown of which building system components contributed to the energy cost. The utility rates for natural gas and electricity were obtained from local estimates of the most current utility rates in Pittsburgh. The estimate created encompasses the entire building, and it was found that lighting contributed to the majority of the energy consumption. This is rather peculiar, however, as typical building design suggests that lighting should not represent nearly sixty percent of the annual energy consumption. An improper designation for internal lighting loads or incorrect electric utility rate could be the answer for this anamoly. Electric resistant heaters in the stairways and vestibules were not included in this analysis. An energy model was not produced for this project by Iams Consulting, the MEP consulting firm for 123 Alpha Drive, and therefore a useful comparison or declaration is likely unable to be make from this data. Figure 10, below, indicates the yearly consumption of natural gas and electricity. Graph 1 illustrates the projected energy consumption for various types of sources such as heating, cooling, and lighting.

1. Monthly Energy Use by System Component

Component	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Air System Fans (kWh)	4710	4254	4710	4558	4710	4558	4710	4710	4558	4710	4558	4710
Cooling												
Electric (kWh)	10480	10489	16624	17918	27076	37491	40066	40385	27870	19561	14020	12168
Natural Gas (Therm)	0	0	0	0	0	0	0	0	0	0	0	0
Fuel Oil (na)	0	0	0	0	0	0	0	0	0	0	0	0
Propane (na)	0	0	0	0	0	0	0	0	0	0	0	0
Remote HW (na)	0	0	0	0	0	0	0	0	0	0	0	0
Remote Steam (na)	0	0	0	0	0	0	0	0	0	0	0	0
Remote CW (na)	0	0	0	0	0	0	0	0	0	0	0	0
Heating												
Electric (kWh)	0	0	0	0	0	0	0	0	0	0	0	0
Natural Gas (Therm)	633	564	255	142	16	1	0	0	3	82	237	451
Fuel Oil (na)	0	0	0	0	0	0	0	0	0	0	0	0
Propane (na)	0	0	0	0	0	0	0	0	0	0	0	0
Remote HW (na)	0	0	0	0	0	0	0	0	0	0	0	0
Remote Steam (na)	0	0	0	0	0	0	0	0	0	0	0	0
Pumps (kWh)	0	0	0	0	0	0	0	0	0	0	0	0
Heat Rej. Fans (kWh)	0	0	0	0	0	0	0	0	0	0	0	0
Lighting (kWh)	92935	83941	92935	89937	92935	89937	92935	92935	89937	92935	89937	92935
Electric Eqpt. (kWh)	47143	42580	47143	45622	47143	45622	47143	47143	45622	47143	45622	47143
Misc. Electric (kWh)	0	0	0	0	0	0	0	0	0	0	0	0
Misc. Fuel												
Natural Gas (Therm)	0	0	0	0	0	0	0	0	0	0	0	0
Propane (na)	0	0	0	0	0	0	0	0	0	0	0	0
Remote HW (na)	0	0	0	0	0	0	0	0	0	0	0	0
Remote Steam (na)	0	0	0	0	0	0	0	0	0	0	0	0

Figure 10: Monthly Energy Consumption



Graph 1: Energy Consumption

Cost

The utility rates used for this simulation are subject to change and could not be completely verified. It is assumed that they represent the average cost for electricity and natural gas in Pittsburgh, Pennsylvania. Variables such as natural gas fracking, urban price hikes, and more can severely adjust the expected utlity rates for this building. Figure 11 provides a monthly analysis of energy cost for electricity and natural gas. The cost of utilities for the HVAC system was expected to be $24,926 per year. The cost per square foot for HVAC utilites in the building is $.39 per square foot.

1. HVAC Costs

Month	Electric ($)	Natural Gas ($)	Fuel Oil ($)	Propane ($)	Remote Hot Water ($)	Remote Steam ($)	Remote Chilled Water ($)
January	1,101	273	0	0	0	0	0
February	1,069	244	0	0	0	0	0
March	1,547	110	0	0	0	0	0
April	1,630	62	0	0	0	0	0
May	2,305	7	0	0	0	0	0
June	3,049	0	0	0	0	0	0
July	3,246	0	0	0	0	0	0
August	3,269	0	0	0	0	0	0
September	2,351	1	0	0	0	0	0
October	1,760	36	0	0	0	0	0
November	1,347	102	0	0	0	0	0
December	1,224	195	0	0	0	0	0
Total	23,897	1,030	0	0	0	0	0

Figure 11: Monthly HVAC Energy Costs

Emissions

Carrier HAP 4.7 produced an emissions calculation for the calendar year. No SO2 or NOX emissions were found during the simulation, but a fairly sizable amount of carbon dioxide emissions were discovered. The amount of CO2 projected is unusually high, however, and it has been determined that the correct emissions factors for electricity and natural gas may not have been obtained from the Penn State AE database. This will be investigated and corrected if necessary in the spring semester.

Component	Sample Building
CO2 Equivalent (lb)	2,414,521

References

THAR Geothermal. Construction Documents Bid Set Volume l. Pittsburgh, PA.

THAR Geothermal. Construction Documents Bid Set Volume ll. Pittsburgh, PA.

Appendix A

Air System Sizing Summary for RTU-1

Project Name: THAR Energy Thesis — 01/03/2014
Prepared by: Iams Consulting LLC — 01:38PM

Air System Information

Air System Name	RTU-1		Number of zones	1	
Equipment Class	PKG ROOF		Floor Area	3456.0	ft²
Air System Type	SZCAV		Location	Pittsburgh IAP, Pennsylvania	

Sizing Calculation Information

Zone and Space Sizing Method:

Zone CFM	Sum of space airflow rates	Calculation Months	Jan to Dec
Space CFM	Individual peak space loads	Sizing Data	Calculated

Central Cooling Coil Sizing Data

Total coil load	6.2	Tons	Load occurs at	Jul 1500	
Total coil load	73.8	MBH	OA DB / WB	89.0 / 72.0	°F
Sensible coil load	59.9	MBH	Entering DB / WB	74.9 / 62.9	°F
Coil CFM at Jul 1500	2931	CFM	Leaving DB / WB	55.1 / 54.0	°F
Max block CFM	2931	CFM	Coil ADP	52.9	°F
Sum of peak zone CFM	2931	CFM	Bypass Factor	0.100	
Sensible heat ratio	0.812		Resulting RH	48	%
ft²/Ton	561.7		Design supply temp.	55.0	°F
BTU/(hr-ft²)	21.4		Zone T-stat Check	1 of 1	OK
Water flow @ 10.0 °F rise	N/A		Max zone temperature deviation	0.0	°F

Central Heating Coil Sizing Data

Max coil load	27.1	MBH	Load occurs at	Des Htg	
Coil CFM at Des Htg	2931	CFM	BTU/(hr-ft²)	7.8	
Max coil CFM	2931	CFM	Ent. DB / Lvg DB	65.5 / 74.5	°F
Water flow @ 20.0 °F drop	N/A				

Precool Coil Sizing Data

Total coil load	0.5	Tons	Load occurs at	Jul 1500	
Total coil load	6.0	MBH	OA DB / WB	89.0 / 72.0	°F
Sensible coil load	6.0	MBH	Entering DB / WB	89.0 / 72.0	°F
Coil CFM at Jul 1500	530	CFM	Leaving DB / WB	78.0 / 68.9	°F
Max coil CFM	530	CFM	Bypass Factor	0.100	
Sensible heat ratio	1.000				
Water flow @ 10.0 °F rise	N/A				

Preheat Coil Sizing Data

Max coil load	23.5	MBH	Load occurs at	Des Htg	
Coil CFM at Des Htg	530	CFM	Ent. DB / Lvg DB	2.0 / 45.0	°F
Max coil CFM	530	CFM			
Water flow @ 20.0 °F drop	N/A				

Supply Fan Sizing Data

Actual max CFM	2931	CFM	Fan motor BHP	0.40	BHP
Standard CFM	2803	CFM	Fan motor kW	0.32	kW
Actual max CFM/ft²	0.85	CFM/ft²	Fan static	0.50	in wg

Outdoor Ventilation Air Data

Design airflow CFM	530	CFM	CFM/person	37.84	CFM/person
CFM/ft²	0.15	CFM/ft²			

Air System Sizing Summary for RTU-2

Project Name: THAR Energy Thesis — 01/03/2014
Prepared by: Iams Consulting LLC — 01:44PM

Air System Information

Air System Name	RTU-2		Number of zones	1	
Equipment Class	PKG ROOF		Floor Area	2912.0	ft²
Air System Type	SZCAV		Location	Pittsburgh IAP, Pennsylvania	

Sizing Calculation Information

Zone and Space Sizing Method:

Zone CFM	Sum of space airflow rates	Calculation Months	Jan to Dec
Space CFM	Individual peak space loads	Sizing Data	Calculated

Central Cooling Coil Sizing Data

Total coil load	5.1	Tons	Load occurs at	Jul 1500	
Total coil load	61.3	MBH	OA DB / WB	89.0 / 72.0	°F
Sensible coil load	48.1	MBH	Entering DB / WB	75.1 / 63.9	°F
Coil CFM at Jul 1500	2507	CFM	Leaving DB / WB	56.5 / 55.5	°F
Max block CFM	2507	CFM	Coil ADP	54.5	°F
Sum of peak zone CFM	2507	CFM	Bypass Factor	0.100	
Sensible heat ratio	0.784		Resulting RH	51	%
ft²/Ton	569.7		Design supply temp.	55.0	°F
BTU/(hr-ft²)	21.1		Zone T-stat Check	1 of 1	OK
Water flow @ 10.0 °F rise	N/A		Max zone temperature deviation	0.0	°F

Central Heating Coil Sizing Data

Max coil load	27.1	MBH	Load occurs at	Des Htg	
Coil CFM at Des Htg	2507	CFM	BTU/(hr-ft²)	9.3	
Max coil CFM	2507	CFM	Ent. DB / Lvg DB	64.0 / 74.5	°F
Water flow @ 20.0 °F drop	N/A				

Precool Coil Sizing Data

Total coil load	0.6	Tons	Load occurs at	Jul 1500	
Total coil load	6.9	MBH	OA DB / WB	89.0 / 72.0	°F
Sensible coil load	6.9	MBH	Entering DB / WB	89.0 / 72.0	°F
Coil CFM at Jul 1500	603	CFM	Leaving DB / WB	78.0 / 68.9	°F
Max coil CFM	603	CFM	Bypass Factor	0.100	
Sensible heat ratio	1.000				
Water flow @ 10.0 °F rise	N/A				

Preheat Coil Sizing Data

Max coil load	26.8	MBH	Load occurs at	Des Htg	
Coil CFM at Des Htg	603	CFM	Ent. DB / Lvg DB	2.0 / 45.0	°F
Max coil CFM	603	CFM			
Water flow @ 20.0 °F drop	N/A				

Supply Fan Sizing Data

Actual max CFM	2507	CFM	Fan motor BHP	0.34	BHP
Standard CFM	2398	CFM	Fan motor kW	0.27	kW
Actual max CFM/ft²	0.86	CFM/ft²	Fan static	0.50	in wg

Outdoor Ventilation Air Data

Design airflow CFM	603	CFM	CFM/person	54.81	CFM/person
CFM/ft²	0.21	CFM/ft²			

Air System Sizing Summary for RTU-3

Project Name: THAR Energy Thesis | 01/03/2014
Prepared by: Iams Consulting LLC | 01:47PM

Air System Information

Air System Name	RTU-3		Number of zones	1	
Equipment Class	PKG ROOF		Floor Area	2563.0	ft²
Air System Type	SZCAV		Location	Pittsburgh IAP, Pennsylvania	

Sizing Calculation Information

Zone and Space Sizing Method:

Zone CFM	Sum of space airflow rates	Calculation Months	Jan to Dec
Space CFM	Individual peak space loads	Sizing Data	Calculated

Central Cooling Coil Sizing Data

Total coil load	7.2	Tons	Load occurs at	Aug 1200	
Total coil load	86.6	MBH	OA DB / WB	84.5 / 70.7	°F
Sensible coil load	73.1	MBH	Entering DB / WB	74.8 / 62.9	°F
Coil CFM at Aug 1200	3732	CFM	Leaving DB / WB	55.8 / 54.7	°F
Max block CFM	3732	CFM	Coil ADP	53.7	°F
Sum of peak zone CFM	3732	CFM	Bypass Factor	0.100	
Sensible heat ratio	0.844		Resulting RH	50	%
ft²/Ton	355.0		Design supply temp.	55.0	°F
BTU/(hr-ft²)	33.8		Zone T-stat Check	1 of 1	OK
Water flow @ 10.0 °F rise	N/A		Max zone temperature deviation	0.0	°F

Central Heating Coil Sizing Data

Max coil load	37.1	MBH	Load occurs at	Des Htg	
Coil CFM at Des Htg	3732	CFM	BTU/(hr-ft²)	14.5	
Max coil CFM	3732	CFM	Ent. DB / Lvg DB	67.9 / 77.5	°F
Water flow @ 20.0 °F drop	N/A				

Precool Coil Sizing Data

Total coil load	0.3	Tons	Load occurs at	Jul 1500	
Total coil load	3.7	MBH	OA DB / WB	89.0 / 72.0	°F
Sensible coil load	3.7	MBH	Entering DB / WB	89.0 / 72.0	°F
Coil CFM at Jul 1500	324	CFM	Leaving DB / WB	78.0 / 68.9	°F
Max coil CFM	324	CFM	Bypass Factor	0.100	
Sensible heat ratio	1.000				
Water flow @ 10.0 °F rise	N/A				

Preheat Coil Sizing Data

Max coil load	15.0	MBH	Load occurs at	Jan 0800	
Coil CFM at Jan 0800	921	CFM	Ent. DB / Lvg DB	29.2 / 45.0	°F
Max coil CFM	324	CFM			
Water flow @ 20.0 °F drop	N/A				

Supply Fan Sizing Data

Actual max CFM	3732	CFM	Fan motor BHP	0.51	BHP
Standard CFM	3569	CFM	Fan motor kW	0.41	kW
Actual max CFM/ft²	1.46	CFM/ft²	Fan static	0.50	in wg

Outdoor Ventilation Air Data

Design airflow CFM	324	CFM	CFM/person	9.52	CFM/person
CFM/ft²	0.13	CFM/ft²			

Air System Sizing Summary for RTU-4

Project Name: THAR Energy Thesis | 01/03/2014
Prepared by: Iams Consulting LLC | 01:48PM

Air System Information

Air System Name	RTU-4		Number of zones	1	
Equipment Class	PKG ROOF		Floor Area	2282.0	ft²
Air System Type	SZCAV		Location	Pittsburgh IAP, Pennsylvania	

Sizing Calculation Information

Zone and Space Sizing Method:

Zone CFM	Sum of space airflow rates	Calculation Months	Jan to Dec
Space CFM	Individual peak space loads	Sizing Data	Calculated

Central Cooling Coil Sizing Data

Total coil load	5.6	Tons	Load occurs at	Aug 1200	
Total coil load	67.6	MBH	OA DB / WB	84.5 / 70.7	°F
Sensible coil load	56.9	MBH	Entering DB / WB	74.8 / 63.0	°F
Coil CFM at Aug 1200	2926	CFM	Leaving DB / WB	56.0 / 54.9	°F
Max block CFM	2926	CFM	Coil ADP	53.9	°F
Sum of peak zone CFM	2926	CFM	Bypass Factor	0.100	
Sensible heat ratio	0.842		Resulting RH	50	%
ft²/Ton	405.2		Design supply temp.	55.0	°F
BTU/(hr-ft²)	29.6		Zone T-stat Check	1 of 1	OK
Water flow @ 10.0 °F rise	N/A		Max zone temperature deviation	0.0	°F

Central Heating Coil Sizing Data

Max coil load	23.9	MBH	Load occurs at	Des Htg	
Coil CFM at Des Htg	2926	CFM	BTU/(hr-ft²)	10.5	
Max coil CFM	2926	CFM	Ent. DB / Lvg DB	67.7 / 75.6	°F
Water flow @ 20.0 °F drop	N/A				

Precool Coil Sizing Data

Total coil load	0.3	Tons	Load occurs at	Jul 1500	
Total coil load	3.0	MBH	OA DB / WB	89.0 / 72.0	°F
Sensible coil load	3.0	MBH	Entering DB / WB	89.0 / 72.0	°F
Coil CFM at Jul 1500	267	CFM	Leaving DB / WB	78.0 / 68.9	°F
Max coil CFM	267	CFM	Bypass Factor	0.100	
Sensible heat ratio	1.000				
Water flow @ 10.0 °F rise	N/A				

Preheat Coil Sizing Data

Max coil load	12.9	MBH	Load occurs at	Jan 0300	
Coil CFM at Jan 0300	689	CFM	Ent. DB / Lvg DB	26.9 / 45.0	°F
Max coil CFM	267	CFM			
Water flow @ 20.0 °F drop	N/A				

Supply Fan Sizing Data

Actual max CFM	2926	CFM	Fan motor BHP	0.40	BHP
Standard CFM	2799	CFM	Fan motor kW	0.32	kW
Actual max CFM/ft²	1.28	CFM/ft²	Fan static	0.50	in wg

Outdoor Ventilation Air Data

Design airflow CFM	267	CFM	CFM/person	10.27	CFM/person
CFM/ft²	0.12	CFM/ft²			

Air System Sizing Summary for RTU-5

Project Name: THAR Energy Thesis — 01/03/2014
Prepared by: Iams Consulting LLC — 01:54PM

Air System Information

Air System Name	RTU-5		Number of zones	1	
Equipment Class	PKG ROOF		Floor Area	1943.0	ft²
Air System Type	SZCAV		Location	Pittsburgh IAP, Pennsylvania	

Sizing Calculation Information

Zone and Space Sizing Method:

Zone CFM	Sum of space airflow rates	Calculation Months	Jan to Dec
Space CFM	Individual peak space loads	Sizing Data	Calculated

Central Cooling Coil Sizing Data

Total coil load	6.8	Tons	Load occurs at	Aug 1200	
Total coil load	81.1	MBH	OA DB / WB	84.5 / 70.7	°F
Sensible coil load	63.0	MBH	Entering DB / WB	75.1 / 63.9	°F
Coil CFM at Aug 1200	3235	CFM	Leaving DB / WB	56.2 / 55.2	°F
Max block CFM	3235	CFM	Coil ADP	54.1	°F
Sum of peak zone CFM	3235	CFM	Bypass Factor	0.100	
Sensible heat ratio	0.777		Resulting RH	52	%
ft²/Ton	287.5		Design supply temp.	55.0	°F
BTU/(hr-ft²)	41.7		Zone T-stat Check	0 of 1	OK
Water flow @ 10.0 °F rise	N/A		Max zone temperature deviation	0.1	°F

Central Heating Coil Sizing Data

Max coil load	34.0	MBH	Load occurs at	Des Htg	
Coil CFM at Des Htg	3235	CFM	BTU/(hr-ft²)	17.5	
Max coil CFM	3235	CFM	Ent. DB / Lvg DB	66.8 / 77.0	°F
Water flow @ 20.0 °F drop	N/A				

Precool Coil Sizing Data

Total coil load	0.4	Tons	Load occurs at	Jul 1500	
Total coil load	4.9	MBH	OA DB / WB	89.0 / 72.0	°F
Sensible coil load	4.9	MBH	Entering DB / WB	89.0 / 72.0	°F
Coil CFM at Jul 1500	430	CFM	Leaving DB / WB	78.0 / 68.9	°F
Max coil CFM	430	CFM	Bypass Factor	0.100	
Sensible heat ratio	1.000				
Water flow @ 10.0 °F rise	N/A				

Preheat Coil Sizing Data

Max coil load	19.1	MBH	Load occurs at	Des Htg	
Coil CFM at Des Htg	430	CFM	Ent. DB / Lvg DB	2.0 / 45.0	°F
Max coil CFM	430	CFM			
Water flow @ 20.0 °F drop	N/A				

Supply Fan Sizing Data

Actual max CFM	3235	CFM	Fan motor BHP	0.44	BHP
Standard CFM	3094	CFM	Fan motor kW	0.35	kW
Actual max CFM/ft²	1.66	CFM/ft²	Fan static	0.50	in wg

Outdoor Ventilation Air Data

Design airflow CFM	430	CFM	CFM/person	8.60	CFM/person
CFM/ft²	0.22	CFM/ft²			

Air System Sizing Summary for RTU-6

Project Name: THAR Energy Thesis
Prepared by: Iams Consulting LLC

01/03/2014
01:55PM

Air System Information

Air System Name	RTU-6		Number of zones	1	
Equipment Class	PKG ROOF		Floor Area	2379.0	ft²
Air System Type	SZCAV		Location	Pittsburgh IAP, Pennsylvania	

Sizing Calculation Information

Zone and Space Sizing Method:

Zone CFM	Sum of space airflow rates	Calculation Months	Jan to Dec
Space CFM	Individual peak space loads	Sizing Data	Calculated

Central Cooling Coil Sizing Data

Total coil load	5.6	Tons	Load occurs at	Jul 1200	
Total coil load	66.8	MBH	OA DB / WB	84.5 / 70.7	°F
Sensible coil load	47.4	MBH	Entering DB / WB	75.5 / 65.6	°F
Coil CFM at Jul 1200	2605	CFM	Leaving DB / WB	57.9 / 57.0	°F
Max block CFM	2605	CFM	Coil ADP	56.0	°F
Sum of peak zone CFM	2605	CFM	Bypass Factor	0.100	
Sensible heat ratio	0.709		Resulting RH	55	%
ft²/Ton	427.1		Design supply temp.	55.0	°F
BTU/(hr-ft²)	28.1		Zone T-stat Check	1 of 1	OK
Water flow @ 10.0 °F rise	N/A		Max zone temperature deviation	0.0	°F

Central Heating Coil Sizing Data

Max coil load	34.3	MBH	Load occurs at	Des Htg	
Coil CFM at Des Htg	2605	CFM	BTU/(hr-ft²)	14.4	
Max coil CFM	2605	CFM	Ent. DB / Lvg DB	60.9 / 73.6	°F
Water flow @ 20.0 °F drop	N/A				

Precool Coil Sizing Data

Total coil load	0.9	Tons	Load occurs at	Jul 1500	
Total coil load	11.0	MBH	OA DB / WB	89.0 / 72.0	°F
Sensible coil load	11.0	MBH	Entering DB / WB	89.0 / 72.0	°F
Coil CFM at Jul 1500	968	CFM	Leaving DB / WB	78.0 / 68.9	°F
Max coil CFM	968	CFM	Bypass Factor	0.100	
Sensible heat ratio	1.000				
Water flow @ 10.0 °F rise	N/A				

Preheat Coil Sizing Data

Max coil load	43.0	MBH	Load occurs at	Des Htg	
Coil CFM at Des Htg	968	CFM	Ent. DB / Lvg DB	2.0 / 45.0	°F
Max coil CFM	968	CFM			
Water flow @ 20.0 °F drop	N/A				

Supply Fan Sizing Data

Actual max CFM	2605	CFM	Fan motor BHP	0.36	BHP
Standard CFM	2492	CFM	Fan motor kW	0.28	kW
Actual max CFM/ft²	1.09	CFM/ft²	Fan static	0.50	in wg

Outdoor Ventilation Air Data

Design airflow CFM	968	CFM	CFM/person	35.84	CFM/person
CFM/ft²	0.41	CFM/ft²			