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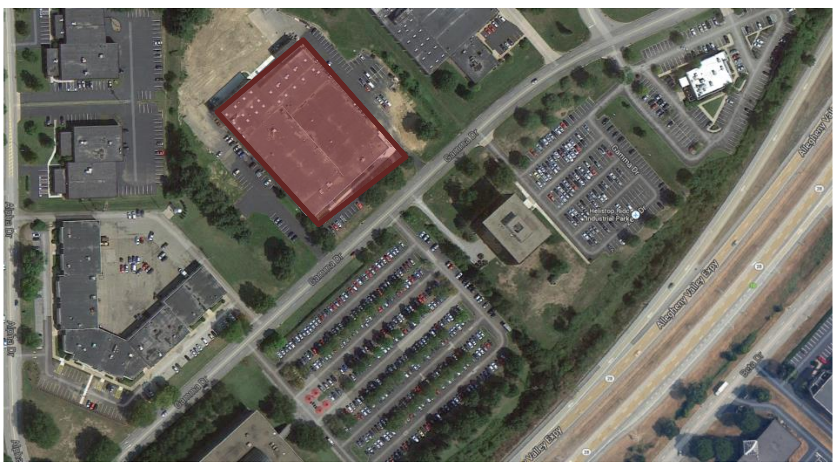
Executive Summary

The purpose of this technical report is to evaluate and analyze the 123 Alpha Drive Renovation in terms of its mechanical system design. An investigation of the mechanical system first cost was conducted and found to be $[redacted] million, which was identified as 17.2% of the total cost for the building. In terms of square area, the cost of this mechanical system was determined to be $[redacted] per square foot. An average annual utility cost was derived from the building energy simulation conducted in Technical Report 2, which leveled out to $24,927. This cost is associated with the energy consumption of the building, which typically averages to about 329,608 kWh or electricity and 1,030 Therms of natural gas.

Investigations such as design requirements, heating and cooling loads, ventilation requirements, energy consumption, and a LEED analysis were completed in order to encompass an overall evaluation of the mechanical system. The purpose of this evaluation was to highlight possible adjustments to the mechanical system design that may aid I the reduction of annual energy costs, mechanical first costs, or other mechanical design improvements.

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.



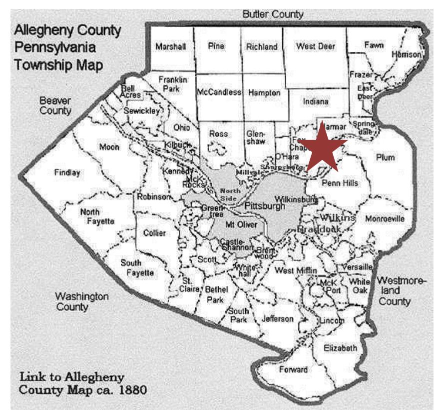


Figure 1: 123 Alpha Drive Location in RIDC Park and Allegheny County

Mechanical System

Design Requirements and Objectives

The renovation that has been conducted on the 123 Alpha Drive property was proposed in order to accommodate for THAR Geothermal , Incorporated, a new tenant to the building. THAR is a company that services buildings with geothermal design and products from across the country and the globe. Such a company demands a significant amount of office space, conference meeting rooms, and warehouse storage for their various products. Larger companies also tend to pride themselves in providing amenities and an improved work environment, and THAR has followed in the footsteps of many other large companies with a building café and other additional workplace enhancements.

With a variety of different spaces, the requirements for each space are prone to vary quite drastically. Warehouse spaces, office space, and lab spaces must be designed in order to accommodate their respective ventilation and occupancy requirements. As a result, the office spaces, which include restrooms, conference rooms, laboratories, and a café, have been grouped together and given their own design specifications and objectives. The warehouse spaces, which are far more open and susceptible to temperature irregularity and poor humidity control, will be considered under different design criteria. One of the advantages of 123 Alpha Drive is that it is a one story building, which allows for a minimal usable space requirements for mechanical systems. The use of rooftop air handling units and a potential radiant floor cooling and heating system result in a relatively small impact on the usable space within the interior of the building. The systems in question will be designed in accordance with IBC 2009, and will aim to achieve a LEED certification under the conditions of LEED 2009. Acoustical design, control systems design, and other design considerations will be examined throughout the course of this investigation.

Design Conditions

Located in Pittsburgh, Pennsylvania, 123 Alpha Drive was found to be within the 5A climate zone as indicated in ASHRAE Standard 62.1. This climate zone data was used in tandem with the design conditions outlined in the Pittsburgh International Airport weather data provided by Carrier HAP 4.7 in order to produce a consistent and logical set of design conditions for the summer and winter months. Table 1, below, shows the outdoor design temperature design conditions for 123 Alpha Drive.

Outside Design Temperature		
	Dry Bulb (F)	Wet Bulb (F)
Winter	2.0	0.3
Summer	89.0	72.0

Table 1: Outdoor Design Temperature

For typical office buildings in Pittsburgh, the industry standard for indoor design temperatures has been assumed and applied to this report. Relative humidity percentages for the summer and winter, indicated in Table 3, present a significant challenge for humidity control. The indoor design temperatures can be found in Table 2.

Indoor Design Temperature		
	Occupied	Unoccupied
Winter	70	74
Summer	55	85

Table 2: Indoor Design Temperature

Humidity	
Winter (%)	25+/-3
Summer (%)	45+/-5

Table 3: Relative Humidity Percentage

Ventilation

The ventilation rates of the various air handling units were determined in previous technical reports, and were confirmed to be compliant with ASHRAE Standard 62.1 Section 6. The six rooftop units being investigated for 123 Alpha Drive were compared with the minimum outside air requirements as specified by ASHRAE 62.1. Design airflows and minimum outside air CFM data were extracted from the construction documents in order to ensure that the building was in accordance with ASHRAE Standard 62.1. Table 4, below, presents an illustrative example of this compliance.

Minimum Ventilation Rates				
Unit	Design CFM	Minimum OA CFM	ASHRAE 62.1 Min. OA CFM	Compliant?
ETR RTU-1	1600	1200	592	Yes
ETR RTU-2	3000	600	510	Yes
ETR RTU-3	3000	600	414	Yes
ETR RTU-4	3000	770	420	Yes
RTU-5	2000	600	495	Yes
RTU-6	1800	680	463.17	Yes

Table 4: Minimum Ventilation Rates

Heating and Cooling Loads

The heating and cooling loads of 123 Alpha Drive were reproduced with the assistance of Carrier Hap 4.7, an industry software used by smaller MEP consulting firms across the country. A zone summary report was produced for each rooftop unit found in the construction documents. Factors such as weather data, occupancy loads, lighting and equipment loads, structural properties, site conditions, and space type were all taken into account in the preparation of the mechanical systems present. A block loading approach was selected because of the generally simple structure of the building, as well as the ease and reliability of the procedure. Upon completion of the space properties, the system type and specifications were selected. The systems were designated to be single zone constant air volume rooftop units, two of which were outfitted with carbon dioxide preconditioning coils and an economizer. The outdoor and indoor temperature setpoints were set to the values found in Tables 1 and 2. Table 5 provides the ventilation air error between the data simulation in HAP and the construction design documents. Energy capacities for both heating and cooling were also analyzed, and compared with a percent error approach. The various block loads associated with these two analyses have been illustrated in Figure 2. It was determined that though some rooftop units were uncharacteristically different from the energy simulations, certain factors such as occupancy discrepancies and an inability to incorporate an accurate representation of the radiant floor cooling and heating systems present in the office spaces, the majority of the heating and cooling calculations were accurate.

Design vs Calculated Airflow (CFM)			
Unit	Design CFM	Calculated CFM	Percent Error
RTU-1	2600	2931	12.73
RTU-2	3000	2507	-16.43
RTU-3	3000	3732	24.40
RTU-4	3000	2926	-2.47
RTU-5	2800	3094	10.50
RTU-6	1800	2492	38.44

Table 5: Design versus Calculated Airflow

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

Table 6: Design versus Calculated Energy Capacities

Figure 2: Space Type Layout

KEY

Office Space	Restrooms
Warehouse	Conference Rooms
Dry Lab	Café Space

Annual Energy Consumption and Energy Cost

The six rooftop units, the warehouse air handling units, exhaust fans, and lighting/electrical loads were combined to produce an annual energy cost and consumption report. The report was produced in Carrier HAP 4.7, and local utility rates for electricity and natural gas were used. Table 7 indicates the yearly cost of electricity and natural gas, as well as the required capacity in kilowatt hours and therms, respectively.

Annual Energy Consumption and Cost				
Natural Gas (Therms)	Natural Gas Cost Per Year	Electricity (kWh)	Electricity Cost Per Year	Total Cost Per Year
2384	1,030	329,608	23,897	24,927

Table 7: Annual Energy Consumption and Cost

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

Table 8, below, highlights certain components of the construction documents' rooftop units, and indicates which RTUs house the preconditioned carbon dioxide coils, as well as an economizer.

Air Handling Unit Schedule						
Unit	Supply Airflow (CFM)	Outside Airflow (CFM)	Cooling Coil LAT DB (F)	Heating Coil LAT DB (F)	Total Capacity (MBH)	Economizer
RTU-1	1600	1200	55	51.8	124.4	No
RTU-2	3000	300	55	63.2	115.2	No
RTU-3	3000	300	55	63.2	138.7	No
RTU-4	3000	770	55	56.4	104.4	No
RTU-5	2000	600	55	51	119.1	Yes
RTU-6	1800	680	55	61.8	155.1	Yes

Table 8: Air Handling Unit Schedule

The only other mechanical systems that are present in the renovation of 123 Alpha Drive are the numerous exhaust fans that service the restrooms and dry lab space. The ten specified downblast roof-mounted exhaust fans in Table 9 are relatively small in size, although they do provide necessary exhaustion of air from contaminated spaces within the building.

Fan Schedule						
Unit	**Design CFM**	**RPM**	**HP**	**External SP (in wg)**	**Voltage**	**Motorized Damper?**
EF-1	150	1550	1/20	0.5	120	Yes
EF-2	600	1140	1/6	0.5	120	Yes
EF-3	755	1140	1/6	0.5	120	Yes
EF-4	300	1550	1/20	0.5	120	Yes
EF-5	300	1550	1/20	0.5	120	Yes
EF-6	300	1550	1/20	0.5	120	Yes
EF-7	300	1550	1/20	0.5	120	Yes
EF-8	500	1140	1/6	0.5	120	Yes
EF-9	75	-	1/6	0.5	120	No
EF-10	500	1140	1/6	0.5	120	Yes

Table 9: Downblast Roof-Mounted Exhaust Fan Schedule

Mechanical First Costs

Discussions with the owner are currently being held in order to obtain a pricing set, or documentation similar to a pricing set in order to produce an accurate approximation of the mechanical first costs for this project. This issue is expected to be resolved within the next two weeks at maximum.

Usable Space

The concept of usable space is a concern and design consideration of every building design. The concept is predicated on the elimination of areas such as mechanical shafts and rooms. These mechanical needs are typically a significant reason for a portion of the building to be deemed unusable by the tenant, which can decrease the value of the tenant space or building in general. This issue is a much more prevalent problem in buildings of more than one story and those that utilize heat pumps and vertically stacked units. Mechanical equipment such as chillers and boilers require large mechanical rooms, which also decreases the percentage of usable space. Since 123 Alpha Drive is a one story building that utilizes rooftop units for the majority of office space and air handling units for the warehouse spaces, the maximum amount of usable space is likely to be achieved. Each air handling unit, rooftop unit, and exhaust fan is electrically controlled, so the use of boilers and chillers is not required for the building. Table 10 indicates how little of the usable space is compromised by the mechanical systems. It should be noted, however, that staircases serve as a type of unusable space, but have not been included in this calculation.

Mechanical Space Requirements				
Level	Floor Area (sq. ft.)	Mechanical Area	Usable Area	% Usable
Ground	63360	1623	61737	99.97

Table 11: Mechanical Space Requirements

LEED Analysis

123 Alpha Drive contains a number of various energy efficient and potentially environmentally friendly design components. The renovation that involved the replacement of certain rooftop units aided in the attempt to develop a more "green" building design. One of the most common ways to categorize and define the efficiency and sustainability of a building's design, construction, and operation is through a LEED Analysis. LEED, which stands for Leadership in Energy and Environmental Design, is a program recognized across the globe that awards buildings for various levels of "green" design. The entire analysis of the LEED system is a rather lengthy and arduous process, however, so in order to deliver a concise and educated analysis on the efficiency of the mechanical systems found in the building, only two of the possible six categories will be investigated. The two categories that will be investigated are 'Energy and Atmosphere' and 'Indoor Environmental Quality'.

Indoor Environmental Quality

It can be estimated with confidence that 123 Alpha Drive would qualify for 10 LEED Credits in the Indoor Environmental Section of the LEED 2009 Checklist. In order to qualify for any points, the two prerequisites for this section had to be met.

Prerequisite 1: Minimum Indoor Air Quality Performance

This prerequisite ensures that the minimum indoor air quality has been met for the building. The requirements and design conditions outlined in ASHRAE Standard 62.1 dictate that the minimum indoor air quality required for LEED points to be awarded be met. Since a prior report indicates that 123 Alpha Drive is in compliance with ASHRAE Standard 62.1, prerequisite 1 has been met.

Prerequisite 2: Environmental Tobacco Smoke (ETS)

The ETS prerequisite ensures that the building and its tenants are not exposed to the harmful, toxic carcinogens found in tobacco. Smoking is prohibited within the building space and on the company property. 123 Alpha Drive meets the second prerequisite.

Credit 1: Outdoor Air Delivery Monitoring – 1 point

This credit is associated with the mechanical control system responding to and supplying the required minimum outdoor air for the zones in need of ventilation. Each air handling unit and rooftop unit is equipped with a mixing box and control system that monitors the outdoor air being drawn into the return air plenum and mixing box. The control system is programmed to deliver a minimum outdoor air volume at least during all occupiable hours of the day, and thus the building fulfills the requirements and earns a credit.

Credit 2: Increased Ventilation – 1 Point
This credit exists in an effort to assist the comfort of tenants and occupants by increasing the amount of ventilation within the space above the minimum requirements. Under this credit, a 30% increase above the minimum requirements must be met in order to earn this credit. It has been determined through analysis of the mechanical drawings and schedules that such an accommodation can be made with the current mechanical equipment and design.

Credit 3.1: Construction IAQ Management Plan, During Construction – 1 Point
This credit ensures that all indoor air quality problems be addressed during the construction phase of the project. Such compliance to this credit would be specified in the rooftop units' specifications, which are currently unavailable for reference. This practice will be assumed, however, as the owner and MEP firm for the project developed an energy efficient plan and design before construction.

Credit 3.2: Construction IAQ Management Plan, Before Occupancy– 0 Points
This credit is linked in part with Credit 3.1, as it further ensures the minimum indoor air quality before the occupants of the building is investigated and checked. Environmental Protection Agency measures and full-building examinations must be conducted in order to ensure that no harmful pollutants exist within the confines of the building. Such a test was not scheduled for 123 Alpha Drive, and therefore, this credit cannot be earned under the current circumstances.

Credit 4.1: Low-Emitting Materials, Adhesives, & Sealants – 1 Point
Adhesives and sealants can be potentially dangerous materials, as they as prone to carry odorous and harmful contaminants. The sealants and adhesives used in this building's design qualify as low-emitting, and thus the credit is earned.

Credit 4.2: Low-Emitting Materials, Paints & Coatings – 1 Point
Paints and coatings follow the same guidelines and principles as adhesives and sealants (see Credit 4.1). All paints and coatings within the building have been deemed to be free of considerately harmful or odorous contaminants. Credit 4.2 can be counted as achieved in this checklist.

Credit 4.3: Low-Emitting Materials, Carpet Systems – 1 Point
Similar to Credits 4.1 and 4.2, this credit establishes that the carpet systems found in the building are not harmful to the occupants. The architectural drawings and finishes sheets of the construction documents confirm that the carpets do not pose a threat to the occupants. Credit 4.3 has been earned.

Credit 4.4: Low-Emitting Materials, Composite Systems – 1 Point
This credit is intended to ensure that wood systems do not contain harmful pollutants or contaminants within the wood resin. Since concrete, masonry, and steel are the only structural materials in use for 123 Alpha Drive, this requirement has been met.

Credit 5: Indoor Chemical & Pollutant Source Control – 1 Point
The purpose of this credit is to monitor and prevent the exposure of occupants to hazardous chemicals and pollutants. Each air handling unit and rooftop unit was outfitted with at least one MERV 13 filter, and the dry lab spaces contain exhaust systems that exhaust air directly outside of the building and at a safe height from the ground.

Credit 6.1: Controllability of Systems, Lighting – 1 Point
Credit 6.1 attempts to deliver a lighting system that is capable of producing occupant comfort, diversity, and manageability. The majority of all lights within the office spaces and conference rooms are dimmable, controllable, and are assigned to a sophisticated lighting control panel.

Credit 6.2: Thermal Comfort – 0 Points
Credit 6.2 is intended to ensure that the majority of occupants have individual control of their thermal comfort in their natural work environment. Under the current design, the majority of occupants are unable to control their thermal comfort, as the rooftop units and air handling units are single zone constant air volume systems.

Credit 7.1 Thermal Comfort, Design – 1 Point
Similar to Credit 6.2, this credit is centered around providing an environment that produces thermal comfort and stimulates productivity and health. ASHRAE Standard 55 can be likened to this credit, and under the category of 'Thermal Comfort Conditions for Human Occupancy', 123 Alpha Drive meets the requirements of Standard 55 and Credit 7.1.

Credit 7.2: Thermal Comfort Verifications- 0 Points
This credit involves an assessment of occupant thermal comfort over a set period of time. No surveys or investigations have been made public since the construction and completion of the project.

Credit 8.1: Daylight & Views, Daylight 75% of Spaces – 0 Points
This credit promotes the use of daylighting to improve the productivity and comfort of the building occupants. Credit 8.1 requires that 75% of the spaces contained in the building have a window or glass door to the outside. 123 Alpha Drive does not qualify for this credit, as many of the office spaces have been found to be designed without the implementation of a window.

Credit 8.2 Daylight & Views, Views for 90% of Spaces – 0 Points
Credit 8.1 was not met, and by the associative law, Credit 8.2 must also be unearned.

Energy and Atmosphere

It can be estimated with confidence that 123 Alpha Drive would qualify for 6 LEED Credits in the Energy and Atmosphere section of the LEED 2009 Checklist. In order to qualify for any points, the three prerequisites for this section had to be met.

Prerequisite 1: Fundamental Commissioning of the Building Energy Systems
Commissioning was overseen and completed by the project team in order to lower the operating costs of many mechanical and electrical devices. Energy usage was also intended to be lowered through the commissioning process. The owner, whose company specializes in geothermal technology and highly efficient design, has ensured that the system is operating to the requirements specified in the project

Prerequisite 2: Minimum Energy Performance
An energy model produced with Carrier HAP 4.7 indicated that the mechanical systems performed above ASHRAE recommendations, allowing for increased savings. This energy model proved that the minimum energy performance required for this prerequisite was met. ASHRAE Standard 90.1 was used to compare with the energy model, and served as the minimum energy performance deemed suitable for this type of construction and building.

Prerequisite 3: Fundamental Refrigerant Management
The refrigerant used in the radiant floor cooling and heating systems was designated to be R410A. This refrigerant has been deemed a suitable replacement to the outdated, now illegal cluorofluorocarbons (CFCs). R410A is considered one of the more eco-friendly refrigerants, and is trusted to have a low environmental impact in the event of a leak or tube rupture.

Credit 1: Optimize Energy Performance – 2 Points
In order to earn this credit, the energy performance of the mechanical system must be optimized. This optimization is referenced to the minimum required energy performance outlined in Prerequisite 2. 123 Alpha Drive is projected, based on energy modeling, to perform at least 15% above the minimum required energy.

Credit 2: On-Site Renewable Energy – 1 Point
A future geothermal site has been planned for 123 Alpha Drive. The well field will be drilled in order to accommodate multiple heat pumps servicing the office spaces of the building. This practice can be considered as an on-site renewable energy practice, and therefore Credit 2 is earned.

Credit 3: Enhanced Commissioning – 1 Point
The commissioning required to earn this credit was considered to completed within the project team. 123 Alpha Drive complies with this requirement.

Credit 4: Enhanced Refrigerant Management – 2 Points
The implementation of refrigerant R410A and a highly efficient radiant floor cooling and heating system ensures that the global warming potential of this system is much lower than the USGBC guidelines states.

Credit 5: Measurement and Verification – 0 Points
Sufficient information on the continued investigation of energy consumption and performance was neither verified nor confirmed. This credit, as of this moment, does not qualify.

Mechanical System Evaluation

An investigation of the mechanical system first cost was conducted and found to be $[redacted] million, which was identified as 17.2% of the total cost for the building. In terms of square area, the cost of this mechanical system was determined to be $[redacted] per square foot. An average annual utility cost was derived from the building energy simulation conducted in Technical Report 2, which leveled out to $24,927. This annual cost is considered relatively low for the square area of the building in conjunction with the space type requirements of the building. Spaces such as warehouse and laboratories are difficult to condition at an efficient rate, which may explain a slightly higher annual energy cost for the HVAC system than expected.

Investigations such as design requirements, heating and cooling loads, ventilation requirements, energy consumption, and a LEED analysis were completed in order to encompass an overall evaluation of the mechanical system. The purpose of this evaluation was to highlight possible adjustments to the mechanical system design that may aid in the reduction of annual energy costs, mechanical first costs, or other mechanical design improvements. Usable space percentages were deemed to be almost completely unaffected by the HVAC systems in place.

The LEED analysis of two categories of the 2009 Checklist proved that the building is fairly equipped and likely to earn a LEED certification if moderate adjustments were made to the building design. LEED considers individual occupant comfort to be paramount, and many more credits could be achieved if a variable air volume system was installed in place of the existing constant air volume system.

References

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