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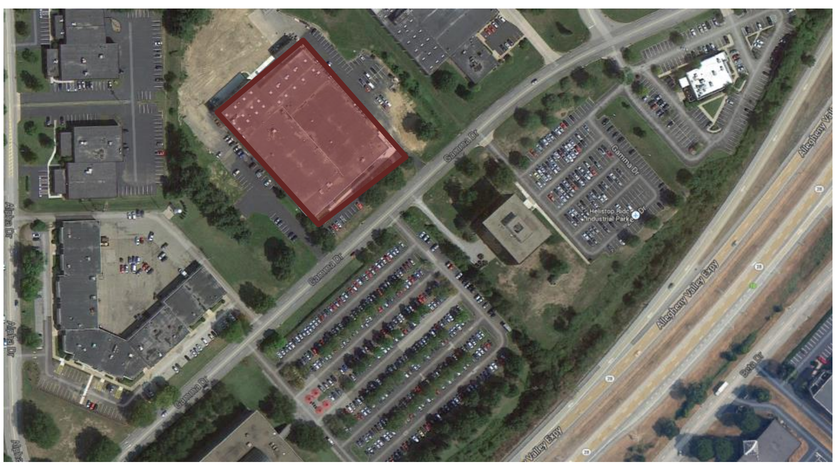
Executive Summary

123 Alpha Drive is a one story, 64,000 square foot mixed office and warehouse building located in Pittsburgh, Pennsylvania. A major renovation of the office, café, and laboratory spaces was completed in 2012, improving the mechanical system by utilizing constant air volume rooftop units and radiant floor cooling and heating loops in various zones. The use of constant air volume rooftop units may not be as efficient as the mechanical design possibly could be, however. The installation and implementation of a new mechanical system that allows units to heat and cool as required may prove to be a more energy efficient and cost effective approach. A proposed system that could accomplish these objectives is a variable refrigerant flow (VRF) system. 123 Alpha Drive operates at nearly a maximum usable space, eliminating the concern of sacrificing usable space for this new style of mechanical system. The VRF system could utilize its mode change units (similar to piping manifolds) to supply an appropriate amount of heating or cooling to specific areas of the building, saving a significant amount of money annually. Slim duct fan coil units could improve the ceiling height of the office spaces and reduce the electrical load in comparison to the rooftop units. Different refrigerants can be tested and examined to determine which will work most efficiently within the VRF system.

Exploring the possibility of a variable refrigerant flow system can also lead to investigations of other solutions to issues within the building. An acoustical study will be conducted in order to evaluate the potential decrease in mechanical background noise level by switching from a rooftop unit with sufficiently large, bulky ductwork, to a VRF piping system that leads to smaller, concealed ceiling unit. An electrical study will also be conducted in order to see if the installation of a variable refrigerant system would benefit the initial cost of the electrical system in terms of smaller wire and conduit needed, smaller or different electrical panels, and a reduction of electrical transformers.

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.



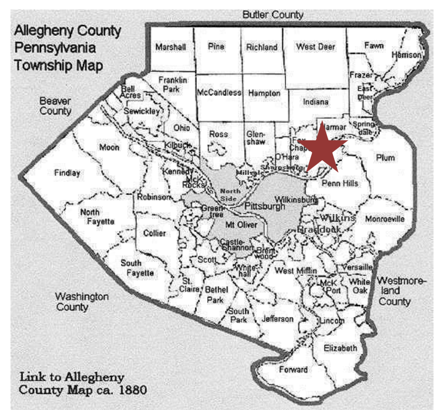


Figure 1: 123 Alpha Drive Location in RIDC Park and Allegheny County

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 Map

Mechanical Proposed Redesign

The redesign of the 123 Alpha Drive office space will be centered around improving the thermal comfort of the occupants, reducing energy consumption, and decreasing the annual carbon emissions produced by the mechanical systems. A variable refrigerant flow system has been chosen as the proposed mechanical redesign for this building.

A variable refrigerant system utilizes multiple small indoor fan coil units which are individually controlled by mode control units. A series of three pipes (suction, liquid, and discharge) are sent from an outdoor condensing unit to the piping manifold mode control units. Several fan coil units can be connected to each mode control unit, although individual mode control units for each fan coil unit is also possible. With this configuration simultaneous heating and cooling can be achieved, if necessary. This type of system allows for a significant energy savings under partial load conditions, if implemented correctly. Since the building footprint of 123 Alpha Drive is so large in comparison to most multi-story buildings, a considerable difference in heating and cooling load requirements exists between the interior office spaces and the exterior spaces exposed to significant daylighting and infiltration. This system is also accompanied with a complex set of controls including an air conditioning inverter and a compressor inverter. These controls will provide the owner and occupants with more freedom to designate their thermal comfort, and will allow the system to operate more efficiently than the single zone constant air volume systems currently in place.

Solution Method

The energy model produced for 123 Alpha Drive will need to be revisited. The system types for each zone will be adjusted to replicate a variable refrigerant flow system. The number of zones for this building load simulation will increase significantly, as the goal of the VRF system is to provide thermal comfort to each individual space based on its specific heating and cooling load demands. A zone summary report for each zone will be produced, which will in turn be used for several other design decisions. Based on the required flow-rate and capacity of each refrigerant line, the possibility of multiple outdoor condensing units will be explored. A balance between cost, feasibility, and a proposed mechanical equipment layout and placement will be met in order to effectively design a mechanical system(s) that is cost effective, energy efficient, and provides significant thermal comfort to the occupants of the building. Since variable refrigerant flow systems are fairly new, loop sizing and flow-rate determinations may not easy to obtain through the use of Carrier HAP 4.7 and/or Trane Trace. With the assistance of Iams Consulting, LLC, the MEP firm responsible for the original design, and their equipment selection representative, an accurately VRF system will be produced for further analysis.

An annual energy consumption and cost report will be produced by Carrier HAP 4.7, and the annual HVAC costs will be compared with the original design annual HVAC costs to determine the cost effectiveness and energy efficiency differences between the two systems. An additional analysis will be conducted in order to determine the first costs of the variable refrigerant flow system. This, in conjunction with the annual HVAC cost, can be compared with the original design to see when the VRF system will begin to be a most cost effective system (i.e. number of years). In addition, a comparison of annual CO2 emissions will be conducted to determine if the VRF system produces considerably less carbon emissions.

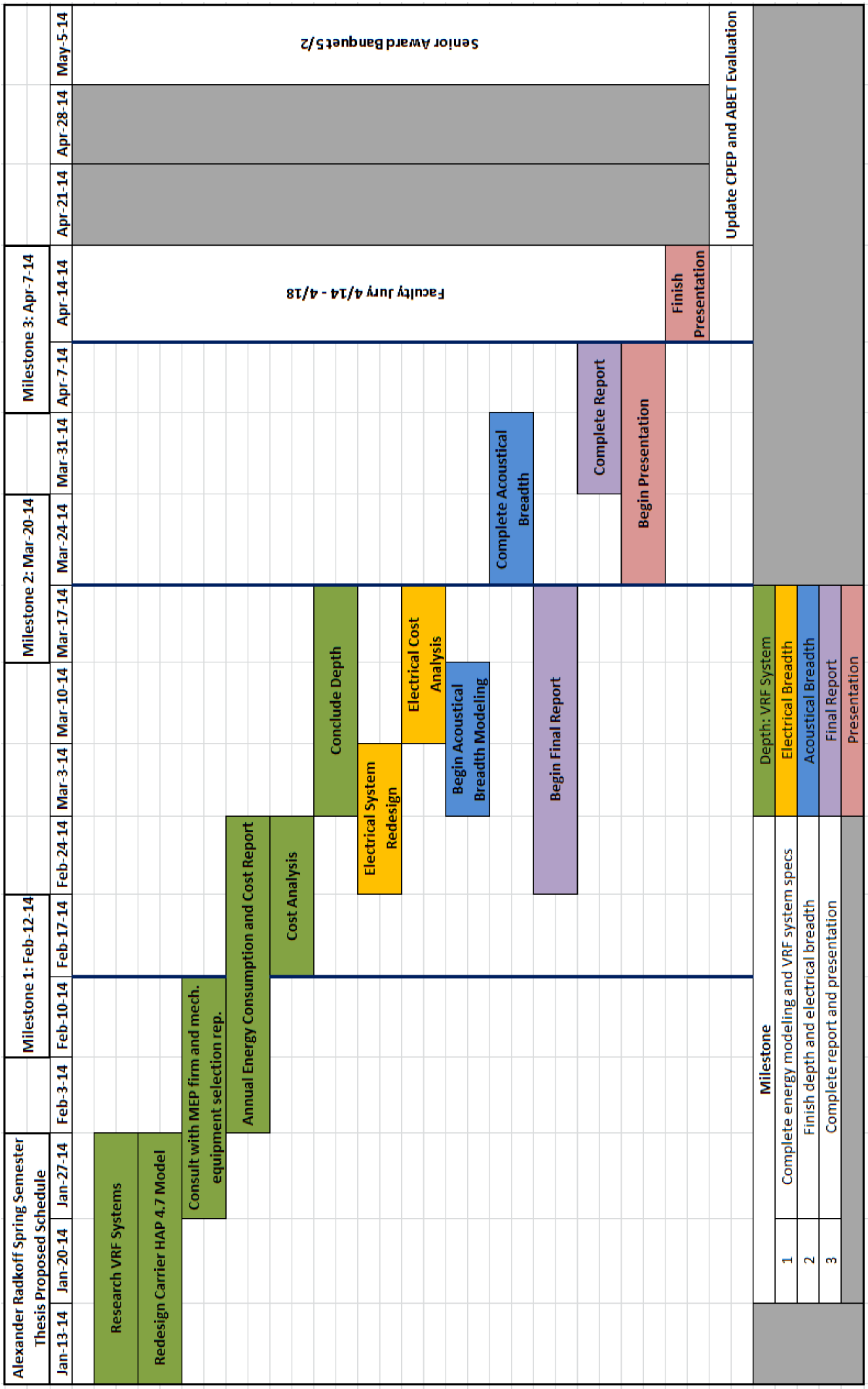
Lastly, an analysis of different refrigerants will be explored. Each refrigerant examined will be investigated based on its efficiency and cost per gallon. The top performing refrigerant will be used in the proposed redesign of the 123 Alpha Drive mechanical systems

Acoustical Breadth

An office space requires a quiet, peaceful work environment so that occupants can effectively work with a sense of comfort. The implementation of a new mechanical system should be prefaced with an extensive investigation of the acoustical consequences of such an alteration. The acoustical property that would be affected the most by a change from a constant air volume rooftop unit to a variable refrigerant flow system would be the HVAC Background Noise Level (BNL). Background noise level is measured by calculating the sound pressure level at the unit and accounting for any duct lengths, elbows, takeoffs, or diffusers along the path to the nearest terminal. The final BNL is compared with the American National Standards Institute (ANSI) Standard S12.60 for office spaces. The VRF system will be analyzed to see if a reduction in HVAC background noise level from the previous design can be accomplished. Dynasonics AIM is a software tool that allows for the creation of duct and terminal systems in spaces created using Google Sketchup. Using this software, the background noise level can be calculated by providing the program with the proper air handling unit and duct properties.

Electrical Breadth

After the mechanical equipment selection has been made for the variable refrigerant flow system, an electrical analysis and redesign will be conducted in order to accommodate for the new HVAC system in place. In all likelihood, the fan coil units and mode control units for the VRF system will be 120 Volt/1 phase/60Hz, which is favorable in the event that the 460 Volt mechanical panels can be eliminated. This could also potentially eliminate a significant amount of transformers that are currently being used in the electrical design. If necessary, a new mechanical power panel will be selected and sized accordingly, in order to service the large number of fan coils installed. The emergency power generator will also have to be examined to see if the 150 kW generator remains to be a sufficient sort of emergency power. The Nation Electric Code (NEC 2012) will be used to properly size conduit, feeders, and the emergency generator, if necessary. Upon completion of the necessary adjustments to the electrical design, a cost comparison will be conducted that includes panel costs, transformer costs, and feeder/wire costs. From this analysis, a determination regarding the cost effectiveness of installing a VRF system in terms of the electrical design will be made.



Alexander Radkoff Spring Semester Thesis Proposed Schedule
Milestone 1: Feb-12-14
Milestone 2: Mar-20-14
Milestone 3: Apr-7-14
Jan-13-14
Jan-20-14
Jan-27-14
Feb-3-14
Feb-10-14
Feb-17-14
Feb-24-14
Mar-3-14
Mar-10-14
Mar-17-14
Mar-24-14
Mar-31-14
Apr-7-14
Apr-14-14
Apr-21-14
Apr-28-14
May-5-14
Research VRF Systems
Redesign Carrier HAP 4.7 Model
Consult with MEP firm and mech. equipment selection rep.
Annual Energy Consumption and Cost Report
Cost Analysis
Conclude Depth
Electrical System Redesign
Electrical Cost Analysis
Begin Acoustical Breadth Modeling
Complete Acoustical Breadth
Begin Final Report
Complete Report
Begin Presentation
Finish Presentation
Faculty Jury 4/14 - 4/18
Senior Award Banquet 5/2
Update CPEP and ABET Evaluation
Milestone
1 Complete energy modeling and VRF system specs
2 Finish depth and electrical breadth
3 Complete report and presentation
Depth: VRF System
Electrical Breadth
Acoustical Breadth
Final Report
Presentation

References

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Johnson Controls. "Variable refrigerant flow system" Milwaukee, WI, 2010.

AHSRAE Journal. "Variable Refrigerant Flow Systems" April 2007.