Grunenwald Science and Technology Building

Clarion University- Clarion, PA

AE 482 Mechanical Project Proposal:

Revised Proposal for Alternative Designs

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Executive Summary

The Grunenwald Science and Technology Building is the new laboratory and classroom building for Clarion University. The mechanical system does use sustainable ideas and energy consumption reduction as a basis for the initial design approach. The building implements 5 VAV AHU's, 3 of which are 100 percent outdoor air for the laboratory spaces which make up 50 percent of the building. The other 2 AHU's are standard VAV systems that use an economizer with CO2 measurement controlling the damper for outside air and serve the classrooms and offices in the Science and Technology Building. The Building uses (2) 250 ton centrifugal chillers which are water cooled by 2 cooling towers. Hot water is produced by passing the campus generated steam through a plate and frame heat exchanger with water, and the water is used in the pre-heating and heating coils of the AHU's. The sustainable design approach can be seen in the energy efficient equipment selected for the building.

The intention of this proposal is to further minimize the energy consumption of the building while not adding a substantial first cost. In order to achieve the energy reduction for the building lowering the effective carbon footprint, several alternative designs have been proposed. These alternative designs are: lab exhaust fan redesign, Dedicated Outdoor Air System with a parallel system, and Geothermal Heat Pumps. The implementation of each of these alternatives will need to be integrated into the Science and Technology Building Systems. The systems will be researched to determine the best possible solution for the building. The best alternative will be determined by which best met the goals of the building project for sustainable and energy efficient.

To analyze the alternative systems energy modeling programs will need to be used along with Labs21 when analyzing the exhaust fan redesign. The other tools that will be used are: energy modeling programs, Trace 700, HAP, or eQuest, ASHRAE Standards, and local building codes.

The breadths that will be studied are architectural, and construction aspects of the project. For the architectural breadth the addition of solar shades to the building facade will be analyzed, while for the construction breadth will study the implementation of the geothermal system.

Mechanical System Design

Introduction:

The Grunenwald Science and Technology Building is a 3-story, 108,560 square foot, university laboratory and classroom building on Clarion University's campus. The building is comprised of approximately 50 percent laboratories, 20 percent classroom, and 10 percent offices. The laboratories are served by a 100 percent outdoor air VAV system, while the other spaces are served by a conventional VAV system. It is designed to achieve a LEED Gold rating through the use of sustainable technologies and innovative design approaches.

Design Objectives and Requirements:

The main design objective for the Science and Technology Building was to focus on sustainability and a reduction in energy consumption while obtaining a LEED certification and meeting the ASHRAE Standards. In order to meet the standards, the building must meet specific energy, ventilation, equipment, and temperature requirements. With these both in mind the designers produced a VAV system using 100 percent outdoor air for the zones handling the laboratory spaces, and used a conventional VAV system for the classrooms and offices. The mechanical system consists of high efficiency chillers and cooling towers, while using the central campus plant steam to pass through a plate and heat exchanger to heat the water used in the heating coils in the systems. The 100 percent outdoor units utilize a glycol runaround coil to pre-treat air entering the AHU's, while the all the systems use energy recovery wheels to pre-treat the air using either the exhaust air or the heat produced by the on-site micro turbine.

Site and Budget:

The site for the Grunenwald Science and Technology Building is located on the campus of Clarion University in Clarion, PA. At Clarion University, the new building was built on the same site as the previous Pierce Science Building constructed in 1968. In the center of the building, the newly renovated planetarium was preserved from the previous Pierce Science Building along with a large lecture hall located on the first floor, directly below the planetarium. The building sits on the same footprint of the previous building and the location of a faculty parking lot as it did not add more impermeable surfaces than what was previously on the site. The building was awarded for $34 million, which was within the established budget for the university. One item that was nearly left out due to budget concerns was the micro turbine as the calculated payback period exceeded 30 years. The university was able to obtain a government grant for the micro turbine allowing the design team the ability to use this technology with no cost to the university who began seeing savings upon installation into the building.

Mechanical System Initial Cost:

The estimated final cost including change orders for the mechanical system for the Grunenwald Science and Technology Building was $6.25 million. This number includes the plumbing that is associated with the HVAC systems. The calculated cost per square foot of the building floor area is $57.57. The total cost of the mechanical system accounts for 18.4 percent of the total construction cost for the building.

Equipment Summary:

The Science and Technology Building consists of 5 air handling units, which are modular units consisting of a mixing box, filter mixing box, preheat coil, cooling coil, supply fan, and access sections for the 2 VAV air handling units. In the three 100% outdoor air units consist of 30% angle pre-filter, 90% bag filter, glycol runaround coil, preheat coil, cooling coil, steam humidifier, supply fan, and access sections. These three serve the laboratory spaces, with 100% outdoor air, within the building and are coupled with 3 equally sized exhaust air handling units. Two of these units are approximately 42,000 CFM, and serve the typical lab spaces in both the NE and SW wings of the building and the chemical storage rooms on all three floors. The 3rd AHU is 23,000 CFM serving the specialized Organic Chemistry Labs arranged throughout the Science and Technology Building. This AHU also has a reheat coil built into the modular unit to strictly control the humidity in these particular laboratories, by being able to use the cooling coil to lower the air temperature past the dew point. The air handling units that serve the laboratory spaces all use a Glycol runaround heat recovery coil to pre-treat the air entering the AHU.

The 2 other air handling units are each 25,000 CFM in size, serving the classrooms, offices, and other public spaces within the building. These units are variable air volume containing VAV boxes with electric reheat coils before the spaces used as classrooms and offices. Both of the air handling units use an economizer to reduce the energy consumption of the building, while having a minimum outdoor air requirement for the spaces served by each AHU. The exhaust air from both systems is used in an Energy Recovery Wheel to pre-heat or pre-cool the outdoor air entering the system depending on the weather conditions, summer or winter. The Energy Recovery Wheel will also use the heat produced by the micro turbine in the winter to preheat the outdoor air being mixed with the return air in the system.

The AHU's use hot water generated from a plate and frame heat exchanger, in which the heat is exchanged from the campus generated steam to the water within the heating coils. The water enters the exchanger at 140 degrees F and leaves at 180 degrees F. The chilled water for the systems is produced by the two 250 ton centrifugal chillers located in the first floor mechanical room. The Science and Technology Building has two 750 gpm cooling towers.

Clarion University did make strives for sustainability that can be seen in design with various systems. Clarion University's Science and Technology Building was designed to meet LEED certification, obtaining a LEED Silver rating upon completion. The use of recycled materials in the construction of the building was done in the facade with the pre-patina colored copper, and the reuse of wood in shelving systems throughout the building. Floors throughout are highly polished concrete rather than carpet or tiling. Incorporated into the design of the building is a 65 kWe turbine, which operates in conjunction with 26 kWe solar photovoltaic panels, located on the roof of the building. These two together are used to provide electricity to the building and heat produced from the turbine will be recovered and used within the buildings heating system. The use of a rainwater collection system supplies non-potable lab water and urinal water. Building automations allow for energy efficient lighting and HVAC design in the classrooms and offices.

Overall Evaluation

The mechanical system for the Grunenwald Science and Technology Building is well designed and implements various sustainable technologies. The use of energy efficient equipment keeps the energy consumption of the mechanical system to a minimum. The use of high efficiency chillers, along with the VAV systems can be very effective when implemented properly. The use of produced steam from the central campus boiler plant is required by the university, and the plant has recently been upgraded to provide energy efficient boilers that burn natural gas rather than coal.

The use of economizers along with CO2 measurement devices allows the mechanical system to reduce the energy consumption further. The designers also incorporated a micro turbine into the design as the university received a grant to purchase this technology, it will provide electricity and the heat will pretreat outdoor air. The chillers used for the mechanical system are variable flow centrifugal chillers, which does make them more efficient than constant flow chillers and reduces the number of pumps along with their associated cost of installation. The cooling towers do not utilize free cooling in the initial design and if implemented savings in energy could be seen for a slight increase in upfront costs.

The VAV system used to supply the laboratories with 100 percent outdoor could work with a dedicated outdoor air system since the laboratories do not require that high of a ventilation rates. The use of the VAV systems keeps the installation and operating costs lower since it is typical of many new office buildings. If a DOAS was used only the ventilation would be provided by supply air while the rest of the load would be taken care of by radiant ceilings, chilled beams, etc., and may increase the first costs of the mechanical system. The cost of the mechanical system accounted for 18 percent of the total construction cost, and this is in the range of normal for construction projects of this type. The operational cost of the building is $1.43/sf. This is relatively low do to the on-site produced energy along with the use of energy efficient equipment.

The mechanical system utilized in the Science and Technology Building consists of chillers, cooling towers, pumps, AHU's, and VAV boxes, which is in the conventional systems installed in many of the new buildings. This will allow for many building engineers to know how to work on this system since there is no special equipment or training required to make repairs. Overall, the maintenance costs should remain low as the system is typical.

The laboratories are 100 percent outdoor air to prevent contaminants within the building, rather being captured by the large fume hoods and flexible snake exhaust ducts in each lab. There are 4 exhaust fans where redundancy is used with the implementation of an extra fan in case of failure of one of the other 3 fans. The exhaust for the building is released at high velocity to increase the throw above 60 feet to prevent contaminants to surrounding buildings.

Proposed Alternative Designs

The current mechanical system was designed to be energy efficient and has been able to aid in the project achieving a LEED Gold rating at this time. The energy savings of the building have been modeled to achieve a 40 percent reduction over the ASHRAE Baseline Building. There are other alternatives that can be implemented to provide an even larger energy reduction than the original design of the Grunenwald Science and Technology Building. These alternative designs can be implemented into the building with minor changes to the system as a whole, while their potential for improving the Science and Technology Building will be discussed further below. The alternatives to be investigated for use in the building are: exhaust fan redesign, Dedicated Outdoor Air System for laboratory wing with various radiant cooling techniques, and the use of Geothermal Heat Pumps to meet partial load.

Exhaust Fan Redesign:

The Science and Technology Building is comprised of 50 percent laboratory spaces each having multiple fume hoods and exhaust fans. The laboratories use more energy than the typical office building by nearly 4 to 6 times according to the preliminary research that was done until now. The fans associated with the fume hoods contribute to the energy consumption of the laboratories more than most of the systems associated with the labs. In the original design, the exhaust fans where oversized and not all were designed to be VAV fans.

The fans will be resized based on the codes in place to meet the required air changes per hour for the different occupancy type labs in the Science and Technology Building. All of the fans will then be designed as VAV fans to reduce the energy consumption of the exhaust fans in the laboratory spaces. A comparison will be made between the original design and the redesign of the exhaust fans to see if the initial cost could be reduced with the use of smaller fan sizes even though they will need to be VAV. The comparison will also determine if sufficient energy savings will be seen with the redesign of the fume hood exhaust system.

Dedicated Outdoor Air System (DOAS):

The Dedicated Outdoor Air System supplies the ventilation requirement to the space with 100 percent outdoor air. The system that the labs use in the building is a 100 percent outdoor air VAV system even though the labs require only a high percentage of outdoor air to meet ASHRAE Standard 62.1. The supply of 100 percent outdoor air was done to prevent cross contamination between the various laboratory spaces. The use of this system will allow for the supply ducts to be reduced in size along with the supply fan, when compared to the VAV system being used in the original design.

The ventilation air will be treated by both an enthalpy wheel and an AHU to meet the latent load attributed with that space. This allows the sensible load to be treated completely separate from the latent load by using a parallel system such as: fan-coil units, radiant panels, chilled beam, etc. The outdoor air that is being introduced into the system will need to be pretreated which requires the use of a heat recovery system. At this time the laboratory spaces do use an enthalpy wheel to pretreat the outdoor air by using both the exhaust air from these spaces and the waste heat from the onsite micro turbine. This was required by ASHRAE 90.1 for the 100 percent outdoor air VAV system since the air also needed to be pretreated before the coils as there was no mixing in the system. This allows the energy of the exhausted air from the lab spaces to be exchanged with the outside air based on the overall efficiency of the heat recovery system.

The use of this type of system to meet the requirements for the Science and Technology Building may provide additional energy savings according to the preliminary research, since the building is comprised of 50 percent laboratories. Along with the energy savings associated with the AHU fan will be savings associated with the reduced load on the coils. There will also be inherent energy increases when using a DOAS system and these will have to be taken into account when calculating the total energy usage of the DOAS system. The results will be compared with the current 100 percent outdoor air VAV system used in the Science and Technology Building.

Geothermal Heat Pumps:

At Clarion University, the buildings are supplied steam to meet the heating loads of all the buildings on the campus using natural gas boilers to generate the steam at the central plant. Any renewable resources that could help to reduce the load of the Science and Technology Building on the central plant may be able to reduce the energy consumption of the building. The Geothermal heat pump will be looked to be a variable method used in conjunction with the campus steam already used in the building to ensure full load is meet and using a supplemental cooling tower.

The area needed for the geothermal heat pump system can be provided in the adjacent quad at the center of the university as there is a considerable amount of open land. The geothermal system could provide energy savings for the university building when compared to the VAV systems in use in the building as a result of the near constant temperature of the ground in Clarion, PA is approximately 52 degrees Fahrenheit. The use of the geothermal heat pumps will be explored in aiding the systems that serve only the offices and classrooms with the VAV system that is used in the original design. In addition to this it will be integrated into the proposed Dedicated Outdoor Air System serving the laboratory spaces comparing the energy consumption of the DOAS with and without the geothermal heat pumps and the associated cost savings that may be obtained through the two separate designs.

The initial cost of the geothermal system can be high, but the maintenance costs are relatively low with a long system life. The geothermal system will add to the construction schedule based on the number and depth of wells that would need to be drilled to meet either the full or part load of the building. This will have to be analyzed to optimize the size of the geothermal field based on the overall cost and energy savings obtained by the design. The construction process associated with the geothermal system will be analyzed in further depth as part of the breadth studies.

Breadth Topics

Architecture:

The use of solar shades will be investigated for possible energy savings, since the inclusion of shades on the exterior architectural facade were not included in the current design of the Science and Technology Building. The solar shades will only be placed on the south and southwest facades of the building. Allowing daylight into the spaces is important as each room does have a photocell to dim the fluorescent lights in the space. The daylight allowed into the space does lead to a positive learning environment for the university building. An overall evaluation will be done into which solar shading can be used comparing the amount and quality of light that will be transmitted through the various shading devices. The building loads and energy consumption will be compared to the current design that does not use solar shading as an element of the architecture. The cost savings associated with the energy use will be used to justify the additional first cost of the facade redesign.

Construction:

The geothermal heat pump will be located on the central quad of Clarion University located adjacent to the building site. Many precautions will have to be made as construction site will be intrusive to all students travelling on campus. Safety and site utilization plans for the central quad construction site will have to be developed to ensure the safety of the students and faculty along with preserving access through the central quad to the adjacent buildings. The schedule of the construction process for installing the geothermal heat pumps will be evaluated to ensure that the Clarion University campus is affected for the least amount of time. Another consideration will be trying to get the construction time frame to fit the summer months when campus has less activity.

Tools for Analysis

Energy Modeling Software:

The energy models will be used to determine the annual and monthly energy consumption along with the associated costs. Energy modeling will be done in Trace 700 as this is the only available program that I am familiar with of the three that are provided in the AE computer labs for student use. Each of the programs may have limitations of what the user will be able to model for the alternative systems. Trace 700 has already been used to obtain values for the energy consumption compared to the values of the design engineer for use in Technical Report 2. It would be beneficial if the same program would be able to run each alternative so each could be more easily compared with one another, which is another reason that Trace 700 has been chosen along with the familiarity of the user to the program. This would eliminate the need to compare results from various programs as each will calculate results for the same system to be off by up to 10 percent.

ASHRAE Standards:

The ASHRAE Standards will be used in the evaluation of the proposed alternative systems similarly to the use of the standards in Technical Report 1 to ensure that each standard was met by the original design. This standard will be referenced when the DOAS system is being designed to ensure that the thermal and ventilation requirements are being achieved.

Labs21:

The government organization of Labs for the 21st century created an area were case studies can be reviewed and an associated program were the system inputs for lab design are input for analysis to determine energy consumption. This program will allow for a comparison to be made between various alternatives including the resizing of exhaust fans to obtain the energy consumption and cost savings associated with each individual laboratory space.

Codes:

The building codes for Clarion, PA will need to be used along with the International Building Coded to determine the occupancy types of each lab. This will allow for the number of air changes per hour to be calculated in order to resize each of the exhaust fans based on the occupancy class.

References

ASHRAE. (2005). *Handbook of Fundamentals.* Atlanta: ASHRAE.

Brinjac Engineering, Inc. MEP Construction Documents & Specifications. Brinjac Engineering, Inc., Harrisburg, PA

Michael Jacobs. Brinjace Engineering, Inc. Harrisburg, PA.

BCJ Architects. Architectural Construction Documents. BCJ Architects, Pittsburgh, PA

Technical Assignments 1, 2, and 3, Shane Helm (2010).

Appendix A: Preliminary Research

Exhaust Fan Redesign:

"Laboratories for the 21st Century: An Introduction to Low-Energy Design." National Renewable Energy Laboratory, (August 2008).

"Optimizing Laboratory Ventilation Rates." National Renewable Energy Laboratory, (September 2008)

- These research articles discuss the various methods a laboratory space can be designed to reduce the energy consumption of the space, including the resizing of the fans to prevent too many air changes per hour. The number of air changes and not the space load in the labs normally will determine the cooling load needed for that space and if this could be reduced energy would be saved.

Dedicated Outdoor Air System (DOAS):

Jeong,J., Mumma, S., and Bahnfleth, W. "Energy Conservation Benefits of a Dedicated Outdoor Air System with Parallel Sensible Cooling by Ceiling Radiant Panels." *ASHRAE Transactions*. (2003): 627-636.

Mumma, S. "Overview of Integrating Dedicated Outdoor Air Systems with Parallel Terminal Systems." *ASHRAE Journal*. (2001): 545-552.

Mumma, S. "Designing Dedicated Outdoor Air Systems."ASHRAE Journal 43.5 (2001): 28-31.

- These articles discuss the possible benefits of using the DOAS system compared to the conventional VAV systems as used in the Science and Technology Building. The different types of applications are discussed for DOAS in buildings along with the various terminal units that can be implemented.

Geothermal Heat Pumps:

Kavanaugh, S. "Ground Source Heat Pumps for Commercial Buildings." September 2008. HPAC Engineering. 8 Dec. 2009 <http:///hpac.com>.

Minea, V. "Ground Source Heat Pumps." ASHRAE Journal 48 (2006): 28-35.

Kavanaugh, S., McInerny, S. 2001. "Energy use of pumping options for ground-source heat pump systems." ASHRAE Transactions(2001):589-599.

- These articles discuss the use of geothermal heat pumps for commercial buildings and the advantages associated with the system and different techniques such as how to lay out the geothermal well.

Appendix B: Spring Semester Work Plan