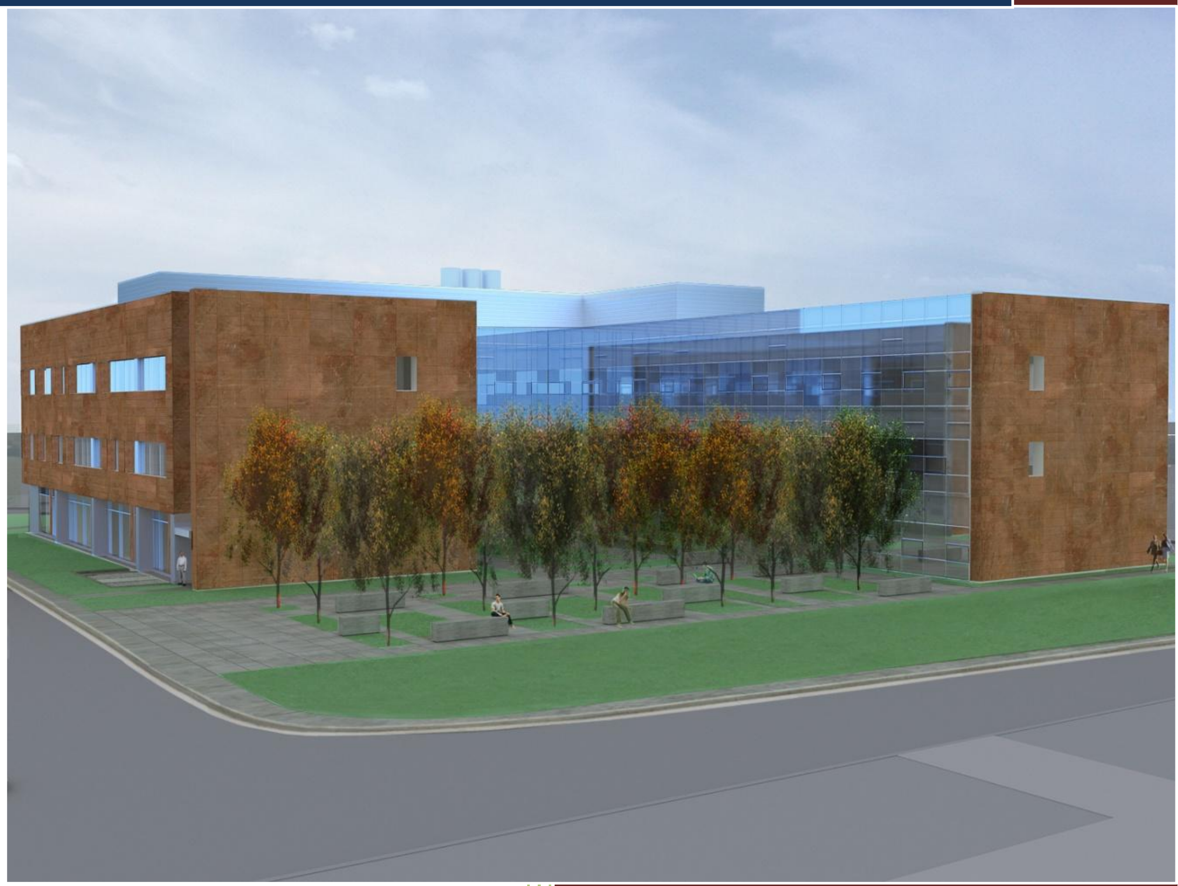
Nassau Community College Life Sciences Building

Garden City, NY

Mechanical Thesis Proposal

Revised Submission



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Executive Summary

Nassau Community College's Life Sciences Building is planned to house the Chemistry Department and the upcoming Nursing Department. The building has been designed with a series of general lecture halls, computer labs, organic and inorganic chemistry laboratories, nursing skill rooms and faculty offices. This wide range of occupancy classifications calls for a diverse mechanical system.

The Life Sciences Building contains three variable air volume air handling units. One air handling unit is a one hundred percent outdoor air unit, which serves the chemistry laboratories and supporting storage spaces. This air handling unit is coupled with a laboratory exhaust system, which is connected to exhaust diffusers in the laboratories as well as the fume hoods. Due to the high energy consumption of a one hundred percent outdoor air unit, a heat recovery run-around loop has been designed to transfer sensible heat released through the exhaust stream to the outdoor air intake. The remaining two air handling units are typical variable air volume units that serve the classrooms and offices.

Fume hoods occupy high energy consumption in laboratory facilities. The hoods also use up a sizeable amount of the construction cost as well. Due to these factors, a study will involve the investigation of an advanced fume hood that will allow the decrease of the supply air to each laboratory. The decrease of supply air will aid in the decrease of the Life Sciences Building's energy cost.

After a redesign of the fume hoods, a new load calculation will be computed in order to determine the heating and cooling loads on each space. The ventilation requirements will be determined from the local code and a decentralized air system will be studied. The decentralized air system is aimed at providing only ventilation air to each space and caring for the heating and cooling loads at the individual space though the use of systems like chilled beams, fan coils and radiant heating. After the new system is designed, an energy calculation will be computed to compare with the designed Life Sciences Building systems in order to determine the differences in energy consumption and first cost. The load and energy calculations will be computed using Trane Trace 700.

Coupled with the new decentralized air system will be a new chilled water plant located within the Life Sciences Building. Currently the Life Sciences Building receives chilled water from a campus loop. However, in published reports, it has been determined that the central utility plant is nearing its chilled water capacity. The new loads calculated for the decentralized air study will be used to size the chiller plant. The plant will also involve an investigation into primary/secondary and variable primary flow pumping configurations.

This proposal contains details of each study to be completed as well as the breadths to be investigated. Descriptions of the tools needed to complete each study are included as well as preliminary research sources.

Mechanical System Description

The Nassau Community College Life Sciences Building will house the expanding Chemistry Department and rising Nursing Department. The building will be a cluster of general lecture halls, computer labs, inorganic and organic laboratories, practical skills nursing rooms and faculty offices. The Life Science Building is a "U-shape" where the courtyard façade is a floor-to-floor glass curtain wall system. Faculty offices on all three floors are facing the courtyard and can have periods of high heat transfer through the curtain wall. The classrooms, lecture halls and laboratories, are located along the opposite exterior perimeter. The façade is composed of copper rain screen panels and long strips of glazing. There may also be periods of high heat transfer through this façade, but it was designed for a high aesthetic appeal rather than thermal function.

The design of the Life Sciences Building was highly influenced by the occupants, both students and faculty, as well as its use. It was designed to easily connect to the greater campus with spaces to accommodate the overall student population, not just the Chemistry and Nursing Departments. Furthermore, function played a role in the design because of the hazardous chemical storage and waste spaces that need to be guarded under restricted access but readily available to the classrooms for learning.

Mechanical Design Objectives

The Life Sciences Building is an educational building located at Nassau Community College. The building was designed with general classrooms and computer labs to be utilized by students of all majors as well as chemistry and nursing laboratories on the upper floors and faculty offices. Therefore a variable air volume (VAV) system was chosen to accommodate the fluctuations in occupancies throughout the day.

The chemistry laboratories contain hazardous chemicals and require fume hoods and a dedicated one hundred percent outdoor air ventilation system. Because of the high energy consumption of a one hundred percent outdoor air system, a heat recovery system is used between the outdoor air intake and exhaust outlet. The heat recovery system needed careful consideration. Cross-contamination between the supply and exhaust air streams is undesirable. Therefore, a run-around loop pre-heat coil was selected as the major heat recovery component. Furthermore, minimum air change rates must be met in order to maintain proper pressurization within the laboratories. The fume hoods and minimum air change rates are the primary design criteria that determined the structure of the mechanical system for the chemistry laboratories.

Other than the laboratories fume hoods and good practice ideas, all spaces in the Life Sciences Building must comply with the ventilation rates specified 2007 New York State Mechanical Code. This code was also a prime factor in the mechanical system design.

Mechanical Equipment Summary

The Life Sciences Building is served by three air handling units located in the penthouse. One air handling unit is a one hundred percent outdoor air unit, which serves the laboratory spaces. The remaining two air handling units serve the offices and classrooms. All three air handling units are variable air volume systems (VAV). The one hundred percent outdoor air unit is coupled with a laboratory exhaust system, which is connected to both fume hoods and space exhaust diffusers. A run-around heat recovery loop transfers sensible heat from the exhaust stream to the outdoor air intake of the one hundred percent outdoor air unit.

The Life Sciences Building is served by both a campus chilled water and high temperature hot water (HTHW) system. The campus chilled water system contains 2 sets of pumps; one set acts as a booster to the campus system in the event of a loss in pressure, and the second set is for the building distribution. The chilled water is piped to all air handler cooling coils and fan coils. The campus high temperature hot water system is both distributed directly through the building and piped to heat exchangers. The HTHW is used directly in the pre-heat coils of the two classroom air handling units. The central utility plant has assured sufficient system pressure to distribute HTHW throughout the building without the needs of pumps. The various heat exchangers drop the temperature of the HTHW down to a typical 180°F, which is used in the perimeter radiation, cabinet unit heaters and re-heat coils. One heat exchanger converts HTHW to a glycol solution used in the heating coil of the one hundred percent outdoor air unit.

Mechanical System Evaluation

The Life Sciences Building resides on the campus of Nassau Community College. Typically educational buildings are mechanically designed as a variable air volume (VAV) system due to the fluctuations in occupancy and scheduling capabilities with offices and classrooms. A VAV configuration usually saves energy through the throttling of fans and control valves. However, the Life Sciences Building is also a laboratory facility that requires a dedicated exhaust system coupled with the large airflow requirements of fume hoods. There is also a higher air change rate in chemistry laboratories due to the need of ventilation air to dilute hazardous chemicals that may be present in the breathing zone. While a VAV design may be typical for an educational building, the energy savings is not as available in a laboratory building as it would be in an office and classroom only facility.

The Life Sciences Building's mechanical system has been estimated to cost a total of $5,320,000, which is approximately 17% of the total building cost. Typically, the mechanical system cost ranges from 15% to 20% of the total estimated budget. Therefore, the mechanical system serving this building falls within the typical range at $73.50 per square foot. However, while the mechanical system first cost is average, the annual energy cost is high. The total utility cost, including electricity, high temperature hot water and chilled water, is calculated to be $241,000. The total cost equates to $3.33 per square foot, which is above the average range from $2 to $3 per square foot. The above average energy cost can be due to the one hundred percent outdoor air handling unit used for the laboratories. Even with heat recovery, there are large quantities of air flowing through the unit, which require both heating and cooling conditioning. Furthermore, the high annual energy cost can be attributed to inaccurate utility costs determined during the computerized analysis.

The large equipment components of the mechanical system are located either in the basement mechanical equipment room or the penthouse on the roof. The basement mechanical room contains the majority of the water-side equipment such as the heat exchangers and pumps along with the campus high temperature hot water and chilled water service entrances. The penthouse contains the three air handling units as well as the laboratory exhaust fans. While a small 8.5% of the Life Sciences

Building floor area occupied by the mechanical system, there is also space in the ceiling plenum that is displaced by mechanical equipment such as ductwork, variable air volume boxes and exhaust valves. The first and third floors of the building utilize a plenum return system, which decreases the need for ducted returns throughout the floor. However, the second floor has a dedicated ducted exhaust to both the fume hoods as well as the chemistry laboratories in order to prevent contamination of other spaces. The laboratories also require large quantities of supply air, which need large ducts to bring air to the spaces. Both of the supply and exhaust systems utilize a large majority of the ceiling plenum. There may be a potential ceiling height decrease as well as energy savings if a decentralized system is used for the laboratory spaces.

The laboratory floor of the Life Sciences Building is served by the one hundred percent outdoor air unit. While the system may use more energy, the abundant amounts of ventilation air provide for a higher indoor air quality. No recirculation of the air from the laboratories assures the hazardous contaminants from the laboratories will not be spread from zone to zone. The offices and classrooms are served by a variable air volume air handling system, which have a higher filter MERV rating than the code minimum due to LEED certification requirements. Furthermore, higher amounts of outdoor air are introduced into the ventilation system due to the nature of the variable air volume system. While the higher amounts of outdoor air cause higher heating and cooling costs, the increased ventilation allows for a higher indoor air quality.

Zones for the Life Sciences Building are organized based on small groups of spaces which contain similar load profiles. It is typical to have three or four offices on the same façade to be grouped into one zone. On the other hand, classrooms are each their own zone. Each zone is provided with an adjustable environmental control. The perimeter radiation and the VAV boxes are coupled and controlled by one device in order to provide the proper environmental settings as preferred by the occupants. There are sufficient controls throughout the building in order to satisfy the requirements for LEED certification.

The VAV design of the Life Sciences Building is adequate for providing conditioned air and ventilation to each space. The mechanical design is sufficient for the safe operation of the laboratory facility and provides adequate thermal comfort while maintaining a reasonable cost to Nassau Community College.

Proposed Alternatives

The Life Sciences Building was designed as a variable air volume system due to industry norms found in educational facilities. The designed mechanical system meets the requirements of governing codes and satisfies the needs of Nassau Community College. However, several alternatives to the designed system may prove to help reduce the initial cost of the building while decreasing the Life Sciences Building's annual energy consumption and occupy less space. The redesign alternatives will require an extensive analysis as to their feasibility.

Alternatives Considered

Several aspects of the Life Sciences Building have the potential for an upgrade. Certain redesign ideas have the potential for space savings, while others are geared at energy savings and others aim at decreasing the first cost of the mechanical system. Below is a list of options that were considered for the Life Sciences Building redesign. Due to time restrictions, only a few of these options could be further investigated.

- Fume hood redesign
- Decentralized air system
- Decouple high temperature hot water from plant
- Convert high temperature hot water to hot water at the building entrance
- Heat recovery system redesign
- New chiller plant for the Life Sciences Building
- Convert high temperature hot water to steam at the building entrance

Two items from the list above have been chosen to be studied further. The topics were chosen based on consultant input, intellectual reasoning and educational value. Each redesign alternative will have an impact on the building as well as the associated mechanical system components. Therefore, the redesign will also incorporate the effect on the associated mechanical system. Each of the three redesign alternatives is detailed further in the following sections.

Decentralized Air System

The current air side system design consists of a variable air volume (VAV) system for each of the three air handling unit. While, this system configuration may be great in conceptual design, it appears to consume more energy than is necessary. The two classroom/office air handling units are designed as VAV systems because of the fluctuations in occupancies in each of the spaces. However, due to the nature of the VAV boxes, the airflow cannot turn down more than 30% of the design airflow. This causes an issue in spaces with high occupancies and low loads, such as a lecture hall during a moderate weather condition where cooling is not necessary. The VAV box will turn down to its lowest setting, which is 30% of the design condition. However, in a lecture hall, there is large ventilation load, which causes the lowest setting on the VAV box to still have airflows near 1,000 CFM. Because of these high airflows, the total system design outdoor air requirements are 50% of the total supply airflow. This is 30% greater than the code required minimum, which causes an increase in energy consumption to heat and cool the outdoor air.

There are several advantages of a decentralized airside system rather than a single air handling unit that serves as the space load and ventilation requirements. One of which is that the decentralized airside system only provides the ventilation air at a constant volume. The remaining heating and cooling load will be satisfied at the space with a fan coil, chilled beam or radiant system. The use of water to distribute energy is more advantageous than air because of the heat capacity properties of water versus air. Water has the availability to transport much more energy per pound than air. Therefore, by using pipes to move energy throughout the building, ceiling space will become more available due to the decrease in duct size.

Another advantage of a decentralized system is the availability of the supply fan to run at the design point for longer periods. If the air handling unit's main objective is to supply the ventilation air to the space, then there is a constant volume of air moving through the fan during each hour of the day. The constant volume of air allows the fan to run at maximum power at its highest efficiency point during occupied hours. Furthermore, there can be a binary control logic that modulates the fan to a decreased flow rate during the scheduled unoccupied hours. The decrease in flow rate will save energy as the electrical input varies proportionally to the cube of the flow rate.

A study will be completed to determine if there is a decreased initial first cost with a decentralized system, if there is an increase in available space with the reduction in ductwork size and if there is energy savings with heating and cooling being provided directly in the space. The study will demonstrate the effect of a decentralized system in the Life Sciences Building.

New Chiller Plant

The Life Sciences Building is receives chilled water and high temperature hot water from a local Central Utility Plant (CUP) operated by Nassau Energy Corporation. In a report produced by Parsons Brinckerhoff, it has been determined that the CUP is near its chilled water capacity. Therefore, a chiller plant located within the Life Sciences Building is being proposed as an alternative to the campus chilled water in order to remediate potential issues in chilled water capacity that may arise during the summer months. This alternative is also serves an educational purpose.

A new chiller plant located in the Life Sciences Building will significantly increase the first cost of the mechanical system. However, there are four existing chilled water pumps on-site as well as a network of chilled water piping. Therefore, any new major cost will arise from the addition of chillers and the supporting equipment.

An electricity-driven chiller and cooling tower will be selected in order to provide chiller and cooling tower information for the purposes of the study. New innovative chilled water system designs are to be explored as a method of energy savings or as initial cost savings for the Life Sciences Building. Variable primary flow systems versus primary/secondary pumping arrangements will be the focus of this study.

The feasibility study of a new chiller plant serves as educational function as well as a study as to the optimization of a new chiller plant. This study will demonstrate the effect of a new chilled water plant on the Life Sciences Building.

Breadth Topics

Daylighting

The Life Sciences Building is applying for LEED certification and it has been predicted to receive both LEED points for providing a minimum of 25 footcandles to 90% of regularly occupied spaces through daylight. However, no mathematical, geometrical or computerized model conclusions have driven this prediction. Therefore, a daylighting breadth will involve the investigation of the LEED points. If the Life Sciences Building does not meet the requirements for the daylighting LEED points, adjustments will be made in an attempt to receive the credit.

The daylighting study will be completed using AutoCAD to create a three-dimensional model of the Life Sciences Building. The model will be imported into AGI32, which will be used to determine the illuminance levels in exterior spaces. The daylighting study will be coupled with the architecture study if there is a need for adjustments in the exterior façade.

Architecture

The architecture breadth is involved both in the daylighting breadth and new chiller plant depth studies. If adjustments are needed to the Life Sciences Building in order to meet the requirements of LEED for daylighting credits, the architectural façade will be changed to do so. These changes may involve the addition or relocation of fenestration or potentially shading devices.

The architecture will also need to be adjusted to allow for the addition of the new chiller plant. If the chiller plant is to be located in the basement, a new mechanical room will be necessary, which will entail an addition to the basement floor plan. If the chiller plant is to be water-cooled, then addition of cooling towers will call for adjustments to the penthouse configuration. Furthermore, there will need to be adjustments in the first floor to allow for the removal and replacement of chillers in the event of a failure.

MAE Course Relation

The requirement for the Master of Architectural Engineering program is the direct relation of the redesigns to 500-level course studies. AE 557, Centralized Cooling Production and Distribution Systems, will be related to the chiller plant design. Discussions and assignments have centered on the comparison between primary/secondary pumping and variable primary flow arrangements as well as the benefits and downfalls of each system.

Tools for Analysis

In order to complete the analyses involved in the depth and breadth studies several programs will be needed. These programs will range from building a three-dimensional model of the Life Sciences Building to complex mathematical equation solving to codes and standards that specify minimum requirements. Each of these programs plays an essential part in the completion of the studies.

Load/Energy Modeling

Trane Trace 700 will be used to determine the Life Sciences Building's annual energy consumption as well as the associated life cycle costs. Trace will be used to compare the new redesign systems to the existing systems in order to determine performance benefits or losses.

Engineering Equation Solver (EES)

EES is a complex equation solving program with built-in material properties that allows for accurate solving of various processes that occur in mechanical systems. EES, coupled with Microsoft Excel, will aid in the determination of the pumping and chiller configurations in the new chiller plant.

AutoCAD

AutoCAD will be used to develop a three-dimensional model of the Life Sciences Building. The 3-d model is essential to the completion of the daylighting breadth. The model will be imported into the program Daysim in order to evaluate the illuminance levels in the exterior spaces.

AGI32

AGI32 is a program used to evaluate daylight levels in a building. Coupled with AutoCAD, a model will be created and imported for the analysis. AGI32 will produce illuminance levels in each exterior space, which allows for a compliance check of LEED credits. AGI32 will also be used for the architecture breadth to determine new illuminance levels with the exterior shades.

Codes/Standards

Codes and standards such as the 2007 New York State Mechanical Code, ASHRAE Standard 90.1-2007 and the LEED checklist will be used during these studies in order to assure the Life Sciences Building's local compliance as well as to meet certain objectives of the studies.

Appendix A – Preliminary Research

- Avery, G. "Improving the Efficiency of Chilled Water Plants." ASHRAE Journal (May 2001): 14-18.

This ASHRAE Journal article describes processes to make chilled water plants more efficient though various flow configurations and piping arrangements. The article discusses primary/secondary pumping systems, which is a design consideration of the new chiller plant. The article will aid in the design of the new chilled water plant that will be located within the Life Sciences Building.

- Bahnfleth, W. & Peyer, P. "Energy Use and Economic Comparison of Chilled-Water Pumping System Alternatives." ASHRAE Transactions (2006).

This ASHRAE Transactions paper discusses the energy differences between primary/secondary and variable primary flow pumping configurations. The paper provides an initial background as to the savings potential in a variable primary flow system as opposed to a primary/secondary arrangement. This paper will aid in the investigation to the optimal chilled water plant configuration for the Life Sciences Building.

- D'Antonio, P. "Optimizing the Performance of Radiant Heating Sysems." HPAC (July 1, 2008).

This HPAC article describes the operation of radiant heating systems. System components such as supply temperature, temperature differential and variable speed pumping are discussed within the article. Radiant heating will be incorporated in the dedicated outdoor air system design and will play an essential part in the heating system for the redesign of the Life Sciences Building.

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

This ASHRAE Journal article discusses the design consideration for a dedicated outdoor air system. Dr. Mumma is an expert on dedicated outdoor air systems and will provide valuable information as to the redesign considerations of the Life Sciences Building.

- Rumsey, P. "European Technology Taking Hold in the U.S.: Chilled Beams." HPAC (January 1, 2010).

This HPAC article discusses the operations and details of chilled beams and why they have been successful in Europe. The article also discusses how to size chilled beams as well as the commissioning, maintenance and operational issues that are associated with these units. The article also describes the benefits and disadvantages of these units over their life cycle. Chilled beams will be involved in the study of decentralizing the air system.

- Taylor, S. "Primary-Only vs. Primary-Secondary Variable Flow Systems." ASHRAE Journal (February 2001): 25-29.

This ASHRAE Journal article discusses the advantages and disadvantages of primary-only chilled water systems. It details about first costs, plant space and pump power consumption as well as chiller staging. The details in this article will aid in the design of the new Life Sciences Building chiller plant.

Appendix B – Preliminary Schedule