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The American Swedish Institute
Minneapolis, MN

Mechanical Thesis Proposal

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Executive Summary

The American Swedish Institute addition and existing mansion will consist of additional multi-purpose and public spaces that demonstrate Swedish architecture and sustainability. Both buildings will contain cultural spaces that display Swedish art and furniture as well as a café, retail areas, meeting spaces, offices, and classrooms.

Conditioned outside air for the American Swedish Institute is provided by a Make-up Air Unit (MAU) that supplies air to all occupied spaces in the existing mansion and addition. All heating and cooling needs are primarily served by a geothermal source closed loop heat pump system. Although the system is already energy efficient since it uses the stable temperatures of the earth to heat and cool the building the winter and summer, two other alternatives were considered.

To compare this designed system accurately the first alternative consists of removal of all water-to-air heat pumps and the MAU, while keeping the existing geothermal system. These items will be replaced with water-to-water heat pumps that are tied into the geothermal system and a dedicated outdoor air unit to supply conditioned air to Variable Air Volume (VAV) boxes located throughout the building that will supply air to the zones. This alternative will be more expensive than the designed system but the increased energy efficiency will be beneficial in decreasing annual energy usage.

The two systems described above, the design and first alternative will be compared to a second alternative that also keeps the existing geothermal system. This method shall require the removal of water-to-air heat pumps and the MAU, similar to the first alternative, but will also remove all VAV boxes located in the addition and existing mansion. These items will be replaced with water-to-water heat pumps that are tied into the geothermal system which supply condensing water to chilled beams. Chilled beams located throughout the building are supplied conditioned air from a dedicated outdoor air unit. Although this alternative will be even more expensive initially in comparison to the design system and alternative the energy savings will be greatly increased due to higher efficiency, smaller fan and duct sizes, and better control.

All three systems will be compared using Trane TRACE 700 to calculate the heating and cooling loads required for the building depending on the system selected. With completion of this energy calculation, the differences in energy consumption and first cost shall be determined to select the method that is most practical based on cost and energy usage.

Additionally, the roof over the hallway joining the addition and existing mansion shall be redesigned to incorporate a green roof. Design of the roof will include redesigning the architecture for an intensive and extensive option for a green roof that reflects Swedish sustainability. For both options the structural dead and live loads shall be recalculated and compared to the original roof design for this hallway.

Details of all studies to be completed are located in this proposal as well as a more descriptive explanation of the depth breadth studies stated above. Additionally, the tools to be used for each study and preliminary research are listed later in this document.

Design Objectives

The American Swedish Institute, scheduled to complete construction in late spring 2012, is a 24,600 square addition and 27,500 renovation, cultural center and museum project. The building consists of multi-purpose and public spaces for the community to gain knowledge about Swedish culture. Both buildings will be used as cultural spaces containing a café, retail, meeting spaces, offices, and classrooms. The Turnblad Mansion and the Nelson Cultural Center encompass a newly designed courtyard with Swedish influence that enhances the exterior public spaces. Glazing on the northern side of the addition is clear low e glass with dark anodized aluminum thermally broken frames to assist in decreasing heat loss and infiltration for the building.

Major design requirements given by the owner included that the addition reflect sustainability practices used throughout the Swedish culture. The basic sustainability goals were defined as exceeding existing energy codes, low lifetime costs, maintaining good indoor air quality and healthy environment, and decreasing long-term operating costs of the building. With these requirements defined the remodeling of the existing mansion would improve the energy efficiency of the building as well as meeting LEED Gold for the addition. The renovation and new construction would be in compliance with ASHRAE Standards and building codes for the state of Minnesota.

There are also many design factors that were taken into consideration with the type of building the American Swedish Institute is and the location of the building, Minneapolis, MN. Due to this location the design required more heating days compared to cooling days. Another design factor for the addition is the 7,000 sq. ft. sloping green roof and terrace which will be used to reflect traditional Swedish architecture and landscape in two areas of the roof. The green roof will assist in reducing energy costs and storm water run-off to the site.

Mechanical System Description

The American Swedish Institute is comprised of a Make-up Air Unit (MAU-1) that provides conditioned outside air to all occupied interior spaces in the addition and existing mansion. Heating and cooling needs for the building are provided by a geothermal source closed loop heat pump system. The geothermal system was decided for the American Swedish Institute since the temperatures in the earth are maintained at stable temperatures in the high 40s and low 50s. This system extracts heat from the earth in the winter for heating. In the summer the system rejects heat from to the earth to provide cooling. The system contains ninety-six well holes with a depth of 250 feet and approximately one ton capacity per hole located in the southern part of the site.

Heat pumps are used throughout the building and are supplied conditioned outdoor air from several VAV (Variable Air Volume) boxes, which are served by the Make-up Air Unit. Throughout the building return air from the occupied spaces in the ceiling plenum is recirculated through the heat pumps with the conditioned supply air.

The mechanical system is primarily heated and cooled by the geothermal heat pumps. Any additional heating required for the museum comes from two 20 HP Fulton condensing boilers located in the lower level of the addition.

Mechanical System Evaluation

The primary goal for the new construction and renovation of the American Swedish Institute was to incorporate the sustainable design of the Swedish culture to make a more energy efficient facility. MAU-

1 serves the varying space types for both the existing mansion and the addition. Due to the main occupancy of the building being considered museum and gallery spaces certain areas had to be designed with better control of humidity and temperature levels.

After review of ventilation rates, energy usage, and overall construction and operating costs, the design of the American Swedish Institute is very efficient and will exceed the owner's expectations upon completion. From the results found in Technical Report 1, it was determined that the ventilation rates would be more accurate with the proper occupancy rates and schedules. Overall, the American Swedish Institute exceeds the minimum requirements established in Standards 62.1 and 90.1. Results from Technical Report 2 were compared to average values and provided realistic results for a building of this type. Comparison of the energy usage and performance, it was found that the American Swedish Institute performs better than the average due to the efficient geothermal system used. Although the system is highly efficient for heating in the cool winter months in Minnesota there is a possible opportunity for improvement.

Overall construction cost of the mechanical system is $2,749,134 and accounts for 21% of the total building costs; this includes costs for all HVAC, plumbing, and fire suppression equipment and accessories. Majority of the mechanical system costs come from the plumbing equipment and accessories that include, the geothermal system and heat pump piping that runs throughout the building. Since the majority of the mechanical costs are plumbing, the cost of earthwork was also reviewed since it is a geothermal system. Costs for earthwork are $327,808 and account for 3% of the total cost of the project.

Maintainability of the geothermal system will be difficult since the well field is planned to be covered with parking lots on the Southern portion of the site. Therefore, initial installation and testing prior to completion of construction are very important. Although the geothermal system is underground it will be easy to maintain but difficult to fix if complications occur with the wells. The MAU, boilers, heat pumps, and VAV boxes are easily accessible throughout the building in the mechanical room or in the ceiling's above occupied spaces.

In general, the mechanical system of the American Swedish Institute is a highly efficient system for the museum. Although the system is highly efficient there are possibilities for other design options to decrease costs and energy usage in other areas of the building with different methods.

Proposed Alternatives

Method 1: Water-to-Water Heat Pumps with Variable Air Volume Boxes

As described in the previous method, the American Swedish Institute supplies conditioned air to Variable Air Volume (VAV) boxes from a Make-up Air Unit to individual heat pumps. This alternative method shall still use the geothermal system currently in place but incorporate water-to-water heat pumps and air handling unit located in the lower level of the addition.

With a VAV system the boxes are designed to modulate airflow to save energy depending on the heating or cooling needed for the zone. Minimum requirements for ventilation air for the zones as specified by ASHRAE will be met as well with the VAV boxes.

Maintenance will be increased for this system since the VAV boxes will need regular cleaning and tuning. This alternative requires more stringent maintenance by the owner on an annual basis unlike other methods.

Floor-to-floor heights in the addition and mansion will increase or stay the same to accommodate for the additional VAV boxes located throughout the buildings. Due to the increase in duct sizes for the VAV boxes, the addition of return air ducts to the air handler unlike the design and alternative 2, and the larger air handler usable space decreases. Although this method is not very economic for the mansion since there is limited space for floor-to-floor heights to be increased.

Comparing this alternate to the original system it is more expensive but will have less energy usage over the years of operation.

A study will be completed to determine the sizes and number of the VAV boxes needed for the zones, and the size of the water-to-water heat pumps needed for the addition and mansion. The amount of usable space that will be lost by incorporating an air handler and VAV boxes will also be determined. Additionally the size of the air handler to be used for this system shall be determined. As well as the initial first cost and annual cost for the VAV boxes, water-to-water heat pumps, and air handling unit. Energy and cost results shall be compared to the original system design and the second alternative to demonstrate the most energy and cost effective choice.

Method 2: Water-to-Water Heat Pumps with Chilled Beams

Currently in the American Swedish Institute conditioned air from the Make-up Air Unit (MAU) is supplied through Variable Air Volume (VAV) boxes to individual heat pumps. Due to the cost of making the system more efficient, VAV boxes were used instead of a different method for supplying conditioned air. Unlike the proposed alternative previously stated this alternative shall be an even more efficient method. The alternative method shall still use the geothermal system and convert all water-to-air heat pumps in the addition and mansion to water-to-water heat pumps to be used with active chilled beams and a dedicated outdoor air unit.

With implementation of active chilled beams the primary airflow for the spaces shall be reduced by 50-67% of the required air to operate VAVs at peak cooling conditions. This reduction in the airflow results in increased fan energy savings which decreases the size of the fan needed in the MAU and cutting costs of electricity supplied to the fan. Also with active chilled beams being used for the museum all gallery and storage spaces containing artwork and furniture shall have better control of temperature and humidity.

Occupants will also be more comfortable with this system since the air delivery is more evenly distributed to the space decreasing the chances of drafts in the space. Air flow patterns for the chilled beams can also be adjusted to direct the air flow in the direction as needed for the space configuration, compensation for any heat gain through the windows and comfort needs of occupants. Indoor air quality for the spaces using chilled beams will be improved since the minimum outdoor air ventilation rates are maintained with the constant supply of primary air through this system.

The low maintenance required for chilled beams will make it possible for the system to operate more efficiently with little work required by the owners. Chilled beams will need vacuumed once every 2 to 3 years to maintain optimum performance.

Floor-to-floor heights in the addition shall be reduced because smaller ductwork and fans are required for the active chilled beam system. Space in the ceiling for the addition will also be maximized do to the smaller mechanical equipment and accessories.

Initial cost for this alternate system is very expensive but will use the least amount of energy and have a quicker payback period.

A study will be completed to determine the size of the fan needed with a chilled beam system, the size of piping required for water-to-water heat pumps for the chilled beams, the number and size of chilled beams needed for the addition and mansion. Additionally the size of the water-to-water heat pumps and dedicated outdoor air unit required for the American Swedish Institute shall be determined. As well as the initial first cost and annual cost for the active chilled beams, dedicated outdoor air unit and water-to-water heat pumps compared to the existing system. Energy and cost results shall be compared to the original system design and the first alternative to demonstrate the most energy and cost effective choice.

Breadth Topics

Architectural Breadth: Green Roof Addition

The mansion and addition are connected by a 10'4" wide hallway that runs 45' from the studio classroom and hallway in the addition to the corridor in the mansion; this hallway can be seen highlighted in orange in Figure 1 below. Since the space in this hallway is unoccupied unless visitors are going between the two buildings the space is low density. To incorporate more of the sustainable design seen in Swedish culture for the American Swedish Institute, the roof of this hallway is another prime location for an additional green roof. Currently this roof space is not used for anything, with the addition of an intensive or extensive green roof; this space can become open to the public and overlook the center courtyard. Access for this green roof will be from the second floor of the addition in the hallway on the western side and the second floor of the mansion from the hallway in the western side.

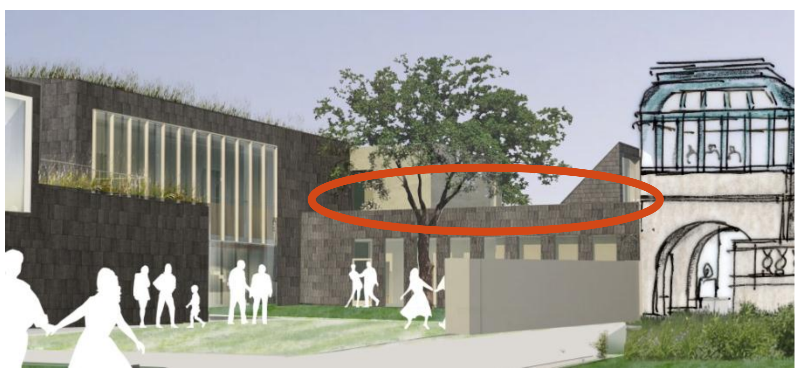


Figure 1: Walkway between Addition and Mansion[1]

A study will be completed to determine the effectiveness of additional green roof space to the hallway roof. Additionally, another study will be completed to see the possibility of expanding the roof over the hallway to allow for additional public space that overlooks the courtyard.

Structural Breath: Roof Redesign

With the redesign of the hallway roof from thermoplastic single ply roofing to a green roof there will be a significant increase in the original loads calculated therefore, impacting the original hallway

[1] The American Swedish Institute © HGA Architects and Engineers, Minneapolis, MN.

structure. By making the green roof open to the public the hallway must be able to support the live load plus the additional dead load. Structural calculations for the roof must be recalculated to support this additional weight.

Tools for Analysis

Mechanical Depth:

Energy simulation software will be used to compare the two alternatives for the mechanical system redesign with the designed system. Trane TRACE 700 shall be the primary software used to calculate heating and cooling loads, energy usage and costs for the three mechanical systems in the American Swedish Institute. Excel will also be used to compare the design requirements for the three systems to one another to determine the most energy and cost effective choice for the building.

Architectural Breadth:

To determine the appropriate size for the walkway and the green roof on the top of the hallway, AutoCAD will be used to model the proper dimensions in comparison to the rest of the building. Additionally, the green roof shall be designed in Google SketchUp to demonstrate what visitors would see from the walkway when looking into the courtyard. Excel will also be used to store the information about the different options for the green roof and the depth of each layer.

Structural Breadth:

Structural calculations for the green roof addition shall be completed in Excel and correlate to the recorded depths from the Architectural Breadth. From the material chosen for the green roof the proper weights shall be determined to calculate the dead loads on the roof and live loads. All loads shall be recorded in Excel to compare the varying loads for the composition of the green roof to the original structure.

Preliminary References

"Chilled Beam & Pinnacle Application Guide." *Semcohvac.com*. Semco. 2010. Web. 04 Dec. 2011.

- This website was used to do preliminary research on active chilled beams and their effectiveness in buildings compared to the traditional VAV boxes. Additionally, information for efficiency and comfort was used to compare with traditional systems.

"Greenroofs101." *Green roofs.com*. Green roofs. 2011. Web. 07 Dec. 2011.

- This website describes the two types of green roofs used on buildings, extensive and intensive. As well as, advantages and disadvantages for incorporating a green roof into the design.

Kavanaugh, Steve. "Ground Source Heat Pumps for Commerical Buildings." *Hpac.com*. HPAC Engineering. 1 Sept. 2008. Web. 08 Dec. 2011.

- Information about the different loop types and advantages for heat pumps is given on this site. Optimal temperatures for water-to-air heat pumps is provided on this website and helped with understanding the heat pumps currently used in the building.

Peters, George. "Geothermal Retrofitting at Commercial Facilities." *Billgladstone.com.* Bill Gladstone Group of NAI CIR. 2011-2012. Web. 08 Dec. 2011.

- This article breaks down two options for a geothermal heat pump system. Additionally, giving examples describing the systems and how they would be retrofitted for a typical building.

Sackrison, Chris. "Why Water Source Heat Pump Systems are so Efficient." *Engineering System Solutions*. McQuay., Oct. 2002. Web. 08 Dec. 2011.

- Provided in this article are the ventilation design, efficiency and description of heat pumps designed by McQuay.

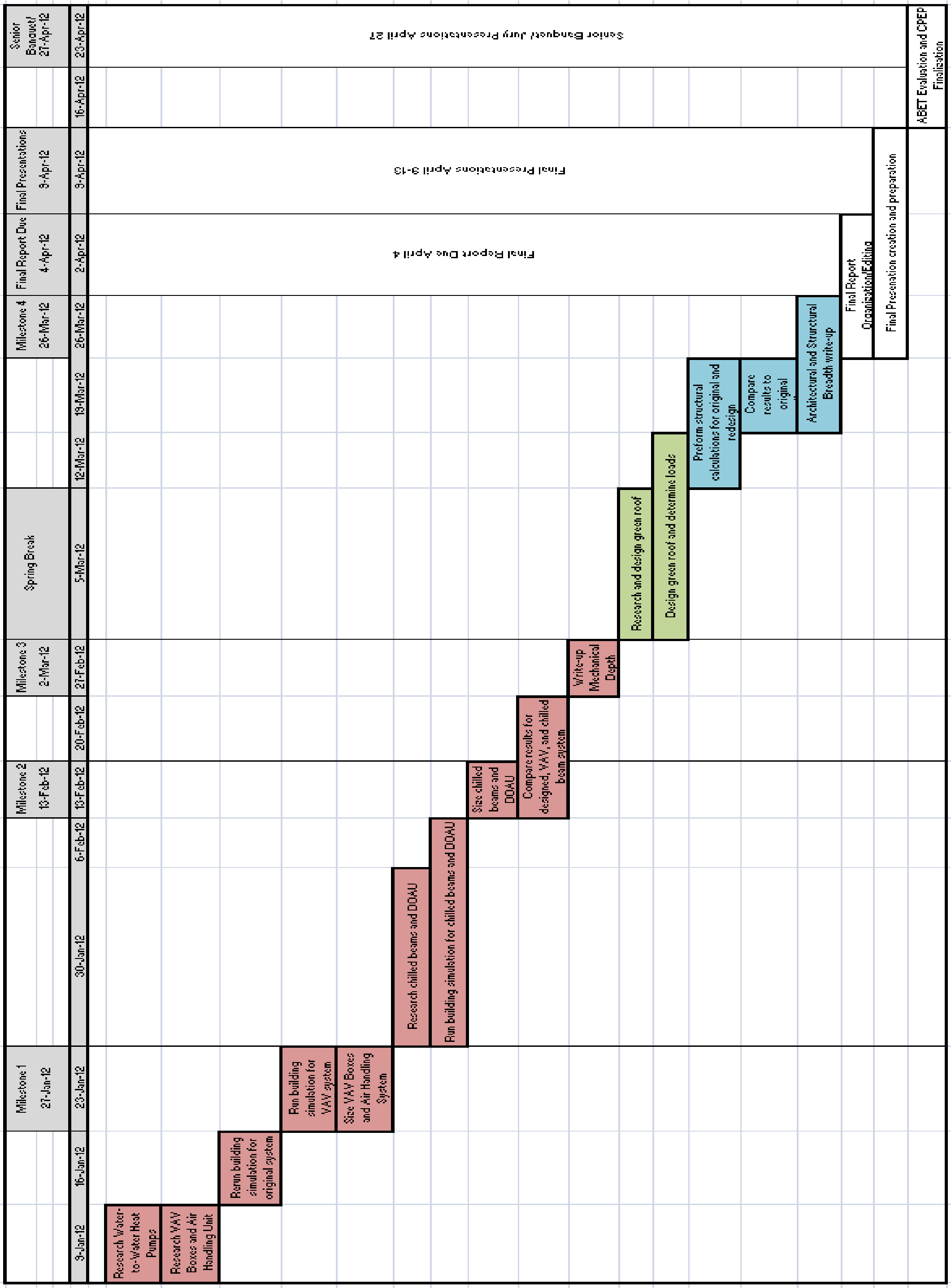
"Variable Air Volume Systems." *Highperformancehvac.com*. High Performance HVAC. 23 Aug. 2011. Web. 08 Dec. 2011.

- Descriptions of the various types of Variable Air Volume (VAV) systems and terminals were provided on this website. This helped with preliminary research for the VAV and water-to-water heat pump alternative.

Vastyan, John. "Chilled-Beam Basics." *HPAC Engineering* July 2011: 26-28, 42. Print

- Information was obtained from this article to get a better understanding of the types of chilled beams, active and passive. From this article it was determined to research active chilled beams since they are more practical to use in comparison to passive chilled beams.

Appendix A – Preliminary Schedule



Milestones:
1) Finish building simulation analyze building loads and energy costs
2) Compare results and organize data for energy usage and costs
3) Complete Mechanical Depth Write-up including all comparisons and selection of best system
4) Complete Breadths Write-up including all comparisons and selection of best roof system

Depth - WAHP & VAV vs. WWHP & VAV vs. WWHP & Chilled Beams	(red)
Breadth 1 - Architectural: Green roof addition	(green)
Breadth 2 - Structural: Roof Redesign	(blue)