Thesis Proposal

Lutheran Theological Seminary at Philadelphia
The New Learning Center

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Executive Summary

The New Learning Center is a 60,000 square foot building on the Lutheran Seminary at Philadelphia campus. At this time, three air handling units and one supply air plenum bring the outdoor air into the building. These air handling units are gas-fired heating with direct expansion cooling and serve the first through third floors. They also are equipped with enthalpy wheels for energy recovery. The supply air plenum serves the basement and the storage areas. One chiller and two boilers provide the rest of the capacity in the building. The boilers and chiller serve treated water to fan coil units for further conditioning of supply air. The fan coils have a four pipe design, allowing them to heat or cool regardless of season.

Although the design operates well, there were a few basic goals to be obtained through redesign. First, humidity control problems must be addressed in the basement. Second, pollutants, emissions, and energy consumption should be limited. Third, the life cycle cost, including initial and annual operating costs, should be minimized. Fourth, some sort of energy recovery technology should be used. Fifth, the advanced individual control should be maintained to the level it is now.

The proposed redesign will attempt to reach all goals. The three air handling units will be resized as necessary. A fourth unit will be added with an enthalpy wheel for energy recovery to help control humidity concerns that the plenum did not address. All of the air handling units will be reselected to operate on the heat pump system. Geothermal heat pumps will be designed to replace the existing fan coil units. These heat pumps should lower operating costs and emissions dramatically. The ability to dispose of the chiller and boiler plants will also limit mechanical system initial costs and increase usable space. The addition of the fourth air handling unit will increase initial cost, but will provide the owner with an improved system.

Two breadth studies will be addressed in the redesign. In the electrical breadth, all necessary panel boards, feeders, branches, and conduits will be resized and redesigned. For the construction management breadth, a time and cost comparison will be done between the initial design and the three proposed redesigns. All of these redesigns will be done with the goals and objectives of the owner in mind.

Building Design Background

The New Learning Center is the most recent construction done on the Lutheran Seminary at Philadelphia Campus. The New Learning Center was designed and built after the last building was deemed structurally unsound and needed to be demolished. The North exterior wall was left standing in its original stone façade form to help the new building tie in with the remainder of the campus.

The New Learning Center is a 4 level building, including a basement. The basement is comprised of the mechanical room, electrical closet, as well as an archive and storage section. The large majority of first floor is comprised of reception halls, lounges, and the kitchen. The second and third floors are made up of classrooms, conference rooms, and offices.

The New Learning Center is one of the main pieces of the campus quadrangle. Aside from the North wall that was left standing, it was designed with a metal clad façade. The first floor is almost entirely glass with an overhang to control direct solar gain into the building. The second and third floors are decorated with a variety of window shapes including diamonds, circles, and rectangles. The typical areas of the building have tile floors with drywall partitions.

There are no site conditions that influenced the mechanical system design. The building is set on a flat site with no large obstruction or shadows cast by landscaping. The mechanical system, however, was designed to work with the neighboring buildings and handle the future expansion of the neighboring library.

Mechanical System Summary

The mechanical system for The New Learning Center is designed as a dedicated outdoor air system. The air is then mixed and reconditioned in the fan coil units before being delivered to the zones. It is designed for proper ventilation, heating, and cooling.

Chilled Water System

The chilled water system is fueled by the air cooled chiller on the roof. The chiller is made for low ambient conditions so it is capable for operation during the colder months to cool rooms with high cooling loads. It also has variable speed for low load conditions. The chiller is sized for 150 tons. The water arrives at the chiller evaporator at 42 F and leaves at 56 F.

Hot Water System

The hot water system consists of two gas fired boilers in the basement mechanical room. Each of these boilers is designed for 1250 MBH. This hot water is run through variable speed pumps to fan coil units and constant volume pumps to the fin tube radiation.

Air Side System

The mechanical system for The New Learning Center is designed as a dedicated outdoor air system. The system is controlled by DDC controls and is all tied back into the main controller. The system has three packaged DX rooftop units with 100% outside air. These units have integral heat recovery through a heat wheel, gas heat, direct expansion cooling, and hot gas reheat. RTU-1 and RTU-2 have 270 MBH of heating capacity and 320 MBH of cooling capacity. The smaller unit, RTU-3, has 90 MBH heating and 100 MBH of cooling capacity. These air handlers feed fan coil units in mechanical closets. The air is mixed within the closet, reconditioned, and then supplied to the rooms. The fan coils are various sizes, all based upon the room or group of rooms that they supply air to. In cooling mode the water is delivered to the coil at 45 F and leave at 55F. When heat is needed the water arrives at the coil at 180 F and leaves at 160 F. All of the fan coils are equipped with a two pipe system for heating and cooling coils.

Proposal Objectives

The objectives for the redesign of The New Learning Center should be based upon the initial objectives of the project. There were several design objectives laid out by Paul H. Yeomans, GYA Architects, and the Lutheran Theological Seminary at Philadelphia. First, they wanted the mechanical system that would fit in a small plenum height. The plenum was shallow since they wanted the floors of the building to coincide with the remaining exterior wall that would be integrated with the new design. Design was to create a DOAS with closets for the fan coil units to save space in the ceiling. Second, the owner wanted and energy efficient building. Since the owner of the building would continue to reap the long-term energy savings benefits, their wishes were to have a building that would save them operation costs over time. This was taken into consideration when the enthalpy wheel was installed in the rooftop unit and when the system was designed with variable frequency drives. Third, it was an objective to give individuals the greatest comfort and control possible. They designed the system with thermostats to control the fan coils units for optimal comfort. Finally, the system must be designed to account for the hot water required for all kitchen equipment.

There are a few goals that will attempt to be obtained with the redesign. First, the redesign will attempt to fix any humidity problems in the basement. With all of the storage and archives in the basement, the humidity concerns should be addressed. Second, the redesign will attempt to limit pollutants. Some mechanical equipment is capable of running on ozone-safe refrigerant. Third, the redesign will attempt to limit life cycle cost. Not only would it be good to reduce initial cost, but operating cost al well. The high and unstable prices of energy would allow for a brief payback period even if initial costs do rise slightly. Also, there will continue to be an energy recovery portion to the design to further limit energy consumption, which is being utilized in the design now. The capability for occupants to control their thermal comfort will be designed just as well as the original design.

Initial Research of Energy Recovery Equipment

Run-Around Coil Systems

The first type of system is the run-around coil system. This is a technique where heating capacity is captured from waste heat and using it. This waste heat is usually captured off of a chiller or process cooling that heats fluid in a coil to be used in an air handling unit. Any of the capacity recovered is applied to the air as preheat or pre-cool. This heat can also be used domestic hot water as well as space heat. The same strategy can also be used by capturing heating or cooling capacity from an exhaust air stream with a finned tube coil and transferring that energy to the supply air stream.

There are some advantages that can make a run-around coil system the right application for energy recovery in certain buildings. First, a run-around coil system is a very economical fist cost choice. With the low first cost, there are large returns on the investment. The payback periods are very short, usually approximately three years. In these systems, there is no chance for contaminants to be transferred into the supply air stream. The lack of contamination could make this system desired for buildings that need extremely clean air, such as hospitals and laboratories. The run-around coil system is easily applicable since the exhaust air and supply air streams do not need to be side by side.

The run-around coil system also has some negatives to deter the system from being used. The system is only about 50-70% effective, which is less than most other energy recovery systems. With the lower capacities recovered, the plants may not be able to be reduced in size, which will not save any initial cost. In fact, the small difference in temperatures needs very accurate simulation and cost models to figure out how useful the run-around coil system could actually be in the long run. Also, this system can only transfer sensible loads; it cannot transfer any latent capacity. These problems also are coupled with the fact that humidity may be difficult to control in some applications.

Enthalpy Wheels

Enthalpy wheels are the most used and effective kind of energy recovery application for HVAC systems. Enthalpy wheels are a revolving disc filled with air permeable medium. These wheels can be made to transfer sensible loads, latent loads, or both. Energy and heat is captured from the exhaust air stream, energy that would merely be wasted, and used to pre-treat the incoming supply air. The moisture is transmitted in vapor form to eliminate bacterial growth in the supply air stream. The wheels also have sieve coatings to minimize contamination to less than 0.04%.

The Enthalpy wheels are very easy to incorporate into the air systems and can even be packaged inside of air handling units. With efficiency from 75-90%, the enthalpy wheels can condition outdoor air enough to save as much as 70% of energy consumed. The can also recover 70-80% of moisture. Applying enthalpy wheels are the best choice when it comes to reducing the size of heating and cooling plants. The cooling requirements can be cut in half as well as the heating and humidification by almost 2/3. This decrease in system sizing has an immediate payback for the extra cost of the enthalpy wheel addition. The energy recovery then will continue to save operating costs en energy consumption.

Although the use of enthalpy wheels may be the best choice of energy recovery systems, a few drawbacks still remain. First, if the outdoor air ratio is not high enough, the addition of the wheel in the mechanical system may add to higher initial cost which can not be offset because of the inability to reduce the size of the heating a cooling plants a substantial amount. The enthalpy wheels require a side by side supply and exhaust air stream to transfer the energy between air streams. These enthalpy wheels also need room since they increase the size of the air handling units. However slight, there remains a chance of contaminant exchange into the outdoor air stream with the use of enthalpy wheels.

Heat Pipes

The use of heat pipes is another way to recovery energy in an HVAC system. A heat pipe is a non-corrosive pipe that contains a heat transfer fluid. A source boils the fluid and the energy is captured during the phase change as the fluid condenses. The pipe provides vapor transport and return of condensate in a closed loop condensation cycle.

One of the main advantages of using heat pipes is that it is very compact. The small size allows for application in nearly any situation, which is especially useful in renovation projects and retrofit of units or systems. Heat pipes can also be applied when supply and exhaust air streams are not side by side. These systems also do not need external energy, the energy recovery for heating and cooling occurs passively without pumps or motors.

There are a few disadvantages of a heat pipe application. Heat pipes only have the ability to transfer sensible loads. Also, humidity control problems may arise. Supply and exhaust air streams must be closely aligned to incorporate heat pipes.

Fixed-Plate Exchangers

Fixed-plate exchangers are large aluminum plates with augmented fins. They are usually applied as coated air to air heat exchangers. Air heats a plate which in turn heats the opposing air stream with no shared medium shared. Air is passed through small passages to increase velocity, turbulence, and heat transfer coefficients. The efficiency and capabilities are based upon square footage of the exchanger.

There is no need of energy to apply this heat recovery system. Heat exchangers operate passively. There is no chance for transport of contamination either. These are very easy to design and use systems.

The biggest issue with the application is the amount of room needed. Since the exchange is based upon square footage, the fixed-plate exchanger must be large to perform effectively. Only sensible heat can be transferred unless it is paired with an evaporative cooling mechanism. With the use of plate exchangers, humidity issues may arise.

Other Energy Efficient Applications

Although all of these energy recovery systems are useful, energy saving does not have to stop there. There are many other energy efficient applications that can be used in HVAC systems. Many systems can apply an energy recovery portion along with other energy efficient techniques all in the same system with proper design.

Applications such as hot gas reheat can be used in direct expansion air handling units. Hot gas reheat uses the hot gas return from the direct expansion and wraps it around to be used as free heating capacity for reheat. A three way solenoid valve controls the hot gas line from the compressor. This helps the indoor air quality by being used in the dehumidification process. The hot gas reheat can also be modulated to increase control. This is best applied in high outdoor air ratio applications.

Proposed Redesign

The proposed redesign will work to accommodate all design objectives. The New Learning Center HVAC system should have the capability to function just as well as before and hopefully have some added value. That value should come in the form of a better controlled system in the basement as well as value in initial and operating costs. A very energy and environmental efficient system was selected. One design has been selected to try to meet all of these goals.

System Redesign

The plenum feeding the outdoor air to the basement will be replaced by an air handling unit. This unit will be equipped with an enthalpy wheel and help with humidity control problems in the basement. The existing air handling units will be modified for operation on the heat pump system and will be resized. All four of the air handling units will be on the same secondary loop as the geothermal heat pumps to condition the air. This is to keep all of the mechanical equipment on the same loop to reduce the mechanical system operating costs and make maintenance more efficient. The enthalpy wheel included in the basement air supply path should reduce the cost of conditioning the air supplied to the zones.

All of the fan coil units will be replaced with geothermal heat pumps. These geothermal heat pumps will help reach some of the goals. These heat pumps should reduce operating costs. One other advantage is the COP and EER capability of the heat pumps. A possible selection has the COP of 5.0 and the EER of 30, which are both very energy efficient. The use of energy efficient equipment will reduce the operation costs and energy consumption. The initial cost of replacing the fan coil units with geothermal heat pumps should not increase greatly if at all, but the operation costs will be substantially less. Implementing them in the system in place of the fan coil units should ensure the same individual thermal comfort in the system as previously designed. Pollutants will be greatly limited with the use of R-410A, and ozone-safe refrigerant used in the geothermal heat pump loops.

The most drastic difference in the implementation of the geothermal heat pumps is that the boilers can be eliminated. Domestic water heaters are already installed to take care of the domestic water supply capacity. The radiation will no longer have a boiler feed, so the hydronic radiation must be on the heat pump loop. The elimination of the boilers will decrease initial cost greatly. The majority of the boilers heating capacity will be replaced with geothermal energy, causing a great decrease in pollutant emissions. Operation costs will decrease greatly as well due to the substitution of the boilers with heat pumps.

The chiller will also be eliminated from the HVAC system. The cooling capacity offered from the chiller will be supplied by the geothermal heat pump system and a cooling tower. The air handling units will be fed by the same geothermal loop including a cooling tower. The elimination of the chiller will have the same advantages as the elimination of the boiler such as decreased initial cost, decreased operation cost, and reduction of emissions.

The pumps and piping system of the heating and cooling systems will be able to be eliminated. They will be replaced by piping and pumps of the geothermal heat pump system and cooling tower. Labor costs will possibly be increased, but equipment and operation costs will absolutely be reduced vastly.

To ensure a proper choice is being made, three different options will be considered. The standard choice is the heat exchanger being sized for the heating load and the cooling tower will make up the capacity difference of the heating and cooling load. The other options will be incorporating a small boiler to reduce the underground running of geothermal pipes and an increased cooling tower. The final option would be sizing the heat exchanger to account for the entire load in the building. Analyzing these three different options, a proper choice can be made.

Breadth Proposals

The construction management plan changes greatly with the mechanical system redesign. The lead time will be looked into to make sure no delay in the start of construction is necessary. The use of geothermal heat pumps instead of fan coil units must take many things into consideration. There will be a detailed comparison of the money saved in labor, cost, and time when the old system is evaluated. These numbers will be compared to the labor, cost of equipment, and time that the alternative options would require. The operating cost and life cycle cost of each alternative will also be compared. The cost of the mechanical equipment will be analyzed. The cost of supporting material such as piping, installation, digging of the ground for the geothermal piping, filling of the land, and other supporting work will also be looked at. Installation of all material will be considered. Not only is initial cost always an issue when dealing with an owner, but operating cost difference is also an important part of good construction management.

The mechanical system change also affects the electrical design. Feeders will need to be changed due to voltage, current, and watts depending on the feed for operation of the geothermal heat pumps. The service will need to be altered to accommodate the compressors and extra pumps. With the capacity changing, the panels will need to be altered as well. The branch circuits and conduit will be changed also. The service will now be three phase with an altered electrical diagram.

Redesign Method

Mechanical Redesign

The mechanical system will need to be redesigned to all codes and specifications. The airflow to each zone will be verified or redesigned based upon ASHRAE. Loads will then be determined for selection and sizing of geothermal heat pumps based upon WaterFurnace product catalogs. The geothermal heat pumps and other mechanical equipment will be designed properly. The air handling units will be converted to operate on the heat pumps loop and will be sized and selected as an AAON unit. The system will be designed with a heat exchanger operating between a primary and secondary loop. The primary loop will be the groundwater loop and the secondary loop will serve all of the mechanical equipment in the building. The mechanical system will then be set up in Trane Trace to figure out load, energy consumption, and annual operation costs. The standard choice is the heat exchanger being sized for the heating load and the cooling tower will make up the capacity difference of the heating and cooling load. The other options will be incorporating a small boiler to reduce the underground running of geothermal pipes and an increased cooling tower. The final option would be sizing the heat exchanger to account for the entire load in the building. Comparisons will be made to the energy consumption, emissions, and operation costs of the previously analyzed system. The wasted interior space due to the mechanical system will also be examined.

Breadth Redesign

The construction management portion of work will be conducted with RS Means. The labor, equipment, and operation costs as well as time will be analyzed. The life cycle cost of the designed system will be directly compared with that of the three alternative systems. A final conclusion will be formulated based upon the best mechanical system design based on cost.

The electrical system will be altered properly. Panel boards, feeders, branches, and conduit will need to be redesigned to code. The geothermal heat pumps have different voltage connections than the fan coil units in the initial design. The electrical diagrams will be altered as necessary to make a completely accurate illustration of the new system.

Tasks and Tools

Task 1. Finish research on air handling units and geothermal heat pumps

a. Use product catalogs and specifications for 100% outdoor air units such as AAON.

b. Use catalogs and specifications for geothermal heat pumps such as WaterFurnace.

c. Account for any new space or other considerations necessary.

Task 2. Size air handling units and geothermal heat pumps

a. Use ASHRAE 62.1 to determine air flow through air handling units and heat pumps.

b. Use necessary equations to calculate heating and cooling capacities for air handling units and heat pumps.

c. Use information to select exact units and heat pumps using proper catalogs.

Task 3. Size panel boards, feeders, branches, and conduit

a. Determine the voltage, current, and connections needed for fans and motors of HVAC equipment.

b. Use NEC tables to size feeders, branches, conduit, and panels.

c. Ensure proper services to building are provided or design necessary transformers.

Task 4. Cost analysis for construction management breadth

a. Receive an approximate value for mechanical equipment from a vendor.

b. Use RS Means to CostWorks to approximate time, labor, maintenance and other costs involved in the redesign.

c. Analyze pros, cons, and cost of redesign.

Task 5. Mechanical system energy analysis

a. Import redesign into Trane Trace.

b. Use the same inputs, energy costs, and other information to do the energy analysis.

Task 6. Report

a. Use Microsoft Excel to make necessary calculations and spreadsheets.

b. Use Microsoft Word to compile the report.

Task 7. Presentation

a. Use Microsoft PowerPoint to make the final presentation.

Timetable

January 14th: Begin classes.

January 21st: Finish research on air handling units and geothermal heat pumps.

February 4th: Size air handling units and geothermal heat pumps.

February 18th: Size panel boards, feeders, branches, and conduit for electrical portion.

March 3rd: Finish cost analysis for construction management breadth.

March 17th: Finish mechanical system energy analysis.

April 9th: Finish final report.

April 9th: Finish presentation.

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