REVISED THESIS PROPOSAL



Water Bottling Facility

Mid-Atlantic, US

Mechanical System Renovation with Acoustical and Architectural Breadths

The Pennsylvania State University
Architectural Engineering
Mechanical Option

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January 14, 2013

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Executive Summary

This Thesis Proposal is based on previous analysis of The Water Bottling Facility in the Mid-Atlantic region of the United States. The facility has three main functions. It acts as an office, a production/packaging facility, and a warehouse. Based on the building's mechanical system analyses run for Technical Reports 1, 2, and 3, the building meets ventilation and load requirements. For this proposal, adaptations to the mechanical design as well as some acoustical and architectural designs will be performed to potentially create a more productive work environment for the employees of the Water Bottling Company, as well as reduce energy costs while acknowledging green practices.

The proposed mechanical redesign includes incorporating a ground-coupled heat pump to replace the air-handing unit used to condition the main office. This will use less energy and prevent the air-handling units in the production area from being overloaded by allowing the office air-handing unit to act as a backup on days of extreme heat. Fabric ducts will also be researched to find one that is durable enough to stay intact with little maintenance while providing an antimicrobial surface. A maintenance plan will be explored to increase ease of access to the fabric duct. The excess heat produced by the production equipment will be exhausted to the outside in the summer months and used as free heating for the packaging area in the winter.

The proposed acoustical breadth will design a system that reduces sound levels in the production and packaging areas of the facility. These high noise levels can be damaging to the employee's hearing on a temporary or permanent basis. Although the Water Bottling Facility requires all people in these loud spaces to use hearing protection to prevent this damage, hearing protection in combination with loud background noise levels can reduce speech intelligibility. Designing an acoustical plan that can reduce the background noise level will create a better work environment for the people in these spaces by reducing their risk for hearing loss and improving communication.

The proposed photovoltaic breadth also focuses on energy savings and utilizing natural resources to reduce waste. Incorporating photovoltaics in the electrical supply for the Water Bottling Facility will allow the company to reach even greener goals in an effort to care for the environment.

All of these redesign considerations will use computer programs as well as reference materials to make an appropriate design. A schedule will be followed to produce the final thesis presentation in April.

Background and Existing Conditions

Introduction

The Water Bottling Facility's mechanical system is made up of six roof top air-handling units. Each of these units is assigned to one of the five conditioned areas of the facility. Cooling is provided by cooling towers in conjunction with ammonia chillers, while heating is provided by gas, electric, or a combination for each of the units. 17 VAV terminal units provide the airflow to the offices spaces. The production space is conditioned with direct ducting to the space. The warehouse space is ventilated with 8 make up air handling units and supply fans.

Design Objectives and Requirements

For the Water Bottling Facility, the main design objective was to create a building that could be easily replicated, constructed in different locations across the United States, and built rapidly. The other large design consideration was LEED® certification to both have a positive impact on the environment and to disprove the common belief that bottling water is bad for the environment. With these design considerations in mind, the mechanical systems were made to use 100% outside air and an enthalpy economizer cycle.

Proposed Design Alternatives

After examining the Water Bottling Facilities mechanical system, it is clear that the cooling load demanded of the air handing units is very great due to the large amount of heat producing pieces of equipment. The goal of the proposed design alternatives are to reduce the heat in the space by using good ducting methods, distribute the excess heat to unheated areas in the winter and create a heat sink using a ground couple heat pump.

Re-Ducting the Space

Currently the production area is ducted using a fabric duct that hangs just below the ceiling above major heat producing pieces of equipment. This fabric duct, while good in theory, has posed a problem for the efficiency of the mechanical system. Because of its elevation and location, maintenance is a challenge. Having little to no maintenance in combination with using a material that may have been improperly selected has caused several tears to occur and go unfixed.

To replace this ductwork it is recommended that the space be re-ducted with sheet metal ducting or a more durable fabric duct. Because the space is used for the production of food, an anti-microbial fabric would be ideal. If maintenance were to be more easily accessible, a washable material would also be a better solution to ensure no contaminants build up on the duct with the potential of being distributed into the air.

Exhausting Excess Heat

Within the Water Bottling Facility's production area, an abundance of heat is generated in both the summer and winter months by the equipment used to create the preforms of the water bottles, to create the finished bottles, and to fill those bottles with water. Although the preform and blow-molding equipment all have internal cooling systems to prevent overheating, temperatures in this portion of the facility can reach 85°F before the air-handling units are set to cool the space. The warehouse and packaging areas of the Water Bottling Facility can become quite cool in the winter months with a heating set point of 48°F before the makeup-heating units turn on.

To reduce the energy cost an examination of the potential uses of the stack effect in the production area should be done. Openings in the roof can act as a chimney to draw heat out of the building as it rises due to natural convection. A heat recovery system will be considered to partner with this design, using the warm exhaust air to preheat the air that will be used to heat the warehouse and packaging area.

Ground Coupled Heat Pump

The environmental aspects of the Water Bottling Facility are important to the company that runs it. Incorporating an environmentally friendly heating and cooling system, that uses less energy than the current air-handling units, can satisfy this desire. The large heating load on design temperature days, when the facility is running at full capacity, can sometimes prove to be too much for the air-handling units designated for the production area. At those times, the comfort of the occupants of the office has to be sacrificed to keep the equipment from overheating and malfunctioning. With the air redirected to the production area, production is not interrupted, but the productivity in the office is. With the excess heat, people do not work as well because they become tired and uncomfortable.

Rather than adding a larger air-handling unit to compensate for those hot days in the summer, adding a ground couple heat pump to the system can take over the main role of the office's air-handing unit. This heat exchanger uses the constant temperatures of the earth (45°F to 75°F)

to both heat and cool the spaces in the building. Using refrigerant conditioned by passing through pipes at least 20ft deep in the earth's surface, the heat exchangers are more efficient than those using outside air because the earth is cooler than the air in the summer and warmer than the air in the winter. This system uses natural conduction to change the temperature and therefore required less energy than a traditional heat exchanger.

An analysis of the benefits of utilizing a central plant design or incorporating multiple heat pumps throughout the building will be done to see what option will best fit the Water Bottling Facility due to its size and available space.

The addition of a ground couple heat pump requires a new or retrofit outside air system that is appropriate for the system. An analysis will be performed to weigh the benefits of each option based on initial cost savings and payback periods.

Breadth Topics

Acoustics

An acoustical design plan will be considered to reduce the sound transferred from the production area's equipment. Currently the equipment produces sound levels over 90dBA, which is the loudest sound level with 8 hours of exposure permitted by the Occupational Safety and Health Administration (OSHA). With levels so high, the Water Bottling Facility requires all employees and visitors to use hearing protection to prevent any hearing loss or damage, be it temporary or long term. Although the OSHA limits are met, long-term exposure for years can still cause hearing loss. To reduce this hazard and increase speech intelligibility for better communication and productivity in the production areas, an analysis of the space will be performed.

This analysis will include examining the feasibility of isolating the production equipment from the concrete slab and adding absorptive materials to the production space via wall panels and/or hanging baffles.

Photovoltaics

The addition of photovoltaics to the Water Bottling Facility will be considered to reduce energy cost and improve environmental impact. An analysis will be run to discover the best type of photovoltaic system for the flat roof of the building. From this the optimal size module will be selected and laid out in a pattern that allows for maximum power generation and maintenance accessibility. A review of the implications of using batteries to store excess energy will be complied along with the system output data.

Tools for Analysis

Different methods and combinations of tools will be used to develop the information needed for the depth and breadth topics. Below describes what programs and tools will be used to gather and report the necessary information.

Mechanical

For the mechanical analysis of the buildings proposed mechanical redesign, Trane Trace 700 will be used to calculate the building loads. This program will also allow for cost analysis of the building to see how energy bills are affected and to discover what the payback period for the installation of a ground coupled heat pump would be. Along with the calculations the ASHRAE Fundamentals hand book with be used to ensure that the design meets the requirement set by the standards found within.

Acoustics

To find a design that will be most appropriate and effective for reducing the sound level in the production area software such as Dynasonics AIM will be used. This software used the room's shape and size to determine the noise levels in the space using NC and dBA ratings. In addition to this software, notes from classes AE 309 and AE 458 will be used to confirm the calculations and develop ideas for materials that can be used to sound absorption. Along with both of these methods, consultations with an acoustical engineer will be held to ensure proper design techniques are used.

Photovoltaics

To develop a plan for the photovoltaic system, the System Advisor Model (SAM) program will be used. This program assists in calculating solar energy available is specific regions and calculates the power generated based on this information for specific solar panels. Along with the SAM program, an online program made by Unirac will aid in developing a layout for the solar modules that will best fit on the roof.

Work Plan

The work plan devised for addressing the topics discussed in this proposal can be seen in Appendix A. It shows the time schedule for task completion as well as blocks of time to research and develop the project.

References

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Water Bottling Facility Specifications and Images

Acknowledgements

A special thanks to the team at the Water Bottling Facility, who have been a constant source of information.

Jack Neborak, Ron Hendeson, and Chris Hoffner,
Thank you for all your help.

Appendix A – Work Plan