Architectural Engineering Thesis Proposal

Photo rendering courtesy of Hooper Shiles Architects

Philadelphia School District Administration Headquarters 440 North Broad Street, Philadelphia, PA

Prepared for
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Mechanical Option

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Executive Summary

For the Spring Semester I have proposed to evaluate the Philadelphia School District Administration Headquarters based on the actual load within the building. When the original shell and core design was completed, the specific space usage and occupancy was not known which created a very conservative design. The actual load will be investigated using the fit-out documents for the project. The current system with newly sized equipment will be evaluated against a new chilled water system.

The second system will comprise of a central chilled water plant and will be designed based on pump and piping first cost savings and energy savings. This design is primarily based on interest in the topic and will hopefully benefit future design in a professional environment.

The final analysis will be based on a variety of factors: first cost, operating cost, required maintenance, energy consumption, and emissions. A decision will be made on whether to suggest the chilled water plant or to suggest keeping the all electric based air handler system.

Part I: Building Background

The Philadelphia School District Administration Headquarters is located at 440 N. Broad Street, Philadelphia, PA. The building was originally built as a printing press in 1948 and was renovated to fit the needs of the Philadelphia School District (PSD). The building footprint is approximately 161,000 SF with a gross area of 848,000 SF. PSD currently occupies floors 1 through 3 (about 375,000 SF) with open office space, private offices, and meeting rooms. Floor 4 is a data center (about 60,000 SF) and the fit-out of floor 5 is still under construction (about 50,000SF). There are two entrances, one at 15th Street and one at Broad Street. The entrance at 15th Street is at ground level which is used for storage and the entrance at Broad Street is at the level of floor 1. The basement is mainly used for storage and a television/radio studio. The atrium is a new architectural design feature that calls much attention for unique mechanical design. It connects the Broad Street lobby with the elevator lobby of the 15th Street lobby. The atrium also allows for visual connectivity of the north and south ends of floors 1 through 3.

Mechanical System Overview

Office Spaces

The shell and core design of PSD Administration Headquarters consists of a VAV system with a two-celled 1500 ton cooling tower and 17 new self-contained direct-expansion air handling units. The cooling tower is located on the roof of floor 5 while the air handling units are located within the core of the building. Condenser water is distributed to an automatic chemical feed unit and a side stream filtration system where it is treated and then pumped by one of the two pumps. The two pumps are piped in parallel but only one is on at any time and the other is used for back-up. Treated condenser water from the pump is supplied to an evaporator or economizer coil within the air handling units on each floor. If the water is less than the entering unit air temperature the economizer coil is used for free cooling, otherwise mechanical cooling helps to provide conditioned air to the building. Heating is provided by electric heating coils within the AHUs and by electric reheat coils in terminal units serving spaces along the exterior wall of the building.

Atrium

Atriums require special mechanical system design. Four smoke purge fans each controlled by a motorized damper provide ventilation for the atrium space in PSD Administration Headquarters.

Part II: Possible Mechanical Systems

There are many mechanical systems that can suit the PSD building in Philadelphia. Two systems that were investigated are described below

System A — A possible mechanical system for the Administration Headquarters is an under floor air distribution system (UFAD). Because the building was originally built as a printing facility, the floor to floor heights are large and would accommodate raising the floor for this system. A ceiling return air plenum would still be needed, but would be less in depth than supplying air through a ducted ceiling system. The floor itself within the building is concrete slab which would also accommodate the structural needs for the UFAD system. UFAD can be done three ways: 1. A pressurized plenum with passive diffusers, 2. Zero pressure plenum with local fan driven supply outlets, and 3. A ducted plenum with supply outlets. For my analysis a ducted plenum will be analyzed. When compared to the pressurized and zero pressure plenum design, the ducted plenum allows for more controllability with acoustics, contaminants and with supply air temperature distribution. Because building occupants are closer to the supply air distribution the supply air temperature can be higher—60-65°F—than normal ceiling VAV or CAV systems, 55°F. This should amount to first cost and energy savings. Humidity control and fire protection may become issues with this system design

System B — The second system that can suit the PSD Administration Headquarters is a dedicated outdoor air system (DOAS) along with a parallel ceiling radiant panel system. The DOAS system takes advantage of using an enthalpy wheel and sensible wheel to lower the energy costs in the cooling coil and reheat coil of the system. The system will allow for a smaller duct system throughout the building. A smaller duct system will save money on a smaller amount of sheet metal and smaller floor penetrations. Also, the air handling units may be smaller since the air supplied to the space is on a ventilation requirement basis.

Although these systems may be workable designs for the building, they were decided against. The final proposal for the mechanical system is based on research done this semester for the Central Cooling class.

Part III: Proposal

Proposed Work and Justification: Office Space

Depth Topic: Mechanical

For the office space of my building I intend to evaluate the current mechanical system against a central chiller plant. The two systems that I intend to evaluate are discussed below.

System I — The first system will be the same as what is currently in PSD Administration Headquarters, a VAV system with a cooling tower providing condenser water to self-contained direct expansion air handling units. However, the equipment will be resized after analyzing the actual load in the building based on usage and occupancy in Trane's Trace program.

The actual load in the building is less than what was designed for in the shell and core mechanical documents. The over sizing of equipment in some areas of the building is a result of the uncertainty in the usage and occupancy of the spaces within the building when the shell and core design was complete. Because of the lack of detailed knowledge at the beginning of the design process, each AHU has the potential to supply more load to the building than it will actually see. Because of this over sizing, money was spent on equipment to provide for non-existent load. The actual load from the fit-out will be the basis of the proposed system comparisons. Electric heating coils will remain as the basis for heating in this system.

System II — The same VAV system will be analyzed but with the use of chilled water distribution from a central chiller plant located in the basement of the building. The plant will be designed on the basis that a higher chilled water ΔT and lower chilled water flow rate will reduce the cost of chilled water pumps and piping, and on the basis that a higher cooling tower range and lower condenser water flow rate will also reduce the cost of pumps and piping. Overall energy costs will be reduced as well. This was found in a research project done for another class. An analysis of the "standard" design of a chilled water plant for the PSD building will be complete if time permits. This cooling system will be analyzed with a steam heating system.

These two systems will be compared based on first cost, operating cost, required maintenance, energy consumption, and emissions.

Breadth Topic: Electrical

The integration of the other building systems is extremely important when designing mechanical systems. The proposed new mechanical systems will have a large impact on the electrical load in the building.

For the equipment of System I, the electrical load will be considerably less than for the current equipment. The proposal is to calculate the difference in electrical equipment cost based on the actual mechanical load in the building.

The electrical load for System II may or may not be less than what is currently in the building. This depends on the electrical requirements for the different chiller plant equipment. The proposal for System II is to calculate the electrical load for the chiller plant equipment, size the new electrical equipment based on this load, and compare the cost of electrical equipment for System I and System II.

Breadth Topic: Constructability

Because the PSD Administration Headquarters is an existing building, constructability was a concern with where to place the new mechanical equipment. This issue will be explored with the newly sized mechanical equipment of System I. The possibility of reducing the amount of mechanical room space will be investigated with the hope of allowing more office space for the School District.

System II will reduce the amount of equipment in the mechanical rooms on each floor but will require the chiller plant to be located in a centralized location in the building. Space usage and occupancy will be considered when inspecting the proper placement of this new equipment.

Part IV: Proposed System Methods with Tasks and Tools

Task I: System I

Task I.A Calculate Actual Building Load
1. Using recently acquired fit-out drawings calculate the actual load in the building.
2. Using ventilation requirements calculated in Technical Report 1 and calculated load from Task I.A.1, put information into Trane's Trace program.

Task I.B Size New Mechanical Equipment
1. Analyze different sized air handling units based on new load, first cost, and energy consumption.
2. Analyze different models of cooling towers based on new load, first cost, and energy consumption.

Task I.C Final Equipment Selection and Energy/Emissions Analysis
1. Choose equipment based on first cost and energy consumption.
2. Perform energy analysis in Trane's Trace.
3. Perform emissions analysis.

Task II: System II

Task II.A Size Chilled Water Plant Components
1. Based on the new load of the building calculated in Task I.A.1, the size of the chiller equipment will be calculated.
2. Piping and pumps will be sized based on the flow rates and water ΔTs of both the condenser water and chilled water.

Task II.B Energy/Emissions Analysis
1. Perform energy analysis
2. Perform emissions analysis

Task III: Evaluation

Task III.A Compare System I and System II based on first cost, operating cost, required maintenance, energy consumption, and emissions.

Task III.B Decide if System I remains with new equipment size or if System II replaces System I completely.

Task IV: Final Report

Task IV Compile Final Report Documents

Task V: Final Presentation

Task V Compile Final Presentation

Part V: Preliminary Research

Although some research has been done this semester, this thesis proposal will require some extensive research during the Spring semester as well. The following literature may need to be referenced and studied.

ASHRAE Handbook, Fundamentals. American Society of Heating Refrigerating and Air Conditioning Engineers, Inc., Atlanta, GA 2005.

ASHRAE Handbook, HVAC Applications. American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., Atlanta, GA 2003.

ASHRAE Handbook, HVAC Systems and Equipment. American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., Atlanta, GA 2004.

CoolTools Chilled Water Plant Design and Specification Guide. Pacific Gas and Electric Company, San Francisco, CA 2000.

Part VI: Tentative Spring Semester Schedule

On the following two pages a tentative schedule for Spring 2006 is found. This is subject to change and will most like change due to other class assignments, tests, projects, and miscellaneous life things.

JANUARY						
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	2	3	4	5	6	7
8	9 Back to Class	10	11 Begin Task I.A	12	13	14
15	16 NO Classes	17	18	19	20	21
22 Complete Task I.A	23 Begin Task I.B	24	25	26	27	28
29 Complete Task I.B	30 Begin Task I.C	31				

FEBRUARY						
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			1	2	3	4
5 Complete Task I.C	6 Begin Task II.A	7	8	9	10	11
12	13	14	15	16	17	18
19 Complete Task II.A	20 Begin Task II.B	21	22	23	24	25
26	27	28				

MARCH						
Sunday	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
			1	2 Complete Task II.B	3	4
5	6 Spring	7 Break	8	9 Spring	10 Break	11
12	13 Begin Task III.A	14	15	16	17	18
19 Complete Task III.A	20 Complete Task III.B	21	22 Begin Task IV	23	24	25
26	27	28	29	30	31	

APRIL						
Sunday	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
						1
2 Complete Task IV	3 Begin Task V	4	5 THESIS DUE	6	7 Complete Task V	8
9	10 THE	11 SIS PRE	12 SENTATIONS	13	14	15
16 Easter	17	18	19	20	21	22 FE EXAM
23	24	25	26	27	28 THESIS FINALS	29
30 FINALS-->	1	2	3	4	5	6 <--FINALS

References

ASHRAE Handbook, HVAC Systems and Equipment. American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., Atlanta, GA 2004.

CoolTools Chilled Water Plant Design and Specification Guide. Pacific Gas and Electric Company, San Francisco, CA 2000.

The Pennsylvania State University Architectural Engineering E-Studio Archives-Mechanical. www.arche.psu.edu/thesis.