Thesis Proposal

CITY HOSPITAL – PHASE I
S.E. Pennsylvania

Prepared for
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Mechanical Option
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The Pennsylvania State University | Department of Architectural Engineering

Table of Contents

Executive Summary

City Hospital campus development included three (3) million square feet of occupible spaces such as research, clinical office, and support service paces. These spaces often require high ventilation rate to minimize the risk of contamination. In recognition of substantial amount of energy required to condition such significant volume of space, the mechanical system must be design as energy efficient as practical.

The existing mechanical systems of City Hospital are designed with careful attention toward occupant health and thermal comfort, energy conservation, reliability, and expandability. The existing mechanical system is considered excellent design for large intuition such as City Hospital campus.

The primary goal of the proposed mechanical system modification is to further reduce energy consumption and annual utility cost. It is also important to maintain occupant health and thermal comfort, system reliability in certain foreseeable events, and the ability to expand as the campus grows. The modification will consequently reduce emissions as well. Furthermore, the alternate solution should have a reasonable payback period to justify its application.

Mechanical Modification

The mechanical redesign will compare the energy and cost reducing capability of cogeneration with an all electric centrifugal chiller plant. Due to the large volume and phasing complexity of City Hospital campus development, capacity and staging of the modified system will be iterated several times to fine the most financially viable situation.

Economic

Electric utility deregulation has significantly changed the electricity market. These will affect cogeneration strategies, since consumers may be able to buy less expensive electricity, sell excess power to other consumers. Reevaluate electric utility deregulation can help energy users understand the regulatory and economic impacts of the evolving market better, and determine whether deregulation actually benefits.

Electrical System

The proposed mechanical redesign will make a significant change to the electrical load. Analysis of electrical system and local code will determine whether a system resize is necessary, and the possibility of eliminating certain components.

Project Background

City Hospital – Phase 1 is the first phase of a multiphase campus development. The entire project will eventually result in the construction of approximately one million square feet of research space, one million square feet of ambulatory care and clinical office space, and one million square feet of parking and support services.

Phase 1 in essence consisted of three buildings, a three-level sub grade vivarium, a three-level sub grade Central Utility Plant (CUP), and a Support Services at street level. The three-level below grade vivarium contained 176,300 square feet of laboratory spaces to promote advancement in medical research. The three-level, 59,500 square feet CUP is constructed adjacent to the vivarium below grade (see Figure 1). The CUP contained mechanical, electrical, and plumbing (MEP) infrastructures to support Phase 1 and future phases.

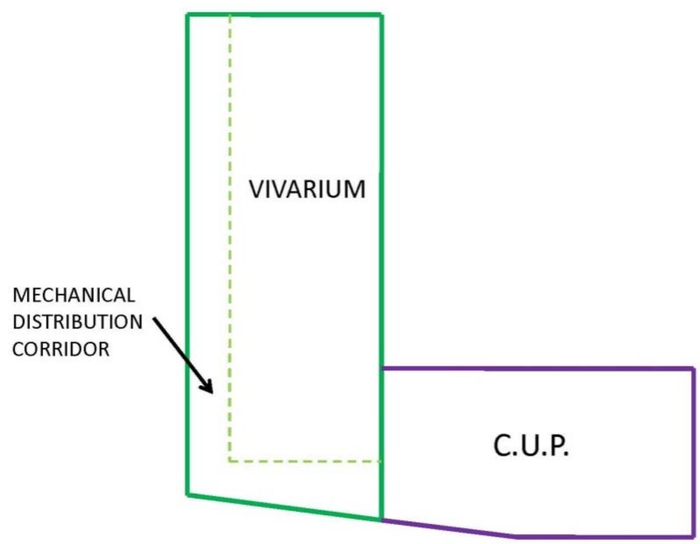

Figure 1

Proposal Objective

City Hospital campus development included three (3) million square feet of occupible spaces such as research, clinical office, and support service paces. These spaces often require high ventilation rate to minimize the risk of contamination. In recognition of substantial amount of energy required to condition such significant volume of space, the mechanical system must be design as energy efficient as practical.

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Disclaimer

This thesis proposal will suggest alternate solutions(s) to the design of City Hospital campus. Modifications and changes are for academic purposes, and do not imply errors or flaws in original design.

Existing Mechanical System

The mechanical system described in this report has the capacity to support Phase 1 and Phase 2 with exception of air side mechanical system. Additional MEP systems will be added in phase to meet the increasing load requirements as City Hospital campus expands (See Technical Assignment 3 for system schematic and details).

Air Side Mechanical System

The ventilation system for Phase 1 - vivarium comprised of six (6) 100,000 CFM air handling units (AHU) equipped with variable speed drives (VSD). All six (6) AHUs are demand based, and supply airflow can be reduced to 50% of the design airflow. Two (2) AHUs are grouped together to deliver 100% outdoor air (OA) to each level by the means of variable air volume (VAV) system with re-heat. Ductworks reach individual zone by ganged/manifold distribution concept through a mechanical distribution corridor on each floor.

Three (3) 120,000 CFM exhaust air handlers (EAHU) with sensible heat recovery remove majority of the room air (RA), and preheat OA which become SA with a runaround glycol loop. The exhaust air (EA) heat recovery system with effectiveness of 74% is interconnected with the low pressure steam system through steam-water heat exchangers to pre-heat OA air to 53°F in winter months. Other exhaust systems compensate for the remaining indoor air removal to maintain 100% OA supply and 100% RA exhaust.

Steam System

The Boiler plant of Phase 1 included four (4) 32,656 MBH dual fuel boilers with VSD blowers and boiler stack economizer (BSE). BSE pre-heat boiler feed water by recovering heat from flue gas to increase boiler efficiency by 3.2%. The steam boilers produce high pressure steam at 125 psig for high distribution efficiency, and drive steam turbine chiller(s) at 120 psig. Additional high pressure steam is reduced to 70 psig medium pressure steam for domestic hot water heating and process equipments on each level. Steam pressure is further reduced to 2 psig low pressure steam for humidification and reheat building hot water loop.

Chilled Water System

The chiller plant of Phase 1 consisted of one (1) 2,000 ton steam turbine chiller and one (1) 2,000 ton electric centrifugal chiller that produce 42°F chilled water. Chilled water is distributed to loads with two (2) secondary chilled water pumps with VSD on a primary/secondary loop. Chillers reject heat by means of four (4) 1,000 ton cooling towers with VSD fans.

Proposed Alternative

Current system is designed to use steam generated by boilers to meet building thermal load, process equipment load, and drive steam turbine chiller(s). Electric centrifugal chiller(s) compensate remaining chilled water load. Current design reduced electric demand, and considered to be fail-safe due to chiller plant's flexible energy source, steam or electricity. However, there is a drawback to such flexibility. Steam turbine chiller(s) specified for the project consume 11.2 pound of steam per hour, an efficiency equivalent of 13,362 Btu/hr-ton. Electric centrifugal chiller(s), rated 0.598 KW/ton, have efficiency equivalent of 2,041 Btu/hr-ton. Therefore, electric centrifugal chiller is 655% more efficient than steam turbine chiller.

Cogeneration

Cogeneration, also known as combined heat and power (CHP), simultaneously generate both electricity and useful heat. Conventional power plants emit the heat created as a byproduct of electricity generation into the atmosphere as flue gas. CHP captures the byproduct heat for domestic heating purposes.

From efficiency point of view, cogeneration has an overall efficiency of 68.9% and source energy reduction of 35%, while conventional electrical system has an overall efficiency of 44.5%. Higher efficiency translated to lower energy consumption, fewer emissions, and lower operating cost.

City Hospital consumes approximately 33 KWh of electricity and 770 Btu of steam per square foot annually. Cogeneration is an alternative to the current design due to the substantial volume of the completed City Hospital campus development, and both electric and thermal loads are necessities. Gas turbine generator(s) with heat recovery will be explored as a part of thesis. Generator(s) will be designed to satisfy campus's thermal load rather than electric demand.

- Excess power sold at wholesale rate cannot recover cost of onsite generation
- Connection(s) to local power grid are maintained at minimum required electric demand
- Boilers' steam generation are replaced by generator(s) heat recovery system
- Emergency power generation may be eliminated

All Electric Chiller(s)

Efficiency of the chiller plant can be increase with an all electric centrifugal chiller plant. Since an all electric centrifugal chiller plant has a much higher efficiency than the current steam turbine/electric centrifugal chiller plant, operation cost and maintenance cost will be lower. Capital cost for an all electric centrifugal chiller plant will be less than the current configuration as well.

Energy source flexibility of the current chiller plant remained as a result of onsite generation. Malfunction of either system, onsite generation or local power grid, will not affect operation of the chiller plant. In addition, electric demand from added electric centrifugal chiller(s) will be offset by onsite generation. An all electric centrifugal chiller plant without onsite generation, however, will not be considered due to energy source rigidity.

Breadth Proposals

Alternative solution to the current design is affect by many external factors, and the modification of the mechanical systems directly affects other building systems. The overall idea is to fully incorporate all areas that play direct or indirect factor in the mechanical system redesign. Understand and improve the overall systems is also an important goal of the thesis.

Economic

Electric utility deregulation has significantly changed the electricity market. It allows for new contractual arrangements and pricing structures. These will affect cogeneration strategies, since consumers may be able to buy less expensive electricity, sell excess power to other consumers, or wheel power to outlying facilities. Reevaluate electric utility deregulation can help energy users understand the regulatory and economic impacts of the evolving market, and determine whether deregulation actually benefits.

Electrical System

The proposed mechanical redesign included the replacement of steam boilers with electric generator(s) with heat recovery, and steam turbine chiller(s) with electric driven centrifugal chillers. Therefore, a significant change to electrical load will occur. Switchgear, main distribution system, as well as the mechanical room panel boards will be resized. In addition, eliminating of emergency power generator is a possibility.

Project Methods

The proposed mechanical modification of the City Hospital campus development will go through multiple iteration and sequences. An energy consumption model of existing system was done with Trane TRACE as part of Technical Assignment 2. Carrier's Hourly Analysis Program (HAP) will be use to remodel the existing system to ensure output accuracy. The proposed mechanical modification shall then be analyzed and simulated to produce a new electric demand and steam load.

Since Phase 1 information is the only information readily available for City Hospital campus development, it is chosen as basis of analysis. Energy consumption rate from Phase 1 along with published energy consumption rate of similar space and condition will be compiled and extrapolated to mimic the state of the completed City Hospital campus.

Electric demand and steam load from modified design will then be used to select power generator for onsite electric and steam generation. Due to limitation of TRACE and HAP, a customized spreadsheet is required to calculate energy consumption for the proposed modification of cogeneration. Since City Hospital campus develop in phases, capacity and staging of the generator(s) can significantly alter the outcome of the modified system life cycle cost. It will be iterated several times to fine the most financially viable way.

The breadth portion of this proposal will be carried out after a preliminary mechanical redesign is completed. In order to better understand how electric utility deregulation affects energy consumers, and cogeneration, it will be necessary to conduct an extensive research on deregulation policy and current electric market.

Electrical system that was affected by the redesign will be resized. This will include updating feeders, switchgear, main distribution panel, branch circuits, and emergency generation. Elimination of emergency power generation will be decided after the investigation of local code requirement.

Capital cost, operation cost, and maintenance cost of existing system and modified system will be collected to perform a comprehensive life cycle cost. Results from life cycle cost and emission rate will then be compared to determine whether the redesign is justifiable.

Preliminary Research Bibliography

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McIntosh, Ian, Chad Dorgan, and Charles Dorgan. ASHRAE Laboratory Design Guide. ASHRAE, 2001.

Orlando, Joseph. "Cogeneration." Penn State ASHRAE. The Pennsylvania State University.

Ryan, William. "Economic of Cogeneration." ASHRAE Journal (October, 2002): 34-40.

Academic, Thesis, China Holidays, US Holidays | **Jan 2008 (Eastern Time)**

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
30	31 New Year's Eve	1 New Year New Year's Day	2	3	4	5
6	7	8	9	10	11	12
13	14 Class Starts Start Remodel	15	16	17	18	19 ASHRAE meeti...
20 ASHRAE meeting @ NYC	21 Martin Luther ... MLK - No Clas...	22	23 Add/Dop - De...	24 Start CHP Res...	25	26
27	28	29	30	31	1 Faculty Consu... Progress Check Review/Update	2 Groundhog Day Start Model New

Academic, Thesis, China Holidays, US Holidays

Feb 2008 (Eastern Time)

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
27	28	29	30	31	1 Faculty Consu... Progress Check Review/Update	2 Groundhog Day Start Model New
3	4	5	6 Chinese New ...	7 Chinese New ...	8	9
10	11 Start Electrical	12 Lincoln's Birth...	13	14 Valentine's Day Valentine's Day	15 Faculty Consu...	16
17	18 President's Day Start Deregula...	19	20	21 Lantern Festival	22 Washington's ...	23
24	25	26	27	28	29 Faculty Consu...	1 Start LLC Anal...

Academic, Thesis, China Holidays, US Holidays

May 2008 (Eastern Time)

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
27	28	29	30	1 International ...	2 Classes End 6pm - Senior ...	3
4 Youth Day	5 Final Exams Cinco de Mayo	6 Final Exams	7 Final Exams	8 Final Exams	9 Final Exams	10
11 Mother's Day Mother's Day	12	13	14	15	16 Commencement	17 Commencement
18 Commencement	19	20	21	22	23	24
25	26 Memorial Day	27	28	29 John F. Kenne...	30	31

Academic, Thesis, China Holidays, US Holidays

Apr 2008 (Eastern Time)

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
30	31	1 April Fool's Day April Fool's Day	2 Start PP Prese...	3	4 Faculty Consu... Qingming Fes...	5
6	7 Final Report D...	8	9	10 Revise/Practice	11 Late Drop - D...	12
13	14 Thesis Presentation	15 Tax Day	16	17	18	19
20	21	22 Earth Day	23	24	25	26
27	28	29	30	1 International ...	2 Classes End 6pm - Senior ...	3

Academic, Thesis, China Holidays, US Holidays **Mar 2008 (Eastern Time)**

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
24	25	26	27	28	29 Faculty Consu...	1 Start LLC Anal...
2 Final Exam Co...	3	4	5	6	7	8 International ...
9 Daylight Saving	10 Spring Break - No Classes	11	12 Arbor Day	13	14	15
16	17 St. Patrick's Day	18	19	20	21 Faculty Consu...	22 Compile Report
23 Easter	24	25	26	27	28	29
30	31	1 April Fool's Day April Fool's Day	2 Start PP Prese...	3	4 Faculty Consu... Qingming Fes...	5