Thesis Proposal

CITY HOSPITAL – PHASE I
S.E. Pennsylvania

Prepared for
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Mechanical Option
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Executive Summary

City Hospital campus development included three (3) million square feet of research, clinical office, and support service spaces. Medical research laboratories and clinical offices required high ventilation rate to minimize the risk of contamination and other adverse effects. 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 an 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, the ability to expand as the campus grows, and the modification should consequently reduce emissions as well. Furthermore, the alternate solution should have a reasonable payback period to justify its application.

Depth: Mechanical Modification

After through assessment of the existing mechanical system, two proposals were developed; an all electric centrifugal chiller plant, and combined heat and power (CHP). After further evaluation, it is determined an all electric centrifugal chiller plant lacked energy redundancy of the existing plant. This proposal is eliminated from consideration for the thesis. CHP is a practicable alternate to the existing mechanical system for Phase 1 due to favorable condition of high and consistent electric and steam demand. It should further reduce energy consumption and cost, and lessen impact on the environment as well.

Breadth: Electrical System

The proposed mechanical redesign included the replacement of steam boilers with CHP generator(s). Demand from local grid will be reduced, and equipments for re-routing electrical source must be integrated as part of the new system. In addition, existing electrical equipments will be analyzed, and if necessary, resized to work with the alternate design. With on-site generation, elimination of existing emergency power generator set is a possibility.

Breadth: Acoustic Properties

CHP generator such as gas turbine has acoustic properties similar to a jet engine, and should be place outdoor. City Hospital campus is located in a dense urban area. Due to limitation of available space and future construction above "roof" of Phase 1, location of CHP generator(s) are limited to the boiler room. Noise and vibration generated by generator(s) might transmit to occupied spaces close to the boiler room. Noise criteria and control methods must be evaluated to ensure occupant comfort in these spaces.

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 (1) million square feet of research space, one (a) million square feet of ambulatory care and clinical office space, and one (1) 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). CUP contained mechanical, electrical, and plumbing (MEP) infrastructures to support Phase 1 and future phases. Future phases will be constructed above and adjacent to Phase 1.

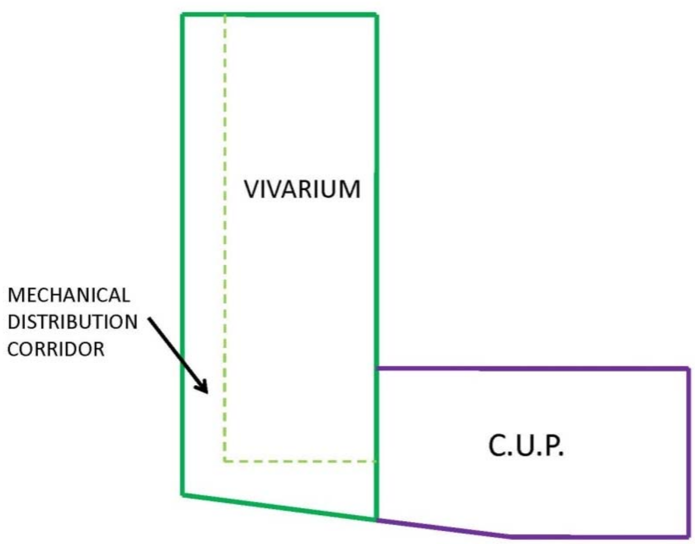

Figure 1

Proposal Objective

City Hospital campus development included three (3) million square feet of spaces such as advance medical research laboratories, clinical offices, and support service spaces. These spaces required high ventilation rate to minimize the risk of contamination and other adverse effects. 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. It is considered an 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, the ability to expand as the campus grows, and the modification should consequently reduce emissions as well. Furthermore, the alternate design should have a reasonable payback period to justify its application.

Note

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 steam plant and chilled water plant described in this report has the capacity to support both Phase 1 and Phase 2 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. In 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

Laboratory and hospital environments such as the one developed by City Hospital in southeast Pennsylvania will have a much higher energy intensity than a standard office building. Energy consumption of City Hospital Campus further dwarfs a standard office building with its three (3) million square feet of floor areas. Due to the nature of activities performed in these spaces, stringent indoor air qualities are required to protect its occupants. Thus, the central plant will be the focus of proposed alternative.

All Electric Chiller Plant

The existing 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. Steam turbine chiller(s) specified for the project consume 11.2 pound of steam per hour-ton, an efficiency equivalent of 13,365 Btu/hr-ton (340°F, 120 PSIG). Electric centrifugal chiller(s), rated 0.598 KW/ton, have efficiency equivalent of 2,041 Btu/hr-ton. Therefore, electric centrifugal chiller is 84.7% more efficient than steam turbine chiller. An all electric centrifugal chiller plant will have 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.

All though an electric centrifugal chiller is much more efficient than a steam turbine chiller, there are disadvantages to such efficiency. Current chiller combination reduced electric demand and consumption, and considered to be fail-safe due to chiller plant's flexible energy source, steam or electricity. Despite the fact that an all electric centrifugal chiller plant consumes less energy than the current chilled water plant, it will not be considered as an alternate mechanical design. Flexibility is essential to critical environments such as vivarium and laboratory spaces on the campus.

Cogeneration

Energy analysis from Technical Assignment 2 showed that Phase 1 of City Hospital campus development required significant amount electricity and steam for indoor environmental control and laboratory equipment process. In addition, Phase 1 was specified for twenty-four (24) hours work period. The combination of these two conditions produced a high and consistent energy demand profile, both electricity and steam. As a result, cogeneration should be a feasible alternative to the existing central plant design.

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.

Generator(s) with heat recovery will be explored as an alternate design to the existing mechanical system. Generator capacity will be selected to meet either electric and/or thermal demand without excess. Other requirements and conditions will be considered as well.

- Must have the capacity to produce steam at 120 PSIG or higher to operate steam turbine chiller(s)
- Location and clearance of CHP generator(s)
- Possibility of CHP generator(s) replace existing boilers' steam generation
- Possibility of CHP generator(s) replace function of emergency generator sets
- Maintain back-up boiler(s) with equivalent heat capacity of CHP for flexibility and maintenance purpose
- Maintain connection to local grid for flexibility and maintenance purpose
- Flexibility to expand and integrate as demand grows
- Excess power sold at wholesale rate cannot recover cost of on-site generation

Breadth Proposals

Alternative solution to the current mechanical 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.

Electrical System

The proposed mechanical redesign included the replacement of steam boilers with CHP generator(s). Demand from local grid will be reduced, and equipments for re-routing electrical source must be integrated as part of the new system. In addition, existing electrical equipments will be analyzed, and if necessary, resized to work with the alternate design. With on-site generation, elimination of existing emergency power generator set is a possibility.

Acoustic Properties

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Project Methods

The proposed mechanical modification of the City Hospital campus development will go through multiple iterations and sequences. An energy consumption model of existing system was done with Trane TRACE as part of Technical Assignment 2. Another energy analysis program such as Design Builder or e-Quest will be use to remodel the existing system to ensure output accuracy and consistency.

Energy cost from existing condition will be used to calculate the spark gap to confirm cogeneration is feasible for the project.

If cogeneration is feasible, energy demand profiles and consumption from existing condition will be assessed and used to select combined heat and power (CHP) generator package(s) for the proposed mechanical modification. Due to limitation of TRACE, a customized spreadsheet will be formulated to calculate energy consumption for the proposed modification of cogeneration.

In addition to energy consumption and cost analysis, mechanical room equipment layout will be examined as well.

The breadth portion of this proposal will be carried out after a preliminary mechanical redesign is completed. 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.

The modified mechanical system will affect acrostic properties of nearby occupied spaces. Noise criteria of nearby occupied spaced will be investigated, and noise transmission calculation will be performed to find affected spaces. If necessary, noise and vibration reduction methods will be applied to remediate problem(s).

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

Since the MEP infrastructures in the CUP are intended to serve the entire City Hospital campus, the proposed system must perform well for Phase 1, as well as the completed campus development. Since Phase 1 information is the only information readily available for City Hospital campus development, it is chosen as basis of analysis. Energy demand from Phase 1 along with published energy demand of similar space and condition will be compiled and extrapolated to estimate energy consumption and cost of the completed City Hospital campus.

Given that timing of construction is an unknown, artificial construction milestones will be created to evaluate several equipment staging scenarios. Simple energy cost saving and payback period will be computed to compare cost and benefits of the existing and the proposed system.

Preliminary Research Reference

2007 ASHRAE Handbook – HVAC applications. ASHRAE, Inc. Atlanta, GA. 2007

ANSI/ASHRAE Standard 62.1-2004 – Ventilation for Acceptable Indoor Air Quality. AHSRAE, Inc. Atlanta, GA 2004

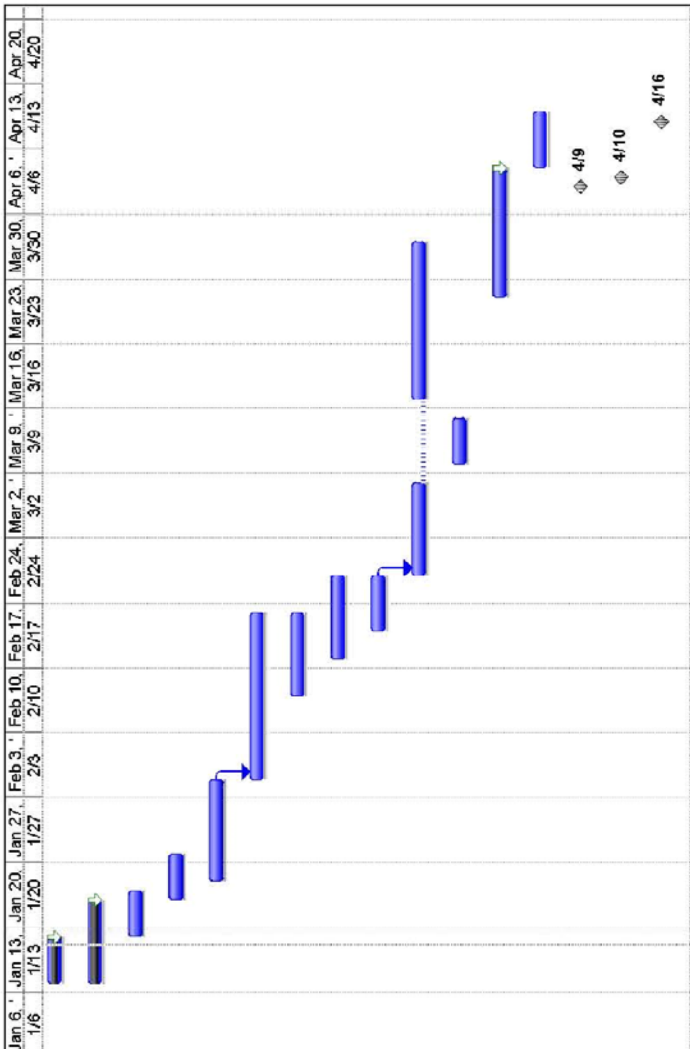
ANSI/ASHRAE Standard 90.1-2004 – Energy Standard for Building except Low-Rise Residential Buildings. AHSRAE, Inc. Atlanta, GA 2004

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.

ID	Task Name	Duration	Start	Finish
1	Revise Proposal	5 days	Mon 1/14/08	Fri 1/18/08
2	Update Schedule	9 days	Mon 1/14/08	Tue 1/22/08
3	ASHRAE meeting	5 days	Sat 1/19/08	Wed 1/23/08
4	Remodel Existing Condition	3 days	Wed 1/23/08	Sun 1/27/08
5	CoGen Research	7 days	Fri 1/25/08	Mon 2/4/08
6	Model New Condition	14 days	Tue 2/5/08	Fri 2/22/08
7	Electrical System redesign	7 days	Thu 2/14/08	Fri 2/22/08
8	Deregulation Research	7 days	Mon 2/18/08	Tue 2/26/08
9	Lab energy Research	4 days	Thu 2/21/08	Tue 2/26/08
10	LCC Analysis	21 days	Wed 2/27/08	Wed 4/2/08
11	Spring Break	5 days?	Mon 3/10/08	Fri 3/14/08
12	Design PowerPoint	10 days	Fri 3/28/08	Thu 4/10/08
13	Practice Presentation	4 days	Fri 4/11/08	Wed 4/16/08
14	Thesis Report Due	0 days	Wed 4/9/08	Wed 4/9/08
15	Thesis Print & Post	0 days	Thu 4/10/08	Thu 4/10/08
16	Thesis Presentation	0 days	Wed 4/16/08	Wed 4/16/08



Project: Proposal Schedule
Date: Fri 1/18/08

Task, Progress, Milestone, Summary, Rolled Up Task, Rolled Up Milestone, Rolled Up Progress, Split, External Tasks, Project Summary, Group By Summary, Deadline

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