Walter Reed National Military Medical Center
Bethesda, MD

Mechanical Project Proposal

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Table of Contents

List of Figures

Executive Summary:

Building A and B will be housing the functions of the existing Walter Reed Hospital after being constructed at the current National Naval Medical Center. Once construction is complete, the facility will be renamed the Walter Reed National Military Medical Center. Building A and B will house medical facilities such as Examination Rooms, Operating Rooms, Rehabilitation Spaces, and Patient Bedrooms. Occupancy patterns within the buildings will be fairly predictable with Building A having occupancy during normal office hours and Building B having 24 hour occupancy.

Both Building A and B are conditioned using 100% outdoor air system that supplies a constant volume of conditioned outside air to the occupied spaces. Due to the large energy usage associated with a 100% outdoor air system, total energy wheels have been installed in custom duct housings in order to offset a portion of the energy costs. Heat recovery chillers have been installed on the water side of the system in order to help recover energy from the condenser water stream.

In order to reduce some of the solar loads that the building façade experiences an analysis of solar shading will be performed. This reduction in skin load may be able to reduce some of the mechanical equipment sizes which will also reduce the initial cost of the equipment. Two forms of solar shading, fixed and electronically controlled, will be investigated due to the stringent façade requirements set forth by the State Historic Planning Commission.

After the solar shading investigation, an analysis into the use of backpressure steam turbines along with a combined heat and power investigation will take place. Backpressure steam turbines have the opportunity to be utilized separately as well as in conjunction with a combined heat and power system to reduce the steam to the required supply pressure. Preliminary research shows that combined heat and power can be a good system candidate for this site due to the large facility size along with Building B's 24 hour operation which helps flatten the building load profile.

An analysis into decentralizing the main supply fans in the basement will also take place. Removing the supply fans from one central location and relocating them throughout the building will potentially be able to reduce the total amount of fan horsepower installed. Reducing the total amount of horsepower will directly result in a reduction in the total amount of energy that is consumed by the fans. An analysis will need to be performed investigating the added cost of the new fans versus the energy savings potential.

Load calculations and energy simulations will be performed utilizing the Trane TRACE model that was created for previous technical reports. Being able to run full 8,760 hour computer simulations with multiple system alternatives at the same time will be able to provide detailed results regarding system considerations. Engineering Equation Solver along with Microsoft Excel will also be utilized for areas such as parametric tables and various liquid and gas property values.

1.0 Mechanical System Description

1.1 New Construction Background

Building A and B are being constructed at the existing National Naval Medical Center Campus located in Bethesda, Maryland. As part of the Base Realignment and Closure Program (BRAC) the existing Walter Reed National Military Medical Center (WRNMMC) will be closed and those facilities duties will be relocated to this existing facility which will then carry the name of WRNMMC. Building A is the larger than Building B and will be housing medical services such as the Children's Health Area, Cancer Treatment Center, Neurology Area, Physical Therapy, and Medical Staff Offices. Building B is where the Patient Bedrooms, Operating Rooms, and the Ambulance Receiving Center are going to be located.

1.2 Mechanical Design Objectives

An effective Heating, Ventilation, and Air Conditioning (HVAC) system was designed to be installed in the two new buildings being constructed on the WRNMMC Campus in order to provide a comfortable, productive, and safe atmosphere for all building occupants. The HVAC system was designed to exceed the minimum system efficiencies stated in ASHRAE Standard 90.1 and the minimum ventilation rates prescribed in ASHRAE Standard 62.1. Due to the need for this facility to operate 24 hours a day year round the mechanical system installed must be reliable and robust in order to provide service to patient care areas without any interruption.

Due to the nature of the facility some of the occupants within the buildings may have decreased immune systems due to the medical treatment which they are undergoing. This decreased ability for the body to fight off disease and infection means that there must be a high regards to the air quality throughout both buildings in order to prevent illnesses. Building pressurization and envelope construction help to ensure the quality of air within the space by preventing unconditioned air from potentially leaking within the envelope, condensing on building materials, and being a site for mold or bacteria growth.

The first building that was constructed on the campus in 1940 still stands today which is a testament to the initial quality of construction and meticulous maintenance of the building systems. Both Building A and B must be constructed with this same quality in mind so that these new facilities can serve the needs of the owner well into future decades.

1.3 Mechanical Equipment Summaries

Both Buildings A and B are served from a 100% outdoor air system which is supplies conditioned air at a constant volume to the occupied zone. Building A has eight AHU's and Building B has three AHU's which are all rated at 50,000 cfm and located in each respective buildings basement mechanical space. Due to the large amount of energy consumption that is associated with having a

100% outdoor air system, eleven total energy wheels were installed in custom duct housings in order to offset some of the energy spent on cooling and dehumidifying such a large quantity of outdoor air. Building A also houses a rehabilitation pool which is served by a dedicated packaged air handler in order to better control the space conditions due to the pools large latent load.

Chilled water for both buildings is produced by three 1,000 ton water cooled centrifugal chillers which are located in the basement mechanical space of Building A. A 180 ton and a 250 ton heat recovery chiller are located in the basement of Building A and B respectively. These heat recovery chillers are able to reduce some of the heating hot water energy consumed by recovering heat from the chillers exiting condenser water stream and using it to produce hot water. Condenser water is piped to the adjacent patient parking structure where three 1,000 ton induced draft cooling towers with counter flow fan arrangements are located. No boilers have been installed in either building due to the existing campus steam generation plant which supplies both buildings with 125 psig steam. This high pressure steam is reduced to either 75 psig or 15 psig and is supplied to either a humidification steam generator or fed to heat exchangers for heating hot water and domestic hot water needs. Two pipe fan coils are used throughout both buildings to condition electrical and telecommunication closets.

1.4 System Evaluation

Due to the large size and type of occupancy, this projects mechanical system needed to provide a healthy atmosphere for its occupants at a low operating cost due to the year round operation. A constant volume 100% outdoor air system was selected to be used for this project due to the inherent IEQ benefits, constructability ease, and reliability. The design engineer realized that this system would consume more energy than comparable VAV systems with OA minimum intakes but the engineer and owner felt that this was the best system for the project. In order to reduce some of the associated energy costs total energy wheels and heat recovery chillers have been installed.

The cost to for the design and installation of the mechanical system is $109,500,000 or roughly $182.84/sf. The mechanical system represents approximately 17% of the buildings entire construction cost. Typically buildings mechanical system costs represent roughly 15%-20% of the total budget so this system falls in the middle of this estimate. The operating cost of this proposed mechanical system saves the owner over $600,000 a year when compared to the baseline mechanical building.

The space that the mechanical system occupies is mainly concentrated in the basement of both buildings. This can be viewed as a positive aspect in that all of the equipment is centrally concentrated making for easy installation as well as convenient for the maintenance staff.

Large plenum spaces are also required on this project to allow both the supply and exhaust ductwork to be routed simultaneously. Ductwork size may be able to be reduced by using a cooling system that is water based. Water is an effective means of transferring thermal energy due to the large heat capacity relative to air. Reducing the size of plenum spaces will also reduce the overall cost of construction to the direct reduction in floor heights. Using a water based system may be investigated further during the next assignment portion, however, a 100% outdoor air system is still preferred for other benefits.

The indoor air quality throughout both buildings should be a significant improvement over the baseline building due to the use of improved filters as well as 100% outdoor air supplied to each room. With no recirculation aspect throughout the mechanical system potential building contaminants will not be spread easily throughout the interior zones of either building.

The buildings thermal comfort and environmental control are provided by distributed CAV boxes throughout the building. Each of these CAV boxes usually serves more than one room of similar occupancy. These room zones should not prove to have problems with thermal comfort due to the similar occupancy and load types that were grouped together during zone assignments.

Overall the mechanical system that was designed for Buildings A and B uses the foundation of a reliable CAV system while integrating energy reduction measures to provide an advanced HVAC system for the owner. The mechanical engineer has been able to provide such a system using creative system design and coupling it with an integrated building control system.

1.5 Proposed System Alternatives

The existing constant volume system that was designed meets the needs of the facility owner at a justifiable system cost and payback period. Other system options to help reduce the initial cost, total energy cost, decrease the payback period, or require less physical space will be investigated during the next portion of research. Making changes in each of these aspects requires an in depth evaluation into system redesign options.

There is an extensive list of areas that can be redesigned or adjusted within the entire mechanical system for such a large building in order to optimize the system design as a whole. Due to time limitations, all of these specific options are unable to be considered in this project. Below is a list of changes that could be made to the existing system design with varying levels of complexity associated with each alternative.

-Reduce OA fraction and supplement with space radiant panels
-Replace the existing pressure reducing stations with backpressure steam turbines
-Investigate changing to a Primary/Secondary pumping system
-Decentralize the fans from the basement to individual floors
-Investigate the use of boilers instead of the campus steam plant
-Change from CAV to VAV (also investigate demand control ventilation)
-Investigate utilizing Combined Heat and Power (CHP)

This is just a portion of the list that could be compiled for a project of this size. Three topics have been chosen out of the list above to be studied further. These topics were chosen based upon initial investigations as shown below and their educational interest to study. When changes are made to the mechanical system they usually affect many other parts of the entire system. Due to this fact a parametric study will be performed in the end to determine the effects that proposed changes have upon each other as well as to determine the best combination that provides a decrease in energy consumption coupled with a reasonable payback period.

1.5.1 Decentralizing Supply Fans

Having centralized supply fans for an air distribution system has inherent benefits that need to be addressed before decentralizing the supply fans can be discussed. When there is a central group of supply fans located in one area of the building the installation cost goes down per supply air cfm designed compared to using a distributed fan arrangement. This is due to the installation team only having to set up equipment in one area instead of moving to remote locations throughout the building. Even though the physical size of the fan is larger the time and cost are both less for the larger fan size.

Another benefit of having large fans, or any mechanical equipment, is that the total equipment cost is less than when compared to a larger quantity of smaller capacity items. The area of savings that comes from decentralizing fans from one area is in the total fan energy usage. The way that the fan horsepower is calculated is based upon the equation below.

$$W_{sh} = \frac{Q \times \Delta P}{6350 \times \eta_{total}}$$

Where:
Q = Total Flow (CFM)
ΔP = Total Pressure Drop (in. wg)
η = Total Fan Efficiency
W_{sh} = Shaft Horsepower

The following example was used to illustrate on a preliminary basis the potential fan energy savings that could be realized for the building. The subscript numbers designate which floor the value is representing. The first calculation was done assuming that one centrally located supply fan is serving both floors.

Q_1 = 25,000 cfm
Q_2 = 15,000 cfm
ΔP_1 = 2 in wg.
ΔP_2 = 2.75 in wg.
η = .85

$$W_{sh\ total} = \frac{(25{,}000 + 15{,}000) \times (2.75)}{6350 \times .85}$$

$$W_{sh\ total} = 20.4\ HP$$

When the fans are centrally located this results in a fan shaft horsepower of 20.4. The next set of calculations shows what the fan sizes would be for individual fans serving the first and second floor individually.

$$W_{sh\ 1} = \frac{(25{,}000) \times (2)}{6350 \times .85}$$

$$W_{sh\ 1} = 9.26\ HP$$

$$W_{sh\ 2} = \frac{(15000) \times (2.75)}{6350 \times .85}$$

$$W_{sh\ 2} = 7.64\ HP$$

$$W_{sh\ total} = 16.9\ HP$$

When decentralizing the fans it results in a 17% reduction in total horsepower. Since the supply air quantities are much larger in Building A and B it can be assumed that the potential total fan horsepower savings could be significant. For every 1 fan shaft horsepower that is able to be shaved it results roughly in a 0.75 kW reduction in energy usage. A study will be completed in order to determine if the total energy savings potential is able to offset the additional cost of the fan installation and provide a reasonable payback period to the owner.

1.5.2 Backpressure Steam Turbines

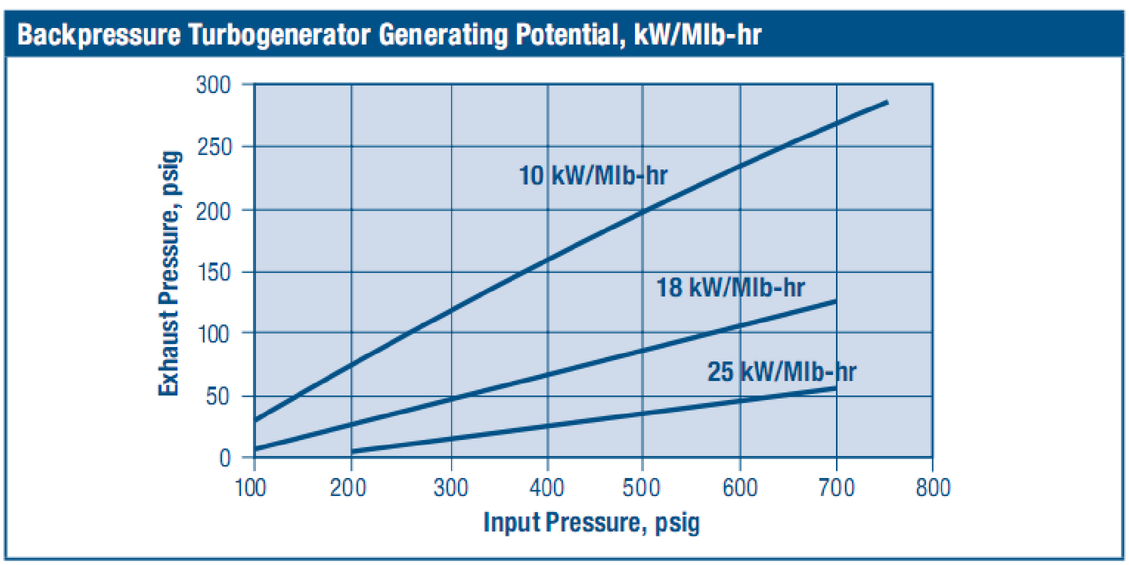
The steam pressure reducing stations that are designed to be installed in Building A will be reducing the steam generated by the campus steam plant to lower pressure to be supplied through the building by using pressure reducing valves in combination with fixed orifice plates. When reducing the pressure of the steam in this way there is a significant amount of wasted energy that is released by changing the pressure of such a large mass. An alternative approach to using pressure reducing stations is through the use of backpressure steam turbines.

Backpressure steam turbines operate similar to turbines that are used in a conventional Rankine cycle power plant. Steam at a high pressure is introduced into the turbine and fed through the blades of the turbines rotor. The blades of the rotor are connected to a shaft which is attached to an electrical generator. The supply steam pressure is reduced when some of the energy in the high pressure steam is used to rotate the turbine rotor blades. After the steam passes through the turbine it exits at the same low pressure that would be achieved after using the pressure reducing station.

Obviously the main advantage in using this approach compared to the conventional steam pressure reduction is the additional electric generation that is achieved from this mechanical process. The main downfall in using a backpressure steam turbine is the large initial cost of the equipment and still the need to install a pressure reducing station in parallel with the turbine in case of turbine failure. While the initial cost may be significant, both of the new buildings on the campus will be utilized well into the future. This presents an opportunity for a case study to take place comparing the payback period to the upfront cost of the equipment.

In order to get a preliminary approximation on how much generation capacity is available in replacing both pressure reducing stations Figure 1 was used from the department of energy. The steam that is supplied to the pressure reducing stations in Building A is at 120 psig and is reduced to 15 psig. When this point is plotted on it falls close to a value of 18 kW/Mlb-hr. The total steam capacity that the pressure reducing station is rated at is 22,650 lb/hr. To get an estimate on the maximum potential electricity generation when using a backpressure steam turbine the steam flow rate and the value from the chart are multiplied by each other to yield a value of 408 kW.

This 408 kW generation would only occur when both buildings are simultaneously calling for their design capacities. The likelihood of this occurrence is rare but if the buildings call for roughly 50% - 75% of their load during the heating season this can result in roughly five months at an electric generation capacity in the range of 204 kW–306 kW. This electric generation will be able to offset a significant portion of the electric demand for both of the buildings and may prove to be a worthwhile investment.



Note: Assumes a 50% isentropic turbine efficiency, a 96% efficient generator, and dry saturated inlet steam.

Figure 1 - Backpressure Steam Turbine Generating Potential

1.5.3 Combined Heat and Power

Combined Heat and Power (CHP) is an alternative technique to conventional heating and electricity distribution. CHP is unlike separate heat and power (SHP) because it is the production of steam while using the exhaust gas for electricity generation. CHP's largest advantage over SHP is that the distribution losses associated with the transmission of electricity across the grid are greatly reduced. Figure 2 below shows the associated losses and thermal input requirements for the same electricity and heat output demands for both CHP and SHP.

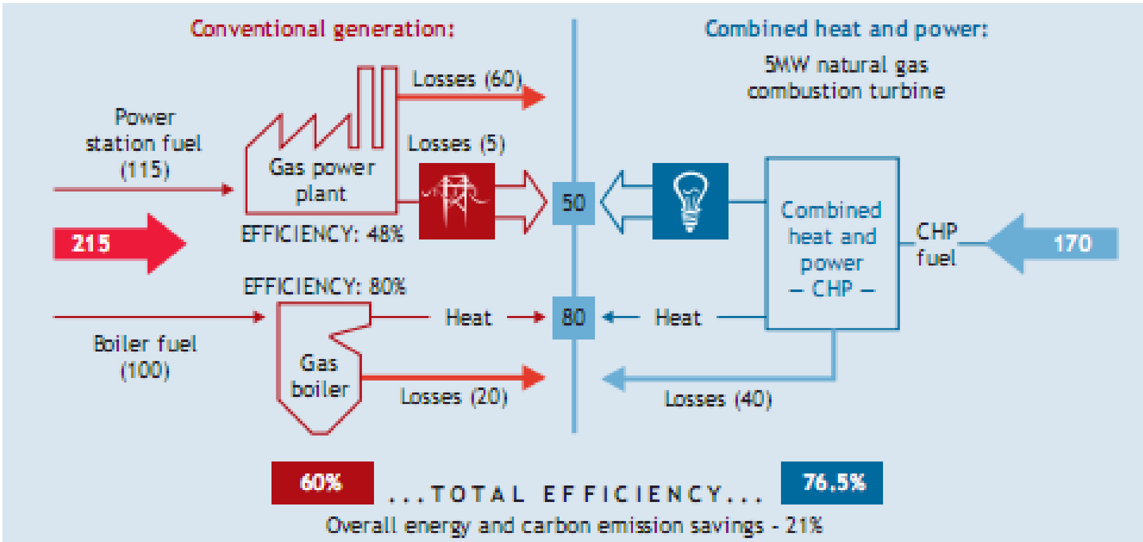


Figure 2 - SHP vs. CHP Input and Losses

The operation of a CHP plant starts with a prime mover which converts the fuel input directly into mechanical power which commonly drives an electric generator. Common prime movers that are utilized for CHP are reciprocating engines, gas turbines, and fuel cells. The hot exhaust gas from the combustion process within the prime mover is then diverted through a heat recovery steam generator or an absorption chiller to produce heating or cooling capacity.

There are a few basic checks that need to take place in order to determine the potential effectiveness of a CHP system for a site. The first value that needs to be investigated is the occurrence of the heating and electricity loads. What is desired about these values is a generally flat load profile throughout the entire day with simultaneous thermal and electric demands due to the large efficiency drop off when generators are throttled to fractional operation. The load profiles of both buildings will be more level than other facilities due to the fact that Building B has 24 hour operation.

Another factor that needs to be considered for the viability of CHP systems is the spark gap which is the price difference between electricity and the fuel that you are using for your system. The larger the spark gap means that utilizing CHP will be more realistic for that particular site application. The spark gap between electricity and natural gas for WRNMMC is 8.9 and the spark gap between campus steam and natural gas is 21. As suggested by the Midwest CHP Application Center a spark gap of greater than $12/MMbtu is usually recommended in order for CHP to be a realistic alternative.

Even though the spark gap between electricity and natural gas is not as high as recommended CHP still may be a worthwhile investment for the owner due to the large spark gap that exists between the campus steam that is currently used. Further investigation will need to be done in order to determine the added initial cost to the system and the total lifecycle cost of the system.

2.0 Tools for Analysis

In order to provide a complete analysis on all of the potential system changes that have been previously described, numerous tools are need to be utilized. A description of the tools that will be employed for each topic above are detailed in the following descriptions.

2.1 Tools for Decentralizing Supply Fan Analysis

The main tool that will be utilized to perform the analysis for decentralizing the supply fans will be a customized program using Engineering Equation Solver (EES). This program along with various Microsoft Excel charts will be able to compare the benefits of adding smaller fans throughout the system while incorporating the additional associated costs. These results may also be entered as an input into the Trane TRACE model that was created for earlier technical reports.

EES is a valuable tool when used for solving large sets of simultaneous equations with exact state property values. Performing parametric studies to conclude how changes with set points such as supply temperature affect other variables within the system is done with relative ease. The main drawback in using this program is the limited user knowledge and difficulty in analyzing errors when they arise within equation sets.

Microsoft Excel is very similar in use to EES except that state functions are not built directly into the program. Excel will mainly be used for this project in setting up large spreadsheets of data with numerous equations and values built within each cells. Again the drawback with using this program is the user knowledge, but for the capacity in which it will be used within the study this is not seen to be an issue.

Trane TRACE is a load and energy modeling software that is able to model in depth various mechanical systems with different configurations. Advantages to using this program are that TRACE is able to run yearly simulations quickly with multiple alternatives to simultaneously compare the results calculated. TRACE also has an excellent user support staff that has been used on numerous occasions to help in creating accurate models and diagnosing file errors. A drawback when using this program is that the equations that are used for the calculations are buried within written code and not easily accessible to the user to investigate how results are calculated. One further drawback, that is associated with all computer programs, is the results that are solely based upon the accuracy of the inputs given.

2.2 Tools for Backpressure Steam Turbine and CHP Analysis

The tools that will be used for this analysis are the same as described in section 2.1. These tools are very versatile in their uses and can be applied to model many different cases. The main tool that will be used within this subsection is Trane TRACE for all of the reasons stated above. Having hourly energy simulations will be able to most accurately convey the benefits of the simultaneous generation of electricity and heat.

Equipment cost data needs to be gathered in order to determine the upfront and life cycle cost data for the proposed system redesign. In order to obtain the most accurate pricing information given today's economy, equipment vendors are going to be utilized as often as possible to ensure pricing accuracy. Some aspects of the redesign will be unable to have cost information provided by the manufacturer so other references such as R.S. Means will be utilized for these areas. Another area that may be used for installation cost information is actual HVAC contractors to receive rough man hour prices to perform various installation tasks.

3.0 Breadth Topics

3.1 Solar Load Reduction

An analysis on the inherent value of solar shading will be considered for both Building A and B. External solar shading was not initially included on the architectural façade due to the requirements set forth by State Historic Planning Commission for the new buildings constructed. With these requirements noted, an analysis will be performed to see the load reduction possibilities for electronically controlled solar shading. Permanent external shading will also be analyzed as a baseline metric to compare the additional cost of the electronic interface that will be required to achieve roughly the same load reduction benefit.

The building load reduction that may be seen after solar shading is analyzed will be put in terms of a total cost savings with energy and equipment. This cost savings when presented to the owner may justify the added cost or architectural façade redesign that may need to take place in order to have this idea approved by the State Historic Planning Commission.

3.2 Central Plant Acoustics

When a change is proposed to the existing mechanical room by the addition of new equipment such as a gas fired turbine, an acoustic evaluation must take place to see what effects have been rendered on the acoustic performance within the space along with adjacent spaces. The acoustics in the mechanical room will change greatly with the addition of equipment for the proposed CHP and backpressure steam turbine investigations. Most likely the result will be an increase in sound level within the space which will need additional absorption and isolation in order to mitigate the travel of sound to the surrounding occupied spaces. This investigation will be into the changes in sound level within the mechanical room and proposed solutions to achieve acceptable sound reduction so disturbances are not noticed within the surrounding spaces.

4.0 Integration of Studies

All of the proposed topics above are related to the addition on a CHP system in order to reduce the utility costs and site emissions for both new buildings. A simultaneous investigation will need to be performed on which combination of the above changes results in reducing the total energy consumption while having a reasonable lifecycle cost and payback period.

The study of adding backpressure steam turbines instead of the pressure reducing valves is directly related to the addition of a CHP system. Backpressure steam turbines can also be coupled with a CHP system for reducing the high pressure steam from the heat recovery steam generator. Performing these studies separately and then integrating the technologies together will determine the individual benefits when used separately as well as when combined.

Both breadth topics also relate directly to the depth topics of study first in the direct result of acoustical noise when adding additional mechanical equipment. Secondly the addition of solar shading will reduce the total load on the building which can reduce the size of the mechanical equipment and CHP system. Due to all of these areas of study being related, the best possible combination potentially may not utilize all of the topics proposed.

Appendix A – Preliminary Research

Agency, I. E. (2008, February). *International Energy Agency.* Retrieved December 6, 2009, from www.iea.org

This article, from the International Energy Agency, details background information on how CHP works along with citing multiple case studies of successful applications. Graphs of the percentage of energy used within various sectors of the economy are also given within the report. Also outlined within the report are the current installed CHP capacities of countries around the world as well as assessing the future capacities that may be realized in the year 2030 under ideal assumptions.

Center, M. C. (2003, September). *Houston Advanced Research Center.* Retrieved December 11, 2009, from http://files.harc.edu/Sites/GulfCoastCHP/Publications/ResourceGuide.pdf

The Midwest CHP Application Center prepared a comprehensive report detailing all steps that must be taken in order to design a successful CHP system. A feasibility evaluation is given to outline the order that information must be gathered in during the evaluation and design phase. Also, many common frequently asked questions are given in the end to dispel any myths as well as promote current technology.

Corporation, O. S. (1999, October). *Department of Energy.* Retrieved December 11, 2009, from http://www.eere.energy.gov/de/pdfs/chp_review.pdf

This report was created for the California Energy Commission and details the various prime mover technologies that exist. The areas of discussion for each prime mover include a description of the technology, design characteristics, performance characteristics, heat recovery applications, emissions, applications, and technology advancements. This is a very comprehensive article that has many valuable areas to compare and contrast the benefits of each prime mover.

Fischer, S. (2004, June). *ASHRAE.* Retrieved December 5, 2009, from ASHRAE: www.ashrae.org

This ASHRAE Journal article states equations and various check values that should be met before a more rigorous investigation of CHP takes place. Typical installed cost data along with operation and maintenance data are given for typical prime movers of varying sizes. Assessing the payback period of installing a CHP system is also talked about within this paper.

Kavanaugh, S. (2009, October). *ASHRAE.* Retrieved December 5, 2009, from ASHRAE Journal: www.ashrae.org

This article from the ASHRAE Journal investigates the results of decentralizing both pumps and fans within building mechanical systems. This article talks about the controllability issues that are raised during decentralization along with the energy savings potential. This article also talks about the kW and horsepower limits that are stated within ASHRAE Standard 90.1 and how they affect the fan choices that are made within HVAC design.

McCoy, G. A. (2006). *Showcase Texas.* Retrieved December 4, 2009, from http://www.showcasetexas.org/FinalPres/PDFs/Galleon%20III/McCoy%20BackpressureTurbine_at_150psigPresentation.pdf

This presentation was given by a member of the Washington State University Energy Program details how to optimize the use of backpressure steam turbines. A case studied about the addition of backpressure steam turbines to the Bremerton Naval Complex is studied throughout. The design process is shown and alternative methods on how to reduce the payback period are given. This case study is on a larger project with over ten pressure reducing stations. Even though the project size is larger the design methodology is still applicable to a project of smaller size.

Program, I. T. (2006, January). *Department of Energy*. Retrieved December 4, 2009, from http://www1.eere.energy.gov/industry/bestpractices/pdfs/steam20_turbogenerators.pdf

This is a small two page article published by the U.S. Department of Energy outlining the use of backpressure steam turbines. This article details the basic operation of how the technology works and gives a figure that was used within the report to check the potential electricity generation when replacing a pressure reducing station.

Zogg, R., Roth, K., & Brodrick, J. (2005, September). *ASHRAE*. Retrieved December 6, 2009, from ASHRAE: www.ashrae.org

This ASHRAE Journal article goes into an analysis on the energy savings potential of CHP along with the market factors that play a role in the selection of a system. One of the key market factors brought up that hurt the implementation of CHP is the fact that most electricity companies still charge the site an electric standby charge incase the CHP system fails. This standby charge can be a significant added cost on a building that is as large as WRNMMC. The article also states that the healthcare industry dominates the commercial CHP applications with roughly two-thirds of the installations which generate greater than 90% of the total capacity.

Appendix B – Preliminary Spring Schedule

ID	Task Name	Start	Finish
1	Semester Start	Mon 1/11/10	Mon 1/11/10
2	Start Fan Decentralization Analysis	Tue 1/12/10	Fri 1/29/10
3	Get Updated Fan Cost Information	Tue 1/26/10	Fri 2/5/10
4	Solar Shading Breadth	Wed 1/27/10	Thu 2/4/10
5	Backpressure Steam Turbine Analysis	Mon 2/1/10	Tue 2/16/10
6	Combined Heat and Power Analysis	Mon 2/1/10	Fri 2/26/10
7	Combined Heat and Power Cost Information	Tue 2/16/10	Thu 2/25/10
8	Parametric Study For All Alternatives	Mon 2/22/10	Mon 3/15/10
9	Spring Break	Mon 3/8/10	Fri 3/12/10
10	Acoustics Breadth Investigation	Wed 3/10/10	Tue 3/23/10
11	Final Report and Presentation	Mon 3/15/10	Mon 4/5/10
12	Final Report Due	Wed 4/7/10	Wed 4/7/10
13	Final Presentation Preparation	Thu 4/8/10	Mon 4/12/10
14	Final Presentaions	Tue 4/13/10	Thu 4/15/10