2010|2011

Mechanical Project Proposal

Duval County Unified Courthouse Facility

Jacksonville, Florida

Zach Polovchik

Mechanical

Advisor: Dustin Eplee

Table of Contents

Executive Summary

The Duval County Unified Courthouse Facility is a 798,000 square foot, 7 level government building that houses 51 total courtrooms, and additional offices and hearing spaces. The facility operates on weekdays with a typical commercial building schedule. The façade is mostly precast concrete panels, but it also includes a large amount of glazing. The climate of Jacksonville, Florida controls a large amount of the load on the building, especially the solar radiation load through the fenestration.

It is currently equipped with 25 Air Handling Units that distribute air through the building. These AHUs are served with outdoor ventilation air by 3 Make Up Air Units. Most areas served by these AHUs are equipped with terminal Variable Air Volume boxes to accommodate for zone conditioning. The heating in the AHUs and VAV boxes is provided by a central heating plant with natural gas boilers on the first floor. The cooling in the AHUs is provided by chilled water that is purchased from a district utility plant and pumped throughout the building.

The object of this proposal is to suggest changes to the system to minimize energy consumption, therefore reducing annual energy expenses. This will also result in a reduction of the carbon footprint of the building, which is a topic becoming more and more popular today. In order to obtain these results, several systems has been proposed as alternatives to the current building systems. These proposals include: Building Envelope Thermal Load Reduction, the Conversion to a Hydronic Thermal Comfort System with DOAS Ventilation, the Implementation of a Facility Chiller Plant, and a Thermal Storage Addition to the proposed chiller plant option.

The implementation of these proposals requires integration within the building and its other systems. Being said, the conversion of the original VAV system to the hydronic and DOAS systems will free up plenum space, allowing the floor-to-floor height to decrease. First cost savings from requiring less building material and construction time will be analyzed with this topic. There is also the possibility that the addition of a facility chiller plant will increase the electricity usage dramatically, while eliminating the purchased chilled water cost. This increase in electricity usage will be offset with the installation of solar photovoltaics to generate electricity on site.

To complete these analyses, tools to calculate the load and energy on the building will be required. Trane TRACE 700 or similar software will be used in conjunction with Microsoft Excel Radiant Time Series Method spreadsheets to calculate load and energy usage of the building. An annual analysis consisting of an 8,760 hour simulation of the facility with its current and proposed systems will be able to provide energy use results that will help decide system selection. Other tools such as Engineering Equation Solver and Microsoft Excel will also be used to do complex calculations regarding sizing equipment and obtaining properties of the proposed equipment.

Mechanical System Description

Mechanical System Design Objectives and Requirements

The Duval County Unified Courthouse Facility is a very large judicial building that requires a system to handle such large floor area and volume of people. The building holds office space for administration and judges, courtrooms and hearing rooms, and a holding area. This being said, the mechanical system does not have to be complex to handle unique loads like laboratories or gymnasiums. The system has loads typical to that of a large office building. The system is designed to meet or exceed the minimum requirements of ASHRAE Standard 62.1 for ventilation and indoor air quality requirements. The system is also designed to meet most of the requirements in ASHRAE Standard 90.1 for energy efficiency. The building will obtain LEED Certification, and the mechanical systems' designs have been designed to earn the necessary LEED credits.

The facility operates on a weekday basis with typical government office building hours. Therefore, the mechanical systems have been designed with setbacks and optimal start and stop controls for higher efficiency and operate at a minimum rate for ventilation during unoccupied hours. Due to the building's location and climate in Florida, the mechanical systems have a large focus on the loads created by the weather. The mechanical system is primarily used for cooling and dehumidification. The facility's heating system is designed to handle the mild winter that the location experiences.

Mechanical Equipment and Operations Summary

The mechanical systems of The Duval County Unified Courthouse Facility include an airside and hydronic side for air distribution and conditioning. Three large Make-Up Air Units bring in the ventilation air for the building. Each of these units is sized for 40,000 cfm of outdoor air. This air is initially conditioned in these MAUs with air filters, heating coils, and a cooling coil. Two of the three MAUs utilize enthalpy wheels to exchange heat with the exhaust air passing through them. This outdoor supply air is distributed to the 25 Air Handling Units around the building that mix the outdoor air with recirculated return air and further condition the air. These AHUs sizes range from 3,300 cfm to 50,000 cfm of total air. The AHUs distribute the air to the zones with terminal VAV boxes. The hydronic side of the system uses heating hot water generated from two on-site 13,390 MBH boilers and purchased chilled water delivered to the site for cooling.

System Evaluation

Due to the large size of the facility, the mechanical system needed to provide a large amount of air throughout the building for ventilation. It did this through selecting three large Make-Up Air Units to distribute air to smaller Air Handling Units that mix and condition the air and send it to the spaces. The design team took advantage of the district chilled water and decided to purchase chilled water instead of operating a chiller plant and generating its own chilled water. The design team has mentioned that the cost of chilled water is expensive in Florida, however. According to utility analysis in the previous section, electricity costs more per unit of energy than chilled water. An option that was considered was to create a chiller plant for the single facility that could more efficiently create chilled water. This could only be feasible, however, by dramatically reducing the cooling loads on the building. The buildings large size, large building envelope area, and large area of fenestration increase the cooling load of the building considerably due to its climate. If these cooling loads can be reduced, the installation of a chiller plant could be practical. Another consideration that could be looked into is moving away from the all air system that is currently utilized. The building uses a total of 28 air handlers to move and condition a massive amount of air. This contributes to a very large amount of electricity being used on fans.

The facility does not lose much usable floor space due to dedicated mechanical spaces. However, the building has very large plenums, most likely due to the ductwork required for the system. The plenums range in size from six to nine feet high. If the plenum sizes can be reduced by using less ductwork in them, a dramatic construction cost could be mitigated.

The facility has attained LEED Certification and can possibly acquire LEED Silver Certification. Most of these credits, however, do not apply to the mechanical systems categories mentioned before. The facility only receives 3 out of the possible 17 points in Energy & Atmosphere. The mechanical systems leave room for energy efficiency improvement. On-site renewable such as solar are also a possibility that can be looked at due to the location's amount of solar gain.

Proposed System Alternatives

A main focus point of the entire proposal is to reduce the cooling loads on the building because they are excessively high due to the climate and large size of the building. Climatic loads are those from the high dry bulb and wet bulb temperatures of outdoor air that must be brought in for ventilation requirements as well as the conductive heat transfer through the building envelope materials and the solar heat gain through the expansive amount of glazing. The following topics are proposed to reduce the cooling load on the building or take care of the cooling load more efficiently. Through this, it may be feasible to implement a chiller plant for the building instead of purchasing chilled water from a district utility plant.

Building Envelope Thermal Load Reduction

The current system is designed to overcome the large cooling loads associated with the thermal and envelope loads of the facility in its climate. The solar load on the building is quite large due to the expansive amount of glazing on the façade walls. It is proposed to reduce the loads on the building through the utilization of shading devices on the windows. There is currently no evidence of internal or external shading on the windows of the facility. Electronically controlled solar shading is to be proposed to track the sun as it follows its path throughout the day. This shading should greatly reduce the solar loads on the building yet still allow adequate visible light into the building and views out of the building. An additional option is to improve the envelope values to be more efficient than Standard 90.1 requirements. An ideal goal to achieve in energy efficiency is 30% better than the requirements mentioned in Standard 90.1. Many building envelope values barely meet the requirements, and the above-grade walls actually do not meet the condition. The option to improve the building envelope values is an additional suggestion in accordance with the solar shading plan to reduce cooling loads on the facility. The roof and wall materials should be changed in order to have assembly U-Values that are more efficient than the standard requirements. The entire building envelope modification plan should provide for a significant drop in the building cooling load.

Conversion to Hydronic Thermal Comfort System with DOAS Ventilation

The facility's HVAC system maintains comfort and indoor air quality levels through the use of an all-air system. This requires many large air handling units to mix air, a significant amount of fan power to move the air, excessive amounts of cooling and heating energy to condition the air, and complex systems of ductwork to transport the air around the building. A different approach to thermal comfort and indoor air quality is to decouple these aspects of the HVAC system into two different systems.

One side can maintain thermal comfort with a hydronic system. This hydronic system would continue to use chilled water for cooling and hot water for heating, but would not be used to condition air that is sent to a space. This system would instead send the water directly to a space to take care of thermal comfort. Water is a very effective means of transferring thermal energy due to its large heat capacity compared to air. Thermal conditioning would be controlled in the zones through use of varying the amount of water flow to the equipment in the space. Equipment that can be used to condition the space could be through the use of fan coil units, chilled beams, or radiant cooling/heating systems that are actually in the space or zone.

The secondary side of the system would take care of indoor air quality through the use of a Dedicated Outdoor Air System. This system would supply only the required amount of outside air to the zone based on its area and occupancy rates. This means that a significantly smaller volume of air has to be moved to the space. This air is initially conditioned upon entering the building in order to control latent heat loads of the building, but most building conditioning will be done with the hydronic system. Energy recovery in such a system is also ideal, and enthalpy wheels to exchange heat between the exhaust air and incoming ventilation air will reduce the amount of energy needed to condition the incoming air.

There is also ability to tie these two systems together in the space through the use of active chilled beams or multiservice chilled beams. These beams condition the space with heating and/or cooling coils in the beam and also bring in the ventilation air at the same location. This saves space and also increases the thermal comfort of the space. The conversion to these two systems can dramatically reduce the amount of air handling equipment, air conditioning equipment, and ductwork. This conversion not only reduces fan energy but also energy utilized for the thermal comfort of the zone. The current system utilizes Variable Air Volume techniques and cannot guarantee the exactly correct fraction of outdoor air to each space. This means that most spaces get an excess amount of outdoor air, requiring extra cooling energy for this air when it is brought in the building. With a DOAS system, the ventilation air for each space can be accurately calculated and the minimum amount of outdoor air can be supplied. With less outdoor air to be conditioned, less energy is required. Less energy should also be required to condition the actual space. The system currently requires a large volume of air to be cooled and then supplied to the space. Due to the higher heat capacity of water, less water, and therefore less cooling energy, can be used by sending the water directly to the space in a hydronic system than by cooling air volumes to be sent to the space.

Implementation of Facility Chiller Plant

The Duval County Unified Courthouse Facility currently purchases chilled water from the J.E.A. Public Utility district plant. The design engineer has mentioned that the price of J.E.A.'s chilled water service is relatively expensive when compared to other locations. The facility will require a relatively large chiller plant to take care of its large loads, however. With the aforementioned proposals, the load building load and demand for chilled water should decrease. This implies that a smaller chiller plant can be used for the same building.

This study will analyze two different types of chiller plant design, these being a vapor compression cycle and an absorption refrigeration cycle. The primary difference in these two cycles is the energy source and the prime mover. Most vapor compression cycles use an electric motor to drive a compressor while absorption processes can be powered by direct firing of fossil fuels and the compressor is replaced with a sorption and desorption process. A vapor compression cycle utilizing water-cooled screw chillers will most likely be the type analyzed for this cycle. A double effect LiBr/H_2O cycle with direct natural gas firing will be the type analyzed for the absorption cycle. These two options are being analyzed because both electricity and natural gas are both available to the site. The utility rates in cost per MBTU of the fuel are described in Table 1 below. The two types are being analyzed due to the large cost difference between electricity and natural gas.

Utility Rates	
Utility	Unit Cost
Electricity	$0.0194/MBTU
Natural Gas	$0.0011/MBTU
Chilled Water	$0.0092/MBTU

Table 1

While an absorption cycle system has a higher first cost than a vapor compression system, its unit energy cost is less. A life cycle cost analysis will be performed on both systems to determine which is ideal for the facility. The unit cost per chilled water is not certain and the actual cost is pending verification from the design engineers in the area.

The feasibility of a chiller plant being applied to this facility depends on the reduction of chilled water capacity for the building. A chiller plant feasibility analysis is going to be investigated for an educational purpose and to gain experience in the field of chiller plant design. Based on which chiller plant is selected, a pumping arrangement analysis will also be compiled if a vapor compression cycle is put into place. The pumping arrangements to be analyzed are primary/secondary and variable primary flow arrangements. These two arrangements differ in the number of pumps utilized and their locations. Primary/Secondary systems maintain constant flow through the chillers that are hydraulically decoupled from the distribution side of the system. Secondary pumps for the system can save energy based on the building loads and help maintain plant stability. A variable primary flow system uses a single pump plant that varies flow through the chillers. This arrangement has a smaller first cost due to fewer pumps and also has less pump energy consumption. However, the controls are more complex and the system is less suitable for absorption cycle chillers.

Thermal Storage Addition to Chiller Plant Option

An option to decrease the size of the chiller plant is possible through the introduction of thermal storage. Thermal storage allows storing cooling capacity that is generated over night in off-peak hours for later use therefore reducing the peak loads. It allows the building to level its load profile. Areas where on-peak electricity charges are higher than off-peak can greatly benefit from these cost savings. This thermal storage process allows for running smaller equipment during these off-peak hours at full load and then using this stored energy during the on-peak hours. Energy efficiency savings are also possible due to equipment rarely running at inefficient part loads. The addition of thermal storage to the proposed chiller plant for the facility would reduce the on-peak cooling hours and lower the operating cost by lowering on-peak electricity use.

Two types of thermal storage are available for research, sensible thermal storage with chilled water and latent thermal storage with ice. Due to space requirements, a chilled water storage system will most likely not be applicable. Ice storage is possible with the space limitations because many smaller tanks can be used inside the building as opposed to one large chilled water tank placed on site. Further analysis of the site, as well as the properties of the proposed chiller plant, will determine which thermal storage system is best.

Breadth Topics

Construction Management – Reduction in Building Height

The Duval County Unified Courthouse Facility currently has a floor-to-floor height of 18 feet. Some rooms, notably courtrooms, have a higher ceiling, but these are still only 13 feet tall. The large ceiling plenums are result from extensive ductwork, VAV terminals, and even entire Air Handling Units placed in the plenum areas. The conversion to a hydronic system with a Dedicated Outdoor Air System requires much less space than the current all air VAV system. The only space required is for water piping, smaller ductwork for ventilation, and smaller equipment for the zones such as chilled beams. With a smaller space requirement, plenum space can decrease, therefore reducing the floor-to-floor height of the building. This reduction in building height will save in materials for the entire building. These include the prefabricated concrete panels and glazing for the façade as well as concrete and steel for the structural system. Once the conversion to the hydronic and DOAS systems has been completed, an analysis on how much space has been saved and reduction in plenum height can be done.

Electrical – Photovoltaic Panel Array

The Duval County Unified Courthouse Facility is located in a climate that has a large amount of solar radiation. The building also has a large area of flat roof that would be ideal for a photovoltaic array. The total roof area that could be suitable for such an array is approximately 100,000 square feet. Photovoltaics (PV) is a method of generating electricity from solar radiation. The PV system converts the incident solar radiation on the panel into direct current electricity. Solar panels can be mounted on this roof area in order to generate this electricity. The growing demand for renewable energy sources has created advances in this technology and more efficient panels are available as well as better funding. Solar panel arrays have the ability to track the sun as it follows its course through the sky in one or two axes, these being the solar angle based on the sun's height in the sky that varies with the seasons, and the time-of-day angle as the sun moves across the sky in the day. This system will have a high first cost, but it is possible that incentives available to decrease the cost of the system. It is not likely that the system will take care of all electrical loads, but the main purpose is to generate some electricity to decrease electricity utility costs of the building, especially if an electric chiller plant is added. The PV array will also make the facility "Greener" and increase the LEED score of the building through use of renewable energy.

MAE Course Related Study

As part of the MAE thesis requirement, graduate level classes must be incorporated into the proposed alternative systems and design. AE 557 is Centralized Cooling Production and Distribution Systems. This class focuses on the design of central chiller plant design and the options available in the practice. The class discusses vapor compression and absorption refrigeration cycles and the associated pumping arrangements of primary/secondary and variable primary flow system. It also introduces thermal storage options for chiller plant design. This course material will be used in the depth analysis of a central chiller plant design and possible thermal storage system of The Duval County Unified Courthouse Facility.

Integration of Studies

All proposed depth ideas for The Duval County Unified Courthouse Facility are integrated in the initiative to reduce loads and energy usage for the building. A reduction of the building envelope loads and necessary cooling capacity allow for a smaller cooling plant to be designed for the facility. A thermal storage study can further reduce the size of the chiller plant and reduce demand loads.

The breadth ideas have two separate goals but both tie back to the main depth goal of energy and cost reductions. The first being a decrease in first cost of the overall building due to the conversion of mechanical systems to save plenum space. With this system change and space saved, the floor-to-floor height is decreased. This decreases required materials and construction time, therefore reducing building first cost. The second breadth includes a higher first cost but will decrease need for purchasing electricity. This idea follows suit with reducing energy costs, especially if an electrically driven chiller is selected for the project. The electricity generated by the solar panel array can help to offset the increase in electricity needed for a chiller plant.

Tools for Analysis

Energy and Load Modeling

To determine building loads and energy usage as well as associated costs, modeling software will be used. Load analysis tools like Microsoft Excel spreadsheets that utilize the Radiant Time Series Method can be used to track the changes in load based on load reducing proposals, as well as for load reductions based on DOAS conversion. More in depth energy modeling software will also be used to collect annual energy usage data for the alternatives. This energy modeling can be done in Trane TRACE 700, Energy Plus, or eQuest. All methods of analysis have advantages and drawbacks. The current building will be further analyzed, as well as an ASHRAE standard 90.1 baseline building, and compared to the different options mentioned in this proposal.

Engineering Equation Solver (EES)

Engineering Equation Solver will be used to do complex calculations that involve the evaluation of the different suggested systems. It can accurately model the analysis of DOAS and hydronic systems, chiller plant design, and thermal storage design. It is capable of providing results such as sizing, capacity, and properties of the aforementioned systems. This program has already been used in many graduate level courses, such as AE 557, for analysis of plant design. Some programming, however, may have to be learned in order to utilize this tool for the analysis of the proposed designs.

Standards and Codes

ASHRAE Standards and Handbooks will be used in the evaluation and design of the proposed mechanical system alternatives. Thermal and ventilation requirements will prove very important in the redesign of the system when implementing the DOAS and hydronic system design. The National Electric Code will also be consulted in the design of the solar panel system design to ensure safety.

Appendix A: Preliminary Research

Building Envelope Load Reduction

Spitler, Jeffrey D. *Load Calculation Applications Manual*. Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, 2009. Print.

- This book describes the process of load calculations provided by ASHRAE. It discusses the load calculation procedure of the Radiant Time Series Method (RTSM). It includes the thermal envelope loads; solar loads; internal loads from people, lighting, and equipment; and infiltration and ventilation loads.

"Chapter 15. Fenestration." *2009 ASHRAE Handbook - Fundamentals (I-P)*. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, 2009. Print.

- This chapter of the ASHRAE Handbook of Fundamentals discusses the load calculations for fenestration on the façade of buildings. It includes analysis on the U-Factor of thermal transmittance and the Solar Heat Gain Coefficient (SHGC) for solar radiation and visible transmittance. It also includes information on shading devices and ways to reduce the solar gain through the fenestration as well the visual and thermal controls associated.

DOAS and Parallel Hydronic System

Mumma, Stanley. "Overview of Integrating Dedicated Outdoor Air Systems with Parallel Terminal Systems." *ASHRAE Transactions*. 107.AT-01-7-1 (2001): 545-552. Print.

Jeong, Jae-Weon, Stanley Mumma, and William Bahnfleth. "Energy Conservation Benefits of a Dedicated Outdoor Air System with Parallel Sensible Cooling by Ceiling Radiant Panels." *ASHRAE Transactions*. 109.KC-03-7-1 (2003): 627-636. Print.

Mumma, Stanley. "Decoupling OA and Space Thermal Control." *IAQ Applications Newsletter* Spring (2002): 12-15. Print.

Alexander, Darren, and Mike O'Rourke. "Design Considerations for Active Chilled Beams." *ASHRAE Journal* September (2008): 50-58. Print.

- These articles discuss the benefits of using 100% outdoor air to take care of ventilation only as opposed to typical VAV systems used for both ventilation and thermal control. The articles explain different applications of DOAS as well as describe different types of terminal units used in these applications for thermal comfort control.

Chiller Plant Implementation

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

- This guide includes design issues such as selection of coils, piping distribution systems, chillers, and controls. It also includes performance specifications. It discusses plant loads and the determination of plant loads, the equipment associated with designing a plant, the distribution systems, and plant optimization and control techniques.

Kelly, David W., and Tumin Chan. "Optimizing Chilled Water Plants." *HPAC Heating/Piping AirConditioning* January (1999): 145-47. Print.

- This article discusses the methods to optimize chilled water plants through chiller and equipment selection to accomplish reduced energy usage and lower first cost.

Bahnfleth, William P., and Eric Peyer. "Variable Primary Flow Chilled Water Systems:Potential Benefits and Applications Issues." *Air-Conditioning and Refrigeration Technology Institute* March (2004). Print.

Kirsner, Wayne. "The Demise of the Primary-Secondary Pumping Paradigm for Chilled Water Plant Design." ." *HPAC Heating/Piping AirConditioning* November (1996): 73-78. Print.

- These articles explain the benefits and key issues of using a Variable Primary Flow pumping arrangement over a primary/secondary system in a chiller plant. The first explains the energy consumption savings that are possible by varying the flow through the chillers and its lower initial cost. It also includes surveys from designers, manufacturers, and owners as well as case studies on the topic. The second article explains the problems known with the typical primary/secondary arrangement.

Thermal Storage

Bahnfleth, William. "Cool Thermal Storage: Is It Still Cool." *HPAC Engineering*. April (2002): 49-53. Print.

- This article discusses the application of thermal storage system and discusses load factors, peak load shaving, and load leveling. It also discusses the great benefits of integration of thermal energy storage systems with other building systems. One method of integration it discusses is that with thermal energy storage and DOAS.

MacCracken, Mark M. "Thermal Energy Storage Myths." *ASHRAE Journal* September (2003): 36-42. Print.

- This article works to disprove common myths about thermal energy storage. This is a Pro-TES article that explains negative myths about the system. These include myths such as too risky and complicated, requires too much space, no energy savings, etc.

Nagengast, Bernard. "A History of Comfort Cooling Using Ice." *ASHRAE Journal* February (1999): 49-55. Print

- This article gives a summary of how thermal storage with latent ice systems works. It explains that ice storage has been used for many years and the technology for it has expanded greatly.

Appendix B: Proposed Schedule