SHA HEADQUARTERS

707 N. Calvert St. | Baltimore, MD

Thesis Proposal

Mechanical System Renovation

Construction Management
&
Lighting/Electrical Breadths

Stephanie Kunkel | www.engr.psu.edu/ae/thesis/portfolios/2011/slk5061 | Mechanical Option

Dr. Bahnfleth | December 10, 2010

Table of Contents

EXECUTIVE SUMMARY

The Maryland State Highway Administration (SHA) Headquarters is located in downtown Baltimore and occupies two office buildings, 707 and 211, which were both originally built in 1959. This report's focus is on the 707 N. Calvert Street building, a 6 story office building with two levels of parking in the Basement and Subbasement; the Basement level also includes a print shop as well as some office space. With each floor approximately 29,000 square feet, the total renovation cost is $4,435,500.

Over the past semester, this thesis has been dedicated to the research and analysis of The Maryland State Highway Administration (SHA) Headquarters 707 Building's existing mechanical system. In Technical Report I, the building was analyzed and found that it exceeded the minimum ventilation requirements set forth in ASHRAE Standards 62.1 and 90.1. Trane TRACE 700 was used in Technical Report II to provide a building load and energy analysis of the current system; thus allowing heating and cooling loads to be calculated and annual energy consumption and operating cost to be estimated. The existing conditions of the complete HVAC systems that were installed in the 707 Building and a LEED analysis were performed in Technical Report III.

The objective of this Thesis Proposal is to explore design alternatives, ultimately applying changes that would, in some way, enhance the present system. A critique of the renovated system can be found later in this report. Active chilled beams were determined to be the best replacement of the current 534 perimeter induction units since they themselves are modern induction units. Interchanging the active chilled beams in the office space will lead to an increase in building usable square footage.

Two breadth topics were also evaluated based off of the implementation of this redesign. A lighting/electrical breadth will examine the benefits of multiservice integration within the chilled beams in the office space. The other breadth, construction management, will evaluate the potential cost and schedule savings of integrating the lighting and/or sprinkler systems into the one single active chilled beam.

MECHANICAL SYSTEM SUMMARY

The 707 building's mechanical system is comprised of two low pressure central station air handling units (AHUs) serving the central core of the building and one high pressure central station AHU serving the central core of the building. Cooling is provided by a chilled water plant, utilizing a centrifugal chiller and an updraft cooling tower, while heating is provided by two low pressure steam boilers and a steam-to-hot water heat exchanger. Overall, the components of the system include 3 constant volume built-up AHUs, 534 perimeter induction units with no operating fans on the 6 office levels, 18 VAV boxes that serve individual areas, a chilled water/hot water indoor unit, and a chilled water/steam indoor unit. An expansive description about the mechanical system design can be found in the following section.

OVERALL SYSTEM EVALUATION

In Technical Report III, a complete system evaluation was performed. Evaluations of the existing and renovated design systems in the areas of construction cost, maintainability, operating cost, and mechanical space requirements, were made. With each floor approximately 29,000 square feet and the total usable square footage occupied by mechanical systems comes to be about 1,500 square feet, the total renovation cost is $4,435,500.

The 707 building meets, and in some cases, exceeds the minimum ventilation requirements based upon Section 6. When determining the population density, the conference rooms were left empty so that the block load would be more accurate. The 707 building was mostly compatible with Standard 90.1 – 2007. The non-compliant fields only make up a fraction of the total building system. ASHRAE Standards 62.1 and 90.1 are necessary items to improve upon when striving towards an energy efficient, healthy building. Overall, 707 should be evaluated as adequate, but definitely needs enhancement, in both Standards. Consistent with these Standards, through more renovations and efficient equipment choices, the 707 building could advance its current condition to one that features commendable indoor air quality and energy efficiency.

According to the energy analysis results from Technical Report II, the 707 building consumes 1,743,765 kWh of energy annually. Knowing the monthly energy usages, an annual building operating cost analysis was performed in Technical Report II. Utility rates for both electricity and natural gas, from the Baltimore Gas and Electric Company (BGE) website were manually inserted into TRACE in the form of utility schedules, so that the energy consumption could be calculated in a yearlong energy simulation. The total annual utility cost that was totaled for the consumed electricity and natural gas is $200,808 or 1.17 $/sf.

Areas of improvement may produce hefty savings in energy and renovation costs. From increasing building usable square footage, to quickening the construction schedule, there are many opportunities for improvement of this 51 year-old building. These, and more, design modifications will be studied during this, and following, reports.

MECHANICAL SYSTEM DESIGN

This section describes the current renovation plans – including what is presently unsuitable within the 707 Building's mechanical system.

Current Design Objectives, Requirements & Influences

The intent of renovating the 707 Building is to improve system reliability, energy efficiency and occupant safety and comfort. The options for renovation were compared using the following criteria: disturbance to Operations (during construction), maintenance requirements of the proposed system, simplicity of the system control strategy, robustness (system resistance to failure – may be in conflict with maintainability). The winning bid for the following renovation plans totaled at $4,435,500, or about $18.90/sf.

Many options were considered for the HVAC renovation of the 707 Building. The current plan is to have nine total phases that will be performed so that work can be completed while maintaining building operations. Due to limited relocation space, a maximum of 20 people can be removed from their areas at a time during the renovation. The contractor will be responsible for submitting a phasing plan and coordinated schedule which will achieve this goal.

To prevent system failure and improve the current levels of building comfort, system reliability and operating efficiency, much of the outdated and dilapidated mechanical system will be replaced. This option is intended to improve comfort to occupants and system efficiency, and lessen maintenance costs as the equipment will be new.

Since much of the equipment at the 707 Building has exceeded its expected service life, it will be replaced to maintain reliable building operation. The following equipment should be replaced with similar equipment: AHU's, the original boiler and pumps. The new AHU's will be equipped with supply fan and return fan VFD's; adding return fans and VFD's will allow proper control of building pressurization and ventilation. The induction unit secondary water system will be modified to only provide reheat water. Also, the existing building automation system will be replaced. Once there are supply fan VFD's and a new controls system, zone dampers can be added for each half of a floor.

The current option for the perimeter spaces' replacement is for the 534 induction units to be replaced, in kind. This requires installation of new floor mounted induction units, cleaning the vertical ducts, adding new branch ducts from the existing verticals, and all new dual temp piping, control valves, and thermostats and tie into BAS. Advantages of this option include limited building operation disturbance, little architectural work needed, and increased system efficiency. The main disadvantage is that this option does not provide any increase in usable floor area. Other impacts of these interior improvements are the cause of the occupant relocation (2 weeks per floor), and system outages of approximately 1 week during equipment replacement.

PROPOSED SYSTEM ALTERNATIVES

After analyzing the problems that have emerged in the existing system, research was performed to examine potential alternatives. The alternatives that are described in the following section may aid in decreasing maintainability issues, while increasing the thermal comfort of the occupants and overall indoor air quality.

Active Chilled Beams (ACB's)

Due to the various design options, the current 534 perimeter induction units can be replaced by active chilled beams (ACB's) because they use forced air induction to both heat and cool a room. Since the induction principle causes a secondary air flow through the heat exchanger, induction units don't require an additional fan.

As seen in Figure 1, the operation of ACB's occurs when primary/ventilation air supply is introduced into the beam through a series of nozzles. This process induces room air to rise to the ceiling and into the ACB, which in turn pulls the air through a secondary water coil. Induced room air is cooled and/or heated by the water coil to the extent needed to control the room temperature. Induced room air is then mixed with the primary/ventilation air and discharged into the space through a diffuser. This ACB induction is less noisy than traditional induction units and also requires less maintenance.

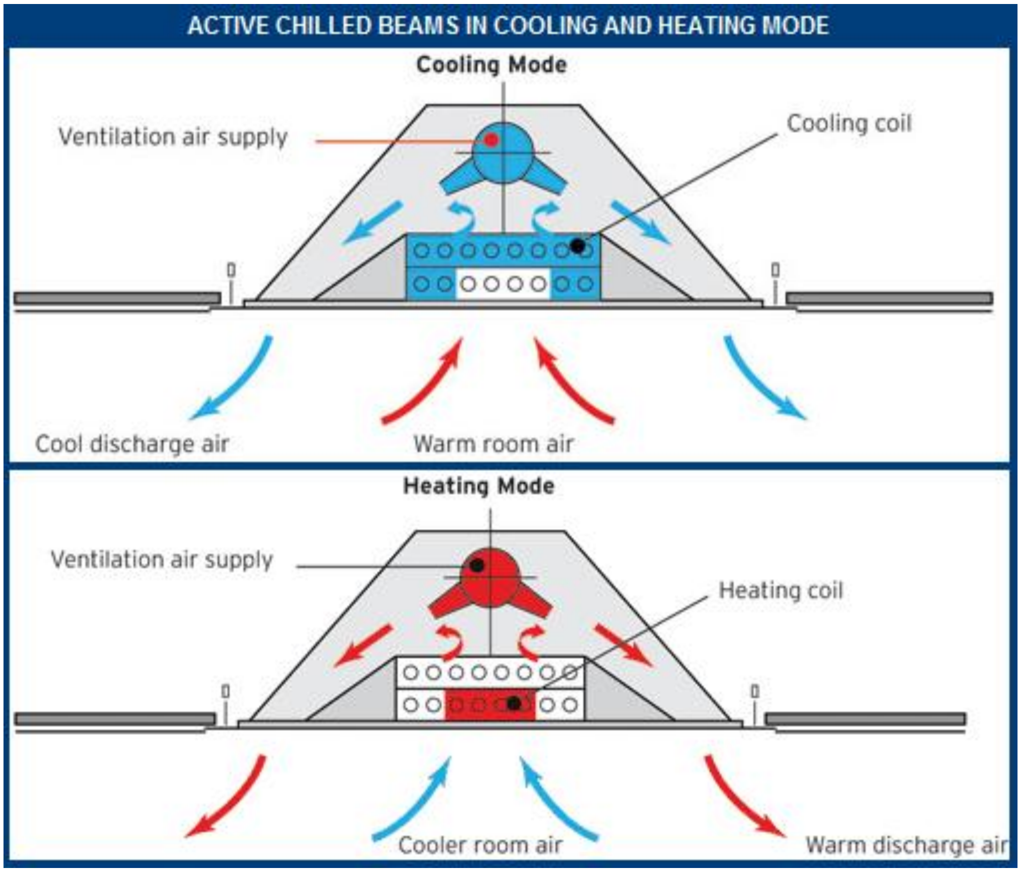

Figure 1: Active Chilled Beams in Cooling and Heating Modes (Courtesy of SmithGroup)

ACB's are the 3rd generation of chilled beam technology and can take care of both the sensible and latent heat gains of a room in a single package and can be operated singly or grouped for zone control. While the room still requires air ducts and the ventilation must be hooked up to the beam, all HVAC requirements can be handled in a single unit.

Additional Mechanical Systems Replacement

With the replacements of the perimeter wall induction units, a resize of the chiller and boiler is inevitable. As previously mentioned, the AHU's have surpassed their expected life and will also need to be replaced.

Mechanical System Space Requirements

The total space that was allocated for mechanical system components is outlined in Table 1, below. The 707 Building's mechanical system renovation requires the replacement of 534 induction units, in kind. This involves the installation of new floor mounted induction units; the main disadvantage of this act is that it does not provide any increase in usable floor area. The area occupied by the VAV boxes and ceiling ductwork was not taken into account during this takeoff. Since most of the mechanical equipment is located in the Penthouse, usable floor area taken up by these systems is minimal for such a large building. Summing the information from the table below, the total square footage occupied by mechanical systems comes to be roughly 1,500 ft^2. With a redesign using ceiling mounted ACB's, the usable square footage will certainly increase.

Table 1: Mechanical Space Requirements

	Area (ft^2)
Induction Units	1,112.5
Basement AHU's	130
Vertical Shafts	256

BREADTH TOPICS

When implemented, any mechanical system redesign will consequently alter other building systems. After feedback from design engineers, the following construction management and lighting/electrical breadths will be analyzed during the Spring 2011 Semester.

Construction Management

This construction management breadth will investigate the potential savings in construction costs and installation schedule. With the design engineer's current prediction of a lengthy 9 phases being implemented in the 707 Building systems renovation, a more rapid installation schedule will be examined. Specific research will be gathered for the cost, schedule, and commissioning for any change to the mechanical system.

Designing a system with chilled beams leads to the ability to combine several services in a single integrated unit. Aside from known HVAC services, a full range of building services such as fully addressable lighting solutions, fire alarms, and sprinkler heads can be incorporated into the beam. A decrease in costs and on-site installation time is nearly guaranteed by incorporating fire protection and/or lighting features into the beam.

Lighting/Electrical

A lighting/electrical breadth will examine the benefits of multiservice integration within the chilled beams in the office space. A reduction in the cooling load is also plausible with this renovation. With the resizing of the chiller and boiler, an alteration in electric load will most likely occur. Design loads for the building's current electrical distribution system will be compared to the redesigned system. An electrical study will be performed comparing the current electric load output to the renovated one.

TOOLS FOR ANALYSIS

The following is a description of tools and methods that will be used to substantiate and ensure the work that will be put forth throughout the redesign of the 707 Building.

Building Loads

Trane TRACE 700 will be used to model the new systems and calculate new building loads. The loads, along with the output energy usage and utility cost will then be able to be compared to the original design. If needed, this information will help to resize equipment such as the boilers and chillers. Early research is required in order to accurately model the active chilled beams since they are still an emerging technology. To determine the legitimacy of the results, they will be compared to building energy data found in the Commercial Building Energy Consumption Survey (CBECS).

Construction Management

Any cost information needed that cannot be obtained from the project manager, design engineer, or approved submittals will be referenced from RS Means. Once the scheduling data is supplied by JMT, Microsoft Project will most likely be used to rework the renovation schedule.

Lighting/Electrical

An electrical analysis will be run using TRACE to determine the overall effect in reducing the cooling load by implementing active chilled beams. Data sheets in Microsoft Excel will also be utilized to compare and contrast the differences between the systems.

REFERENCES

"Designing Chilled Beams for Thermal Comfort." ASHRAE Journal, October 2009.

The article that appeared in the 2009 October issue of the ASHRAE Journal describes how ACB's are both an in-room space conditioning device and the room air diffusion device. ASHRAE Standard 55-2004 for thermal comfort is used to help sizing and locating the beams for acceptable levels of occupant thermal comfort.

"Design Considerations for Active Chilled Beams." ASHRAE Journal, September 2008.

The article that appeared in the 2008 September issue of the ASHRAE Journal describes how ACB's are gaining popularity in managing large sensible cooling loads while using as little as only the required ventilation air. It also describes the various ceiling installation applications that can be utilized.

"Active Chilled Beams Frequently Asked Questions." DADANCO LLC, July 2009.

This document includes information on comparing ACB's to other alternatives, air and water-side application considerations, heating, installation, controls, commissioning and maintenance.

"Induction Units Frequently Asked Questions." DADANCO LLC, December 2007.

This document includes information on improving existing induction systems, air and water-side application considerations, controls, commissioning and maintenance.

APPENDIX A – PRELIMINARY SPRING SCHEDULE

Task Name	Start	Finish
CLASSES BEGIN	Mon 1/10/11	Mon 1/10/11
Research Active Chilled Beams	Mon 1/10/11	Sun 1/16/11
Mechanical System Upgrades	Wed 1/12/11	Thu 1/20/11
Canning Weekend #3	Fri 1/21/11	Sun 1/23/11
Create new TRACE files for ACB	Mon 1/24/11	Fri 1/28/11
ASHRAE National Conference 2011	Fri 1/28/11	Wed 2/2/11
L/E Breadth	Thu 2/3/11	Fri 2/18/11
THON 2011	Fri 2/18/11	Sun 2/20/11
CM Breadth	Mon 2/21/11	Sat 3/5/11
SPRING BREAK	Sat 3/5/11	Sun 3/13/11
CM Breadth	Mon 3/14/11	Wed 3/16/11
Organize Final Report	Wed 3/16/11	Fri 3/18/11
Finalize CM Breadth	Thu 3/17/11	Fri 3/18/11
Final Report and Presentation	Fri 3/18/11	Thu 4/7/11
FINAL REPORT DUE	Thu 4/7/11	Thu 4/7/11
Practice Presentation	Fri 4/8/11	Mon 4/11/11
FACULTY JURY PRESENTATIONS	Mon 4/11/11	Fri 4/15/11