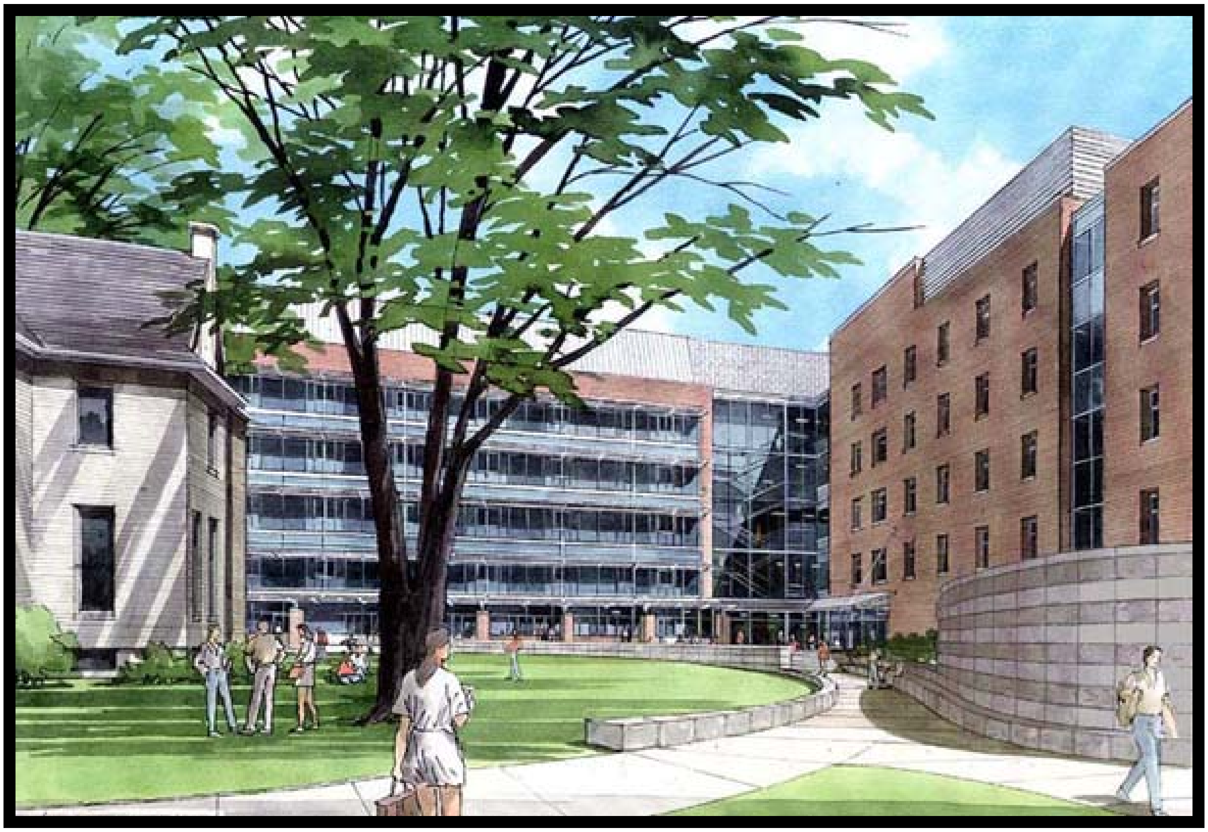
SENIOR THESIS PROPOSAL



THE PENNSYLVANIA STATE UNIVERSITY CHEMISTRY BUILDING

UNIVERSITY PARK, PENNSYLVANIA

PREPARED FOR:
DR. SREBRIC
ASSISTANT PROFESSOR
THE PENNSYLVANIA STATE UNIVERSITY OF ARCHITECTURAL ENGINEERING

BY:
ADAM J. SENK
MECHANICAL OPTION
DECEMBER 9, 2005

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report contains proposed changes redesign topics for the Pennsylvania State University Chemistry Building located at the University Park, PA Campus. The ventilation requirements of laboratory facilities are complex compared to other building types. The chemistry Building uses a ventilation system as the primary safety shield, not only for the researchers working at the fume hood, but also for all building occupants by preventing noxious fumes from migrating outside the lab. Maintaining proper room pressurization requires that the total exhaust and make-up air supply always be balanced. In addition to safety, comfort must also be maintained in spaces that require conditioning as continuous supply of outside air. The energy costs for operation of a laboratory facility are quite high due to ventilation requirements. This paper will develop on saving energy while still fulfilling those ventilation and thermal comfort requirements. The paper will first develop on the existing systems in place, which will lead into considered alternatives for those systems. And will be followed by a proposed redesign to make the building more efficient. The redesign will be supported by a justification section, and integration/coordination section. Other additional improvements to the building will be mentioned in a breadth section. A proposed method for completing this redesign and schedule for doing so will follow last.

The redesign will look at the implications of using a VAV system for its energy saving qualities. The new VAV system will produce a pressure independent system by varying exhaust and supply. The redesign also includes a heat recovery system between exhausted laboratory air and outdoor air intake, and the changing from electric chillers to steam driven chillers for energy conservation.

Breadth areas include a smoke evacuation design for an atrium space, and acoustical design to reduce noise carry over between labs and office spaces.

BUILDING BACKGROUND

The Pennsylvania State University Chemistry Building is located on Penn State's University Park, PA campus. The building is occupied by the Penn State University Chemistry Department, and carries out a multitude of functions for the Department. These functions include classrooms, offices for professors and grad students, and a large variety of laboratory spaces. Laboratory spaces have many variations such as chemistry, synthetic chemistry, biology, radio isotope, large instruments, medium instruments, and small instrument laboratories.

The building overall size is 181,890 square feet. Five floors along with a mechanical penthouse and basement area make up the Chemistry Building.

SYSTEM OVERVIEW

AIR SIDE SYSTEM

Conditioned air is supplied from four air handlers AHU-1 (90,000 cfm), AHU-2 (90,000 cfm), AHU-3 (100,000 cfm), and AHU-4 (100,000 cfm). Air handlers AHU-1, AHU-2, and AHU-3 are constant volume air supply which supply the laboratory spaces throughout the building. In addition, these air handlers are 100% outdoor air to satisfy the building ventilation requirements. Air handler AHU-4 is a variable volume air supply comprised of 25% outdoor air. This air handler supplies the offices, conferences, and computer labs. The conditioned air for the building is supplied to each level through one of three central mechanical shafts.

Air is continuously exhausted from laboratory areas on each level. Each run of exhausted air travels to the penthouse were it is exhausted into a plenum. The plenum air is then exhausted through the roof through an exhaust stack. The air exhausted uses the same mechanical shaft as the conditioned air does.

STEAM SYSTEM

Steam service enters through the basement wall as HPS. It first passes through a steam meter; it then branches off into three branches. One branch will directly feed into CP-1. The other two branches will travel through a series of pressure reducing valves PRV-1A and PRV-B for LPS, and PRV-2 for MPS. The LPS will travel directly to the penthouse to HE-1 and HE-2(Stand-By). LPS will also be distributed to AHU-1, AHU-2, AHU-3, and AHU-4.

The MPS will be distributed to HE-3 and HE-4 in the basement for the building hot water, and to the 2nd and 3rd floor for autoclaves to sterilize lab equipment.

Condensate is drained to the basement and pumped back to the cogeneration plant by CP-1 through the service pipe which enters next to the steam service pipe.

HOT WATER SYSTEM

Hot water will be generated at HE-1 and HE-2 by LPS. The hot water will first pass through expansion tank TK-1 and an air separator before entering HWP-1 and HWP-2. HWP-1 (570 gpm) and HWP-2 (570 gpm) pump the hot water to 6 other hot water pumps and 10 outlets on the six levels of the building which feed VAV and CAV boxes. The six hot water pumps supply the building façade with conditioned water. HWP-3 (32 gpm), HWP-4 (44 gpm), HWP-5 (44 gpm) supply the North and South facade VAV and CAV boxes. HWP-6 (20 gpm), HWP-7 (25 gpm), and HWP-8 (10 gpm) supply the East and West facade VAV and CAV boxes.

CHILLED WATER SYSTEM

Chilled water service enters through the basement foundation wall. The chilled water immediately passes through an air separator and expansion tank TK-2. The water then travels to CHP-1 (2,022 gpm), CHP-2 (2,022 gpm), CHP-3 (2,022 gpm), and CHP-4 (2,022 gpm) were it is pumped to CH-1, CH-2, and CH-3 for further cooling. The water is then pumped to AHU-1, AHU-2, AHU-3, and AHU-4 or to PCHP-1 and PCHP-2. Water traveling to the air handlers will pass through the cooling coils for cooling air supplied by the handler. Water traveling to PCHP-1 and PCHP-2 will travel through an air separator and expansion tank TK-3 before traveling to HE-3 and HE-4 for further cooling before continuation on to the VAV and CAV boxes on the 6 building levels.

CONDENSER WATER SYSTEM

Condenser water is supplied to the mechanical equipment in the basement using 6 pumps. CWP-1 (3,823 gpm), CWP-2 (3,823 gpm), CWP-3 (3,823 gpm), and CWP-4 (3,823 gpm) supply condenser water to CH-1 (1,350 tons), CH-2 (1,350 tons), and CH-3 (1,350 tons). CWP-5 (360 gpm) and CWP-6 (360 gpm) supply the heat exchanger HE-4 which conditions chilled water traveling to the VAV and CAV boxes. The returned condenser water from the mechanical equipment is then pumped to the roof where it will reconditioned by cooling towers CT-1 (1,015 tons) CT-2 (1,015 tons), CT-3 (1,015 tons), and CT-4 (1,015 tons) before returning to the pump stations.

ELECTRICAL SYSTEM

The building is serviced by Allegheny power, which supplies 3,000 AMP, 480/277V 3-Phase, 4 wire service. The building also has a back up system in place, an emergency generator located in the basement. The generator supplies 5,000 kW/625 kVA, 480/277V 3-Phase, 4 Wire electrical services on stand-by.

CONSIDERED ALTENATIVES

The Pennsylvania State University Chemistry Building offered many opportunities to change and explore ways to conserve energy. The building is not typical in the sense it is not primarily comprised of office space or classrooms as most building located on the campus. Instead the majority of the building space is consumed by laboratory facilities. Because of the facility being comprised mostly of laboratory spaces, the ventilation systems are very complex, and account for a large amount of energy consumption in order to keep the spaces at proper pressurization and thermally comfortable.

An initial idea to solve the large amount of electricity the building consumed was to attack the chiller plant located in the basement of the building. The chiller plant is comprised of three electric chillers. The first alternative considered was to replace these chillers with absorber chillers using byproduct steam from the cogeneration plant supplying the building already. Yet, after comparing dimensions and efficiencies to that of steam driven chillers, it seemed more economical and space efficient to use steam driven chillers.

Additional ideas were to save energy by recovering some of the energy from the air being exhausted to meet the ventilation requirement. Ideas include using a sensible wheel to transfer heat from exhausted air to outdoor intake air. The problem with this solution is that the air being exhausted is full of contaminants. A special setup would be required to clean the contaminants off the wheel to avoid cross contamination between air streams. However, after considering the space confinements a different method was sought that was not so space intensive. A second solution was determined to be an air to air heat exchanger. This solution was not as space intensive as the sensible wheel. Although both solutions involved the rerouting of duct work to be near one another so that the exchangers could be implemented. Once again, space requirements restricted this being a viable solution. Because of the space restrictions it was thought that the best solution would then be a recirculation loop using a heat exchanging coils in the exhaust stream and intake air stream. This seems to be the best solution due to the fact the piping needed will be small enough that it will be easily routed around existing equipment. Using this solution to energy conservation will also allow additional financial savings. Additionally implementing a heat recovery system permits the resizing of building mechanical equipment to smaller sizes.

Other areas explored were the use of radiant floors for the spaces served by AHU-4. This solution was ruled out do to the feasibility of implementation. The initial cost of the equipment greatly out weighed the benefits. Furthermore, the space confinement limitations made it difficult for additional pump stations to be erected in the basement or penthouse areas.

PROPOSED REDESIGN

SCOPE

The ventilation requirements of laboratory facilities are complex compared to other building types. The chemistry Building uses a ventilation system as the primary safety shield, not only for the researchers working at the fume hood, but also for all building occupants by preventing noxious fumes from migrating outside the lab. Maintaining proper room pressurization requires that the total exhaust and make-up air supply always be balanced. In addition to safety, comfort must also be maintained in spaces that require conditioning as continuous supply of outside air. The energy costs for operation of a laboratory facility are quite high due to ventilation requirements. Because of these reasons, I would like to look at the implications of using a VAV system for its energy saving qualities. By doing so, I hope to produce a pressure independent system by varying the exhaust and supply.

Furthermore, a large of amount of conditioned air is leaving the building, an additional energy consumption savings could be saved through heat recovery. Many of the fume hoods are connected through common ducting which leads to the penthouse. Before the air is exhausted into a plenum space, passing through heat recovery coils will allow recovery of some energy that would otherwise be lost. The energy recovered could be used to condition the incoming outdoor air.

Another solution, for energy conservation for the Chemistry Building, is to investigate whether or not the cogeneration power plant has the steam capacity to change the electrical chillers in the Chemistry Building's Chiller plant to steam driven chillers.

JUSTIFICATION

As mentioned previously, the energy costs for operation of a laboratory facility are quite high due to ventilation requirements. With growing energy rates it is in the best interest of the university to lower operating cost and make the building as efficient as possible.

INTEGRATION & COORDINATION

The largest issue with integrating this new design into the old design is space constraints. Since the building has already been erected and operating well over a year now, space adjustment will be limited, which may cause difficulties in areas with the change out from a constant air volume system to a variable volume system.

Additional space limitations will be noted in mechanical areas, such as the basement. The replacement steam driven chillers will have to meet a space criteria not only to fit, but also to be operable in the space where they will be located. Room will need to be acquired in order to run steam to these chillers. Also, the service steam line will need to be evaluated for capacity. However, this whole process is pending on whether or not the cogeneration plant has the capacity to supply the needed amount of steam to the Chemistry Building.

BREADTH AREAS

Additional area to be redesigned is an atrium space. The space is comprised of a stair and elevator lobby which connects the 1st through 5th floors. A smoke evacuation is required by code to all atrium spaces by the mechanical code. An atrium space is defined as any space which is connected to another above it without any physical barriers. Atrium spaces cause significant problems with smoke during fires, in addition to creating a path for the fire to spread from floor to floor. During the design of the Chemistry Building the smoke evacuation system was left out, due to money constraints and having egress ways located in close proximity to the location of the atrium. Implementing, an exhaust fan and make-up air fan, sized using the NFPA guidelines will increase the safety of personnel occupying the building.

Other breadth topics include acoustics for the numerous conference and meeting spaces around the laboratory spaces. The laboratory spaces have a much higher noise criterion due to the large amount of equipment in use and the exhaust fans that run continuously. After surveying the building, it was noted that noise carried from lab areas to these conference and meeting spaces. Redesign of the duct lay out and incorporation of sound attenuation equipment and sound absorbing materials will reduce or eliminate the noise coming from the laboratory spaces and allow them to become more functional spaces for education.

PROJECT METHODS

To analyze the systems that are being proposed will require the use of different tools. For the consideration of switching out the CAV system to a VAV system the Carrier Hourly Analysis Program (HAP), or Trace will be utilized to determine the new loads and equipment sizing.

Additional programs for the control sequences and heat recovery technology will be found at Phoenix Laboratory Controls Corporation Website.

The design of the smoke evacuation system for the atrium space will be initially designed using the most recent version of the Mechanical Code. After the exhaust fans and make-up fans are sized and their positions are calculated, a model will be developed using NIST developed by the NFPA. After the model is developed, running the model will determine plume sizes and smoke ceiling heights. Additional information which will be able to be gathered is temperature slices from the 5^{th} to 1^{st} floors to show temperature stratification. Information gathered from this program will determine whether the system implemented meets the requirement set.

Acoustics will be evaluated using methods learned in AE 458 (Advanced Acoustics), and consultation with Courtney Burrows, instructor for Advanced Acoustics. Additional evaluation of the spaces will be done using the acoustic program TAP.

PROPOSED SCHEDULE FOR SPRING SEMESTER 2006

The following is a tentative schedule for next semester's senior thesis workload.

January 2006

AE SENIOR THESIS PROPOSAL SCHEDULE

Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	2	3	4	5	6	7
8	9 Research VAV Lab Setups	10	11 Faculty Consultation	12	13 Work Period	14
15	16 Research Absorption & Steam Driven Chillers	17	18 Faculty Consultation	19	20 Work Period	21
22	23 Research Heat Recovery Coils & Circuits	24	25 Faculty Consultation	26	27 Work Period	28
29	30 Research Fume Hoods	31				

February 2006

AE SENIOR THESIS PROPOSAL SCHEDULE

Sun	Mon	Tue	Wed	Thu	Fri	Sat
			1 Faculty Consultation	2	3 Work Period	4
5	6 Research Lab Controls for VAV & Fume Hoods	7	8 Faculty Consultation	9	10 Work Period	11
12	13 Load Analysis	14	15 Faculty Consultation	16	17 Work Period	18
19	20 Run Analyses	21	22 Faculty Consultation	23	24 Work Period	25
26	27 Integrating Proposed Systems	28				

March 2006

AE SENIOR THESIS PROPOSAL SCHEDULE

Sun	Mon	Tue	Wed	Thu	Fri	Sat
			1 Faculty Consultation	2	3 Work Period	4
5	6 Spring Break	7 Spring Break	8 Spring Break	9 Spring Break	10 Spring Break	11
12	13 Integrating Proposed Systems	14	15 Faculty Consultation	16	17 Work Period	18
19	20 Buffer Week For Unre-solved Issues	21	22 Faculty Consultation	23	24 Work Period	25
26	27 Thesis Report Write-Up	28	29 Faculty Consultation	30	31 Work Period	

April 2006

AE SENIOR THESIS PROPOSAL SCHEDULE

Sun	Mon	Tue	Wed	Thu	Fri	Sat
						1
2	3 Practice Thesis Presentation	4	5 Faculty Consultation	6	7 Practice Thesis Presentation	8
9	10 Thesis Presentations	11 Thesis Presentations	12 Thesis Presentations	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

REFERENCES

- 2005 ASHRAE Handbook of Fundamentals. ASHRAE Incorporated. Atlanta, GA. 2005
- 2005 ASHRAE Handbook Systems and Equipment. ASHRAE Incorporated. Atlanta, GA. 2005
- Steam Generation and Use. Babcocks and Wilcocks. NY, NY 1973
- ASHRAE/IESNA Standard 62-2004. ASHRAE Incorporated. Atlanta, GA. 2004
- ASHRAE/IESNA Standard 90.1-2004. ASHRAE Incorporated. Atlanta, GA. 2004
- Adam Senk’s Technical Report 1 for AE 481W
- Adam Senk’s Technical Report 2 for AE 481W
- Adam Senk’s Technical Report 3 for AE 481W
- Carrier. 2004. Hourly Analysis Program (HAP), Version 4.20a
- LEED Green Rating System. 2002. US Green Building Council , Version 2.1
- ASHRAE/IESNA Addendum n to ASHRAE/IESNA Standard 62-2004. ASHRAE Incorporated. Atlanta, GA. 2004