Thesis Proposal

TEMPLE UNIVERSITY –TYLER SCHOOL OF ART

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Executive Summary

The primary goal of the Temple University Tyler School of Art mechanical system redesign is to increase the energy efficiency and energy savings while maintaining the existing comfort levels of the spaces. The redesign is performed for educational purposes and does in any way suggest original design mistakes.

The Tyler School redesign will focus on the replacement of the airside systems of the building. Temple University's central heating and cooling plants will not be the concentration of the thesis redesign. The current mechanical system uses a joint variable air volume reheat (VAVR) and constant air volume reheat (CAVR) system. The proposed redesign will use a dedicated outdoor air system (DOAS) coupled with chilled beams. This system allows the sensible and latent loads to be handled separately, which can greatly increase the energy savings and efficiency.

The use of cost efficient energy recovery will be dependent on the ability to redesign the architectural layout of certain department spaces, which will be accomplished as a breadth topic. It is important to condense the exhaust of these studio and workshop spaces, so that centralized exhaust can promote energy recovery systems. The energy recovery ventilators (ERV) that will be evaluated for use in the Tyler School are enthalpy wheels, heat exchangers, and heat pipes. Additionally, the change in systems mechanical systems will require a cost comparison. Detailed cost estimation must be performed to assess the practicality of the redesign. The estimate will include the cost estimation as well as a mechanical scheduling and coordination issues. This estimation and scheduling will represent the second part of the Tyler School breadth.

The mechanical system comparisons will be evaluated with the use of the eQuest modeling program as opposed to the previously used, Trane Trace. The program will calculate the mechanical system loads of the redesign as well as be useful for energy simulation and cost analysis. Microsoft Project and RS Means will additionally be used for cost estimation and scheduling.

Background

The new 234,000 square foot Temple University Tyler School of Art is a 3-story art education building located in Philadelphia, PA. The Tyler School is moving from its current location in the Philadelphia suburb, Elkins Park. The three floors and basement consist of 234,000 square feet of administration, art education, and auditorium space.

The move from Elkins Park, PA will create a complete Art Campus at the Temple University Main Campus. The goal is to create a “mini arts campus” within the Temple University main campus. The Tyler School will become the signature building of the Arts Campus. As a premier art school of the Mid-Atlantic region, the Tyler School will benefit from the move into one of the largest culturally rich art cities in the country.

The Tyler School of Art building will provide studios, classrooms, shops, assembly spaces, and office space. The new building will house the painting, printmaking, metals, ceramics, sculpture, glass, fibers, and photography departments. The Tyler School of Art will house approximately 120 faculty members and about 800 students.

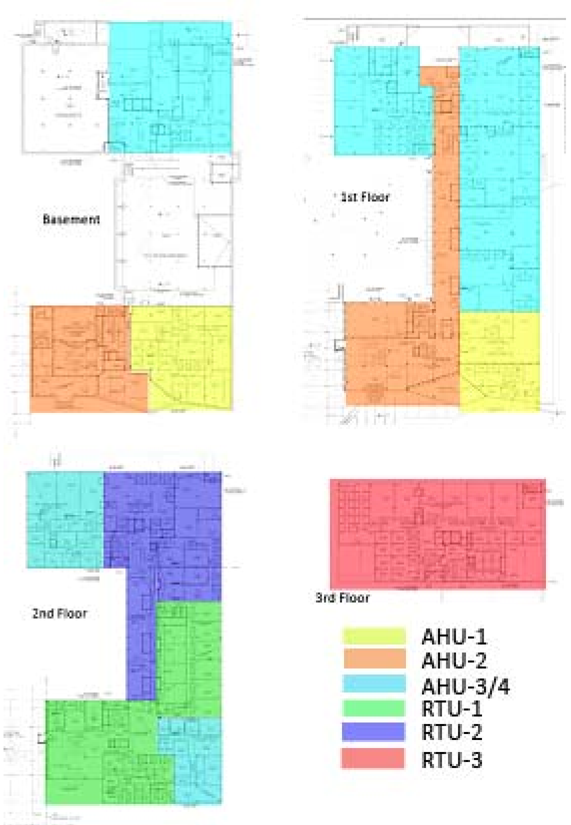
The disciplines in the Tyler School of Art are divided over the three stories and basement. The basement floor is separated into two sections connected by a large mechanical space. The south section is connected to the main lobby by a two-story basement lobby and houses the auditorium and photography studios. The lower level shops are located on the north end of the basement. The 1^{st} floor is broken into zones representing the ceramics, sculpture, and glass departments as well as the school’s exhibition space and 1^{st} floor core, which features the main lobby and two-floor promenade that stretches between the two branches of the building. The 2^{nd} floor is broken down into administration and the departments of metals, printmaking, foundations, gaid, and fibers. The painting studios are located on the top floor at the north end of the building.

The Tyler School of Art began construction is currently under construction and will be finished by January 2009.

Mechanical Systems Overview

The Tyler School of Art is a unique education building because the excessive amount of ventilation required. The building was treated primarily as a laboratory. The system consists of four (4) air handling units (AHU) housed in the basement and three (3) rooftop units (RTU). Of the seven units, AHU-1, AHU-2, RTU-1, and RTU-2 are all variable air volume reheat (VAVR) systems. The remaining units, RTU-3, AHU-3, and AHU-4, are all constant air volume reheat (CAVR) systems. These units predominantly serve the studios spaces and shops.

The graphic shows the floor breakdown of the AHUs and RTUs.



High pressure steam is supplied from the Temple University central heating plant. The building taps into the campus steam lines. The steam is brought to the building and then steam-to-water heat exchangers convert it to hot water. This hot water is then sent through the building to be used in the domestic hot water system as well as the reheat coils, unit heaters, air handling units, and for the steam in the humidifiers. Steam provides the humidification in the Tyler School.

The water is circulated throughout the building by the use of four variable speed drive end suction pumps. The hot water supply is designed at 180 °F and the hot water return is 160 °F. Hot water reset is used to adjust the temperature of the supply water as the ambient conditions vary. Temperature control valves are used to mix the supply and returns lines to adjust to lower hot water supply temperatures.

The chilled water is taken from the Temple University central plant. The chilled water distribution is handled by four variable speed drive, vertical split-case pumps. There is also a standby pump. The pumping arrangement is a secondary pump system that delivers chilled water to the air handling units and uses direct return with two-way control valves. The chilled water system is designed to have a supply temperature of 48°F and return is 60°F.

The building features a large variety of departments that require considerable amount of exhaust in the studios and workshops. To handle this exhaust, additional ventilation is required which greatly increases the load of the building. The Tyler School of Art does not use any energy recovery technology because much of the exhaust is not centralized. The layout of the departments and the additional cost for energy recovery was not seen as beneficial by the university. There as an opportunity to recover the energy the Tyler School by the use of the technology available. Different energy recovery configurations will be considered further.

Proposed Thesis Depth

The 234,000 SF building features a large variety of departments that require considerable amount of exhaust in the studios and workshops. To handle this exhaust, additional ventilation is required which greatly increases the load of the building. The Tyler School of Art does not use any energy recovery technology because much of the exhaust is not centralized. The layout of the departments and the additional cost for energy recovery was not seen as beneficial by the university. There as an opportunity to recover the energy the Tyler School by the use of the technology available. Different energy recovery configurations will be considered further.

Temple University has a unique opportunity with the Tyler School of Art. The building is moving from the suburbs to the metropolitan cultural center of Philadelphia. As the face of the complete Arts Campus at Temple, the Tyler School can expand its reach to the campus and the city. The Tyler School is the most known arts school in the mid Atlantic region, and it has the opportunity to make an important architectural and energy conscious statement as its vision for the next century. The Tyler School could have the ability to not only affect the students in the school, but the rest of the campus and the surrounding community. An energy efficient building can set the tone for the vision of the school and the campus. As energy consumption becomes more of an issue in the future, universities should look to lead in educating students with the hope that the future will become brighter than the past and we will learn from our mistakes. Unfortunately, as a state funded university, Temple University often has to consider the first cost primarily in the construction process. Long term life of the building is not considered, although, in the case of higher education it should be one of the first issues because there will always be the same owner and occupant of the building.

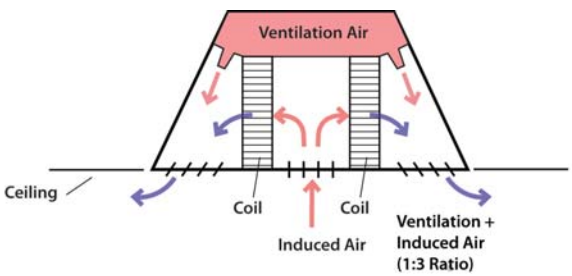
DOAS

The goal of this thesis is to improve the energy efficiency and consumption of the building. To achieve this goal, the VAVR system will be redesigned as a dedicated outdoor air system (DOAS). DOAS offers many advantages associated with building ventilation. The primary advantage of DOAS is the lower ventilation that translates to energy savings. Variable air volume (VAV) systems require a high minimum amount of airflow and the VAV system does not supply the proper ventilation air quantities to the spaces. The VAV box is sized based on the ventilation requirements in the room and a percentage of the ventilation air in the supply air. If the possible need for reheat in the VAV box is considered as well, the wasted energy load becomes even higher. The higher ventilation requirements coupled with the need to reheat this extra air justifies the consideration of DOAS.

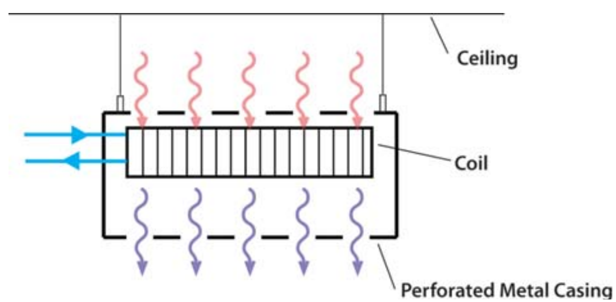
The use of DOAS separates the sensible and latent loads. DOAS handles the latent load and some of the sensible load. However, DOAS needs to be coupled with a system to handle the rest of the sensible load. The ability to separate these two loads is a great advantage in mechanical system design optimization. The main reason for the loads to be separated is the ability to avoid high relative humidity in the space at low sensible loads. The humidity issues leads to moisture problems which affect the overall indoor air quality of the space.

Chilled Beams

Chilled beams and radiant ceiling panels are two technologies that efficiently can be coupled with the DOAS and handle the sensible load of the building. The chilled beams will be the technology considered for its application in the Tyler School of Art. Chilled beam technology has been common place in Europe for quite some time; however, just recently the technology has increased in popularity here. The system offers energy savings and reductions in mechanical equipment and duct. Chilled beams can be a passive or active mechanical system. Active systems are connected to the supply air ductwork. The active chilled beams mix the supply air and the existing air that has been cooled. The passive system uses natural convection to cool the space. The warm air rises naturally into the system, which cools the air and then the air falls. The figure below shows the difference the active and passive systems.



Active Chilled Beam



Passive Chilled Beam

Specifically, chilled beams offer a variety of advantages that are summarized in the table below.

Potential Advantages	Disadvantages
Mechanical System and Duct Reductions	Noise
Reduced or Eliminated Reheat	Coordination w/ Lighting Equipment
Pump Energy Instead of Fan Energy	Rooms w/High Loads
Fit in Tight Space	Condensation
Free Cooling and Improved Chiller Efficiency	Cost

Energy Recovery
Various energy recovery configurations will also be considered. The use of enthalphy wheel, The three most common systems that will be evaluated for the Tyler School are enthalpy wheels, flat-plate heat exchangers, and refrigerant filled heat pipes. The heat exchanger is the most reliable system because it is a passive system. It usually transfers only sensible heat energy (temperature only) back into the outdoor supply air. For the system to work effectively, the temperature and humidity must be comparable to the treated space, and the exhaust airflow rate must be similar to the outdoor air flow rate entering the system. The enthalpy wheel or energy wheel rotates, mixing the sensible heat energy as well as the humidity with the outdoor air. They are more complex than heat exchangers because the mass and heat transfer are paired together. It is referred to as an enthalpy wheel because of its ability to transfer both heat and humidity into the supply side by the use of a desiccant coating. Energy wheels are usually used for high humidity climates and large ventilation systems.

Alternatives Considered

Radiant Ceiling Panels
Radiant cooling ceiling panels are another system that can be coupled with DOAS. The panels work in a similar way as the chilled beam system. In this case, water is run through the coils to condition the space temperature and control humidity levels. The issue with these panels, are that most professionals fear a possible condensation problem with them, however, effective controls should alleviate any problem that could occur. A radiant panel is seen below.

Underfloor Air Distribution
Underfloor air distribution (UFAD) is a system that delivers air to the spaces through a raised underfloor plenum. The system is beneficial in terms of indoor air quality, thermal comfort, and energy use. It could be used effectively in the studio spaces because many of the spaces have high ceilings. Adding the supply at the ground allows for savings by not having to condition down to the occupancy spaces. Also, the UFAD diffuser location can be modified if the layout of the interior spaces were to change. This life cycle cost analysis could prove useful as the building and interior space change over the years. UFAD certainly has its application in the administrative space, studios, and classroom, however, the system could be affected in the workshop spaces that have a great deal of machinery.

Breadth Topics

Architectural Breadth

An architectural breadth will be done for the Tyler School. The use of energy recovery requires centralized exhaust systems. The Tyler School is difficult because the various departments create a scattered localized exhaust. The Tyler School department layouts will be reconsidered in a way to maximize the use of energy recovery. The goal is an energy efficient architectural building layout. The redesign will not eliminate any of the programs and spaces in the present design. The design should maximize the space and flow throughout the building.

Construction Management

The addition of DOAS and chilled beams will significantly affect the mechanical cost of the building. A detailed cost estimate will be performed, which will be compared to the original mechanical design. The cost estimate will include a payback period analysis for the energy savings associated with the use of the DOAS/chilled beams coupled system. The schedule for the redesign will be assessed with the use of Microsoft Project. This assessment will focus on potential scheduling setbacks with the system redesign.

Tools and Methods

The mechanical system redesign is the primary basis for the thesis proposal. It is important to have an accurate existing heating and cooling load program for energy analysis. The existing and redesign comparison will be futile if an effective and accurate program is not used. The load calculation program used so far for this project is Trane Trace, however, the program has been difficult to use for analysis. The start of the redesign will be used to develop the energy modeling using eQuest. The eQuest program has been suggested because of its unbiased perspective and it is easier to work with. As mentioned above, the project schedule will be analyzed with the use of Microsoft Project. The specific cost estimation program to be used for the Tyler School redesign has not been determined yet.

References

ASHRAE Handbook – 2005 Fundamentals. American Society of Heating, Refrigerating, and Air Conditioning Engineers. Atlanta, GA, 2005.

ASHRAE Handbook –2004 HVAC Systems and Equipment. American Society of Heating, Refrigerating, and Air Conditioning Engineers. Atlanta, GA, 2004.

ASHRAE Handbook –2003 HVAC Applications. American Society of Heating, Refrigerating, and Air Conditioning Engineers. Atlanta, GA, 2003.

Barista, Dave. "Chill the Ceiling for Cool Energy Savings." *R & D Magazine.*

Brinjac Engineering, Inc. 2007, Mechanical Construction Documents. Brinjac Engineering, Inc., Harrisburg, PA, 2007.

Dedicated Outdoor Air Systems. <doas-radiant.psu.edu>

Dieckmann, John, Kurt Roth, and James Broderick. "Dedicated Outdoor Air Systems." *ASHRAE Journal.* March 2003, pgs. 58-59.

Mumma, Stanley. "Dedicated Outdoor in Parallel with Chilled Ceiling System." *Engineered Systems.* November 2001.

Rumsey, Peter. "Chilled Beams in Labs: Eliminating Reheat & Saving Energy on a Budget." *ASHRAE Journal.* January 2007, pgs. 18-25.

Schedule

The following is the proposed schedule to be completed in the Spring 2008 semester redesign of the Temple University Tyler School of Art. The schedule is subject to change as semester adjustments might be necessary.

January 2008						
SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
		1	2	3	4	5
6	7	8	9	10	11	12
13	14 Semester Begins	15 Model Tyler School using Trane Trace	16 Model Tyler School using Trane Trace	17 Model Tyler School using Trane Trace	18 Model Tyler School using Trane Trace	19 ASHRAE Conference New York
20 ASHRAE Conference New York	21 ASHRAE Conference New York	22 ASHRAE Conference New York	23 ASHRAE Conference New York	24 Energy Recovery/Chilled Beams/DOAS Research	25 Energy Recovery/Chilled Beams/DOAS Research	26
27	28 Energy Recovery/Chilled Beams/DOAS Research	29 Energy Recovery/Chilled Beams/DOAS Research	30 Energy Recovery/Chilled Beams/DOAS Research	31 Energy Recovery/Chilled Beams/DOAS Research		

February 2008						
SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDA
					1 Energy Recovery/Chilled Beams/DOAS Research	2
3	4 Energy Recovery/Chilled Beams/DOAS Research	5 Energy Recovery/Chilled Beams/DOAS Research	6 Begin Analysis	7 Begin Analysis	8 Begin Analysis	9
10	11 Model Tyler DOAS System	12 Model Tyler DOAS System	13 Model Tyler DOAS System	14 Model Tyler DOAS System	15 Model Tyler DOAS System	16
17	18 DOAS and Chilled Beams Equipment	19 DOAS and Chilled Beams Equipment	20 DOAS and Chilled Beams Equipment	21 DOAS and Chilled Beams Equipment	22 DOAS and Chilled Beams Equipment	23
24	25 Life Cycle Cost Analysis	26 Life Cycle Cost Analysis	27 Life Cycle Cost Analysis	28 Life Cycle Cost Analysis	29 Life Cycle Cost Analysis	

March 2008						
SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
						1
2	3 Architecture Breadth	4 Architecture Breadth	5 Architecture Breadth	6 Architecture Breadth	7 Architecture Breadth	8
9 SPRING BREAK	10 SPRING BREAK	11 SPRING BREAK	12 SPRING BREAK	13 SPRING BREAK	14 SPRING BREAK	15 SPRING BREAK
16	17 Mechanical Cost Estimating	18 Mechanical Cost Estimating	19 Mechanical Cost Estimating	20 Mechanical Cost Estimating	21 Mechanical Cost Estimating	22
23	24 Mechanical Cost Estimating	25 Mechanical Cost Estimating	26 Final Analysis	27 Final Analysis	28 Final Analysis	29
30	31 Final Analysis					

April 2008						
SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
		1 Final Analysis	2 Final Analysis	3 Final Analysis	4 Final Analysis	5
6	7 Final Analysis	8 Prepare Presentation	9 Prepare Presentation	10 Prepare Presentation	11 Prepare Presentation	12
13	14 Faculty Jury	15 Faculty Jury	16 Faculty Jury	17 Faculty Jury	18 Faculty Jury	19
20	21	22	23	24	25	26
27	28	29	30			

May 2008						
SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
				1	2 Last Day of Class Awards Jury Senior Banquet	3
4	5 Final Exams	6 Final Exams	7 Final Exams	8 Final Exams	9 Final Exams	10
11	12	13	14	15	16 Graduation	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31