THESIS PROPOSAL

The Regional Learning Alliance at Cranberry Woods

850 Cranberry Woods Drive. Cranberry Township, PA 16066

PREPARED FOR:

Dr. William Bahnfleth, Ph.D, PE
The Department of Architectural Engineering
The Pennsylvania State University

PREPARED BY:

Caitlin L. Hanzel
Mechanical Option

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EXECUTIVE SUMMARY

Over the past three months, this thesis has been dedicated to the research and analysis of The Regional Learning Alliance Center's existing mechanical system and plant. Technical Assignment 1 demonstrated the facilities compliance with ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality* and Standard 90.1, which sets forth requirements for the energy efficient design and construction of buildings. Utilizing Trane's TRACE 700 computer program, a building plant and energy analysis of the current system was performed, allowing heating and cooling loads to be calculated and annual energy consumption and operating costs to be approximated. The purpose of this report is to investigate design alternatives, ultimately applying changes that would, in some way, enhance the present system. Technical Assignment 3 required a critique of the current mechanical system, in which the following problems were discovered. The issues are listed in order of importance, with 1 being the most imperative:

1.) Acoustical Performance: With a majority of the building being dedicated to office, classroom and discussion space, the acoustical performance of the current fan coil units has been unacceptable. Rattling of ceiling tiles and lighting fixtures have been reported, creating a distracting and unproductive environment for students and employees. A quieter system needs to be implemented.

2.) Maintainability, Reliability and Ease of Operation: The fan coil units have relatively complex hydronic components and controls. The owner/management team has been forced to hire a full-time maintenance manager to address daily issues that tend to arise with the current system. Typically, over $33,000 is spent each year on preventative maintenance and repairs for the units, adding to the overall operating cost of the facility.

3.) Thermal Comfort and IAQ. : In large open areas, primarily the main lobby and atrium, thermal comfort has been a concern. Temperatures recorded from one end of the atrium to the other have varied by up to ten degrees, causing occupants to often complain about being too hot or cold. Thermal comfort and indoor air quality in the offices and discussion classrooms are also important in order to provide a productive work and learning space.

In addition to these three key issues, it was important to remember that the building must still allow for simultaneous heating and cooling of spaces. Also, any redesign would need to either meet or exceed the current LEED Silver rating. After analyzing these criteria and researching various solutions, the final redesign includes the replacement of the current fan coil units with quieter and often more energy efficient, chilled beams. The dedicated outdoor air system will remain in operation. Moreover, the current overhead air distribution in the immense lobby/atrium space will be substituted for displacement ventilation with possible radiant floor heating. This system will be served either by the current CAV air handling unit, or a more sophisticated VAV unit. This decision is still being made. A more in-depth explanation, including the integration and coordination of these systems, is included in this report.

Finally, two breadths will be evaluated based off of the implementation of this redesign. An acoustical breadth will examine the benefits of the chilled beams in the discussion classrooms and office space. The second analysis will either be architectural, dealing with the lobby's glazed curtain wall (that currently acts as a huge heat source/sink) or construction management, which will evaluate the potential cost and schedule savings of integrating the lighting and sprinkler systems into one, multiservice chilled beam.

BUILDING DESIGN OVERVIEW

The Regional Learning Alliance Conference and Learning Center is a 76,000 ft^2, mixed use, educational facility, located in Cranberry Township, PA. The building is used primarily as office and conference space during the day and transforms into an educational alliance during the evening and weekends. Currently, there are 18 classrooms (each around 750 ft^2), two smaller seminar rooms, two computer labs, a technical classroom, a 1600 ft^2 meeting room, a conference/banquet room (which can be split into two separate 1600 ft^2 spaces) and an 800 ft^2 board room. Other amenities, which are available to both populations of users, include two, 2500 ft^2 office suites, a 2600 ft^2 wellness center and an 1800 ft^2 daycare center. As shown in the sections below, the building is composed of these three primary sections; discussion (conference) classroom space, highlighted in blue, office space, highlighted in yellow and public/interaction space, highlighted in orange.

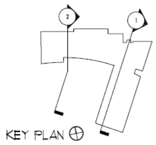
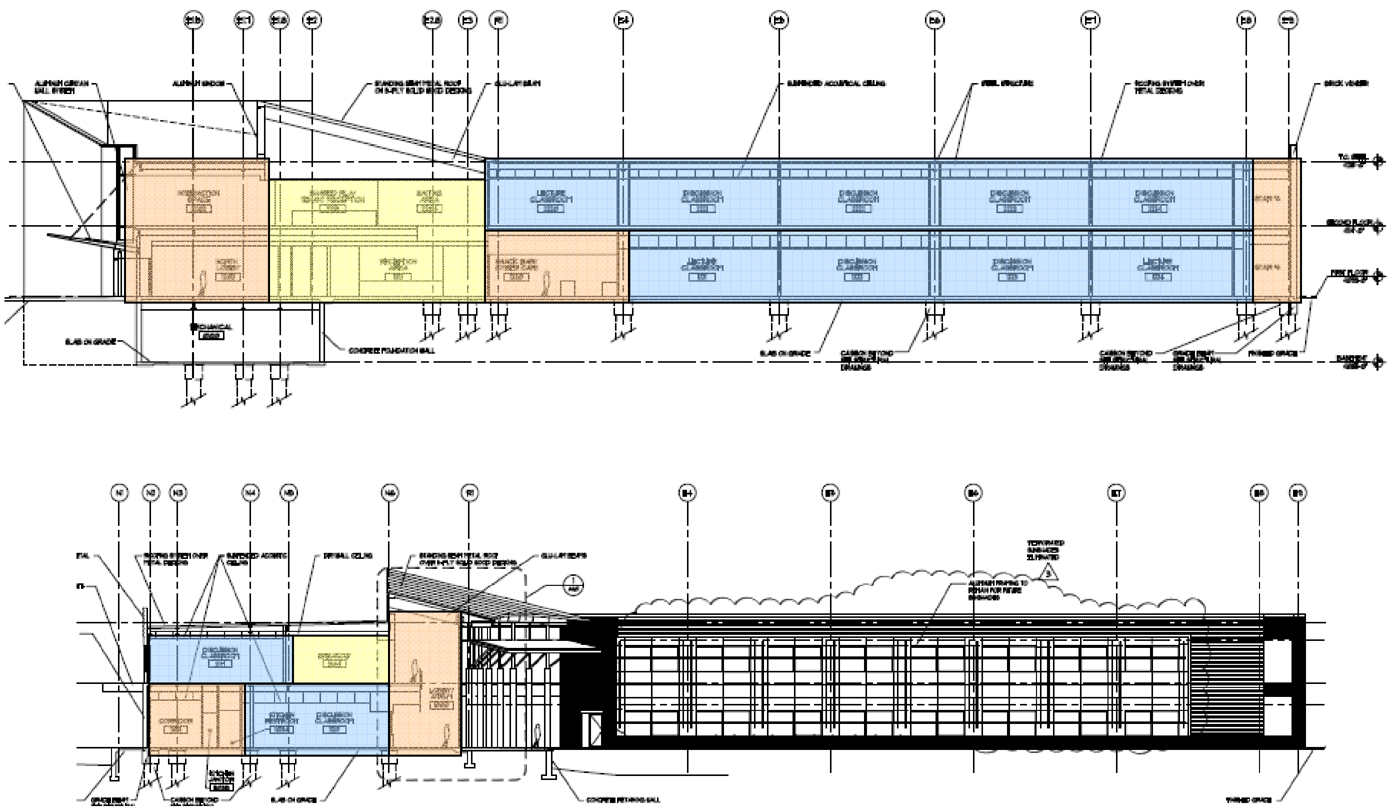


FIGURE 1: AREA BREAKDOWN & SPACE RELATIONSHIPS



The placement and configuration of the building was intended to limit the impact of new development on the wooded site and natural wetlands surrounding the area. The resulting footprint of the building leaves two wings of the L-shaped building embracing these wetlands. Both of the wings are exposed to maximum day-lighting and natural views through the use of large curtain walls, used most predominantly in the buildings two-story lobby/atrium. Where used, this architectural feature greatly impacted the cooling and heating loads. The environmentally friendly building was designed to meet a LEED Silver rating, as well as ASHRAE Standard 62.1 and ASHRAE Standard 90.1, which set forth minimum requirements for the effective ventilation and design of energy efficient buildings.

MECHANICAL DESIGN OBJECTIVES

Due to the intense conference and educational use of the facility, the current mechanical system design evolved from the significant objectives that follow:

1.) Occupancy (and therefore *outside air ventilation requirements),* tended to be a major factor in the cooling and heating load calculations.

2.) Each space could be used at any given time, at any given intensity. Therefore, the dramatically *fluctuating loads* that occur during the facility's long operating hours needed to be accounted for when modeling schedules for the energy model.

3.) *Acoustical performance* of both the central HVAC equipment and terminal units was crucial. The owner did not want any noise generated by mechanical system components to hinder the productivity of employees and students.

4.) As a building composed of primarily educational, conference and office space, *indoor air quality and thermal comfort* was also one of the most important design concerns. This would be assured through adequate air distribution and sophisticated temperature and humidity controls.

5.) The owner, architects and design team were striving to create a LEED certified building. Therefore, *energy efficiency and environmental impacts* were analyzed thoroughly.

6.) Maintainability, reliability and ease of operation.

Factoring in these objectives, the design team knew that the HVAC system would need to respond to the changing load conditions that would occur in both the cooling and heating seasons. In addition, the system would have to be capable of simultaneously conditioning spaces whose requirements may drastically vary due to occupancy and internal loads.

CURRENT MECHANICAL SYSTEM

Due to its cost, overall efficiency and "green" characteristics, the owner and design team decided on a distributed four-pipe fan coil unit system with a variable air volume dedicated outdoor air unit. In a building devoted to office, learning and conference space, the thermal comfort of the tenants was extremely important. By choosing the fan coil unit system, the team hoped the occupants would have the advantage of better control by having the actual terminal units located in each thermal zone.

A complete heating, ventilation and air conditioning system was provided for The Regional Learning Alliance, and will be briefly explained in the next few paragraphs. The building's automatic temperature control (ATC) system is manufactured by Kivic and consists of stand-alone application specific direct digital controllers.

AIR HANDLING SYSTEMS

AHU-1 is a demand controlled, dedicated AAON air handling unit that provides 100% conditioned outdoor air through variable air volume terminal boxes to fifty, four-pipe fan coil units located throughout the building. Return air is recirculated directly from the space and sent back to the fan coil unit to produce mixed, supply air to each zone. CO_2 sensors, connected into the main BAS system, are located in each zone and determine the amount of outdoor air that needs to be provided. The unit is equipped with a total sensible heat recovery wheel, hot gas reheat for positive dehumidification and variable speed drives on the exhaust and supply fans.

AHU-2 is a constant-volume Aaon air handling unit, equipped with both chilled water and hot water coils. The unit is dedicated to serving 10,000 CFM of conditioned air to both the lobby and two-story atrium. The unit, which has a 96" X 36" outdoor air intake, is located on the north end of the first floor in the facility's Maintenance Garage.

HOT WATER SYSTEM

The Regional Learning Alliance's hot water distribution system consists of two gas-fired boilers, which supply hot water to the entire building via two primary pumps and two secondary pumps. Each of the two high-efficiency, Lochinvar boilers are designed for a net output of 1402.5 MBH and are configured with a 150 PSI pressure relief valve and temperature sensor.

The heating system is initiated through the DDC panel when AHU-1 is indexed in the occupied mode. During this occupied cycle, the heating system is activated when the outside air temperature is below 55 F and the temperature differential between the hot water supply and hot water return is greater than 30 F. During the unoccupied cycle, the system is activated when the outdoor air temperature is less than 45 F.

CHILLED WATER SYSTEM

The chilled water system is composed of one, 75-ton, water-cooled chiller (with self-contained evaporative condenser and scroll compressor). The chiller runs off of environmentally friendly R-410A refrigerant, which added to the green design strived by the owner. The primary AAON, inline pump (P-5) and secondary pump, (P-6), are used to circulate chilled water to the building's HVAC components. These components include the chilled water coils present in AHU-1, AHU-2 and each of the fifty fan-coil units.

PROBLEM STATEMENT

As discussed in the initial objectives, the mechanical system was designed with the intent to meet standards placed on occupancy thermal comfort, indoor air quality, maintainability and acoustical performance. Sustainability and energy efficiency also played a huge role in the design, with the building attempting a LEED Silver rating. While the current system is valuable energy wise, the following aspects will need to be addressed in any redesign alternative:

► Acoustical Performance.

Although it is beneficial to have the fan coil units indoors, the acoustical performance of the units has been unacceptable. Rattling of ceiling tiles and lighting fixtures have even been reported, creating a distracting and unproductive environment for students and tenants.

►Maintainability, Reliability and Ease of Operation.

With its relatively complex hydronic system components (not to mention complicated ducting layouts), the owner/management team has been forced to hire a full-time maintenance manager to address daily issues that tend to arise with the current fan coil unit system. Typically, over $33,000 is spent each year on preventative maintenance and repairs for the units, adding to the overall operating cost of the facility.

►Thermal Comfort and IAQ.

In large open areas, primarily the main lobby and atrium, the space can get rather uncomfortable, with occupants often complaining of being too hot or too cold. Temperatures recorded from one end of the atrium to the other have varied by up to ten degrees. Thermal comfort and indoor air quality in the offices and discussion classrooms are also important in order to provide a productive work and learning space.

►Flexibility.

The fan coil units are accommodating in that each zone contains a thermostat that allows for individual temperature adjustment. Therefore, zones that are on the exterior of the building that need more heat in the winter, are able to adjust the temperature accordingly, without affecting interior zones. The system also allows for some zones to be heating while others are cooling. Any potential redesign will need to have similar capabilities.

►Energy Efficiency.

The designed mechanical system has met standards for a LEED Silver rating, and currently complies with both ASHRAE Standards 62.1 and 90.1. Any redesign of the system would need to either meet, or exceed the current energy efficiency of the system, decreasing the amount of energy consumed annually.

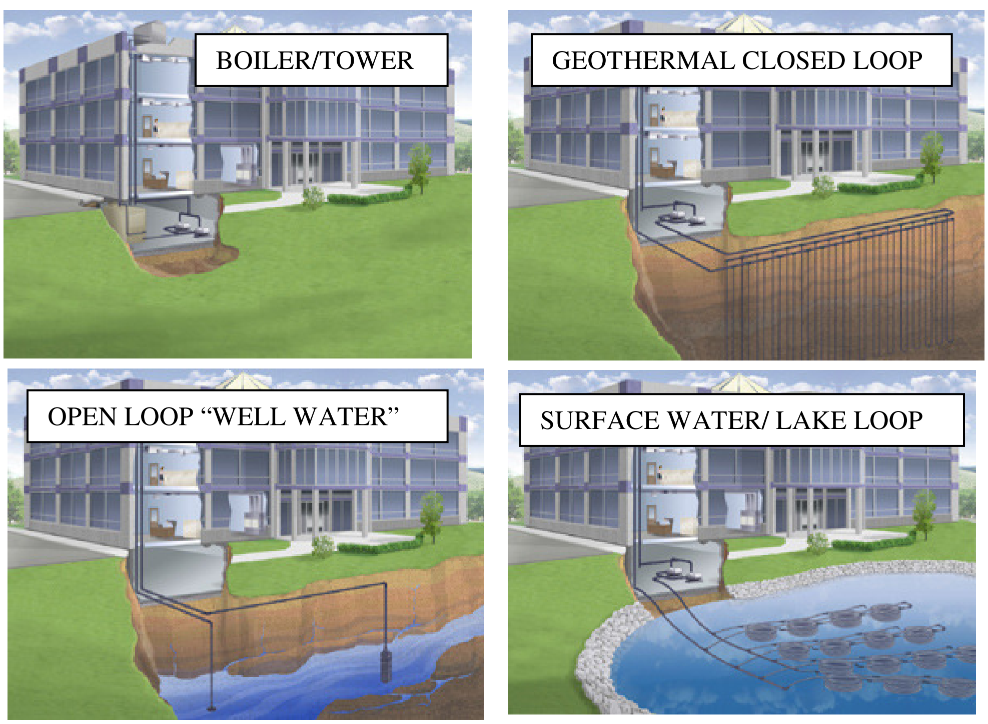
REDESIGN ALTERNATIVES CONSIDERED

After analyzing the problems that have emerged in the existing system, research was done to examine potential alternatives. These alternatives, which are described in the following section, can potentially help to decrease the acoustical and maintainability issues, while increasing the thermal comfort of the occupants and overall indoor air quality. They will also attempt to decrease energy consumption, maintaining an overall sustainable system.

WATER SOURCE HEAT PUMPS

Heat pumps were initially investigated for the *current* mechanical design and was the only system proposed that was typically more energy efficient than the fan coil units. Therefore, this was an obvious alternative to be explored. A water source heat pump uses water as its heat source as well as its heat sink. During the heating mode, the heat pump extracts heat from the heat pump loop and transfers it to the room air. Similarly, during the cooling mode, a heat pump extracts heat *from* the room air and transfers it to the heat pump loop. During the cooling season, heat must be removed from the heat pump loop, typically via cooling towers or other heat rejection devices. In the winter, boilers are used to add heat to the loop. As shown in Figure 2, geothermal closed and open loops are available, as well as a surface water/lake loop option.

FIGURE 2: HEAT PUMP CONFIGURATIONS



A heat pump system would be configured relatively similar to the existing fan coil system. Each zone would have one of more heat pumps to condition the space. A make-up air system, either constant or variable volume would also need to be provided. Although CAV units are cheaper to install, the VAV unit has significantly more efficient outdoor air conditioning.

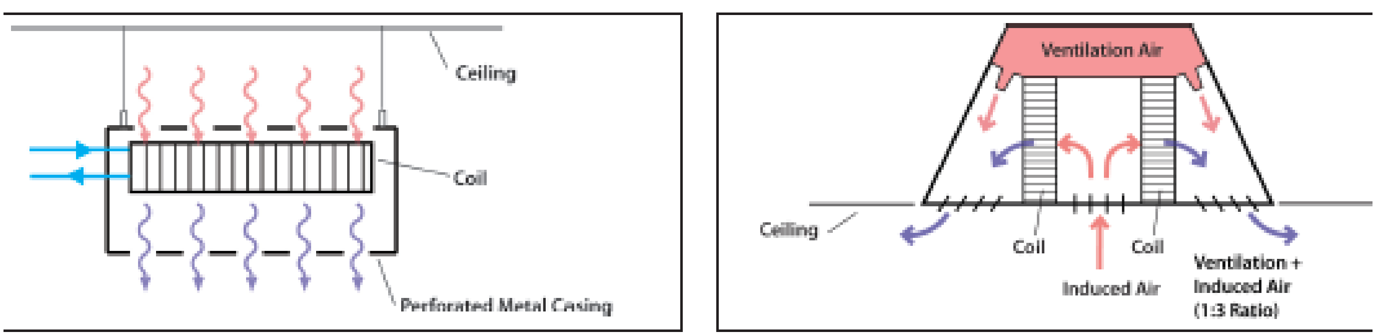
Advantages of water source heat pumps include extremely high COP/EER performance values which would tend to lower annual operating costs of the system. Depending on the circumstances, operating costs of heat pumps can be up to 75% less than electric heating devices and 50% less than air source heat pumps. They also have the capability of having some zones heating while others are cooling and they can even isolate and shut down unoccupied areas of the building. Typically, heat pump equipment has good efficiencies for cooling, but lower efficiencies for heating. Other drawbacks include a higher installation cost and a more complex hydronic system that will need to be served. Acoustical performance may or may not be altered, since heat pumps are also typically installed in the zones they serve.

CHILLED BEAMS

Chilled beams, which have been applied primarily in Europe thus far, are finally breaking through into mechanical design in the United States. Chilled beam systems use chilled water pipes in ceiling mounted modular units. Heat is transferred primarily through convection, instead of radiation as in radiant chilled ceiling panels. The system can be either passive, which only supplies cooling and is typically used in conjunction with a larger system, or active, which are similar to induction diffusers. Active beams are more complex in that in addition to the cooling coil they have an integral supply air design to meet outdoor air requirements. Typically, this outdoor air is provided by a DOAS system, similar to the one already installed at The Regional Learning Alliance.

As shown in Figure 3, the beam is connected to ventilation ductwork and water pipework. Most of the cooling and heating capacities are transferred through the water. The primary air is supplied through the beam into the room, inducing the room air to circulate through the beam's heat exchanger. The beam then mixes the primary and circulated air before diffusion into the room. It is because of the forced convection that active beams have almost twice the cooling density when compared to passive beams. Also, active beams can be used for heating, cooling and ventilation.

FIGURE 3 : PASSIVE & ACTIVE CHILLED BEAM CONFIGURATIONS



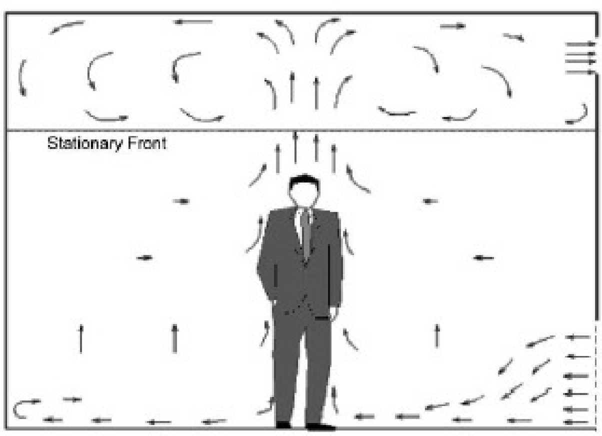
Chilled beams can save energy in several ways, the first being that they deliver sensible cooling directly to the zones, reducing ventilation fan energy consumption. Second, chilled beam systems tend to use a higher chilled water temperature than conventional air-conditioning systems (55F to 63F vs. 39F to 45F). Therefore, the corresponding chiller can operate at a 15-20% higher efficiency because of this lower temperature lift. According to the September 2007 ASHRAE Journal, when deployed with a dedicated outdoor air system, chilled beams can reduce commercial building energy consumption by approximately 0.6 quad (0.64 EJ).

In addition to the efficient life cycle cost performance that will occur, the acoustical issues do not pose a problem since the fan powered motor has been eliminated. Chilled beams tend to self-regulate, which also allows for a less complex control system when compared to fan coil units.

DISPLACEMENT VENTILATION

While water source heat pumps and chilled beams are potential design solutions for the existing fan coil unit system, displacement ventilation may be suitable to implement in the lobby/atrium area. Currently, the constant volume unit simply dumps supply air down from second story diffusers. This has resulted in large temperature swings and inadequate thermal comfort levels for the tenants. Displacement Ventilation (DV) tends to improve indoor air quality by providing supply air directly to the building occupants by conditioning only the lower occupied portion of the space. As shown in Figure 4, the fresh air, supplied near the floor at low velocity, falls towards the floor due to gravity and spreads across the room until it comes into contact with a heat source. The cool air then rises as it picks up heat from the loads until it is exhausted from the space. By doing this, cooling and heating energy can be drastically reduced. The first floor of the lobby/atrium is most densely occupied compared to the second floor, which consists primarily of a main hallway. Therefore, displacement ventilation may be a good alternative to provide stratification of the two-story space.

FIGURE 4 : DISPLACEMENT VENTILATION AIR FLOW PATTERN



Source: Architectural Energy Corporation

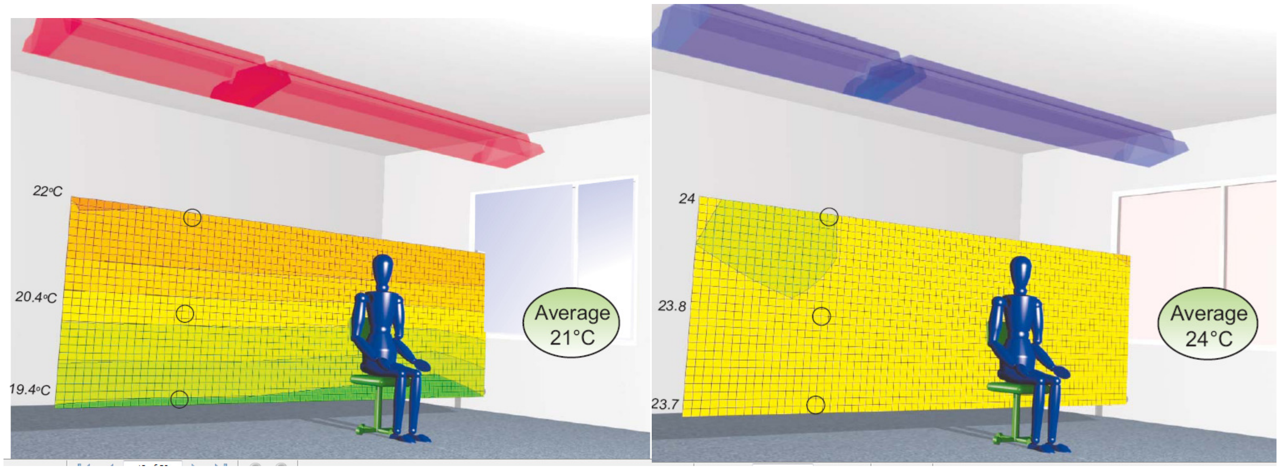
PROPOSED REDESIGN

After analyzing the researched alternatives, the following redesign is being proposed in hopes to enhance indoor air quality, occupant comfort and energy efficiency. The newly proposed system will also help to reduce the distracting acoustical issues caused by the fan coil units, while providing simpler controls and easy maintenance for in-house personnel.

In the redesign, active chilled beams will replace the facilities main fan coil unit system. A DOAS (similar to the one already in operation) will be provided to supply fresh outdoor air to the individual beams. Since the fan coil configuration also required outdoor air (OA) to be supplied to each unit, the main ductwork that supplies outdoor air should be able to stay intact, reducing any extra cost of installation. Chilled beams can also be easily incorporated into the acoustical ceiling tile grid that currently resides in all the office and discussion classroom space. Although the initial construction cost may increase, the efficiency of the system will most likely provide a shorter payback period and lower life-cycle cost.

With the majority of The Regional Learning Alliance being composed of office, conference and classroom space, the thermal comfort and consequently, the productivity of the occupants, is crucial. Frenger Systems, a main supplier and manufacturer of multiservice chilled beams, has conducted research on its product to examine the effects it has on thermal comfort. In the United Kingdom, where chilled beams are frequently being used for heating and cooling, the requirements for comfort conditions is a temperature gradient of less than 3C from 0.1m to 1.1m (in the seated occupied zone). The illustrations shown in Figure 5 provide a representation of predicted internal temperatures during cooling and heating modes, both meeting this standard and providing optimum thermal comfort for visitors, students and tenants.

FIGURE 5 : THERMAL GRADIENTS IN OCCUPIED ZONES



In comparison to the fan coil unit system, no additional energy will be needed to power the chilled beams since the cooling is primarily done through convection. Lastly, and most importantly, this redesign will solve the drastic acoustical issues that are occurring with the fan coil units. Many chilled beam manufacturers, including Frenger, employ air distribution nozzles that are pierce-punched from the metal air chambers. By eliminating the vibration and noise development that often occurs with plastic, rubber or neoprene nozzles, the beams are amongst the quietest air distribution systems on the market. Specific Frenger products have been able to reduce the noise level to less than 25 dBA. According to Architectural Acoustics, by Marshall Long, noise levels in offices and lecture classrooms should be between an NC25 and NC30 rating. Typically, fan coil units achieve somewhere around an NC40 rating. The use of chilled beams also eliminates the use of fans, so that there is no fan noise, breakdown, electrical consumption or maintenance. Moreover, there are no filters or condensate drains/leaks since there are no wet coils. These features will allow for easier in-house maintenance, a concern that has been previously addressed by the owner.

For the lobby/atrium a Displacement Ventilation (DV) distribution system will be implemented, using either a VAV or CAV unit. This final decision will come during the spring coursework. Displacement Ventilation provides several benefits, including improved air quality, reduced energy use and improved acoustic performance due to the low velocity air supply. Compared to overhead mixing ventilation, outside air is distributed more effectively to the space and the vertical flow pattern towards the ceiling exhaust promotes the removal of any heat-borne contaminants. According to ASHRAE Standard 62.1-2004, the air distribution effectiveness of a DV system is 1.2. This means that DV provides the same indoor air quality as a mixing ventilation system that uses 20% more outdoor air.

When compared to traditional ventilation systems, displacement ventilation uses a significantly higher supply air temperature, which results in energy savings. The higher supply air temperature will allow mechanical cooling equipment to operate at a higher efficiency, while the lower air velocity reduces the system pressure drop, fan energy usage and any acoustical issues that may arise with other systems. Table 1 summarizes the advantages of displacement ventilation over typical overhead mixing.

TABLE 1 : ADVANTAGES OF DISPLACEMENT VENTILATION

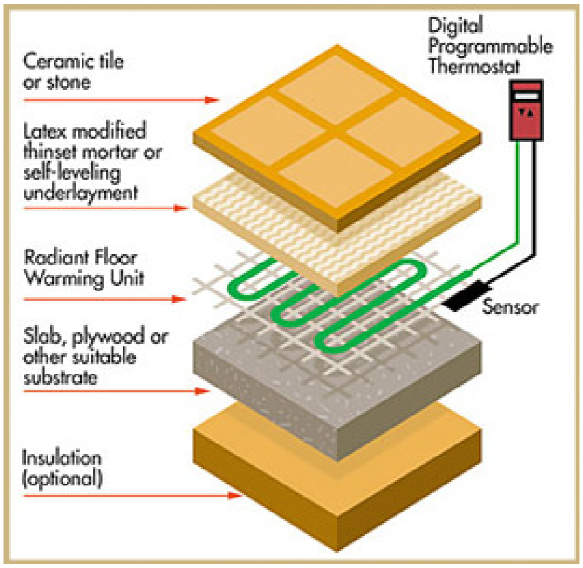
	OVERHEAD MIXING	LOWER WALL (DISPLACEMENT)
DESCRIPTION	Diffusers located in ceiling deliver 55F air at a veloctiy 400-700 fpm.	Diffusers mounted neat the floor level deliver 65F ait at less than 75 fpm. Air flow causes a thermall stratified space and vertical air movement.
SUPPLY CONDITIONS	Nominally 55F for cooling	Typically 63-68F in cooling
THERMAL COMFORT	Even temperatures throughout space	Very good thermal comfort
VENTILATION EFFECTIVENESS	Fair-- supply air mixes with room air to dilute contaminants	Very Good-- supply air is delivered directly to occupants and contaminants are displaced to upper less occupied zone.
APPLICATIONS	Any	Resteraunts, atriums, schools or any other space with high ceilings

INTEGRATION AND COORDINATION CONCERNS

Although displacement ventilation provides benefits of energy efficiency, air quality and thermal comfort during the cooling season, research has uncovered that it is often not well designed for heating. Since the warm air is supplied from the diffusers at a lower velocity, the air sometimes tends to rise towards the ceiling exhaust before it can effectively heat the space. While a computational fluid dynamics analysis would help to explore the possibility of this issue, the integration of a supplemental heating system, such as electric or hydronic radiant flooring, is a viable option. As seen in Figure 6 on the next page, hydronic (liquid) systems, pump heated water from the boiler through tubing laid in a pattern underneath the floor. In some systems, temperature in different zones can be controlled by regulating the flow of hot water through each tubing loop. This is done by a system of zoning values or pumps and thermostats.

There are many benefits to utilizing a radiant floor system, including but not limited to the following:

FIGURE 6 : RADIANT FLOORING



► **Silent operation**: there is no hum or whistle of a forced air system.

►**Energy Savings:** evenly distributed heat from radiant floor heating system can allow the thermostat to be set 2-4 degrees less than in forced air systems. In addition, radiant flooring heats the room from the floor up, minimizing any losses that occur with overhead forced air systems. This can reduce energy cost by 5-30%, depending on your local utilities.

► **Better IAQ:** forced air systems can spread dust, pollen and germs.

Supplemental systems such as these tend to occur with displacement ventilation when significant heating is required during occupied periods, as in The Regional Learning Alliance Center. Although it may increase the initial construction cost, it will more importantly increase the thermal comfort of the occupants in the lobby. Since the primary floor covering of the lobby is currently carpet, it may be a good idea to look into using wood or some other material that the heat can easily radiate through. Also, the glazed curtain wall that runs the entire length of the lobby/atrium may be investigated in one of the breadths, in hopes to find a way to reduce the heat gain/loss into this space.

With the chilled beam system, attention to the HVAC design will be needed to avoid condensation of moisture on the chilled water supply pipes and cooling coils. For commercial buildings, the common strategy for avoiding condensation on the beams is to manage indoor moisture levels such that the dew point temperature of the indoor air is *lower* than the chilled water temperature. In most cases, ventilation outdoor air and infiltration are the main sources of humidity, so the systems usually require dedicated outdoor air systems, as will be provided in the redesign. Another option is to maintain the building at a slightly positive pressure, with respect to the outside, to control infiltration of humid air. If the system can not maintain the room design humidity level, a last resort can always be to increase the temperature of the secondary chilled water.

By implementing the chilled beams, the need for chilled water may increase or decrease in comparison to what was needed for the fan coil units. Also, it is important to keep in mind that the chiller efficiency will be increased due to the higher supply temperatures that can be used. Therefore, it is reasonable to assume that the installed chilled water plant size and electric consumption will be reduced. By installing the hydronic radiant flooring, it is most likely that the boiler capacity will increase. Therefore, flow calculations will need to be performed to see if the chiller, boiler and pumps are adequately sized. Since the chilled beams will be located within the zones, as were the fan coil units, noise criteria will have a huge impact on the selected system. All of the proposed changes will strive to meet or exceed the current LEED Silver rating.

BREADTH TOPICS

When implemented, any mechanical system redesign would consequently alter other buildings systems. Two, of the following three, proposed breadths will be analyzed during the 2009 Spring Semester.

ACOUSTICAL BREADTH

The driving decision to switch from fan coil units to chilled beams was the reduction in acoustical interference in the space. The acoustical performance of the chilled beams in the offices and discussion classrooms will be analyzed to make sure they meet standardized noise criteria for the activities that will take place. By reducing the distracting vibrations and rattling that occurred with the fan coil units, the overall productivity of the students and tenants will increase.

ARCHITECTURAL BREADTH

By installing the supplemental radiant flooring the in lobby/atrium space, the initial construction cost for the mechanical system will definitely increase. Although the system, in congruence with the displacement ventilation, will enhance the thermal comfort of the occupants, it might be possible to reduce the amount of heat gain/loss in the space. This will be done through altercations of the glass curtain wall system that runs the entire length of the space. Enhancing the thermal properties of the glazing, adding additional shading devices or changing a certain percentage of the wall to a different material are all viable options to help decrease the loads. As a result, the air handling unit can reduce in size, and the extra boiler capacity needed to heat the radiant flooring will be minimized.

CONSTRUCTION MANAGEMENT BREADTH

One of the most appealing qualities about chilled beams is the ability to bring together several services in an integrated unit. A full range of building services (apart from heating, ventilating and air conditioning), can be incorporated into the beam. These include uplighting or downlighting, fully addressable lighting solutions and fire alarms and sprinkler heads. By integrating fire protection and/or lighting features into the beam, a reduction in costs and on-site installation time is almost assured. The breadth would explore the potential savings on the construction costs and installation schedule.

TASKS AND TOOLS

Steps will need to be taken in order to determine the feasibility and level of improvement of the proposed redesign. The computer programs and tools on the following page will be required during the analysis in order to complete the tasks scheduled for the spring semester. A copy of this schedule can be found in APPENDIX A.

► **Trane TRACE 700:** will be used to model the new systems and to calculate the 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. It should be noted that emerging technologies such as the chilled beams and radiant flooring may be difficult to model in such a program. Early research/brainstorming will be needed in order to accurately model these systems.

► **EASE Version 4.2:** EASE is an acoustical program that allows you to model specific spaces along with mechanical equipment. The use of this program, in conjunction with chilled beam performance cut sheets, may be helpful in conducting the acoustical breadth.

► **RS Means:** Any cost information needed that can not be obtained from the project manager or approved submittals will be referenced from RS Means. This source will be frequently used if a construction management breadth is chosen.

► **Manufacturer Data:** manufacturer data for chilled beams, radiant flooring, and perhaps VAV air handling units will be needed to obtain information on size, cost, capacities and acoustical performance. These changes and equipment locations will then need to be shown on altered floor plans.

► **LEED Version 2.2:** After the redesign, the project's LEED points will be recalculated to determine if at least a Silver rating was achieved.

RESEARCH AND REFERENCES

Architectural Acoustics. Long, Marshall. New York, NY: Elsevier Academic Press, 2006. pg 89.

►The book, which is currently used for AE458, Advanced Acoustics, was used to obtain the maximum noise criteria levels for discussion classrooms and office space. Information regarding the noise criteria levels from fan coil units was also obtained from this source.

"Chilled Beams vs. Fan Coils" http://www.designbuild-network.com/contractors/construct_machinery/flakt-woods/press3.html

►The press release from Flakt Woods, a global company that is providing solutions for ventilation and air treatment, was entitled "Chilled Beams vs. Fan Coils", and discussed the benefits of chilled beams over fan coils and vice versa. Although chilled beams are still an emerging technology in the US, their higher initial cost seems to be offset by their overall life-cycle cost, energy efficiency, thermal comfort and acoustic performance.

"Chilled Beam Cooling". ASHRAE Journal, September 2007.

►The article that appeared in the 2007 September issue of the ASHRAE Journal, described the emerging chilled beam technology and the difference between passive and active beams. Designed operation, energy saving potentials and market factors were also discussed. Figure 3 was referenced from this article.

Displacement Ventilation. http://www.energydesignresources.com/Portals/0/documents/DesignBriefs/EDR_DesignBriefs_displacementventilation.pdf

►The article, sponsored by Pacific Gas and Electric, Edison, and Sempra Energy provided information on the benefits, applications and architectural and mechanical design considerations for displacement ventilation. It discussed the differences between displacement ventilation and overhead mixing, and provided ways to perform rough or detailed load calculations for the space. Table 1 and Figure 4 were referenced from the site.

Heat Pumps.
http://www.mcquay.com/McQuay/ProductInformation/WSHP/WSHPpage
►Most of the research done on water source heat pumps was through the McQuay website. The site provided information on different types of installation, as well as benefits and drawbacks of the system. Figure 2 was taken from the McQuay site.

Multiple Service Chilled Beams
http://www.frenger.co.uk/Documents/Literature/LT_Active%20MSCB.pdf
►Frenger's website, a prominent manufacturer of chilled beams in the UK, provided information on multiple service chilled beams, which may be helpful if the construction management breadth is chose. Data that resulted from thermal comfort and stratification experiments was also available and included in Figure 5.

Renaissance 3 Architects. 2007. Architectural Documents. R3A. Pittsburgh PA. 2004.
►Building sections provided in Figure 1 were taken from the initial architectural documents.

Tower Engineering. 2007. Mechanical Documents. Tower Engineering. Pittsburgh PA. 2004.
►Information was referenced from mechanical documents, including the original HVAC narrative, to figure out what systems were initially considered and what the main design objectives consisted of.

APPENDIX A: SPRING SCHEDULE

NOTE: Days highlighted in dark grey denote either time spent away from State College, or time *unable* to be dedicated to thesis.

JANUARY '09						
SUNDAY	**MONDAY**	**TUESDAY**	**WEDNESDAY**	**THURSDAY**	**FRIDAY**	**SATURDAY**
				1	2	3
				GOAL FOR OVER BREAK:	1.OBTAIN COST AND SCHEDULE INFORMATION FROM LANDAU OVER BREAK	2. START PRELIMINARY RESEARCH ON NEW SYSTEMS
4	5	6	7	8	9	10
INTERVIEW w/ MUELLER in Baltimore	**INTERVIEW w/ MUELLER in Baltimore**					
11	12	13	14	15	16	17
	CL ASSES RESUME	Conduct more research on chilled beams, displacement ventilation & radiant flooring	Conduct more research on chilled beams, displacement ventilation & radiant flooring	Conduct research & experiment on how to model in TRACE	Conduct research & experiment on how to model in TRACE	
18	19	20	21	22	23	24
CREATE NEW TRACE FILES for chilled beams, DV & radiant floor combonation	**NO CLASS**	CREATE NEW TRACE FILES for chilled beams, DV & radiant floor combonation	CREATE NEW TRACE FILES for chilled beams, DV & radiant floor combonation	CREATE NEW TRACE FILES for chilled beams, DV & radiant floor combonation	CREATE NEW TRACE FILES for chilled beams, DV & radiant floor combonation	
25	26	27	28	29	30	31
ORGANIZE load data and energy consumption	**ASHRAE TRIP**	**ASHRAE TRIP**	**ASHRAE TRIP**	ORGANIZE load data and energy consumption	Equipment Selection	

APPENDIX A: SPRING SCHEDULE cont'd

FEBRUARY '09

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
1	2	3	4	5	6	7
Equipment Selection	Equipment Selection	Equipment Selection	Equipment Layout and design	Equipment Layout and design	Equipment Layout and design	
8	9	10	11	12	13	14
Equipment Layout and design	Cost Analysis	Cost Analysis	Cost Analysis	Cost Analysis	Compare results, including energy consumption, operating costs and construction costs	
15	16	17	18	19	20	21
Compare results, including energy consumption, operating costs and construction costs	Compare results, including energy consumption, operating costs and construction costs	Recalculate LEED points according to Version 2.2	Recalculate LEED points according to Version 2.2	Recalculate LEED points according to Version 2.2	Begin research on acoustical breadth **THON**	**THON**
22	23	24	25	26	27	28
Research acoustical breadth components **THON**	Obtain information on acoustical performance of chilled beams	Obtain information on acoustical performance of chilled beams	Perform any modeling to do with acoustic breadth	Perform any modeling to do with acoustic breadth	Modeling Analysis	

APPENDIX A: SPRING SCHEDULE cont'd

MARCH '09						
SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
1	2	3	4	5	6	7
Modeling analysis	Compare FCU performance to chilled beams	Begin research on either CM breadth or architecture breadth	Work on CM or architecture breadth	Work on CM or architecture breadth	SPRING BREAK IN CABO	SPRING BREAK
8	9	10	11	12	13	14
SPRING BREAK	SPRING BREAK	SPRING BREAK	SPRING BREAK	SPRING BREAK	SPRING BREAK	SPRING BREAK
15	16	17	18	19	20	21
SPRING BREAK	Work on CM or architecture breadth	Work on CM or architecture breadth	Work on CM or architecture breadth	Work on CM or architecture breadth	Work on CM or architecture breadth	Start compiling information needed for final report
22	23	24	25	26	27	28
Compile information	Compile Information	Organize Final Report	Organize Final Report	Organize Final Report	Begin written work on Final Report	Work on final report
29	30	31				
Work on final report	Work on final report	Work on final report				

APPENDIX A: SPRING SCHEDULE cont'd

APRIL '09						
SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
			1	2	3	4
			Work on final report	Work on final report	Proofread report, begin Powerpoint presentation	Proofread report, Powerpoint presentation
5	6	7	8	9	10	11
Proofread report, Power point presentation	Powerpoint presentation	Powerpoint presentation	**FINAL REPORTS DUE-5PM**	Practice Presentation	Practice Presentation	Practice presentation
12	13	14	15	16	17	18
Practice Presentation	**FACULTY JURY PRESENTATIONS**	**FACULTY JURY PRESENTATIONS**	**FACULTY JURY PRESENTATIONS**	**FACULTY JURY PRESENTATIONS**	**FACULTY JURY PRESENTATIONS**	
19	20	21	22	23	24	25
26	27	28	29	30		