AE Senior Thesis Final Report

Geisinger Hospital for Advanced Medicine
Danville, Pennsylvania

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And all my family and friends for their support.

Executive Summary

The Geisinger Hospital for Advanced Medicine is being constructed in Danville, PA on the existing Geisinger campus. The hospital includes eight above ground floors, a lower level, and a ninth floor mechanical penthouse. The building will include exam rooms, operating rooms, offices, and patient rooms. Some of the building is also dedicated to shell spaces for future needs of the hospital.

The current designed mechanical system includes VAV boxes, a new boiler plants, and an addition to the existing chiller plant. Air handling units will be located in the ninth floor penthouse and in the fourth floor mechanical room.

This redesign investigates ways to improve the mechanical system and decrease the energy use of the building. The redesign includes changing the mechanical system to a dedicated outdoor air system (DOAS) with ceiling radiant cooling panels (CRCP). The redesign also looks at installing a combined heat and power plant (CHP). A DOAS should also decrease the energy use of the building and improve the indoor air quality of the building by increasing ventilation and decrease the ability of contaminants from traveling through the building. Incorporated into the DOAS will also be energy recovery devices to further reduce the energy used by the building.A CHP plant will decrease the amount of energy used by the building, decrease electricity needed from the local utility, and reduce the emissions caused by the building.

This redesign also includes two breadths, which look at how other systems will be affected by the redesign of the mechanical system. The first is the electrical system which will be greatly affected by the installation of a CHP plant and a DOAS and will need to be redesigned accordingly. The second is the architecture; changes will need to be made to the boiler plant to accommodate the additional CHP equipment and since the DOAS will decrease the sizing of the air handling units, more space will open up on the fourth floor and the ninth floor penthouse will need to be redesigned.

The redesign concludes that the installation of a dedicated outdoor air system will be extremely beneficial to the building. It also concludes that a combined heat and power plant is unfeasible due to existing energy costs and conditions on the campus.

Building Design Overview

Geisinger Hospital for Advanced Medicine is a 300,600 square foot building being constructed at Geisinger Main Campus in Danville, PA. The new hospital will adjoin the existing Geisinger Medical Center. The hospital will be nine stories tall with a lower basement level and a ninth floor penthouse, housing most of the building's air handling units. Construction was begun in June 2007 and the expected completion is Spring 2010. The estimated construction cost total is $108 million.

The building's design includes several shell spaces and floors designated for future use as the hospital's needs grow; these shell spaces total about half the square footage of the complete building. No future spaces will be analyzed in this report as little information is known about future intended uses.

The lower level is a partial shell floor but includes the dining room, toilet rooms, and staff areas. The first floor is also a partial shell floor but also includes the non-invasive cardiology areas. The second floor contains four operating rooms and space for an additional four. The third floor is a complete shell floor. The fourth floor contains a large mechanical room and the cardiology clinic. The fifth floor houses the cardiothoracic and vascular clinics, and lab clinics. The sixth floor is also a complete shell floor. The seventh and eighth floors are relatively the same and contain patient rooms.

Mechanical Systems Overview

The mechanical design includes eight air handling units, five to be installed now and three for future use. Other major mechanical work includes a new chiller building and an addition to the existing boiler house.

Air handling units AHU-4-1 and future AHU-4-2 will supply air for the operating rooms. The operating rooms require their own air handling units because the rooms need to be cooled to a lower temperature of 60°F and humidity levels must be more stringently controlled. AHU-4-1 will be installed now and sized to supply a current cfm of 12,000 of mixed outdoor air and return air and a future cfm of 18,000. AHU-4-2 is the future air handling unit and will be installed when the remaining four operating rooms are designed and constructed. Both of these air handling units will be located in the fourth floor mechanical room and both are designed for variable air volume. The mechanical system for the operating rooms also includes a energy recovery unit, which along with a cooling and heating coil pretempers the outside air and provides dehumidification.

Air handling unit AHU-4-3 will be installed now for the surgical pharmacy. AHU-4-3 supplies 2,700 cfm of return air to its spaces only cooling the air, reheat coils will take care of any heating loads. The air handling is located in the fourth floor mechanical room and is a constant volume unit. These areas will receive outdoor air ventilation through transfer air from surrounding spaces supplied by the south air handling units.

Air handling unit HV-4-4 is a future air handling unit for the kitchen hood make-up. This air handling unit will also be located in the fourth floor mechanical room and will be variable air volume.

The remaining areas of the building will be supplied by four air handling units, which includes one future unit. AHU-M-S1 and AHU-M-S2 will supply the south side of the building, both sized for a current cfm of 50,000 and a future cfm of 80,000. AHU-M-N2 and future AHU-M-N1 will supply the north side of the building. AHU-M-N2 will be sized for a current cfm of 80,000 and a future cfm of 77,000. The two south air handling units will be manifolded together and the two north air handling units will also be manifolded together. This provides one supply and return duct riser for the south side of the building and one supply and return duct riser for the north side of the building.

The hospital will use VAV boxes for most of the spaces and variable frequency drives will enable the air handling units to respond to the space loads. In spaces where positive pressure is required, according to AIA guidelines, return air boxes will be used. All supply air will be distributed through ceiling-mounted air devices.

Supplemental heating and cooling for several spaces is provided through fan coil units and radiant heating panels. Several spaces, mainly elevator machine rooms and electrical rooms will be provided with fan coil units to supply cooling and heating. Radiant heating panels will be installed at the perimeter glazing of levels three through eight.

ASHRAE 62.1- 2007 Compliance

ASHRAE Standard 62.1 Section 5 discusses requirements for systems and equipment to help improve building indoor air quality.

5.1 Natural Ventilation

No natural ventilation is used so these requirements do not apply.

5.2 Ventilation Air Distribution

Ventilation air is designed to met both ASHRAE Standard 62.1-2007 and AIA hospital guidelines. Balancing and testing requirements are included in the specifications.

5.3 Exhaust Duct Location

There are many spaces in the hospital that must be completely exhausted, including toilet rooms, isolation patient rooms, and operating rooms. All exhaust fans exhausting potentially harmful contaminants are located on the roof and mechanical level roof. All ductwork from exhausts is negatively pressurized.

5.4 Ventilation System Controls

All air handling units are provided with sufficient controls to ensure that spaces are kept at required conditions. Air handling units are controlled by a Johnson DDC system and contain variable frequency drives enabling them to adjust according to space loads.

5.5 Airstream Surfaces

All surfaces are both resistant to mold growth and erosion as required. Ductwork is constructed of sheet metal and therefore exempt from this requirement.

5.6 Outdoor Air Intakes

Outdoor air intakes for air handling units AHU-M-S1, AHU-M-S2, AHU-M-N2, and future AHU-M-N1 are located along the wall of the ninth floor penthouse. This is a significance distance from the ground and therefore from any traffic, parking, or landscaping. Air handling units AHU-4-2 and future HV-4-4 are located in the fourth floor mechanical rooms with intakes coming in from the walls. They are also far enough away from traffic, parking, or landscaping due to their distance from the ground. The exhaust from the building can be classified as significantly contaminated exhaust and therefore needs to be located a minimum of 15 feet from any air intakes. Most of these exhausts are located on the ninth floor of the penthouse, this takes them a more than adequate distance from the air handling units located on the fourth floor and also far enough away from the ninth floor penthouse intakes.

5.7 Local Capture of Contaminants

All necessary equipment and hoods are exhausted directly to the outdoors. Kitchen hood exhaust fans are located on the mechanical level roof. All other hoods and equipments exhaust fans are located on the roof.

5.8 Combustion Air

The only source of combustion air comes from the two new boilers. These boilers are lacted in the boiler house which puts them at a significant distance from the hospital. The boilers are both exhausted through the roof of the boiler house and contamination into the hospital is not a concern.

5.9 Particulate Matter Removal

The air handling unit for the operating rooms contains a MERV 8 pre-filter and a MERV 14 after-filter. The air handling unit for the surgical pharmacy contains a MERV 8 and MERV 13 pre-filter and a MERV 17 after-filter. The three air handling units for the remainder of the building contain a MERV 8 pre-filter and a MERV 14 after-filter. These filters all meet the MERV 6 requirement in this section.

5.10 Dehumidification Systems

The operating rooms are designed to 45% relative humidity. The surgical pharmacy is also designed to 45% relative humidity. The remainder of the building is designed for 30% relative humidity. This is well below the required 65% relative humidity for occupied spaces specified in the standard.

5.11 Drain Pans

The specifications require that insulated double wall sloped drain pans be installed under air handling unit cooling coils to comply with ASHRAE 62.1. Drain pans are also required for chilled water pumps and fan coil units. All drain pans are specified to be made of stainless steel, sloped, and insulated.

5.12 Finned-Tube Coils and Heat Exchangers

Coils all are required to have drain pans installed and meet the requirements for cleaning.

5.13 Humidifiers and Water- Spray Systems

The humidifiers use steam; all water used to produce steam is treated and monitored.

5.14 Access for Inspection, Cleaning, and Maintenance

Ventilation equipment includes access doors and sufficient room to inspect and maintain all equipment.

5.15 Building Envelope and Interior Surfaces

The building envelope includes vapor barriers in accordance with this section. All required piping will be insulated to prevent condensation on interior surfaces.

5.16 Buildings with Attached Parking Garages

The future parking garage will not be attached to the hospital so these requirements do not apply.

5.17 Air Classification and Recirculation

According to Table 5-2 and 6-1 most of the spaces in the building are classified as Class 1. The kitchen hood air is classified as Class 3 and will all be exhausted. Bathrooms are not listed but all air will be exhausted. Table E-1 which lists ventilation requirements for health care facilities does not specify classes for the air. Regular patient rooms recirculate air and isolation rooms exhaust all air. The building meets the requirements for this section of the standard.

5.18 Requirements for Buildings Containing ETS Areas and ETS-Free Areas

Since the hospital is completely smoke-free these requirements do not apply.

The following tables shows the total airflow rates required for each air handling unit.

	Service	V_{ou}	Max Z_p	E_v	V_{ot}	Min. OA Supplied	Complies?
AHU-4-1	Operating Rooms	840	0.07	1.0	840	2400	YES
AHU-4-3	Surgical Pharmacy	55.7	0.03	1.0	55.7	0	NO
AHU-M-N2	North Side	6746.04	0.27	0.8	8432.55	19250	YES
AHU-M-S1	South Side	4743.16	0.30	0.8	5928.95	15000	YES
AHU-M-S2	South Side	4743.16	0.30	0.8	5928.95	15000	YES

This table shows that air handling units AHU-4-1, AHU-M-N2, AHU-M-S1, and AHU-M-S2 all well exceed the required amount of ventilation air for the spaces. The building was designed using the Guidelines for Design and Construction of Hospitals and Health Care Facilities, 2006 Edition, and ASHRAE Standard 62.1 -2007 this standard recommends much higher ventilation rates for spaces in hospitals.

AHU-4-3 appears to not meet the requirements of ASHRAE Standard 62.1 but the spaces actually use transfer air from the south air handling units to supply their outside air. Ducts transfer 1,100 cfm into the space from the surrounding areas. Since the air from the south air handling units is comprised of about 30% outdoor air, this supplies 330 cfm of outdoor air to the surgical pharmacy, well above the 56 cfm required.

ASHRAE 90.1 -2007 Compliance

Section 5 Building Envelope

The hospital is located in Danville, PA, part of zone 5A. Since the building vertical fenestration area is less than 40% of the gross total wall, and the skylight fenestration area is less that 5% of the gross roof area, according to section 5.2 the prescriptive building envelope requirements in section 5.5 apply.

The building is constructed of the following wall assemblies, precast wall, formawall system, concept wall system, spandrel glass. There are three roof system, metal deck, concrete deck, and green roof. The following table compares the actual U-Values of the building with the requirements in Table 5.5-5:

	Actual U-Value	Max U-Value	Complies?
Precast Wall	0.054	0.090	YES
Formawall System	0.061	0.113	YES
Concept Wall System	0.062	0.113	YES
Spandrel Glass	0.058	0.064	YES
Roof (Metal Deck)	0.040	0.065	YES
Roof (Concrete Deck)	0.039	0.048	YES
Roof (Green Roof)	0.046	0.048	YES

All of the wall assemblies comply with the standard.

The building also uses two types of glazing, the following table shows complies with the requirements in Table 5.5-5:

	Actual U-Value	Actual SHGC	Max U-Value	Max SHGC	Complies?
Glazing 1	0.46	0.26	0.55	0.4	YES
Glazing 2	0.46	0.27	0.55	0.4	YES

All of the glazing complies with the standard.

Section 6 Heating, Ventilation, and Air-Conditioning

The hospital is a new building and therefore must meet the requirements set in section 6.2. Section 6.2 lists the sections of compliance. Due to the buildings size section 6.4, mandatory provisions, and section 6.5, prescriptive path must be followed.

There will be two new boilers for this building. One hot water, gas fired, B-4, and the other electric, B-5. Table 6.8.1F states the requirements for gas-fired boilers. Boiler B-4 has an input of 11,824 MBH and according to the table requires a minimum efficiency of 80%, the efficiency of this boiler is 87.5% and meets requirements.

Other requirements in section 6.4 include labeling or equipment, thermostats for each zone, and necessary controls. The hospital meets all of these requirements. In regards to off-hour operation the HVAC system is intended to operate continuously and is exempt from these requirements. All necessary dampers are specified in the mechanical drawings and specifications. Demand control ventilation will be installed in high occupancy areas with CO_2 sensors in return air ducts to monitor space air. Fire/smoke dampers will be installed in every duct entrance and exit from shaft enclosure. Supply and return air duct smoke detectors will be installed in each air handling unit. Smoke dampers and duct-mounted smoke detectors will be installed where ever a duct crosses a smoke barrier.

Section 6.4.4 lists requirements for HVAC insulation. All supply, return, outside air, dishwasher exhaust, and grease exhaust will include exterior insulation.

Section 6.4.2 lists requirements for duct and plenum leakage. According to the specifications all ducts will be sealed according to seal Class A and leakage Class C. Class A is well within the requirements for duct seal level.

Section 7 Service Water Heating

The hospital is a new building and according to section 7.1 of the standard must comply with section 7.2. Section 7.2 lists the sections of compliance. The hot water is supplied by two semi instantaneous hot waters generators powered by steam. An equivalent type could not be found in Table 7.8, the standard states that equipment not listed has no minimum performance requirements. All piping insulation meets the requirements set by standard 7.4.3.

Section 8 Power

All feeders are sized for a maximum voltage drop of less that 2% and all branch circuits are sized for a maximum voltage drop of less than 3%.

Section 9 Lighting

The hospital may be reviewed for compliance by either the space-by-space method or the building area method according to section 9.2 of the standard. Using the building area method, section 9.5, according to Table 9.5.1 states that a hospital's lighting density be below 1.2 W/sf. The table below shows the total square footage and watts for the hospital.

Total Area (sf)	135951
Total Watts	153406
Watts/SF	1.13

According to this table the hospital meets this section of the standard. Refer to Appendix for individual space square footages and watts.

In section 9.4, the standard states requirements for lighting control, tandem wiring, and exit signs. In compliance with this standard, all required spaces have occupancy sensors. Spaces where it is necessary for patient care and spaces that are intended for 24-hour operation are exempt from this requirement and therefore do not have occupancy sensors. Tandem wiring requirements are met and two-lamp tandem-wired ballasts are used where required. The standard requires exit signs to be no more than 5 watts per space, the exit signs specified for the hospital are all 3 watts, well below the standard.

Mechanical System Redesign

Dedicated Outdoor Air System and Ceiling Radiant Cooling Panels

A typical mechanical system combines fresh outdoor air and recirculated air and distributes the conditioned air to all spaces. It is designed to meet both sensible and latent loads and ventilation requirements. However; due to varying loads in the building it can be difficult for this system to constantly meet latent loads and ventilation requirements while keeping spaces at the required temperatures. This can lead to humidity problems and poor indoor air quality both of which contribute to sick building syndrome.

Hospitals should be designed with the health of their occupants as the number one priority; this includes designing mechanical systems which can constantly meet ventilation requirements and control humidity. The hospital should also be able to accomplish these tasks in an energy efficient manner. The Geisinger Hospital for Advanced Medicine was designed with a variable air volume (VAV) system. VAV systems do have several advantages; they can easily meet different loads in different spaces and do so at a fairly low energy use. A better system however; would be a Dedicated Outdoor Air System (DOAS) which would improve ventilation in the building, control humidity decrease the energy usage of the building.

Objective

The mechanical redesign for the Geisinger Hospital for Advanced Medicine includes designing a DOAS for the hospital along with chilled beams to meet additional sensible loads. Energy recovery will also be used to help decrease energy use. The main objective of this is to improve indoor air quality of the building and lower energy use of the building.

A dedicated outdoor air system offers many benefits. The first is through the use of two different systems, one to meet the latent loads and ventilation requirements and the other to meet remaining sensible loads. Typical systems are controlled by thermostats which are directly controlled by the sensible loads in the building, as the temperature in the space drops so does the amount of sensible and latent cooling. This can often lead to high humidity problems in spaces at part-loads. By separating the sensible and latent loads, humidity issues can be resolved. The separation of two systems also allows ventilation airflow rates to be more easily controlled (Murphy).

A second advantage of DOAS is improved indoor air quality (IAQ) in the building. In July 1976, Legionnaires' disease spread through a hospital in Philadelphia, sickening 221 people and killing 34. Since then indoor air quality has been more a rising issue in buildings as people began to see the correlation between a building's IAQ and its occupants health (Manuel). Studies have shown that there a direct correlations between IAQ and sick building syndrome (SBS) and the health and productivity of those inside. According to Fisk's study, it is shown that by increasing the quality of air for workers, potentially billions of dollars can be saved annually by the United States (Fisk). Another study performed showed that many schools with conventional mechanical systems were not meeting the require 15 cfm per student required by ASHRAE 62.1, instead provided an average of 5.4 cfm per student. However schools with a DOAS provided the 15 cfm per student required and also had an average absenteeism of 9% lower than those schools with a conventional system (Manuel.)

A third advantage is a savings in energy use and cost. The main reason the energy cost goes down is there is less reheating required then with the use of VAV boxes. Reheating the air requires energy to be used to cool then air and then further energy required to reheat the air. Much of this reheating is due to the need to dehumidify the air to try to control the humidity levels in the space. Reheat coils also increase the electricity needed and/or the piping needed to be installed (Larranaga). Using DOAS in conjunction has proven to lower energy costs substantially.

Since a DOAS is sized to meet ventilation and latent loads, a secondary system must be installed to meet sensible loads in the building. There are several options available including a parallel all-air VAV system, fan coil units, water-source heat pumps, or ceiling radiant cooling panels. The best choice for the hospital is ceiling radiant cooling panels (CRCP).

The choice of CRCP's is due to several benefits over other parallel systems. One of the main advantages is increased comfort level over other systems. This is due to radiant loads being treated directly and the amount of air motion in the space. In a conventional system, most of the cooling comes from convection, while in a CRCP system the majority of cooling is due to radiation. Another advantage is a lower first cost, about 15% less than other systems. There are also increasing long term saving, approximately 20% to 30% due to decreased fan power (Mumma).

Dedicated Outdoor Air System and Chilled Beams Redesign

Dedicated outdoor air handling units will be replaces four of the five existing air handling units, the three future air handling units do not have the information available to size and due to the requirements of the operating air handling units which are equipped with their own chilled water systems, the air handling unit will stay as is. The surgical pharmacy air handling unit, AHU-4-3 will be incorporated into the south air handling units, due to the small ventilation rate required by the spaces.

The dedicated outdoor air system and ceiling radiant cooling panels were designed using the steps outlined in “Designing a Dedicated Outdoor Air System with Ceiling Radiant Cooling Panels” by Jae-Weon Jeong, Ph.D. and Stanley A. Mumma, Ph.D., P.E.

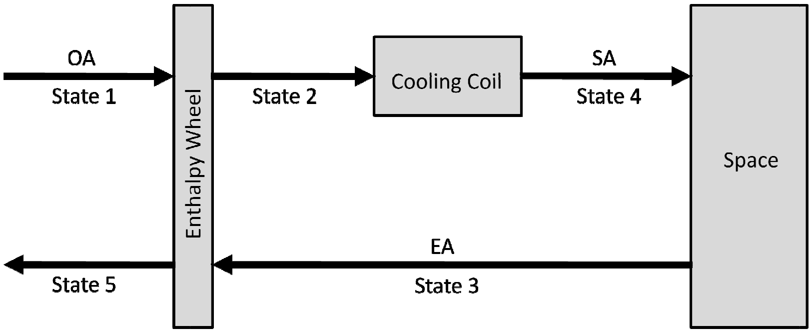


Figure 1. Basic Diagram of the System

Outdoor design conditions were determined using the 2005 ASHRAE Handbook- Fundamentals

- Outdoor Design Conditions
    - Location: Williamsport, Pennsylvania
        - Latitude: 41.27N
        - Longitude: 77.05W
        - Elevation: 525 ft
    - Summer Conditions (0.4%)
        - 90.1°F DB
        - 72.9°F WB
        - Winds: W 9.8 mph
    - Winter Conditions (99.6%)
        - 3°F DB
        - Winds: WNW 7 mph

Target space conditons are as follows:

- Indoor Design Conditions
    - Operating Rooms
        - Room temperature: 60°F to 70°F (adjustable by room)
        - 50%-55% RH at 60°F
        - 35%-40% RH at 70°F
    - Cath Labs
        - Room temperature: 70°F to 75°F (adjustable by room)
        - 30%-60% RH (adjustable by room)
    - MRI and CTI Rooms
        - Room temperature: 68°F to 75°F (adjustable by room)
        - 30%-60% RH (adjustable by room)
    - Patient Rooms
        - Room temperature: 70°F to 75°F (adjustable by room)
        - 30% RH min (winter)
        - 60% RH max (summer)
    - Exam/Treatment
        - Room temperature: 75°F
        - 30% RH min (winter)
        - 50% RH max (summer)
    - Mechanical and Electrical Rooms
        - Summer: 10°F above outdoor air temperature
        - Winter: 65°F
    - Kitchen
        - Summer: 85°F maximum
        - Winter: 65°F minimum
    - Other spaces:
        - Summer: 75°F, 50% RH maximum
        - Winter: 70°F, 30% RH minimum

According to the article, the use of chilled radiant cooling panels can allow the space temperature to be increased by 2°F to 4°F without negative impact on the thermal comfort of its occupants. Because the space temperatures used are required by the hospital, the system will still be designed for the space temperatures given.

The required ventilation rates were determined using both ASHRAE Standard 62.1-2007 and AIA Guidelines for Design and Construction of Hospitals and Health Care Facilities, 2001. The AIA Guidelines require a higher level of ventilation for spaces especially patient rooms; they also have set requirements for air changes in the spaces. Difficulty arose while trying to determine how to meet the air change requirements while avoiding recirculating air throughout the hospital or sizing the DOAS to meet the air change rates through all outdoor air. After reading Mumma's article "Meeting Air Change Criteria" from ASHRAE's IAQ Applications, it was determined that using a DOAS with high induction diffusers will "meet or exceed the performance of a conventional all-air

VAV system under design conditions from a diffuser performance, space air mixing and [Air Diffuser Performance Index] ADI perspective." The cooling loads for the hospital were determined using Carrier's Hourly Analysis Program (HAP).

The supply air conditions were determined using the equations in the article. The DOAS must be sized using the critical space it serves, the one that requires the driest supply air.

$$W_{sa} = W_{sp} - \frac{Q_L}{0.68 \times \dot{V}_{sa}}$$

W_{sa} = SA humidity ratio, gr/lb
W_{sp} = target space humidty ratio, gr/lb
Q_L = space latent load, BTU/h
V_{sa} = space SA flow rate, cfm

The following table shows the calculated supply air humidity ratios and corresponding supply air temperatures, assuming the supply air leaves the cooling coil at the saturated condition:

AHU	W_{sp} (gr/lb)	# of People	Q_L (Btu/hr)	V_{sa} (CFM)	W_{sa} (gr/lb)	T_{sa} (F)
AHU-M-S1	64.4	389	92250	8720	48.84	47.7
AHU-M-S2	64.4	389	92250	8720	48.84	47.7
AHU-M-N2	64.4	484	116000	9510	46.46	46.4

Though these supply air temperatures are a bit lower than typically used, research has shown that a supply temperature of as low as 45°F is acceptable with the use of high induction diffusers.

The enthalpy wheel effectiveness and design cooling coil loads are determined next. The following equation is used:

$$T_2 = T_1 - \varepsilon_S(T_1 - T_3)$$

$$W_2 = W_1 - \varepsilon_L(W_1 - W_3)$$

T_1 = dry bulb temperature of outdoor air (°F)
T_2 = dry bulb temperature of air after enthalpy wheel (°F)
T_3 = dry bulb temperature of exhaust air (°F)
W_1 = heat ratio of outdoor air (gr/lb)
W_2 = heat ratio of air after enthalpy wheel (gr/lb)
W_3 = heat ratio of exhaust air (gr/lb)
ε_S = sensible effectiveness of the enthalpy wheel
ε_L = latent effectiveness of the enthalpy wheel

The values for the effectiveness of the wheels are estimated at ε_S = 85% and ε_L = 83% assuming a silica gel enthalpy wheel is used. The following table shows the conditions of the air for each air handling unit after passing through the enthalpy wheel:

AHU	T_1	T_3	W_1	W_3	ε_s	ε_L	T_2	W_2
AHU-M-S1	90.1	70	93.8	64.4	0.85	0.83	73.02	69.40
AHU-M-S2	90.1	70	93.8	64.4	0.85	0.83	73.02	69.40
AHU-M-N2	90.1	70	93.8	64.4	0.85	0.83	73.02	69.40

The design cooling coil load can now be determined using the following equation:

$$Q_{cc} = 0.06 \cdot \rho \dot{V}_{sa,tot}(h_2 - h_4)$$

Q_{cc} = cooling coil capacity required (kBtu/h)
ρ = average supply air density (lb/ft^3)
$V_{sa,tot}$ = total air supply quantity (cfm)
h_2 = supply air enthalpy after enthalpy wheel (Btu/lb)
h_4 = supply air enthalpy after cooling coil (Btu/lb)

The following table shows the cooling coil capacities required by the air handling units:

AHU	ρ	$V_{sa,tot}$	h_2	h_4	Q_{cc}
AHU-M-S1	62.43	8720	28.4	19	307026
AHU-M-S2	62.43	8720	28.4	19	307026
AHU-M-N2	62.43	9510	28.4	18.3	359776

Now the sensible cooling load required by the ceiling radiant cooling panels is calculated by the following equations:

$$Q_{sen,sa} = 1.08 \cdot \dot{V}_{sa}\left(T_{sp} - T_{sa}\right)$$

$$Q_{sen,p} = Q_s - Q_{sen,sa}$$

$Q_{sen,sa}$ = supply air cooling capacity (Btu/h)
$Q_{sen,sp}$ = panel sensible cooling load (Btu/h)
Q_s = space sensible cooling load (Btu/hr)
V_{sa} = supply air flow rate in each space (cfm)
T_{sp} = space dry-bulb temperature (°F)
T_{sa} = supply air dry-bulb temperature (°F)

These calculations are shown in Appendix A- Ventilation Schedules. Since some of the spaces end up with a negative panel cooling capacity, reheat coils may need to be installed. Some of these negative values can also be solved by looking at adjoining areas and adjusting diffuser placement to reduce the amount of reheating.

Next the design panel cooling capacity must be determined. The panel cooling capacity is estimated at 42 Btu/h·ft^2 when high induction diffusers are used.

The required ceiling radiant cooling panel size can be determined by the following equation:

$$A_p = \frac{Q_{sen,p}}{q_p}$$

A_p = the ceiling radiant cooling panel area required (ft^2)
$Q_{sens,p}$ = space sensible cooling load (Btu/h)
q_p = the cooling capacity of the panel (Btu/h·ft^2)

The results of these calculations are also shown in Appendix A – Ventilation Schedules.

Results

Outdoor Air Savings

One benefit of a dedicated outdoor air system is savings in the amount of outdoor air conditioned for the building. The following table shows the amount of outdoor used in the VAV system versus the DOAS:

AHU	VAV System	DOAS	Difference	% Decrease
AHU-M-S1	15000	8720	6280	42%
AHU-M-S2	15000	8720	6280	42%
AHU-M-N2	19250	9490	9760	51%
Total	49250	26930	22320	45%

Increased space

As originally designed air handling unit, AHU-M-3, was a York Solutions 36” x 48” unit, which has now been eliminated. This allows the mechanical room on the fourth floor to be made slightly smaller increasing rentable space.

The originally designed north and south air handling units, AHU-M-S1, AHU-M-S2, and AHU-M-N2 were custom designed York air handling units, 154” x 224”. The redesigned air handling units are Trane M-Series Size 21 air handling units, 52” x 77”. This greatly decreases the amount of space needed in the top floor penthouse. This decrease construction costs of the penthouse and also decreases any conditioning being done in that space, saving energy.

Additional space will be available around duct shafts, since the main ducts are significantly reduced in size. The main supply duct for the south air handling units was 108” x 138” in the mechanical shaft on the eighth floor, this duct could now be resized to 42” x 44”, similar resizing down the shaft would occur.

Indoor Air Quality

As mentioned previously, a main result of the DOAS and CRCP’s is the increased indoor air quality of the hospital. Air from patient rooms, lobbies, and various other areas will no longer be recirculated throughout the hospital, reducing the amount of germs and bacteria that can be spread throughout the hospital. The use of high induction diffusers increases the mixing in the room which increases the ventilation efficiency factor and improves IAQ. Various studies have shown that DOAS can improve indoor air quality and increase occupant comfort.

Energy Savings

The installation of a DOAS will lower the energy use of the building and decrease the energy costs. Load calculations were done on the building, Appendix B includes the design load outputs for each air handling unit and Appendix C includes the energy simulation results. The following table compares the existing energy use to the energy use of the redesigned system:

	Annual Electrical Use (kWh)	Annual Gas Use (kbtu)
Currrent Design	9,470,283.00	3,292,933.00
DOAS/CRCP	7,794,004.00	803,323.00
Difference	1,676,279.00	2,489,610.00
% Difference	18%	76%

From the table it is evident that most of the energy savings is due to less reheating being necessary.

CHP

Typical commercial buildings receive their electrical power from the local electrical grid. This electricity could be have produced from many different sources, coal, natural gas, various other fossil fuels and more recently an increase in solar and wind use is present. Typically in the production of electricity, thermal heat is produced and usually wasted. This energy could be used for a variety of different things, space heating, water heating, even cooling through the use of absorption chillers. By wasting all of this potentially useful energy, emissions increase, the cost of electricity increases, and more fossil fuels are used than necessary.

A hospital should be concerned with the amount of emissions it produces to keep air pollution at a minimum; it should also want to keep its energy costs and uses as low as possible. Though there are some benefits to the use of off-site power, no maintenance costs, reliable of service, and lower first cost; a combined heat and power (CHP) system, also called cogeneration, should be considered. The Geisinger Hospital for Advanced Medicine is an ideal building for CHP; health-care installations represent approximately two-thirds of all CHP applications in commercial buildings. This is partially because of flatten thermal and electrical loads on the building, much of the hospital is in operation 24 hours a day, 7 days a week, electricity is always being used and the building must always stay heated or cooled.

Objective

The redesign of the Geisinger Hospital for Advanced Medicine includes a look at installing a CHP plant to provide electricity and thermal energy for the building. CHP is the use of a prime move to create electrical power and of thermal energy from one energy source.

Installing a CHP plant has many advantages. By using energy most efficiency, it can lower energy costs and use and therefore lower emissions caused by energy use. Through the use of excess heat, CHP plants can reach an efficiency of up to 89%, typical plants that do not recover heat have an efficiently of about 55%. Through the use of a CHP plant for the hospital, energy uses should be lowered along with energy cost.

Combined Heat and Power

Feasibility

A sparks spread of greater than \$12/MMBtu means that CHP could be feasible. The first step in determining the feasibility of a CHP plant is to calculate the sparks gap for the hospital.

Natural gas and electricity are supplied to the hospital. The electricity is supply by PP&L Electric Utilities. The following chart shows the prices of electricity:

	$/kWh
First 200 kWh	0.0657
next 600 kWh	0.0586
over 800 kWh	0.0544

Since the hospital uses well over 800kWh, a price of \$0.0544/kWh will be used. Natural gas is supplied by UGI Penn Natural Gas. The price is \$11.11 per Mcf. The sparks spread is calculated by the difference in price of electricity and natural gas.

Electricity: $(\$0.0544/\text{kWh})*(1\ \text{kWh}/3412\ \text{Btu}) = \$1.59\text{x}10^{-5}/\text{Btu} = \$15.90/\text{MMBtu}$
Natural Gas: $(\$11.11/\text{Mcf})*(1\ \text{Mcf}/1000\text{cf})*(1\ \text{cf}/1020\ \text{Btu}) = \$1.09\text{x}10^{-5}\ /\text{Btu} = \$10.90/\text{MMBtu}$

Sparks Spread = \$15.90x10/MMBtu - \$10.90 /MMBtu = \$5 /MMBtu

This spread is much less that the required \$12/MMBTU, so a CHP system may not be feasible.

Another factor which may make the use of a CHP plant for the Geisinger Hospital of Advanced Medicine less feasible is the location of the hospital on a pre-existing campus. The campus already has an infrastructure to provide heating, cooling, and electricity to its building, the integration of a CHP plant may be too costly to justify given the equipment that already exists. Also little information is known about the other hospitals on the campus so it would be difficult to try to size a CHP plant to provide for the entire campus. For the CHP plant to be useful all times of the year, it would help to use absorption chillers so that the thermal power can be used. Unfortunately, a chiller plant is already established and while some changes are being made to it to provide for the new hospital building, converting the entire thing to an absorption chiller plant may cost more than it’s worth. Existing boilers are already in place for the campus and the transformer was recently upgraded in 2006 to provide power to the new building.

With all of the factors of a low spark spread and the existing conditions of the campus, a CHP plant does not really seem like it would be cost effective for the hospital. An overview of the steps that would be taken if a CHP plant was installed will be reviewed.

Combined Heat and Power Redesign

Though the addition of a CHP system may not be cost effective and practical for the hospital, estimates were done to determine the effect a CHP system to take care of some of the thermal loads on the building would have. A gas turbine was sized to replace the gas boiler that was to be installed, a decrease the capacity of the electric boiler used. The boilers were a 10,050 MBH gas boiler, B-4, and a 20,273 MBH boiler, B-5.

A Solar gas turbine generator was chosen, the Saturn 20, which has an output power of 1210 kW and a heat rate of 14,025 Btu/kW-hr. The heat produced by the turbine is:

$$1{,}210\ kW \times 14{,}025 \frac{Btu}{kW \cdot hr} = 16{,}970\ MBH$$

The fuel used by the gas turbine is calculated assuming 1020 Btu/1 cf gas. The following is the amount of gas used by the turbine:

$$16{,}970\ MBH \times \left(\frac{1000\ Btu}{1\ MBH}\right) \times \left(\frac{1\ cf\ gas}{1020\ Btu}\right) \times (8760\ hr) = 145{,}742{,}352\ cf$$

The cost of the gas used, using the price \$11.11/Mcf, is:

$$145{,}742{,}352\ \ cf \times \left(\frac{1\ Mcf}{1000\ cf}\right) \times \left(\frac{\$11.11}{1\ Mcf}\right) = \$1{,}619{,}197$$

The cost and energy savings come from the electricity produced by the turbine. The amount of electricity produced in a year assuming the turbine is in operation 8,760 hours a year is:

$$1{,}210\ kW \times 8{,}760\ hr = 10599.6\ MkWh$$

This is greater than the 1,676,279 kWh calculated previously for the building. This electricity could be used by other buildings on the campus. At a price \$0.0544/kWh the cost savings from electricity are:

$$10{,}599{,}600\ kWh \times \$0.0544 = \$576{,}618$$

The cost of the turbine can be estimated at \$1000/kW, this totals \$1,210,000 for the turbine. Immediate cost savings include the elimination of the natural gas boiler, \$120,000, and the electrical boiler, \$280,000. A smaller electrical boiler costing around \$200,000 would need to be installed instead. The first cost would increase by approximately \$1,010,000.

The amount of natural gas being used by the building would increase, due to the increase of the gas powered boiler over the electric boiler and is calculated:

$$(16{,}970\ MBH - 10{,}050\ MBH) \times \left(\frac{1000\ Btu}{1\ MBH}\right) \times \left(\frac{1\ cf\ gas}{1020\ Btu}\right) \times (8760\ hr) = 594{,}305\ cf\ gas$$

The cost of this additional gas would be:

$$594{,}305\ cf \times \left(\frac{1\ Mcf}{1000\ cf}\right) \times \left(\frac{\$11.11}{1\ Mcf}\right) = \$660{,}273$$

This cost is actually more than the savings derived from the electrical costs; therefore a CHP system is economically inefficient.

Electrical Breadth

The redesigns to the mechanical system greatly affect the electrical system of the building. The installation of the DOAS/Chilled Beam system affects the necessary power for the building. The possible installation of a CHP plant affects the power distribution to the building.

Effects due to DOAS and Chilled Beams

Installing a dedicated outdoor system and chilled beams will affect the amount of power required by the building. Since large AHU's are eliminated and replaced with smaller DOAS units the amount of power required for the mechanical system is reduced. Resizing feeders and other electrical equipment can provide first cost savings to the building.

The following table shows the motor horsepower of the existing designed air handling units and the redesigned DOAS air handling units:

AHU	Supply Fan Motor HP	NEW Supply Fan Motor HP
AHU-4-1	50	50
AHU-4-3	6.2	-
AHU-M-N2	150	15
AHU-M-S1	150	15
AHU-M-S2	150	15

The following table shows the breakers added and removed in the electrical system:

Service	Breakers Removed	Breakers Added
AHU-4-3	50	-
	50	-
	50	-
AHU-M-N2	225	20
	225	20
	225	20
AHU-M-S1	225	20
	225	20
	225	20
AHU-M-S2	225	20
	225	20
	225	20

Effects of Combined Heat and Power

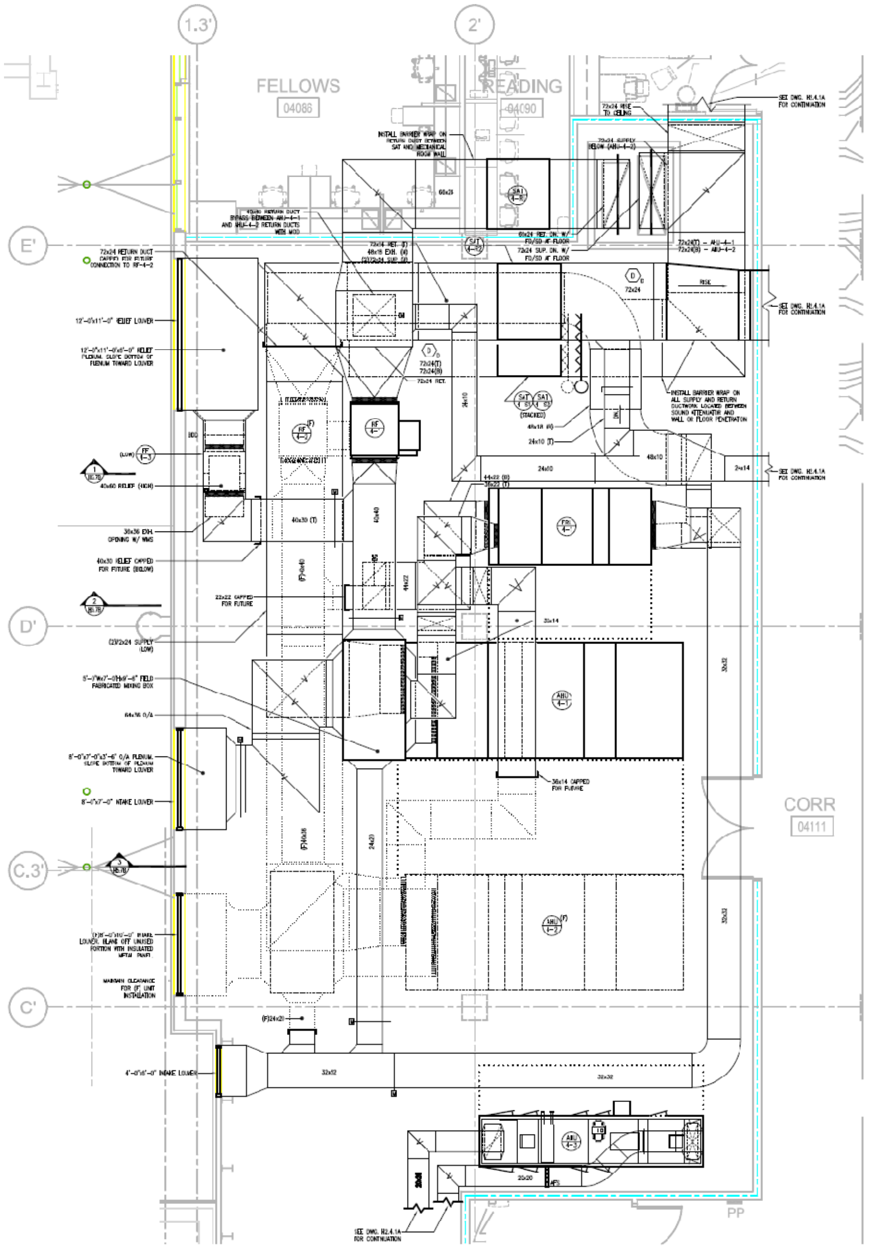
If the combined heat and power plant was installed, significant changes would have to be made to the electrical system. The main power would have to be reconfigured to be supplied from the CHP plant and backup power from the utilities would have to be supplied in case of problems with the plant or done times due to maintenance. If the plant plans to sell electricity back to the utility this would also have to be configured into the system.

Architectural Breadth

The redesigns to the mechanical system have some effect to the architecture of the building. The installation of the DOAS means that less room is needed for the air handling units in the building. If the CHP plant was to be installed, designs to the boiler plant may need to be changed.

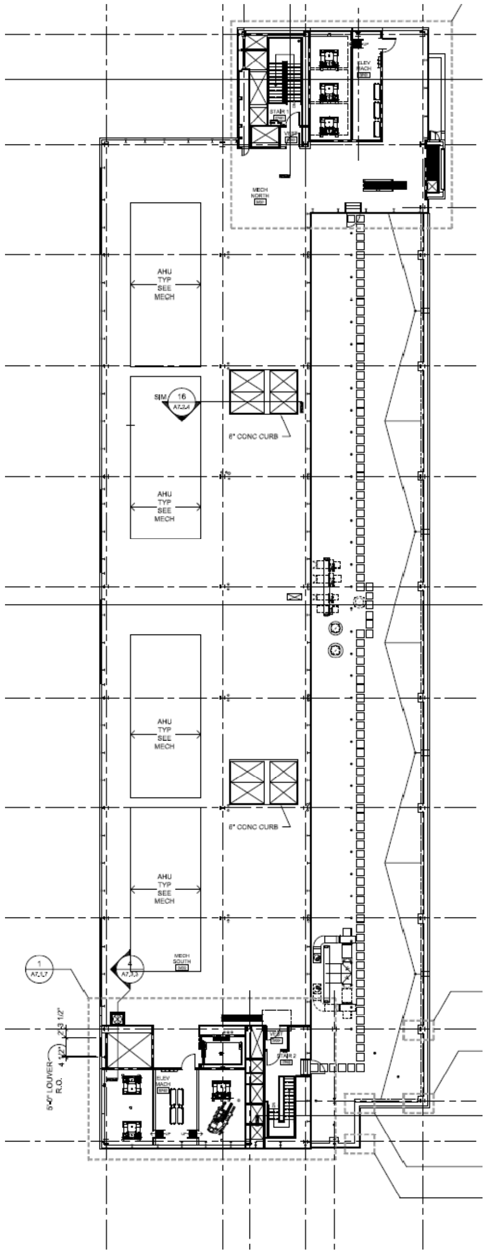
Effects of DOAS and Chilled Beams

The fourth floor mechanical system of the hospital houses the air handling units for the operating rooms, AHU-4-1 and space for AHU-4-2, and also the air handling unit for the surgical pharmacy AHU-4-3. The elimination of AHU-4-3 allows for a slightly smaller mechanical room. The following is a floor plan of the currently designed mechanical room:



AHU-4-3 is located in the lower right of the room; though removing it does significantly it does increase the amount of rentable space in the hospital slightly, approximately 50 sf. It is difficult to provide a new floor plan, since I was unable to obtain autocad drawings of the floor plans.

The redesign of AHU-M-N2, AHU-M-S1, and AHU-M-S2 cause a larger change in the architecture of the building. The penthouse mechanical room is a large area of the hospital and the decreasing of three air handling units and one future air handling unit from 154" x 224" to 52" x 77" would greatly reduce the amount of space needed in the penthouse. The following is the floorplan of the penthouse:



Reducing the size of the penthouse would decrease construction costs and decreasing any conditioning being done in that area.

Effects of Combined Heat and Power

If a CHP plant was being installed, the boiler house would need to be enlarged to make space for additional equipment. Very few other architectural modifications would need to be made.

Conclusions and Recommendations

The dedicated outdoor air system and ceiling radiant cooling panels mechanical redesign would be extremely beneficial to the Geisinger Hospital of Advanced Medicine. The system provides energy savings, which reduce life cycle cost and emissions in the area, and improve the indoor air quality of the building.

The results of this report have demonstrated that the energy usage of the building will decrease if a DOAS system was installed. Though researching articles, it can also be determined that the indoor air quality will improve as this system has worked in so many other instances.

Though a combined heat and power plant can offer benefits for many buildings, it does not appear to be feasible for the Geisinger Hospital for Advanced Medicine. Factors include the energy costs in the area and the location of the building on a medical campus with existing infrastructure.

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Master Coursework

AE 551 Combined Heat and Power: The material covered in this class was used to determine the feasibility of a CHP system for the hospital. Material learned in this class also helped with determining the type of combined heat and power plant to be installed.

AE 522 – Air Quality in Buildings: The material covered in this class was relevant to the increased indoor air quality in the hospital. Material learned in this class stressed the importance of good indoor air quality in buildings to decrease the chances of sick building syndrome.