

Carl R. Darnall Army Medical Center



Thesis Proposal Dedicated Outdoor Air System With VRF system and WSHP

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Executive Summary

The purpose of the following report is to identify possible alternative designs to the current medical center. The current design of the medical center meets ASHRAE 62.1 and 90.1-2013 standards, and it is certified LEED Gold. By analyzing the design through technical reports 1 through 3, an educated decision was made to explore multiple design options for the current building.

The medical center utilizes a central utility plant comprised of centrifugal chillers for the chilled water, natural gas and fuel boilers to create steam for the heat exchangers to supply hot water for the building. Steam is supplied to the building for humidification and cleaning purposes. An absorption chiller preheats the domestic water while meeting the base cooling load during the cold season. The medical center provides 100% outdoor air to cool and heat the building, well above the ventilation air requirements. The medical center uses the extra space provided by the interstitial floors to maximize the efficiency of the air system.

Evaluating the current system brought up many possible changes to benefit the system. The considerations included adopting a combined heat and power plant, implementing water source heat pumps, switching to a dedicated outdoor air system, chilled beams, and a solar hot water heating system.

After careful consideration, the main focus of the depth of the investigation will be switching to a dedicated outdoor air system to supply the minimum ventilation air with a hydronic system to condition the spaces. The two systems identified are a variable refrigerant flow system and a water source heat pump system to condition the spaces provide optimal control for individual zones' conditions. The systems are able to simultaneously heat and cool at the same time by transferring heat from a room in cooling mode to a room in heating mode. The two systems will be compared by the energy consumption, construction costs, and life cycle costs.

The proposed alternative will provide opportunity to explore new ideas for the building, and an educational opportunity to explore indoor air quality. Through the depth analysis, indoor air quality will be monitored to ensure the air remains clean at the low ventilation rates. By reducing the air side system, the amount of ductwork will change thus affecting the construction cost. There will be no need for the extra space in the interstitial floors, so the interstitial floors will reduce down to large plenums which will affect the structural costs and ease of maintenance. With the addition of new equipment to the roof, and the change in air handlers, a structural breadth will be investigated into the redesign of the roof.

The investigation of the depth and breadths will require tools to assist in load simulation. IES Virtual Environment will be used to observe energy consumption and load simulation. The spring semester is laid out in a schedule in the following sections.

Mechanical Overview

The army medical center has an off-site central utility plant which consists of its chilled water plant and heating hot water plant. The medical center receives the services from an underground tunnel. The two heat recovery chillers help provide chilled water during colder weather, and they preheat the heating hot water return. It is base loaded, so during the winter, the centrifugal chillers and cooling towers do not need to run. Each of the four centrifugal chillers has a capacity of 1,250 tons, and the heat recovery chiller provides a capacity of 150 tons. Overall, the system provides enough capacity for future air handlers. The chilled water system provides a supply temperature of 44°F to the air handlers, fan coil units for electrical and telecom rooms. The building uses hot water produced by four gas fired steam boilers. The heated hot water system provides a supply temperature of 140°F.

Floors 5 and 6 of the east bed tower are conditioned by two air handlers in the penthouse on the roof that supply 100% outdoor air at 55F. Both air handlers have an enthalpy recovery wheel which recovers energy from the exhaust air. AHU-2 serves constant air volume terminal units on floor 5 which consists of the pediatric department, as well as, a general medical / surgical department. AHU-3 serves constant air volume terminal units on floor 6 which consists of offices for the departments, officers, and the medical library.

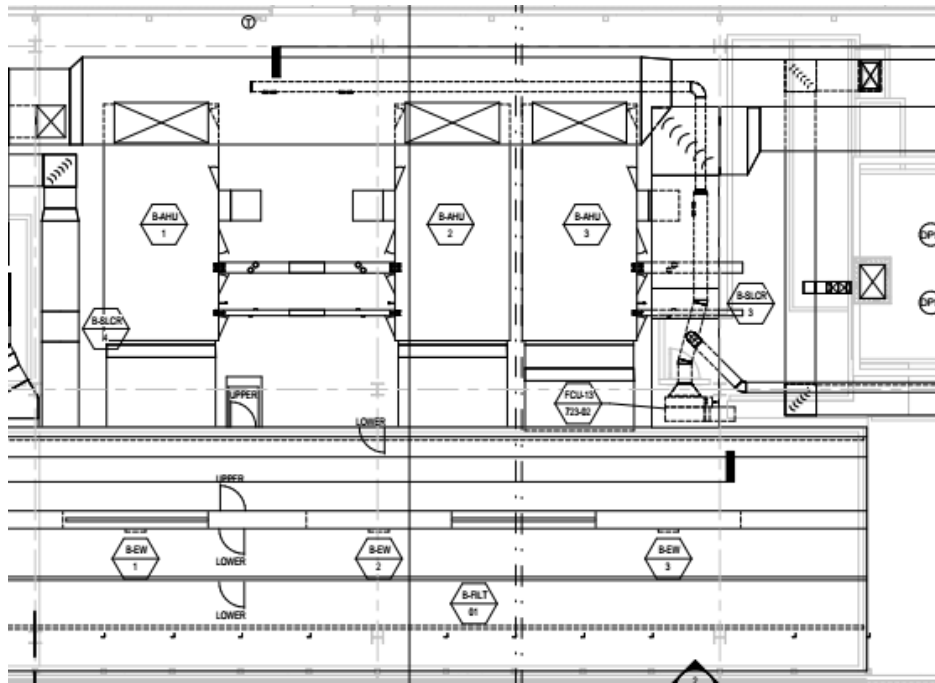


Figure 1 Bedtower Penthouse

Existing Mechanical System

The mechanical system for the medical center receives chilled water and heating water from the central utility plant located next to the building via an underground tunnel. The building also receives steam from the plant for equipment cleaning purposes. The heating water is distributed to heating coils in the air handlers in the penthouses as well as the heating coils in the constant air volume terminal units throughout the building. The chilled water is supplied to the cooling coils within the air handlers. The air handlers preheat the 100% outdoor air using a heat recovery wheel to transfer heat from the general exhaust before it leaves the building.

Airside

The air handlers' intake 100% outdoor air and humidify it using steam from the humidification clean steam generator. All air handlers have two filter banks outperforming the combined MERV rating of 13 prescribed by ASHRAE 170-2013. BAHU-1 and BAHU-2 each supply 40,000 cfm of conditioned outdoor air to levels 5 and 6 respectively. The air handlers handle the cooling and heating loads while the CAV units heat the supply air to the room conditions. The air handlers also use enthalpy wheels to use the general exhaust from the medical surgery rooms and restrooms to precondition the outdoor air before the air is exhausted by constant speed fans.

Terminal Units

The air handlers serve the constant air volume terminal units located in the offices and medical rooms. The CAVs are served by the hot water loop for their reheat coils. There are also fan coil units for the electrical rooms that are served by the chilled water loop for the cooling coils.

Zoning

The general medical surgery rooms and pediatric patient rooms are located on level 5 along with the waiting rooms, isolation rooms, and various medical support rooms. The administrative offices for the different departments and commanders are on the sixth floor. There are also conference rooms and a library. Between the two floors there are various activities occurring in adjacent spaces. The floors are separated by 9 feet dedicated to the interstitial floor (IBS). The IBS floor allows maintenance to easily access the terminal units, diffusers, and other building communication systems. It allows the medical rooms to remain in service while the systems can be maintained.

Cooling

The central utility plant supplies the medical center with chilled water produced by four water cooled centrifugal chillers for a combined capacity of 5220 tons of 44F chilled water. This chilled water loop supplies to computer room air conditioning units, fan coil units, blower coil

units, and the air handlers located in the penthouses. A heat recovery chiller covers the base cooling load during the winter. It is a water cooled scroll chiller with a 200 ton capacity, and it preconditions the domestic hot water.

Heating

The steam plant is used to produce the hot water for the heating coils in the CAVs and the air handlers. Four forced draft steam boilers use natural gas and fuel oil to produce 150 psig steam for heating and cleaning purposes. The steam passes through a shell and tube heat exchanger to produce hot water for the reheat coils in the CAV units. The steam is brought to the building to serve as sterilization for equipment and it is used for humidification in the air handlers.

Alternatives Considered

Several alternative design systems were considered for this in depth analysis of a new system. Throughout the initial investigation of the preexisting systems, the following alternatives were considered, but eventually dismissed:

- Combined heat and power plant
- Water Source Heat Pumps
- Dedicated Outdoor Air System
- Chilled beams on the sixth floor
- Condensate recovery for cooling towers
- Solar hot water heating system for domestic water

A few of the alternatives will be analyzed during thesis, however, some were eliminated due to complexity, time restrictions, and costs. The central utility plant will not be investigated during thesis because of the inability to accurately model the entire medical center in a load simulation program.

Proposed Redesign

The current design of the medical center conditions the spaces by providing 100% conditioned outdoor air to the spaces. The VAV units at each zone reheat the air according to the room conditions. The airside system currently contributes to the high amount of energy in

The alternatives chosen were in part due to the energy conservation it may bring to the medical center. Alternatives were chosen based on climate, cost benefits, and educational purposes. The list of alternatives above all have potential to make for an intellectual analysis.

The redesign is based on changing the system to a dedicated outdoor air system. The dedicated outdoor air system will only condition the minimum ventilation air and supply it to the

terminal units at the zones. A dedicated outdoor air system was chosen in order to demonstrate that indoor air quality can be maintained at lower outdoor air flows, and the air ducts can reduce in size, thus eliminating the IBS floors.

Dedicated Outdoor Air System

The medical center is currently supplied with 100% outdoor air well above the minimum ventilation requirements set by ASHRAE 170-2013. The current design is based on the ventilation requirements set by UFC 4-510-2012, which are more stringent than ASHRAE 170-2013. For the offices on level 6, the air handler supplies over double the amount of ventilation air required. During the analysis of the medical center, reducing to ventilation air will

The first redesign component will be to use a dedicated outdoor air unit (DOAS) to supply the minimum ventilation air requirement. The result of this change will reduce the size of the air handlers and reduce the cooling and heating loads provided by the air handlers. By supplying the minimum ventilation air flows, the air ducts will reduce in size for both the supply and exhaust side. The height of the IBS floors will reduce to a large plenum, thus unable to be accessible via walkways, but reducing the height of the building thus cost.

The purpose of this new redesigned system is to investigate the effect of the outdoor air reduction on the indoor air quality while reducing the overall size of the system. Since this medical center treats both soldiers and their families, there must be a guarantee of optimum quality of health starting with the indoor air quality.

Furthermore, the DOAS units remove the latent and sensible heat from the ambient air, however, another system must be implemented for the terminal units in order to condition the air for each zone. The system paired with the DOAS unit must remove the latent and sensible heat of the zone it serves. A few options were considered for the type of system: variable refrigerant flow, fan coil units, and water source heat pumps.

Variable Refrigerant Flow

The sensible loads within the spaces will be conditioned using a variable refrigerant flow system. This system allows better control over each spaces' conditions by using valve controls for each unit. By implementing a VRF system, the benefits of the heat recovery side can be used to displace heat from one space to condition another. There will no longer be a need for the terminal units' heating coils to use the hot water loop, however, the DOAS units will still need hot water for the heating coils when the heat recovery wheels cannot provide enough preconditioning. The variable refrigerant system will be used alongside the fan coil units. The fan coil units will supply the minimum ventilation air requirements while using the variable refrigerant flow for the cooling coils. The fan coil units may present higher savings when used on the 6th floor due to the ability to recirculate the class 1 air in the offices. The fan coil units can be placed directly above each space due to their size, however, they may present disturbance among patients which could present another breadth to analyze.

Variable refrigerant flow systems require condensing units which will be placed on the roof. A structural breadth will result from the addition of condensing units for the terminal units, as well as the downsizing of the air handlers which will change the structural load on the roof.

Water Source Heat Pump

Water Source Heat Pump is another valid system to use in parallel with the dedicated outdoor air unit to remove the sensible loads in rooms. Investigation of parallel systems has led to closed loop water-source heat pumps with a cooling tower to handle the heat rejection. Due to the high capital cost of a ground source heat pump, the cooling tower and boiler combinations for the WSHP was considered because of the minimal heating the building requires. Since the cold season lasts from the end of November until March, it might be possible to eliminate the boiler or provide a small boiler, if the heat pumps are balanced and reject heat into other spaces within the building. On the other hand, due to the higher average ambient air temperature, an efficient cooling tower designed for a larger approach will need to be considered for this system. The WSHP system utilizes 2 pipes which allows them to reverse from condenser to evaporator during heating and cooling modes. The climate in Killeen is optimal for water source heat pumps because there is a long period of the year when balancing heating between the units can save energy. The two designs will be compared by their energy consumption, air quality, life cycle costs, and installation costs.

Breadth

Construction

By switching to a DOAS unit supplying minimum ventilation air, the amount of air supplied to the zones will decrease by half. The IBS floors which are only used for maintenance, currently consume up to 9 feet per floor of the entire building. However, with the proposed system, the IBS floors can be converted into large plenums for the building's systems. The large plenums will reduce the overall height of the building, thus saving structural and façade materials. The cost benefit of reducing the overall height of the building will be analyzed to determine if the loss in maintenance accessibility is worth the savings. A cost estimate will be created in order to compare the cost savings between the original design and the new system. The effect of these design changes on the schedule will be reviewed as well.

Structural

The structural loads on the roof will change by converting the air handler into a smaller dedicated outdoor air unit. The structural loads for each system will vary as well. With the implement of a variable refrigerant flow system, condensing units will be placed on the roof, thus adding to the dedicated outdoor air unit. The water source heat pump will need a cooling tower which will most likely be located on the central utility plant, however, it may be placed on the roof of the medical center in order to reduce the amount of piping.

Masters Coursework

Content from Centralized Cooling Production and Distribution Systems, AE 557, will be used in the analysis of the three systems being considered. Since the supply air will be reduced to the minimum ventilation air, an indoor air quality analysis will use the course content of AE 552: Air Quality in Buildings.

Tools

Trane Trace 700 was used during the original technical reports in order to compare the energy consumption of the original design. For the redesign proposed, IES Virtual Environment will be used to run load simulations comparing the three different air systems. Engineering Equation Solver will be used when evaluating complex equations presented during the redesign of the HVAC system.

With the proposed DOAS unit consuming the minimum ventilation air requirements, Contam 3.1 will be used to ensure the quality of indoor air remains up to LEED v4 standard as did the original design.

Research

Variable Refrigerant Flow System w Fan Coil Units

Goetzler, William. "Variable Refrigerant Flow Systems."

ASHRAE Journal, April 2007. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. 7 Dec. 2013.

In the article, Goetzler identifies the benefits of the variable refrigerant flow system over a chiller system. The VRF modules are lightweight and can be easily installed into small plenums. Since the VRF system provides heating and cooling, it can be paired with a system to provide the ventilation air. Although the VRF system has a shorter life expectancy than chillers, it requires minimal maintenance, changing of filters and cleaning the coils. Newer VRF systems using R-410a and compressors with ECM motors achieve energy savings of 30% to 40% more than chillers. Contractors concerns are the long refrigerant piping will be hard to comply with ASHRAE standard 15-2001 for safe refrigerant systems.

Water Source Heat Pump

Trane. "Energy-Saving Strategies for Water-Source Heat Pump Systems." Trane Engineers Newsletter, vol. 36-2. 7 Dec. 2013. Retrieved from <http://www.trane.com/content/dam/Trane/Commercial/global/products->

[systems/education-training/engineers-newsletters/energy-environment/admapn024en_0507.pdf](#)

In the newsletter, the benefits of both water source heat pump system and ground source heat pump systems are discussed. Although the ground source heat pump eliminates the boiler and cooling tower, it requires a large heat exchanger to adjust for the imbalance between heat stored and extracted from the ground. In a cooling climate, the ground source heat pump can be paired with a cooling tower in order to keep the ground temperature from rising. A ground source heat pump system may also have a bypass valve when the temperature is within a certain range, the refrigerant may bypass the exchanger and reduce pumping energy.

