Army Reserve Center
Newport, Rhode Island

Proposal:
Redesign of the Army Reserve Center

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December 10, 2010

Table of Contents

List of Figures and Tables

Executive Summary

The main goal in designing the Army Reserve Center was to achieve a LEED Silver or Gold certification while maintaining good design practices such as following the applicable codes and following the requests of the United States Army Corps of Engineers. The codes that were followed were the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 62.1 and 90.1, the United Facilities Criteria (UFC) 4-171-05 and 3-400-02, and all applicable National Fire Protection Association (NFPA) codes and standards. To achieve this goal, a constant volume air handling unit was used for the auditorium, two variable air volume air handling units were used for the entire second floor and the core of the first floor, and smaller unit ventilators met the loads and ventilation requirements for the classrooms on the first floor and several other smaller zones on the first floor.

In order to make the Army Reserve Center more energy efficient, a variable refrigerant flow (VRF) system will be installed to take care of the heating and cooling loads. The outside air required by ASHRAE will be taken care of using a dedicated outdoor air system (DOAS). Another alternative that will be explored is the use of a DOAS to handle the latent loads and the outside air requirements and a ground source heat pump (GSHP) to handle the remaining loads.

The systems will be designed based on ASHRAE Standards using Microsoft Excel for the majority of calculations with some calculations done by hand. The Army Reserve Center will be modeled with these systems in place using Trane Trace 700.

An acoustical study and a structural study will be performed. The acoustical study involves analyzing the sound and vibration of a rooftop condenser for the VRF system. It also entails analyzing the sound and vibration of the new air handlers required for the DOAS. The structural study involves changing the beams and columns to handle the extra weight of the rooftop condenser. It also involves examining the beams under the mechanical rooms to determine if they can be sized smaller since the air handlers will be smaller and possibly moved to the roof.

Mechanical System Overview

The Army Reserve Center contains three air handling units. All three air handling units are located in mechanical rooms on the second floor. AHU-1 serves the first floor offices, is of the variable air volume type, and provides 3700 CFM of supply air which is 24% outside air. AHU-2 serves the second floor, is also of the variable air volume type, and provides 13,200 CFM of supply air which is 18% outside air. AHU-3 serves the auditorium, is of the constant volume type, and provides 2100 CFM of supply air which is 64% outside air. The rest of the ventilation for several other spaces on the first floor is done using small unit ventilators. Each air handling unit is manufactured by Trane and contains a supply fan, return fan, cooling coil, heating coil, filter, and enthalpy economizer.

The heating accounts for 198 MMBtu/year which is 10.3% of the total energy used in the Army Reserve Center. This comes mainly from the two boilers present in the building. Both boilers have 959 MBH of heating capacity, are manufactured by AERCO, have enter water temperatures of 100 degrees Fahrenheit and leaving water temperatures of 130 degrees Fahrenheit.

The cooling accounts for 250 MMBtu/year which is 13% of the total energy used in the Army Reserve Center. There are two air-cooled rotary screw packaged water chillers piped in parallel in the building. The chillers have capacities of 40 and 52 tons respectively, are both manufactured by Trane, and both have scroll compressors that use R-410A as the refrigerant.

Design Objectives and Requirements

The main goal in designing the Army Reserve Center was to achieve a LEED Silver or Gold certification while maintaining good design practices such as following the applicable codes and following the requests of the United States Army Corps of Engineers. The codes that were followed were the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 62.1 and 90.1, the United Facilities Criteria (UFC) 4-171-05 and 3-400-02, and all applicable National Fire Protection Association (NFPA) codes and standards. To achieve this goal, a constant volume air handling unit was used for the auditorium, two variable air volume air handling units were used for the entire second floor and the core of the first floor, and smaller unit ventilators met the loads for the classrooms on the first floor and several other smaller zones on the first floor. The design met this goal because it follows the codes mentioned above and will achieve 36 to 42 LEED points, giving it a LEED Silver or Gold rating.

Mechanical System Design and Operation

The Army Reserve Center uses a Direct Digital Control (DDC) system with electronic actuation for control of all HVAC systems and equipment. The DDC system includes controllers for all air handling units, hydronic pumping systems, VAV terminal units and lighting. It monitors electricity, natural gas, and water usage, is Johnson Control, Inc. (JCI) based, and is JCI N2 and LonWorks compatible.

Airside

The Army Reserve Center uses three air handling units in order to heat, cool, and supply outside air to the building. AHU-1 is of the variable air volume type and serves the first floor offices along with several other spaces on the first floor. The load and required outside air for the rest of the spaces on the first floor is met with unit ventilators. AHU-2, also of the variable air volume type, handles the loads and outside air required for the second floor. AHU-1 and AHU-2 have enthalpy based economizers and variable frequency drives on both the supply and return fans. Both AHU-1 and AHU-2 have a minimum and maximum amount of air. The maximum is determined by the maximum load that has to be met and the size of the system required to meet this load. The minimum, in this case, is determined by the required outside air for the zone. However, if the heating coil was electric instead of hot water, the minimum outside air across it could be the amount required for the coil to not overheat. Both AHU-1 and AHU-2 have chilled water cooling coils, hot water heating coils, and variable air volume boxes with hot water re-heat coils in each separate zone. The re-heat coils for each box contain 2-way modulating hot water control valves, are designed for an entering water temperature of 130°F with a 30°F temperature drop across the coil, and a pressure differential of 0.6 inches of water across the box. After the air reaches each zone, it is returned through a plenum until it eventually reaches the return fan of AHU-1 or AHU-2 and is sent outside.

AHU-3, a constant volume air handling unit, serves the assembly area. The assembly area contains occupancy sensors which provide information to the air handling unit in order to determine the amount of supply air required to meet the heating loads, cooling loads, and required outside air. After a constant volume of air is supplied to the auditorium, it is returned to the outside by one of two rooftop ventilators that are ducted to the auditorium from above.

Unit Ventilators one through eight (UV-1 through UV-8) are used throughout the first floor to handle the loads and outside air requirements of several smaller spaces. They each contain a chilled water cooling coil, a hot water heating coil, and motorized dampers in order to have economizer mode operation. They return air through the plenum until it reaches a relief ventilator. The spaces they serve have occupancy sensors to determine the amount of supply air required to meet the outside air and load requirements.

Waterside

In the Army Reserve Center, two boilers are present to heat the building. Each boiler, B-1 and B-2, has inline primary boiler circulation pumps and secondary pumps with variable frequency drives to send hot water throughout the building. Hot water is supplied at 130°F and returned at 100°F with automatic reset based on outdoor air temperature. Hot water minimum flows are sent through coils when the outside air temperature is below 40°F in order to prevent freezing.

In the Army Reserve Center, two air-cooled rotary screw packaged water chillers which are piped in parallel are used to cool the building. A variable flow primary pump with a variable frequency drive is used, with secondary pumps to send chilled water to the coils. The chilled water supply temperature is 42°F and the chilled water return temperature is 58°F.

Mechanical System Redesign

After analyzing the Army Reserve Center's current mechanical systems and talking to the design engineer, I discovered several options that could be explored in the redesign. The design engineer specifically mentioned that a variable refrigerant flow (VRF) system should be considered as an alternative to the current variable air volume (VAV) system.

Variable Refrigerant Flow

A variable refrigerant flow (VRF) system contains multiple indoor evaporators connected to a single condensing unit allowing heat to be transferred directly to the space by pipes containing the refrigerant located throughout the building. The pipes will be smaller than the ducts of a variable air volume (VAV) system because the heat capacity of the refrigerant is larger than that of air. This handles all of the loads for the building. However, either operable windows or a separate air handler must be used for ventilation. A picture of a VRF system is shown in Figure 1 below.

A variable refrigerant flow system has many benefits. VRF systems are lightweight, easily transported, and can fit into an elevator. This helps to reduce the structural requirement for the roof. To maintain the same load, the pipes of a VRF system take up less space than ductwork, and the only required ductwork is to supply outside air. This leads to a reduced building height and cost in many cases. A VRF also usually has the condensing units on the outside which thus requires no mechanical room. Another benefit of a VRF system is that the maintenance cost of a VRF should be lower than that of a water-cooled chiller.

Variable refrigerant flow systems have higher energy efficiency than conventional variable air volume systems. VRF systems have no ducts, thus duct losses are eliminated. They also have multiple compressors in each condensing unit which allows for wide capacity modulation and thus high part-load efficiency. Heat recovery VRF systems can be used for buildings that have simultaneous heating and cooling. Heat is transferred from interior spaces that require cooling to exterior spaces that require heating. The energy savings for variable refrigerant flow systems is estimated to be about 30% to 40%.

The cost of a variable refrigerant flow system varies based on the project. It is estimated to be approximately 5% to 20% higher than a chilled water system with the same capacity.

Figure 1

Ground Source Heat Pump

A heat pump either extracts heat from the outside during the winter to warm a space or sinks heat to the outside in the summer to cool a space. There are both ground source and air source heat pumps. However, a ground source heat pump will be used because, below the frost line, the Earth temperature remains relatively constant from 50°F – 60°F. This leads to a higher efficiency than an air sourced heat pump. The Army Reserve Center has a lot of space covered by grass or asphalt, thus, there is room to install a ground source heat pump. Although the life of a ground source heat pump is longer than other systems and the maintenance costs are lower, ground source heat pumps are more expensive because wells must be dug for them to be underground.

Dedicated Outdoor Air System

A dedicated outdoor air system (DOAS) brings in excess outside air to meet the ventilation requirements as well as the space latent load. The outside latent load is taken care of by the presence of desiccants and/or cooling coils. It also meets some of the sensible load. Chilled beams (active or passive) or even a variable refrigerant flow system could be used to meet the rest of the sensible load.

Some of the advantages of a DOAS are that the duct sizes are smaller as compared to a variable air volume (VAV) system which allow for there to be more space in-between floors or the building to be smaller which would reduce the cost. Another advantage is that in using 100% outside air, there is no return air. Problems that occur in VAV systems such as duct leakage and minimum air volume settings are not problems in a DOAS. To meet ASHRAE Standard 62.1-2004 with a VAV system, anywhere from 20-70% more outside air is required in order to make sure that air is properly distributed. A DOAS also saves energy through the use of enthalpy and sensible wheels to pre-heat or pre-cool outside air.

Breadth Topics

Acoustical Breadth

If a variable refrigerant flow system is used, there will be a need for only a small air handler in order to supply the required outside air. The air handler will be placed on the roof because, with a VRF system, there is not a need for as much mechanical room space and they can probably even be eliminated. The air handler and the condenser for the VRF system will both make noise and an acoustical study will be done to determine the required material that must surround each of them to minimize the noise to an acceptable level.

Structural Breadth

If a variable refrigerant flow system is used, the three large air handlers will be eliminated thus (possibly) reducing the structural requirements for the two mechanical rooms where the air handlers used to be. There will also have to be increased structural requirements for the roof in order to support the condenser and the air handling unit.

Integration and Coordination

The Army Reserve Center should become far more energy efficient by decoupling the loads and ventilation. This will be done through the installation of a variable refrigerant flow (VRF) system to handle the load requirements with a dedicated outdoor air system (DOAS) to handle the ventilation requirements. A ground source heat pump is another possible idea which would improve the building's energy efficiency with either a DOAS or a variable air volume (VAV) system to handle the ventilation requirements and possibly the rest of the loads.

The VRF system and DOAS will be compared to the existing VAV system in order to determine the best system for the Army Reserve Center. There will probably be structural changes due to the re-sizing / removal of air-handling units as well as the addition of a condenser on the roof for the VRF system. An air-handling unit may be removed from the mechanical room and sent to the roof as well. Acoustically, there will be changes as well due to the addition of the condenser and changing the number of air-handling units. There should be no other changes in the lighting, electrical, or architectural aspects of the building.

Tools and Materials

ASHRAE standards will be used in designing the mechanical systems for the Army Reserve Center. Trane Trace will be used to model the building. Microsoft Excel will be used for most of the calculations required, although some of the calculations will be done by hand.

Spring 2011 Proposed Schedule

Spring 2011 Preliminary Schedule			
Task	**Start Date**	**Finish Date**	**Duration**
Research Proposed System	1/10/2011	2/9/2011	30
Trace 700 Model	2/9/2011	2/19/2011	10
Analyze Results	2/19/2011	2/24/2011	5
Design / Size New System	2/24/2011	3/6/2011	10
Acoustical Breadth	3/6/2011	3/13/2011	7
Structural Breadth	3/13/2011	3/20/2011	7
Finish Calculations	3/20/2011	4/7/2011	18
Prepare Presentation	4/7/2011	4/11/2011	4
Presentation	4/11/2011	4/11/2011	

Table 1

References

Mumma, Stanley A. "Designing Dedicated Outdoor Air Systems" ASHRAE Journal May (2001): pages 28-31. 9 December 2010.

This article offered a description of dedicated outdoor air systems (DOAS). It lists their advantages, their applications, and the equipment they are composed of.

Goetzler, William. "Variable Refrigerant Flow Systems" ASHRAE Journal April (2007): pages 24-31. 9 December 2010.

This article offered a description of variable refrigerant flow systems.

Kavanaugh, Steve. "Ground Source Heat Pumps for Commercial Buildings." 1 Sept 2008. Web. 2 Dec 2010. <http://hpac.com/fastrack/ground-source-heat-pumps/>.

This article offered a description of ground source heat pumps.