THESIS PROPOSAL

Mechanical Systems Re-Design and Breadth Topics

Northfield Mental Healthcare Center

Northfield, Ohio

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Executive Summary

The Northfield Mental Healthcare center is located on the Northfield, Ohio. The building is a five story mental clinic building, and the project is renovation of three existing buildings and expansion of the existing facilities. Approximately 200,000 square feet would be added to the existing buildings, and the new portions of the buildings would be served as patient wings, administration, gymnasium, and clinic center. The new buildings were designed to provide better quality of building, safety of patients and staff, and aesthetically pleasing environment. The building is not yet constructed but still in constructional document phase. The total estimated project cost is approximately $62.5 million, including $10.3 million of HVAC and fire protection equipment cost.

This proposal contains redesign of the mechanical system and electrical and acoustical breadth topics. This proposal also contains suggested timeline of the mechanical system redesign processes. Previous reports contain evaluations of the existing mechanical systems and descriptions of system operations including efficiencies of each mechanical system. Prior to this proposal, brief studies on efficient mechanical systems were conducted. This proposal suggests alternative mechanical systems that are more suitable and more efficient and briefly explains why they are more efficient and which programs will be used.

The alternative mechanical system that will be applied for the building is a condenser water heat recovery system. Both humidification controls and heating controls are critical for a huge healthcare project, because large amount of heat needs to be produced with reduced humidity and minimum airflow change rate. The condenser water heat recovery system will help to reuse the heat rejected from the cooling water system for the heating water system through

heat exchanger. The efficiency of the energy usage will be greatly improved.

Another alternative mechanical system that will be applied for the building is a desiccant system. If the heat recovery system increases the efficiency of heat usage, the desiccant system increases the efficiency of dehumidification control. Reheating processes to prevent overcooling generally require a lot of energy consumption. The desiccant system will help to reduce energy consumption during reheating process by lowering dew point of the supply air below than discharging temperature from cooling coil.

Demand controlled ventilation (DCV) will be applied for the indoor air quality. DCV will reduce the energy required for ventilation based on actual occupancy. An automatic damper and a sensor for DCV system will be coordinated with a CO_2 Sensor, an occupancy sensor, and BAS. This system will be applied to patient rooms, physical therapy room, lobbies, waiting areas, and dietary areas and not be applied to the areas that require direct exhaust.

This proposal also contains a brief explanation on two breadth studies that will be conducted and evaluated for the future research. The first breadth is acoustical aspects of the mechanical systems and reductions of noise productions from mechanical equipment. The second breath is reduction in electrical energy usage.

Mechanical System Summary

Mechanical Equipment Summary

10 different air-handling units are equipped in the Northfield Mental Healthcare Center including two existing air handlers. The two patient wings are served by two of 65,000 CFM rooftop units. 7,950 CFM rooftop air handler serves clinic and administration areas. 3,700 CFM

indoor air handler and 8,400 CFM indoor air handler serve the gymnasium area and dietary area respectively. Boiler plant, chiller plant and electrical room are served by the other three indoor air handlers which have maximum capacity of 5,000 CFM, 5,000 CFM, and 6,000 CFM respectively.

Two 450 tons of centrifugal chillers are located on the chiller plant and connected to a 2-cell-cooling tower which is located outside of the energy center. Chilled water is supplied to each air handling equipment and distributed to the entire building. Each chiller consists of two chilled water pumps: primary and secondary chilled water pump. The secondary chilled water pumps are aligned with the primary chilled water pumps and serve cooling loads.

Six of 113.5 horsepower condensing boilers are located on the boiler plant and serve heated water. Each boiler consists of a primary heating water pump, and two secondary heating water pumps are connected to the two of expansion tanks. Variable frequency drive devices are used for most of the HVAC equipment including heating water pumps, chilled water pumps, chillers, and cooling towers. In addition, the building uses BAS system, programmable temperature controls, and occupancy sensors for sustainability.

Design Criteria

The main goal of the Northfield Mental Healthcare center is to provide comfortable and safe environment for both patients and staff members. The main purpose of this project is to establish more spaces for additional patients transferred from Cleveland healthcare campus that is going to be closed after completion of this project. Since some of the mechanical systems remain the same, the newly designed mechanical systems need to be balanced with the existing one. Ten air handlers will serve the entire building, but two of them are existing one serving partially renovated areas and existing administration areas. Since the total pressure drop over the ductwork finally connected to the existing air handler remain the same, the total pressure drop accumulated through the newly designed ductwork needs to be balanced with that of ductwork which will be demolished.

The total designed energy load consists of cooling, heating loads and dominatingly hospital equipment load. This equipment load can significantly be reduced by using programmable temperature control sensor and occupancy sensors. Since the most of openings in the building are not operative, infiltrations as well as ventilation are one of the major design concerns. The amount of the outside air takes an account of infiltrations, and the amount of the outside air would be defined in accordance of ASHRAE 62.1 and ASHRAE 170. The amount of the outside air was oversized in order to achieve the better indoor air quality. In order to maintain the comfortable temperature even with the great amount of the outside air entering into the building, cabinet unit heaters and horizontal unit heaters were designed to be placed for the winter.

The heating water systems and cooling water systems have primary and secondary distribution systems that are recommended by ASHRAE Standard 90.1. It is recommended to use primary and secondary pumping system for large complexes for energy efficiency. The primary and secondary pumping arrangements help to increase system controllability and decrease total horsepower required. The primary pump serves chillers and boilers, while the secondary pump serves the cooling load and heating load.

Design Conditions

The Northfield Mental Healthcare Center is located in Northfield, OH. Since the Northfield area is not listed in the ASHRAE Fundamental 2009, the nearest big city, Cleveland, was used for the analysis. The table 1 shows the weather data inputs that were used for the analysis. The weather data from the ASHRAE Fundamental 2009 is described in Appendix A in Technical Report 2 as well. The design temperatures are shown in Table 2. The sequences of temperature control would be achieved by programmable temperature controller. The supply air temperature would be maintained at set point by modulating the economizer control damper and valves' positions.

Cleveland, OH	
Latitude	41.4N
Longitude	81.85W
Elevation	804
Heating DB (99.6%)	2.5F
Cooling DB (0.4%)	89.4F

Table 1. Weather Conditions

Temperature Set Points	DB Temp (F)
OA	90 F DB, 71 F WB
RA	72 F DB, 50 % RH
SA	55 F DB
MA	Depends on OA %

Table 2. Design Temperatures

Mechanical First Costs & Energy Consumption

The mechanical first cost, calculated in the report 3, was approximately $16,180,000 with a cost per square foot of $81.00 / SF. The detailed cost breakdown can be referred to the Appendix B in the report 3.

The total energy consumption was also calculated using Trane TRACE model based on the outputs of the program and reported in the technical report 2. Some of the heating units were not taken an account into the TRACE model, so the heating usage in reality would be much more than calculated value. Some of small HVAC equipment's electricity loads were omitted as well. It was assumed that the building would be continuously operated, but in reality the lighting load would be less than the calculated value.

The total annual utility cost was calculated to be 55,697 dollars, and the utility cost per square feet was calculated to be 0.14 dollars. As expected, the utility cost meets the peak value on July of which has extreme weather data in the Cleveland. The detailed energy consumption breakdown can be referred to the table 14, table 15, and table 16 in the report 3.

Overall Evaluation Summary

The mechanical systems of the Northfield Mental Healthcare Center comply with the mandatory provisions in ASHRAE Standards, but the maximum efficiencies of the systems were not achieved due to the project budget issue. Some of the energy efficiencies were achieved by equipping programmable temperature controllers, occupancy sensors, BAS controllers, and variable frequency-derive controllers. For a high performance design, it is important to integrate the mechanical systems with the building envelope and lighting system. The overall performance of mechanical systems for the building, however, could be improved if the building accepts more natural light for energy conservations or if the building uses renewable resources for its mechanical systems.

Indoor air quality of the Northfield Mental Healthcare Center is achieved by increasing outdoor air intake for mechanical ventilations and equipping pre-filters and final-filters inside of each air handling unit. Even if there will be routine maintenance required for those filters and results in higher maintenance costs, those installed filters result in longer equipment lifetimes. VAV system will also enhance the higher indoor air quality of the building; varying the supply air volume will reduce the building energy usage by reducing work done by fans but still increase indoor air quality by producing a very little margin of error from desired temperature. In addition, VAV system enables the individually controlled zones have their own thermostats controlling their thermal comfort by adjusting the controller.

The cooling loads and heating loads are also efficiently served by using condensing boilers and centrifugal chillers. Also, VFD installed to pumps and fans saves energy by controlling their outputs based on the needs of occupants. However, the energy usage for the condensing boilers and centrifugal chillers are tremendous compared to any other mechanical equipment used for this building. The heat rejected from the chillers can be converted as energy form and reused for heating water system through heat exchanger. In addition, installing desiccant system can control reheating processes that require a lot of energy consumption.

Proposed Alternatives

Condenser water heat recovery system

Both heating and cooling loads are large enough to make the heat recovery system efficient when its equipment cost, installation cost, and operation cost are considered. A large amount of heat rejected from cooling coil will be reused for heating water system. Since healthcare facilities require both large amount of heat to generate hot water and cooling for the humidification control, the heat rejected from the cooling processes can ideally be used for steaming the hot water. Heating coils with their inlet water temperatures of between 100F and 140F need to be selected in order to maximize the efficiency of the system. The payback periods of this system are typically two to four years but it depends on the fuel to electric cost ratio. The first cost and operational cost of this system will be analyzed as well as estimated payback periods and will be compared with the typical payback periods.

Desiccant system

Desiccant systems are highly recommended for the healthcare facilities that typically require humidity control systems. Different temperature and humidity are required depends on the function of each room. Cool temperatures between 68 F and 73 F are normally required for operating rooms, clean workrooms, and endoscopies suits, while warmer temperature of 75 F is required for patient rooms and waiting rooms. Especially cold rooms require below than 60 % RH which is hardly achieved by traditional systems. There are several methods of drying air, and the most efficient method will be chosen and evaluated based on the studies that will be conducted in the future. The desiccant system will reduce energy consumption for controlling humidification processes as well as increase indoor air quality.

Demand controlled ventilation (DCV)

Demand controlled ventilation (DCV) will be equipped with CO_2 Sensor, occupancy sensor, and building automation system. Even if further maintenance and calibration are required for energy saving after installation of this system, the indoor air quality will be much improved by controlling CO_2 concentration and ventilation rate. As mention in the executive summary, this system will be applied to certain areas, such as patient rooms, physical therapy room, lobbies, waiting areas, and especially for dietary area and not be applied to the areas where require direct exhaust to the outside. There is a huge dietary area and kitchen area and a lot of small kitchenettes in the building, and great amount of energy saving and cost saving will be achieved by applying this system to those areas.

Breadth Topics

Electrical Breadth

Due to the additions and changes of mechanical systems, electrical load will be affected. The feeders' sizes and conduits' sizes need to be considered based on the new electrical load calculated with the new systems. However, health care facilities require maximized electromagnetic protection of wiring and minimized electrical hazard that can be caused by potential voltage flow between medical equipment and patients. Electrical equipment and wires will be resized according to the new electrical load in accordance of the requirements.

Acoustical Breadth

The noise reduction is one of the major considerations for the healthcare facilities. Considerable amount of the noise generated by mechanical equipment and electrical equipment needs to be reduced for patient safety. Especially this facility, mental clinic, needs to create better healing environment to ensure all the patients to have comfortable spaces. Airborne noise creation and noise attenuation through ductwork will be evaluated to ensure if all the exhaust and supply diffusers are properly selected and placed. Placement of HVAC equipment especially VAV boxes will be evaluated. If those mechanical equipment create too much noise transmitting to adjacent rooms, proper acoustical equipment will be selected and placed in order to increase noise attenuations, or rearrangement of rooms will be conducted.

Tools for Analysis

An energy-modeling program, Trane TRACE 700 will be used to calculate new energy consumption rate with the redesigned mechanical equipment. Previously evaluated file for the existing mechanical equipment will be compared with the new energy consumption calculation to evaluate how much energy will be reduced for the new system. Auto CAD and Revit programs will be used for drafting flow diagram and control diagram for the new mechanical system. When the mechanical systems will be redesigned, codes and standards, such as ASHRAE Standard 62.2 and 170 will be reapplied in order to ensure everything meets its requirement.

Preliminary Research

ASHRAE. Advanced Energy Design Guide for Large Hospitals. Atlanta: W. Stephen Comstock, 212. PDF.

This documentation is a ASHRAE design guide explains recommendation of energy saving HVAC system for large hospitals. It also contains energy efficiency strategies for each climate zone. This source will be useful to determine which system and supplementary equipment will be suitable for this project.

Bhatia, A. HVAC Design for Healthcare Facilities. Stony Point: CED Engineering, n.d. PDF.

This document is a guideline for HVAC system of healthcare facilities. The document contains how to calculate air change rates and recommended air change rates for healthcare facilities. It also descries optimum indoor air quality level for the healthcare facilities.

Demand Controlled Ventilation Demand Controlled Ventilation System Design. Syracuse: Carrier Comfort Network, 2011. PDF.

This document is a good guideline for ventilation control and carbon dioxide control. It also explains what carbon dioxide concentration in a building means and how to reduce carbon dioxide concentration rate through effective ventilation system.

Marmion, Paul. Rethinking Hospital Design. N.p.: ASHRAE Journal, June 2012. PDF.

This documentation shows 2012 ASHRAE technology award case studies. It describes energy saving method and its real life application. One of the mechanical approaches that the example in the document has is a flue gas heat recovery system. The document explains how much the flue gas heat recovery system saved the total energy consumption.

Pearson, Andy. Thermal Coupling of Cooling and Heating Systems. N.p.: ASHRAE Journal, Feb. 2011. PDF.

This document compares energy ratings and life cycle costs for four different types of HVAC system. It also describes pros and cons for each type of HVAC system. This document will be helpful when the existing and redesigned HVAC systems are going to be compared.

Sheerin, Michael P. Minimizing Noise in Healthcare HVAC Design. Orlando, Florida: ASHRAE Technical Committee 2.6 Sound & Vibration, Jan. 2009. PDF.

This document is a powerpoint that explains HVAC design strategies to reduce noise in healthcare facilities. Healthcare settings least affected by noise will be guidelines for acoustical analysis for the future report.

Using Demand Controlled Ventilation to Reduce HVAC Costs. Boulder: E Source Companies, 2005. PDF.

This document explains how much HVAC costs will be reduced with the application of demand controlled ventilation system. It also describes benefits of DCV system and special limits for the system.

Proposed Schedule