Walter Reed National Military Medical Center
Bethesda, MD

Technical Report Three:

Mechanical Systems Existing Conditions Evaluation

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Executive Summary:

Building A and B are both being constructed at the existing National Naval Medical Center located in Bethesda, Maryland. Building A will be housing areas for services such as the Cancer Treatment Center, Children's Health Area, Medical Staff Offices, and Examination Rooms. Building B is the smaller of the two buildings and is the location for the ambulatory receiving center, operating rooms, and houses all of the patient bedrooms.

The mechanical system that was designed for both of these buildings uses a constant volume supply of 100% outdoor air. This is supplied to remote CAV boxes located throughout both buildings which provide occupant control. In order to offset some of the energy costs associated with a dedicated outdoor air system (DOAS), total energy wheels and heat recovery chillers were installed on this project. The chilled water plant for both of the buildings is electric based, while steam from the campus steam plant is routed through heat exchangers for both heating hot water and domestic hot water needs.

The total mechanical cost of the system for both design and construction is $109,500,000. If this cost is broken out on a per square foot basis it yields $182.84/sf. The total mechanical portion of the contract represents roughly 17% of the total contract which is within the typical 15%-20% of the construction budget that mechanical systems usually cost.

Both new buildings will be applying for a Silver Rating from the Leadership in Energy and Environmental Design (LEED) which is a subsidiary of the United States Green Building Council (USGBC). A LEED analysis was performed using the version three rating scale which is the most current rating system available. When going through this analysis, only the areas in Energy and Atmosphere along with Indoor Environmental Quality were considered due to the mechanical systems direct correlation with these categories. This analysis showed that the design team was focused on delivering a high quality system while making significant strides at reducing energy consumption and improving the indoor environment.

An overall system evaluation was performed and provides critiques of the design system in the areas of construction cost, maintainability, operating cost, and mechanical space requirements. It was concluded that the engineers design was appropriately selected for this project type. Though areas of improvement potentially may not yield large savings in energy or construction costs, there are still design changes that will be investigated during later reports and presentations.

1.0 Mechanical System Description

1.1 New Construction Background

Building A and B are being constructed at the existing National Naval Medical Center Campus located in Bethesda, Maryland. As part of the Base Realignment and Closure Program (BRAC) the existing Walter Reed National Military Medical Center (WRNMMC) will be closed and those facilities duties will be relocated to this existing facility which will then carry the name of WRNMMC. Building A is the larger than Building B and will be housing medical services such as the Children's Health Area, Cancer Treatment Center, Neurology Area, Physical Therapy, and Medical Staff Offices. Building B is where the Patient Bedrooms, Operating Rooms, and the Ambulance Receiving Center are going to be located.

1.2 Mechanical Design Objectives

An effective Heating, Ventilation, and Air Conditioning (HVAC) system was designed to be installed in the two new buildings being constructed on the WRNMMC Campus in order to provide a comfortable, productive, and safe atmosphere for all building occupants. The HVAC system was designed to exceed the minimum system efficiencies stated in ASHRAE Standard 90.1 and the minimum ventilation rates prescribed in ASHRAE Standard 62.1. Due to the need for this facility to operate 24 hours a day year round the mechanical system installed must be reliable and robust in order to provide service to patient care areas without any interruption.

Due to the nature of the facility some of the occupants within the buildings may have decreased immune systems due to the medical treatment which they are undergoing. This decreased ability for the body to fight off disease and infection means that there must be a high regards to the air quality throughout both buildings in order to prevent illnesses. Building pressurization and envelope construction quality help to ensure the quality of air within the space by preventing unconditioned air from potentially leaking within the envelope, condensing on building materials, and being a site for mold or bacteria growth.

The first building that was constructed on the campus in 1940 still stands today which is a testament to the initial quality of construction and meticulous maintenance on the building systems. Both Building A and B must be constructed with this same quality in mind so that these new facilities can serve the needs of the owner well into future decades.

1.3 Energy Sources

Possible energy sources that are able to be used at WRNMMC include electricity, natural gas, and district steam generated from the campus steam plant. The electricity rates that are available to this site are provided by Pepco and the consumption and demand charges are listed below in Tables 1 and 2. The rates that are charged to the buildings using campus steam were taken from the RFP and are listed in Table 3 below. Natural gas service for this location is provided by Washington Gas and the rate that applies to WRNMMC is outlined in Table 4.

	January-May	June-October	November-December
Electric Demand ($/kW)	6.741	8.551	6.741

Table 1 - Electric Demand Utility Rates

	January-May	June-December
Electric Consumption On Peak ($/kWh)	0.051	0.053
Electric Consumption Mid Peak ($/kWh)	0.048	0.048
Electric Consumption Off Peak ($/kWh)	0.043	0.043

Table 2 - Electric Consumption Utility Rates

	January-December
Purchased Steam ($/therm)	2.985

Table 3 - Purchased Steam Utility Rates

	$/Therm
Baltimore Gas and Electric	0.89

Table 4 - Natural Gas Utility Rates

In order to better compare the different fuel options available at WRNMMC all of the potential sources have been converted to a price per Btu basis shown in Table 5. This shows that the least expensive source of energy that is available to the site is natural gas and the most expensive is the campus steam. These prices however do not include the added infrastructure cost that needs to be added in order to get utility service from each source. These added costs from excavation, material, space, and schedule requirements need to be evaluated in a future technical report if changes are going to be made to the utilities service infrastructure.

	$/Mbtu
Electricity	0.0141
Natural Gas	0.0089
Campus Steam	0.0299

Table 5 - Source Energy Comparison

1.4 Design Conditions

The outdoor design conditions that were used for this site are listed in Tables 6 and 7 along with the indoor design conditions for each space type. The outdoor design conditions were taken from either the ASHRAE Handbook of Fundamentals or from the weather data that was loaded within the TRACE 700 program. The weather data highlighted are the values that were used during this analysis and provide the most conservative values regarding design loads. The indoor design conditions were taken from the mechanical design documents and are listed for both the winter and summer seasons.

	Summer		
	Indoor Design (°F)	Outdoor Design 0.4% (°F)	TRACE 700 Default (°F)
Office	75	94.5	93.2
Exam	75		

Table 6 - Summer Design Conditions

	Winter		
	Indoor Design (°F)	Outdoor Design 99.6% (°F)	TRACE 700 Default (°F)
Office	68	15.9	9.6
Exam	73		

Table 7 - Winter Design Conditions

1.5 Design Ventilation Requirements

An analysis was performed using ASHRAE Standard 62.1 to determine the minimum ventilation rates that need to be supplied to the occupied spaces. The HVAC system that was designed supplies a constant volume of 100% outside air to both buildings. This use of a Dedicated Outdoor Air System (DOAS) ensures that the minimum ventilation rates prescribed by ASHRAE Standard 62.1 will always be exceeded.

A ventilation calculation for using a DOAS system was performed and compared the ventilation rates that were calculated by the design engineer. The ventilation rates that were calculated by both the design engineer and within the 62.1 analysis are shown within Table 8. The value that was calculated using Standard 62.1 is 6% lower than the value calculated by the design engineer. The reason for this difference is most likely the simplifying assumptions that were used which are stated in more detail in Technical Report Two. An example of a simplifying assumption that was used rooms were modeled on a zone basis so individual loads were unable to be tailored to each room modeled.

	CFM
Calculated	489898
Designed	519040

Table 8 - Calculated vs. Design Ventilation

1.6 Design Load Estimates

A Trane TRACE model was created in order to perform a building energy consumption analysis as well as to determine the design heating and cooling loads. The design engineer performed this analysis using a model that was created on a room by room basis so that the most accurate results could be obtained. A block load model was created for Technical Report Two in order to compare these results to what the design engineer calculated. More information regarding the assumptions and other design input information that was used for the creation of the block load energy model can be found in Technical Report Two.

Various cooling, heating, and ventilation check values are listed in Table 9 to compare the block load model results to those that were calculated by the design engineer's model. The values that were calculated using the block load model resulted in larger values in each of the areas except the ventilation air requirements. This result in larger values is most likely due to the simplifying assumptions that were made during the creation of the block load energy model. These values, even though slightly different, still represent an accurate model of the ventilation requirements along with the design heating and cooling load for both Building A and B.

	Cooling (ft^2/ton)	Heating (Btuh/ft^2)	Supply and Ventilation Air (cfm/ft^2)
Building A	230.81	27.48	0.84
Building A Designed	242.34	20.81	0.89
Building B	197.76	41.70	0.82
Building B Designed	224.29	32.93	0.87

Table 9 - Block Loads vs. Design Loads

1.7 Estimated Annual Energy Use

The Trane TRACE model that was used to determine the design heating and cooling load values was also used to perform a full 8,760 hour energy analysis of the proposed HVAC system. All of the cooling equipment uses electricity to operate while the heating equipment uses purchased steam from the campus steam generation plant. The equipment that was modeled is based upon the data provided within the mechanical equipment schedules from the design documents. Other design parameters that were modeled are the use of occupancy, lighting, and equipment schedules which are detailed more within Appendix B of Technical Report Two.

The design engineer performed a yearly energy analysis as well which resulted in a use of 69,351 MMBtu. The block load model that was created in Technical Report Two resulted in a yearly energy consumption of 74,010 MMBtu. These two models differ by only 7% in their energy consumption values which is most likely a result of the simplifying assumptions that were used to create the block load model.

The energy consumption breakdown by mechanical subsystem for the block load energy model is shown in Figure 1 below. The category which consumes the largest portion of energy is the supply fans due to the large volume of air that they need to push from the basement throughout the entire building. Another reason that the fans consume a large portion of energy is their need to overcome the large static pressure drop created by the total energy wheels. This figure below will help in identifying potential energy saving areas that may be examined during the next assignment phase.

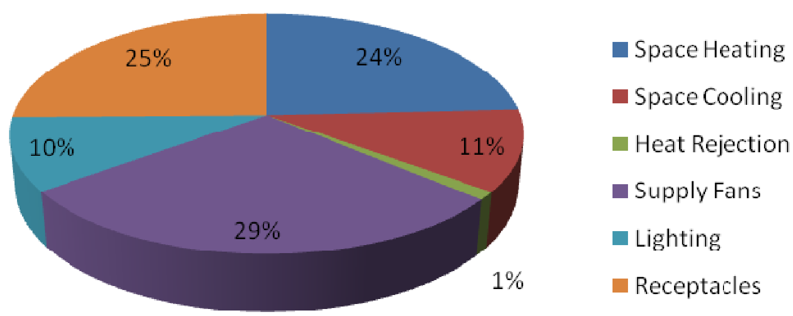

Figure 1 - Mechanical Equipment Energy Consumption

1.8 Mechanical Equipment Summary

The systems that are installed within both Building A and B utilize similar mechanical equipment located in each buildings mechanical room. Both buildings utilize custom 100% Outside Air Handler's that are detailed within Table 10 below. Due to the large energy usage associated with having a100% outside air system, total energy wheels have been installed in custom duct housings for each air handler. The specifications of these energy wheels are listed in Table 11. Each separate zone throughout the building is fed by a Constant Air Volume (CAV) Terminal having performance specifications outline in Table 12.

	Airflow (cfm)	Supply Air Temperature (°F)	Filter Rating	EWT (°F)	LWT (°F)	Flow (gpm)
AHU 1A-8A	50,000	55	MERV 14	42	60	265
AHU 1B-3B	50,000	55	MERV 17	42	60	283

Table 10 - Air Handling Unit Specifications

	Sensible Efficiency (%)	Latent Efficiency (%)	Recovered Energy (Mbh)	RPM
EW 1A-8A	83.3	85.9	1778	20
EW 1B-3B	87.5	90.4	1655	20

Table 11 - Energy Wheel Specifications

CAV Terminal	EAT (°F)	LAT (°F)	EWT (°F)	LWT (°F)	Flow (gpm)
CAV-06	55	93.7	125	111.7	2.6
CAV-08	55	90	125	108.2	2.6
CAV-10	55	89.5	125	102.8	2.7
CAV-12	55	89.7	125	99.9	3.3
CAV-14	55	89.8	125	96.2	4.2
CAV-16	55	89.5	125	94.9	5
CAV-19	55	85.8	125	96.2	7

Table 12 - CAV Box Specifications

The chillers and heat recovery chillers performance characteristics are listed in Table 13. The cooling towers are located on the adjacent patient parking garage with the specifications given in Table 14.

	Type	Nominal Capacity (Tons)	kW/Ton (ARI)	2 Pass Evaporator		2 Pass Condenser	
				EWT (°F)	LWT (°F)	EWT (°F)	LWT (°F)
Chiller 1-3	Water Cooled Centrifugal	1000	0.627	60	42	83	98
HRC-1A	Water Cooled Scroll	180	1.1	60	42	104	125
HRC-1B	Water Cooled Scroll	225	1.1	60	42	104	125

Table 13 - Chiller and Heat Recovery Chiller Specifications

	Arrangement	Nominal Capacity (Tons)	EWT (°F)	LWT (°F)	Airflow (cfm)	Maximum Water Flow (gpm)
CT 1-3	Induced Draft Counter Flow	1000	98	83	190,900	1875

Table 14 - Cooling Tower Specifications

1.9 Mechanical System Cost

The total mechanical and plumbing system package cost for both of the new buildings is $109,500,000. This system price includes both the design and construction portions due to the project being delivered as design-build. When this mechanical system cost is broken down on a per square foot basis it yields a cost of $182.84/sf. This mechanical system cost is greater than other building types but due to the size of this facility and the increased ventilation supplied to the building it is a reasonable installed cost.

1.10 Mechanical System Space Requirements

The total space that was allocated for mechanical system components such as pump, air handlers, duct risers, and chillers is outlined in Tables 15 and 16 below. Most of the equipment is centrally located within the dedicated mechanical rooms in the basements of both buildings. The space taken up by the CAV boxes and distribution ductwork within the ceiling plenums was not taken into account during this takeoff. Actual usable floor areas that are utilized for any mechanical equipment are the areas included within this calculation.

Building A	Area (sf)
Basement	29019
Floor 1	1650
Floor 2	1650
Floor 3	1650
Floor 4	1650
Floor 5	1036
Floor 6	1009
Roof	335
Total	**37999**

Table 15 - Building A Mechanical Space Requirements

Building B	Area (sf)
Basement	11097
Floor 1	643
Floor 2	643
Floor 3	643
Floor 4	196
Roof	863
Total	**14086**

Table 16 - Building B Mechanical Space Requirements

2.0 System Operation and Schematics

2.1 Airside System Operation

All of the air handlers in both buildings have variable speed drives installed on each of their supply fans. The initial start command is sent based upon an occupancy schedule within the energy management control system. The outside air damper will start to open and once it has proven the open condition the supply fan will start. Due to the varying occupancies Building A has an unoccupied mode while Building B does not. During Building A's unoccupied mode the CAV terminal boxes will set back to 30% of the design flow with the air handlers adjusting proportionally based upon the static pressure. Total energy wheels are installed for each air handler with both a heating and cooling mode of operation. The heating or cooling mode of operation is determined by the difference in outside air and return air temperature. The enthalpy wheels will slow their rotation if the freeze protection set point is being triggered in order to prevent the coils from freezing.

2.2 Waterside System Operation

The chillers default mode of operation is that one of the main centrifugal chillers will be base loaded by both of the heat recovery chillers at all times during cooling mode. If the cooling load is not being met by both of the heat recovery chillers then the central chillers will start to come online. A second chiller will start up when the first chiller is running at greater than 70% of its rated load for more than a 20 minute interval as calculated by the chillers flow meter and temperature sensor shown in Figure 2. The same load rating is used to bring the third chiller online or if the chilled water supply temperature exceeds 47°F for longer than 10 minutes the third chiller will begin its start up procedure.

When either two or three chillers are running and the total load falls below 32% of the rated capacity one of the chillers is disabled. When only one chiller is running and the total load chiller load falls below 10% the chiller shuts down and the chilled water header bypass line is opened. Figure 2 shows an evaporator bypass line which remains closed unless the VFD on the chilled water pump has modulated down to its minimum evaporator flow rate. At this minimum evaporator flow rate the bypass line begins of open up in order to ensure that the minimum flow is always going through the evaporator.

Three cooling towers with variable frequency drive motors along with three constant speed condenser water pumps operating in lead/lag are shown in Figure 3. When the first chiller is required to start, one of the condenser water pumps starts and the cooling tower bypass line begins to open. When another chiller is being brought online it uses the same sequence of pump starting except that this is done five seconds before the additional chiller is brought online in order to maintain minimum flow through the first chiller. When the condenser water supply temperature exceeds its set point for a set duration of time the tower isolation valve begins to open the bypass valve starts closing. Due to one of the chillers being base loaded, cooling tower freeze protection is obtained by pipe heat tracing and having one condenser water pump being on at all time when the outdoor drybulb temperature falls below 32°F.

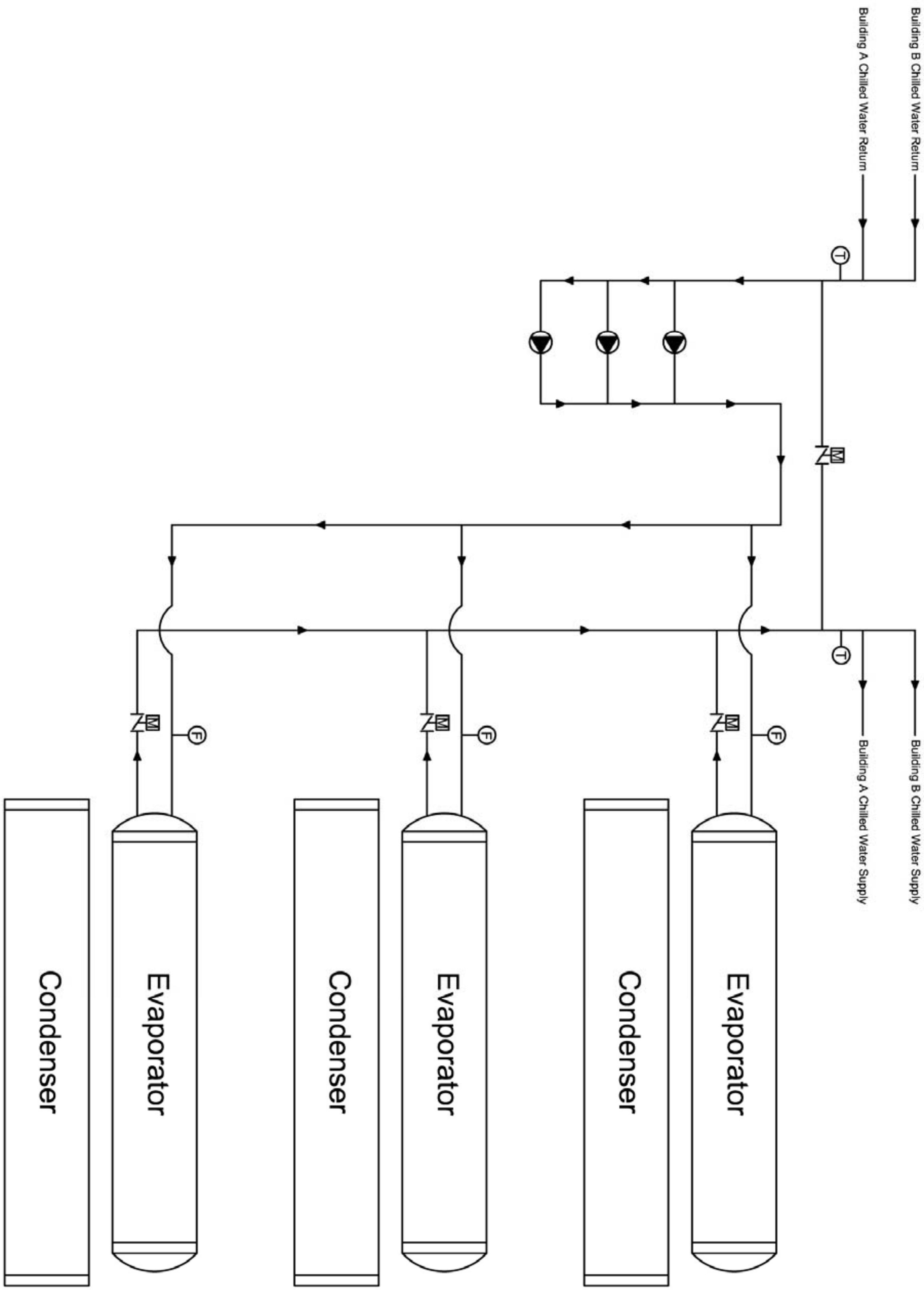

Figure 2 - Chilled Water Schematic

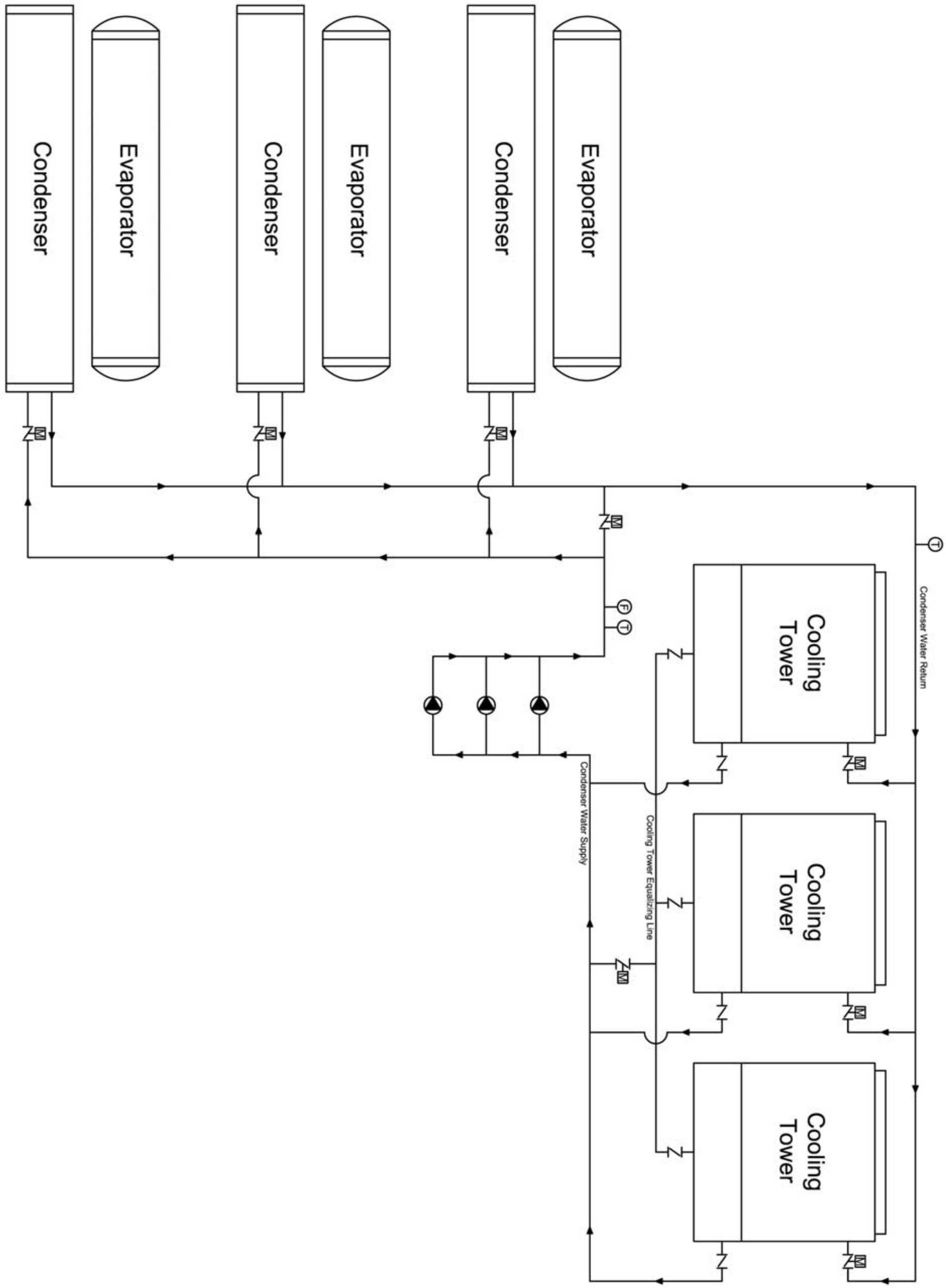

Figure 3 - Condenser Water Schematic

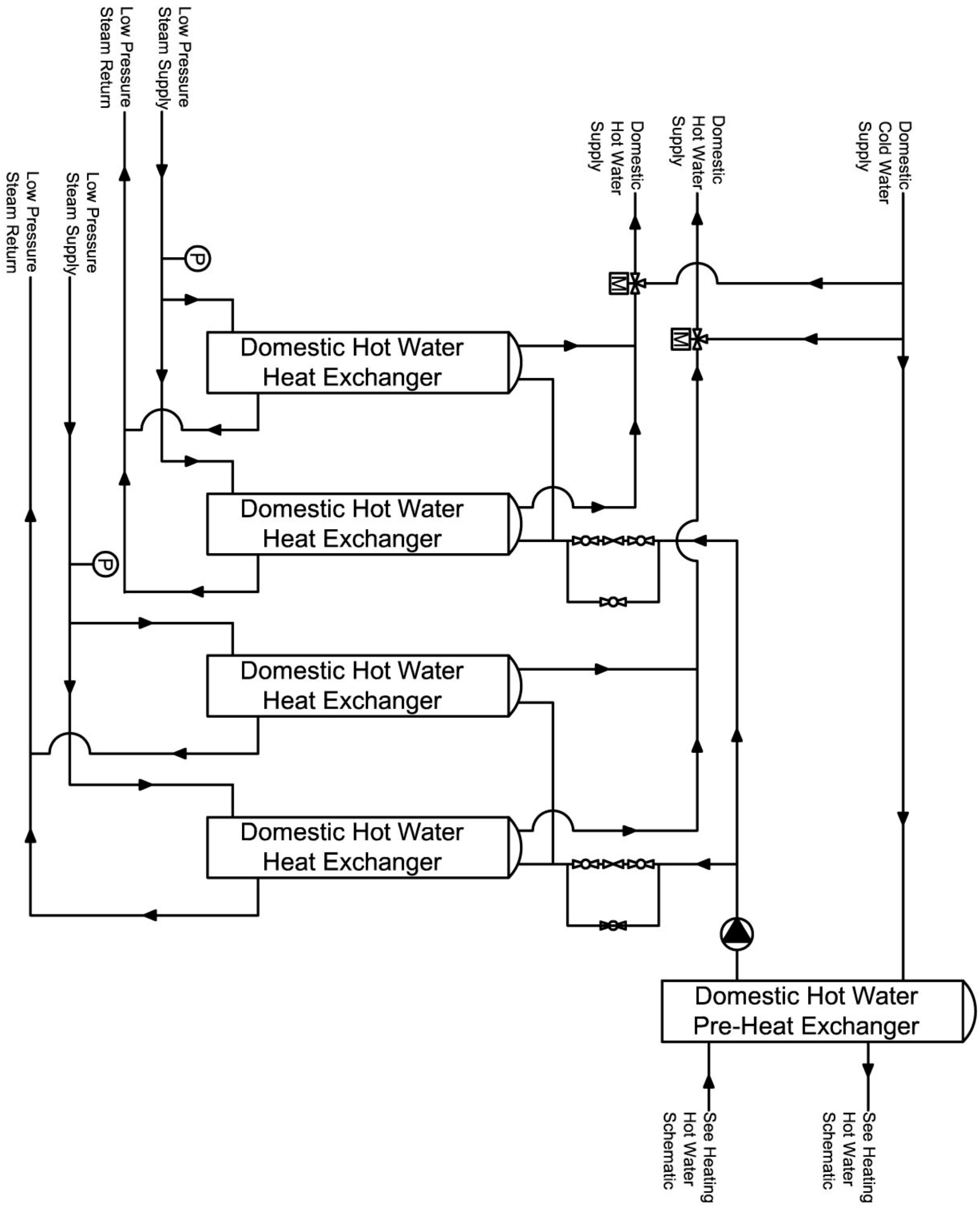

Figure 4 - Domestic Hot Water Schematic

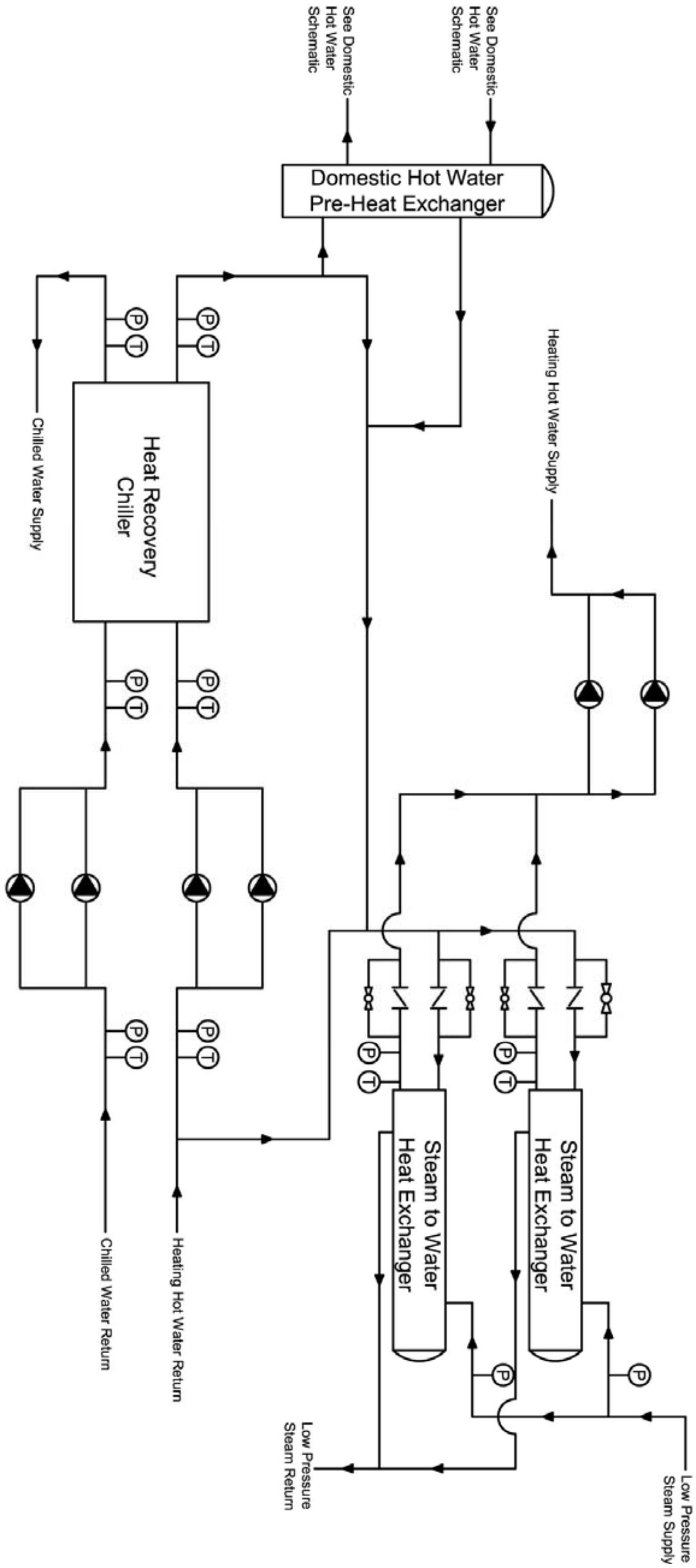

Figure 5 - Heating Hot Water Schematic

3.0 LEED®-NC Analysis

The Leadership in Energy and Environmental Design (LEED®) was created by the United States Green Building Council (USGBC) in order to help both building owners and design teams realize the importance of energy efficient and environmentally friendly construction practices. LEED has two primary categories that are influenced directly by the mechanical design engineer which are Energy and Atmosphere (EA) along with Indoor Environmental Quality (IEQ). Currently WRNMMC is seeking to receive the LEED Silver certification. During this analysis only the potential credits from these two categories were analyzed.

3.1 Energy and Atmosphere

EA Prerequisite 1: Fundamental Commissioning of Building Energy Systems - Yes

Intent: To ensure that the buildings mechanical system is installed and adjusted as specified by the design engineer

WRNMMC: A commissioning authority with previous new construction commissioning experience will perform a full controls and mechanical system run through. All results that are gathered from the commissioning reports will be compiled and reported directly to the owner upon completion of the project.

EA Prerequisite 2: Minimum Energy Performance - Yes

Intent: To set forth minimum energy efficiency levels that must be met by the designed systems.

WRNMMC: As detailed in Technical Report One both Building A and B comply with ASHRAE Standard 90.1-2007 along with exceeding the minimum 10% energy improvement over the ASHRAE 90.1-2007 Appendix G baseline building.

EA Prerequisite 3: Fundamental Refrigerant Management - Yes

Intent: To make a reduction in the use of CFC based refrigerants that contribute to stratospheric ozone depletion.

WRNMMC: All of the refrigeration equipment that is used within the facility uses R-134a or R-407c which are both HFC refrigerants.

EA Credit 1: Optimize Energy Performance - Yes

Intent: To achieve higher levels of energy efficiency within the buildings systems

WRNMMC: The ASHRAE Standard 90.1-2007 baseline building was calculated to consume 94,063 MMbtu/year at a cost of $2,255,330. The model that was created by the design engineer showed an energy use of 69,351 MMbtu/year resulting in a utility cost of $1,623,215. This energy cost reduction results in a savings of 28% a year on the buildings utility bills. A 28% reduction in energy costs results in a total of 9 points being awarded using the table given within this subsection of the LEED manual.

EA Credit 2: On-site Renewable Energy - No

Intent: To help reduce the associated impacts from using fossil fuel energy sources.

WRNMMC: The design engineers on this project did not incorporate the use of any renewable energy sources such as solar, wind, geothermal, or biomass. The result is that this project does not receive any points for this credit.

EA Credit 3: Enhanced Commissioning - Yes

Intent: To extend the commissioning process early into the design phase as well as extend it to after the design is complete for performance verification testing.

WRNMMC: A separate commissioning authority, Goetting & Associates, Inc., have been hired by the MEP team for all of their commissioning needs. Training and systems operations manuals will be turned over to the owner upon completion of the project in compliance with this section. The commissioning agent will also provide the results of any findings directly to the owner of the project. This results in the project receiving two points for completion of this credit.

EA Credit 4: Enhanced Refrigerant Management - Yes

Intent: To reduce atmospheric ozone depletion and support of the Montreal Protocol

WRNMMC: Since refrigerants are being used within the building the following formula must be followed.

$$LCGWP + (LCODP \times 10^5) \leq 100$$

Where:

$$LCODP = \frac{[ODPr \times (Lr \times Life + Mr) \times Rc]}{Life}$$

$$LCGWP = \frac{[GWPr \times (Lr \times Life + Mr) \times Rc]}{Life}$$

LCODP: Lifecycle Ozone Depletion Potential

LCGWP: Lifecycle Direct Global Warming Potential

GWPr: Global Warming Potential of Refrigerant

ODPr: Ozone Depletion Potential of Refrigerant

Lr: Refrigerant Leakage Rate (2%)

Mr: End of Life Refrigerant Loss (10%)

Rc: Refrigerant Charge (lb/ton)

Life: Equipment Life (20 years)

When using this equation for all of the equipment containing refrigerant along with the associated values corresponding to each type of refrigerant used, a total of 89.27 was obtained which is less than the maximum of 100 for this point. This results in two points being received for this credit.

EA Credit 5: Measurement and Verification - No

Intent: To make buildings accountable for the energy that they use.

WRNMMC: This project will not be monitoring their energy use for an entire year after post construction occupancy. This credit is expensive to obtain and was not required by any contract documents. However, the mechanical engineer will be monitoring the performance of the energy wheels and heat recovery chillers to verify that the expected performance is being obtained. The result is that this project does not receive any points for this credit.

EA Credit 6: Green Power - No

Intent: To use renewable energies through the electricity grid.

WRNMMC: This project will not be purchasing any of its power through such a program that generates electricity using green power. The result is that this project does not receive any points for this credit.

3.2 Indoor Environmental Quality

IEQ Prerequisite 1: Minimum Indoor Air Quality Performance - Yes

Intent: To enhance occupant well being by establishing minimum indoor air quality performance requirements.

WRNMMC: Sections four through seven in ASHRAE Standard 62.1-2007 have been met as detailed in Technical Report 1. Mechanical ventilation was used in all of the spaces and has been designed using the ventilation rate procedure outlined in ASHRAE Standard 62.1-2007.

IEQ Prerequisite 2: Environmental Tobacco Smoke (ETS) Control - Yes

Intent: To minimize building occupants and indoor surfaces exposure to ETS.

WRNMMC: Both of the new buildings do not allow smoking inside them due to the nature of the work being performed. Smoking is also only permitted in designated smoking areas throughout the entire campus which is in compliance with this credits requirement.

IEQ Credit 1: Outdoor Air Delivery Monitoring - No

Intent: To promote occupant well being within ventilated spaces.

WRNMMC: With the ventilation system being 100% outdoor air it was not deemed necessary to measure the CO_2 concentrations within the spaces due to the constant volume of air being supplied. The result is that this project does not receive any points for this credit.

IEQ Credit 2: Increased Ventilation - Yes

Intent: To supply additional outdoor air to occupied spaces to improve indoor air quality (IAQ).

WRNMMC: The ventilation rates supplied to each occupied zone exceed the 30% increase over ASHRAE Standard 62.1-2007 as stated within this section. The design engineer thought that it was important for the occupant's safety to try and eliminate the spread of particles and disease by the use of a constant volume 100% outdoor air system. This results in the project receiving one point for successful completion of this credit.

IEQ Credit 3.1: Construction Indoor Air Quality Management Plan (During Construction) - Yes

Intent: To reduce Indoor Air Quality (IAQ) related problems resulting from the construction process.

WRNMMC: A standard practice adopted by the mechanical team is that all ductwork being shipped to the site have a protective plastic sheathing already installed prior to entering the construction site. This protective sheathing prevents building construction products from being entrained within the ductwork while it is waiting to be installed. All of the filters on the air handling systems exceed the minimum MERV 8 rating that is stated within this section. The result is that this project receives one point for this credit.

IEQ Credit 3.2: Construction Indoor Air Quality Management Plan (Before Occupancy) - Yes

Intent: To reduce IAQ related problems resulting from the construction process.

WRNMMC: After construction is complete a total building flush out will be performed by letting the HVAC system run in order to help reduce the levels of indoor contaminants that the building occupants are initially exposed to from material off gassing. One point is able to be awarded based upon completion of this credits requirements.

IEQ Credit 4.1: Low-Emitting Materials Adhesives and Sealants - Yes

Intent: To reduce the quantity of contaminants which are harmful to the construction team or building occupants.

WRNMMC: All adhesives that were used within the building met or exceeded the maximum VOC limits stated within this subsection. The result is that this project receives one point for this credit.

IEQ Credit 6.2: Controllability of Systems (Thermal Comfort) - No

Intent: To promote thermal comfort control for individual occupants.

WRNMMC: Due to the large size of this building, rooms with similar occupancies were zoned together and served by a single CAV box with one corresponding thermostat. Due to this zoning technique less than 50% of the occupants within the building have access to individual temperature control systems making this credit unattainable. The result is that this project does not receive any points for this credit.

IEQ Credit 7.1: Thermal Comfort (Design) - Yes

Intent: To provide a thermally comfortable environment to help promote occupant well-being.

WRNMMC: All of the Heating Ventilation and Air Conditioning (HVAC) systems that were designed for both buildings meet the criteria stated by ASHRAE Standard 55-2004. The result is that this project receives one point for this credit.

IEQ Credit 7.2: Thermal Comfort (Verification) - No

Intent: To asses that acceptable thermal comfort is achieved after occupancy

WRNMMC: A thermal comfort survey must be conducted 6 to 18 months after occupancy and result in less than 20% of the occupants being dissatisfied. There are currently no plans to provide a survey of this nature which results in no points being awarded for this credit.

4.0 Overall System Evaluation

Due to the large size and type of occupancy, this projects mechanical system needed to provide a healthy atmosphere for its occupants at a low operating cost due to the year round operation. A constant volume 100% outdoor air system was selected to be used for this project due to the inherent IEQ benefits, constructability, and reliability. The design engineer realized that this system would consume more energy than comparable VAV systems with OA minimum intakes but the engineer and owner felt that this was the best system for the project. In order to reduce some of the associated energy costs total energy wheels and heat recovery chillers have been installed.

The cost to for the design and installation of the mechanical system is $109,500,000 or roughly $182.84/sf. The mechanical system represents approximately 17% of the buildings entire construction cost. Typically buildings mechanical system costs represent roughly 15%-20% of the total budget so this system falls in the middle of this estimate. The operating cost of this proposed mechanical system saves the owner over $600,000 a year when compared to the baseline mechanical building.

The space that the mechanical system occupies is mainly concentrated in the basement of both buildings. This can be viewed as a positive aspect in that all of the equipment is centrally concentrated making for easy installation as well as convenient for the maintenance staff. However, potential fan energy savings may be realized once a study is completed for decoupling the centralized fans from the basement to individual floors. This will result in more space being taken up on upper levels but an architectural redesign of a few areas may free up the space required.

Large plenum spaces are also required on this project to allow both the supply and exhaust ductwork to be routed simultaneously. Ductwork size may be able to be reduced by using a cooling system that is water based. Water is an effective means of transferring thermal energy due to the large heat capacity relative to air. Reducing the size of plenum spaces will also reduce the overall cost of construction to the direct reduction in floor heights. Using a water based system may be investigated further during the next assignment portion, however, a 100% outdoor air system is still preferred for other benefits.

The indoor air quality throughout both buildings should be a significant improvement over the baseline building due to the use of improved filters as well as dedicated outdoor air supplied to each room. With no recirculation aspect throughout the mechanical system potential building contaminants will not be spread easily throughout the interior zones.

The buildings thermal comfort and environmental control are provided by distributed CAV boxes throughout the building. Each of these CAV boxes usually serves more than one room of similar occupancy. These room zones should not prove to have problems with thermal comfort due to the similar occupancy and load types that were grouped together during zone assignments.

Overall the mechanical system that was designed for Buildings A and B uses the foundation of a reliable CAV system while adding energy reduction measures to provide an advanced HVAC system for the owner. The mechanical engineer has been able to provide such a system using creative system design and coupling it with an integrated building control system. Making improvements on this system will provide a challenge but areas of potential redesign have risen and will be investigated during future reports.

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