TECHNICAL REPORT THREE

National Law Enforcement Museum – Washington, D.C.

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EXECUTIVE SUMMARY

Mechanical system design is composed from a variety of design considerations including the goals of the design, local energy costs, the site location, and code requirements. A major design consideration for the National Law Enforcement Museum is the weather in Washington, DC. The excessive humidity in combination with the expected crowds in the museum makes humidity control a very important part of the system design. This problem is managed by modulating the intake of outdoor air and having humidity control components as part of the mechanical system.

The design for this structure follows multiple code guidelines including ASHRAE. These codes are applied to the overall design of the building mechanical system and are adequately executed to meet the city's guidelines. The site of the construction is a compact area in the center of the city, with multiple buildings causing shade upon the structure. This also affects the air intake so the intake and exhaust systems for NLEM and therefore these elements are aligned accordingly.

Overall cost of the building mechanical system is 4.5 million dollars. This results in a per square foot cost of $83.33. This is a little higher than average, but because it is a museum, this is acceptable. Review of the mechanical related LEED requirements show that the design meets the criteria to get to LEED Silver. All required references are detailed throughout the text and appendices.

The designed system works well for this type of building and is a good choice. There are some possible improvements that could be made. Perhaps a variable fluid system may improve the design by using less ceiling space and perhaps reducing noise into the building.

PROJECT BACKGROUND

The National Law Enforcement Museum is a 54,000 SF museum will be located in Washington, D.C. between 4th and 5th Street on E Street NW. This structure will complement the Law Enforcement Officer's Memorial and complete the overall aesthetics of the Courthouse Complex of Judiciary Square.

The defining architectural element of the structure are the two glass pavilions that function as the entrance to the museum. Upon entry, the guests will be lead via escalator to the two museum floors. The museum will hold a ticketing area, exhibit space, a research space, café, gift shop and a theater. The third floor below ground will be contain the central plant and utility connections for the structure.

This $50 million dollar project is expected to take 28 months of construction beginning June 2014 and ending September 2015. The contract is set up as a Design-Bid-Build. The Architects and Owners worked together to develop the building design. Following this the Engineers, Consultants and Construction Manager were hired. Finally, the project was bid out to specific subcontractors.

The historical location of the project required cooperation and approval of a number of historical and zoning associations such as the US Commission of Fine Arts, the DC Preservation Review Board and others. The building design is also pursuing LEED© Silver status and preparing to meet compliance with the Section 106 Review as an extra Environmental Assessment.

Mechanical System Overview

The museum is designed to be supplied by six air handling units (AHUs) located in various areas and supplying the multiple spaces in the building. Two 5000 CFM AHUs are specifically assigned to the East and West pavilions, another two 33000 CFM air handling units are situated to serve the exhibit area. Two 4000 CFM units serve the theater and the central plant area. The building is cooled using a combination of a chiller and two cooling towers. The water cooled system is the heat sink for the air handling units. A heat exchanger is also part of the system to support partial or complete free-cooling should the building conditions meet certain criteria.

Air is supplied from the air handling units at a temperature ranging from 50-56 degrees Fahrenheit and then ducted to variable air volume units. The air supply system is separated into three major components: the East & West pavilions, the exhibit areas, and the theater. The theater air handling unit varies its supply to the space with a variable frequency drive at the AHU. Heating in the building is supplied with electric heat at the air handling units and electric reheat at the VAV boxes. Air is returned using a return air plenum for each area and then ducted to be mixed with outside air intakes. Fifteen fan coil units are also used to supplement minor areas such as the café, gift shop and research center.

The entire system is controlled by a direct digital control (DDC) building automation system (BAS). The entry pavilions, theater, and exhibit space each have different control algorithms within the BAS. This control system will use the inputs from various carbon dioxide, oxygen and occupancy sensors. The occupancy schedule is set by the owner with the engineers confirming this with site visits in the one year after construction. Temperature sensors are located within the space and input information to the variable air volume boxes to supply adequate heating or cooling to the spaces. Humidity is maintained at the air handling units from information received by humidity sensors within the return ductwork.

Design Considerations

In the design of a mechanical system, various criteria must be considered to create a unique and optimum plan for each building situation. These criteria include the objectives of the design, local energy sources and their rates, the building site's cost, location and incentives, design benchmarks for indoor and outdoor weather conditions, local code requirements, and, finally, ventilation requirements for occupants. From these standards, results can be found for the building's heating & cooling loads, equipment, energy use, mechanical system operation sequence, and system controls. The lost usable space due to mechanical equipment and ductwork is also an important aspect of design.

Design Objectives

Multiple topics must be considered in the design of a mechanical system for a structure. An effective and functional system is required for all mechanical designs. The engineers for the National Law Enforcement Museum designed to meet more stringent objectives. The NLEM mechanical design will use high efficiency equipment, be energy efficient and generate a minimum amount of noise. These criteria will guarantee a design that will complement the high standard of architecture and honor expected for a building of this nature.

It is also imperative that the design meet all code standards as dictated by the District of Columbia during the permitting process. These include, but are not limited to, the International Mechanical Code 2006, International Building Code 2006, International Energy Conservation Code 2006, 2008 amendments by the DC Department of Consumer and Regulatory Affairs, United States Green Building Council version 2.2, and ASHRAE Standards 2004 Sections 90.1, 62.1 and 55.

Energy Sources & Rates

The National Law Enforcement Museum is an all-electric building. All equipment supporting the structure are powered using PEPCO as their utility provider. The museum taps into a main electrical line running below E Street NW, North of the building site. The power connects to a PEPCO substation located on the Plant Level. The energy rates for this utility is located in Table 1. The table displays both on and off peak costs for electricity as dictated by the PEPCO website.

Table 1 - NLEM Utility Costs

NLEM Utility Costs		
Electric Consumption On Peak	$/kwh	0.09
Electric Consumption Off Peak	$/kwh	0.08

BUILDING SITE

Downtown Washington DC is a congested area with very little construction space available. Presently, most new buildings in this area are on lots where previous buildings have been demolished. Therefore, it is an astute decision to place the National Law Enforcement Museum within the courtyard space of the District of Columbia Court of Appeals. The crystalline, modern look of the structure will be a beautiful compliment to the curtain wall and limestone exterior of the rear of the DC Court of Appeals.

A positive design condition of this site is that the museum will be bordered to the south, east and west by the Court of Appeals. This will decrease energy intense solar heat from the south and west from entering the mostly glass pavilions. The museum will also be connected to the adjacent structure for its loading dock and some auxiliary spaces. The location also allows for easy connections to all utilities existing below E Street NW.

BUILDING COST

Overall cost of the National Law Enforcement Museum is expected to be $50 million with $4.5 million for the combined mechanical and plumbing systems. No actual cost is yet available as construction is not yet completed. The National Law Enforcement Officers Memorial Fund gathered funds to design and build the museum from a variety of donors including Motorola Solutions, various Fraternal Orders of Police, Target, the US Congress and the District of Columbia. Revenue bonds totaling $80 million was approved at a tax exempt status by the District. All sponsors of the museum can be found on the NLEOF website. Other information concerning tax relief and rebates is not available because the information is proprietary and therefore not available.

OUTDOOR & INDOOR DESIGN CONSIDERATIONS

The outdoor design conditions are based on data collected in recent years as updated by ASHRAE. The summer dry bulb and wet bulb temperatures used for design are 91.9 F and 75.3 F. These follow the ASHRAE 1% cooling design temperature. The winter dry bulb temperature is 15.9 degrees, following the ASHRAE 99.6% for heating design temperature. A summary of these conditions can be found in Table 2.

Table 2 - Outside Design Temperatures

Outdoor Design		
Summer Design Dry Bulb	91.9 F	ASHRAE 1%
Summer Design Wet Bulb	75.3 F	ASHRAE 1%
Winter Design Dry Bulb	15.9 F	ASHRAE 99.6%

The engineers also established interior design temperatures to best fit the space. In summer, the indoor temperature will be 75 F with a variance of 2 degrees and at 50% humidity with a variance of 5 percent. In winter, the temperature will be set to 70 F and 40% humidity with the same variance as in the summer. These conditions were determined to be the optimum for the space and allows for use of free cooling when available. These conditions are also shown in Table 3.

Table 3 - Indoor Design Temperatures

Indoor Design		
	Temperature	Humidity
Summer	75 ± 2	50 ± 5 %
Winter	70 ± 2	40 ± 5 %

Building enclosure is vital to the design of the mechanical system for a structure as this is the location where most energy is gained or lost. There are six major components to the structure whose u-values affect building loads. These are the above and below grade walls, roof, skylights, skylight shading devices and curtain wall. Their u-values and the shading coefficient for the skylight are listed in Table 4. These values are based on the estimates made by the mechanical engineers in conjunction with input from the architects.

Table 4 - Building Envelope U-values

Envelope U-values	
Above Grade Walls	0.05
Below Grade Walls	0.08
Roof	0.05
Skylight	0.29
Curtain Wall	0.29
Skylight Shading Coefficient	0.33

Other indoor conditions that must be accounted are the building's lighting and power loads, its operating hours, filtration process, noise, and maximum occupancy. The power and lighting loads indicate the amount of energy output by these elements for various types of spaces. These are the office areas, auditorium, hall of remembrance, atrium, and exhibit space. A summary of the lighting and power loads for the building are shown in Table 5. The museum's operating hours and occupancy were determined for modeling purposes with input from the client and architects. Finally, the filtration type for the mechanical system and its expected noise criteria are indoor design conditions. Noise levels of 35 to 40 NC levels will be used for the office and exhibit areas as designated by the ASHRAE HVAC Applications handbook. A MERV 13 level of filtration is required for the building per ASHRAE Standard 52.1.

Table 5 - Building Power & Lighting Loads per Square Foot

Lighting Loads	Watts/SF
General Office Area	1.0
Auditorium	1.0
Hall of Remembrance	1.0
Atrium	1.0
Exhibits	1.0
Power Loads	Watts/SF
General Office Area	2.0
Exhibits - Process Lights	10.0

Ventilation Requirements

ASHRAE Standard 62.1 and 55 dictate requirements for the ventilation of a building space. These calculations are based on the occupancy of a space and its function. The building engineers, for the various spaces in the museum, made certain assumptions. These include the maximum occupancy of the auditorium at 120 persons, the hall of remembrance at 110 persons, the exhibits at 440 persons, the atrium with 100 persons and other areas having 45 persons. The outside air ventilation rate used in the mechanical system design is referenced from the ASHRAE Standard for general office areas, assembly areas and museums. A summary of the ventilation rates and assumed occupancy are listed in Table 6 and Table 7. The overall ventilation values for equipment is listed with the equipment summaries in a later section.

Table 6 - Outside Air Ventilation Rates

Outside Air Ventilation	CFM/Person	CFM/SF
General Office	5	0.06
Assembly Area	5	0.06
Museum	7.5	0.06

Table 7 - Assumed Building Area Occupancy

Assumed Occupancy	Persons
Auditorium	120
Hall of Remembrance	110
Atrium	100
Exhibits	440
Other Area	45

Design Heating & Cooling Loads

To calculate the heating and cooling loads for the National Law Enforcement Museum, the engineers used Trane Trace 700 ©. This program takes the input about the various spaces in the building including dimensions, materials, u-values, locations and all the data discussed in the prior sections and outputs the estimated heating and cooling loads of the space. This program also has the capability of approximating the expected energy use of a project based on the equipment and schedule.

After creating and calculating the building model in Trace 700©, the engineers determined there to be a total of 246 tons of cooling load and 673 MBH of heating load in total. This data is then used to determine the cooling and heating systems most effective for the space. It is the benchmark, also, for the equipment chosen to be part of the mechanical system.

Table 8 - Heating and cooling load, BTU/hr., by space

Room Name	Space Total Cooling	Coil Peak Heating
Admin offices 222/Work space 223	14186	8332
Bridge 214	64648	58239
Café 221	39677	32414
Changing Exhibit 315	10275	10013
Changing Exhibit 311	166741	144544
Corr 113 & Stair 6 & 7	87379	27147
Corr 207	15346	9347
Corr 307 & 307 1	10462	10603
Corr 318	3008	2086
Corr 102	48460	20054
Corr 107 & Stair 3	85182	27442
Corr 109	58325	20686
East El Lobby 103	1271	640
East Mech Room 203	34954	24995
Elec 209	1886	865
Elec 306, 305 & 301 1	17149	8432
Elec 316	1398	1128
Elev Cont 106	19683	2192
Entry Lobby 101	164168	52810
Exhibit AV 317	38623	18236
Exhibit Hall 329 & AV Room 320 1	918941	853040
Exhibit Support 308	20855	18421
Exit Lobby 108	144086	56628
Fire Control 105	4828	2795
Gift Shop 217 off 217 1	24935	11762
Gift Shop Storage 211	1282	1089
Hall of Remembrance 310	82938	74415
J Edgar Hoover 111	29244	10503

Room Name	Space Total Cooling	Coil Peak Heating
Locker 302 Restroom 303	2682	2155
Multipurpose 301	14777	15544
Off 304 & 305	55741	4611
Rest Rm 218, Lckr 219, Rest Rm 220	10677	7658
Rest Rms 314 & 313	7983	7028
Service Elev Lobby 206	4286	2966
Storage 204	1935	1104
Storage 309	1219	766
Substation	140318	0
Tel 210	4382	327
Theater 319	132105	67569
Ticket/Info 201 & E El Lobby 202	328098	188146
W Elev Lobby 312	2367	1853
W TVS Lby, El Lby & Corr 215, 216, 216 1	280966	94621
Warming Kitchen 208	5070	2704
West Elev Lobby 110	984	477
West Mech Room 224	15061	10166

Annual Energy Use

There was no energy analysis completed on this structure by the engineer. Consequently, there is no cost analysis for the building. From an earlier calculation done for Technical Assignment Two by this author, a summary of the building energy use is shown in Table 9 - Summary of total building energy use per system per year

Table 9 - Summary of total building energy use per system per year

	Building Energy (kBtu/yr.)
Heating	384539
Cooling	766230
Auxiliary Mechanical Equipment	289599
Lighting	474226
Other Electrical Loads	1162671

Building Equipment Summary

Multiple components are required for the mechanical system to function and cool and heat the building. This includes all equipment from the cooling tower and chillers to the fan coil units and variable air volume units.

There are two cooling towers located in the East Penthouse. They complete the air-cooled system and cool the coolant, water, which then returns to the chiller. This coolant then is pumped to the air handling units and fan coil units. From there, the cooled air travels through the ducted system to the variable air volume units or directly to the space.

A full list of equipment is listed in Appendix A – Equipment Schedules. The engineers used Trane as the basis of design for the air handling units, the variable air volume units, and fan coil units. Pump basis of design is Aurora, cooling towers use Baltimore Aircoil Company and the exhaust fans are Greenheck.

Sequence of Operation

This next portion will go through the various components and their control systems from the chiller to the variable air volume units. It will discuss the type of equipment and their controls. An important factor for all this is the temperatures at which each unit functions in its various modes.

The figure in Appendix B - Mechanical System Flow Diagram shows the general sequence of the building mechanical system. On the airside, conditioned air is supplied from the air handling units to the VAVs and then the spaces and fan coil units directly to its spaces. Return air is transferred through the plenum into the mechanical rooms where the air handling units take the air after it's mixed with outdoor air and reprocesses it through the building. Harmful exhaust is specifically ducted out, but other exhaust air is released through louvres located on the sides of the buildings at the penthouses.

For the water-side, the components are the cooling towers, chiller, heat exchanger, air handling units and fan coil units. The cooling tower takes the water from the chiller and reduces its temperature. The water is then sent back to the chiller and energy is exchanged. This follows through to the heat exchanger, AHUs and FCUs.

The chillers are four modular units that containing the chilled water and condenser water. The chiller supplies the mechanical cooling and are connected to the cooling towers. This equipment is capable of functioning at partial capacity and is function is controlled by building automation system via its variable frequency drive. Chiller use is very limited when the outdoor air temperature decreases to 45F. This is when the ambient free cooling will be used. However, should the building humidity reach 55%, the chiller will be brought back into use.

The cooling towers work in conjunction with the chillers, operating with variable drives to match the required loads of the building. The overall sequence of this equipment rotates every seven days and the cooling towers are required to have a minimum of 5 minutes off period every day. This equalizes the run time of both fans in the cooling towers. To prevent freezing, when outside temperatures are below 35F a heat tap will be enabled. If temperatures are below 40F, a sump heater is brought in but disabled if temperatures are above 42F.

The settings of the cooling towers and chillers is pressure controlled via a valve. Both pieces of equipment are fully loaded when wet bulb temperature is 78F and above, 75% at 74F, 50% at 70-60F depending on humidity, and 25% at 66F. The plant control system will dedicate at which rate the equipment run. This is from taking the input of the outside wet bulb temperature, the incoming water temperature, chilled water and condenser water flow rate and the efficiency of the chiller. A more precise narrative will be provided to the building maintenance people.

Air handling units take a large amount of input to send out conditioned air. These are space sensors, fan status, filter status, smoke detectors, low temperature sensors, occupancy sensors, other temperature sensors within the ducts, and pressure sensors. All these data points go into the building automation system. All air handling units are directly wired to the occupancy, CO2 and temperature sensors. Each has a heating coil for pre-heat. Appendix A – Equipment Schedules has a specific list of the AHUs and the areas they service. All the AHUs supply VAV boxes for various zones in the building. The variable air volume units have another heating coil to bring the supply air to the zone required temperature.

The National Law Enforcement Museum utilizes a building automation system to control its mechanical system. At the beginning of the day, the system will wait as long as possible before beginning operation so as to reach the optimum temperature just at the start of building occupancy. Therefore, it will not begin any more than 120 minutes prior to occupation. During the cooling period, the BAS determines when to turn on depending upon the modes zone's VAV units. During the heating season, the local preheat elements in the zones will change the supply the temperatures as required. Should the building operator require a time override, the BAS will shut down that zone for 120 minutes.

In the night mode, the building shall function as if unoccupied. The ventilation functions will be disabled and the outdoor air supply will not be used. If cooling, the building will be night cooled and prevent the building from reaching temperatures above 85F. The air flow will remain to maintain the pressure in the duct system. For the heating night mode, the building automation system will utilize AHU to maintain the building temperature at a minimum of 60F. The VAVs will also help maintain the temperature. The airflow will not halt in this situation either.

Building humidity needs to be controlled because the structure is a museum. A humidity sensor is located near the fan discharges to modulate the humidifier. Each space also has a humidity sensor that will send the information back to the BAS. Ventilation is controlled directly at the air handling units which maintain the required amount of outdoor air supplied to its zones.

There are special instructions for AHU-5, the air handling unit supplies the theater in a single zone capacity. Normal conditions apply to this equipment during occupied hours. However, for the morning warm up or cool down period, the system will only operate in cooling or heating mode (as required) if the space temperature is 2 degrees or more away from the space setpoint.

The variable air volume units are the last step in control before air enters a space. The space temperature dictates whether the unit functions in heating or cooling mode. Cooling supply setpoint minimum is 40F and maximum is 110F. Heating supply setpoint minimum is 40F, also, and maximum is 105F. When in cooling mode, the unit will reference the normal setpoints for all building equipment: occupied cooling setpoint – 74F, unoccupied cooling setpoint – 85F, and occupied standby cooling setpoint – 78F. In heating mode, the setpoints change to 71F, 60F and 67F, respectively. All VAV units are equipped with reheat which activates when the space temperature is below the cooling setpoint and the airflow is at the minimum cooling flow. This adds a redundancy and prevents the use of the reheat coil unless necessary.

Generally speaking, the building automation system controls five aspects of the VAVs. These are space temperature setpoints, occupied status, unoccupied status, heat or cool mode, and priority shut down. With these elements controlled, the equipment is adequately controlled and waste energy is eliminated.

The various fan coil units in the building follow the same operation as the air handling units. They have the same function for occupied and unoccupied time, morning warm up and cool down, and heating and cooling setpoints. However, in addition to the BAS controlling the regular occupied, unoccupied, heat/cool mode and priority shutdown, it also has the capability of enabling the economizer that is a part of the FCU.

Finally, the building automation system also manages smoke control in the event of a fire. When the fire alarm system signals the BAS of the presence of smoke, all automatic dampers of each fan will open. AHU-5, supplying the theater, will allow the supply and return air fans to operate at full speed. It will also close the return air damper completely and completely open the relief and outside air damper. For the other AHUs, the supply fans will operate at full speed while the outside air damper opens and the return air damper closes.

Following these immediate reactions, all the exhaust fans will begin or maintain function and the smoke isolation dampers will become fully open or fully closed, depending upon their designation as specified in the mechanical drawings. Also, all the cooling coil control valves will be opened fully and the chiller turned off. However, the chilled water pump will continue to run the fluid at full speed to prevent it freezing. Only when the smoke is completely cleared will the building be manually reset into operation.

SYSTEM COST

The cost estimate for the National Law Enforcement Museum is confidential and was not released. Via an email conversation, the Clark Construction stated that the overall mechanical and plumbing system cost is $4,500,000. Therefore, the cost of the mechanical system per square foot of NLEM is $83.33/SF.

LEED REVIEW

The museum is designed to reach LEED Silver status. Mechanical systems directly influence the energy use of the building and indoor air quality. Energy is conserved by designing and selecting equipment for a system such that it functions efficiently. This tactic is augmented by the use of the building automation system which modulates all the equipment to maintain performance at maximum efficiency. The BAS monitors the outdoor air intake and ventilation. This also allows functional maintenance of thermal comfort.

To maintain indoor air quality, low-emitting materials such as adhesives, sealants, paints, coatings, carpet, wood and agrifibers are monitored during and after the construction process. There is also an active policy of no smoking within the building.

Evaluation of System

Overall, the variable air volume system is the very useful for this type of structure. It is easy to maintain because it is very modular. The use of the fan coil units to the very variable and high load areas. It prevents the air handling units, which are larger pieces of equipment, from overworking and using excess energy. The building automation system is pivotal in maintaining energy balance and system control.

A possible improvement to this system may be to use a less invasive mechanical system. A variable fluid flow system may work better because it would use smaller duct and less ceiling space. This may also reduce the noise resulting from the large volumes of airflow and equipment noise from the ceiling mounted variable air volume system. This and other conditions will be evaluated in a future proposal for improvement of the mechanical system.

Appendix A – Equipment Schedules

AHUs									
Name	Services	Supply (CFM)	Outside Air (CFM)	Type	HP	RPM	Control Type	Unit Arrangement	Basis of Design
AHU-1	Ground Floor/West Entry	5000	500	Plug	5	2045	VFD	Horizontal	Trane Performance Climate Changer, VAV
AHU-2	Ground Floor/East Entry	5000	500	Plug	5	2045	VFD	Horizontal	Trane Performance Climate Changer, VAV
AHU-3	Exhibits	33000	7000	Plug	(2) 20 each	1506	VFD	Horizontal	Trane Performance Climate Changer, VAV
AHU-4	Exhibits	33000	7000	Plug	(2) 20 each	1506	VFD	Horizontal	Trane Performance Climate Changer, VAV
AHU-5	Theater	4000	990	Plug	5	1901	VFD	Horizontal	Trane Performance Climate Changer, VAV
AHU-6	Pepco Substation/Switchgear Room	4000	-	Centrifugal	5	1367	-	Vertical	Trane Climate Changer Model LPCAD08F, CV

Cooling Tower											
Name	Location	Water GPM	Entering Temp (F)	Leaving Temp (F)	Electric Heater (KW)	CFM	HP	Control	Winterized	Capacity	Basis of Design
CT-1	Penthouse Mech East	252	100	85	7	45870	25	VFD	Yes	152	BAC VTL0152-M
CT-2	Penthouse Mech East	252	100	85	7	45870	25	VFD	Yes	153	BAC VTL0152-M

Chiller								
Name	Location	Chiller Fluid	Chiller GPM	Condenser GPM	V/PH/HZ	Capacity (Tons)	Basis of Design	Operating Weight
CH-1	Chiller Plant	Water	437	504	460/3/60	255	(4) Multistack MS070X	10000

Fan Coil Units							
Name	Location	Supply (CFM)	Outside Air (CFM)	Total Capacity (MBH)	HP	Drive	Basis of Design
FCU-1	Ground - West	1800	500	61.95	1.00	Belt	Trane Model BCVC054 (Vertical Pre-Swirl)
FCU-2	Ticketing - West	650	-	21.86	0.33	Belt	Trane Model BCVC024 (Vertical Pre-Swirl)
FCU-3	Ground - East	360	20	12.16	0.24	ECM	Trane Model FCBB06 (Vertical Cabinet)
FCU-4	Ticketing - West	1200	220	42.49	0.75	Belt	Trane Model BCHC036 (Horizontal)
FCU-5	Ticketing - West	1900	640	71.72	1.00	Belt	Trane Model BCHC072 (Horizontal)
FCU-6	Ticketing - West	1900	640	71.72	1.00	Belt	Trane Model BCHC072 (Horizontal)
FCU-7	Exhibit - East	300	-	9.77	0.24	Belt	Trane Model FCBB04 (Vertical Cabinet)
FCU-8	Exhibit - West	1800	-	74.75	0.75	ECM	Trane Model BCVC072 (Vertical)
FCU-9	Central Plant	300	-	7.16	0.33	Belt	Trane Model BCHC012 (Horizontal)
FCU-10	Central Plant	900	-	23.36	0.33	Belt	Trane Model BCHC024 (Horizontal)
FCU-11	Central Plant	450	40	12.15	0.33	Belt	Trane Model BCHC018 (Horizontal)
FCU-12	Ticketing - West	400	-	8.26	0.33	Belt	Trane Model BCHC012 (Horizontal)
FCU-13	Ticketing - East	1000	-	25.18	0.50	Belt	Trane Model BCHC024 (Horizontal)
FCU-14	Exhibit - East	900	-	18.7	0.50	Direct	Spotcool Above Air Model SPC-024
FCU-15	Exhibit - East	900	-	18.7	0.50	Direct	Spotcool Above Air Model SPC-024

Fans									
Name	Location	Area Served	Type	Fan CFM	BHP	Emergency Power?	Inlet dBA	Control Type	Basis of Design
EF-1	Generator Room East	Generator Room	Inline	1000	0.14	No	57	-	Greenheck SQ-1-A
GEF-1	Penthouse Mech East	General Exhaust	PRV	5000	2.06	Yes	70	VFD	Greenheck CUBE-22
RAF-1	Ticketing/Visitor East	AHU-5 Relief Fan	Mixed Flow	5000	2.16	Yes	68	VFD	Greenheck QEI-16-1
SEF-1	Penthouse Mech West	Smoke Exhaust	Axial	40000	17.91	Yes	91	VFD	AX-103-275
SEF-2	Penthouse Mech West	Smoke Exhaust	Axial	40000	17.91	Yes	91	-	AX-103-276

SEF-3	Penthouse Mech East	Smoke Exhaust	Axial	40000	17.91	Yes	91	-	AX-103-277
SEF-4	Ticketing/Visitor East	Smoke Exhaust	Axial	20000	9.59	Yes	84	-	AX-80-275
SEF-5	Ticketing/Visitor West Elev Lobby	Smoke Exhaust	Axial	5000	3.26	Yes	83	-	AX-41-190
SEF-6	Exhibit West Changing Exhibit Prep	Smoke Exhaust	Axial	5000	1.86	Yes	76	-	AX-63-275
SEF-7	Exhibit East Exhibit Support	Smoke Exhaust	Axial	5000	1.86	Yes	76	-	AX-63-275
SPF-1	Penthouse Mech West	Stair #7 Press.	Backward Inclined	4000	1.29	Yes	72	VFD	20-BISW-41
SPF-2	Penthouse Mech West	Stair #6 Press.	Backward Inclined	4000	1.29	Yes	72	VFD	20-BISW-41
SPF-3	Penthouse Mech East	Stair #4 Press.	Axial	4000	0.97	Yes	68	VFD	AX-47-160
SPF-4	Penthouse Mech East	Stair #3 Press	Axial	4000	0.97	Yes	68	VFD	AX-47-160
TEF-1	Penthouse Mech West	Toilet Exhaust	Backward Inclined	4020	1.06	Yes	63	-	SWB-222
TEF-2	Penthouse Mech East	Toilet Exhaust	PRV	400	0.19	Yes	57	-	CUBE-101HP

Pumps										
Name	Location	System Served	GPM	Total Head (FT)	Operating Press. (PSIG)	HP	RPM	Type	Control	Basis of Design
P-1	Central Plant Room	Condenser Water	504	50	175	10	1750	End Suction	VFD	Aurora Series 360
P-2	Central Plant Room	Condenser Water	504	50	175	10	1751	End Suction	VFD	Aurora Series 360 (Standby)
P-3	Central Plant Room	Chilled Water	430	65		15	1752	End Suction	VFD	Aurora Series 360
P-4	Central Plant Room	Chilled Water	430	65		15	1753	End Suction	VFD	Aurora Series 360 (Standby)

VAV					
Type	CFM Max.	CFM Min.	Max Radiated NC	Heater Coil KW	Basis of Design
A	400	18	20	2	Trane VCEF06
B	700	400	26	3	Trane VCEF08
C	1100	700	30	5	Trane VCEF10
D	1600	1400	31	10	Trane VCEF12
E	2400	1800	36	15	Trane VCEF14
F	3500	3000	39	25	Trane VCEF16
G	400	150	25	-	Trane VCEF06

APPENDIX B - MECHANICAL SYSTEM FLOW DIAGRAM