TECHNICAL REPORT ONE

National Law Enforcement Museum – Washington, D.C.

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ANYA GODIGAMUWE – MECHANICAL OPTION
AE Faculty Consultant – Dr. Stephen Treado, Ph.D., P.E.
Architectural Engineering Dept. – The Pennsylvania State University

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EXECUTIVE SUMMARY

This technical report analyzes the National Law Enforcement Memorial according to certain sections of ASHRAE 62.1 and 90.1. The structure is located in the heart of Washington, DC, and will house a museum space, auditorium, office space, café, gift shop and research center. Its 54,000 square feet will begin construction in July 2014 and progress until September 2016. The museum is designed to achieve LEED Silver status.

The initial portion of this report is a Mechanical Overview discussing the various equipment utilized in this building. System processes and controls are discussed and the operational order for all equipment from the chiller and cooling towers to the air handling units and electric duct heaters.

Next, the mechanical system design will be compared to the ASHRAE 62.1 Sections 5 and 6 for HVAC equipment and building ventilation. These analyses consider a variety of criteria including dehumidification, particulate contaminants, and building exhaust. Most criteria are found to be compliant except for 5.9, 5.14, and 6.2 which refer to dehumidification, building envelope and ventilation procedure.

The second portion of this document studies ASHRAE 90.1, energy standards for the building envelope, power, water heating, lighting, and HVAC equipment. There are only three non-compliant aspects: building envelope, chiller efficiency and fan power efficiency. The building envelope can be modified in the same fashion as stated above for ASHRAE 62.1. Building materials with a higher U-value can also be used for the pavilions. For the equipment, however, different models to those specified as the design base should be utilized to improve the efficiency of the chiller and fans.

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.

ASHRAE 62.1 COMPLIANCE

The following will discuss the National Law Enforcement Museum's compliance with ASHRAE 62.1 Section 5 and 6. Section 5: Systems & Equipment will specifically analyze the building drawings and specifications to determine their compliance with the standard. Section 6: Ventilation Rate Procedure will calculate the museum's required ventilation rates and compare these results to those provided by Loring Consulting Engineers in the construction documents.

SECTION 5: SYSTEMS & EQUIPMENT

5.1 VENTILATION AIR DISTRIBUTION

This museum's energy design goal is LEED Silver. Therefore, the air balancing is a requirement will be met according to the ASHRAE 62.1, Section 7.2.2. The ceiling plenums present throughout the design allow for the required minimum air flow rates to be met in all the zones. Finally, the documentation of these calculations and balancing will be present in the construction documents, LEED Air-Balance Report, and the as-built drawings.

5.2 EXHAUST DUCT LOCATION

Special negative pressurization is applied to the smoke exhaust and stair pressurization ducts to prevent the spread of harmful smoke or fumes in the event of an emergency. This requirement is particularly important in this building design because of the lack of windows and immediate access to the outdoors. A contingency plan is also in place to assist in the exhausting of smoke via the ducts. Certain doors and other openings will be made to remain open to assist in the discharge of the contaminated air. This plan is detailed in the construction documents.

5.3 VENTILATION SYSTEM CONTROLS

Control of the ventilation requirements for the building is maintained by the building automation system. This system, whose basis of design is Trane, will control all outdoor air supply to all six air handling units and the air flow rate at the variable air volume boxes. The data input for the system will be received from a variety of sensors including oxygen, carbon dioxide, humidity and temperature sensors. Air recirculation will occur between all zones except for the pavilions. This is because they have high, atrium-like, glass structure and require exhausting.

5.4 AIRSTREAM SURFACES

All ducts within the building are to be constructed with mold and fungus resistant materials. The construction method for these elements are also required to be very controlled to prevent contamination. Built-in air cleaners are also specified at various locations in the duct work. The building documents also specify that all surfaces exposed to the airstream will have aluminum or polymer barriers to prevent erosion.

5.5 Outdoor Air Intakes

Outdoor air intake for the structure occurs via louvers located in the East & West pavilions that pull air into the mechanical rooms. The location of these louvers is more than the required distance away from the street. Unfortunately, because of the limited space, the exhaust fans push unwanted air out of a roof opening in the same mechanical rooms. The short distance between the intake and the exhaust is acceptable because of the velocity of air at the exhaust fans. These calculations are shown in the construction documents. The outdoor air intake louvers and roof opening both are required to have bird screens. Snow entrainment and water infiltration & entrainment standards are also to be met and documentation presented during the submittal process.

5.6 Local Capture of Contaminants

HEPA filters are located at various positions with in the ventilation system to remove airborne contaminants. These "intelligent filters" will remove all contaminants greater than 0.1 microns in diameter. The specified filters will allow the building to meet the indoor air quality standards required by both ASHRAE and the LEED Silver certification.

5.7 Combustion Air

There is no equipment using combustion. The museum is part of the overall Judiciary Square complex and will have its emergency generators and other combustive equipment in the adjacent buildings' mechanical spaces.

5.8 Particulate Matter Removal

MERV 15 filters are used at the air handling units to remove particulate matter from the ventilation system. This is to clean the air and to aid in achieving the noise criteria standards for the museum space. Cabinet unit heaters will meet MERV 7 to allow continuous airflow. The various fan coil units will have MERV ratings from 7 to 13 as defined by their area served.

5.9 Dehumidification Systems

Air dehumidification occurs at the air handling units from sensors located in the return air ducts. The humidity set point for design is 50%. During the free cooling and partial free cooling periods, the limiting factor is a maximum relative humidity of 55%. Concerning the exfiltration of the building, the air intake for the structure is much greater than the exhaust rate. This positively pressurizes the space preventing the intake of excessively hot or cold air from the outdoors.

5.10 Drain Pans

The design specifications outline that all drain pans must have their outlets at the lowest point and have drain seals installed to the standard level. The drain pans are sized to meet the cooling coil load and are sloped at 0.125 in./ft.

5.11 Finned-Tube Coils & Heat Exchangers

The chiller and heat exchangers for this project are designed with the required drain pans per ASHRAE 62.1. Section 5.10 as stated above. The coils are also designed at the correct spacing and pressure drop. Access panels are provided at the equipment for cleaning purposes.

5.12 Humidifiers & Water-Spray Systems

Electric steam humidifiers are used to supplement the ticketing and service areas with AHUs 3-5 and fan coil unit 1. No specific outline is made concerning the water quality for these units, however all water supplied to the building must meet the standards of the District of Columbia Water and Sewer Authority.

5.13 Access for Inspection, Cleaning, & Maintenance

All equipment is stated in the specifications to follow the manufacturer's standards for clearances and access panels.

5.14 Building Envelope & Interior Surfaces

The only structure above ground are the glass pavilions. The curtain wall there is fully sealed with a silicone sealant that works in combination with the continuous polyamide thermal separation.. A continuous vapor retardant seal is specified where the curtain wall connects to the base structure. Further continuous seals are specified at all joints on the exterior structure.

The walls for the levels below ground is cast-in-place concrete. The waterproofing system for this area contains multiple water and vapor repellant elements including multiple membranes, flashing, water-stops and drainage board. Because of most of the museum structure is underground and Washington, DC, has a very low elevation, these details are particularly important to construction and building maintenance.

The plumbing and mechanical details both require vapor barrier insulation to meet the requirements. This is also imperative for maintaining the temperature of the fluid within the pipes.

5.15 Buildings with Attached Parking Garages

This section does not apply to the National Law Enforcement Museum as there are no parking garages attached to the structure.

5.16 Air Classification & Recirculation

All circulated air within the museum is Class 1 or Class 2 air. Class 1 air is provided to spaces either from the air handling units to VAV boxes or from the separate fan coil units that supply specific areas. The used air, now classified as Class 2, is allowed to freely circulate into the restroom areas. The restroom and chiller plant air is exhausted out of the building.

5.17 Requirements for Buildings Containing ETS Areas and ETS-Free Areas

The National Law Enforcement Museum will be a smoke-free environment. Section 5.17 does not apply in this case.

Section 6: Procedures

The below analysis is used to determine whether the standard required amount of fresh outdoor air is made available for the occupants of the National Law Enforcement Museum. This procedure is also known as the Indoor Air Quality Procedure or the Natural Ventilation Procedure. This analysis depends on a number of variables including occupancy type, square footage, number of occupants, required ventilation rate per minute and the effectiveness of air distribution based on the location of the air supply diffusers.

6.2 Ventilation Rate Procedure

All outdoor air utilized to ventilate a space must be treated to remove outdoor contaminants. This may be done with the use of filters that trap particulate matter larger than 10 micrometers. Because the building is located in the center of a city, a certain amount of ozone control must take place. These filters are to be cleaned every three years and must function at a higher rate.

6.2.2.1 Breathing Zone Outdoor Airflow

The ventilation rate required for occupants is called the breathing zone outdoor airflow, V_{bz}. This is a function of the zone floor area, the number of population designated for the space, the air flows required per unit area and per person according to table 6.2.2.1. The equation is defined below:

$$V_{bz} = R_p \times P_z + R_a \times A_z$$

Following calculating the required outdoor air, the zone outdoor air flow, V_{oz}, is calculated. This is the outdoor air flow required for the space after consideration of the occupancy type and function. E_z is the zone air distribution effectiveness and can be found on Table 6.2. The building uses ceiling supply and plenum return, so E_z is 1.0. The equation is shown below:

$$V_{oz} = {V_{bz}}/{E_z}$$

The next step is to determine the type of system that the building uses. The National Law Enforcement Museum utilizes a multi-zone recirculating system (Section 6.2.5). This now requires the calculation of the primary outdoor air fraction or Z_{pz}. Equation 6.2.5.1 is shown below, where V_{pz} is the lowest zone primary air flow because the overall system :

$$Z_{pz} = {V_{oz}}/{V_{pz}}$$

Now the outdoor air fraction is found, ASHRAE Table 6.3 can be referenced to determine the system ventilation efficiency or E_v. Next, the uncorrected outdoor air intake, V_{ou} must be calculated to take into account the variety of different spaces present in the building. This equation is shown below along with the diversity equation:

$$V_{ou} = D \times \sum_{all\ zones} (R_p \times P_z) + \sum_{all\ zones} (R_a \times A_z)$$

$$D = \frac{P_z}{\sum_{all\ zones} P_z}$$

Finally, the uncorrected outdoor air intake will be used to calculate the outdoor air intake flow, V_{ot}, as shown below:

$$V_{ot} = {V_{ou}}/{E_v}$$

A summary of the calculated versus designed ventilation rates for the museum can be found in Table 1. The main air handling units meet the required outdoor air ventilation as resulted from the ASHRAE 62.1 calculations. Three of the fan coil units, however, do not meet the outdoor air criteria. The fan coils must supply more ventilation because they all service occupied spaces such as the café, lobby areas, and AV room. A full table of ventilation calculations can be found in Appendix A.

Table 1 - Ventilation calculation comparison to design

System Summary			
System Summary	**Design V(ot)**	**Calculated V(ot)**	**Compliant?**
AHU-1	500	500	Yes
AHU-2	500	500	Yes
AHU-3	7000	1560	Yes
AHU-4	7000	1370	Yes
AHU-5	980	310	Yes
AHU-6	0	0	Yes
FCH-01	500	220	Yes
FCH-02	0	0	Yes
FCH-03	20	0	Yes
FCH-04	210	310	No
FCH-05	640	1100	No
FCH-06	640	270	Yes
FCH-07	0	20	No
FCH-08	40	40	Yes
FCH-09	0	0	Yes
FCH-10	0	0	Yes
FCH-11	0	0	Yes

Summary of ASHRAE 62.1 Compliance

For the most part, the designed system complies with ASHRAE 62.1. There are a few aspects that would merit from improvement. These are the dehumidification, building envelope and outdoor air ventilation rate at some of the fan coil units.

The overly humid atmosphere of the Washington, DC, area combined with the load of museum patron and solar gain from the glass pavilions may result in an uncomfortable atmosphere. Further analysis of this is required through the calculation of the building energy and thermal loads.

Next, the design of the structure utilizes a greater than standard amount of glass. This value may be reduced with the utilization of varying the design of the pavilion façade to include some metal paneling or other non-glass envelope material.

Finally, fan coil units 4, 5, and 7 do not meet the ventilation criteria. This equipment must be reevaluated to provide adequate ventilation to the spaces it serves. This can be done by directly connecting the main outdoor air duct to the fan coil unit.

ASHRAE 90.1 COMPLIANCE

The next section studies the museum's compliance with the ASHRAE Energy standard. The analysis will focus on the building envelope, HVAC systems, service water heating, power, lighting and electric motor efficiency. Elements that do not meet the standard will be outlined specifically and alternate solutions will be discussed. Elements that exceed compliance will be called out as well. Specifically, the tradeoff for having the more efficient component and how it affects the other building systems.

SECTION 5: BUILDING ENVELOPE

5.1 GENERAL

5.1.2 SPACE CONDITIONING CATEGORIES

The National Law Enforcement Museum is categorized as a nonresidential conditioned space. The building design should follow all standards that reference this space type.

5.1.4 CLIMATE

From referencing Figure B1-1 in ASHRAE Standard 90.1, the climate zone for Washington, DC, is Zone 4A. This means that the climate is has mixed-humid conditions, less than 4500 cooling degree days and between 3600 and 5400 heating degree days. The image from the ASHRAE Standard is found in Figure 1. This area

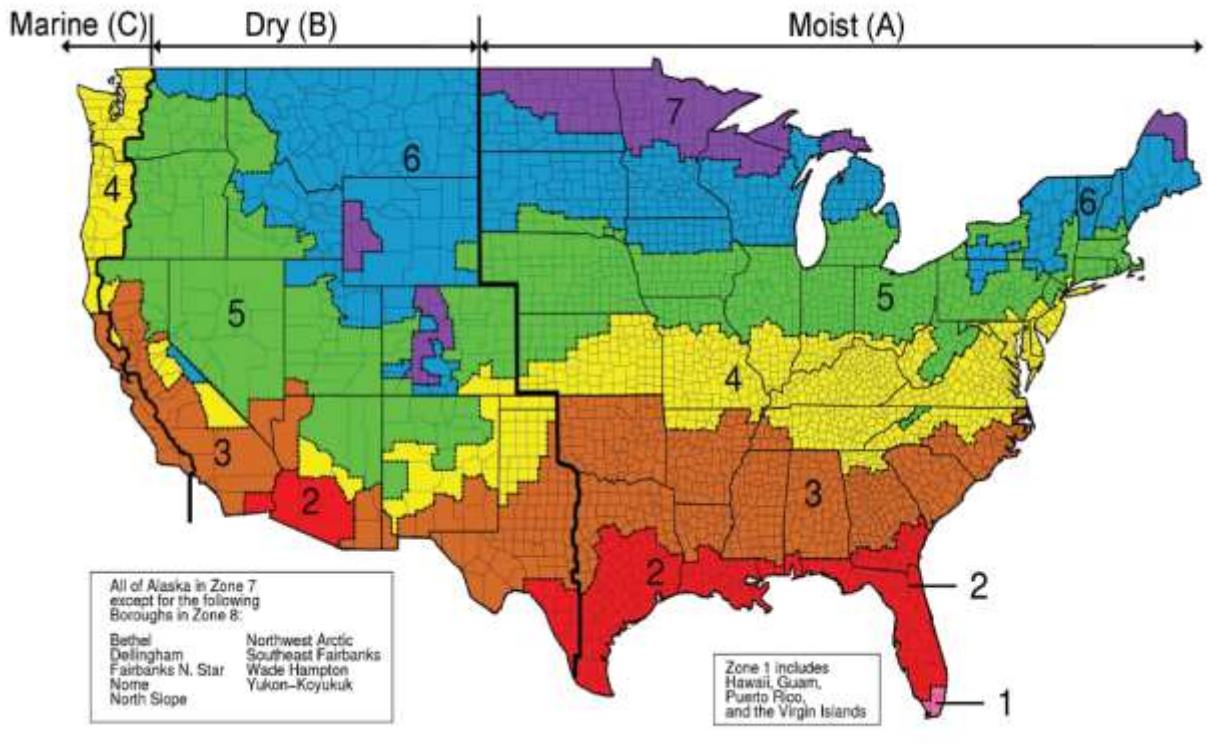

Figure 1 - US climate zone map from Appendix B of ASHRAE 90.1 2013, from ASHRAE 90.1, Figure B1-1

is hot and humid in the summer with mild spring and autumn. The winters are generally mild with some snowfall.

5.2 Compliance Path

Because of the excessive window to wall ratio caused by the glass pavilions, the compliance path to be followed to evaluate the energy compliance of the National Law Enforcement Museum is ASHRAE 90.1 Section 5.1 , 5.4, 5.7, and 5.8. Section 5.6 Building Envelope Trade-off option applies here as well and will be discussed later. The window to wall ratio calculation is shown in Table 2.

Table 2 - Window to wall ratio calculation

Window to Wall Ratio			
East Pavilion	Wall Area (SF)	Window Area (SF)	Window %
N	727	1092	60%
E	650	200	24%
S	536	1092	67%
W	200	350	64%
West Pavilion			
N	727	1092	60%
E	650	200	24%
S	536	1092	67%
W	94	1033	92%
SUM	**4120**	**6151**	**59.89%**

5.4 Mandatory Provisions

The majority of the utilized space in the museum is underground, therefore there is no major use of insulation. Some portion of the east and west pavilions utilize metal paneling for the exterior wall. This wall is utilized to prevent the passers-by from viewing the equipment in the mechanical room. An air barrier for the pavilions is provided by the quarter inch silicone sealant applied between the curtain wall panels and its bracing.

5.5 Prescriptive Building Envelope

The designed building envelope must meet the criteria of ASHRAE 90.1 Section 5.5 to meet minimum energy requirements. The structure is a museum with a theater and some office space, therefore, it must meet

nonresidential envelope requirements for Zone 4 as outlined in Table5.5-4 of ASHRAE 90.1. It is important to note that the building vertical fenestration exceeds the maximum 40% of the wall. The comparison table is shown in Table 3.

Table 3 - Building envelope construction comparison to ASHRAE 90.1

Building Envelope Construction				
	Description	**Actual U - Value**	**ASHRAE 90.1 U-value**	**Compliant?**
Roof	1 5/8" insulated glass panels with ceramic frit coating	0.29	0.037	**Yes**
Metal Panel	aluminum plate panel assembly	0.05	0.064	**No**
Curtain Wall	1 5/8" insulated glass panels with ceramic frit coating	0.29	0.42	**No**
SGHC		*0.37*	*0.40*	**Yes**
Below Grade Wall	1'-4" cast in place concrete	0.11	0.119	**No**
Slab	4'-8" cast in place concrete	0.15	0.057	**Yes**

5.5.4 Fenestration

Because the total vertical fenestration are is greater than the maximum amount specified in ASHRAE 90.1, the specified curtain wall must meet the criteria in exception 3 of Section 5.5.4.4.1 requiring that vertical fenestrations must have a solar heat gain coefficient no greater than what is outlined in Table 5.5-4 of the standard. As shown in Table 3Table 3, the SHGC is better in the specified fenestration type than the standard.

Section 6: Heating, Ventilating & Air Conditioning

6.2 Compliance Path

The total area of the museum exceeds the 25,000 SF cap for utilizing the Simplified Approach in Section 6.3. Therefore, Section 6.4 will be followed to determine equipment compliance to the standard.

6.4 Mandatory Provisions

To meet the requirements of this standard, all equipment in the building must meet the efficiency standard listed for their equipment type in ASHRAE 90.1 Tables 6.8.1.1-13. The structure's equipment and compliance are found in the Table 3.

The control system for the building HVAC is through a building automation system that can be managed by the facility managers. The sensors that supply input to the system are located in various location throughout the spaces and ductwork. These include temperature, carbon monoxide and oxygen sensors in

all spaces and humidity sensors located within the return ducts. The control of the system is separated by the various zone functions such as the theater, exhibit area, offices and plant room. The BAS system will also implement the special procedures required by the duct work in the cases of excessive smoke. Because of the nature of this structure, several doors will be opened and the VAVs will work in conjunction with the exhaust fans to remove the harmful air out of the building.

The indoor design temperature used in the design of the HVAC system for the museum was 75 degrees Fahrenheit. The winter design temperature is set for 70 degrees Fahrenheit. The high summer temperature allows for less use of energy to cool but also provides an opportunity for the use of electric heat to dehumidify during the humid summer. The humidity level that is required for the museum space is between 40 to 50% humidity.

Table 4 - Equipment efficiencies for units defined in ASHRAE 90.1 Section 6

Equipment Efficiencies				
Equipment	*Size*	*Specified Performance*	*Required Performance*	*Compliant?*
Air Handling Units				
AHU-1	5000 CFM	12.0 EER	12.1 EER	**Yes**
AHU-2	5000 CFM	12.0 EER	12.1 EER	**Yes**
AHU-3	33000 CFM	12.0 EER	12.1 EER	**Yes**
AHU-4	33000 CFM	12.0 EER	12.1 EER	**Yes**
AHU-5	4000 CFM	12.0 EER	12.1 EER	**Yes**
AHU-6	4000 CFM	12.0 EER	12.1 EER	**Yes**
Modular Chiller				
CH-1 (4)	225 tons	0.598 IPLV	0.580 IPLV	**No**
Electric Heater				
CUH-1			No criteria	
EUH-2			No criteria	
Fan Coil Units				
FCU-1	61.95 MBH	12.0 EER	10.0 EER	**Yes**
FCU-2	21.86 MBH	12.0 EER	10.0 EER	**Yes**
FCU-3	12.16 MBH	12.0 EER	10.0 EER	**Yes**
FCU-4	42.49 MBH	12.0 EER	10.0 EER	**Yes**
FCU-5	71.72 MBH	12.0 EER	10.0 EER	**Yes**
FCU-6	71.72 MBH	12.0 EER	10.0 EER	**Yes**
FCU-7	9.77 MBH	12.0 EER	10.0 EER	**Yes**
FCU-8	74.75 MBH	12.0 EER	10.0 EER	**Yes**
FCU-9	7.16 MBH	12.0 EER	10.0 EER	**Yes**
FCU-10	23.36 MBH	12.0 EER	10.0 EER	**Yes**
FCU-11	12.15 MBH	12.0 EER	10.0 EER	**Yes**
FCU-12	8.26 MBH	12.0 EER	10.0 EER	**Yes**
FCU-13	25.18 MBH	12.0 EER	10.0 EER	**Yes**
FCU-14	18.70 MBH	12.0 EER	10.0 EER	**Yes**
FCU-15	18.70 MBH	12.0 EER	10.0 EER	**Yes**

6.5 Prescriptive Path

To aid in the control of energy consumption by the HVAC systems, a water-side economizer is used during the free cooling period. This allows the economizer to carry all of the load as required by Section 6.5.1.2.1. Further control of the system is provided with the use of high efficiency electric motors and light fixtures, Low U-value shading coefficients for skylights, above & below grade walls, direct digital controls and lighting controls. Variable frequency drives will modulate various equipment such as the cooling tower fans, fan motors and air handling units. A two-way control valve modulates the chilled and hot water coils and a chilled water reset reduces energy consumption during the part-load operating times.

Humidity is controlled with electric steam-generation units for the theater and exhibit hall spaces. Dehumidification occurs at the air handling units with the use of electric heaters. Various other controlling elements include the variable frequency drives at the AHUs and the variety of sensors placed throughout the system that input to the direct digital building automation system. The use of heat recovery from the air that gathers at the upper part of the atrium and free cooling with the heat exchanger provide further contingencies for energy management. All major motors, including those of the chiller and air handling units, function with variable frequency drives so they do not operate at the same rate continuously. This reduces the overall amount of energy required to run the building and extends the life of the equipment by not working at full capacity.

Fan system power and efficiency must meet the criteria in place for ASHRAE 90.1 Section 6.5.3.1. The relationship between the fan's volumetric flow and horsepower is limited. Using the nameplate horsepower, Table 5 analyzes this with adjustments for particulate filters, exhaust filters and sound attenuation sections. As shown, all fans used in the National Law Enforcement Museum meet the power limitation standard.

Section 7: Service Water Heating

Service water heating for the museum is supplied using commercial, storage electric water heaters. These four units are located East and West on the Ticket Level and Exhibit Level. The efficiency of the water heaters must meet or exceed those specified in Table 7.8 of ASHRAE 90.1 Standard. The basis of design for this system were AO Smith Models DSE-40 to 65. These models exceed the Energy Factor minimum performance.

All pipes for supplying service hot water are specified to have 1 inch of insulation. The controls for the heaters are located at the units and can be connected to the building automation system as required. This can control temperature, heating cycle, and economy operations. The piping system for the service water is organized to contain all required heat traps, relief valves, drain pans, and check valves.

Section 8: Power

The basis of the electrical power design of the National Law Enforcement Museum followed the International Building Code 2006 and National Electrical Code 2005. The design also aided in the building design goal of achieving LEED Silver Certification.

Table 5 - Fan power limitations

Fan Power Limitation Check						
Fans	**Type**	**HP**	**CFM**	**CFM*0.00094**	**Exhaust flow control adjustment**	**Compliant?**
EF-1	Generator Room	0.25	1000	0.94		Yes
GEF-1	General Exhaust	3	5000	4.7		Yes
RAF-1	AHU-5 Relief Fan	3	5000	4.7		Yes
SEF-1	Smoke Exhaust	25	40000	37.6		Yes
SEF-2	Smoke Exhaust	25	40000	37.6		Yes
SEF-3	Smoke Exhaust	25	40000	37.6		Yes
SEF-4	Smoke Exhaust	15	20000	18.8		Yes
SEF-5	Smoke Exhaust	5	5000	4.7		No
SEF-6	Smoke Exhaust	3	5000	4.7		Yes
SEF-7	Smoke Exhaust	3	5000	4.7		Yes
SPF-1	Stair Pressurization	2	4000	3.76		Yes
SPF-2	Stair Pressurization	2	4000	3.76	0.5	Yes
SPF-3	Stair Pressurization	1.5	4000	3.76	0.5	Yes
SPF-4	Stair Pressurization	1.5	4000	3.76	0.5	Yes
TEF-1	Toilet Exhaust	1.5	4020	3.7788		Yes
TEF-2	Toilet Exhaust	0.25	400	0.376		Yes

Electricity is supplied to the museum from PEPCO, the local utility provider, via two 13.2 kilovolt feeders connecting to a 15 kilovolt switchgear with a 1200 amp circuit breaker. This is then connected to two 15000 kilovolt-amp dry type transformers to distribute power to the rest of the space. All equipment for power distribution will be located in the Central Plant level, the third floor below grade, at a PEPCO substation.

Electrical distribution to the building is separated into four components: Lighting, Power, HVAC and Life Safety. Distribution to the lighting systems are 480/277 V with each major room having its own switch so that changing exhibits can be isolated. Power distribution utilizes 208/120 V and has its own transformer. HVAC loads are supplied separately and also subdivided into motors, VAVs, snow melting system and air handling units. Finally, the life safety system is supplied via a 450 kilowatt generator on the ticketing level. This will supply such components as egress lighting, smoke control systems, fire pumps, and elevator loads.

Section 9: Lighting

Spaces: interior, exterior, grounds lighting; Lighting power densities for spaces; 9.2 compliance path (space by space or building area); lighting control; 9.4.1.3 Special application – display/accent lighting

9.2 Compliance Path

The lighting power density for the museum was likely found using the Building Area Method. The building area types include museum, motion picture theater, office, retail and dining.

9.4 Mandatory Provisions

All spaces within the structure utilize vacancy and occupancy sensors to manage the lighting. The lighting schedule is also paired with the building automation system's schedule in order to have tighter control over the building processes. Daylighting controls are also utilized because of the abundant light available from the glass pavilions.

9.5 Building Area Method Compliance Path

The interior lighting power allowance is shown in Table 6. Reference information is taken from ASHRAE90.1 Table 9.5.1. The exact number of fixtures within the museum is unknown, but the estimated total wattage is at 28,000 watts. This is likely because many of the lighting elements are LED. The LPD calculation is shown in Table 6.

Table 6 - Lighting power allowance based on ASHRAE 90.1 Table 9.5.1

Lighting Power Density			
Area Type	**Square Footage**	**LPD - W/ft^2 [ASHRAE 90.1 Table 9.5.1]**	**Interior Lighting Power Allowance [W]**
Museum	23130	1.02	23593
Motion Picture Theater	2750	0.76	2090
Office	5550	0.82	4551
Retail	1350	1.26	1701
Dining: Café	900	0.9	810
TOTAL			**32745**

Section 10: Other Equipment

10.2 Compliance Paths

Sections 10.4 Mandatory Provisions and 10.8 Product Information must be evaluated for this project.

10.4 Mandatory Provisions

All electric motors with power ratings greater than 1 horsepower must comply with the energy requirements outlined in Table 10.8-1 to 10.8-6.

10.4.1 Electric Motors

All motors for HVAC and plumbing within the National Law Enforcement Museum meet energy efficiency requirements as specified by NEMA MG 1. This follows that all motors meet ASHRAE 90.1 criteria as well.

Summary of Compliance: ASHRAE 90.1

Most components of the building achieve the standards of ASHRAE 90.1 except for some efficiency ratings in equipment and the building envelope.

Non-Compliant Systems

Chiller and fan power efficiency are below the required energy efficiency standard. This may be modified by selecting a more efficient modular chiller to meet the needs of the space. The non-compliant fans are smoke exhaust fans and their specifications do not necessarily have to be modified because they are only active on an as-needed basis.

The U-values of the building envelope are fare below par. Particularly the roof and metal panels. In defense, the metal panels are only located on the exterior walls of the mechanical room and not a common space. This may not require change. However, a full energy model must be executed to determine the total negative impact of these materials.

Over-Compliant Systems

The profuse use of LEDs reduces the total light power density of the museum. However, a first cost and life-cycle cost analysis may reveal that the payback period of such devices may not be as effective to the owner as initially surmised.

APPENDIX A –

I. WINDOW TO WALL RATIO TABLE
II. BUILDING ENVELOPE CONSTRUCTION TABLE
III. EQUIPMENT EFFICIENCIES TABLE
IV. FAN POWER LIMITATION CHECK TABLE
V. PLUMBING EQUIPMENT EFFICIENCIES TABLE
VI. LIGHTING POWER DENSITY CALCULATION TABLE
VII. VENTILATION CALCULATION TABLE & SYSTEM SUMMARY TABLE

I. WINDOW TO WALL RATIO TABLE

Window to Wall Ratio			
East Pavillion	Wall Area	Window Area	Window %
N	727	1092	60%
E	650	200	24%
S	536	1092	67%
W	200	350	64%
West Pavillion			
N	727	1092	60%
E	650	200	24%
S	536	1092	67%
W	94	1033	92%
SUM	**4120**	**6151**	**59.89%**

Total Building SF 54000

II. BUILDING ENVELOPE CONSTRUCTION TABLE

Building Envelope Construction				
	Decripion	**Actual U -Value**	**ASHRAE 90.1 U-value**	**Compliant?**
Roof	1 5/8" insulated glass panels with ceramic frit coating	0.29	0.037	Yes
Metal Panel	aluminum plate panel assembly	0.05	0.064	No
Curtain Wall	1 5/8" insulated glass panels with ceramic frit coating	0.29	0.42	No
Below Grade Wall	1'-4" cast in place concrete	0.11	0.119	No
Slab	4'-8" cast in place concrete	0.15	0.057	Yes

III. EQUIPMENT EFFICIENCIES TABLE

Equipment Efficiencies				
Equipment	Size	Specified Performance	Required Performance	Compliant?
Air Handling Units				
AHU-1	5000 CFM	12.0 EER	12.1 EER	Yes
AHU-2	5000 CFM	12.0 EER	12.1 EER	Yes
AHU-3	33000 CFM	12.0 EER	12.1 EER	Yes
AHU-4	33000 CFM	12.0 EER	12.1 EER	Yes
AHU-5	4000 CFM	12.0 EER	12.1 EER	Yes
AHU-6	4000 CFM	12.0 EER	12.1 EER	Yes
Modular Chiller				
CH-1	225 tons	0.598 IPLV	0.580 IPLV	No
Cooling Tower				
CT-1	152 tons		10.0 EER	
CT-2	152 tons		10.0 EER	
Heat Exchanger				
HX-1			No criteria	
Electric Heater				
CUH-1			No criteria	
EUH-2			No criteria	
Fan Coil Units	**Table 6.4.1-4**			
FCU-1	61.95 MBH	12.0 EER	10.0 EER	Yes
FCU-2	21.86 MBH	12.0 EER	10.0 EER	Yes
FCU-3	12.16 MBH	12.0 EER	10.0 EER	Yes
FCU-4	42.49 MBH	12.0 EER	10.0 EER	Yes
FCU-5	71.72 MBH	12.0 EER	10.0 EER	Yes
FCU-6	71.72 MBH	12.0 EER	10.0 EER	Yes
FCU-7	9.77 MBH	12.0 EER	10.0 EER	Yes
FCU-8	74.75 MBH	12.0 EER	10.0 EER	Yes
FCU-9	7.16 MBH	12.0 EER	10.0 EER	Yes
FCU-10	23.36 MBH	12.0 EER	10.0 EER	Yes
FCU-11	12.15 MBH	12.0 EER	10.0 EER	Yes
FCU-12	8.26 MBH	12.0 EER	10.0 EER	Yes
FCU-13	25.18 MBH	12.0 EER	10.0 EER	Yes
FCU-14	18.70 MBH	12.0 EER	10.0 EER	Yes
FCU-15	18.70 MBH	12.0 EER	10.0 EER	Yes

IV. FAN POWER LIMITATION CHECK TABLE

Fan Power Limitation Check						
Fans	**Type**	**HP**	**CFM**	**CFM*0.00094**	***Exhaust flow control adjustment***	**Compliant?**
EF-1	Generator Room	0.25	1000	0.94		Yes
GEF-1	General Exhaust	3	5000	4.7		Yes
RAF-1	AHU-5 Relief Fan	3	5000	4.7		Yes
SEF-1	Smoke Exhaust	25	40000	37.6		Yes
SEF-2		25	40000	37.6		Yes
SEF-3		25	40000	37.6		Yes
SEF-4		15	20000	18.8		Yes
SEF-5		5	5000	4.7		No
SEF-6		3	5000	4.7		Yes
SEF-7		3	5000	4.7		Yes
SPF-1	Stair Pressurization	2	4000	3.76		Yes
SPF-2		2	4000	3.76	0.5	Yes
SPF-3		1.5	4000	3.76	0.5	Yes
SPF-4		1.5	4000	3.76	0.5	Yes
TEF-1	Toilet Exhaust	1.5	4020	3.7788		Yes
TEF-2		0.25	400	0.376		Yes

V. PLUMBING EQUIPMENT EFFICIENCIES TABLE

Plumbing Equipment Efficiencies

	Capacity	Kilowatts	Energy Factor	Required Performance [.97-.00035V]	Compliant?
Electric Hot Water Heater #1	65 Gallon Tank	12	0.88	0.0220675	Yes
Electric Hot Water Heater #2	65 Gallon Tank	12	0.88	0.0220675	Yes
Electric Hot Water Heater #3	40 Gallon Tank	9	0.92	0.01358	Yes
Electric Hot Water Heater #4	50 Gallong Tank	9	0.91	0.016975	Yes

VI. LIGHTING POWER DENSITY CALCULATION TABLE

Lighting Power Density			
Area Type	Square Footage	LPD - W/ft2 [ASHRAE 90.1 Table 9.5.1]	Interior Lighting Power Allowance [W]
Museum	23130	1.02	23593
Motion Picture Theater	2750	0.76	2090
Office	5550	0.82	4551
Retail	1350	1.26	1701
Dining: Café	900	0.9	810
TOTAL			32745

VII. VENTILATION CALCULATION TABLE & SYSTEM SUMMARY TABLE

See following pages.