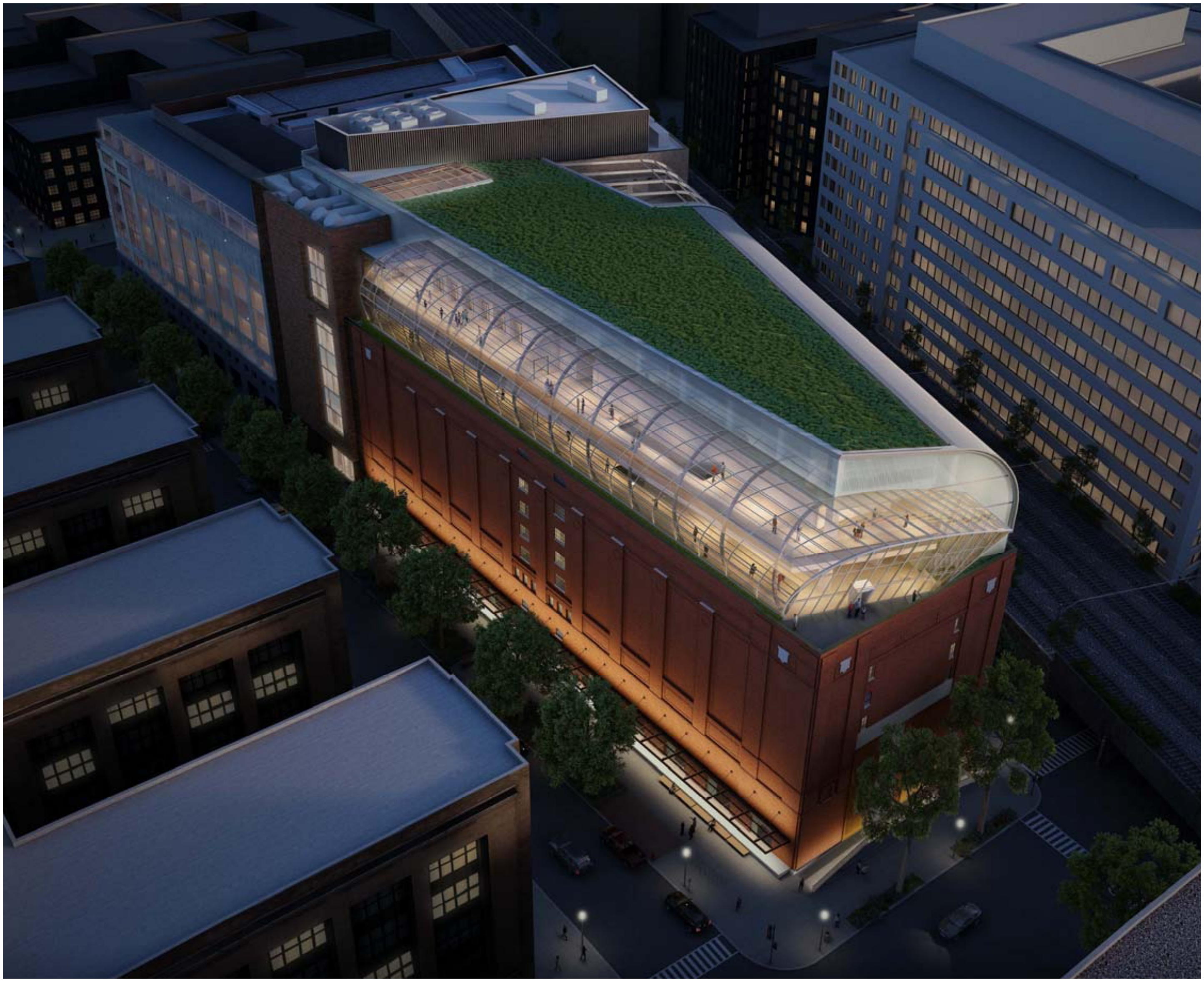
THE MUSEUM OF THE BIBLE

Washington, DC



TECHNICAL REPORT TWO

Paige Donnell
L/E Option
Advisors - Richard Mistrick + Gary Golaszewski

EXECUTIVE SUMMARY:

This report focuses on an analysis that was performed to compare the existing electrical systems with the proposed design criteria for the Museum of the Bible, located in Washington DC. The first part of this report evaluates the required criteria for the electrical systems in this building including power distribution, occupancy criteria, material specifications and emergency power. This criteria was developed in accordance with the standards defined by ASHRAE, NEC and IBC. Load calculations were performed in order to evaluate the differences in the estimated and actual building loads based on occupancy and equipment types. The actual load of the building was determined to be 8,680 kVA which was very different then the original estimated value.

In summary, the building performs a bit differently then expected. It utilizes a voltage of 480/277V, 3 PH, 4W which feeds from a secondary service, provided by Pepco distribution company, to several different panelboards on multiple levels. This power is distributed into separate risers which provide each floor with a 480/277V and a 208/120V power option, which are tapped into by bus-ducts where needed. Additional transformers assist in the step-down process of the voltage when necessary. Tele-communication systems, audio/visual equipment, and security are a huge component of this building, therefore they have been backed up heavily to allow for secure and reliable protection and overall function of the building. Regarding wiring techniques, copper is the most widely used material option. A reliable emergency power system, supported by eight generators on the penthouse level, is designed to allow for sufficient functionality of the building in the case of an emergency or power shut down. Overall, this building relies on an extremely complex electrical system which will be further assessed for means of improvement in a later analysis.

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BUILDING OVERVIEW:

The Museum of the Bible (MOTB) is a non-sectarian museum focusing on the history and impact of the Bible with a core collection compilation of more than 40,000 biblical antiquities and rare biblical texts and artifacts. The Museum has several uses which include exhibit space, library resources, meeting spaces and guest rooms for visiting scholars, space for certain affiliated museums and their exhibits, and ground floor accessory retail uses, such as a gift shop and café or food service establishment. The MOTB will also be a center of study for the Green Scholars Initiative, where established scholars and students will conduct research to pioneer new biblical and classical discoveries on items from the collection.

The Washington Design Center (WDC) originally was an eight-story 241, 073,000 SF brick and concrete building, designed in the Renaissance Revival style, and built for the Terminal Refrigerating and Warehousing Company in 1922. In 1982, the original building was renovated to house the WDC, which included the construction of an addition to the east. The Washington Design Office Center -Phase II (WOC) was later added in 1989 to complete the block.

The new construction of MOTB includes a demolition of the 1982 addition, adding six stories above the original footprint. This addition includes over 430,000,000 square feet of construction, including three stories below grade, to accommodate rotating exhibit gallery collections, storage, and a lower level central plant. The exterior aesthetics honor the historic characteristics of the building, and a curved glass roof will be added to allow daylight exposure as well as beautiful views of central D.C. as well as the capital building.

GENERAL FACTS:

Building Name | Museum of the Bible (MOTB)

Location and Site | Washington, D.C.; property name known as Washington Design Center (WDC)

Building Occupant Name | Museum of the Bible

Occupancy or Function Types (type of building) | Museum

Size (total square feet) | 430,000 SF

Number of Stories | 6 stories above grade; 9 total levels

Primary Project Team | Museum of the Bible - http://www.museumofthebible.org/

SmithGroupJJR - http://www.smithgroupjjr.com/

Tadjer Cohen Edelson Associates Inc. - http://www.tadjerco.com/

RK&K - http://www.rkk.com/

Michael Vergason - http://www.vergason.net/

Fluidity Fountain - http://www.fluidity-design.com/

Theatre Consultants Collaborative, Inc. - http://theatrecc.net/non_flash/

Dates of Construction | Feb 2015 – Fall 2017

Actual Cost Information | Contract Value: $237 million

Project Delivery Method | Design – Bid – Build

PART 1: ELECTRICAL CRITERIA & SCOPE

Primary Load Calculation:

This preliminary electrical load calculation takes into account the different parameters of the building, including building type, lighting and receptacle loads, mechanical equipment loads, and any other special equipment needs. These numerical values are meant to represent a rough estimate of the overall electrical load required for the building based on its size and standard rates for the systems included within the building.

	Lighting	Receptacle	Mechanical	Special Equipment
Estimated Load (VA/sf)	1.5	3.0	7.0	2.0
Demand Factor	1.25	First 10kVA at 1; everything after at .5	1.0	1.0
Area (sf)	430,000	430,000	430,000	430,000
Allowable Load (VA)	806,250	650,000	3,010,000	860,000
Allowable Load (kVA)	806	650	3,010	860
Total Allowable Load (kVA)				**5,326**

Figure 1: Estimated Load Calculation

Power Company:

Pepco, a subsidiary of Pepco Holdings, Inc. (PHI), is an electrical distribution service that delivers safe, reliable electric supply to more than 815,000 customers throughout Maryland and the District of Columbia.

Preliminary Utility Rate:

The following information represents the expected service for the building function and size. An exert from the company's rate schedule has been provided for a detailed outline of monthly cost information.

Building Category: Large Commercial

Assumed Service: General Service Primary Service , "GS - 3A"

pepco

A PHI Company

DISTRICT OF COLUMBIA
GENERAL SERVICE PRIMARY SERVICE
SCHEDULE GS 3A
UPDATED MARCH 1, 2015

	Billing Months of June – October 2014 (Summer)	Billing Months of November 2014 – May 2015 (Winter)	Billing Months of June – October 2015 (Summer)	Billing Months of November 2015 – May 2016 (Winter)
Generation [1]				
First 6,000 kwh	$ 0.06410 per kwh	$ 0.06410 per kwh	$ 0.07913 per kwh	$ 0.08500 per kwh
Additional kwh	$ 0.06410 per kwh	$ 0.06410 per kwh	$ 0.07913 per kwh	$ 0.08500 per kwh
Admin Charge *	$ 0.00500 per kwh	$ 0.00500 per kwh	$ 0.00500 per kwh	$ 0.00500 per kwh
First 25 kw	No Charge	No Charge		
Additional kw	$ 0.03218 per kw	$ 0.03218 per kw		

Procurement Cost Adjustment http://www.pepco.com/_res/documents/dc_pca.pdf **for monthly rate**

	Billing Months of June – October (Summer)	Billing Months of November – May (Winter)
Transmission[2]		
All kwh	$ 0.00485 per kwh	$ 0.00485 per kwh
Distribution[3]		
Customer Charge	$ 209.04 per month	$ 209.04 per month
All kwh	$ 0.01317 per kwh	$ 0.00993 per kwh
All kw	$ 6.46 per kw	$ 6.46 per kw
Delivery Tax[4]	$ 0.0077 per kwh	$ 0.0077 per kwh
Public Space Occupancy Surcharge[5]	$ 0.00204 per kwh	$ 0.00204 per kwh
Administrative Credit	http://www.pepco.com/_res/documents/dc_admin-charge.pdf **for monthly rate**	
Sustainable Energy Trust Fund[6]	$ 0.00150 per kwh	$ 0.00150 per kwh
Energy Assistance Trust Fund[7]	$ 0.0000607 per kwh	$ 0.0000607 per kwh
RADS Surcharge[8]	$ 0.000294 per kwh	$ 0.000294 per kwh
Bill Stabilization Adjustment[9]	http://www.pepco.com/_res/documents/dc_BSA.pdf **for monthly rate**	
Underground Project Charge[10]	$ 0.00 per kwh	$ 0.00 per kwh

Figure 2: Pepco Service Utility Rate

Building Utilization Voltage:

The building is expected to run on a utilization voltage of 480/277V, 3PH to accommodate the larger mechanical systems found throughout the building that will run at 480V. Transformers will be used to accommodate smaller voltages, such as lighting and receptacle voltages which are expected to run at 120V.

Emergency Power Requirements:

In accordance with the International Building Code (IBC) 2012, Section 2702 Emergency and Standby Power Systems, the following considerations are required. The information provided below has been taken directly from the IBC code. All emergency and standby systems are required to be maintained in accordance with the *International Fire Code.*

> **2702.1.1 Stationary generators.** Stationary emergency and standby power generators required by this code shall be *listed* in accordance with UL 2200.
>
> **2702.2.1 Group A occupancies.** Emergency Power shall be provided for emergency voice/alarm communication systems in Group A occupancies in accordance with *Section 907.5.2.2.4.*
>
> > **907.5.2.2.4 Emergency voice/alarm communication captions.** Where stadiums, arenas and grand stands are required to caption audible public announcements in accordance with *Section 1108.2.7.2,* the emergency/voice alarm communication system shall also be captioned. Prerecorded or live emergency captions shall be from an *approved* location constantly attended by personnel trained to respond to an emergency.
>
> **2702.2.2 Smoke control systems.** Standby power shall be provided for smoke control systems in accordance with *Section 909.11.*

909.11 Power systems. The smoke control system shall be supplied with two sources of power. Primary power shall be from the normal building power systems. Secondary power shall be from an *approved* standby source complying with Chapter 27 of this code. The standby power source and its transfer switches shall be in a room separate from the normal power transformers and switch gears and ventilated directly to and from the exterior. The room shall be enclosed with not less than 1-hour *fire barriers* constructed in accordance with Section 707 or *horizontal assemblies* constructed in accordance with Section 711, or both. The transfer to full standby power shall be automatic and within 60 seconds of failure of the primary power.

2702.2.3 Exit signs. Emergency power shall be provided for *exit* signs in accordance with *Section 1011.6.3.*

1011.6.3 Power source. Exit signs shall be illuminated at all times. To ensure continued illumination for a duration of not less than 90 minutes in case of primary power loss, the sign illumination means shall be connected to an emergency power system provided from storage batteries, unit equipment or an on-site generator. The installation of the emergency power system shall be in accordance with Chapter 27.

2702.2.4 Means of egress illumination. Emergency power shall be provided for *means of egress* illumination in accordance with *Section 1006.3.*

1006.3 Emergency power for illumination. The power supply for *means of egress* illumination shall normally be provided by the premises' electrical supply. In the event of power supply failure, an emergency electrical system shall automatically illuminate all of the following areas:

1. *Aisles* and unenclosed egress stairways in rooms and spaces that require two or more *means of egress*.

2. *Corridors*, *interior exit stairways* and *ramps* and *exit passageways* in buildings required to have two or more *exits*.

3. Exterior egress components at other than their levels of *exit discharge* until *exit discharge* is accomplished for buildings required to have two or more *exits*.

4. Interior *exit discharge* elements, as permitted in Section 1027.1, in buildings required to have two or more *exits*.

5. Exterior landings as required by Section 1008.1.6 for *exit discharge* doorways in buildings required to have two or more *exits*.

The emergency power system shall provide power for a duration of not less than 90 minutes and shall consist of storage batteries, unit equipment or an on-site generator. The installation of emergency power system shall be in accordance with Section 2702.

2702.2.5 Accessible means of egress elevators. Standby power shall be provided for elevators that are part of an *accessible means of egress* in accordance with Section 1007.4.

1007.4 Elevators. In order to be considered part of an accessible means of egress, an elevator shall comply with emergency operation and signaling device requirements of Section 2.27 of ASME A17.1. Standby power shall be provided in accordance with Chapter 27 and Section 3003. The elevator shall be accessed from either an area of refuge complying with Section 1007.6 or a horizontal exit.

2702.2.15 High-rise buildings. Emergency and standby power shall be provided in high-rise buildings in accordance with *Sections 403.4.8* and *403.4.9.*

403.4.8 Standby power. A standby power system complying with Chapter 27 and Section 3003 shall be provided for standby power loads specified in 403.4.8.2. Where elevators are provided in a *high-rise building* for *accessible means of egress*, fire service access or occupant self-evacuation, the standby power system shall also comply with Sections 1007.4, 3007 or 3008, as applicable.

403.4.9 Emergency power systems. An emergency power system complying with Chapter 27 shall be provided for emergency power loads specified in Section 403.4.9.1.

2702.2.19 Elevators. Standby power for elevators shall be provided as set forth in *Sections 3003.1, 3007.9 and 3008.9.*

3003.1 Standby power. In buildings and structures where standby power is required or furnished to operate an elevator, the operation shall be in accordance with Sections 3003.1.1 through 3003.1.4.

3007.9 Electrical power. The following features serving each fire service access elevator shall be supplied by both normal power and Type 60/Class 2/Level 1 standby power:

1. Elevator equipment.
2. Elevator hoistway lighting.
3. Elevator machine room *ventilation* and cooling equipment.
4. Elevator controller cooling equipment.

3008.9 Electrical power. The following features serving each occupant evacuation elevator shall be supplied by both normal power and Type 60/Class 2/Level 1 standby power:

1. Elevator equipment.
2. Elevator machine room *ventilation* and cooling equipment.
3. Elevator controller cooling equipment.

2702.2.20 Smoke-proof enclosures. Standby power shall be provided for smoke-proof enclosures as required by *Section 909.20.6.2.*

909.20.6.2 Standby power. Mechanical vestibule and *stair* shaft ventilation systems and automatic fire detection systems shall be powered by an *approved* standby power system conforming to Section 403.4.8 and Chapter 27.

Special Occupancy Requirements:

In accordance with NEC 2012 Chapter 5, the following special occupancy requirements will be taken into consideration throughout the process of design.

Article 518: Assembly Occupancies. This article relates to the special considerations in overcurrent protection, wiring, and other electrical features in portions of a building intending for the gathering of 100 or more persons for the purpose of deliberation, worship, entertainment, eating, amusement, etc. Some of the specific spaces in the Museum of the Bible that fall under this category include auditoriums, dining and drinking facilities, exhibition halls, and other museum related spaces. For additional information, consult pages 70-458 to 70-459.

Article 520: Theatres and Similar Locations. This article relates to the special considerations in overcurrent protection, wiring, and other electrical features in portions of a building intending for presentation, dramatic expression, musical performances and related spaces that require audience seating areas. The specific space in the Museum of the Bible that falls under this category is the performance hall. For additional information, consult pages 70-459 to 70-468.

Priority Assessment:

The following variables to design were considered for priority assessment in regards to their importance to the project in relation to building type and use.

Priority	Variables	Reasoning
HIGH	Reliability Flexibility Power Quality	These parameters are important because they relate to the overall function and security of the building. The museum relies heavily on visual attractions, and needs the ability to transform spaces when required for future exhibits.
MEDIUM	Redundancy Low Life Cycle Cost	Back-up or failure systems are important to allow occupants to safely exit the facility in the case of an emergency. Being a large building requiring a lot of power, it is important to design for sustainable systems to decrease functional costs.
LOW	Low First Cost	While cost is always a concern in buildings this large, funds are available to create an interesting experience while investing in a sustainable future.

Optional Back-Up Power:

The addition of an uninterruptable back-up power system is necessary to keep the building in commission during a power failure. Loads that assist in lighting egress paths as well as security systems are important to occupant safety and protection of the sacred artifacts held within the building.

Special Equipment & Communication Systems:

The following list represents special low-voltage systems that should be implemented in order to provide safety and communication throughout the entire building.

Telephone / Data

Video Surveillance & CCTV

Access Control

Audio / Visual Display Systems

Fire Alarm Systems (outlined below)

According to the 2012 IBC Section 907 Fire Alarm and Detection Systems:

907.2 Where Required - new buildings and structures. An approved fire alarm system installed in accordance with the provisions of this code and NFPA 72 shall be provided in new buildings and structures in accordance with Sections 907.2.1 through 907.2.23 and provide occupant notification in accordance with Section 907.5, unless other requirements are provided by another section of this code. A minimum of one manual fire alarm box shall be provided in an approved location to initiate a fire alarm signal for fire alarm systems employing automatic fire detectors or water flow detection devices. Where other sections of this code allow elimination of fire alarm boxes due to sprinklers, a single fire alarm box shall be installed.

907.2.1 Group A. A manual fire alarm system that activates the occupant notification system in accordance with Section 907.5 shall be installed in Group A occupancies having an occupant load of 300 or more. Manual fire alarm boxes are not required where the building is equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1 and the occupant notification appliances will activate throughout the notification zones upon sprinkler water flow.

Exception: Where approved, the prerecorded announcement is allowed to be manually deactivated for a period of time, not to exceed 3 minutes, for the sole purpose of allowing a live voice announcement from an approved, constantly attended location.

907.2.2 Group B. A manual fire alarm system shall be installed in Group B occupancies where one of the following conditions exists:

1. The combined Group B occupant load of all floors is 500 or more.
2. The Group B occupant load is more than 100 persons above or below the lowest level of exit discharge.
3. The fire area contains an ambulatory care facility.

Exception: Manual fire alarm boxes are not required where the building is equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1 and the occupant notification appliances will activate throughout the notification zones upon sprinkler water flow.

907.2.14 Atriums connecting more than two stories. A fire alarm system shall be installed in occupancies with an atrium that connects more than two stories, with smoke detection installed throughout the atrium. The system shall be activated in accordance with Section 907.5. Such occupancies in Group A, E or M shall be provided with an emergency voice/alarm communication system complying with the requirements of Section 907.5.2.2.

907.3 Fire safety functions Automatic fire detectors utilized for the purpose of performing fire safety functions shall be connected to the building's fire alarm control unit where a fire alarm system is required by Section 907.2. Detectors shall, upon actuation, perform the intended function and activate the alarm notification appliances or activate a visible and audible supervisory signal at a constantly attended location. In buildings not equipped with a fire alarm system, the automatic fire detector shall be powered by normal electrical service and, upon actuation, perform the intended function. The detectors shall be located in accordance with NFPA 72.

907.5 Occupant notification systems. A fire alarm system shall annunciate at the fire alarm control unit and shall initiate occupant notification upon activation, in accordance with Sections 907.5.1 through 907.5.2.3.4. Where a fire alarm system is required by another section of this code, it shall be activated by:

1. Automatic fire detectors.
2. Automatic sprinkler system waterflow devices.
3. Manual fire alarm boxes.
4. Automatic fire-extinguishing systems.

Where notification systems are allowed elsewhere in Section 907 to annunciate at a constantly attended location.

Major Equipment Space Requirements:

Major electrical equipment in this building that will need a substantial amount of space reserved for it include emergency power generators, step-down transformers, electrical distribution panels and switchboards. When taking into consideration the building program and its usage, it can be assumed that about 5 - 8% of the building will be used for mechanical and electrical space. With this initial assumption, it is safe to estimate that about 2% of the building's square footage will be dedicated solely to electrical equipment. While this number appears to be low, when considering the massive size of the building in total it is a reasonable estimate. A breakdown of the calculated square footage is below.

Estimated % Floor Area: **2%**

Total Floor Area: **430,000 sf**

Therefore 430,000 * .02 = **8,600 sf**

It can be estimated that approximately 8,000 square feet will be dedicated to electrical equipment.

Additional systems that will be required for this building include the consideration of fire-rated walls and egress pathways. Due to the massive size and winding function of the museum, emergency egress should be taken into high consideration. An analysis will take place to access the ease of exit and the safety aspects of the building in relation to the electrical control systems.

PART 2: EXISTING ELECTRICAL SYSTEM

Primary Load Calculation:

The actual electrical building load calculation takes into account the different parameters of the building, including building type, lighting and receptacle loads, mechanical equipment loads, and any other special equipment needs. The total connected VA from each category is totaled at the bottom of the table. Colors on the left hand side of the table help to represent the differentiation in panelboard sheets on each floor.

	Panel	Lighting	Receptacle	Mechanical	Special Equipment	Power	Appliance
E7-4-1: WOCA	LP4OS			6892		200	
E7-4-2: WOCA P3,P2,P1	LP2OS			7000			
	HP2L	9088	18000	25283		70	
	LP2LS					1200	
E7-4-3: Level B2	HB2EQ			75580			
	HB2L	6667					
	LB2R		23040	293		70	
	LB2ER		16940	8991	200		1200
E7-4-5: Level B1 ER	SWBD-B1-1			1494379			
	SWBD-B1-2			2956577			
	SWBD-B1-3			1961833			
E7-4-6: Level B1 A	LB1KT		2160	8054	3816		81073
	LB1WR		3600	10053			
E7-4-7: Level B1 B	HB1L	16757					
	LB1R	1500	9640	1127			
	LB1ER		7980	1000		5600	
E7-4-8: Level B1 B	XB1L	28300	5220				
	XB1AV	2000	23170				
E7-4-11: Level 1 A	L1WAV		7200				
	L1WR	5040	10340	3312		15075	
	X1AV1		6000				
	X1AV2		5000				
E7-4-12: Level 1 B	X1AV3		18850				
	X1AV4					116640	
	L1ER		8820	6760		6100	
	H1L	25696					
	L1R	384	12800			635	
	H1EQ			42121			
E7-4-13: Level 1 B	X1AV5		22760				
	X1L1	11000	2160				
	X1L2	10500	1620				
	X1L3	720				14400	
E7-4-15: Level 1M	H1ML	5839		10000			
	L1MCS		3600				39449
	L1MR	2040	23300	3237		3200	

	Panel	Lighting	Receptacle	Mechanical	Special Equipment	Power	Appliance
E7-4-16: Level 2 A	X2WL	119925					
	X2WAV		25190			31845	
	L2WR		180				
E7-4-17: Level 2 B	HL2	12469					
	H2EQ			119231		18947	
	L2R	620	4680				
	X2EL	79397					
	L2ER		7800	2000		5600	
	X2EAV		7467			29724	
	X2ER		7200			23009	
E7-4-19: Level 3 A	H3WQ					98828	
	X3WL	57560	10560			34024	
	X3WAV	800	44400			20100	
	L3WR		1080			8736	
E7-4-20: Level 3 B	X3ER					52416	
	H3L	8668					
	H3EQ			124731			
	X3EAV		47400			15416	
	L3R	600	6660				
	X3EL	47097	16200			11560	
	L3ER		9240	2000		5600	
E7-4-22: Level 4 A	X4WAV		27831			577	
	X4WL	87149					
	L4WR		900				
E7-4-23: Level 4 B	H4L	11875					
	X4EAV		23793			3877	
	H4EQ			119231			
	L4R	500	5220				
	X4EL	73246					
	L4ER		7440	2000		5600	
E7-4-25: Level 5 A	L5WR		14420	1127			1200
	X5AV1		16920				
E7-4-26: Level 5 B	X5AV2		23200				
	X5AV3		15270				
	L5R	740	12740	3556		9800	
	H5L	8519					
E7-4-27: Level 5 B	X5EL1	38000	6120				
	X5EL2		9720				
	X5EL3		5940				
E7-4-29: Level 5M	H5MWQ			161607		3000	
	L5MR		2550	7627	9667	10167	
	H5ML	2400					

	Panel	Lighting	Receptacle	Mechanical	Special Equipment	Power	Appliance
E7-4-31: Level 6 B	H6L	9839					
	L6R	360	30260	16305		3600	
	H6DIM	10812					
	L6ER		19040	805		5600	
	L6EAV	2264					
E7-4-32: Level 6 Kitchen	L6KT		3240				81016
	L6EKT-1		3060	2367			82954
E7-4-34: Level 6M	H6MWQ			57065			
	L6MR		2860	5334		35	
	PTMPS	144				27000	
	PTDIM	46500					
	PTMBP	7849					
	L6MPTR		47610		1800		
E7-4-36: Penthouse	HPH		4140	58056		35	
	LPHR		4140	4657		35	
E7-4-39: Level 9 A	HA9	13637	130187	70043	100	1300	1200
E7-4-40: Level 9 B	HB9	11584	61400	51630		1200	1200
	EHB9	2526					
	ELB9		3340	1150		1900	
E7-4-41: Level 9 Existing	HA8			12665	42901		
	HB8			10930	46698		
	MCCR			759065			
Section Total		780611	901598	8215674	105182	592721	289292
Building Total (VA)	**10,885,078**						

	Lighting	Receptacle	Mechanical	Special Equipment	Power	Appliance
Total Calculated VA	780611	901598	8215674	105182	592721	289292
Demand Factor Used	1	First 10kVA at 1; everything after at .5	0.8	1	1	0.6
Total Demand (kVA)	781	456	6573	105	593	174
				Total kVA		**8,680**

Figure 3: Actual Connected Load

Power Company:

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Preliminary Utility Rate:

The following information represents the expected service for the building function and size. An exert from the company's rate schedule has been provided for a detailed outline of monthly cost information.

Building Category: Large Commercial

Assumed Service: General Service Low Voltage Service - Schedule "GS-LV" pepco

A PHI Company

DISTRICT OF COLUMBIA
GENERAL SERVICE LOW VOLTAGE
SCHEDULE GS – LV
UPDATED MARCH 1, 2015

	Billing Months of June – October 2014 (Summer)	Billing Months of November 2014 – May 2015 (Winter)	Billing Months of June – October 2015 (Summer)	Billing Months of November 2015 – May 2016 (Winter)
Generation [1]				
First 6,000 kwh	$ 0.06410 per kwh	$ 0.06410 per kwh	$ 0.07679 per kwh	$ 0.07900 per kwh
Additional kwh	$ 0.06410 per kwh	$ 0.06410 per kwh	$ 0.07679 per kwh	$ 0.07900 per kwh
Admin Charge *	$ 0.00500 per kwh	$ 0.00500 per kwh	$ 0.00500 per kwh	$ 0.00500 per kwh
First 25 kw	No charge	No charge		
Additional kw	$ 0.03218 per kw	$ 0.03218 per kw		

Procurement Cost Adjustment http://www.pepco.com/_res/documents/dc_pca.pdf **for monthly rate**

	Billing Months of June – October (Summer)	Billing Months of November – May (Winter)
Transmission [2]		
All kwh	$ 0.00563 per kwh	$ 0.00563 per kwh
Distribution [3]		
Customer Charge	$ 27.11 per month	$ 27.11 per month
All kwh	$ 0.04535 per kwh	$ 0.03602 per kwh
All kw	$ 4.53 per kw	$ 4.53 per kw
Delivery Tax [4]	$ 0.0077 per kwh	$ 0.0077 per kwh
Public Space Occupancy Surcharge [5]	$ 0.00204 per kwh	$ 0.00204 per kwh
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Energy Assistance Trust Fund [7]	$ 0.0000607 per kwh	$ 0.0000607 per kwh
RADS Surcharge [8]	$ 0.000294 per kwh	$ 0.000294 per kwh
Bill Stabilization Adjustment [9]	http://www.pepco.com/_res/documents/dc_BSA.pdf **for monthly rate**	
Underground Project Charge [10]	$ 0.00 per kwh	$ 0.00 per kwh

Figure 4: Pepco Service Utility Rate

Building Utilization Voltage:

The primary building utilization voltage of 480/277V 3PH, 4W. The power is distributed from the main electrical room which is located in the basement, at level B1. Being such a large building, there are two main voltages dispersed up the length of the building, one at 480/277V and the other at 208/120V. Bus-plugs tap into this power at each level and use transformers to step down the voltage as needed. A breakdown of the voltages for different functions of the building can be seen on the next page. These values represent common values but it should be noted that there exist exceptions in certain categories.

Lighting - 120 V

Receptacles - 120 V

Mechanical - 480 V (120 V and 208 V exceptions)

Special Equipment

Elevators - 480 V

Kitchen Appliances - 120 V and 208 V (480 V exceptions)

Emergency Power System:

The emergency power system is located on the penthouse level of the building and supplies a large generator in parallel with the normal switchboard. The system runs at 480/277 V, 6000 Amps. The 3 phase, 4 wire system runs 8 separate generators off natural gas at 400KW. These generators successfully disperse power throughout the building using an electrical riser shaft. The systems provides continuous electrical output power for standby operation of not less than 400 kW, at 80% lagging power factor, with a rated engine speed of 1800 rpm. The generators fuel system consists of a carburetor, fuel-shutoff solenoid valves and flexible fuel connectors that help to supply a heater voltage of 120V or 208 V, single phase. The system has an automatic starting system sequence of operation that allows for alarm function, heating and cooling, and data connection to still be available in a state of emergency. Additionally, the generators have adequate overcurrent and fault protection. A summary of the automatic transfer switch schedule and total connected load for the emergency system is located below.

AUTOMATIC TRANSFER SWITCH (ATS) SCHEDULE					
No.	DESIGNATION	AMPS	VOLTS	POLES	KAIC
1	ATS-P4OS	4000	480	4	65
2	ATS-P2OS	600	480	4	65
2	ATS-B1LS	1600	480	4	65
4	ATS-PHSE	2000	480	4	65
5	ATS-LS	600	480	4	65

Figure 5: Emergency Automatic Transfer Switch Schedule

Location	Panel	Lighting	Receptacle	Mechanical	Special Equipment	Power	Appliance
E7-4-37: Penthouse Emergency	SWBD-PHGEN	57464	72517	4733509		60880	8000

Connected Emergency Load (kVA)	4,932

Figure 6: Emergency Power Connected Load

Special Occupancy Requirements:

In accordance with NEC 2012 Chapter 5, the following special occupancy requirements were taken into consideration throughout the process of design.

Article 518: Assembly Occupancies. This article relates to the special considerations in overcurrent protection, wiring, and other electrical features in portions of a building intending for the gathering of 100 or more persons for the purpose of deliberation, worship, entertainment, eating, amusement, etc. Some of the specific spaces in the Museum of the Bible that fall under this category include auditoriums, dining and drinking facilities, exhibition halls, and other museum related spaces. For additional information, consult pages 70-458 to 70-459.

Article 520: Theatres and Similar Locations. This article relates to the special considerations in overcurrent protection, wiring, and other electrical features in portions of a building intending for presentation, dramatic expression, musical performances and related spaces that require audience seating areas. The specific space in the Museum of the Bible that falls under this category is the performance hall. For additional information, consult pages 70-459 to 70-468.

Special Equipment:

In accordance with NEC 2012 Chapter 6, the following special occupancy requirements were taken into consideration throughout the process of design.

Article 620 - Elevators.

Article 640 - Audio Signal Processing and Amplification.

Article 645 - Information Technology Equipment.

Article 695 - Fire Pumps.

Electrical System Equipment Ratings:

The following descriptions represent a summary of the power distribution equipment used and outlined in the drawings and specifications for this building.

Main Service

Utility power enters the building at the ground level from an existing vault below the sidewalk. This incoming secondary power is rated at 480Y/277 V, 4000 A and is protected by an MCB system. The power then disperses itself between 3 switchboards in the main electrical room . No primary transformers exist with this system because the building is directly receiving secondary power therefore no initial step-down is required.

Step Down Transformers

Several step-down transformers are located in designated electrical room on each level of the building. The transformers on each floor are used to address the different needs for lighting, receptacles, mechanical equipment and small appliances that require 208/120 V power. A schedule is located on the next page to represent the names of the various transformers in the building, their ratings, their supporting phase/wiring systems and a note to indicate which panelboards they each supply power to.

Transformer	kVA	Primary	Secondary	Phase	Feeds
T-LP2R	112.5	480/277V	208/120V	3 ᶲ; 4 wires	Panel LP2R
T-LP4R	30	480/277V	208/120V	3 ᶲ; 4 wires	Panel LP4R
T-LB1EQ	45	480/277V	208/120V	3 ᶲ; 4 wires	Panel LB1ER
T-XB1AV	45	480/277V	208/120V	3 ᶲ; 4 wires	Panel XB1AV
T-LB1	300	480/277V	208/120V	3 ᶲ; 4 wires	Panel LB1
T-B1EBUS	1000	480/277V	208V/3P	3 ᶲ; 4 wires	DS-B1-EBUS Breaker
T-B1WBUS	1000	480/277V	208V/3P	3 ᶲ; 4 wires	DS-B1-WBUS Breaker
T-LB1KT	75	480/277V	208/120V	3 ᶲ; 4 wires	Panel LB1KT
T-LB1WQ	30	480/277V	208/120V	3 ᶲ; 4 wires	Panel LB1WR
T-XAV1	45	480/277V	208/120V	3 ᶲ; 4 wires	Panel X1AV1
T-X1AV2	45	480/277V	208/120V	3 ᶲ; 4 wires	Panel L1AV1
T-L1WAV	45	480/277V	208/120V	3 ᶲ; 4 wires	Panel L1WAV
T-X1AV3	45	480/277V	208/120V	3 ᶲ; 4 wires	Panel X1AV3
T-X1AV4	45	480/277V	208/120V	3 ᶲ; 4 wires	Panel X1AV4
T-X1AV5	45	480/277V	208/120V	3 ᶲ; 4 wires	Panel X1AV5
T-L1MCS	75	480/277V	208/120V	3 ᶲ; 4 wires	Panel L1MCS
T-X2WAV	75	480/277V	208/120V	3 ᶲ; 4 wires	Panel X2WAV
T-X2EAV	75	480/277V	208/120V	3 ᶲ; 4 wires	Panel X2EAV
T-X3EAV	75	480/277V	208/120V	3 ᶲ; 4 wires	Panel X3EAV
T-X3WAV	75	480/277V	208/120V	3 ᶲ; 4 wires	Panel X3WAV
T-X4WAV	45	480/277V	208/120V	3 ᶲ; 4 wires	Panel X4WAV
T-X4EAV	45	480/277V	208/120V	3 ᶲ; 4 wires	Panel X4EAV
T-X5AV2	45	480/277V	208/120V	3 ᶲ; 4 wires	Panel X5AV2
T-L5AV3	45	480/277V	208/120V	3 ᶲ; 4 wires	Panel X5AV3
T-X5AV1	45	480/277V	208/120V	3 ᶲ; 4 wires	Panel X5AV1
T-L6EAV	45	480/277V	208/120V	3 ᶲ; 4 wires	Panel L6EAV
T-L6KT	75	480/277V	208/120V	3 ᶲ; 4 wires	Panel L6KT
T-L6EKT	75	480/277V	208/120V	3 ᶲ; 4 wires	Panel L6EKT-1
T-LPHR	30	480/277V	208/120V	3 ᶲ; 4 wires	Panel LPHR

Figure 7: Transformer Schedule

Switchboards + Panelboards

Several Eaton Electrical Inc. switchboards are located within the electrical system of this building which provide both front and rear access to the main devices and branch devices. The main devices are fixed and individually mounted while the branch devices are designed to be panel mounted. The switchboards are rated as steel, NEMA 250, Type I for indoor enclosures and run on a nominal system voltage of 480/277 V, 4000 A. The panelboards are flush, surface mounted cabinets rated for dry and clean indoor locations (NEMA 250, Type I), outdoor locations (NEMA 250, Type 3R) and kitchen locations (NEMA 250, Type 4X) depending on their placement throughout the building. All buses and connections are designed to be three phase, four wires and made from hand drawn copper of 98 percent conductivity. The following table describes the designed panelboards, distribution panels, associated loads and locations for each.

Panelboard	Voltage System	Mains Type	Main Rating	AIC Rating	Location
SWBD-P4OS	480/277V; 3PH, 4W	MCB (100%)	4000A	65,000	Chiller Room P401
HP4OS	480/277V; 3PH, 4W	MCB	250A	35,000	Boiler Room P400
HP4L	480/277V; 3PH, 4W	MCB	100A	25,000	Chiller Room P401
LP4OS	208/120V; 3PH, 4W	MCB	100A	10,000	Boiler Room P400
LP4R	208/120V; 3PH, 4W	MCB	100A	10,000	Chiller Room P401
HP2OS-1	480/277V; 3PH, 4W	MCB	600A	50,000	Mechanical P201
HP2OS-2	480/277V; 3PH, 4W	MCB	600A	50,000	Mechanical P201
LP2OS	208/120V; 3PH, 4W	MCB	100A	10,000	Mechanical P201
HP2L	480/277V; 3PH, 4W	MCB	250A	35,000	Mechanical P201
LP2R	208/120V; 3PH, 4W	MCB	250A	22,000	Mechanical P201
LP2R-MAINT	208/120V; 3PH, 4W	MCB	150A	10,000	Maintenance Shop P202
LP2LS	208/120V; 3PH, 4W	MCB	100A	10,000	Mechanical P201
HB2EQ	480/277V; 3PH, 4W	MCB	150A	25,000	Electrical B218
HB2L	480/277V; 3PH, 4W	MCB	100A	25,000	Electrical B218
LB2R	208/120V; 3PH, 4W	MCB	250A	10,000	Electrical B218
LB2ER	208/120V; 3PH, 4W	MCB	150A	10,000	Electrical B218
SWBD-B1-1	480/277V; 3PH, 4W	MCB (100%)	4000A	100,000	Electrical B124
SWBD-B1-2	480/277V; 3PH, 4W	MCB (100%)	4000A	100,000	Electrical B125
SWBD-B1-3	480/277V; 3PH, 4W	MCB (100%)	4000A	100,000	Electrical B126
HB1KT	480/277V; 3PH, 4W	MCB	300A	35,000	Support Kitchen B117
SWBD-B1EQ	480/277V; 3PH, 4W	MCB (100%)	1000A	65,000	Mechanical B119
HB1WQ	208/120V; 3PH, 4W	MCB (100%)	250A	10,000	Support Kitchen B117
LB1KT	480/277V; 3PH, 4W	MCB	250A	25,000	Mechanical B119
LB1WR	208/120V; 3PH, 4W	MCB	100A	10,000	Mechanical B119
HB1L	480/277V; 3PH, 4W	MCB	100A	25,000	Electrical B115
LB1	208/120V; 3PH, 4W	MCB	1000A	65,000	Electrical B116
HB1EQ	480/277V; 3PH, 4W	MCB	150A	25,000	Elec. Closet B114
LB1R	208/120V; 3PH, 4W	MCB	150A	10,000	Electrical B115
LB1ER	208/120V; 3PH, 4W	MCB	150A	10,000	Elec. Closet B114
XB1L	208/120V; 3PH, 4W	MCB	250A	22,000	Elec. Closet B114
XB1AV	208/120V; 3PH, 4W	MCB	150A	10,000	Exhibit AV B114A
L1WAV	208/120V; 3PH, 4W	MCB	100A	10,000	AV/IT 133
L1WR	208/120V; 3PH, 4W	MCB	250A	22,000	Cooridor 115
X1AV1	208/120V; 3PH, 4W	MCB	150A	10,000	Museum Shop 136
X1AV2	208/120V; 3PH, 4W	MCB	150A	10,000	AV/IT 133
X1AV3	208/120V; 3PH, 4W	MCB	150A	10,000	AV/IT 112
X1AV4	208/120V; 3PH, 4W	MCB	400A	10,000	AV/IT 112
L1ER	208/120V; 3PH, 4W	MCB	250A	22,000	Cooridor 111
H1L	480/277V; 3PH, 4W	MCB	100A	65,000	Electrical B115
L1R	208/120V; 3PH, 4W	MCB	150A	50,000	Electrical B115
H1EQ	480/277V; 3PH, 4W	MCB	150A	25,000	Cooridor 111
X1AV5	208/120V; 3PH, 4W	MCB	400A	10,000	AV/IT 112
X1L1	208/120V; 3PH, 4W	MCB	250A	50,000	Electrical B115

X1L2	208/120V; 3PH, 4W	MCB	250A	50,000	Electrical B115
X1L3	208/120V; 3PH, 4W	MCB	250A	50,000	Electrical B115
H1ML	480/277V; 3PH, 4W	MLO	N/A	65,000	Electrical M107
L1MCS	208/120V; 3PH, 4W	MCB	250A	10,000	Storage M112
L1MR	208/120V; 3PH, 4W	MCB	150A	50,000	Electrical M107
X2WL	208/120V; 3PH, 4W	MCB	600A	22,000	IT/AV/LGT Control 214
X2WAV	208/120V; 3PH, 4W	MCB	250A	10,000	IT/AV/LGT Control 214
X2WAV2	208/120V; 3PH, 4W	MCB	150A	10,000	AV/IT 213
L2WR	208/120V; 3PH, 4W	MCB	100A	22,000	Elec. Rm 224
HL2	480/277V; 3PH, 4W	MLO	N/A	65,000	Electrical 212
H2EQ	480/277V; 3PH, 4W	MCB	250A	25,000	Mechanical 210
L2R	208/120V; 3PH, 4W	MLO	N/A	50,000	Electrical 212
X2EL	208/120V; 3PH, 4W	MCB	400A	22,000	IT/AV/LGT Control 214
L2ER	208/120V; 3PH, 4W	MCB	150A	50,000	Mechanical 210
X2EAV	208/120V; 3PH, 4W	MCB	250A	10,000	IT/AV/LGT Control 214
X2ER	208/120V; 3PH, 4W	MCB	150A	10,000	Flyboard Theater 217
H3WQ	480/277V; 3PH, 4W	MCB	250A	25,000	Mechanical 313
X3WL	208/120V; 3PH, 4W	MCB	400A	22,000	IT/AV/LGT Control 314
X3WL2	208/120V; 3PH, 4W	MCB	150A	22,000	IT/AV/LGT Control 314
X3WAV	208/120V; 3PH, 4W	MCB	250A	10,000	IT/AV/LGT Control 314
L3WR	208/120V; 3PH, 4W	MCB	100A	22,000	Mechanical 313
X3ER	208/120V; 3PH, 4W	MCB	250A	10,000	Mechanical 310
H3L	480/277V; 3PH, 4W	MLO	N/A	65,000	Electrical 312
H3EQ	480/277V; 3PH, 4W	MCB	250A	25,000	Mechanical 310
X3EAV	208/120V; 3PH, 4W	MCB	250A	10,000	IT/AV/LGT Control 314
L3R	208/120V; 3PH, 4W	MLO	N/A	50,000	Electrical 312
X3EL	208/120V; 3PH, 4W	MCB	400A	22,000	IT/AV/LGT Control 314
L3ER	208/120V; 3PH, 4W	MCB	150A	22,000	Mechanical 310
X4WAV	208/120V; 3PH, 4W	MCB	150A	10,000	IT/AV/LGT Control 414
X4WL	208/120V; 3PH, 4W	MCB	400A	22,000	IT/AV/LGT Control 414
L4WR	208/120V; 3PH, 4W	MCB	100A	22,000	Mechanical 413
H4L	480/277V; 3PH, 4W	MLO	N/A	65,000	Electrical 412
X4EAV	208/120V; 3PH, 4W	MCB	150A	10,000	IT/AV/LGT Control 414
H4EQ	480/277V; 3PH, 4W	MCB	250A	25,000	Mechanical 410
L4R	208/120V; 3PH, 4W	MLO	150A	50,000	Electrical 312
X4EL	208/120V; 3PH, 4W	MCB	400A	22,000	IT/AV/LGT Control 414
L4ER	208/120V; 3PH, 4W	MCB	100A	22,000	Mechanical 410
L5WR	208/120V; 3PH, 4W	MCB	150A	50,000	Electrical 511
X5AV1	208/120V; 3PH, 4W	MCB	150A	10,000	AV/IT 525B
X5AV2	208/120V; 3PH, 4W	MCB	150A	50,000	AV/IT 507A
X5AV3	208/120V; 3PH, 4W	MCB	150A	10,000	AV/IT 512
L5R	208/120V; 3PH, 4W	MLO	N/A	50,000	Electrical 511
H5L	480/277V; 3PH, 4W	MLO	N/A	65,000	Electrical 511
L5ER	208/120V; 3PH, 4W	MCB	50A	10,000	JC 503

X5EL1	208/120V; 3PH, 4W	MCB	250A	50,000	Electrical 511
X5EL2	208/120V; 3PH, 4W	MCB	250A	50,000	Electrical 512
X5EL3	208/120V; 3PH, 4W	MCB	250A	50,000	Electrical 513
Cp - 1.0	208/120V; 3PH, 4W	MCB	50A	10,000	Equip. Plat. EP500
H5MWQ	480/277V; 3PH, 4W	MCB	300A	65,000	Equip. Plat. EP500
L5MR	208/120V; 3PH, 4W	MCB	100A	10,000	Equip. Plat. EP500
H5ML	480/277V; 3PH, 4W	MLO	N/A	65,000	Equip. Plat. EP500
GRELTS	208/120V; 3PH, 4W	MCB	60A	10,000	Electrical 613
H6L	480/277V; 3PH, 4W	MLO	N/A	65,000	Electrical 613
L6R	208/120V; 3PH, 4W	MLO	N/A	50,000	Electrical 613
H6DIM	480/277V; 3PH, 4W	MCB	100A	25,000	Members Lounge 610
L6ER	208/120V; 3PH, 4W	MCB	150A	22,000	Corridor 640
L6EAV	208/120V; 3PH, 4W	MCB	150A	10,000	AV/IT 645
H6KT	480/277V; 3PH, 4W	MCB	150A	25,000	Catering Pantry 648
L6KT	208/120V; 3PH, 4W	MCB (100%)	250A	10,000	Catering Pantry 648
H6EKT	480/277V; 3PH, 4W	MCB	250A	25,000	Kitchen 609
L6EKT-1	208/120V; 3PH, 4W	MCB (100%)	250A	10,000	Kitchen 609
H6MWQ	480/277V; 3PH, 4W	MCB	150A	25,000	Mechanical 601
L6MR	208/120V; 3PH, 4W	MCB	100A	10,000	Mechanical 601
PTMPS	208/120V; 3PH, 4W	MCB	100A	10,000	Theater Support 604
PTDIM	208/120V; 3PH, 4W	MCB	250A	10,000	Theater Support 604
PTMBP	208/120V; 3PH, 4W	MCB	200A	10,000	Theater Support 604
L6MPTR	208/120V; 3PH, 4W	MCB	250A	10,000	Theater Support 604
HPH	480/277V; 3PH, 4W	MCB	400A	35,000	Mechanical Penthouse
LPHR	208/120V; 3PH, 4W	MCB	100A	10,000	Mechanical Penthouse
LA9	208/120V; 3PH, 4W	MCB	400A	25,000	Electrical 905
LA9EQ	208/120V; 3PH, 4W	MCB	150A	10,000	Electrical 905
LA9-2	208/120V; 3PH, 4W	MCB	150A	10,000	Electrical 905
DPA9	480/277V; 3PH, 4W	MCB	600A	50,000	N/A
HA9	480/277V; 3PH, 4W	MCB	400A	35,000	Electrical 905
LA9AV	208/120V; 3PH, 4W	MCB	100A	10,000	AV 979
HB9	480/277V; 3PH, 4W	MCB	250A	22,000	E RM 932
LB9	208/120V; 3PH, 4W	MCB	400A	25,000	E RM 932
LB9EQ	208/120V; 3PH, 4W	MCB	150A	10,000	E RM 932
EHB9	480/277V; 3PH, 4W	MCB	100A	25,000	E RM 932
ELB9	208/120V; 3PH, 4W	MCB	50A	10,000	E RM 932
EHLR	480/277V; 3PH, 4W	MCB	300A	14,000	E RM 932
ELLR	208/120V; 3PH, 4W	MCB	125A	14,000	E RM 932
HA8	480/277V; 3PH, 4W	MLO	N/A	14,000	Existing Busduct
HB8	480/277V; 3PH, 4W	MLO	N/A	14,000	Existing Busduct
MCCR	480/277V; 3PH, 4W	MCB	1500A	65,000	Exist Central Plant 991
DPHR-1	480/277V; 3PH, 4W	MCB	800A	50,000	Exist Central Plant 991
DPHR-2	480/277V; 3PH, 4W	MCB	800A	35,000	Exist Central Plant 991

Figure 8: Panelboard Schedule

Overcurrent Protection Devices

The panelboards located in this building are protected by circuit breakers that range from 4000A to 50A predominantly of type MCB, and occasionally MLO.

Main Risers + Feeders

The main feeders are copper, solid No. 10 AWG and smaller conductor materials. For larger systems, a stranded No. 8 AWG wire is applied. Exposed feeders are type THHN/THWN-2, single conductors in a raceway. Feeders concealed in the ceilings and partitions or the concrete are type THHN/THWN-2 or type XHHW-2, respectively.

Conductors

The primary conductor type in this building is a copper wire or cable insulated for 600V unless otherwise applicable by code. The building also uses bare copper conductors with the following sizing data:

1. Solid Conductors: ASTM B 3.
2. Stranded Conductors: ASTM B 8.
3. Bonding Cable: 28 kcmil, 14 strands of No. 17 AWG conductor, 1/4 inch (6 mm) in diameter.
4. Bonding Conductor: No. 4 or No. 6 AWG, stranded conductor.
5. Bonding Jumper: Copper tape, braided conductors terminated with copper ferrules; 1-5/8 inches (41 mm) wide and 1/16 inch (1.6 mm) thick.

In terms of the power and communications grounding bus, there are pre-drilled rectangular bars of annealed copper with 9/32 inch holes spaced 1-1/8 inches apart. Stand-off insulators for mounting shall comply with UL 891 for use in switchboards, 600V. Lexan or PVC is impulse tested at 5000V.

Conduit

There are multiple types of conduit used throughout this building. These types are outlined below.

Metallic Conduit + Tubing

1. Galvanized Rigid Steel Conduit (GRC) - complies with ANSI C80.1 and UL6.
2. Aluminum Rigid Conduit (ARC) - complies with ANSI C80.5 and UL6A.
3. IMC - complies with ANSI C80.6 and UL1242.
4. PVC - Coated Steel Conduit - PVC coated IMC, complies with NEMA RN.1, 0.04 inch min. coating thickness
5. EMT - complies with ANSI C80.3 and UL797.
6. FMC - zinc coated steel, complies with UL1.
7. LFMC - flexible steel conduit with PVC jacket, complies with UL360.

Non - Metallic Conduit + Tubing

1. Rigid Nonmetallic Conduit (RNC) - type EPC-40-PVC
2. Liquid Tight Flexible Nonmetallic Conduit (LFNC) - complies with UL 1660.

Bus Assemblies

Low impedance, feeder and plug-in bus assemblies will function at 120/208 and 277/480 V, 3 phase.

Wiring Devices

The service entrance uses a type SE or USE mulitconductor cable. Exposed branch circuits, including crawlspaces, use type THHN/THWN-2 single conductors in a raceway. Branch circuits concealed in the ceilings, walls, partitions, and concrete use type THHN/THWN-2 single conductors in a raceway as well. Branch circuits in cable trays use nonmetallic-sheathed cable, Type NM.

Receptacles

The standard receptacle type in the building is a 125 V, 20 A general duty duplex receptacle. This specification complies with NEMA WD 1, NEMA WD 6 configuration 5-20R and UL 498. Some other common straight blade receptacles used throughout the project include designer style duplex receptacles, duplex receptacles with USB ports, isolated-ground duplex convenience receptacles (120V, 20A) and tamper resistant convenience receptacles (125V, 20A). Additionally, there is occasional use of duplex GFCI convenience receptacles and single convenience receptacles (both 125V, 20A).

Switch and Receptacle Faceplates

Throughout the project, a manufacturer's standard faceplate was specified with flush mounting. The material and grade could not be determined through the construction documents and specifications.

Motor Starters

Variable-frequency motor controllers (VFCs), rated at 600V or less are enclosed and preassembled throughout the project to control the speed of three-phase, squirrel-cage induction motors. All motors are listed and labeled as defined by NFPA 70 and comply with NEMA ICS 7, NEMA ICS 61800-2, and UL 508A. They are designed to match load types, such as fans, blowers, and pumps; and type of connection used between motor and load such as direct or through a power transmission connection. The output rating is three phase; 10 - 60 Hz, with voltage proportional to the frequency throughout voltage range with a maximum voltage equals input voltage.

Uninterruptible Power Supply (UPS) Systems

The UPS systems are expected to act as three-phase, on-line, double-conversion, static-type, high efficiency units. The systems is also expected to perform under automatic operation, manual operation, maintenance bypass/isolation switch operation as well as under certain environmental conditions. It will function from an input voltage of 208V, 3 PH, 3 wire plus ground and output a voltage of 208Y/120V, 3 PH, 4 wire plus ground. A minimum duration of supply is 15 minutes, assuming the battery is the sole source supplying the load current at an 80% power factor. The system will comply with NEMA 250, Type I conditions and mount on modular plug-ins, readily accessible for maintenance.

Communication Systems:

The following systems were integrated into the design of the building.

Telephone + Data Communication

Horizontal cable and its connecting hardware provide the means of transporting signals between the telecommunications outlet/connector and the horizontal cross-connect located in the communications equipment room. The maximum allowable cable length is 295 feet, allowing for an extra 33 feet for the distance to the workstation equipment and the distance for the service loop in the telecommunications room. All telephone and communications cable will be labeled with an inscription on orange colored tape. General purpose communication cable will be type CM or CMG, with alterations to type CMP and CMR for plenum rated and riser rated systems, respectively. These cables will comply with transmission standards in TIA/EIA-568-C.1 and will be tested to meet requirements for flame-spread and smoke scenarios.

Video Surveillance + Intrusion Detection

The intrusion detection system consists of sensors hardwired to the physical access control system. Interference protection shall be unaffected by electrical induction of 15 V/m over a frequency range of 10 to 10,000 MHz. Tamper protection switches on detection devices and control units will initiate an alarm signal when a unit is when entering conductors are cut or disconnected. Motion detectors and vibration detectors are also specified for security purposes. These systems will integrate with several others including doors, elevators, network lighting controls, intercommunications, public access, fire alarm systems, perimeter security and video surveillance. Video management systems (VMSs) will integrate with the physical access control systems and will have the ability to record data at all times throughout the day. UTP cable will be provided for this system by others. Plenum rated cable will be provided (type CMP No. AWG stranded tinned copper conductors) and well as non-plenum rated, paired cable (type CMG No. AWG stranded tinned copper conductors).

Access Control

Access control systems with integrate with other systems including intrusion, detection, intercommunications and video. The system will respond to alarms and interact with the door hardware interface as well. The system will include key pads, card readers, and magnetic contact designs. UTP cable will be provided for this system by others. Plenum rated cable will be provided (type CMP No. AWG stranded tinned copper conductors) and well as non-plenum rated, paired cable (type CMG No. AWG stranded tinned copper conductors).

Audio / Visual Display Systems

Different audiovisual systems will be located in rooms throughout the building, including the lobby, multi-purpose room, performance hall, conference hall, classroom, large/small conference rooms, security conference room, gathering room, members lounge, and biblical gardens. While each system is different, some of the general cabling systems are outlined below.

1. Microphone - No. 22 AWG shielded twisted pair cable
2. High Impedance Loudspeaker - No. 16 AWG unshielded twisted pair cable
3. DC Power Cables - No. 16 AWG unshielded twisted pair cable

Other cables, such as those for video displays, are not specifically outlined in the specifications.

Fire Alarm Systems

The fire alarm system is intended to be provided by a qualified fire alarm specialist. System is to be integrated with an emergency transfer switch that will automatically turn on egress lighting in the event of a power outage. The fire alarm interface will also link with egress lock controls and reporting and monitoring system controls.

Electrical + Telecommunications Floor Space:

The spaces outlined in the table on the next page were dedicated to electrical or telecommunications. The table references the total square footage allotted for each of the floor levels. The total square footage used for the purpose of electrical or telecommunications distribution and retrieval was 11,175 sf. When comparing this value to the overall square footage of 430,000 sf, these systems occupy 2.67% of the overall building area.

Level	Room Label	Area (sf)
B2 WDC	B218	145
B1 WDC	B112, B115, B124, B125, B126, B127, B128, B129	4,088
1	101, 112, 125, 129, 133	1885
1M	M107, M108	318
2	212, 213, 214	1,035
3	309, 312, 314	1,304
4	402, 409, 412, 414	1,424
5	507A, 511, 512, 512A, 525A, 525B	1,013
9 WOC	904, 905, 932, 934	278
Total Area (sf)		**11,490**

Figure 9: Electrical + Telecommunications Dedicated Floor Space

Energy Reduction Methods:

As outlined in the building's basis of design documents and specifications, the designers for this building strove to achieve LEED accreditation through different sustainable efforts. Most of the accreditation points are expected to be obtained during the construction process of the structure. In relation to the specific electrical components that will help achieve LEED accreditation, the specifications do not mention any.

Single Line + Riser Diagram

The single line diagrams as well as the riser diagrams, including the emergency power diagram, can be found in the appendix of this report.

PART 3: EVALUATED DESIGNED SYSTEMS VERSUS CRITERIA

Primary Load Calculations:

The actual building electrical load is 8,680 kVA compared to the estimated load of about 5,320 kVA. As you can see, the estimated value was severely conservative given the end result. For a building of this size, a total electrical load of five thousand kVA is a reasonable assumption under usual circumstances, however given the unique function of the building some variation from the norm is not surprising. A large portion of the actual calculated load, approximately 5,000 kVA, accounts for the emergency system transfer switches that have a necessary functionality during all times of the day. A low estimation of the extent of power needed to run these systems is most likely the reasoning behind the numerical difference between the estimated and calculated values. The table below summarizes the differences between the values in a more in depth manner.

	Lighting	Receptacle	Mechanical	Special Equipment	Total Load
Estimated Load (VA)	806250	645005	301000	860000	5321255
Calculated Load (VA)	780611	455799	6572539	871478	8680427
Difference (VA)	25639	189206	6271539	11478	3359172
%Error (Difference/Calculated)	3.28	41.51	95.42	1.32	38.70

Figure 10: Comparison of Estimated and Calculated Loads

When comparing the loads calculated specifically for the different components of the load, some of the individual estimations were relatively close while others were not. Both the lighting and special equipment portions of the analysis showed a very small percentage of error in the estimation of the load. On the other hand, the receptacle load estimation was significantly higher than the actual load. Since this building is meant to function as a museum, it makes sense that the receptacle load would be smaller than average because a limited number of outlets are needed. As discussed previously, the mechanical load is almost double the expected value considering the lack of consideration for such a large emergency power system. These loads could be analyzed in the future for their importance and methods could be used to lower the costs associated with additional power supply to the building.

Utility Rate Schedule:

The utility rate schedule that was assumed applicable for this building type and location was different than the actual rate found. Given the immense size of the building, the power supply was expected to be of primary service. On the contrary, the supply was actually a low voltage service. While there are positives and negatives associated to each type of service, altering the utility type to a primary service present to opportunity to save building costs in relation to the transmission and distribution of electrical power per kwh.

Building Utilization Voltage:

The predicted and actual building utilization voltage compared nicely, both suggesting a 480/277V, 3PH, 4W system with a step down to 208/120V when necessary. It would be wise to keep this strategy throughout further analysis.

Electrical Equipment:

The current design of the building has a rather large building load and therefore the fact that there are several panel boards is not surprising. The panelboards and other equipment located in both the electrical and telecommunication rooms seem to be strategically designed to stack atop one another, to minimize distances of wiring and therefore reduce costs. The design of the risers seems logical, providing two different voltage options for each floor to tap into with the bus-ducts. However, it is odd that some of the panelboards requiring 208/120V still tap into the 480/277V riser to acquire power, meaning that some of the transformers used throughout the building may be unnecessary. In regards to the materials used for the wiring in the building, which in this case is copper, there is potential for improvement from a cost standpoint. Transitioning to a cheaper option, such as aluminum, has the opportunity to lower costs given that the reliability of the building's system is not severely effected.

Emergency Power + Back-Power System:

The designed emergency power system includes the use of eight generators located on the penthouse level of the building. These generators individually run off 400kW for a combined power of 3200kW from a natural gas source. Given that the total connected emergency load is just under 5000 kVA, it appears that the system was designed somewhat conservatively to account for that fact that the system won't be expected to supply loads to all of the different panel boards at one time. To save on initial cost as well as lifetime costs, it may be beneficial to further study this.

Energy Reduction Strategies:

There are several different design strategies that if implemented would have the opportunity to promote energy reduction in this building . While LEED accreditation has been considered for many of the other aspects of the building, there has been little to no effort put forth to implement electrical system design that helps in this effort. The addition of more building control systems , integrated into the electrical and mechanical areas of the building, could be an adequate method of energy reduction throughout the building. Currently, there are some sensors located in the public areas that access occupancy controls, however additional daylighting sensors present the potential for electrical and mechanical integration to control heating/cooling systems in relation to solar heat gain. Shade control on the exterior façade is another method that could prove to be useful for energy saving strategies.

REFERENCES

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