2012

Technical report 1

American Art Museum

ASHRAE Standard 62.1-2007
And
Standard 90.1-2007 Analysis

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Table of Contents

Executive Summary

This thesis technical report was conducted on the American Art Museum (AAM), which will be located in New York downtown, Meat packing district. The purpose of this report is to analyze the American Art Museum corresponding to two main sections of ASHRAE Standard:

> *62.1-2007 Ventilation for Acceptable Indoor Air Quality* and *90.1-2007 Energy Standard for Buildings Except Low Rise Residential Building*.

These two sections offer a set of reference standards for providing occupant comfort and energy efficiency. This analysis will embrace the understanding of the design conditions in American Art Museum and identifying the potential criteria for further design.

American Art Museum will be about 200,000 sq. ft., which will consist of museum galleries, a restaurant, office space, classroom, and an auditorium. The museum will provide outdoor activities and galleries in rooftops located on different levels. The construction started in February 2012and will be completed in late 2014.

62.1-2007 Ventilation for Acceptable Indoor Air Quality

The purpose of this section is to ensure that the indoor air quality and the ventilation rate of AAM will achieve at least minimum level. The part of ASHRAE Standard this report focuses on is Section 62.1.5: System and Equipment and System with the specified calculation on Section 62.1.6: Procedures. The section 62.1.5 is mainly about the minimum requirement of how a ventilation system should operate, such as outdoor intake requirements, exhaust duct location, and particulate filtration.

90.1-2007 Energy Standard for Buildings except Low Rise Residential Building

The purpose of this section is a reference standard of equipment and system energy efficiency and building envelop, such as the control of HVAC and lighting system, maximum energy density, and the efficiency of service water heater.

The AAM will receive LEED Gold certification. This report provides a break-down analysis of the failure and achievement of mechanical systems and equipment in the museum.

Project Background

Name	American Art Museum
Location	New York, NY
Occupancy Type	Group A-3 Museum
Size	195000 sq. ft.
Function	Gallery, Classroom, Office, Auditorium, Restaurant
Floors	9 levels with cellar mezzanine and cellar level underground
Construction	Start in February 2012, End in late 2014
Main Architectural Feature(s)	1. Cantilevered entrance 2. The Biggest column-free gallery in New York 3. Ground floor restaurant and top floor café 4. Rooftops on Multiple levels for outdoor exhibition 5. Glazing system, pre-cast concrete, and stud wall as façade
Sustainability	Goal: LEED Gold Certification

Figure 1 Courtesy of the owner

Figure 2 Courtesy of the owner

Figure 3 Courtesy of the owner

Mechanical Summary

Heating and Cooling System

Cooling System

According to the cooling system in AAM, the main refrigeration plant will consist of 3 electrically driven centrifugal chillers with refrigerants R-123 or R-134a. There will be 5 cooling towers and free cooling heat exchangers. The cooling towers will be located on the roof and each of them will hold 200 ton cross-flow or counter-flow typed cells.

Cold water fluid-applied roofs and greenroofs on multiple floors will provide a passive cooling in this museum. This roofing system will reduce solar heat gain from the roof.

Heating System

A hot water heating boiler plant also will be located on Cellar Level. This plant will consist of 5 condensing water firetube boilers generating hot water with supply temperature, 150 ℉, and return temperature, 120 ℉. The system will lower its pollution with built-in water treatment and a combustion chamber with gas filters. This system will provide radiation and air heating services. The radiation heaters will be conducted in finned tube convector along the exterior walls to reduce heat losses.

Unit heaters and fan coil type heaters will provide heat on all mechanical rooms, exit and entrances. Lobbies will be heated and cooled by fan coil units along the glass façade walls.

Ventilation

In AAM, there will be 3 air conditioning systems located on the Cellar Level (-1) and one on Level 9. Each of the 3 systems on Cellar Level will handle 1/3 of the load and manage the air in floors C through 7. The system on Level 9 manages the air condition in 8th floor. The whole museum is divided into several main zones with different ventilation distribution: galleries with Variable Air Volume (VAV) system, lobbies with VAV system, restaurant with constant air volume (CAV) system, and auditorium with CAV system. Both of the main air condition system will consist of fogged type humidifier systems. According to air filtration, 95% efficient filters will be used in air conditioning systems, which ventilate air to the galleries.

Control System

The control system of American Art Museum, Direct Digital Control (DDC), will operate with the following modes of setting to minimize the energy cost: Unoccupied Mode, "Summer" Occupied Mode, "Winter" Occupied Mode, and "Auto" Mode. The DDC will receive the data from all sensors, gradually adjust the damper position and provide the needed de/humidification. The "Auto" Mode will conduct the data from astronomical time clock to schedule the "Summer" and "Winter" Occupied Mode.

ASHRAE Standard 62.1-2007

Section 5: System and Equipment

Section 5.1 Natural Ventilation

Window systems will be located on all sides of American Art Museum. However, the current information is not provided with window dimensions and the possibility of manual operation.

Section 5.2 Ventilation Air Distribution

The ventilation design follows the regulations of ASHRAE. Through calculation, the air conditioning systems will provide more than enough volume of outside air.

Table 1 Comparison of the Rate of Intake Outside Air between Requirement and the System in AAM

Air Conditioning Systems serve…	Minimum Rate of Outside Air Supplied [cfm]	Required Rate of Outside Air [cfm]	Comply?
From Cellar Level to Level 7	89300	45114.62	Yes
From Level 8 to Level 9	9435	8349.62	Yes

Section 5.2.2 Plenum Systems

The return air will be taken out through the above-ceiling plenum grid of the occupied zones, such as auditorium, lobby, executive boardroom, theater lobby, coat check, gallery and restaurant. In offices and gallery support areas, there will be return grilles. So, the requirement is met.

Section 5.3 Exhaust Duct Location

In restaurant, there will be a fume hood exhaust systems with exhaust fans, which will discharge its exhaust air directly to the outside with high discharge velocity, high plume cannon fans. And, the kitchen exhaust air will be sent to the roof through fume hoods.

Section 5.4 Ventilation System Controls

The ventilation system will have the following energy management functions for different zones:

- Supply air reset.
- Economizer control.
- Holiday programming.
- Owner-Tailored Program.

This system will be associated with direct digital control unit (DCC). As the main air conditioning system, the supply air will be controlled by VAV assembly; lobbies, auditorium, and the restaurant will be supplied with minimum outside air flow. All the supply and return fans in ventilation systems will run with variable speed drive and be controlled by DCC.

Section 5.5 Airstream Surfaces

The airstream surfaces in ductwork will be ensured to be sealed and constructed properly. In the specification, there will be a leakage duct test after construction to ensure the ductwork operating well. The test will be in accordance with the 1995 SMACBA 'HVAC" Air Duct Leakage Test Manual.

Section 5.5.1Resistance to Mold Growth

Exhaust ductworks will be installed with 1 inch thick non-fibrous, polymid foam lining. This acoustic lining must be approved by the NDPA, UL 181 for mold growth, according to New York Energy Code and ASHRAE.

Section 5.6 Outdoor Air Intakes

The main outdoor air intakes will be on North side and West side of the Museum. The outdoor air intake on West will be sized 7' x 28' and intake 56,000 cfm. And, there will be two other outdoor air intakes on North. Each of them will size 16'x5' and intake 35,000 cfm. The main intakes will be located with the distances, which will be greater than the minimum distances listed in ASHREA standard 62.1 Table 5-1.

Section 5.6.2 Rain Entrainment

All louvers must be rated with wind driven rain rating and tested by the manufacturers, except the louvers with the length and width according to AMCA 500-L. There will be drainable blade louvers. The blades will be with gutters, which collect rainwater and sent it to the bottom of unit.

Section 5.7 Local Capture of Contaminants

The fume hood located in the kitchen on Level 8 will capture and exhaust the fumes, vapor and pollutant particles. The hood will maintain constant volume for safety.

Section 5.8 Combustion Air

Each boiler will have a combustion chamber.

Inside a co-generator, there will be a dry type replaceable air cleaner element.

The chilled plant will be low emission typed, and the products of combustion exhaust air will not exceed the EPA requirements.

Section 5.9 Particulate Matter Removal

All the filters will have an UL class 1 listing. The filter efficiencies and rate capacities must meet ASHRAE standard 52-76 requirement. Permanent Prefilters will have two types of prefilters, roughing prefilters and prefilters. Roughing prefilters will be 4 inch thick and be rated no less than MERV 8 with a 5 micron particle efficiency of 95%. Prefilters will be rigid-type filters with high lofted glass microfiber media. The filters must have minimum rating of MERV 11. Also, high-efficiency final filters will be similar filters with prefilters, but have the initial resistance with the following requirements:

MERV (ASHRAE 52.2)	Duct spot Efficiency (ASHRAE 52.1)	Flow Rate	Pressure Drop
16	98%	1400 cfm	1.1 inches w.g.
15	95%	2000 cfm	0.68 inches w.g.
13	85%	2000 cfm	0.50 inches w.g.
11	65%	2000 cfm	0.28 inches w.g.
10	55%	2000 cfm	0.25 inches w.g.
8	30%	2000 cfm	0.20 inches w.g.

Table 2High-Efficiency Final Filter (Rigid Type)

In addition, the gas filter in each air conditioning units on 9th floor is activated carbon filter with 30% efficient prefilter tracks.

There will be a sawdust system. It is designed with a self-cleaning fabric typed dust collector. And, the product must state that the dust collector is made for collecting wood dust.

Section 5.10 Dehumidification System

The DDC software program of this museum will monitor the return air humidity transmitter and gallery humidity transmitter. If the readings are higher than the set point, it will cause the air conditioning unit valve to open and dehumidify the supply air.

Section 5.11 Drain Pans

All auxiliary drain pans will at least 6 inches larger in the height and width of the equipment it serves and 2 inches deep. The slope of each drain pan will be along the direction of the corresponding drain pipes. The drain pipe connections will be over ¾ inches. The construction of drain pans should be flexible for eliminators in the future.

Section 5.12 Finned-Tube Coils and Heat Exchanger

Finned tube convector will be located on the floor from 3rd to 8th floor. And, there will be only 4 inches space, which is for continuous heavy duty grille. Therefore, it complies with the standard of Section 5.12.

Each unit electric heater will consist of a hand access doors for access to the valve and trap, which the doors will be located on hot water centrifugal fan type.

Section 5.13 Humidifiers and Water-spray Systems

There will be a complete fog type humidifier system, which will serve for the two main mechanical rooms on Level cellar and Level 9. The system will be rated to humidify supply air from 5°F/10% RH to the room conditions of 70°F/50%R.H.

Section 5.13.1 Water Quality

There will be a reverse osmosis water treatment in the humidifier system. This system will protect against from the dusting air with minerals salt and bacteria growth, including the possible condition of dangerous bacteria growth.

Section 5.14 Access for inspection, Cleaning, Maintenance

Access doors will provide accessibility to the following:

- Valves.
- Volume dampers.
- Fire dampers, some dampers, and combination fire and smoke dampers.
- Controls, coil, and terminal equipment.
- Smoke detectors.
- Plenums.

Fume Hood Exhaust Systems will be accessible through internal or/and external ladders and platforms for maintenance and service.

In the specification, it states that the responsibility will be on the Contractor, due to the variation of different manufacturers' equipment.

Section 5.15 Building Envelope and Interior Surfaces

There are 3 types of exterior surfaces: concrete, glazing system and stud wall.

- Concrete: there will be crystalline waterproofing. And, the exterior walls will have
- Stud wall: it will be with steel plate rain screen cladding system.
- Glazing system: It will be incorporated with appropriated waterproofing and vapor barrier tie-in.

The interior surfaces of elevator pits and sewage ejection pits will be applied crystalline waterproofing.

Section 5.16 Buildings with Attached Parking Garages

This section is not applicable, because there is no attached parking garage.

Section 5.17 Air Classification Recirculation

There are three types of air circulation system, which are Variable Air Volume (VAV), 100% return air and100% outside supply air. 100% outside supply air will serve in a kitchen, a restaurant and lobbies. The offices and gallery storage areas will be served with 100% return air. VAV system will apply in other areas, such as galleries and auditorium. There is no cross contamination.

Section 5.18 Requirements for Buildings Containing ETS Areas and ETS

This section is not applicable, because it does not allow smoking in this museum.

Summary of ASHRAE Standard 62.1-2007

American Art Museum should comply with the requirements in ASHRAE 62.1 Section 5. The quality of indoor air is high in the museum. However, based on the control system and the components of heating and cooling, it may cause high energy consumption. Therefore, receiving the credit of LEED Optimize Energy Performance will be challenging. It will be discussed further in the next section.

ASHRAE Standard 90.1-2007

System and Equipment Energy Standard for Building Except Low-Rise Residential building

Section 5 Building Envelope

Section 5.1 General

Section 5.1.4 Climate

The American Art Museum is located in New York, NY, which is in Zone 4A. It is in a mixed-humid zone.

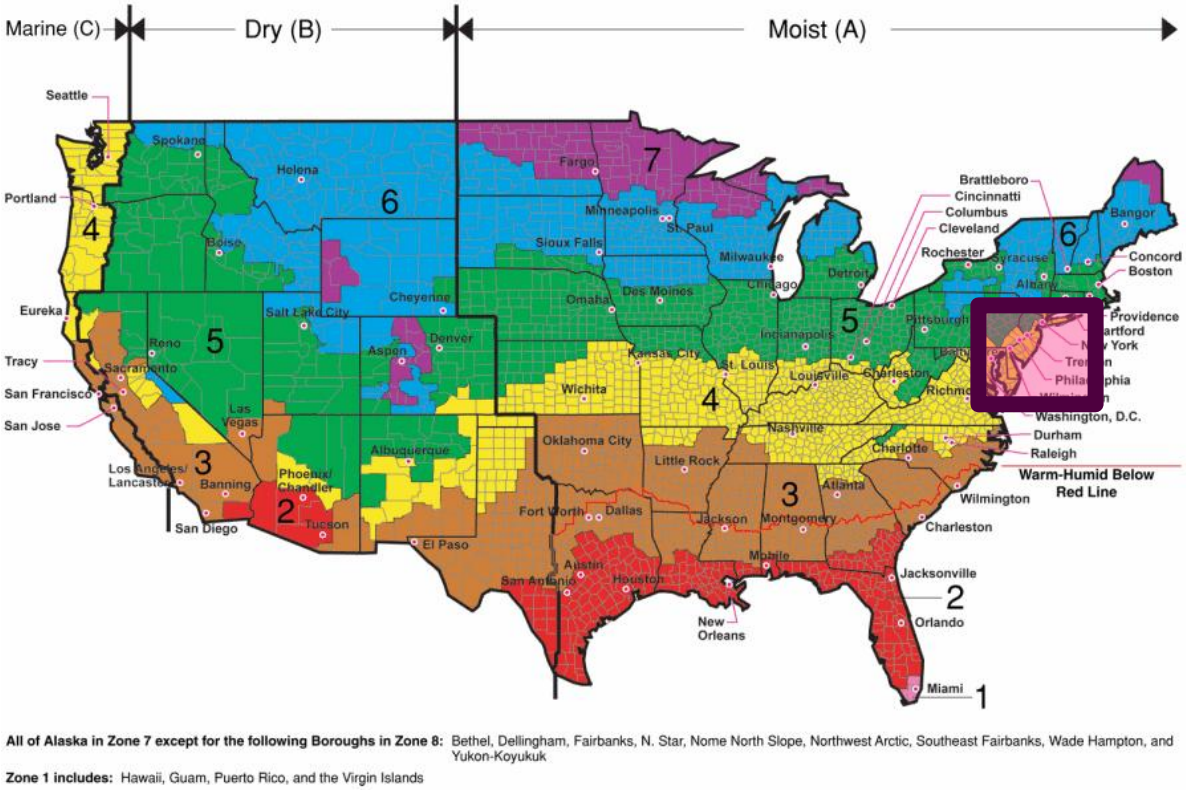

Figure 4 Climate zones for United States locations

Section 5.2 Compliance Paths

According to the diagram of this section, there are three options to analyze this museum. And, the chosen section is Section 5.5. But, due to lack of building envelope dimension, the compliance path cannot be completed.

Section 5.4 Mandatory Provisions

Section 5.4.1 Insulation

The building envelope will be sealed with the followings:

- Fiberglass blanket/batt insulation
- Mineral wool fire safing insulation
- Rigid insulation
- Insulated CMU
- Foamed in Place insulation

Section 5.4.2 Fenestration and Doors

According to the specification of fenestrations in AAM, vapor retarders will be sealed tight around.

And, all the glazing systems will be gazed with silicone sealant, and it will incorporate with the adjacent construction condition, which will be with waterproofing and vapor barrier tie-in.

Exterior doors will be weatherstrip gasketed, and interior doors will be smoke, light, or sound gasketed.

Section 5.5 Prescriptive building Envelope Option

In this section, Table 5.5-4 Building Envelope Requirements for Climate Zone 4 (A, B, C) is applied, since AAM will be located in Zone 4A and a nonresidential building. In this table, only the wall and roof insulations of metal building are considered. It is because the types of glass are not specified in the AAM construction drawings and specifications. Comparing to the Table 5.5-4, most of the wall and all the roof insulations of AAM will not achieve the minimum R-value. The calculation

	Insulation			
Surface	Type	R-value	Min. R-value	Comply?
Wall	A	14.5	13	Yes
	B	15.6	13	Yes
	C	17.9	13	Yes
	D	11.0	13	No
	E	4.8	13	No
	F-3 to 11	13.9	13	Yes
	F-12 to 14	14.5	13	Yes
	F-16 to 20	1.6	13	No
	G-1 to 3, 7,8	1.7	13	No
	G-4&5	13.9	13	Yes
	H	9.8	13	No
	M	1.1	13	No
Roof	E-1	2	19	No
	R-1	2	19	No
	R-2	Not used	19	--
	R-3	0.6	19	No
	R-4A	1.1	19	No
	R-4B	1.6	19	No
	R-5	2.2	19	No
	R-6	2.7	19	No
	R-7	5.8	19	No
	R-8	13.9	19	No
	R-9	1.6	19	No
	GR-1	1.9	19	No
	R-10	Not used	19	--

Table 3 Compliance with Section 5.5

Section 5.5.4 Fenestration

Section 5.5.4.2 Fenestration Area

Section 5.5.4.2.1 Vertical Fenestration Area

The total vertical glazing area will be about 20% of the gross wall area, which compiles the standard in this section.

American Art Museum: Glazing Ratio				
Orientation	Glazing Area [ft^2]	Wall Area [ft^2]	% of Glazing	Comply? (<40%)
North	5504	12214	45%	no
East	5734.76	37440.17	15%	yes
Wes	6204.92	19157.06	32%	yes
South	4930.93	37440.17	13%	yes
Overall	22374.61	106251.4	26%	yes

Table 4 Glazing Ratio

Section 5.5.4.2.2 Skylight Fenestration Area

The percentage of the area of skylight is over 5%. So, the skylight does not comply to this section.

American Art Museum: Skylight Ratio			
Gross roof Area [ft^2]	**Skylight Area [ft^2]**	**% of Skylight**	**Comply? (<5%)**
15374.06	4657.29	30%	No

Table 5 Skylight Fenestration Area Ratio

Section 6 Heating, Ventilation, and Air Conditioning

Section 6.4 Mandatory Provision

Section 6.4.1 Equipment Efficiencies, Verification, Labeling Requirement

Section 6.4.1.1 Minimum Equipment Efficiencies—Listed Equipment – Standard Rating and Operating Conditions

According to Table 6.8.1 in 60.1 Standard of ASHRAE, all boilers and cooling towers will comply with the requirements.

Compliance with Section 6.4.1.1 – ASHRAE Table 6.8.1F						
Condensing Boilers						
Tag	**Equipment Type**	**Subcategory**	**Size Category (BTU/h)**	**Minimum Efficiency**	**Design Efficiency**	**Comply ?**
B-C1-1	Hot water	Gas-fired	>2,5000 MBH	80%	87%	Yes
B-C1-2	Hot water	Gas-fired	>2,5000 MBH	80%	87%	Yes
B-C1-3	Hot water	Gas-fired	>2,5000 MBH	80%	87%	Yes
B-C1-4	Hot water	Gas-fired	>2,5000 MBH	80%	87%	Yes
B-C1-5	Hot water	Gas-fired	>2,5000 MBH	80%	87%	Yes

Table 6 Compliance with Section 6.4.1.1 - ASHRAE Table 6.8.1F

Compliance with Section 6.4.1.1 – ASHRAE Table 6.8.1G					
Cooling Towers					
Tag	**Equipment Type**	**Subcategory**	**Performance Required**	**Design performance**	**Comply ?**
CT-R-1	Centrifugal Fan Cooling Tower	95 F Entering Water 85 F Leaving Water 75 F wb Outdoor Air	≥20.0 gpm/hp	80 gpm/hp	Yes

Table 7Compliance with Section 6.4.1.1 – ASHRAE Table 6.8.1G

Section 6.4.3.4.3 Shutoff Damper Controls

The dampers of minimum outdoor air, variable outdoor air, return air, spill air, fan discharge dampers will be closed, when an air conditioning system is closed. This will maintain the lowest temperature, 50 °F.

Section 6.4.3.7 Humidification and Dehumidification

DDC system will control both humidification and dehumidification system. Every zone will have a relative humidity sensor of return air, and there will also be a humidity common alarm in the gallery zone.

Section 6.4 HVAC System Construction

Section 6.4.4 HVAC System Construction and Insulation

Section 6.4.4.1 Insulation

Section 6.4.4.1.1 General

There will be 2 types of pipe insulation materials. One insulation material will be capable to serve at a pipe temperature of 450 °F with the conductivity of 0.23 $\frac{BTU-in}{hr-sq\ ft-°F}$. The other material will be used at the temperature, 1,200 °F with the conductivity, 0.46 $\frac{BTU-in}{hr-sq\ ft-°F}$.

B. Insulation Thickness:

Service	Pipe Size	Temp	Thickness
Emergency Generator Exhaust Piping and Muffler	All	1,000°F	4 in. Calcium Silicate
Hot Water Heating within Convector and Fan Coil Unit Enclosures Only	All	450°F	None
Primary Hot Water, Hot Water Radiation, Hot Water Reheat and Heat Recovery	1-1/2 in. and under 2 in. and over		1 in. 2 in. Fiber glass
Chilled Water and Secondary Water (Condenser Water)	1-1/2 in. and under 2 in. and over		1 in. 1-1/2 in. Fiber glass
Fresh Water Makeup	All		1 in. Fiber glass
Condensation Drains - Risers, Mains and Branches	All		1/2 in. Fiber glass

Figure 5 Spec 237019 Insulation thickness of HVAC piping

Section 6.5 prescriptive Path

Section 6.5.1 Economizers

According to the Table 6.5.1, there is no requirement of economizer. All air conditioning systems will run as an outdoor air economizer system. There will be a variable frequency drive attached with each supply fan.

TABLE 6.5.1 Minimum System Size for Which an Economizer is Required

Climate Zones	Cooling Capacity for Which an Economizer is Required
1a, 1b, 2a, 3a, 4a	No economizer requirement
2b, 5a, 6a, 7, 8	≥135,000 Btu/h
3b, 3c, 4b, 4c, 5b, 5c, 6b	≥65,000 Btu/h

Section 6.5.2 Simultaneous Heating and Cooling Limitation

Section 6.5.2.1 Zone Controls

The DDC system will have the following zone controls:

- Gallery: An outdoor air economizer Variable Air Volume air conditioning system.
- Lobby: An outdoor air economizer Variable Air Volume system.
- Restaurant: An outdoor air economizer Constant Air Volume system.
- Auditorium: An outdoor air economizer Constant Air Volume system.
- 9th Floor: An outdoor air economizer Variable Air Volume system.
- Cellar and Back-of-House: An outdoor air economizer Variable Air Volume system.
- Kitchen: An outdoor air economizer Constant Air Volume system.

Section 6.5.3 Air system Design and Control

Section 6.5.3.2 Fan System Power Limitation

Section 6.5.3.2.1 Part-Load Fan Power Limitation

Every fan will be attached with an electrical variable-speed drive. But, some of the fans will not be vane-axial fans.

Section 6.5.3.2.3 Setpoint Reset

According to the Main Air Conditioning Systems on cellar Level, DDC system can reset the set points of RA temperature, OA temperature, minimum OA flow rate and OA humidity. And, the temperature and the flow rate of SA reset can be operator-adjustable.

Section 6.5.8 Radiant Heating System

Copper aluminum finned tube radiation convectors will be applied on the radiant heating system of this museum. The finned tubes will be located on the floor along exterior walls and cooperate with the surrounding floor panels.

Section 6.7 Submittals

The construction documents, operation and maintenance manuals, and submittals will be returned to the owner, after the construction is completed. According to the Commissioning for HVAC, there will three training sessions: Control System. Building Systems, and a discuss session about the operation of the system.

Section 7 Service Water Heating

Section 7.4 Mandatory Provision

Section 7.4.2 Equipment Efficiency

There will be five condensing water firetubed boilers to provide service heat with brazed plate heat exchangers. The design performance of these boilers will pass the standard of this Section, which is greater than 80 % thermal efficiency. All boilers will be tested in accordance with at least one of these standards, which are ASHRAE, ASME, ASTM, FIA/IRI, NEMA, and UL.

Compliance with Section 7.4.2 – ASHRAE Table 7.8					
Condensing Boilers					
Boiler Tag name	Fuel	Type	Design Performance	Required Performance	Comply?
B-C1-1 to 5	Natural gas	Condensing firetube	96%	>80%	Yes

Table 8 Compliance with Section 7.4.2 – ASHRAE Table 7.8

Section 7.4.3 Service Hot-Water Piping Insulation

The hot water system will input minimum 40 °F and output maximum 150°F, with the consideration of water to water heat exchanger. In Figure. 6, the pipe size will be with 1 or 2 in. thickness and fiberglass, which complies with the minimum pipe insulation thickness in Table 6.8.3.

Section 7.5 Prescriptive Path

Section 7.5.1 Space Heating and Water Heating

There will be two separated sub-systems to serve the service water and space heating.

Section 8 Power

In all feeders and branch circuits, the conductors will be sized will be No. 12 AWG or larger. Also, all conductors will be sized corresponding to Building Code of City New York and New York City Electric Code. Both codes surpass the requirements listed in this section.

Section 8.7 Submittals

After the completion of construction, the manuals will be returned to the owner, which is stated in Submittal Procedures and Electrical Submittal.

Section 9 Lighting

Section 9.4 Mandatory Provisions

Section 9.4.1 Lighting Control

Section 9.4.1.1 Automatic Lighting Shut Off

Switching/Relay system will consist of exterior photosensors, astronomical time clock and digital timer switches to automatically shut off lighting. The exterior photosensors will point towards North sky, and the sensors will assist time clock to provide control with on/off event schedule. On the other hand, the digital timer switches will automatically turn lights off at the certain time, which will be chosen by the operator.

In addition, there will also be a centralized control system with ceiling and wall mounted occupancy/vacancy sensors. A sensor will turn off the lightings after reasonable time period, when it sense enough daylight or unoccupied area.

Section 9.6 Space-by-Space Method

For a museum, the max lighting power density is 1.1 W/ft^2. The lighting power density of this museum will reach 1.14W/ft^2, which will be slightly over the maximum set point of this section. The detail calculation will be in Appendix B.

Section 10 Other Equipment

Comparing to the Table 10.8 Minimum Nominal Efficiency for General Purpose Design A and Design B Motor, all motors will have higher efficiency than the minimum requirement. The following tables are the list of motors in AAM and the Table 10.8.

Nominal Efficiencies (%)

	Open Dripproof		Totally Enclosed Fan Cooled	
HP	3,600 rpm	1,750 rpm	3,600 rpm	1,750 rpm
1	77	85.5	77	85.5
1.5	84	86.5	84	86.5
2	85.5	86.5	85.5	86.5
3	85.5	89.5	86.5	89.5
5	86.5	89.5	88.5	89.5
7.5	88.5	91	89.5	91.7
10	89.5	91.7	90.2	91.7
15	90.2	93	91	92.4
20	91	93	91	93
25	91.7	93.6	91.7	93.6
30	91.7	94.1	91.7	93.6
40	92.4	94.1	92.4	94.1
50	93	94.5	93	94.5
60	93.6	95	93.6	95

Table 9 Spec 220513 Common motor requirements for plumbing equipment

TABLE 10.8 Minimum Nominal Efficiency for General Purpose Design A and Design B Motors[a]

	Minimum Nominal Full-Load Efficiency (%)					
	Open Motors			Enclosed Motors		
Number of Poles ⇒	2	4	6	2	4	6
Synchronous Speed (RPM) ⇒	3600	1800	1200	3600	1800	1200
Motor Horsepower						
1	—	82.5	80.0	75.5	82.5	80.0
1.5	82.5	84.0	84.0	82.5	84.0	85.5
2	84.0	84.0	85.5	84.0	84.0	86.5
3	84.0	86.5	86.5	85.5	87.5	87.5
5	85.5	87.5	87.5	87.5	87.5	87.5
7.5	87.5	88.5	88.5	88.5	89.5	89.5
10	88.5	89.5	90.2	89.5	89.5	89.5
15	89.5	91.0	90.2	90.2	91.0	90.2
20	90.2	91.0	91.0	90.2	91.0	90.2
25	91.0	91.7	91.7	91.0	92.4	91.7
30	91.0	92.4	92.4	91.0	92.4	91.7
40	91.7	93.0	93.0	91.7	93.0	93.0
50	92.4	93.0	93.0	92.4	93.0	93.0
60	93.0	93.6	93.6	93.0	93.6	93.6
75	93.0	94.1	93.6	93.0	94.1	93.6
100	93.0	94.1	94.1	93.6	94.5	94.1
125	93.6	94.5	94.1	94.5	94.5	94.1
150	93.6	95.0	94.5	94.5	95.0	95.0
200	94.5	95.0	94.5	95.0	95.0	95.0

[a]Nominal efficiencies shall be established in accordance with NEMA Standard MG1. Design A and Design B are National Electric Manufacturers Association (NEMA) design class designations for fixed-frequency small and medium AC squirrel-cage induction motors.

Figure 6 Table 10.8 Minimum Nominal Efficiency for General Purpose Design A and Design B Motor

Summary of ASHRAE Standard 90.1-2007

American Art Museum will achieve most of the standard in ASHRAE 90.1-2007. The museum is required to consist of enough high-efficiency equipment or high quality of glazing system, in order to achieve the LEED scores of Optimizing Energy Performance. It is because American Art Museum doesn't comply with Section 5.5 Prescriptive building Envelope Option, Section 5.5.4.2.2 Skylight Fenestration Area and Section 9.6 Space-by-Space Method. Therefore, it is very important to have a further analysis of building insulation and the energy cost of different equipment.

Reference

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Appendix A

Appendix A

Table.1

Calculation.5.2.(1)--Breathing Zone Outdoor Air Flow from Cellar Level to Sixth Level

The air conditioning system on Cellar Level

Floor	Room	People O.A (cfm/persc	# of Occup Pz (person)	Area OA ra Ra	Area Az (sf)	Breathing Zone O.A. Flow Required Vbz (cfm)
Cellar Lvl	Fuel tank	0	1	0.3	200	60
	Fire pump	0	1	0.3	250	75
	Mech Rm	0	1	0.3	300	90
	Carpentry	10	11	0.18	1154	317.72
	Recycling	0	1	0.3	497	149.1
	Storage	0	1	0.3	338	101.4
	Stair A					0
	Elect Rm	0	6	0.3	2000	600
	Chiller Rm	0	5	0.3	1700	510
	Fuel oil rm	0	1	0.3	130	39
	Carpentry	10	12	0.18	1205	336.9
	Gas Rm	0	1	0.3	220	66
	Kitchen	7.5	8	0.18	1700	366
	stair C					0
	Storage	0	1	0.3	280	84
	Trash	0	1	0.3	280	84
	Storage	0	2	0.3	480	144
	Mech Rm	0	38	0.3	11500	3450
	Office	5	3	0.06	312	33.72
	Lockers	0	7	0.3	353	105.9
	Storage	0	2	0.3	550	165
	Boiler Rm	0	4	0.3	1100	330
	Mech Rm	0	4	0.3	1253	375.9
Cellar Mez	Office	5	5	0.06	500	55
	Lockers	0	5	0.3	235	70.5
	Lockers	0	7	0.3	345	103.5
	Coat Check	0	1	0.3	520	156
	Office	5	2	0.06	536	42.16
	Storage	0	2	0.3	209	62.7
	Lobby	5	0	0.06	1300	78
	Stair C					0
	Stair A					0
First floor	Lobby	5	0	2.5	6200	15500
	Guard	5	1	0.06	60	8.6
	Lobby	5	0	0.06	917	55.02
	Loading	0	9	0.3	2750	825
	Storage	0	1	0.3	45	13.5
	Gallery	7.5	37	0.06	1326	357.06
	Restaurant	7.5	166	0.18	2495	1694.1
Second floo	Mech Rm	0	8	0.3	2444	733.2
	Storage	0	1	0.3	248	74.4
Third floor	Office	5	7	0.06	730	78.8
	Classroom	7.5	39	0.06	781	339.36
	Storage	0	1	0.3	334	100.2
	Lobby	5	0	0.06	2426	145.56
	Office	5	39	0.06	3997	434.82
	Coat Check	0	2	0.3	200	60
	Storage	0	3	0.3	700	210
	Storage	0	2	0.3	400	120
	Office	5	56	0.06	5620	617.2
	Theatre	10	204	0.06	2448	2186.88
Fourth floo	Proj Rm	0	6	0.3	650	195
	Office	5	49	0.06	4935	541.1
	Office	5	119	0.06	11958	1312.48
	Staff Loung	5	50	0.06		250
	Conference	5	17	0.06		85
Fifth floor	Art Handl'g	0	31	0.3	3010	903
	Gallery	7.5	513	0.06	17940	4923.9
	Proj/stor	10	3	0.12	270	62.4
	Film/video	10	70	0.12	1032	823.84
Sixth floor	office	5	4	0.06	466	47.96
	Terrace	5	22	0.06	773	156.38
	Conserv.	5	2	0.06	265	25.9
	Conserv.	5	24	0.06	2420	265.2
	Study CTR.	7.5	15	0.06	1572	206.82
	Terrace	5	83	0.06	2915	589.9
	Gallery	7.5	325	0.06	11384	3120.54
					Total Calculated:	45114.62
						Vbz (cfm)

Note: The numbers of occupants are referenced by the drawings, 'Code analysis'.

Note: (ASHRAE 62.1)6-1

Appendix A

Table.2

Calculation.5.2.(1)continued--Breathing Zone Outdoor Air Flow from Cellar Level to Sixth Level

The main air conditioning system on Cellar Level

Location	Tag name	Mini. OA (cfm)	Max SA (cfm)
Cellar Leve	ACS-C1-1		1000
	ACS-C1-2		1000
	ACS-C1-3	17000	17000
	ACS-C1-4	5000	5000
	ACS-C1-5	6000	16500
	ACS-C1-6	4000	9000
	ACS-C1-7	5000	11000
	ACS-C1-8	2000	5000
	HV-C1-1	14000	14000
	HV-C1-2	5500	5500
	HV-C1-3	2300	2300
Fourth Lev	AC-4-1		1000
	AC-4-2		1000
Total in system:		60800	89300

Appendix A

Table.3

Calculation.5.2.(2)--Breathing Zone Outdoor Air Flow from Seventh Level to Nineth Level

The air conditioning system on Level 9

		People O.A	# of Occup	Area OA ra	Area	Breathing Zone O.A. Flow Required
Floor	Room	Rp	Pz (person)	Ra	Az (sf)	cfm
Seventh floor	Library	5	19	0.12	973	211.76
	Curatorial	7.5	31	0.06	3193	424.08
	Terrace	5	42	0.06	1471	298.26
	Gallery	7.5	260	0.06	9100	2496
Seventh Mezzanine	Libr. Stor.	0	10	0.3	521	156.3
Eighth floor	Office	5	9	0.06	920	100.2
	Conference R	5	81	0.06	1215	477.9
	Office	5	0	0.06	432	25.92
	Kitchen	7.5	4	0.18	800	174
	Terrace	5	42	0.06	1475	298.5
	Gallery	7.5	133	0.06	4650	1276.5
	Gallery	7.5	91	0.06	1365	764.4
Nineth floor	Mech Rm	0	15	0.3	4454	1336.2
Nineth floor Mezzanine	Elev M Rm	0	3	0.3	1032	309.6
					Total Calculated:	8349.62

Note: The numbers of occupants are referenced by the drawings, 'Code analysis'.
Note: (ASHRAE 62.1)6-1

Appendix A

Table.4

Calculation.5.2.(2)continued--Breathing Zone Outdoor Air Flow from Seventh Level to Nineth Level

The air conditioning system on Level 9			
Location	Tag name	ıi. OA (cfm)	Max SA (cfm)
9th Floor MER	ACS-9-1	6000	20000
Air conditioning system	ACS-9-2	1785	2200
	HV-9-1	1150	1150
	HV-9-2	500	500
	HV-9-3	2300	2300
	Total in system:	9435	26150

Appendix B

Appendix B

Table.5

Calculation.96.(1)--Space-by-Space Method

The Overall Lighting Density of a Building

		Area		
Floor	Room	Az (sf)	LPD/ft^2	LPD
Cellar Lvl	Fuel tank	200	1.5	300
	Fire pump	250	1.5	375
	Mech Rm	300	1.5	450
	Carpentry	1154	1.9	2192.6
	Recycling	497	1.5	745.5
	Storage	338	0.8	270.4
	Stair A		0.6	0
	Elect Rm	2000	1.5	3000
	Chiller Rm	1700	1.5	2550
	Fuel oil rm	130	1.5	195
	Carpentry	1205	1.9	2289.5
	Gas Rm	220	1.5	330
	Kitchen	1700	1.2	2040
	stair C		0.6	0
	Storage	280	0.8	224
	Trash	280	1.5	420
	Storage	480	0.8	384
	Mech Rm	11500	1.5	17250
	Office	312	1.1	343.2
	Lockers	353	0.6	211.8
	Storage	550	0.8	440
	Boiler Rm	1100	1.5	1650
	Mech Rm	1253	1.5	1879.5
Mezzanine	Office	500	1.1	550
	Lockers	235	0.6	141
	Lockers	345	0.6	207
	Coat Check	520	0.6	312
	Office	536	1.1	589.6
	Storage	209	1.5	313.5
	Lobby	1300	1.3	1690
	Stair c		0.6	0
	Stair A		0.6	0
First floor	Lobby	6200	1.3	8060
	Guard	60	1.3	78
	Lobby	917	1.3	1192.1
	Loading	2750	1.5	4125
	Storage	45	1.5	67.5
	Gallery	1326	1	1326
	Restaurant	2495	0.9	2245.5
econd floor	Mech Rm	2444	1.5	3666
	Storage	248	1.5	372
Third floor	Office	730	1.1	803
	Classroom	781	1.4	1093.4
	Storage	334	0.8	267.2
	Lobby	2426	1.3	3153.8
	Office	3997	1.1	4396.7
	Coat Check	200	0.6	120
	Storage	700	0.8	560
	Storage	400	0.8	320
	Office	5620	1.1	6182
	Theatre	2448	1.2	2937.6
ourth floor	Proj Rm	650	1.3	845
	Office	4935	1.1	5428.5
	Office	11958	1.1	13153.8
	Staff Lounge		1.2	0
	Conference Rm		1.3	0
Fifth floor	Art Handl'g	3010	1.7	5117
	Gallery	17940	1	17940
	Proj/stor	270	0.8	216
	Film/video	1032	1.1	1135.2
Sixth floor	office	466	1.1	512.6
	Terrace	773	0	0
	Conserv.	265	0.7	185.5
	Conserv.	2420	0.7	1694
	Study CTR.	1572	1.2	1886.4
	Terrace	2915	0	0
	Gallery	11384	1	11384
Seventh flo	Library	973	1.2	1167.6
	Curatorial	3193	1.7	5428.1
	Terrace	1471	0	0
	Gallery	9100	1	9100
Seventh M	Libr. Stor.	521	1.7	885.7
Eighth floo	Office	920	1.1	1012
	Conference	1215	1.3	1579.5
	Office	432	1.1	475.2
	Kitchen	800	1.2	960
	Terrace	1475	0	0
	Gallery	4650	1	4650
	Gallery	1365	1	1365
Nineth floo	Mech Rm	4454	1.5	6681
Nineth floo	Elev M Rm	1032	1.5	1548
	Total Calcu	154759		176659.5 1.141514
		(Area)		(LPD) (avg LPD/ft^2)

Appendix C

U-value of Different Wall Types					
Type	insulation	thickness (in)	total r-factor	Density	Specific Heat
			(hr-F-ft^2/BTU)	lbm/ft^3	(BTU/lb-F)
A	gypsum board	0.625	1.136	40	0.270
	insulation (fiberglass)	4	13.333	0.7	0.200
		5.25	0.069	10.057	0.217
		total thickness	total u-value	avg density	avg specific heat
B	gypsum board	0.625	2.273	40	0.270
	insulation (fiberglass)	4	13.333	0.7	0.200
		6.5	0.064	15.815	0.227
		total thickness	total u-value	avg density	avg specific heat
C	gypsum board	0.625	1.136	40	0.270
	insulation (fiberglass)	2.5	16.667	0.7	0.200
		6.25	0.056	8.560	0.214
		total thickness	total u-value	avg density	avg specific heat
D	gypsum board	0.625	2.273	40	0.270
	insulation (fiberglass)	2.5	8.333	0.7	0.200
	Air		0.333		
		5	0.091	20.350	0.235
		total thickness	total u-value	avg density	avg specific heat
E	gypsum board	0.625	1.136	40	0.270
	insulation (fiberglass)	3	3.333	0.7	0.200
	Air		0.333		
		4.25	0.208	12.259	0.221
		total thickness	total u-value	avg density	avg specific heat
F-1 to 2	gypsum board	0.625	0.568	40	0.270
	insulation (fiberglass)	3	10.000	0.7	0.200
	Air		0.000		
		3.625	0.095	7.476	0.212
		total thickness	total u-value	avg density	avg specific heat
F-3 to 11	gypsum board	0.625	0.568	40	0.270
	insulation (fiberglass)	4	13.333	0.7	0.200
	Air		0.000		
		4.625	0.072	6.011	0.209
		total thickness	total u-value	avg density	avg specific heat
F-12 to 14	gypsum board	0.625	1.136	40	0.270
	insulation (fiberglass)	4	13.333	0.7	0.200
	Air		0.000		
		5.25	0.069	10.057	0.217
		total thickness	total u-value	avg density	avg specific heat
F-16 to 20	Plywood	0.75	1.080	28	0.45
	gypsum	0.625	0.568	40	0.270
		1.375	0.607	33.455	0.368
		total thickness	total u-value	avg density	avg specific heat
G-1 to 3, 7,	Steel plate	0.3125	0.012	489	0.120
	Plywood	0.75	1.080	28	0.45
	gypsum	0.625	0.568	40	0.270
		1.6875	0.602	117.815	0.322
		total thickness	total u-value	avg density	avg specific heat
G-4&5	gypsum board	0.625	1.136	40	0.270
	acoustics tile	5	11.905	21	0.000
	gypsum board	1	0.909	40	0.270
		7.25	0.072	26.897	0.270
		total thickness	total u-value	avg density	avg specific heat
H	gypsum board	0.625	1.136	40	0.270
	acoustics tile	3	7.143	21	0.000
	gypsum board	1	0.909	40	0.270
		5.25	0.102	29.143	0.270
		total thickness	total u-value	avg density	avg specific heat
M	masonary	4	1.110	100	0.21
		4	0.901	100.000	0.210
		total thickness	total u-value	avg density	avg specific heat

U-value of Roof			
	R-value	thickness [in]	total u value
E-1 Sidewalk & plaza (over Tempered) & conditioned below-grade space)			
4" reinforced concrete wearing surface	0.1	4	0.4
Filter fabric	0	0	0
Rigid insulation (polystyrene)	0.2	6	1.2
Composite Drainage Panel	0	0	0
Protection board	0	0	0
Waterproofing membrane	0	0	0
Sloped structural concrete slab or fill	0.1	4	0.4
		total u value	0.5
R-1 Terrace Roofs			
4" reinforced concrete wearing surface	0.1	4	0.4
Filter fabric	0	0	0
Rigid insulation (polystyrene)	0.2	6	1.2
Composite Drainage Panel	0	0	0
Protection board	0	0	0
Leak detection mat	0	0	0
Waterproofing membrane	0	0	0
Sloped structural concrete slab or fill	0.1	4	0.4
		total u value	0.5
R-2 Clerestory Gutters+(Over Conservation Spaces)			
Galvanized (Or stainless steel) Grating			
Counter flashing at skylight			
snow melting cables TBD	Not Used		
Primary flexible PVC Membrane			
Steel Substrate			
R-3 M&O building roof terrace (Over Substrate By Others)			
Pre-cast Concrete Pavers on Adjustable Pedestals	0.1	2.25	0.225
Roofing Substrate By M&O			0.333
		total u value	1.791
R-4A South Roof Perimeter (Over Conservation Spaces)			
Metal Grating	0	0	0
snow melting cables (5ft in width or less)	0	0	0
Gravel	0	0.5	0
Rigid Insulation (Polystrene)	0.2	3.6	0.72
Composite Drainage Panel	0	0	0
Protection Board	0	0	0
Waterproofing membrane P.M.M.A.	0	0	0
Slope structural Concrete Slb or Fill or Steel Structure	0.1	4	0.4
		total u value	0.893
R-4B South Roof Perimeter			
4" reinforced concrete wearing surface	0.1	4	0.4
Filter fabric	0	0	0
Rigid insulation (polystyrene)	0.2	4.2	0.84
Composite Drainage Panel	0	0	0
Protection board	0	0	0
Waterproofing membrane	0	0	0
Sloped structural concrete slab or fill	0.1	4	0.4
		total u value	0.610
R-5 North Roof (Over Mechanical Space)			
Integrally Footed Pre-cast Concrete Pavers	0.1	2.25	0.225
Rigid insulation (Polystrene)	0.2	7.75	1.55
Composite Drainage Panel	0	0	0
Protection Board	0	0	0
Waterproofing membrance H.R.A.	0	0	0
Sloped structural concrete slab or fill	0.1	4	0.4
		total u value	0.460
R-6 Loading Dock (Upper Deck Area)			
4" reinforced concrete wearing surface	0.1	4	0.4
Rigid insulation (polystyrene)	0.2	7.75	1.55
Composite Drainage Panel	0	0	0
Self adhering rubberized Asphalt	0.333	1	0.333
Structural Concrete Slab	0.1	4	0.4
		total u value	0.373
R-7 Truck Loading Dock			
4" reinforced concrete wearing surface	0.1	4	0.4
30 # felt in Hot Asphalt	0.3333	6	1.9998
Foamglas insulation in hot asphalt	3	1	3
Composite Drainage Panel	0	0	0
Waterproofing membrane	0	0	0
Sloped structural concrete slab or fill	0.1	4	0.4
		total u value	0.172
R-8 Exterior Plenum			
Waterproofing Membrane (Elastatex)	0		0
Sloped structural concrete slab or fill	0.1	4	0.4
4-1/2" Spray-applied ployurethane insulation	3	4.5	13.5
		total u value	0.072
R-9 Smoke Plenum (Level 7 - Stair D)			
Waterproofing Membrane (Elastatex)	0	0	0
Densdeck	0.67	0.625	0.419
Tapered Rigid insulation (Polystyrene)	0.15	5.04	0.756
Structural Concrete slab	0.1	4	0.4
		total u value	0.635
GR-1 Greenroof			
extensive growing medium (Soil) 4' min	0.083	4	0.333
Filter Fabric	0	0	0
Drainage Tray	0	0	0
Moisture Retention Mat	0.2	2	0.4
Rigid Insulation (Polystyrene)	0.2	4	0.8
Root Barrier	0	0	0
Waterproofing Membrane H.R.A.	0	0	0
Structural Concrete Slab	0.1	4	0.4
		total u value	0.517
R-10 North Flue roof			
Metal Grating			
Gravel			
Polyester mat			
PMMA waterproofing membrane	Not Used		
5/8" Densdeck			
Tapered rigid insulation			
5/8 " Densdeck			
Corrugated metal deck			