THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF ARCHITECTURAL ENGINEERING

AN ARCHITECTURAL ENGINEERING STUDY AND LIGHTING DESIGN PROPOSAL FOR THE HOUSTON MUSEUM OF AMERICAN ART

CHANG LIU
SPRING 2013

A thesis
submitted in partial fulfillment
of the requirements
for a baccalaureate degree
in Architectural Engineering
with honors in Architectural Engineering

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Houston Museum of American Art

new york, ny

Architecture

The Houston Museum of American Art's design takes a strong and strikingly asymmetrical form, which responds to the industrial character of the neighboring loft buildings and adjacent overhead railway. The upper stories of the building will stretch toward a nearby river on the west side and step back gracefully from the elevated railway on the east side.

Lighting/Electrical

Building system voltage: 208Y/120 volts, 3 phase
75 KVA UPS system
750 KW diesel generator
75 KW gas-fired reciprocating cogeneration unit
Digital network lighting control system
Dual-technology occupancy/vacancy sensors
Interior and exterior daylight sensors

Structural

Concrete slab on composite metal deck on steel framing
Caisson pile-supported foundation
Concrete secant wall around the perimeter of the site
Framing system of long span beams with deck framing
Special steel concentric braced lateral framing system with special steel seismic detailing
Cable supported lobby façade

Mechanical

(4) Air conditioning systems located on cellar & 9th floor
Lobby façade heated and cooled by fan coil units (4-pipe) located along the glass façade wall
All-air VAV system for gallery-type areas, auditorium
All-air constant volume system for lobby, restaurant
(3) Electrically driven centrifugal refrigeration machines 300 TR
(5) Cell roof-top cooling towers with 600 GPM/cell

Statistics

Size:	222,952 sf
Levels:	9 stories above grade
Cost:	$266 million
Construction Dates:	Aug 14, 2012 - Nov 28, 2014
Project Delivery:	Design-Bid-Build

Project Team

Design Architect:	Renzo Piano Building Workshop
Executive Architect:	Cooper, Robertson & Partners
MEP Engineer:	Jaros, Baum & Bolles
Lighting Engineer:	Ove Arup & Partners
Construction Manager:	Turner Construction, LLC

Chang Liu

Lighting + Electrical

http://www.engr.psu.edu/ae/thesis/portfolios/2013/cwl5153/index.html

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Dr. Richard Mistrick	Honors Advisor, AE Lighting Associate Professor, Penn State
Dr. Kevin Houser	Thesis Advisor, AE Lighting Professor, Penn State
Leslie Beahm	Electrical Advisor, Reese Engineering

Family and friends for their support

ABSTRACT

This thesis report was conducted on the Houston Museum in New York City, New York. The Houston Museum of American Art is located at the west side of Manhattan, in the Meatpacking district. The building takes an asymmetrical form with upper stories of the building stretching toward the Hudson River on the west side and step back gradually to the elevated park of the High Line on the east side. The project includes more than 50,000 square feet of indoor galleries and 13,000 square feet of outdoor exhibition space on a series of rooftops facing east. The building also includes an education center, a multiuse black box theater, a study center, conservation lab and library reading room.

This Thesis report discusses the topics, methods, and results that were investigated during a yearlong capstone study on the Houston Museum of American Art. Existing designs were studied in the first semester to examine and find potential spaces to be further studied in the second semester. Engineering and architectural design alternatives were developed in the following semester with the objective of forming an in-depth thesis on building system design.

This thesis is comprised of lighting and electrical depth topics, as well as four additional breadth topics focused on mechanical, acoustical, and architectural engineering. The lighting depth is an investigation into design alternatives for a large work space, a circulation space, a special purpose space and building facade based on the re-imagined lighting concept. The electrical depth is interrelated to the CHP system to change the system voltage from 208Y/120V to 480Y/277V.

The first breadth is an investigation of the daylighting integration for the 8th floor gallery space. The second breadth is an investigation of the social aspects that can contribute to the re-imagined lighting concept, include self-congregation, motivation as well as scale perception. The third breadth is an investigation of the acoustical property of the theater space. The findings were coordinated with the alternate lighting design for the space. The fourth breadth is an investigation on the application of on-site energy production and waste heat recovery, also known as combined heat and power or cogeneration. The study will investigate the feasibility of cogeneration for the project based on EPA recommendations.

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SECTION ONE | project background

The existing Houston Museum is located in uptown, Manhattan. The new building which is the basis of this thesis report will vastly increase the Houston's exhibition and programming space. At the moment of this thesis being written, the new Houston is under construction in downtown Manhattan, and will be open to the public in 2015. The new building is designed by architect Renzo Piano and will situate between the High Line and the Hudson River.

The concept for the re-design is inspired by the following statement by Neil G. Bluhm, president of the Board of Trustees for the Houston, and Renzo Piano, the architect, respectively:

> *"The museum will be a dynamic new presence downtown … as a vital resource that engages the neighborhood, enlivens the cultural dialogue, and welcomes the people of New York and beyond."* *- Neil G. Bluhm*

> *"The future Houston is designed to embrace and reciprocate the energy of the neighborhood and provide a stimulating and immersive space in which to experience art."* *- Renzo Piano*

SECTION TWO | building statistics

SITE INFORMATION

The Whitney's new building will be located in the Meatpacking District on Gansevoort Street at the southern entrance to the High Line.

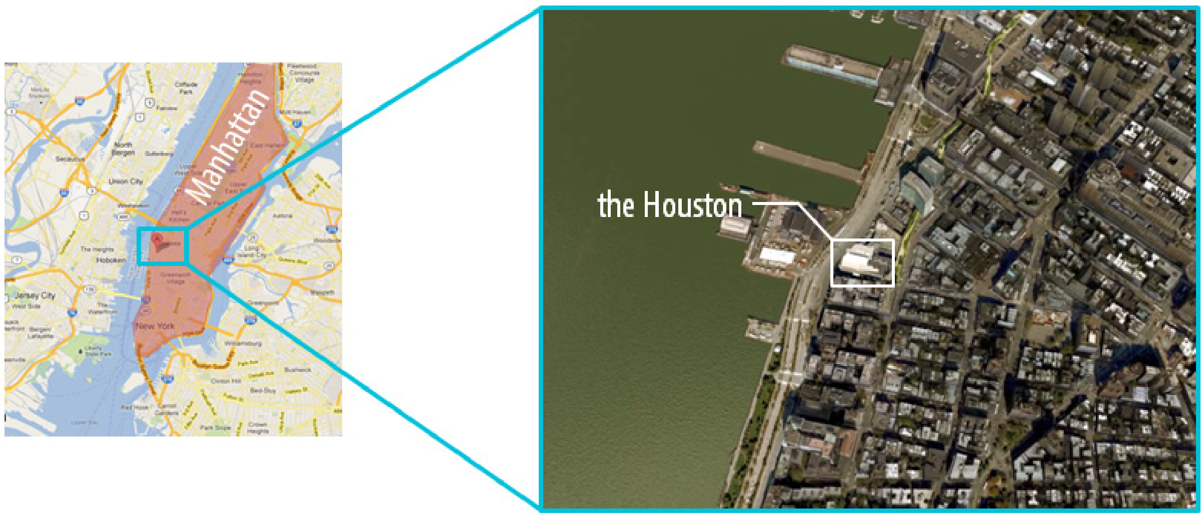


Figure 1 | Site information

The meatpacking district is a twenty-square-block neighborhood on the far West Side of Manhattan. Just north of Gansevoort Street are some of New York's most notable restaurants, bars, fashion boutiques, clubs, and hotels. The neighborhood is bordered to the north and east by Chelsea, renowned for its art galleries, cultural organizations, and educational institutions. To the south is the West Village and its nineteenth-century townhouses, charming streets, and unique shop. To the West is the Hudson River.

The High Line is New York City's newest and most unique public park. It's one of the most ambitious urban reclamation projects. Located thirty feet above street level on a 1930s freight railway, the High Line is a linear park that extends for 22 blocks running from Gansevoort Street in the Meatpacking District to 34th Street in Clinton/Hell's Kitchen, allowing pedestrians to pass from neighborhood to neighborhood without coming in contact with a single vehicle and to see the city from a floating vantage point. It features an integrated landscape combining meandering concrete pathways with naturalistic plantings. The park opens from 7:00am to 7:00pm during winter seasons and 7:00am to 11:00pm during summer seasons.

Figure 2 | Meatpacking district pictures

GENERAL BUILDING DATA

Building Name: Houston Museum of American Art
Location and Site: New York, NY
Building Occupant Name: Houston Museum of American Art
Occupancy or function types: A-3 (Assembly). The proposed building will contain dedicated gallery space, education and studio spaces, art-handling spaces, a restaurant, a café, a theatre, special-events spaces, museum shop, and a conservation lab.
Size: 222,952 SF
Number of Stories above Grade: 9
Primary Project Team:
Owner: Houston Museum of American Art
Design Architect: Renzo Piano Building Workshop www.rpbw.com
Executive Architect: Cooper, Robertson & Partners www.cooperrobertson.com
MEP Engineer: Jaros, Baum & Bolles www.jbb.com
Lighting/Daylighting Engineer: Ove Arup & Partners www.arup.com
LEED Consultant: Viridian Energy and Environmental, LLC www.viridianee.com
Structural Engineer: Robert Silman Associates www.rsapc.com
Construction Manager: Turner Construction, LLC www.turnerconstruction.com
Dates of Construction: August 14, 2012 - November 28, 2014
Actual Cost: Building is under construction; estimated cost is 266million (100% CD)
Project Delivery Method: Design-Bid-Build

ARCHITECTURAL INFORMATION

The Houston Museum of American Art's design takes a strong and strikingly asymmetrical form, which responds to the industrial character of the neighboring loft buildings and adjacent overhead railway. The upper stories of the building will stretch toward a nearby river on the west side and step back gracefully from the elevated railway on the east side. The building's massing is shaped in a faceted manner to provide view corridors between the adjacent elevated railway and the adjacent river. Additionally, the bulk of the building's mass is concentrated on the west side of the site. The building steps down toward the east in order to defer to the scale of the elevated railway and the existing neighborhood. Outdoor terraces will be located on each of these steps. One of the terraces will be used as "Testing Platform" for outdoor sculpture. A dramatically cantilevered entrance will shelter an 8,500SF outdoor plaza. The building will include more than 50,000SF of indoor galleries and 13,000SF of outdoor exhibition space on a series of rooftops, including an 18,000SF column-free museum gallery. The building also will include an Education Center offering dedicated space for state-of-the-art classrooms; a multi-use black box theater for film, video, and performance with an adjacent outdoor gallery; a 170-seat theater, a Works on Paper Study Center, large art Conservation Lab, Library Reading Room, a retail shop and restaurant on the ground-floor level and a top-floor café.
Major National Model Codes: IBC 2007
Zoning: District(s) M1-5 light manufacturing district (high performance)
Historical Requirements: Not applicable

SUSTAINABILITY FEATURES

This project is registered with the U.S. Green Building Council under the Leadership in Energy and Environmental Design (LEEDTM) rating system:

Version: LEED 2009 for New Construction
Rating: Minimum Silver Certification
Owner's environmental requirements for construction including

Ensure good indoor air quality (IAQ) during construction.
Support reduced future maintenance and operation costs.
Ensure reduced energy use and cost during construction.
Reduce primary and secondary usage of fossil fuels and other Greenhouse gasses during construction.
Ensure reduced water usage during construction and facilitate minimizing planned overall annual facility water usage.
Give added decision-tree weight to minimizing life-cycle costs and overall embodied energy of systems, products and materials incorporated into the project.
Manage demolition, sitework and construction to minimize waste, promote salvaged reuse, recycling or energy conversion, and specifically minimize amounts sent to landfills.
Take preventative measures to reduce or eliminate environmental pollution and damage during construction.

CONSTRUCTION METHOD

Turner Construction Company is the primary construction management firm for this project. The delivery method is design-bid-build with a project estimation cost of 266 million dollars. BIM is used for MEPS Trade Coordination for the project. The entire building system include ventilation, lighting, power, systems, fire systems and security systems are operated with BMS via BACnet.

ELECTRICAL SYSTEM

The building utilization voltage is 208Y/120V, 3 phase with 750KW diesel fuel for emergency power system. The electrical system also includes a 75KVA UPS back-up system for electronics. The utility company for the project is the Consolidated Edison Company of New York. Four indoor free-standing, dead-front single ended 4000A service switchboards are used to feed the power to the building. The panelboards are MCB, bolt-in with NEMA 1 for indoor enclosure, NEMA 3R for wet locations. Copper conductors with soft-drawn annealed copper are used.

LIGHTING SYSTEM

Track lighting systems are used for the majority of the space inside the building including gallery areas, lobby, theater, etc. The system utilizes digital network lighting control as well as dual-technology occupancy/vacancy sensors. A solar clock is used to track the position of the sun to control the shades to limit penetration of direct sunlight. A lighting management hub utilizes Ethernet to integrate control station devices, power panels, shades, preset lighting controls, and external inputs.

MECHANICAL SYSTEM

Gallery-type areas and auditorium are served by all-air VAV system located on the cellar level(3) and level 9(1). Lobby and restaurant are served by all-air constant volume system located on level 1. The lobby façade is heated and cooled by fan coil units located along the glass façade wall. The main refrigeration plant consists of three electrically driven centrifugal refrigeration machines sized at 300 tons-refrigeration each on the Cellar level and a five 200 tone cells cooling tower. The building is heated by hot water heating boiler plant consists of five condensing 3 million Btuh input hot water boilers.

STRUCTURAL SYSTEM

The structural system for the Houston Museum of American Art is primarily composed of concrete slab on composite metal deck on steel framing. The framing system is composed of long span beam with deck framing and special steel concentric braced lateral framing system with special steel seismic detailing. The foundation is caisson pile (encased in steel with diameters of either 9.875" or 13.375") supported and perimeter of the site is surrounded by concrete secant walls.

SECTION THREE | lighting depth

> *"The museum will be a dynamic new presence downtown … as a vital resource that engages the neighborhood, enlivens the cultural dialogue, and welcomes the people of New York and beyond."* *- Neil G. Bluhm*
>
> *"The future Houston is designed to embrace and reciprocate the energy of the neighborhood and provide a stimulating and immersive space in which to experience art."* *- Renzo Piano*

The overall lighting concept was developed based on the architect and building owner's vision for the future Houston. Their vision emphasize on creating a dynamic, welcoming, enlivening, energetic, stimulating, immersive and most importantly engaging museum. The lighting concept extends from the idea of engaging the neighborhood, the culture, the energy and most importantly the people.

The design process is complex and powerful. The lighting approach and purpose in this thesis work is as much social as they are functional and aesthetics. The core lighting study started with investigating the relationship between people and their perceived world and valuing the idea that our field of view contributes largely to our complete understanding and experiences of the space.

By examining the different scale of human perception and the amount of interaction between people and their surroundings, the goal is to interpret and predict how lighting design will influences our understanding of the space. Finally, the lighting concept is re-imagined with the knowledge that specific and varying kinds of encounters, key to the unique social structure of the public life in New York City. (Refer to the honors breadth for the detailed analysis of the social concepts taken into consideration)

Exterior space | BUILDING FAÇADE

DESCRIPTION
The overall building shape is very sculptural and unusual. The building's massing is shaped in a faceted manner to provide view corridors between the Highline Park and the Hudson River. The bulk of the building's mass is concentrated on the west side of the site. The architect designed the building to step down toward the east in order to defer to the scale of the High Line Park and the existing neighborhood.

During the daytime, the façade becomes a dynamic presence and interaction with nature by constantly reflecting the mood of the sky. It captures and makes perceptible the delicacy, daily and seasonal dynamic, temporal rhythms, light and shadow and shifting color.

The exterior façade of the future Houston plays a prominent role in composing its identity at night. A design that really responds to the site and its neighborhood, the lighting solution should be established to enhance the building's dynamic presence and echoes the neighborhood's vibrant energy.

SURFACE MATERIAL

Surface	Name	Description	Reflectance
Façade	C-4	Pre-cast concrete panel with smooth-as-cast finish, 2-hr fire rated with double seal and weep tubes at vertical joint	0.5
	M-1	Carbon Steel. Custom color metallic feve	0.6
	WT-2	Steel plate rainscreen cladding system	0.7
	WT-6	Cable Wall glazing	

Table 1 | building facade surface material

The building façade is composed of Steel Plate Rainscreen Cladding System. The system consists of 5/16" thick light gray enamel steel panels cladding with stainless steel mounting hardware and exposed stainless steel fasteners. Other materials utilized are precast concrete, and cable wall.

DESIGN CRITERIA
Qualitative Criteria:
The exterior façade of Renzo Museum of American Art plays a prominent role in composing its identity. The unique asymmetrical façade calls for a complementary lighting solution. The owner's vision for the museum is for it to embrace and reciprocate the energy of the neighborhood and provide a stimulating and immersive space in which to experience art. A cohesive exterior lighting design should not only showcase the vitality of the space, but at the same time provide a safe and pleasant gathering space and cultural harbor. At the same time, light pollution and trespass should be taken into consideration during design.

IES suggested important criteria:
Appearances of Space and Luminaires
Light Distribution on Surfaces
Light Pollution / Trespass
IES suggested very important criteria:
Point(s) of Interest
Reflected Glare
Shadows
Source/Task/Eye Geometry
Surface Characteristics
Color Appearance (and Color Contrast)
Direct Glare

Modeling of Faces or Objects

Quantitative Criteria:

Illuminance Recommendation [IES Lighting Handbook 10^{th} Edition (Table26.2, 26.4, 22.4)]:

Space Type	E_v
Building Façade	Lighter-toned façade materials (Reflectance ≥0.5), 200 lux ; Darker-toned façade materials (Reflectance <0.5), 400 lux

Note: High activity, LZ-3

Energy Allowance [ASHRAE standard 90.1]:

Space Type	Power Density (W/sqf)	Note
Building Façade	0.2 W/ft^2 for each illuminated wall or surface or 5.0 W/linear foot for each illuminated wall or surface length	Tradable
Building Grounds	1.0 W/linear foot for walkways less than 10 ft wide. 0.2 W/ft^2 for walkway 10 ft wide or greater, plaza areas, and special feature areas	Nontradable
Canopies	1.25 W/ft^2	Tradable

DESIGN APPROACH

The lighting design takes two general approaches to the building façade based on the scale of perception discussed in the architectural breadth.

1. Activating the north façade to grab High Line pedestrian's attention. It is important to avoid a flat wash, instead using different lighting intensity to bring out the depth of the building volumes.
2. The interior luminaires also play an important role in constructing the appearance of the façade at night. Placement, consistency as well as intensity throughout the building is paramount.
3. Another emphasis of the façade lighting is at the south east for walking pedestrian passing by on Washington and Gansevoort streets. Thus, lobby lighting need to be incorporated to coordinate.

COMPUTER RENDERINGS

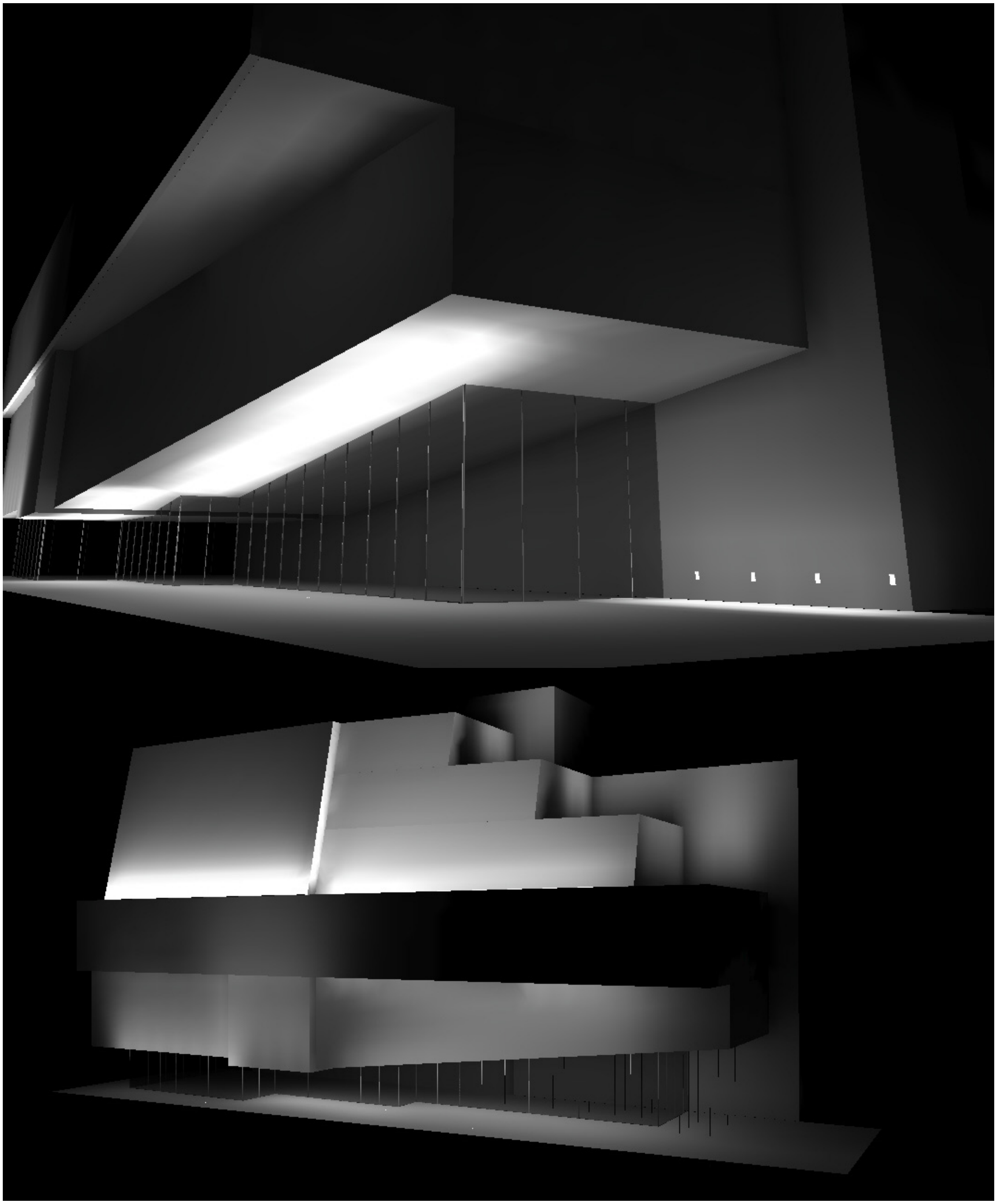


Figure 3 | facade rendering

LUMINAIRES
AL-7, LED ingrade
AL-8, LED step light

AL-9, LED linear luminaire

PERFORMANCE DATA
Using LED is able to increase the light level while still be able to maintain under the power density requirement set by ASHREA.

PERFORMANCE SUMMARY
The lighting redesign for the building façade is thoroughly investigated before implementation. Situated in the city that never sleeps where extravagant lighting is everywhere, the Houston Museum's light design has a more elegant and subtle take that is oriented toward the public experiences. The overall goal of engaging the people through an element of construction that is not touchable is achieved. The central idea of "people, building, city – in that order" presents itself through the lighting design.

The design approach was realized through different lighting element. The activation of the north façade is through the silhouette produced by the interior light and the surrounding lighting with the city as the back drop. Not only were the cream-color façade plates able to catch the natural light, they were perfect mirror of what's going on around the Houston. Thus the building will reflect a decent amount of light from other buildings around.

The south façade was lit with the emphasis of human scale. Instead of using large luminaires and lighting design that focus on the form of large units that removed life from the streets, more intimate luminaires were implemented. Additionally, to blend into the surrounding, the lighting design is subtle and simple. The outset goals were achieved. Additionally, the illuminance levels meet those specified in the IESNA handbook.

Circulation space | MAIN LOBBY

DESCRIPTION
The main lobby of the Houston Museum of American Art consists of a 1000-sqf gallery that is free of charge and open to public. Sculptures and outdoor installations will be exhibited, along with a membership booth located in the center of the lobby and a ticketing booth on the south-east corner. The main lobby has two different ceiling heights. From the center of the membership booth to the east, ceiling height is 14ft, and from the center of the membership booth to the west, ceiling height is 17ft. Figure 4 shows the spatial information of the main lobby through floor plan, reflected ceiling plan and interior elevations. The lobby space serves as an indoor plaza and the primary tasks in this space are circulation, socialization and exhibition.

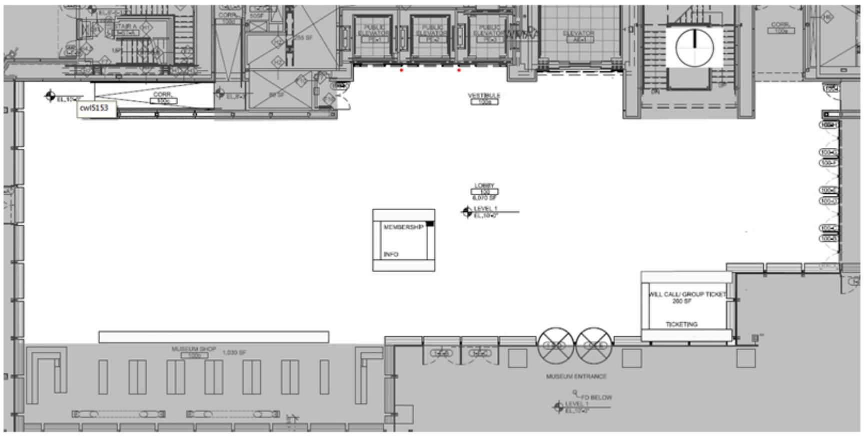


Figure 4 | Lobby floor plan

Dimensions:
Area = 6070 ft^2
Length = approx. 142 ft.
Width = approx. 43 ft.
Ceiling Height =
West portion 14 ft.
East portion 17 ft.

SURFACE MATERIAL

Surface	***Name***	***Description***	***Reflectance***
Floor	*S-1*	*3CM stone thermal finish*	*0.2*
Wall	*C-5*	*Pre-cast concrete panel with smooth-as-cast finish, Non fire rated with double seal and weep tubes at vertical joint*	*0.5*
Ceiling	*CL-7*	*Acoustic plaster*	*0.75*

Table 2 | Lobby surface material

The exterior wall of the main lobby use cable wall system which consists of two 3/4” diameter pre-tensioned stainless steel cables taking lateral and gravity loads, with custom stainless steel patch fittings supporting laminated glass lites. Glazing module is 3’-4” wide.

DESIGN CRITERIA
Qualitative Criteria:
Traditionally, lobby is the space used to for visitors to transit from exterior to interior and vice versa. However for the Houston Museum of American Art, the lobby space is also an exhibition space, and an interior plaza. Thus, the main lobby serves three main purposes: it is the space adjacent to the entrance for circulation, it invites and gathers the neighborhood, and it is also an exhibition space. The circulation and general lighting in the lobby should meet the illuminance recommendation for safety reason. Flexible lighting solution should be applied to adapt to the various uses of the lobby space. As the public’s primary physical and visual link to the rest of the museum, the lighting solution for the main lobby need to attract

the neighborhood and correspond to the exterior changes, such as daylight. The lighting in the lobby also aims to create an engaging and welcoming environment. High quality color rendering is also important for visitors to truly experience the art installations in the space. Furthermore, IES 10^{th} edition also suggested that for purpose of visual consistency and of maintenance convenience, lamp types and color qualities should match those used elsewhere.

IES suggested very important criteria:
Appearance of Space and Luminaires
Daylighting Integration and Control
Point(s) of Interest

IES suggested important criteria:
Modeling of Faces or Objects
Surface Characteristics

Quantitative Criteria:
Illuminance Recommendation [IES Lighting Handbook 10^{th} Edition (Table21.2)]:

Space Type	E_h	E_v	Avg:Min
Lobby - Day	100 lux @ floor	30 lux @ 5ft AFF	4:1
Lobby - Night	50 lux @ floor	20 lux @ 5ft AFF	4:1

Energy Allowance [ASHRAE standard 90.1]:

Space Type	Power Density (W/sqf)
Lobby	1.3 W/ft^2

DESIGN APPROACH
The temporary artworks displayed in the lobby provide an attractive selection of experiences and unpredictability.

1. Exhibition lighting should solely rely on directed light (spotlights) to bring out the shapes of the exhibits. The reflection from the walls always produces an indirect, diffuse component of light, and that is often enough of ambient light for navigation/orientation.
2. The lobby will be illuminated in a way that both provides intuitive way finding for visitors to the museum and highlight the sculptures and as well as stage on a show of people.
3. The lighting design in the lobby approaches from the social aspect of people flow and correspond to the strong and striking asymmetrical form. To reinforce the unpredictability of the exhibition selection, light tracks are installed based on the people mapping of the space. How potential movement is distributed is studied. Data is proposed based on movement paths and stop locations.
4. Track-mounted spotlights are deployed throughout the lobby, recessed into ceiling channels. The linear language of tracks and recessed slots accentuate the architectural vocabulary and ceilings while provide spotlighting, wall washing and general lighting flexibility throughout.

DAYLIGHT CONDITION

A preliminary daylighting analysis was conducted to investigate the sun penetration of the lobby area throughout the year. Daylight and sunlight will be embraced in the space as a possibility for man to claim a slice of the sun, and to see all the possibilities an artworks possess. To embrace the cool the warmth of the sun in this concrete jungle. To be grasped by the warmth of the sunlight and the marvelous change of mood of the sky, to experience the intertwined realms of public and private created by the light and shadow. Shadow study is done for the lobby space. Following images show the shadows on multiple dates (December 21, September 21, June 21 and March 21) under a clear sky. The images are in sequence from 11am when the museum opens to 6pm when the museum close to the public.

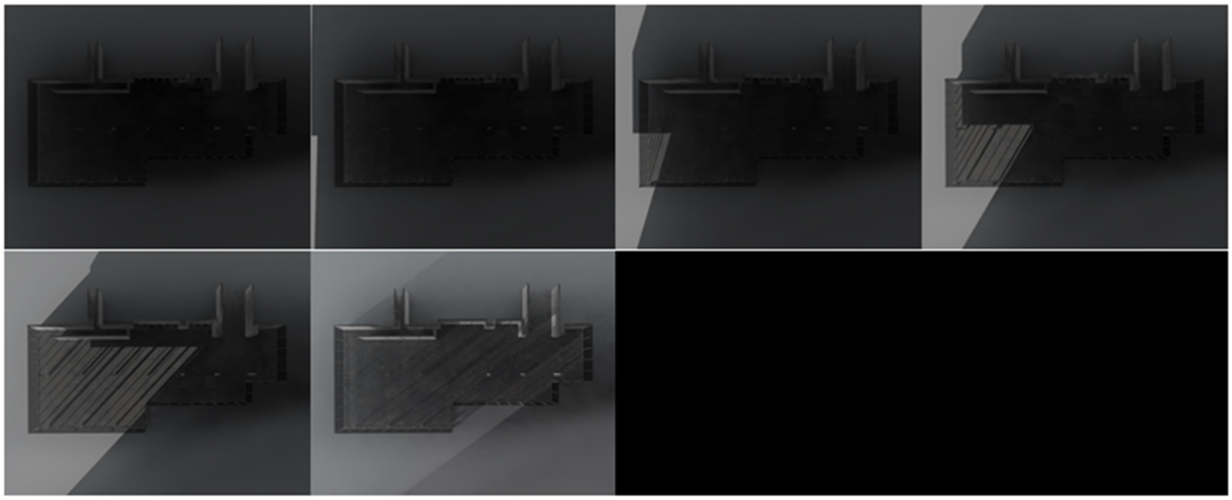


Figure 5 | December 21 Shadow Study - lobby

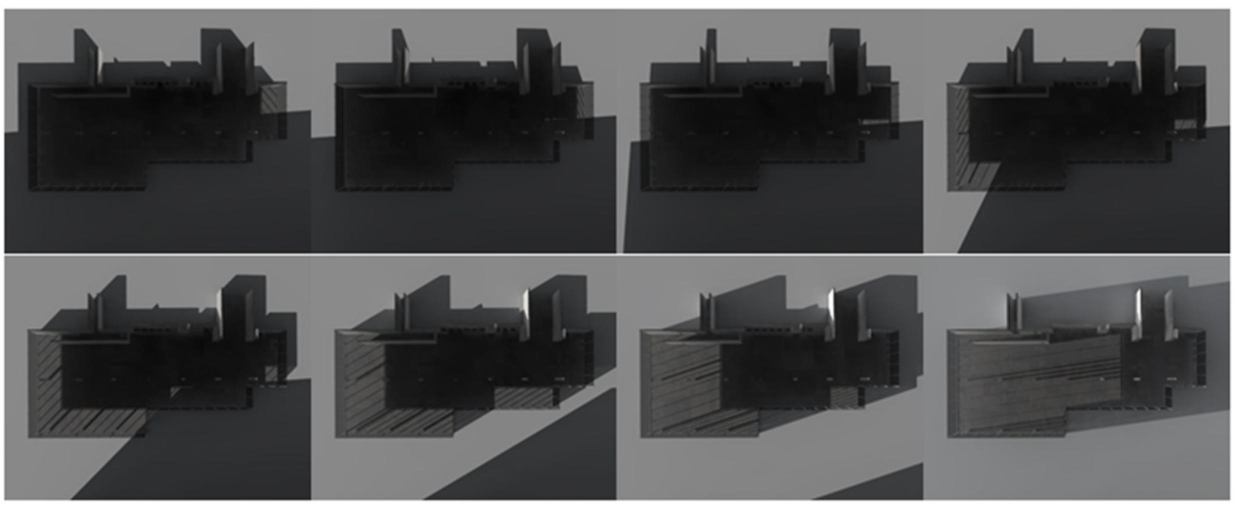


Figure 6| September 21 Shadow Study – lobby

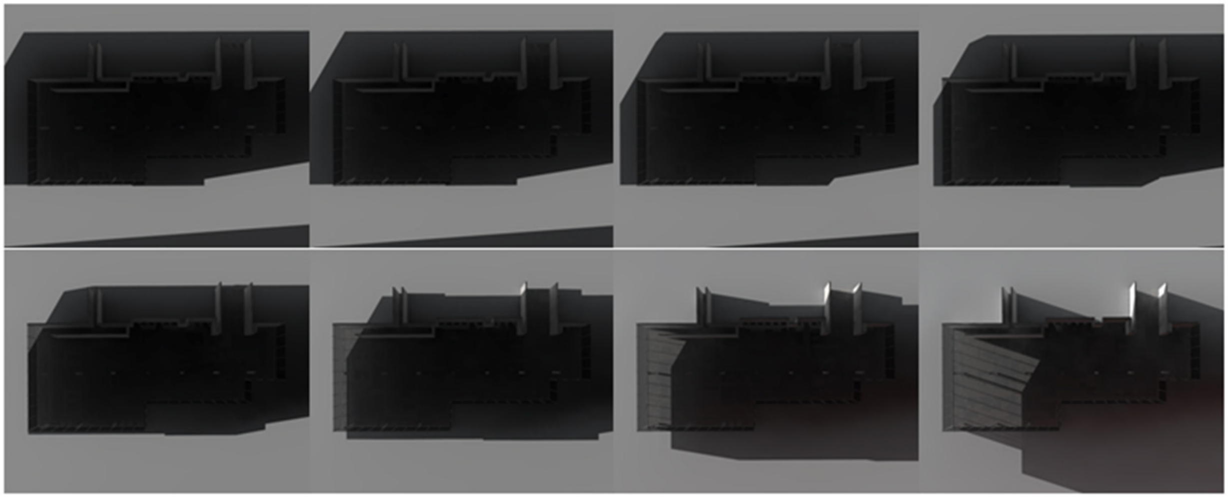


Figure 7 | June 21 Shadow Study - lobby

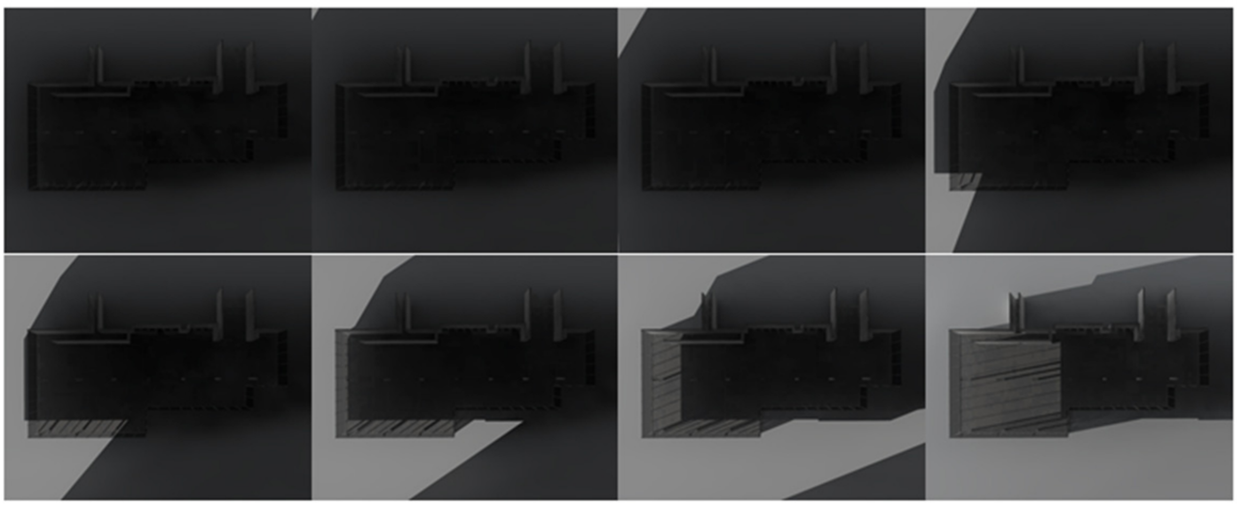


Figure 8| March 21 Shadow Study - lobby

Figure 5, Figure 6, Figure 7, *and* Figure 8 shows the museum lobby receive direct sunlight penetration during the afternoons when sun is very low. The adjacent apartment complex was taken into consideration in building the daylight model, as well as the upper floors of the museum. However, it is very likely that buildings beyond the extents of the model can block the direct sunlight.

COMPUTER RENDERINGS

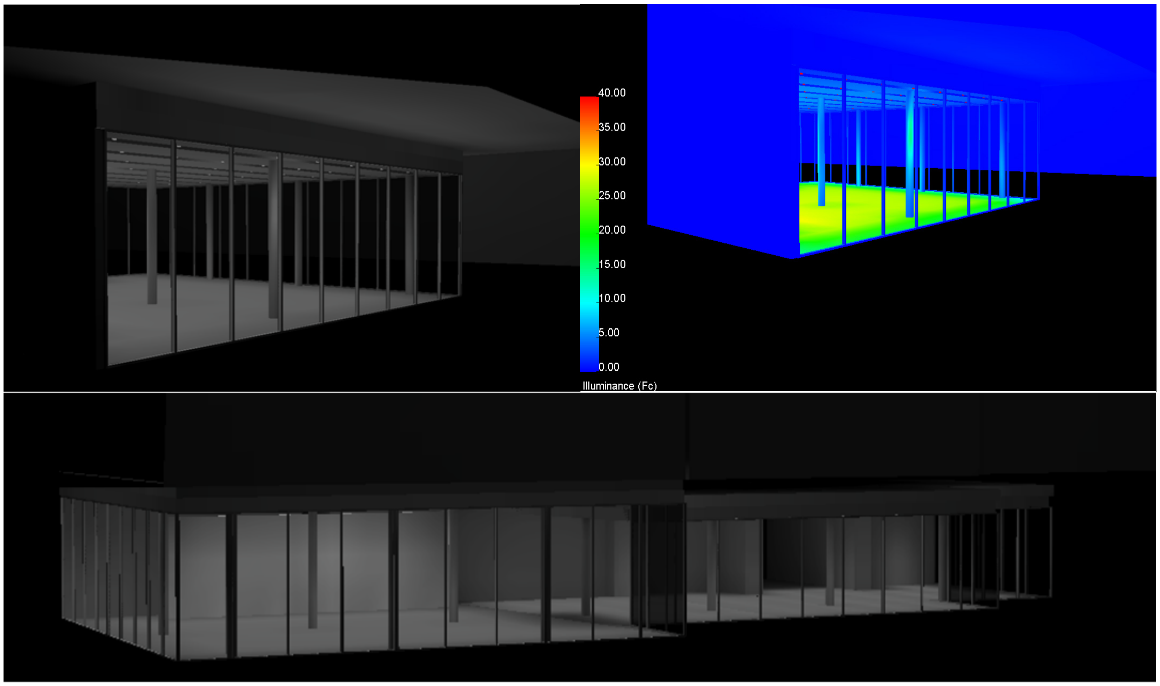


Figure 9 | Lobby renderings

LUMINAIRES

AL-1, LED spotlights with flood distribution lens
AL-2, LED spotlights with spot distribution lens
AL-4, LED wall washer

LIGHTING PLAN

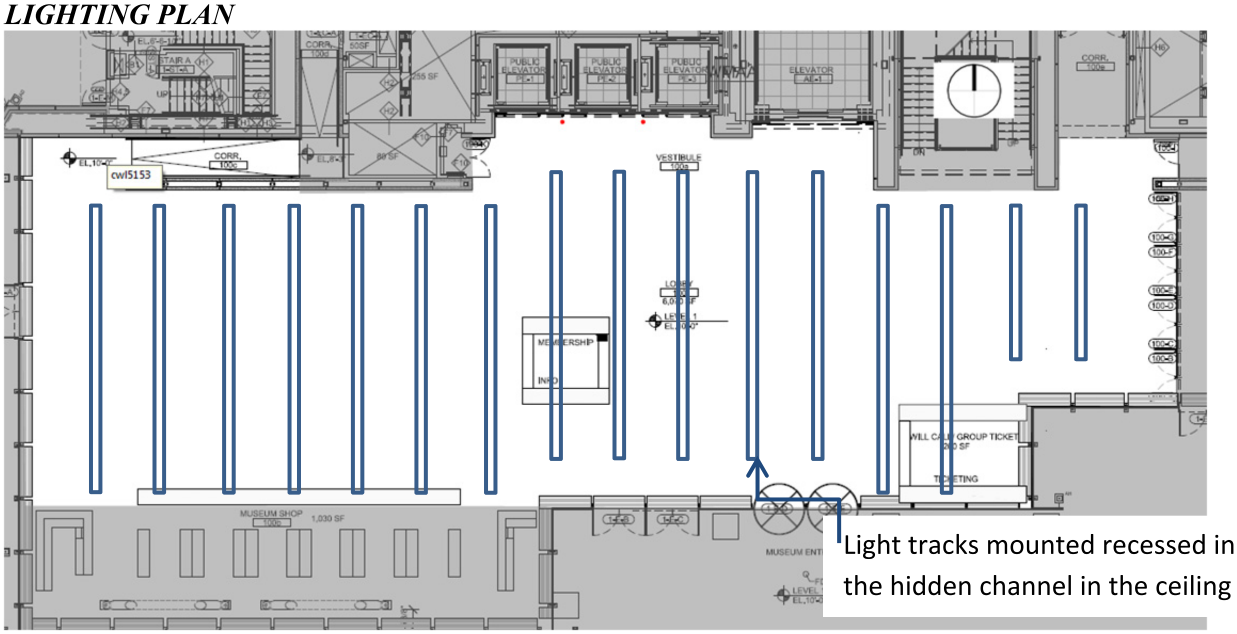


Figure 10 | lobby lighting plan

PERFORMANCE DATA

Illuminance level – target | provided	100lux |87 lux
Avg:Min – target | provided	4:1 | 3.7:1
Power density – target | provided	1.3W/ft^2 0.69 W/ft^2

PERFORMANCE SUMMARY

Depending on the sculptures in the space, spotlights from different directions will need to be aimed to perform the desired sculpture lighting. Overall lighting system in the lobby space is very simple and flexible. The goal of achieving an obtrusive system construction is also achieved through recessed channels that allow tracks and luminaires to be hidden.

The target of 100 lux is achieved with a preliminary light level calculation in lobby. However, depend on the museum's intention of the space; spotlights will need to be particularly aimed for the sculpture and installations. The shadow study introduces the idea that while direct sunlight penetration can occur in the space, it is not necessary to block it. Since the lobby area acts as a plaza rather than a regular museum lobby, it was decided that most of the times, the sunlight would not being treated as disturbing, but rather as a connection to the nature.

Overall, the light redesign for the space took a different approach from the original light design where the general areas in the museums are lit using surface mounted track lighting system. The hidden channels introduce less bright spot on the ceiling when pedestrians walk by at night. Rather, the idea of depth is introduced as people can see deep into the space because of the obtrusive lighting system. Design criteria were met.

Special purpose space | THEATER

DESCRIPTION

The theater located on the south east corner of the third floor, houses 170 seats. The theater space is used for multiple configurations and activities, including performances, films, and installations. A similar track system as the lobby is proposed with the addition of wall washers to wash the walls to create a more pleasant space for the audience in between performances. Because of the multipurpose nature of the room, the lighting solution needs to be flexible. One typical problem with adding linear tracks is that lines introduce directions. To reinforce the flexibility of the room, the track drew inspiration from the industrial character of the neighborhood and overhead railway, mimicking a railway track change pattern.
It has an area around 2,400 square feet (64 ft x 37 ft) with a ceiling height of 25’ 11”.
Black box Theater application includes:

1. Multi-media presentations
2. Motion picture films
3. Lectures
4. Podium discussions
5. Performances
6. Screening of new artwork
7. Rentable for outside parties

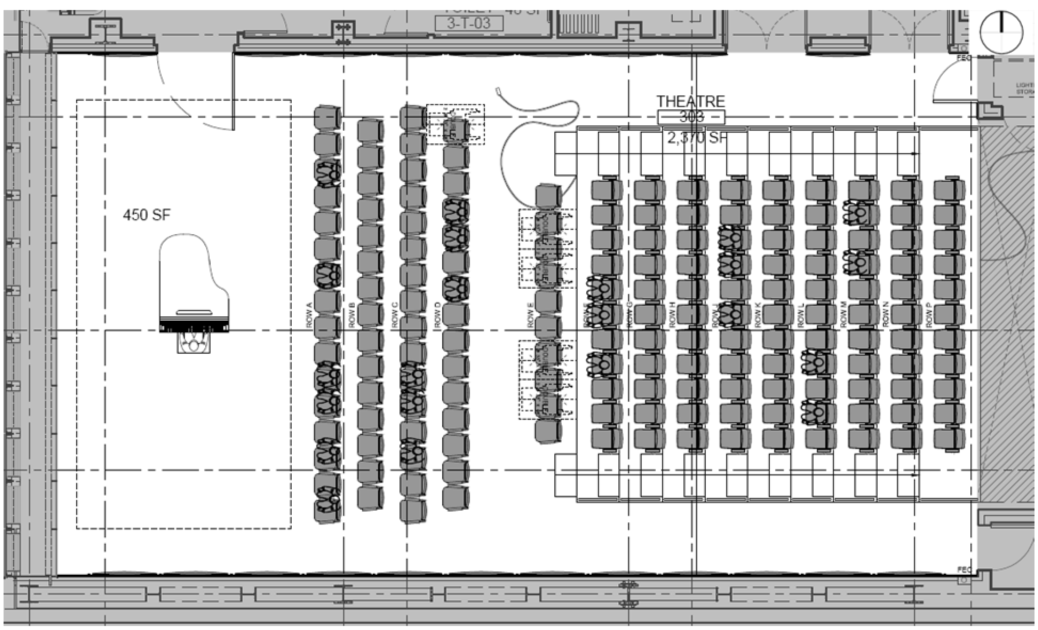


Figure 11 | Theater floor plan

SURFACE MATERIAL

Surface	Name	Description	Reflectance
Floor	W-1	Yellow Pine Flooring 4” Width	0.4
Wall	P-2	Gypsum wall board, painted	0.6
	PLYWO	3/4" thick square edge Plywood Panel	0.5
Ceiling	CL-10	Theater ceiling assembly - reflective	0.7
	CL-11	Theater ceiling assembly - absorptive	0.7

Table 3 | Theater surface material

The glazing system consists of WDW-1 windows integrated with WT-2 system, of a 10 mm low iron outer lite, 12 mm argon filled cavity, and 10 mm laminated inner lite (5 mm low iron/1.5 mm clear PVB interlayer/ 5 mm low iron) with neutral appearance high performance low-e coating on the #2 surface, and laminated outer lite for acoustical performance.

DESIGN CRITERIA

Qualitative Criteria:

As the theater architectural lighting serves different functions for film, performance and installation, flexibility of the design is crucial. Some other very important criteria for the space include high color rendering (CRI≥85) as well as good dimming ability (smooth, excellent dimming range, etc.). Aisle lighting need to meet the requirement for illuminance and uniformity to allow for safe and convenient access into and out of the space at all times. Minimum shadow for aisle lighting is desired.

IES suggested important criteria:
System Control and Flexibility
IES suggested very important criteria:
Color Appearance (and Color contrast)
Daylighting Integration and Control
Modeling of Faces or Objects

Quantitative Criteria:

Illuminance Recommendation [IES Lighting Handbook 10th Edition (Table28.2)]:

Space Type	E_h	E_v	Avg:Min
Audience Seating - During production	2 lux @ floor	1 lux @ 5ft AFF	2 : 1
Audience Seating - pre/post production and during intermissions	100 lux @ floor	30 lux @ 5ft AFF	2 : 1
Circulation - During production	2 lux @ floor	4 lux @ 5ft AFF	5 : 1
Circulation - pre/post production and during intermissions	100 lux @ floor	30 lux @ 5ft AFF	2 : 1

Energy Allowance [ASHRAE standard 90.1]:

Space Type	Power Density (W/sqf)
Audience/Seating Area for Performing Arts Theater	2.6 W/ft^2

DESIGN APPROACH

The black box theater located on the third floor is designed to be used for multi-media presentations, motion picture films, lectures, podium discussions, performances, screening of new artwork, and it can also be rented for outside parties.

The lighting design in this space explores the idea of coverage vs. flexibility. For the extreme variable purpose and activities that will be going on in this room, a very flexible lighting system can be essential. However exactly how flexible does the system needs is raised, can coverage give you flexibility without over complicate the system. Another important consideration for the space is unlike any other spaces in the building, theater is a place where people will most likely need to wait for the show to start and observe the architecture not necessarily intentionally. So simplicity needs to be fused with drama. The concept offers a great opportunity for the lighting design to shine, to tap the underlying architectural features and at the same time, not losing touch to the museum, to its neighborhood, and to the melancholic, unruly beauty of the high line. To ensure the coverage, adjustable mono-points are recessed into the ceiling. A track system inspired by the rail tracks and the patterns of railroad switch is proposed. The track is to provide spotlighting possibilities of the space.

COMPUTER RENDERINGS

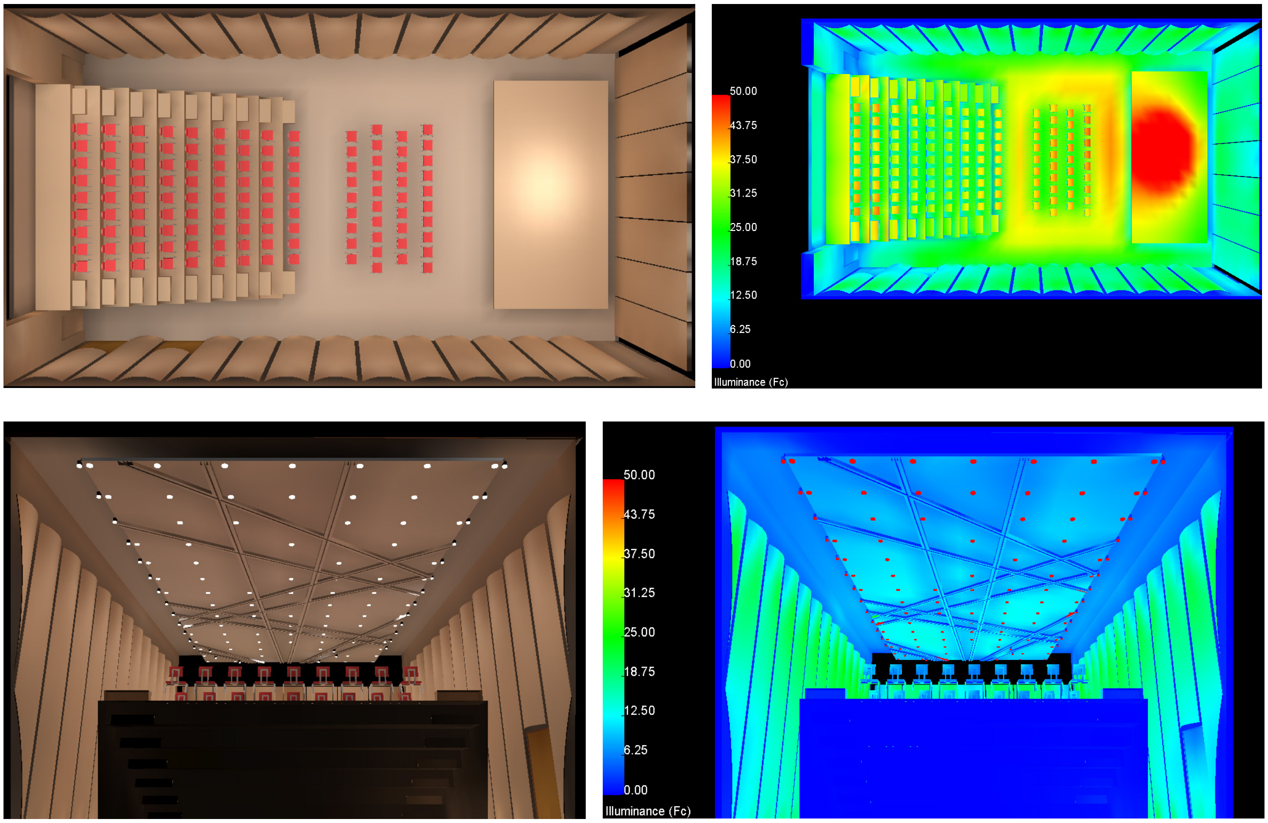


Figure 12 | theater renderings

LUMINAIRES

AL-3, LED wall washer
AL-5 LED downlight
AL-1, LED spotlights with flood distribution lens
AL-2, LED spotlights with spot distribution lens

LIGHTING PLAN

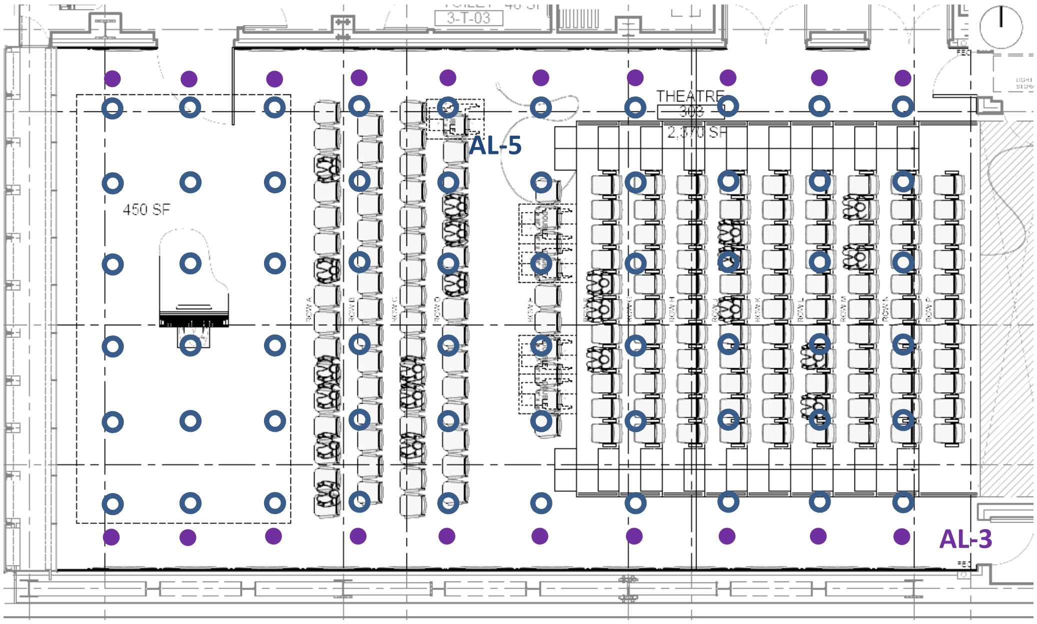


Figure 13 | theater lighting plan

PERFORMANCE DATA

Illuminance level – target | provided	100lux |92 lux
Avg:Min – target | provided	2:1 | 1.8:1
Power density – target | provided	2.6W/ft2 1.19 W/ft2

PERFORMANCE SUMMARY

The lighting design in the theater successfully creates different options for different presets for variable activities. Two color temperature luminaires will be used in the space, but will not be on at the same time. The wall washers, as well as the downlights have warmer color (3000K) for events such as film or small performances. The warm color will help bring out the texture of the wood panel along the wall as well as the flooring. However, during events just as new collection screening, a cooler tone may be required to accurate appreciate the artwork.

The adjustable mono-points offered the flexibility that the space requires. While the railway inspired tracks are a great ceiling variation that offers flexibility and at the same time create drama for the space. Additional theatrical lighting design is required as the main design purpose for theater is house lighting. Similarly to main lobby, the use of primarily LED is able to reduce the power density much lower than traditional HID lighting system.

Large workspace | GALLERY

DESCRIPTION
The 8thfloor gallery is used to display parts of the permanent collection – typically a mixture of oil paintings and some sculpture with some works on paper. Because the gallery is on the top floor, it is the only indoor gallery that has daylight design potential. Arrays of north facing skylights are designed to incorporate natural daylight into the space. The main task in this space is to display artworks.

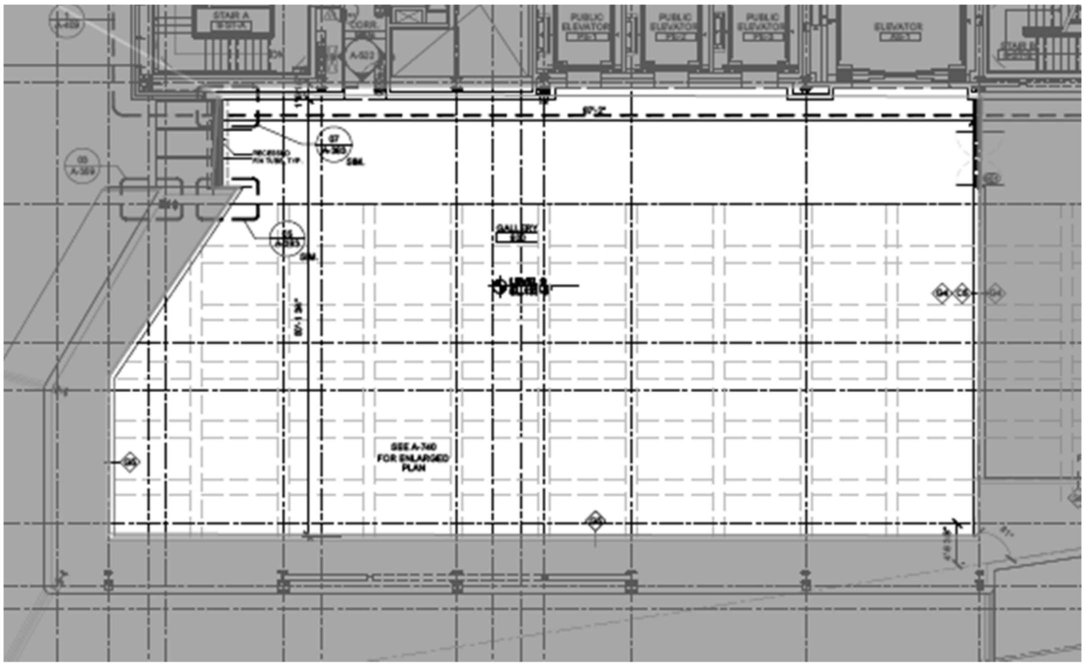


Figure 14 | gallery floor plan

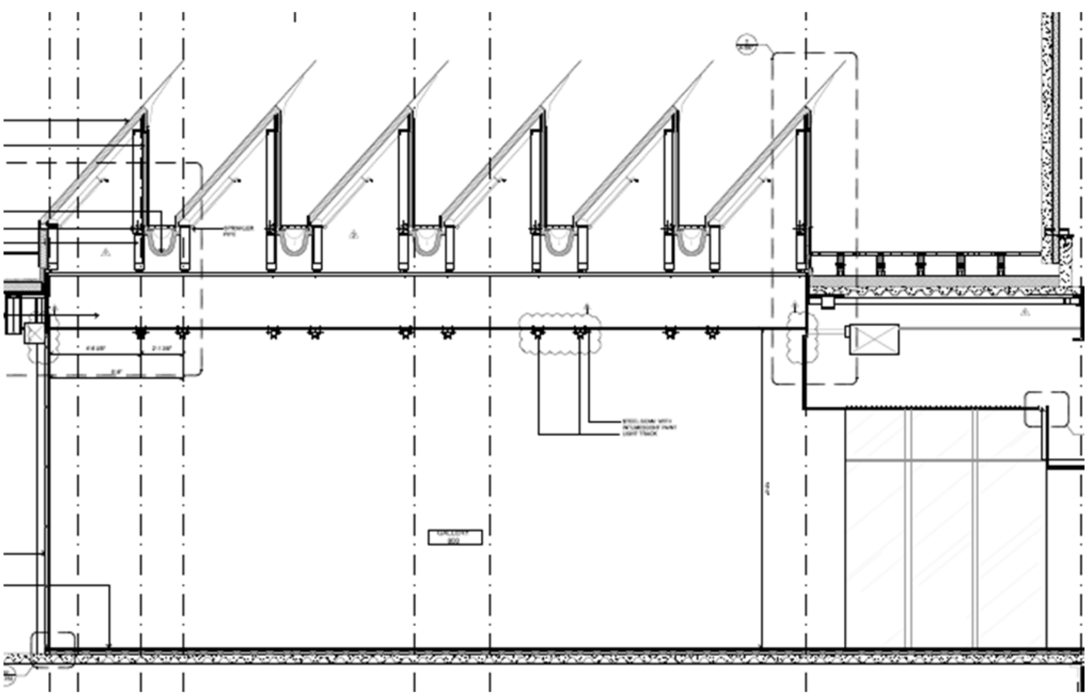


Figure 15 | gallery section

SURFACE MATERIAL

Surface	Name	Description	Reflectance
Floor	W-3	Yellow pine flooring 8" width	0.5
Wall	P-2	Gypsum wall board, painted	0.6
Ceiling	CL-3	Exposed ceiling	0.7

Table 4 | gallery surface material

The ceiling is composed of the exposed structure with gypsum board finish with paint.

DESIGN CRITERIA

Qualitative Criteria:

The circulation and general lighting in an exhibit or gallery space should establish the background against which the displayed objects are to be experienced. Ultraviolet induces photochemical damage on many materials and is generally more detrimental than visible radiation. Thus, UV filters will be added to luminaires to preserve the arts. Room surface reflectances are assumed to be IES-recommended values of 90-60-20. Additionally, the magnitude of daylight must be well-controlled or automatically responsive to available daylight or both.

IES suggested important criteria:

Color Appearance (and Color contrast)
Daylighting Integration and Control
Direct Glare
Light Distribution on Surfaces
Light Distribution on Task Plane (Uniformity
Modeling of Faces or Objects
Reflected Glare
Shadows
Source/Task/Eye Geometry

IES suggested very important criteria:

Appearance of Space and Luminaires
Luminances of Room surfaces
Point(s) of Interest
Sparkle/Desirable Reflected Highlights
Surface Characteristics
System Control and Flexibility

Quantitative Criteria:

Illuminance Recommendation [IES Lighting Handbook 10th Edition (Table21.2)]:

Space Type	**E_h**	**E_v**	**Avg:Min**
Object with low sensitivity to light	200 lux @ floor	200lux @ 5ft AFF	2:1
Circulation/general	Avg=0.2 times object Eh but with min>10lx	Avg of 0.2 times object Ev	4:1

Energy Allowance [ASHRAE standard 90.1]:

Space Type	**Power Density (W/sqf)**
Gallery	1.02 W/ft^2

DESIGN APPROACH

As the only indoor gallery that has daylighting design potentials, it is the perfect space to create spatially diverse experiences for the visitors. The lighting solution is to embrace the temporality of natural light, to create experience that varies from time to time, to allow the visitors to confront different perception and sensation of each artwork. Natural light should be used to illuminate museum spaces so that visitors may be able to relate to nature and the effects of changing weather while inside the gallery.

The design derives from the principle that natural light is the ideal illumination for the contemplation of works of art. The gallery lighting will be amplified and regulated by the LED track system according to exhibition needs and the daylight available through the skylights. To take the biggest advantage of the natural northern light and for visitors to fully experience the nature, electrical lighting is reduce to the minimum.

The architectural lighting for the galleries is envisioned as a very simple and unobtrusive system. A ‘hidden grid’ idea for the track system is proposed. However, different from the lobby where the tracks are recessed into the ceiling, and the theater where the tracks are mounted at the ceiling surface, the gallery tracks are integrated with the structure elements to serve the purpose of discrete mounting position. Additionally, the lighting will be supplemented with the lighting provided by the exhibition designers for the exhibits.

COMPUTER RENDERINGS

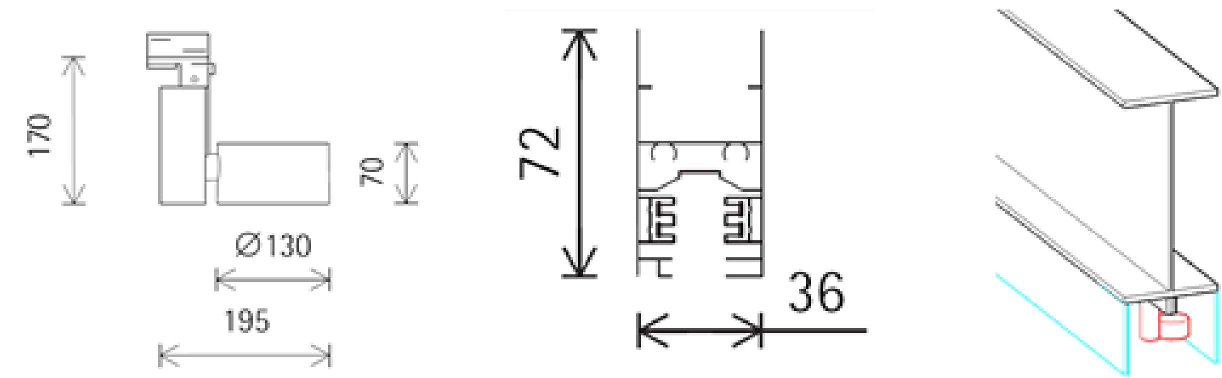


Figure 16 | Light track and structure integration details

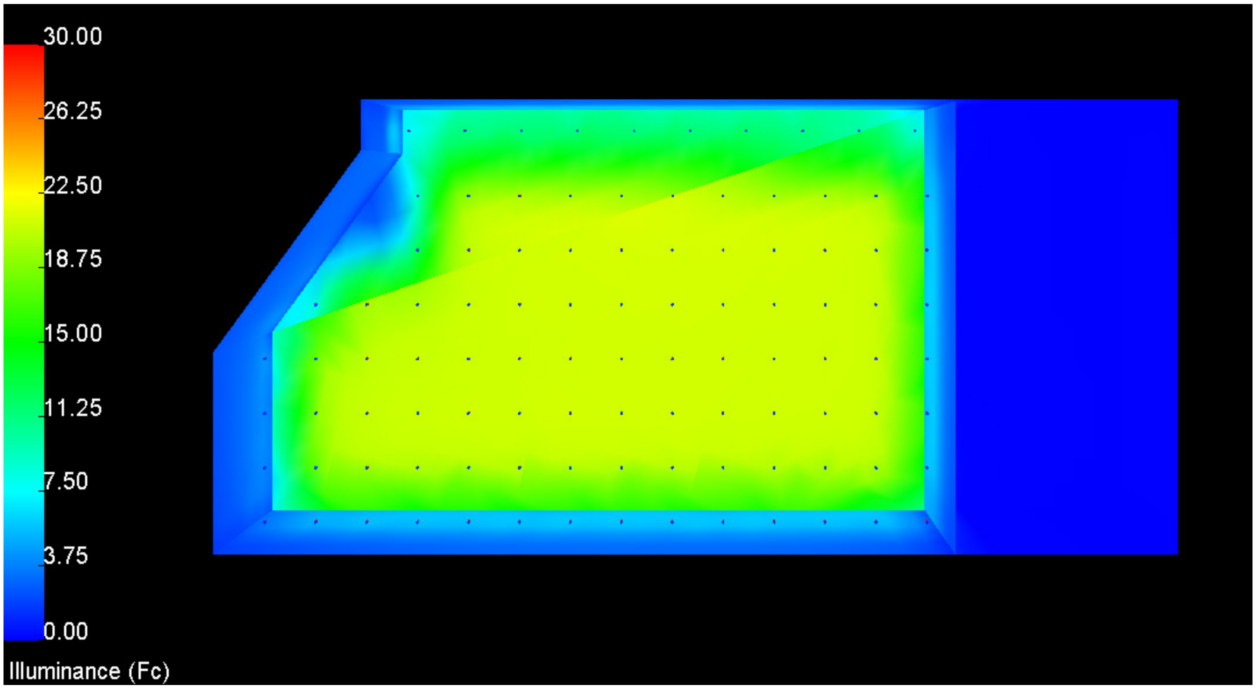
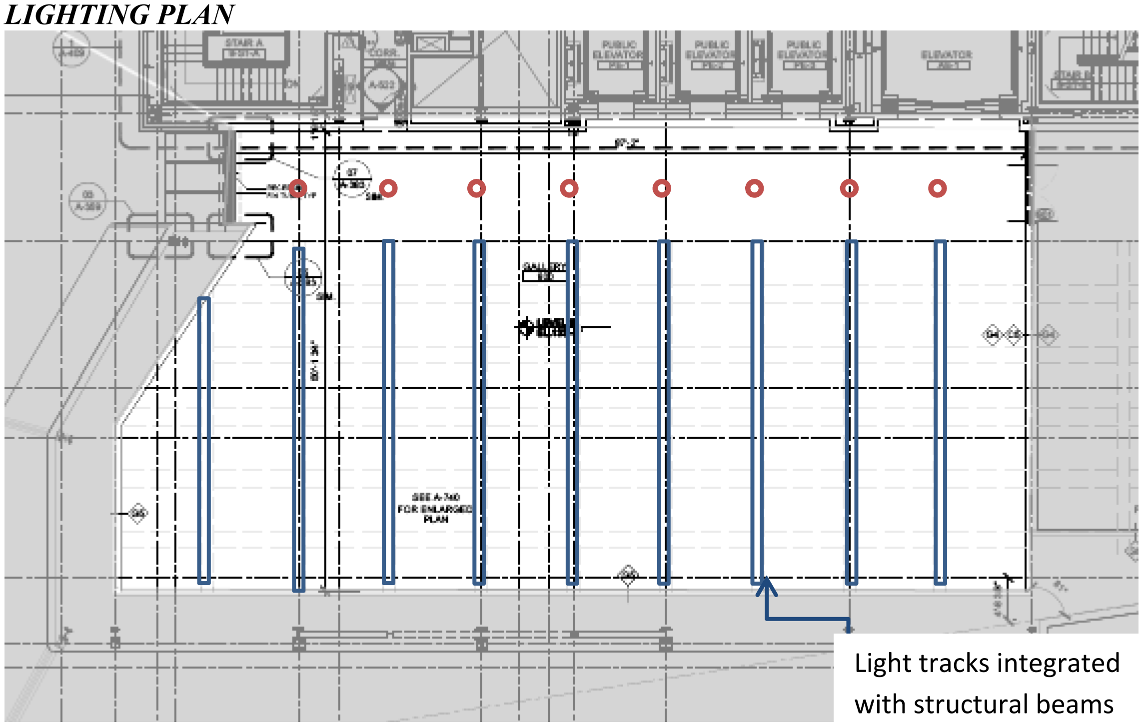


Figure 17 | gallery rendering

LUMINAIRES
AL-1 LED spotlights with flood distribution lens
AL-6 LED downlight

LIGHTING PLAN



PERFORMANCE DATA

Illuminance level – target | provided	200lux |186lux
Avg:Min – target | provided	2:1 | 1.9:1
Power density – target | provided	1.02W/ft2 0.5 W/ft2

PERFORMANCE SUMMARY

The electrical lighting system in the room is well balanced in relation to the daylighting introduced by the skylights. Detailed daylighting analysis of the 8^{th} floor gallery can be found in section four.

Additionally, with the original light tracks going perpendicular to the exposed steel beams on the ceiling, the newly proposed light tracks are going along with the I beams. The alternate lighting design introduced less ceiling distraction. Additionally, hidden channels are proposed that ate integrated with the structure to create a visually unifying ceiling system. Qualitative criteria are achieved as well as the quantitative ones.

SECTION THREE| electrical depth

A system upgrade integrated with the mechanical breadth is investigated.

With the CHP system upgrade discussed in section seven, the system voltage can be upgraded to 480Y/277V from the existing 208Y/120V without relying on the central grid for the main power supply. Because the CHP system is selected based on a preliminary estimation, the exact electrical load that can be provided with the on-site generator is undefined. Thus assumptions were made that the electric loads will be met by the CHP system.

EXISTING ELECTRICAL SYSTEM

The existing electrical design for the Houston Museum of American Art utilizes two parallel service entrances connects to the switchgears located on the cellar level. The service is feed by the Consolidated Edison Company of New York, with incoming service voltage of 208Y/120V. Following image shows the service entrance detail.

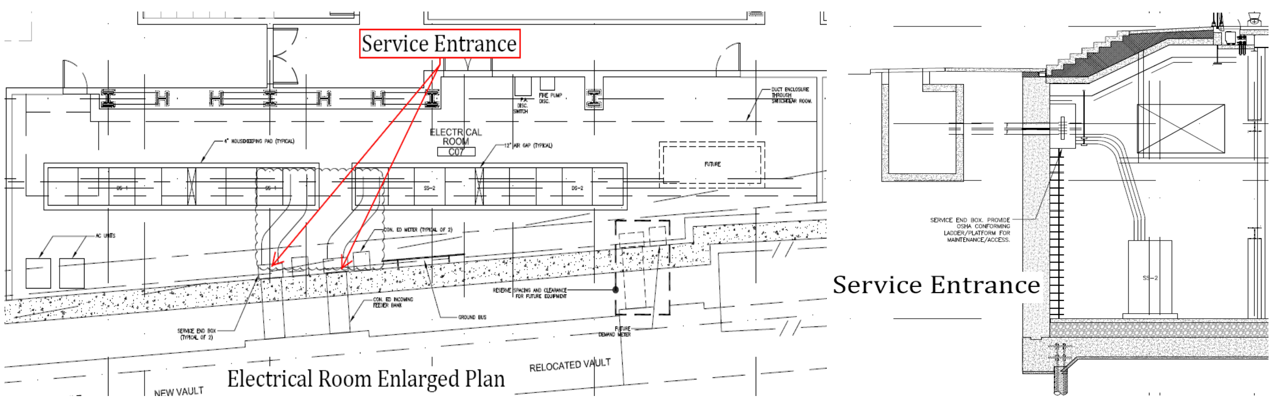


Figure 18 | cellar electrical enlarged plan and service entrance detail

SYSTEM UPGRADE

The existing switchboard schedule for the (2) service switchboards and (2) distribution switchboards are shown as below.

SERVICE SWITCHBOARD SCHEDULE 208 / 120 V - 3 PHASE - 4 WIRES - 200,000 AIC

SWITCHBOARD DESIGNATION	BUS RATING	REAR ACCESSIBLE	SWITCHBOARD OPTIONS: GND. BUS	SWITCHBOARD OPTIONS: 3 PHASE VOLT METER	SWITCHBOARD OPTIONS: SPD	SWITCHBOARD OPTIONS: POWER METER	FEEDER SWITCH: No.	FEEDER SWITCH: SWITCH SIZE	FEEDER SWITCH: SWITCH TYPE	FEEDER SWITCH: FUSE SIZE	FEEDER SWITCH: POLES	SWITCH OPTIONS: 3 PHASE AMMETER	SWITCH OPTIONS: BLOWN FUSE INDICATION (NO TRIP)	SWITCH OPTIONS: SHUNT TRIP	SWITCH OPTIONS: AUX. CONTACTS OPEN/CLOSE TRIP	SWITCH OPTIONS: OTHER	FEEDER DESIGNATION	LOAD DESCRIPTION	LOAD (KVA)	QUANTITY OF FEEDERS (SETS)	FEEDER (EACH): PHASE LEGS No.	PHASE LEGS SIZE	NEUTRAL No.	NEUTRAL SIZE	GROUND No.	GROUND SIZE	INSULATION TYPE (SEE SPECIFICATION)	CONDUIT SIZE	METER FOR M&V	REMARKS
SS-1	4000A	YES	YES	YES	YES	YES	1	4000A	BPS	4000A	3	YES	YES	–	2	–	SS-1#1	BUS CONNECTION TO DS-1	1645.6	–	–	–	–	–	–	–	–	–	–	–
							2	–	–	–	–	YES	–	–	2	–	SS-1#2	FEED TO AUTOMATIC FIRE PUMP DISC. SWITCH	93.3	1	3	500KCMIL	–	–	–	–	EPC	3"	–	SEE NOTE #1
							3	800A	BPS	800A	3	YES	YES	–	2	–	SS-1#3	DP-C-K	262.2	6	3	250KCMIL	1	250KCMIL	–	–	THHN	2 1/2"	YES	PROVIDE SUB-METER
							4	1200A	BPS	1000A	3	YES	YES	–	2	–	SS-1#4	CH-C1-1	227.2	3	3	400KCMIL	–	–	1	2/0	THHN	3"	–	WITH VFD
							5	1200A	BPS	1000A	3	YES	YES	–	2	–	SS-1#5	CH-C1-2	227.2	3	3	400KCMIL	–	–	1	2/0	THHN	3"	–	WITH VFD
							6	1200A	BPS	–	–	–	–	–	–	–	–	SPARE	–	–	–	–	–	–	–	–	–	–	–	–
DS-1	4000A	YES	YES	YES	YES	YES	1	400A	QMQB	400A	3	YES	YES	–	2	–	DS-1#1	EODP-C	50.0	1	3	600KCMIL	1	600KCMIL	–	–	XHHW	3 1/2"	–	VIA ATS-C-0
							2	400A	QMQB	250A	3	YES	YES	–	2	–	DS-1#2	UP-C-A1, UP-LL-A1, LCP-1-A1, UP-2-A1	61.7	1	3	600KCMIL	1	600KCMIL	–	–	XHHW	3 1/2"	–	–
							3	400A	QMQB	350A	3	YES	YES	–	2	–	DS-1#3	LCP-3-A1, UP-3-A1/A2, LCP-4-A1, UP-4-A1/A2	87.0	1	3	600KCMIL	1	600KCMIL	–	–	XHHW	3 1/2"	–	–
							4	400A	QMQB	350A	3	YES	YES	–	2	–	DS-1#4	LCP-5-A1/A2/A3, UP-5-A1	89.7	1	3	600KCMIL	1	600KCMIL	–	–	XHHW	3 1/2"	–	–
							5	600A	QMQB	450A	3	YES	YES	–	2	–	DS-1#5	LCP-6-A1/A2, UP-6-A1, UP-7-A1, LCP-7-A1/A2	116.5	2	3	600KCMIL	1	600KCMIL	–	–	XHHW	3 1/2"	–	–
							6	400A	QMQB	200A	3	YES	YES	–	2	–	DS-1#6	LCP-8-A1/A2, UP-8-A1, UP-9-A1	55.9	2	3	250KCMIL	1	250KCMIL	–	–	XHHW	2 1/2"	–	–
							7	600A	QMQB	600A	3	YES	YES	–	2	–	DS-1#7	DP-9-A	105.6	5	3	600KCMIL	1	600KCMIL	–	–	XHHW	3 1/2"	–	–
							8	400A	QMQB	–	–	–	–	–	–	–	–	SPARE	–	–	–	–	–	–	–	–	–	–	–	–
							9	1600A	BPS	1600A	3	YES	YES	–	2	–	DS-1#9	EDS-2-EM-A	404.6	8	3	600KCMIL	1	600KCMIL	1	500KCMIL	XHHW	3 1/2"	–	VIA ATS-2-EM-A
							10	400A	QMQB	350A	3	YES	YES	–	2	–	DS-1#10	UP-3-C1 LCP-3-C1, UP-4-C1/C2, LCP-4-C1	87.0	1	3	600KCMIL	1	600KCMIL	–	–	XHHW	3 1/2"	–	–
							11	400A	QMQB	400A	3	YES	YES	–	2	–	DS-1#11	PP-C-1	41.0	1	3	600KCMIL	1	600KCMIL	–	–	THHN	3 1/2"	–	FOR CARPENTRY SHOP
							12	200A	QMQB	150A	3	YES	YES	–	2	–	DS-1#12	ACOUSTIC LOUVER/BANNER MOTOR CONTROL PANEL	35	1	3	350KCMIL	1	350KCMIL	–	–	XHHW	2 1/2"	–	VIA LOCAL FUSED DISCONNECT SWITCHES
							13	800A	BPS	800A	3	YES	YES	–	2	–	DS-1#13	DP-C-A	196.4	3	3	600KCMIL	1	600KCMIL	–	–	THHN	3 1/2"	–	–
							14	400A	QMQB	250A	3	YES	YES	–	2	–	DS-1#14	UP-1-RETAIL	5.0	1	3	250KCMIL	1	250KCMIL	–	–	XHHW	2 1/2"	YES	–
							15	800A	BPS	800A	3	YES	YES	–	2	–	DS-1#15	DP-C-CH-A	173.0	2	3	600KCMIL	1	600KCMIL	–	–	THHN	3 1/2"	–	–
							16	400A	QMQB	–	–	–	–	–	–	–	–	SPARE	–	–	–	–	–	–	–	–	–	–	–	–
							17	400A	QMQB	–	–	–	–	–	–	–	–	SPARE	–	–	–	–	–	–	–	–	–	–	–	–
SS-2	4000A	YES	YES	YES	YES	YES	1	4000A	BPS	4000A	3	YES	YES	–	2	–	SS-2#1	BUS CONNECTION TO DS-2	1694.8	–	–	–	–	–	–	–	–	–	–	–
							2	400A	QMQB	250A	3	YES	YES	–	2	–	SS-2#2	UP-4-AUD-1/2/3/4	56.6	2	3	250KCMIL	1	250KCMIL	–	–	XHHW	2 1/2"	–	–
							3	400A	QMQB	–	–	YES	–	–	2	–	SS-2#3	FA FEED TO FA DISCONNECT SWITCH	30.0	1	3	1/0	1	1/0	–	–	THHN	1 1/2"	–	SEE NOTE #1
							4	800A	BPS	800A	3	YES	YES	–	2	–	SS-2#4	EOPP-4	75	2	3	4/0	1	4/0	–	–	XHHW	2 1/2"	–	VIA ATS-4
							5	400A	QMQB	400A	3	YES	YES	–	2	–	SS-2#5	FEED FROM CHP	94	1	3	500KCMIL	1	500KCMIL	–	–	XHHW	3"	–	–
							6	1200A	BPS	1000A	3	YES	YES	–	2	–	SS-2#6	CH-C1-3	227.2	3	3	400KCMIL	1	400KCMIL	1	2/0	THHN	3"	–	VIA VFD
DS-2	4000A	YES	YES	YES	YES	YES	1	1600A	BPS	1600A	3	YES	YES	–	2	–	DS-2#1	EDS-2-EM-B	413.0	5	3	600KCMIL	1	600KCMIL	1	300KCMIL	XHHW	3 1/2"	–	VIA ATS-2-EM-B
							2	400A	QMQB	400A	3	YES	YES	–	2	–	DS-2#2	LCP-LL-B1/B2, UP-LL-B1, UP-3-B1/B2, UP-4-B1	108.3	1	3	600KCMIL	1	600KCMIL	–	–	XHHW	3 1/2"	–	–
							3	600A	QMQB	450A	3	YES	YES	–	2	–	DS-2#3	LCP-5-B1, UP-5-B1/B2, UP-6-B1, LCP-6-B1	120.9	2	3	4/0	1	4/0	–	–	XHHW	2 1/2"	–	–
							4	400A	QMQB	300A	3	YES	YES	–	2	–	DS-2#4	UP-5-V1/V2	73.0	2	3	4/0	1	4/0	–	–	XHHW	2 1/2"	–	–
							5	400A	QMQB	400A	3	YES	YES	–	2	–	DS-2#5	UP-7-B1, UP-8-B1, LCP-8-B1	114.4	1	3	600KCMIL	1	600KCMIL	–	–	XHHW	3 1/2"	–	–
							6	800A	BPS	800A	3	YES	YES	–	2	–	DS-2#6	DP-9-B	185.1	6	3	600KCMIL	1	600KCMIL	–	–	XHHW	3 1/2"	–	–
							7	400A	QMQB	400A	3	YES	YES	–	2	–	DS-2#7	UP-C-C1/C2, LCP-C-C1, UP-1-C1	75.4	1	3	600KCMIL	1	600KCMIL	–	–	XHHW	3 1/2"	–	–
							8	400A	QMQB	400A	3	YES	YES	–	2	–	DS-2#8	LCP-5-C1/C2/C3, UP-5-C1	89.7	2	3	300KCMIL	1	300KCMIL	–	–	XHHW	2 1/2"	–	–
							10	600A	QMQB	600A	3	YES	YES	–	2	–	DS-2#9	LCP-6-C1, UP-6-C1, UP-7-C1, LCP-7-C1/C2	116.5	2	3	300KCMIL	1	300KCMIL	–	–	XHHW	2 1/2"	–	–
							11	800A	BPS	800A	3	YES	YES	–	2	–	DS-2#10	DP-C-B	226.1	3	3	600KCMIL	1	600KCMIL	–	–	THHN	3 1/2"	–	–
							12	800A	BPS	800A	3	YES	YES	–	2	–	DS-2#11	DP-C-CH-B	120.1	2	3	600KCMIL	1	600KCMIL	–	–	THHN	3 1/2"	–	–
							13	200A	QMQB	200A	3	YES	YES	–	2	–	DS-2#12	PP-2-A1, PP-2-HT, PP-1-LD, PP-2-CHP	45.4	1	3	3/0	1	3/0	–	–	XHHW	2"	–	–
							14	400A	QMQB	400A	3	YES	YES	–	2	–	DS-2#13	M&O TERRACE COMPANY SWITCHES	72	4	3	400KCMIL	1	400KCMIL	–	–	XHHW	3"	YES	VIA TROUGH
							15	400A	QMQB	–	–	–	–	–	–	–	–	SPARE	–	–	–	–	–	–	–	–	–	–	–	–
							16	400A	QMQB	400A	3	YES	YES	–	–	–	DS-2#14	DP-C-C	24	1	3	600KCMIL	1	600KCMIL	–	–	THHN	3 1/2"	–	–
							17	400A	QMQB	–	–	–	–	–	–	–	–	SPARE	–	–	–	–	–	–	–	–	–	–	–	–

Figure 19 | existing service switchboard schedule

As no individual lighting panelboards are provided, the switchboard schedule is used to determine the loads switchboards need to feed for different sets of feeders. Assumptions were made that all feeders feed to lighting panels will be supply by the 480Y/277V system. Modification of feeder sizing will be resulted.

	–	SPARE	–
DS-1	DS-1#1	EODP-C	50.0
	DS-1#2	UP-C-A1, UP-LL-A1, LCP-1-A1, UP-2-A1	61.7
	DS-1#3	LCP-3-A1, UP-3-A1/A2, LCP-4-A1, UP-4-A1/A2	87.0
	DS-1#4	LCP-5-A1/A2/A3, UP-5-A1	89.7
	DS-1#5	LCP-6-A1/A2, UP-6-A1, UP-7-A1, LCP-7-A1/A2	116.5
	DS-1#6	LCP-8-A1/A2, UP-8-A1, UP-9-A1	55.9
	DS-1#7	DP-9-A	105.6
	–	SPARE	–
	DS-1#9	EDS-2-EM-A	404.6
	DS-1#10	UP-3-C1 LCP-3-C1, UP-4-C1/C2, LCP-4-C1	87.0
	DS-1#11	PP-C-1	41.0
	DS-1#12	ACOUSTIC LOUVER/BANNER MOTOR CONTROL PANEL	35
	DS-1#13	DP-C-A	196.4
	DS-1#14	UP-1-RETAIL	5.0
	DS-1#15	DP-C-CH-A	173.0
	–	SPARE	–
	–	SPARE	–

	[illegible]	[illegible]	[illegible]
DS-2	DS-2#1	EDS-2-EM-B	413.0
	DS-2#2	LCP-LL-B1/B2, UP-LL-B1, UP-3-B1/B2, UP-4-B1	108.3
	DS-2#3	LCP-5-B1, UP-5-B1/B2, UP-6-B1, LCP-6-B1	120.9
	DS-2#4	UP-5-V1/V2	73.0
	DS-2#5	UP-7-B1, UP-8-B1, LCP-8-B1	114.4
	DS-2#6	DP-9-B	185.1
	DS-2#7	UP-C-C1/C2, LCP-C-C1, UP-1-C1	75.4
	DS-2#8	LCP-5-C1/C2/C3, UP-5-C1	89.7
	DS-2#9	LCP-6-C1, UP-6-C1, UP-7-C1, LCP-7-C1/C2	116.5
	DS-2#10	DP-C-B	226.1
	DS-2#11	DP-C-CH-B	120.1
	DS-2#12	PP-2-A1, PP-2-HT, PP-1-LD, PP-2-CHP	45.4
	DS-2#13	M&O TERRACE COMPANY SWITCHES	72
	–	SPARE	–
	DS-2#14	DP-C-C	24
	–	SPARE	–

Table 5 | Distribution switchboard 1&2 schedule

The shaded panelboards and feeders are modified with the new voltage rating. The following table demonstrate the new feeder sizes.

	Load (kVA)	ampere	Growth	Existing Size phase legs	New Size phase legs
DS-1#3	87	104.7	130.9	600KCMIL	(1) 1/0
DS-1#4	89.7	107.9	134.9	600KCMIL	(1) 1/0
DS-1#5	116.5	140.2	175.2	(2) 600KCMIL	(1) 3/0
DS-1#6	55.9	67.3	84.1	(2) 250KCMIL	4
DS-1#7	105.6	127.1	158.8	(5) 600KCMIL	(1) 2/0
DS-2#2	108.3	130.3	162.9	600KCMIL	(1) 2/0
DS-2#3	120.9	145.5	181.9	(2) 4/0	(1) 3/0
DS-2#5	114.4	137.7	172.1	600KCMIL	(1) 2/0
DS-2#7	75.4	90.7	113.4	600KCMIL	2
DS-2#8	89.7	107.9	134.9	(2) 300KCML	(1) 1/0
DS-2#9	116.5	140.2	175.2	(2) 300KCML	(1) 2/0

Table 6 | Distribution Switchboard feeder size compare

The resizing of the feeder showed significant difference in terms of feeder sizes. The wire size is much smaller when sized on a conservative basis.

WIRE UPSIZING

The next related investigation is about whether upsizing wires can demonstrate real savings to the owners as well as the advantages of lower generated heat and increased flexibility of the installation, resulted into reduced energy requirements for fans and air conditioning systems. Many factors can affect the economic incentives of installing larger wire sizes. Through research it was found that for most new applications, the cost of labor and conduit for the installation outweigh the cost of wire, as a result, the increased size of the wire can pay for itself in less than two years. Elements such as duty cycle, load factor and electricity price are key in determine the cost benefit of upsizing wires.

The study was performed to understand the impact of wire size on energy efficiency and costs. Assume a single-phase 15 ampere lighting load that operates 8 hours a day, and assume the load is concentrated about 100 feet from the panelboard. The savings due to less voltage drop is presented in following table prepared by Copper Development Association Inc.

	#12 AWG	#10 AWG
Conduit Size	1/2 in.	1/2 in.
Estimated Loss (at 15 amp load and 40°C, and 37°C,respective conductor temps.)	77 W	48 W
Wire Cost	$11.82	$18.57
Conduit Cost	$42.00	$42.00
Incremental Cost		$6.75
Energy Savings		254 kWh/year
Dollar Savings: at $0.07 per kWh Payback		$17.78/year 5 months
Dollar Savings: at $0.10 per kWh Payback		$25.40/year 3 months
Dramatic, short term paybacks in a single-phase run, with flexibility for future load changes.		

Table 7 | wire upsizing example - lighting load

The research on the benefit of wire upsizing has concluded that upsizing wires generally have short payback periods. With owners pay more upfront to buy wires larger in size, the energy loss is reduced when in use. However, the detailed analysis will need to be conducted to investigate the accurate benefit of upsizing wires for the project owners.

SECTION FOUR| MAE breadth

Daylighting plays a prominent role in the 8th floor gallery. A daylight study of the spatial conditions is conducted to analyze the amount and extent of daylight penetration into each space. A photosensor dimming system will be used to control the amount of electric light used during the day into the space. The critical point was calculated to see which point in the space needed the most amount of light to reach its target illuminance during the day.

The following images show the daylighting analysis on multiple dates (December 21, September 21, and June 21) for the gallery. The images are in sequence from 11am when the museum opens to 6pm when the museum close to the public. (The detailed glazing material can be found in Appendix)

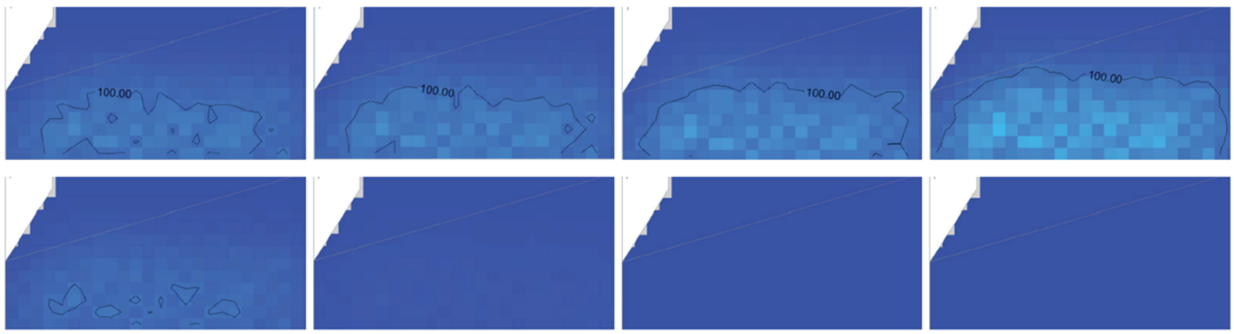


Figure 20 | December Daysim calculation - gallery

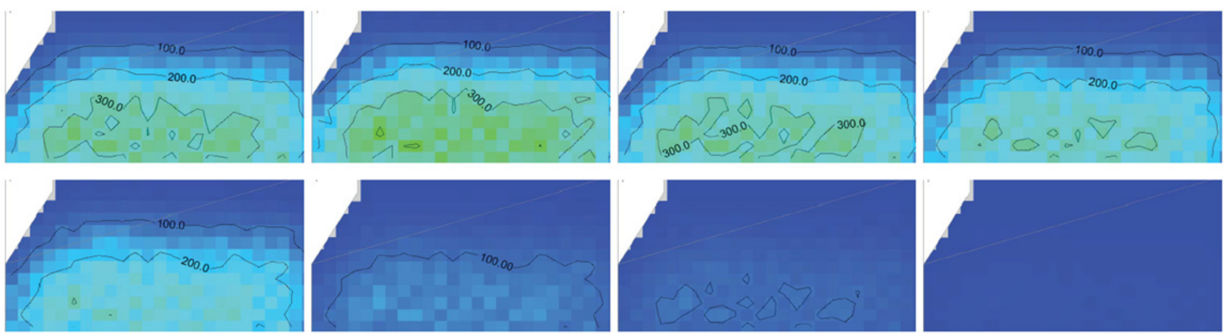


Figure 21 | September Daysim calculation - gallery

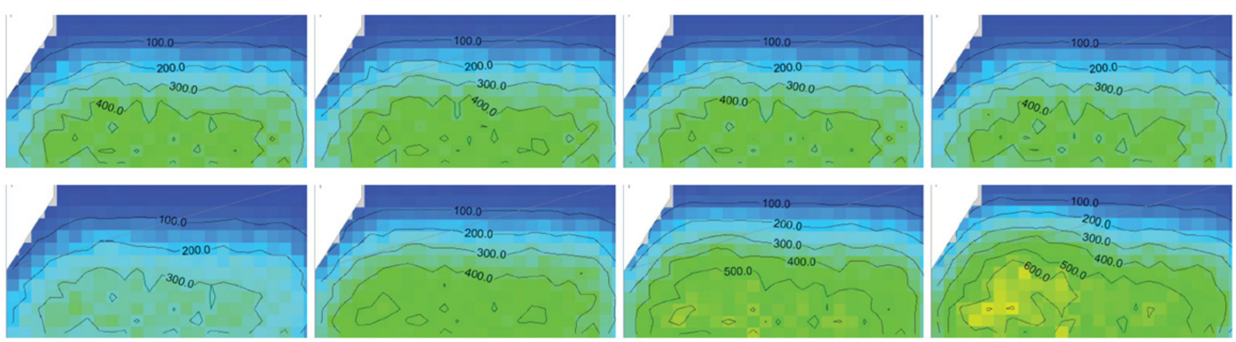


Figure 22 | June Daysim calculation - gallery

Annual results were analyzed and displayed below. Daylight autonomy, continuous daylight autonomy as well as useful daylight illuminance are graphed for a target illuminance of 200 lux for horizontal illuminance of the space.

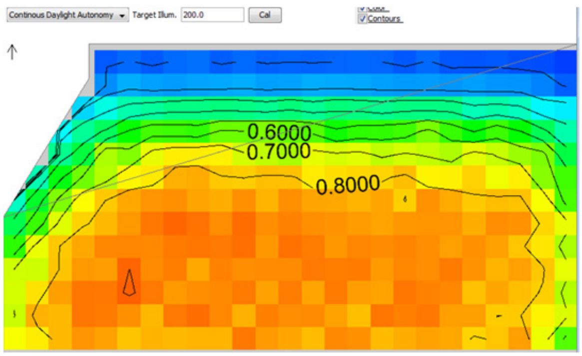


Figure 23 | Continuous daylight autonomy - gallery

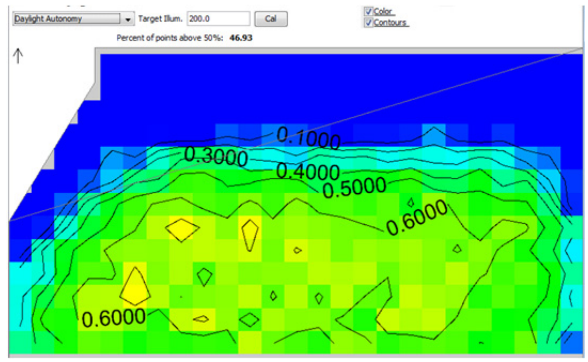


Figure 24 | Daylight Autonomy

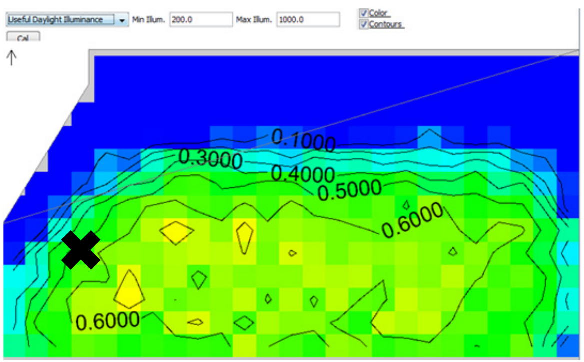


Figure 25 | useful daylight illuminance

Data generated by Daysim were analyzed and determined that generally, no sunlight penetration will occur in the space. Additionally, the highest possible illuminance on the floor contributed by the daylight is lower than 1000 lux (based on June's data). However, special conditions can not be eliminated and thus shades are recommended. Due to the data set provided does not include very large illuminance value contributed daylight, calibration of the photosensor for the shades were not done.

Electrical light in the room are dimmable and an open loop photosensor is used to dim the lights based on the daylighting condition for the space for a particular moment. The image below demonstrate the signal vs. optimal dimming level for the photosensor placement and selection.

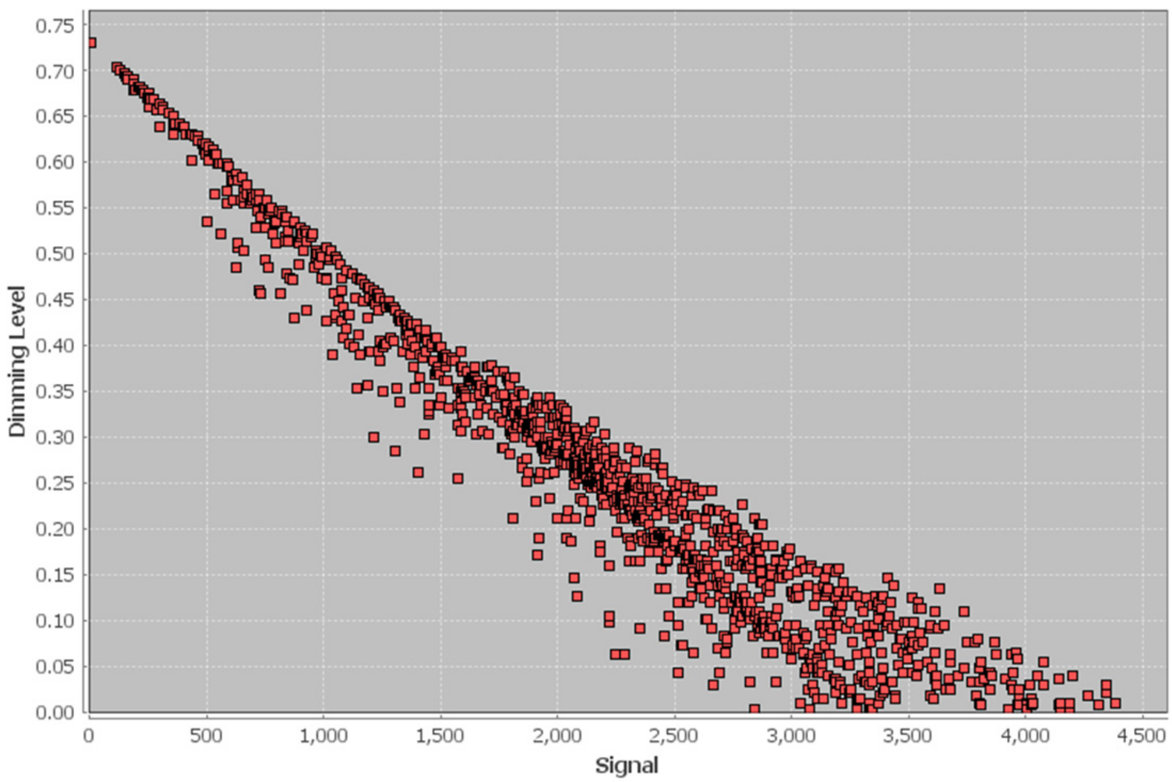


Figure 26 | signal vs. optimal dimming level

Summary

Overall, the skylight design is analyzed. Promising daylighting conditions are resulted by the skylights design. Dimming system is implemented to integrate with the daylighting design. However, spotlights for artworks will still need to be on the dimming level requested by the artists.

SECTION FIVE | honors breadth

The honors breadth aims to investigate the social concepts that can affect lighting design and in turn influence the human perception and interpretation of the space. Three concepts researched including the motivation of why people visit museums, how people self-congregate, and different scale of perception, focusing on the idea "life, space, buildings – in that order".

MOTIVATION

One of the first social concepts investigated is the descriptive and predictive framework introduced by Dr. John Falk, professor at Oregon State University, for identifying museum visitors on the basis of their motivations, as related to their identity. The concept started with acknowledging the complex physical and social environments in a museum where different groups of people interact with each other in multiple ways.

Falk's research stated that museum visitors have different level of interest, motivation and curiosity, and often different appreciative and experiential knowledge. He categorized them into five groups reflecting different motivations: explorers, facilitators, experience seekers, professional hobbyists, and rechargers. According to Falk, explorers are driven by their personal curiosity, their urge to discover new things. Facilitators visit the museum on behalf of other's special interests in the exhibition or the subject-matter of the museum. Experience seekers desire to see and experience a place, such as tourists. Professional hobbyists are those with specific knowledge in the subject matter of an exhibition and specific goals in mind. Rechargers seek a contemplative or restorative experience, often to let some stream out of their systems.

However, the variable visitor identities do not mean museums have to design many different activities or exhibits, but rather to present a range of different experiences by respond to the audience's expectations and their perceptions of the institution. Thus, lighting approach through means to provide visitors personal context with whether the exhibition, the architecture, the atmosphere, or each other based on their unique identities is the key.

SELF-CONGREGATION

Self-congregation is the second social concept investigated. According to William H. whyte, an American urbanist, what attract people most, are other people. The concept was first brought home to Whyte in a study of street conversations. He found out that people didn't move out of the main pedestrian flow, rather they stayed in it or moved into it. They go to the lively places where there are many people. And they go there by choice – not to escape the city, but to partake of it.

To benefit from this concept, the natural junctions and transfer point of the lobby is studied to act as the basis of the lobby lighting Design.

SCALE PERCEPTION

The last but not least social concept studied is mentioned in Jan Gehl's book Cities for People, that the quality of a city space is directly related to its degree of concern for the human dimension.

The social field of vision was investigated by Gehl to study the relationship between the senses, communication and dimensions. According to Gehl, our sense of sight has adapted and developed to enable us to move linearly and horizontally at a walking. Earlier in our history it was important for walkers to be able to detect dangers and enemies lurking ahead, and on the path in front of them. It was also crucial to be able to keep an eye on what was happening on both sides of the path. As a result, our eyes can see clearly and precisely straight ahead and at a great distance. Furthermore, the rods and cones in the photoreceptor layer of the eye are organized primarily horizontally, enabling use to see movement further out in the field of vision, perpendicular to the walking direction. However, our downward and upward sight has developed very differently. Looking down where it is important to see what we are stepping on, we humans can see up to 70-80 degrees below the horizon. Upwards, where in the later phases of evolutionary history we had only few enemies to beware of, the angle of vision is limited to 50-55 degrees above the horizon. Our horizontal field of visions means that when we are walking along building facades, only the ground floors can offer us interest and intensity. If ground floor facades are rich in variation and detail, our city walks will be equally rich in experience.

Since our senses and locomotors apparatus has only a limited field of upward vision, this whole account of the horizontal sensory apparatus is the key to how we experience space, for example, how much of buildings pedestrians experience when walking along streets. In general, the upper floors of tall buildings can only be seen at a distance and never close up in the cityscape.

At eye level the scene comes alive with movement and color. While the designer sees the whole building – the clean verticals, the horizontals, the way corner turns, and so on. But the museum visitors may be quite unaware of such matters. He is more apt to be looking in the other direction: not up at other buildings, but at what is going on at eye level or his handling of space.

To create a close-up experience for the visitors, a lighting approach will need to bring all the senses to bear. Every effort is made to keep the dimensions and design of outdoor space in harmony with the human scale and comfortable perception range.

SUMMARY

Three social concepts were investigated and implemented throughout the design phase of the project. While considering motivation and designing the space for all types of visitors, considering self-congregation to design for lobby based on human behaviors and habits, and last but not least considering the scale of perception to deem the parts of façade need to be lit while keep the others dark for energy conservation.

SECTION SIX | acoustical breadth

OVERVIEW
In this analysis, the acoustical situation for the 8th floor gallery is analyzed and calculated to determine whether the acoustical performance resulted in desirable reverberation times and echo levels and investigate the need for sound absorbing or reflecting materials.

DETAILED ANALYSIS
The space is essential a large rectangular box with gypsum board walls, wood flooring and skylights ceiling. The acoustical design needs to balances the necessary control of reverberation – to limit activity noise and help public address intelligibility- with the creation of an aural sense of the space. Reverberation time is one major parameter that carries clues on the intelligibility and noise levels due to the suspended sound within enclosed interior spaces. Interior finishing materials, form of gallery facing surfaces, related dimensions and the volume are variables that directly affect the reverberance that occur within galleries. Mid-frequency (500Hz-1000Hz) reverberation time maximum targets in the range of 1.2 -1.8 seconds with reference made to a wide range of previous gallery studies to refine the targets for reverberation control.

Dimensions
The gallery spans a total area of 4650 sf. Refer to the lighting section for the detailed room dimension and plans.

Calculation methods
Using the Sabine method, the absorptive co-efficient of materials applied across the space were compiled by unit surface area in order to obtain the reverberation time for common frequencies. The following formula was then used to calculate the reverberation time for each frequency:

$$T=0.05 \times \frac{V}{a}$$

Where T= reverberation time required for sound to decay 60db after time has stopped (seconds)
v= room volume (cf)
a = total sf of room absorption (sabins)

These values and results are summarized in the table below:

Table 8| Reverberation analysis - gallery

8th floor gallery reverberation analysis														
surface	material descirption	area (sf)	Sα - sabins by Frequency (Hz)											
			125Hz		250Hz		500Hz		1000Hz		2000Hz		4000Hz	
ceiling	gypsum board	1121	0.55	616.6	0.14	156.9	0.08	89.7	0.04	44.8	0.55	616.6	0.98	1,098.6
	glass	2475	0.35	866.3	0.25	618.8	0.18	445.5	0.12	297.0	0.07	173.3	0.04	99.0
	exposed structural steel	1946	0.73	1,420.9	0.69	1,343.0	0.99	1,926.9	0.89	1,732.3	0.52	1,012.1	0.31	603.4
Floor	yellow pine flooring	4650	0.02	93.0	0.14	651.0	0.08	372.0	0.04	186.0	0.55	2,557.5	0.55	2,557.5
Wall	painted gypsum wall	4504	0.55	2,477.2	0.14	630.6	0.08	360.3	0.04	180.2	0.55	2,477.2	0.55	2,477.2
people	values per 1/10 person	200	0.25	50.0	0.35	70.0	0.42	84.0	0.46	92.0	0.50	100.0	0.50	100.0
total Sabine ∑Sα=a				5,523.9		3,470.3		3,278.4		2,532.3		6,936.6		6,935.7
Reverberation Time				0.781		1.243		1.316		1.704		0.622		0.622

Conclusion

The reverberation time for the mid frequency (500Hz-1000Hz) are within the criteria set of 1.2-1.8s. Thus the acoustical condition for the space is acceptable.

SECTION SEVEN | mechanical breadth

OVERVIEW

A complete, fully operational combine heat and power generation (CHP) system is originally designed for the Houston Museum of American Art. The designed CHP system is a 75kW gas-fired reciprocating cogeneration unit. However the CHP system is only responsible for a small portion of the building's total electrical and thermal load. Thus, a thorough feasibility analysis of using CHP system as the primary energy system for the entire project is conducted. A larger sized engine is investigated to comply with the increase load requirement. An in-depth of the cogeneration system will not be deliberated in this breadth; rather an overall feasibility analysis is conducted to estimate the performance and cost advantages of using a full scale Combined Heat and Power system.

BACKGROUND

Houston Museum of American Art relies largely on the central grid for power. There are several factors that indicating that using power from the grid is not the best option. First of all, a large amount of energy is lost during production and transmission; the end users generally can only get 33 percent of the primary energy input from the electricity power plant. Relying on the power grid also exposes the facility to potential surges, brownouts, and unexpected service interruptions, for example climatic hazards (Sandy). With increasing energy costs and growing concern on the environment, on-site energy generation can be a beneficial alternative to the grid. Additionally state and federal government provide financial incentives for CHP projects. Following *Table 9* displays the policy/incentive for the state of New York.

Policy/Incentive Name	Policy/Incentive Type
Agriculture Energy Efficiency Program	Rebate
CHP Acceleration Program	Grant
Custom Measures Commercial and Industrial Rebate Program	Rebate
Energy Smart New Construction Program	Production Incentive
Existing Facilities Program	Production Incentive
FlexTech Program	Grant
Industrial and Process Efficiency Performance Incentives	Production Incentive
Linked Deposit Program (LDP)	Loan
Local Option - Solar, Wind & Biomass Energy Systems Exemption	Tax
Manufacturing Assistance Program (MAP)	Grant
National Grid (Gas) - Commercial Energy Efficiency Rebate Programs (Metro NY)	Rebate
National Grid (Gas) - Commercial Energy Efficiency Rebate Programs (Upstate NY)	Rebate
New York Natural Gas Rates	Utility Rate
Tax-Exempt Equipment Leasing Program (TELP)	Tax

Table 9 Policy/Incentives for CHP projects in New York

FEASIBILITY ANALYSIS

The analysis is based on the Combined Heat and Power (CHP) Partnership by the U.S. Environmental Protection Agency (EPA), a government agency whose mission is to protect human health and the environment. A five stages process that guides the projects from conception to completion is proposed by the EPA. This analysis will follow the stage 1 guidelines.

Measure 1
Stage 1 determines whether CHP is worth considering at a candidate facility. The goal is to identify project goals and potential barriers. Measure one is stage 1 is a checklists that helps the candidate to answer "is my facility a good candidate for CHP?" The preliminary checklist provided by EPA is answered and the results are displayed in ***Figure*** *27*. Result shows that the Houston Museum of American Art is determined to be a good candidate for CHP.

- ☐ Do you pay more than $.07/ kilowatt-hours on average for electricity (including generation, transmission, and distribution)?
- ☑ Are you concerned about the impact of current or future energy costs on your business?
- ☑ Is your facility located in a deregulated electricity market?
- ☑ Are you concerned about power reliability? Is there a substantial financial impact to your business if the power goes out for 1 hour? For 5 minutes?
- ☐ Does your facility operate for more than 5,000 hours/year?
- ☐ Do you have thermal loads throughout the year (including steam, hot water, chilled water, hot air, etc.)?
- ☐ Does your facility have an existing central plant?
- ☐ Do you expect to replace, upgrade, or retrofit central plant equipment within the next 3-5 years?
- ☐ Do you anticipate a facility expansion or new construction project within the next 3-5 years?
- ☑ Have you already implemented energy efficiency measures and still have high energy costs?
- ☑ Are you interested in reducing your facility's impact on the environment?

Figure 27 | CHP preliminary checklist by EPA

Measure 2
Another qualification for stage 1 is the consideration of the "spark spread". A Spark Spread Estimator is provided on the website to serve as a tool that evaluates the anticipated spark spread of a CHP system compared to using separate heat and power (SHP). Spark spread is the difference per kilowatt-hour(kWh) between the current delivered electricity price and the total cost to generate power with a CHP system. Generally, a numerically positive spark spread result indicates that the CHP project returns more than the cost of capital. The greater the spark spread, the higher the potential return in investment.

Building information was submit to the estimator. Results are generated.

Facility Energy Use*	
Facility Average Electric Demand, kW	1,826
Facility Average Heating, MMBtu/hour	5.7
CHP system information	
CHP System Type	Recip Engine
CHP System Capacity, kW	1,322
CHP Electric Efficiency	35.0%
CHP Thermal Output, Btu/kWh	4,299
CHP Thermal Output, MMBtu/hour	5.7
CHP System Fuel Cost (Natural Gas), $/MMBtu	$11.50
CHP Installed Cost, $/kW	$2,300
CHP O&M Cost, cents/kWh	$0.0160
CHP Cost to Generate Power	
Operating Cost to Generate	
CHP Fuel Costs, $/kWh	$0.1122
Thermal Credit, $/kWh	($0.0378)
Incremental O&M, $/kWh	$0.0160
Operating Costs to Generate Power, $/kWh	*$0.0904*
Capital Charge, $/kWh	$0.1209
Total Costs to Generate Power, $/kWh	*$0.2113*
Current Average Electricity Price, $/kWh	$0.1920
Spark Spread, $/kWh*	***($0.0193)***

Table 10 | CHP Spark Spread Results

Energy Use	No CHP	With CHP	Difference
Annual Electricity Use			
Annual Purchased Power, kWh	3,797,626	1,186,142	(2,611,484)
Annual CHP Power Generation, kWh	0	2,611,484	2,611,484
Total Annual Electricity Use, kWh	*3,797,626*	*3,797,626*	*0*
Annual Thermal Energy Use			
Non-CHP Thermal Use*, MMBtu/yr	11,818	591	(11,227)
CHP Thermal Used, MMBtu/yr	0	11,227	11,227
Total Thermal Energy Use, MMBtu/yr	*11,818*	*11,818*	*0*
Annual Fuel Use			
Non-CHP Thermal Fuel Use*, MMBtu/yr	14,772	739	(14,033)
CHP Fuel Use, MMBtu/yr	0	25,488	25,488
Annual Total Fuel Use, MMBtu	*14,772*	*26,227*	*11,455*
Operating Costs			
Purchased Electricity	$729,144	$277,880	($451,264)
Purchased Fuel	$103,995	$301,607	$197,612
Incremental O&M	$0	$41,784	$41,784
Annual Operating Costs	*$833,140*	*$621,270*	*($211,869)*
Annual Operating Savings			***$211,869***

Table 11 | Estimate of Annual Energy Use and Operating Costs

The annual operating savings predicted by the Spark Spread Estimator is $211,869 which takes into account CHP's system capacity, electric efficiency, thermal output, system fuel cost, installed cost, and operation and maintenance costs.

As a result, based on the stage 1 of the feasibility analysis provides by EPA for combined heat and power, Houston Museum is a very good candidate for using cogeneration. A full scale CHP system can be predicted to provide an annual operating savings of approximately $200,000. Thus, it is highly recommended for the owner to consider the system as well as further in-depth analysis to be conducted to further assess the system and its practicality for this particular project.

SUMMARY AND CONCLUSION

Overall, great effort was exercised to provide designs for all the proposed systems in the Houston Museum of American Art. The lighting design for each of the four spaces closely follows the overall concept that focus around the idea to engage. The exterior luminaires was able to be more appealing to the human scale and more emphasis on how visitors and pedestrians see the space. Upon entering the lobby, occupants are able to enjoy the plaza-like indoor experience. The theater encompasses a lighting design that portrays the industrial inspiration of the nearby railway tracks. 8th floor gallery's lighting design integrates with other disciplines and creates a visually fascinating experience for the museum patrons. The lighting design in each space meets the required light levels and specified criteria.

Analysis of the existing skylight features in the gallery proved that north facing skylights are providing comfortable daylight while letting no direct sunlight coming through. An open-loop photosensor was determined to be used for controlling the ambient lights. The acoustical analysis of the room concluded that the acoustical condition in the room is acceptable. The cogeneration feasibility analysis established the first step towards developing combined heat and power system for the project.

Overall, the integration between different systems were thoroughly investigated and implemented enables both functional and visual impacts.

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APPENDIX A: LUMINAIRE SCHEDULE AND CUT SHEETS

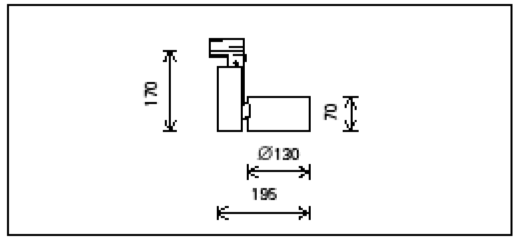
Type	Description	Manufacturer	Catalog Number	Lamp Type	Input watts
AL-1	Optec LED spotlight with flood lens, dimmable, 4000K	Erco	71058.000	LED	24W
AL-2	Optec LED spotlight with spot lens, dimmable, 4000K	Erco	71022.000	LED	24W
AL-3	Optec LED lens wall washer, 3000K	Erco	71063.000	LED	24W
AL-4	Optec LED lens wall washer, 4000K	Erco	71033.000	LED	24W
AL-5	Quintessence downlight with LED, 3000K	Erco	47812.000	LED	24W
AL-6	Quintessence downlight with LED, 4000K	Erco	41511.000	LED	24W
AL-7	Hensley LED ingrade	Winona	HELED-9006-12V-L4-L0-SIS-F0-SHO-TF-0-STD	LED	18W
AL-8	Axis Walklight	Erco	33750.000	LED	1.7W
AL-9	Winline Surface Linear 309 Wet	Winona	WSL-309	LED	64.2W

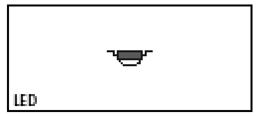
AL-1

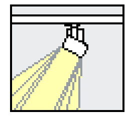
ERCO

Optec Spotlight

with LED



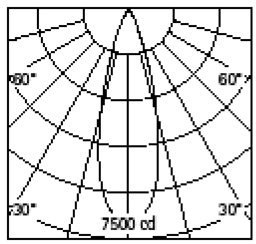




DALI
PLUG+
PLAY

71058.000 White
LED 24W 2400lm 4000K neutral white
DALI
Version 1
Spherolit lens, flood

Product description
Cylindrical light head: cast aluminium, powder-coated. 270° tilt.
Housing: plastic, rotatable on DALI adapter through 360°.
DALI control gear, with plug and play connectivity.
ERCO DALI adapter for DALI track: plastic.
LED module: high-power LEDs on metal-core PCB. Collimating lens made of optical polymer.
Weight 1.10kg
LMF E



LED 24W 2400lm 4000K neutral white

h(m)	E(lx)	D(m) 30°
1	6904	0.54
2	1726	1.07
3	767	1.61
4	431	2.14
5	276	2.68

Mounting
ERCO DALI track
Hi-trac DALI track
Monopoll DALI track
DALI singlet

ERCO GmbH
Brockhauser Weg 80-82
58507 Lüdenscheid
Germany
Tel.: +49 2351 551 0
Fax: +49 2351 551 300
info@erco.com

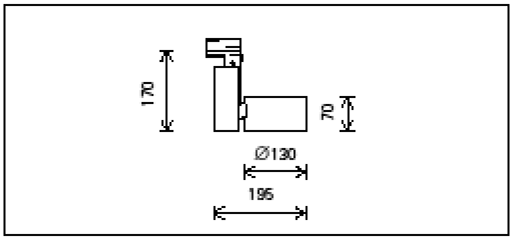
Technical Region: 230V/50Hz
We reserve the right to make technical and design changes.
Edition: 27.10.2012
Current version under
www.erco.com/71058.000

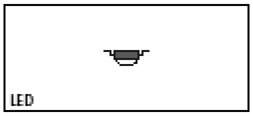
AL-2

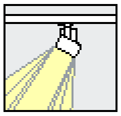
ERCO

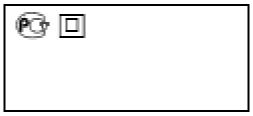
Optec Spotlight

with LED



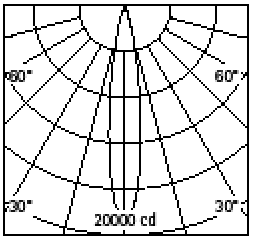






71022.000 White
LED 24W 2400lm 4000K neutral white
Version 1
Spherolit lens, spot

Product description
Cylindrical light head: cast aluminium, powder-coated. 270° tilt.
Housing: plastic, rotatable on 3-circuit adapter through 360°.
Electronic control gear, dimmable.
Potentiometer for brightness control 1%-100%.
ERCO 3-circuit adapter: plastic.
LED module: high-power LEDs on metal-core PCB. Collimating lens made of optical polymer.
Dimming with external dimmers possible (trailing edge).
Weight 1.08kg
LMF E



LED 24W 2400lm 4000K neutral white

h(m)	E(lx)	D(m) 17°
1	18261	0.30
2	4565	0.60
3	2029	0.90
4	1141	1.20
5	730	1.49

Mounting
ERCO 3-circuit track
Hi-trac 3-circuit track
Monopoll 3-circuit track
1-circuit singlet

ERCO GmbH
Brockhauser Weg 80-82
58507 Lüdenscheid
Germany
Tel.: +49 2351 551 0
Fax: +49 2351 551 300
info@erco.com

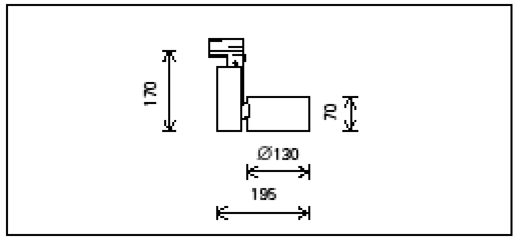
Technical Region: 230V/50Hz
We reserve the right to make technical and design changes.
Edition: 27.10.2012
Current version under
www.erco.com/71022.000

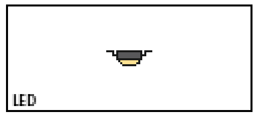
AL-3

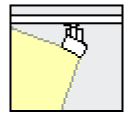
ERCO

Optec Lens wallwasher

with LED







DALI
PLUG+
PLAY

71063.000 White
LED 24W 1920lm 3000K warm white
DALI
Version 1
Spherolit lens, wallwash

Product description
Cylindrical light head: cast aluminium, powder-coated. 270° tilt.
Housing: plastic, rotatable on DALI adapter through 360°.
DALI control gear, with plug and play connectivity.
ERCO DALI adapter for DALI track: plastic.
LED module: high-power LEDs on metal-core PCB. Collimating lens made of optical polymer.
Weight 1.10kg
LMF E

Mounting
ERCO DALI track
Hi-trac DALI track
Monopoll DALI track
DALI singlet

ERCO GmbH
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Germany
Tel.: +49 2351 551 0
Fax: +49 2351 551 300
info@erco.com

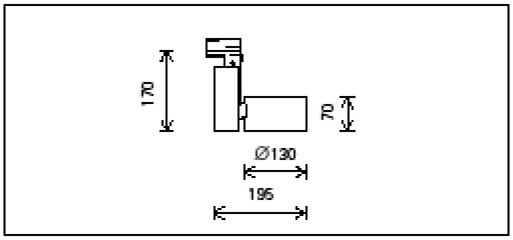
Technical Region: 230V/50Hz
We reserve the right to make technical and design changes.
Edition: 27.10.2012
Current version under
www.erco.com/71063.000

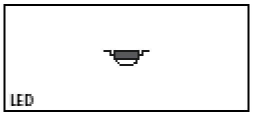
AL-4

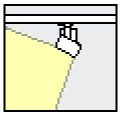
ERCO

Optec Lens wallwasher

with LED







71033.000 White
LED 24W 2400lm 4000K neutral white
Version 1
Spherolit lens, wallwash

Product description
Cylindrical light head: cast aluminium, powder-coated. 270° tilt.
Housing: plastic, rotatable on 3-circuit adapter through 360°.
Electronic control gear, dimmable.
Potentiometer for brightness control 1%-100%.
ERCO 3-circuit adapter: plastic.
LED module: high-power LEDs on metal-core PCB. Collimating lens made of optical polymer.
Dimming with external dimmers possible (trailing edge).
Weight 1.08kg
LMF E

Mounting
ERCO 3-circuit track
Hi-trac 3-circuit track
Monopoll 3-circuit track
1-circuit singlet

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info@erco.com

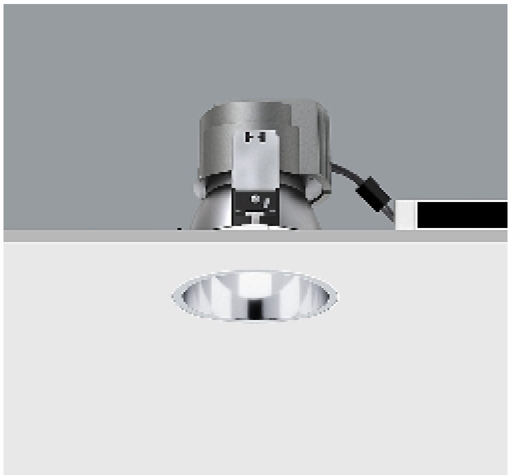
Technical Region: 230V/50Hz
We reserve the right to make technical and design changes.
Edition: 27.10.2012
Current version under
www.erco.com/71033.000

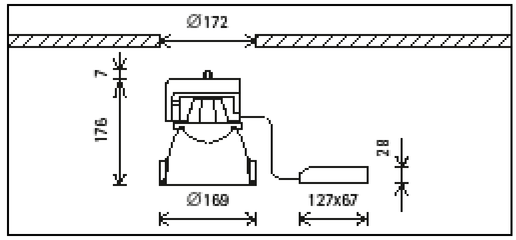
AL-5

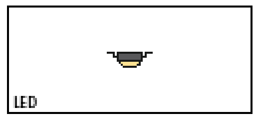
ERCO

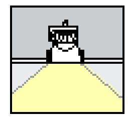
Quintessence Downlight

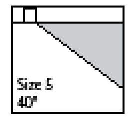
with LED







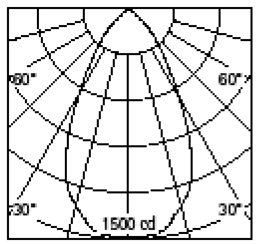




DALI
PLUG+
PLAY

47812.000
LED 24W 1920lm 3000K warm white
DALI
Version 3
Flush mounting detail
Wide diffuser

Product description
Housing: cast aluminium, designed as heat sink, with connection cable L 750mm. Fixing ring: plastic, black. Mounting ring: plastic, white (RAL9002). Mounting for ceiling thicknesses of 1-30mm with covered mounting detail and 12.5-25mm with flush mounting detail.
Including DALI control gear with plug and play connectivity. 4-pole terminal block.
LED module: high-power LEDs on metal-core PCB. Reflector for mixing light: aluminium, silver, mirror-finish anodised.
Darklight reflector: aluminium, bright anodised. Cut-off angle 40°.
Diffuser: glass, frosted.
Weight 1.20kg
LMF D



LED 24W 1920lm 3000K warm white

LOR	0.70
UGR	16.3
55° <	200 cd/m²

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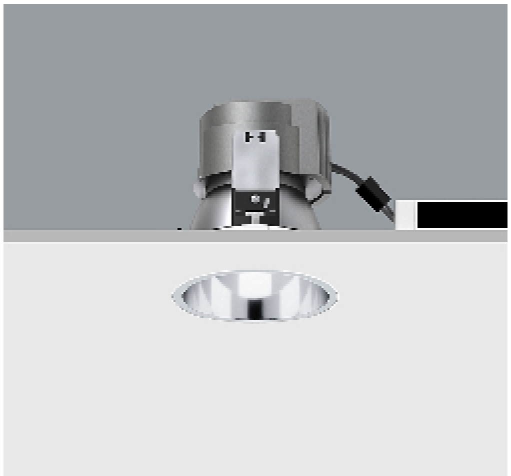
Technical Region: 230V/50Hz
We reserve the right to make technical and design changes.
Edition: 27.10.2012
Current version under
www.erco.com/47812.000

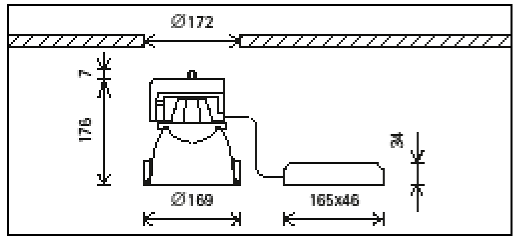
AL-6

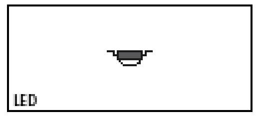
ERCO

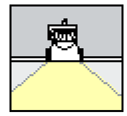
Quintessence Downlight

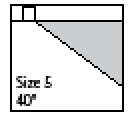
with LED

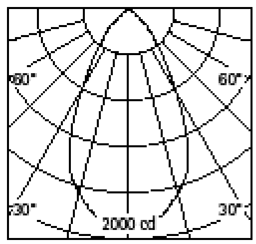












LED 24W 2400lm 4000K neutral white

LOR	0.70
UGR	17.1
55° <	200 cd/m²

41511.000
LED 24W 2400lm 4000K neutral white
Version 3
Flush mounting detail
Wide diffuser

Product description
Housing: cast aluminium, designed as heat sink, with connection cable L 750mm. Fixing ring: plastic, black. Mounting ring: plastic, white (RAL9002). Mounting for ceiling thicknesses of 1-30mm with covered mounting detail and 12.5-25mm with flush mounting detail.
Including electronic control gear, dimmable. Through-wiring possible. 4-pole terminal block.
LED module: high-power LEDs on metal-core PCB. Reflector for mixing light: aluminium, silver, mirror-finish anodised.
Darklight reflector: aluminium, bright anodised. Cut-off angle 40°.
Diffuser: glass, frosted.
Dimming with external dimmers possible (trailing edge).
Weight 1.20kg
LMF D

ERCO GmbH
Brockhauser Weg 80-82
58507 Lüdenscheid
Germany
Tel.: +49 2351 551 0
Fax: +49 2351 551 300
info@erco.com

Technical Region: 230V/50Hz
We reserve the right to make technical and design changes.
Edition: 27.10.2012
Current version under
www.erco.com/41511.000

Type: AL-7

WINSCAPE™ Project:______________________ Qty:______

Hensley LED • LED-32

ingrade

Construction: Housing injection molded from composite material. Top machined from ALUMINUM. Lens cut from tempered borosilicate glass for superior clarity and strength.
LED Unit: Winscape proprietary unit using nine (9) High Output LEDs and an integral low voltage AC LED driver. Available in three (3) beam spreads; 10° Spot, 25° Narrow Flood, and 40° Flood. Available in Warm White (3000K) and Cool White (5000K) color temps.
Dimming: Dimmable with a standard low voltage MAGNETIC dimmer.
Finishes: Available in 12 standard TGIC polyester powdercoat finishes. Custom powdercoat finishes available (contact factory for more information). Ingrade housing is always black.
Features: Watershed™ Lens included standard and is field replaceable. Any combination of up to 2 lens accessories/color filter/shielding can be specified and are held securely by a removable stainless steel clip ring behind the lens. Concrete pour collar available. Sealed wiring compartment to prevent water intrusion into lamp compartment. Glare Shield and Rock Guard available, see page 2. Lamp adjustable 22° from vertical and 360° around.

General: This fixture requires a 12V MAGNETIC transformer to function properly. Transformer must be purchased separately (see Accessories section on our website). Visible screws are Black Zinc plated, color matched screws available on request. Six 1/2" conduit entry holes on bottom and side for wiring. Fixture is suitable for concrete pour with pour collar option and is suitable for drive-over applications up to 6 tons. For in-ground use only. IP68 rated, not for submersion.

1. **HELED** SERIES — HELED – HENSLEY LED

2. LIGHT SOURCE

*Warm White, 3000K, 390 lumen ***	*Cool White, 5000K, 490 lumen ***
9002 – 15W/10° SP/WW LED	9005 – 15W/10° SP/CW LED
9003 – 15W/25° NFL/WW LED	9006 – 15W/25° NFL/CW LED
9004 – 15W/40° FL/WW LED	9007 – 15W/40° FL/CW LED

**Lumen output is rated "in fixture" as tested at about 11.5 vac input power. Actual lumen ouput will vary based on input voltage and beam spread.

3. **12V** VOLTAGE — 12V – 12 VOLT

4. LENS OPTION — L4 – CLEAR LENS; NSL – NON-SLIP LENS

5. ACCESSORY LENS — L0 – NONE; L1 – PRISMATIC; L2 – LINEAR; L3 – SOFTENING

6. FINISH

BKS – BLACK SMOOTH	IVS – IVORY SMOOTH
BKT – BLACK TEXTURED	CHS – CHROME SMOOTH
BRS – BRONZE SMOOTH	NBS – NATURAL BRONZE SMOOTH
BRT – BRONZE TEXTURED	VET – VERDE TEXTURED
WHS – WHITE SMOOTH	SAT – SAND TEXTURED
WHT – WHITE TEXTURED	CPF – CUSTOM FINISH
SIS – SILVER SMOOTH	

7. COLOR FILTER

F0 – NONE	FG – GREEN
FM – MERCURY VAPOR	FGD – GREEN DICHROIC
FR – RED	FLB – LIGHT BLUE
FRD – RED DICHROIC	FMB – MEDIUM BLUE
FP – PINK	FMBD – MEDIUM BLUE DICHROIC
FA – AMBER	

8. SHIELDING — SH0 – NONE; SH6 – HONEYCOMB LOUVER

9. **TF** TOP STYLE — *TF – FLAT TOP

10. OPTIONS — 0 – NONE; PC – CONCRETE POUR COLLAR; *RG – ROCK GUARD; *GS – 180° GLARE SHIELD

11. SPECIAL — STD – STANDARD; MOD – MODIFIED

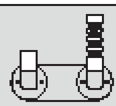
* Rockguard (RG) and 180° Glare Shield (GS) can only be used with Flat Top (FT). Rockguard (RG) and 180° Glare Shield (GS) are not rated for drive over application.

Modification Descriptions: (if needed)

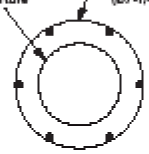
Note: Winona Lighting reserves the right to make design revisions without prior notice.

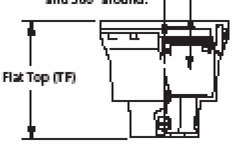
MOUNTING OPTIONS:


BELOW GROUND MOUNT


MODIFIED STANDARD

ETL Listed:
Indoor/Outdoor Conforms to UL STD 2108



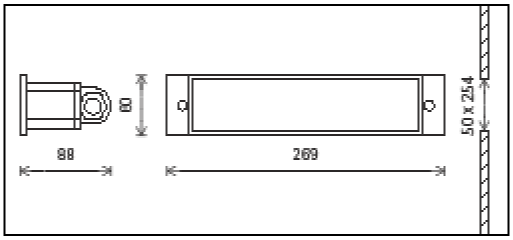


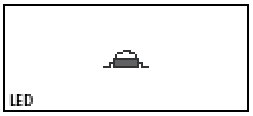
AL-8

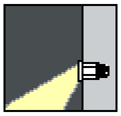
ERCO

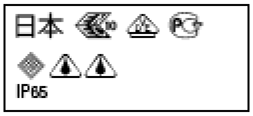
Axis Walklight

with LED



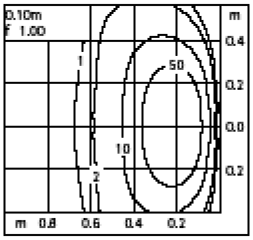






33750.000
LED 1.7W 230V AC 90lm 4000K neutral white
Version 2

Product description
Housing: corrosion-resistant cast aluminium, No-Rinse surface treatment. Graphit m, double powder-coated. Fixing element: plastic. Clamp extension 7-20mm.
2 cable entries. Through-wiring possible. 3-pole terminal block.
Asymmetric reflector lens system: aluminium, silver anodised. Optimised screening for the LEDs ensures no direct light emission. LED module.
Cover frame with Softec lens: corrosion-resistant cast aluminium, graphit m double powder-coated.
Protection mode IP65: dust-proof and water jet-proof.
On site protection must be provided using a residual current circuit breaker, FI≦30mA.
Weight 0.85kg
LMF E



LED 1.7W 230V AC 90lm 4000K neutral white

ERCO GmbH
Brockhauser Weg 80-82
58507 Lüdenscheid
Germany
Tel.: +49 2351 551 0
Fax: +49 2351 551 300
info@erco.com

Technical Region: 230V/50Hz
We reserve the right to make technical and design changes.
Edition: 27.10.2012
Current version under
www.erco.com/33750.000

AL-9

Winline Surface Linear 309 Wet

Series: WSL - Winline Surface Linear

Model: Model 309 Wet

Run Length Code: **Total Run Length in Feet**
309W Offered in 6" Increments Starting at 12"
Ex. 24 FT= 24 Foot Run

Preconfigured Run Length Code
See Submittal at www.winonalighting.com

To Be Determined
TBD When Run Length Unknown

Beam Spread:
15 - 15
30 - 30°
60 - 60°
100 - 100°

LED Code:
27K -
30K -
35K -
40K -

300 Series Color Temperature	Model 309W lm/ft	W/ft
ANSI-2700K White	708	16.0
ANSI-3000K White	723	16.0
ANSI-3500K White	846	16.0
ANSI-4000K White	875	16.0

Voltage:
ND24V - Non-Dimming 24 Volt AC
DM24V - Dimming 24 Volt AC

Mount:
F - Fixed
A - Adjustable

Finish:
NAA - Natural Type III Anodized Aluminum
SGB - Semi-Gloss Black Paint
SGW - Semi-Gloss White Paint
CPF - Custom Paint Finish

Power Feed:
SE - Surface End Feed
*RB - Recessed Bottom Feed
*available on F (fixed mount) only

Options: X - None

Special:
STD - Standard
MOD - Modified

Power and Dimming

The Winline 200 Series operates on 24VAC and can be dimmed with commonly available low voltage magnetic dimming equipment. A wide range of remote transformers are available in 120V and 277V primary (see pages 65-66).

Mounting and Adjusting

Both fixed and adjustable mounts combined with an integral wire tray allow for ease of installation and organized wiring. The low profile fixed mount is 1/8" high and the adjustable mount allows for a 300 degree rotation around the centerline of the fixture.

Operating Temperature

-22°F to 122°F (-30°C to 50°C)

Color and Light Output

The 300 Series utilize Nichia 757 white LEDs in four standard color temperatures.

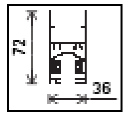
Winline Surface Linear - **WSL**	WSL	series
Model 309W wet - **309**		model
Total Run Length in Feet offered in 6" increments starting at 12" *ex. 24 FT= 24 foot run* *or* **Preconfigured Run Length Code** *see page 5* *or* **To Be Determined** *TBD when run length unknown*		run length code
15° - **15**; 30° - **30**; 60° - **60**; 100° - **100**		beam spread
ANSI-binned 2700K - **27K**; ANSI-binned 3000K - **30K**; ANSI-binned 3500K - **35K**; ANSI-binned 4000K - **40K**		LED code
non-dimming 24 volt AC - **ND24V**; dimming 24 volt AC - **DM24V**		voltage
fixed - **F**; adjustable - **A**		mount
natural (type III) anodized aluminum - **NAA**; semi gloss black paint - **SGB**; semi gloss white paint - **SGW**; custom paint finish - **CPF**		finish
surface end feed - **SE**; recessed bottom feed - **RB***; **available on F (fixed mount) only*		power feed
none - **X**	X	options
surface end feed - **SE**; back to back - **B2B**; right angle - **RA**; recessed bottom feed - **RB***		special

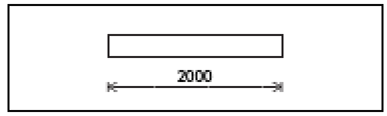
*Recessed Bottom feed available on fixed mount only

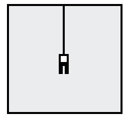
Describe Modification:

ERCO

ERCO Hi-trac track







13400.000 White
Length 2000mm

Product description
Panel profile: aluminium, powder-coated.
Upper part: empty compartment, for fixing of uplights, through-wiring or cover profile.
Lower part: track. 4 isolated copper conductors and impressed earth conductor.
When used as DALI track: one 16A circuit and two conductors for connecting to the DALI data line.
When used as a 3-circuit track: three separately switchable circuits 16A each.
The ERCO track system is approved to IEC 60570 (EN 60570/VDE 0711 part 300).
Weight 4.00kg

ERCO GmbH
Brockhauser Weg 80-82
58507 Lüdenscheid
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Tel.: +49 2351 551 0
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Technical Region: 230V/50Hz
We reserve the right to make technical and design changes.
Edition: 26.10.2012
Current version under
www.erco.com/13400.000

<u>Academic Vita</u>

Chang Liu

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EDUCATION	The Pennsylvania State University Schreyer Honors College BAE/MAE E.I.T. status upon graduation	08. 2009 – 05. 2013
EMPLOYMENT	Office for Visual Interaction, New York, NY Lighting Design Intern • Worked with a team of lighting designers on different aspects of the design process • Responsibilites include conceptual design, design development, layout, specification, lighting Mock-up study, manufacturer communication, Chinese translation, calculations, renderings, control strategy research and presentation	05. 2012 – 08. 2012
	Joseph R. Loring and Associates, Inc., New York, NY Electrical Intern • Assisted with lighting and electrical system calculation and design • Worked extensively with AutoCAD • Participated in field surveys on institutional based projects	05. 2011 – 08. 2011
	The Penn State Food Service, State College, PA	09. 2009 – 01. 2012
ACTIVITIES	Illuminating Engineering Society Phi Alpha Epsilon, Architectural Engineering Honor Society Tau Beta Pi, Engineering Honor Society Student Society of Architectural Engineers Penn State International Dance Ensemble Habitat for Humanity Service Spring Break, Clay County, Florida IALD Enlighten Americas 2011 Conference	
ACHIEVEMENTS	Schreyer Scholar AE Class of 1975 Scholarship Henrietta M. Fisher Scholarship IES-Phila. Sect. of Illumination Engr. Society Scholarship	
SKILLS	AGI32, Daysim, Radiance, Ecotect, 3D AutoCAD, Revit, Photoshop, In-design, Chinese	
SPECIALIZED COURSE	BIM studio - Lighting/Electrical Consultant (Spring 2012) Integrated design is accomplished in a highly collaborative environment by teams of 6 students from each discipline, using building information modeling technology and integrated project delivery.	