spertus | Institute of Jewish Studies | 610 S Michigan Ave Chicago, IL

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# ARCHITECTURAL ENGINEERING SENIOR THESIS
# FINAL REPORT

**Consultants:**
**Lighting - Dr. Kevin Houser I Electrical - Ted Dannerth**

**kanis glaewketgarn** | lighting/electrical | april 7, 2009

Kanis Glaewktgarn
Lighting/Electrical Option
Lighting Consultant: Dr. Kevin Houser
Electrical Consultant: Professor Ted Dannerth
Design Integration Consultant: Professor Robert Holland

Spertus Institute of Jewish Studies
610 S Michigan Ave. Chicago, IL
April 7, 2009

## Executive Summary

Spertus is a Jewish institution grounded in Jewish values that invites people of all ages and backgrounds to explore the multi-faceted Jewish experience. The building itself is used as tool to open up people's minds to learn and experience other cultures.

The core of the report is an analysis and redesign of the lighting and electrical systems for the four spaces within the building including the building façade/exterior, the main lobby space, the Feinburg Theater, and the open office. The 'Star of David' concept is used as a design inspiration throughout the building. The architecture of the building expresses itself through forms, clean lines, and materials. All these elements are successfully enhanced through the use of light and shadow. Subtle and integrated lighting design solutions are the key to blend lighting with the architecture while introduce functions and drama into the space.

To make lighting design a reality, electrical systems of the four spaces are redesigned to meet the lighting design objectives and goals. The electrical scope of work includes the panelboard redesign, the implementation of control systems, and the study fault current analysis. The two electrical depth studies are conducted. One is the analysis of the cost saving from utilizing energy efficient loads. The analysis particularly focuses on energy efficient light sources. In addition a feasibility-cost analysis was conducted for changing all the existing non-energy efficient transformers in the building with energy efficient transformers.

For the breadth topics, an acoustical system in the Feinburg Theater is analyzed and redesigned. The ceiling panels are proposed to not only enhance the acoustical performance, but also to better integrate other systems including mechanical and lighting with interior architecture of the space. Design integration and coordination study is conducted to ensure feasibility of the solutions as well as to forecast any potential conflicts.

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## project team

- **Owner:** Spertus Institute of Jewish Studies
- **Architect:** Krueck+Sexton Architects
- **MEP/FP &** Tel/Data: Environmental Systems Design, Inc
- **Lighting Design:** SPI Design Inc. / Schuler Shook
- **Structural Engineer:** Tylk Gustafson Reckers Wilson Andrews
- **General Contractor:** W.E. O'Neil Construction Co.
- **Theater Consultant:** Schuler Shook

## architecture

Unlike surrounding buildings, Spertus offer dynamic glass façade that compels the folding and movement of material. The Spertus is designed to celebrate, share and explore wisdom gained over centuries of Jewish thought and study. The Institute comprises of the Spertus Museum, the Asher Library, and the Spertus College.

## electrical

Three service entrances with two 480Y/277V switchboards for mechanical equipment and one 208/120V switchboard for lighting and receptacles. 450KW, 480Y/277V emergency generator supplies four automatic transfer switches.

## lighting

General ambient light is provided by a combination of halogen downlight and fluorescent direct light that is integrated with ceiling grid system. High intensity discharge source is utilized to illuminate lobby atrium and sculpture wall. The museum space is equipped with recessed track system allowing for flexibility and control. Integration of daylight is employed throughout the building by skylight and fritted glass façade.

## mechanical

The central plant consists of air cooled packaged liquid chiller and electric heating coil. Two air handling units located on the roof and the 5th floor distribute air to series of fan powered variable air volume units to supply air.

## structure

The gravity loads resisting system consists of composite floor deck supported by steel beams and columns and concrete core walls in truss supported on concrete grade beams on deep concrete caissons. The lateral load resisting system consists of concrete shear walls and steel cross-bracing.

## building information

**address:** 610 S Michigan Ave Chicago, IL
**size:** 155,000 sq.ft.
**levels:** 10 stories above grade
**cost:** $59 million (actual construction cost)
**construction time:** Sep 07 - Sep 09
**delivery method:** design-bid-build GPM

**kanis glaewketgarn** | lighting/electrical | 2009 senior thesis

www.engr.psu.edu/ae/thesis/portfolios/2009/kvg5003/

## General Building Statistics

**Building name:** Spertus

**Location and site:** 610 South Michigan Ave Chicago, IL 60605

**Building occupant name:** Institute of Jewish Studies

**Occupancy / function types:** Institutional facility that includes the following space types:

- Museum
- College
- Library

**Size:** 155,000 Sq.ft.

**Number of stories above grade:** 10 (total levels: 11)

**Primary projects team:**

- Owner: Spertus Institute of Jewish Studies
- Architects: Krueck+Sexton Architects
- MEP/FP & Tel/Data: Environmental Systems Design
- Structural Engineer: Tylk Gustafson Reckers Wilson Andrews
- Lighting Design: ISP Design, Inc. / Schuler Shook
- General Contractor: W.E. O'Neil Construction Co.
- Theater Consultant: Schuler Shook

**Dates of construction:** September 2007 – September 2009

**Actual cost information:** $59 million (actual construction cost)

**Project delivery method:** Design-bid-build – GPM

**Architecture:**
The new Spertus is both resolutely contemporary and respectful of its distinguished neighbors. Unlike surrounding buildings, Spertus offer dynamic glass façade that compels the folding and movement of material. The use of natural daylight has played a significant role in the programming to create dramatic and functional spaces.

The Spertus is designed to celebrate, share and explore wisdom gained over centuries of Jewish thought and study. The Institute comprises of the Spertus Museum, the Asher Library, and the Spertus College. Spertus Museum has made use of new technology and new approaches to exhibit design and artwork. It consists of two-storey of flexibly planned exhibit spaces. In the Asher Library, ancient manuscripts and rare maps are maintained in state-of-the-art storage systems including movable stacks. Spertus College contains classrooms and offices that offer students and faculties a facility to interact and being productive. Spertus also offers a state-of-the-art theater for live performance and film, space for community events and celebrations, and a kosher café in partnership with Wolfgang Puck Catering.

**Major and National model code:** Chicago Building Code (CBC 2004)

**Zoning:**
According to City of Chicago Department of Zoning, Spertus site is situated on Private Lakefront Zone (Lot DX-16). Building Maximum height is 161’-0” (excluding mechanical equipment) and the maximum projection into the public way is 5’-0”.

**Histrorical requirements:**
Although the building is located on Michigan Ave which is considered the street of historic landmark buildings, there is no real restriction on the historical requirements. However the building design and architecture has to be approved by the Commission on Chicago Landmarks (CCL) under the Commission’s Guidelines for Alterations to Historic Buildings and Construction.

**Building envelope:**
The geometry of the façade is unique because the surface is constantly tilting in three dimensions. There are total of 720 individual pieces of 250 different shapes with a typical size of 4'-4" x 7'-0". Glass pieces are held by custom aluminum mullion spanning 14' on floors 1 through 8 and 21' on floors 9 and 10. 1" silicone joint is used to insulate glass and keeping wind and moisture from entering the building. The wall was tested for leakage while subjected to wind pressure of 47 lbs. per square foot and wind speed of 136 miles per hour at Construction Consulting Laboratory. Roof system is comprised of 1-1/2” metal roof deck, garden roof assembly, and precast concrete pavers.

**Construction:**
W.E. O’Neil Construction Co. is the primary construction management firm for this project. The delivery method was original GMP with a project budget of $57.7 million. Actual project cost came over budget to $59 million (includes Museum, Library, FF&E buildouts, Soft costs, internal systems, etc). Budgeted Construction cost was $37.5 million. Actual construction also came over budget to $39.6 million.

Groundbreaking began late September 2005 and building substantially completed on September 29, 2007.

**Electrical:**
The power distribution system consists of an electrical service provided by ComEd. Five feeders deliver power to Spertus from the utility company's transformer vault. Two 58,000 AIC transformer each serves 2,000A, 480/2277V service entrance switchboard. Another 2,000A, 208/120V service entrance switchboard is served by 40,000 AIC transformer. Two out of five service entrance switchboards are dedicated for emergency service including fire pump and fire alarm power. A backup diesel generator provides emergency power.

A combination of 480Y/277V, 3-phase, 4-wire and 208Y/120V, 3-phase, 4-wire voltages are utilized in the building. Majority of lighting system is served by 120V, while most of mechanical equipments are fed from 480Y/277V, 3-phase appliance.

**Lighting:**
Lighting design of Spertus compliments the architectural concept of the building by featuring and highlighted many design elements in the subtle way. General lighting layout designed around grid system to provide consistent appearance while maintaining quality of light. IESNA lighting design guideline and criteria were implemented to create appropriate visual performance and environment. Lighting design and systems were designed to meet ASHRAE/IESNA Standard 90.1 Energy code requirement using space-by-space method.

General ambient light is provided by a combination of halogen downlight and fluorescent direct light that is integrated with ceiling grid system. High intensity discharge source is utilized to illuminate lobby atrium and sculpture wall. The museum space is equipped with recessed track system allowing for flexibility and control. Integration of daylight is employed throughout the building by skylight and fritted glass façade.

**Mechanical:**
The central plant consists of two 149 tons air cooled packaged liquid chillers with R-134 refrigerant located on the roof and electric heating coils located in AHUs. 60,000 CFM air handling unit locates on the 5$^{th}$ floor distribute air to basement-7$^{th}$ floor. While 40,000 CFM air handling unit located on the roof supplies air to 7$^{th}$-10$^{th}$ floor. Air is supplied to series of fan powered variable air volume units to supply air. 2,400 gallon bladder expansion tanks are located in the mechanical room on the fifth floor. Cooling in the

**Structural:**
The gravity loads resisting system consists of composite floor deck supported by steel beams and columns and concrete core walls in truss supported on concrete grade beams on deep concrete caissons. Typical beam sizes utilized in upper floors (4-10) are W8X67 at the bay next to the façade and W16X26 for the rest of the floor area. Composite floor deck consists of 2" 20 GA composite metal deck and 3 ¼" light weight concrete topping. Roof framing consists of 3" 20 GA composite metal deck and 5" normal weight concrete. The lateral load resisting system consists of concrete shear walls and steel cross-bracing. Typical shear walls are located around the two stair wells, hoist way for freight elevator and passenger elevators.

**Communication Systems**

- Fire Alarm System
    - The fire alarm system is normally powered by its own feeder from ESWB-1 emergency service entrance switchboard. If power is lost, automatic transfer switch ATS-2 switches the power source to the emergency generator. This system includes heat detector, smoke detector, beam detector, sensors, voice communication speaker with visual alarm device, light safety alarm notification light, and manual pull boxes located throughout the building.

- Information Technology System
    - The main NET POP/ Data closet is located in the basement of the building. It supplies data through 100 PAIR ARMM to serve sub data closets on the fourth, sixth, eighth, and tenth floor and main sever room on the fifth floor. Data outlets are located throughout the building, to provide service for computers, phones, and AV equipment

- Security System
    - The security system includes door contacts, card readers, electric strike, security closed circuit television system outlet, and video cameras.

## Lighting Design: Building Façade / Exterior

**Description:**

The geometry of the façade is unique because the surface is constantly tilting in three dimensions. There are total of 720 individual pieces of 250 different shapes of laminated fritted glass assembly with a typical size of 4'-4" x 7'-0". Glass pieces are held by custom aluminum extrusion spanning 14' on floors 1 through 8 and 21' on floors 9 and 10. 1" silicone joint is used to insulate the glass and keep wind and moisture from entering the building.

**Space Category:** Building exterior/façade

**Area:** approx. 12,700 Sq.ft. (vertical projected area)

**Dimension:** 79’-0” x 161’-0”

**Elevation:**

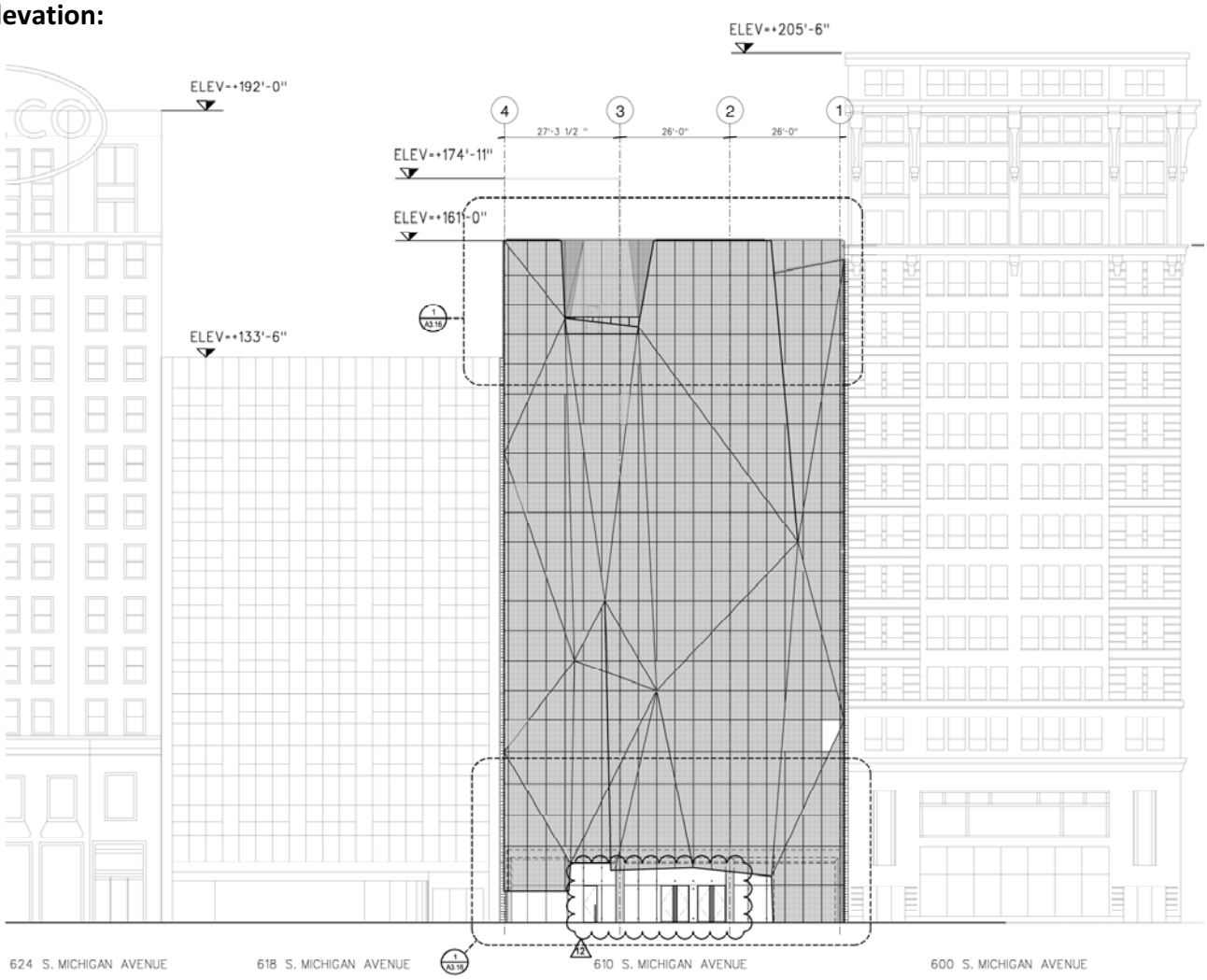



FIGURE 1: BUILDING EXTERIOR ELEVATION

**Photographs:**

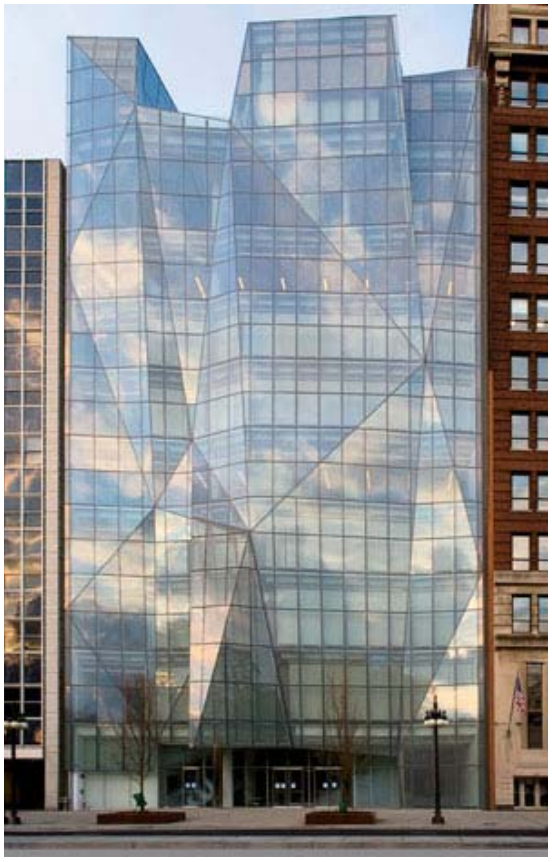


FIGURE 2: SPERTUS FAÇADE (EAST FACING)


FIGURE 3: VIEW FROM MICHIGAN AVE.

**Surface Materials:**

| Surface | Material | Reflectance |
|---|---|---|
| **Glass Façade** | Interior surface of the outer lite of glass has a low-E (low emissivity) coating and a 40% ceramic frit pattern made up of 0.125" white dots. | .4 (transmittance) |
| **Channel Set Glazing** | Aluminum extrusion frame, bright silver finish | .3 |
| **Solar Shade** | NYSAN Green screen fabric with 3% light transmission | .5 |

**Activities/Tasks:**

- Entrance to building
- The expression of warm welcoming through the transparency of the façade.

## Design Consideration / Criteria

**Design Consideration:**

- Reinforcement of Architectural concept
  - Façade lighting should convey the concept of 'The energy inside the building' and the idea of 'The animated façade that spells out what is going on inside'.
  - During the day, the glass façade refracts and reflects the image of the clouds moving across the sky. The idea of dynamic and movement of light is also very important in this design. Lighting can be used to mimic this natural effect during night time.

- Reinforcement of Architectural Features
  - The dynamic glass façade that compels the folding and movement of materials is the most important design element of the Spertus building.
  - Such design element should be emphasized during nighttime using lighting as a tool.

- Color Dynamics
  - The idea of the energy inside the building can be conveyed through shades of color
  - The perception of color is related to individual psychological interpretation. Most of them are commonly interpreted. That means colors can be used to express emotional feeling and relate people to this piece of art. For example, colors can be used for seasonal expression.
  - To emphasize dynamic apparent of the glass façade, the use of color could be implement to reinforce architectural feature.

- Constructability
  - The shape of glass façade is irregular and asymmetric. Depending on the design and location of fixtures, constructability may be an issue and may dictate many locations of the fixtures.
  - Small linear fixture may be appropriated for easy fitting or recessing.

- Glare Issue
  - Depending on the orientation and location of the façade lighting, direct glare could potentially be a problem for both building occupants and people on the street.
  - Smaller light source can be utilized to reduce discomfort glare.

- Glass Transmittance/ Opaqueness/ Material Properties
  - In order to make glowing effect, it requires surface with some reflectance or level of opaqueness to interact with light.
  - This may be an issue because frosted or translucent glass may minimize the outside views from the interior spaces.
  - Fritted glass with certain percentage of fritted dots maybe a good compromise for viewing and façade lighting purpose.

- Energy Considerations
  - Energy Code Requirements – ASHRAE 90.1-2004 – Lighting Power Densities for Building Exteriors
    - **1.25w/sq ft.** for attached canopies and overhangs
    - Exterior Building Grounds Lighting – All exterior building grounds luminaires that operate at greater than 100watts shall contain lamps having minimum efficacy of 60lm/w unless the luminaire is controlled by a motion sensor.

- Exterior lighting (below glass façade)
  - Visual Environment
    - Welcoming mat should be created by lighting to anchor the building and invite people into the building.
    - The area is right in fort of the vestibule. It should act as a transitional space before people enter the building. (illuminance levels gradually increase as progressing inside the building)
  - Visual Performance
    - **5 fc** on Horizontal workplane (ground) (Active pedestrian/conveyance – Entrances – Building Exteriors – Lighting design guide from the IESNA handbook)
    - **3 fc** on Vertical surfaces (Active pedestrian/conveyance – Entrances – Building Exteriors – Lighting design guide from the IESNA handbook)

## Lighting Redesign

### Lighting Solutions:

The 'Star of David' concept is first applied through the architecture of the façade and its lighting. Six triangular pieces are chosen to represent the six triangles on the Star of David. The use of custom design LED nodes allows the three-dimensional façade to be illuminated. The three-dimensional characteristic of the facade is enhanced through the combination of illuminated panels and voided (not illuminated) spaces. The grid pattern keeps the array of lights organized and less cluttered. In order to keep the clean lines of the façade during the day, the custom LED node is designed to fit between the glass panels. The four watts RGB LEDs from Lamina are chosen as a light source to feature rage of flexibility and color dynamics. Lighting Science Group Cooperation will be designing the fixture with the coordination of lighting designer and the curtain wall fabricator.

The general illumination at the building entrance is provided by a series of wet listed, ceramic metal halide recessed downlights. Matt of light is created on the floor by the entrance to not only provide adequate light level for mean of egress but also to create a sense of hierarchy and navigation to the entrance of the building.

The curtain walls on either sides of the façade opening are grazed and up-lit by linear LED fixtures to anchor the building and create an emphasis on the ground level. It is recommended that the bottom parts of the curtain glass walls are intensely frosted and faded as it continues to the top of the ground level. The same technique applies to the canopy/overhang. The canopy/overhang will be illuminated by 10 degrees beam Color Blast fixture from Color Kinetics. The color of the canopy lights will be matched and controlled with the LED nodes on the façade.

### Controls:

Lutron Grafik Eye control system is specified to control the façade and the exterior lighting. The façade LED nodes and canopy lights are connected to the DMX controller which is powered by the Lutron processor. All the zones listed below will be controlled from the control station behind the security desk by the entrance. Refer to Appendix C for Control diagrams.

**Facade Summary Load Schedule**

| Lutron Zone | Customer Zone | Zone/Circuit Description | Customer Circuit # | Voltage | Load Type | Actual Load (W/VA) |
|---|---|---|---|---|---|---|
| A3-1 | Exterior | Exterior CMH | L1/34 | 120V | Non-Dim | 264 |
| A3-2 | Facade1 | Linear LEDs | L1/41 | 120V | Non-Dim | 418 |
| A3-3 | Facade2 | Canopy LEDs | L1/40 | 120V | Non-Dim | 300 |
| A3-4 | Facade3 | LED Markers | L1/36 | 120V | Non-Dim | 950 |

### Summary Performance Evaluation:

The building façade/exterior lighting design successfully reinforces architectural forms and concepts. An adequate average illuminance level (5 fc) is provided at the area near the entrance of the building. Highlights and hierarchies are appropriately addressed to define the entry and ground the building to the site. The custom design LED nodes by Lighting Science must be provided for mock-up and performance comparison.

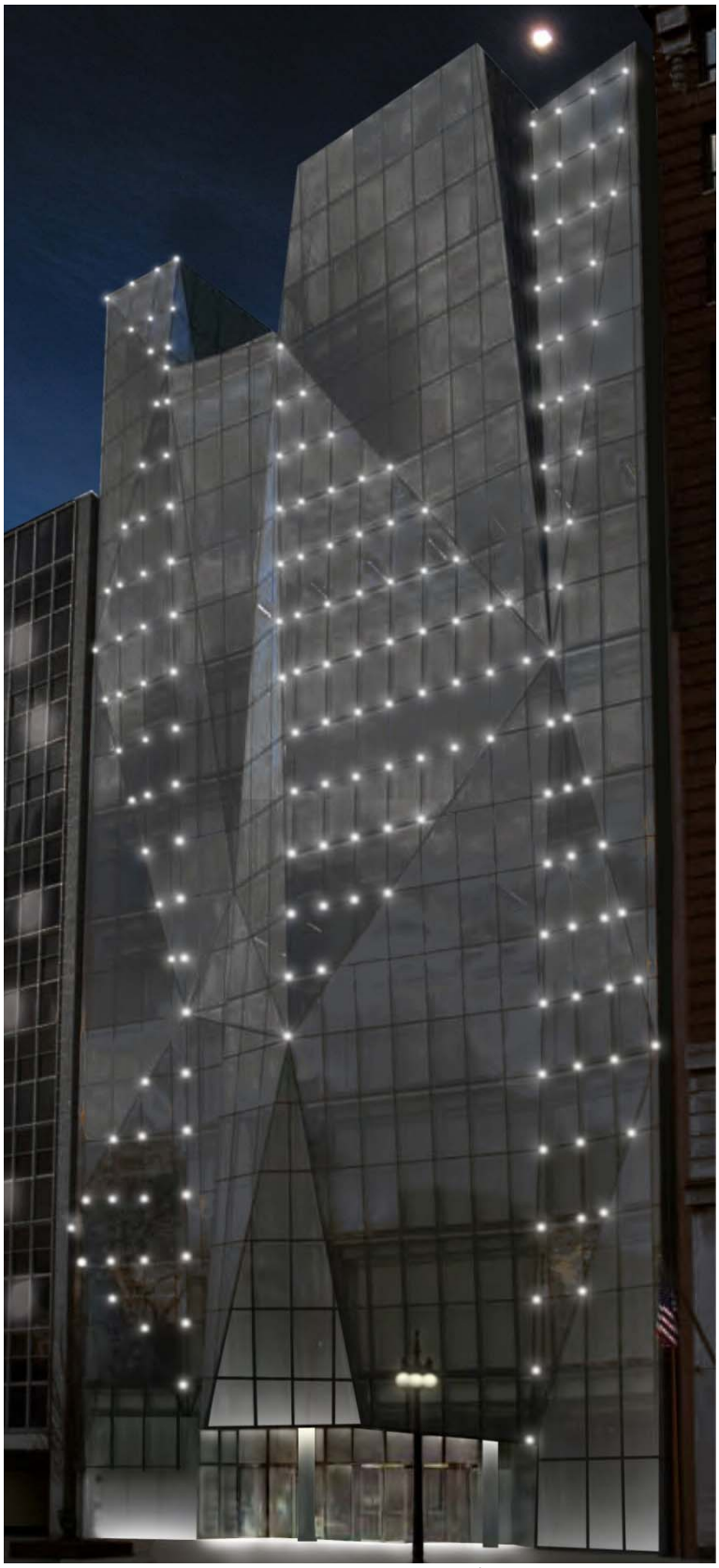


FIGURE 4: SCHEMATIC DESIGN FOR FAÇADE/EXTERIOR LIGHTING

## Coordination Study for Fixture Type F29:

The renderings below show the initial coordination study on how to integrate the LED nodes into the framing of the curtain wall. The LED nodes must be installed and prewired during the frame construction specifically before the seal insertion. The coordination effort for design and construction of this fixture involves the architects, project lighting designer, custom LED fixture manufacture, and curtain wall fabricator. These parties must review and approve the design, drawings, details, and specifications.

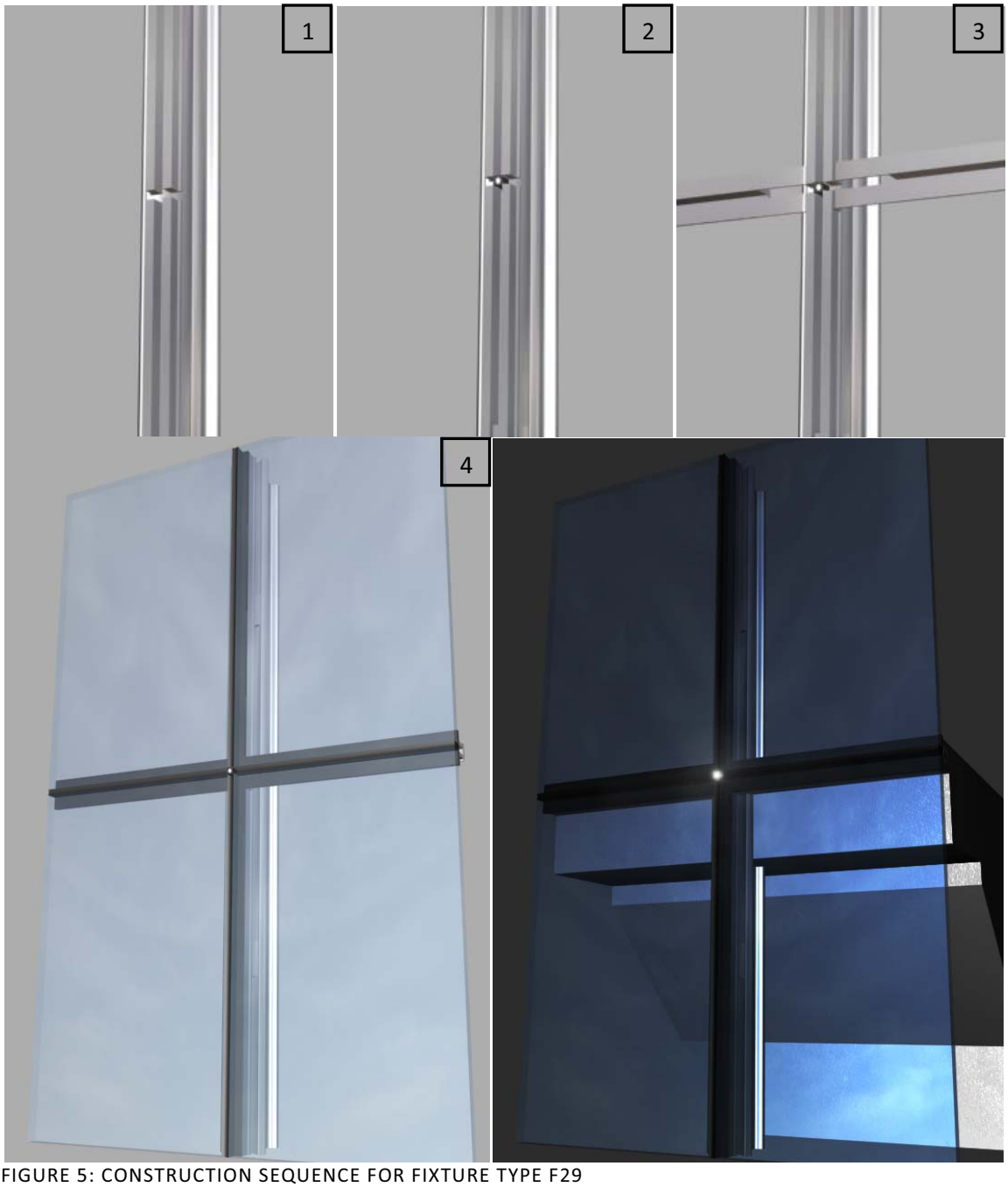



FIGURE 5: CONSTRUCTION SEQUENCE FOR FIXTURE TYPE F29

## Coordination Study for Fixture Type F28:

Fixture Type 28 (Color Blast Powercore by Color Kinetics) will be mounted on the center of each of the structural steel frames shown below. Electrical junction boxes must be supplied at each of the locations. The locations of the electrical junction boxes must be coordinated with the architects and the electrical engineers because they are exposed and visible from below. After the installation, these fixtures are recommended to be aimed and focused by the designer or its representative.

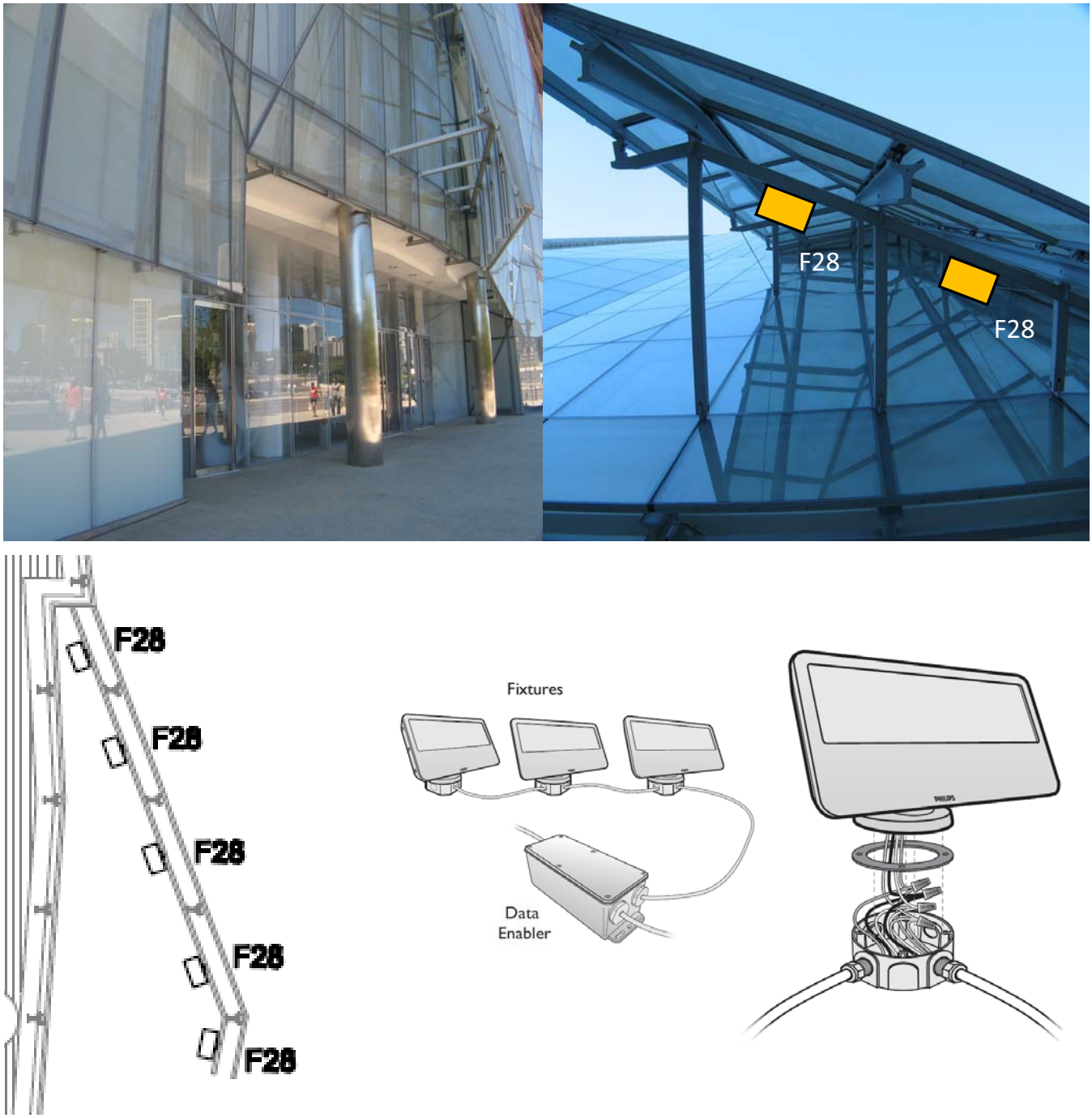



FIGURE 6: FIXTURE TYPE F28 MOUNTING LOCATION AND INSTALLTION DETAIL (COLOR KINETICS)

## Lighting Schedule

Refer to Appendix A for a complete schedule.

| Type | Manufacturer | CatalogNumber | Description | Electrical | Wattage |
|---|---|---|---|---|---|
| F26 | Cooper Ltg - io | 0.04.I.3K.90.102 | Surface-mounted LED strip light, rigid housing with LED (in cross-section). Optics: acrylic clear lens. | Remote transformer | 12 |
| F27 | Prescolite | RHD639T6EB-120V-MD-CP-ST6T4/6 | 6" recessed metal halide downlight with 1-39W T6 single-ended base lamp. Optics: tempered glass clear lens , painted or anodized aluminum reflector. | Integral electronic ballast | 44 |
| F28 | Color Kinetics | 123-000009-04 | A 10° beam for extended light projection. Locking canopy base offers friction-free rotation of up to 350°, and 110° fixture tilting lets you quickly aim the fixture without special tools. It accepts a universal power input range of 100 to 240 VAC, allowing the installation of many units in a continuous run. Fully sealed for maximum fixture life and IP66 rated for outdoor applications, ColorBlast Powercore fixtures meet or exceed specifications for use in wet locations. Rugged, die-cast aluminum housing is available in white or black powder-coated finish. Works seamlessly with the complete Philips line of controllers, including iPlayer 3 and Light System Manager, as well as third-party DMX controllers. | n/a | 50 |
| F29 | Lighting Science | CUSTOM ORDER | Custom LED marker, design to fit between glass panels to provide clean look from the outside. Fully sealed for maximum fixture life and IP66 rated for outdoor applications. Four watts Atlas RGB LEDs from Lamina will be used as a light source for this fixture. The Atlas RGB, through three independently controlled input / output channels (red, green and blue), produces any of 16 million beautifully saturated and blended colors (including white with variable color temperature) from a single point source. | Provide power and data supply from Lighintg Science:<br>Product# 500-002-921 | 4 |

## Lighting Plans

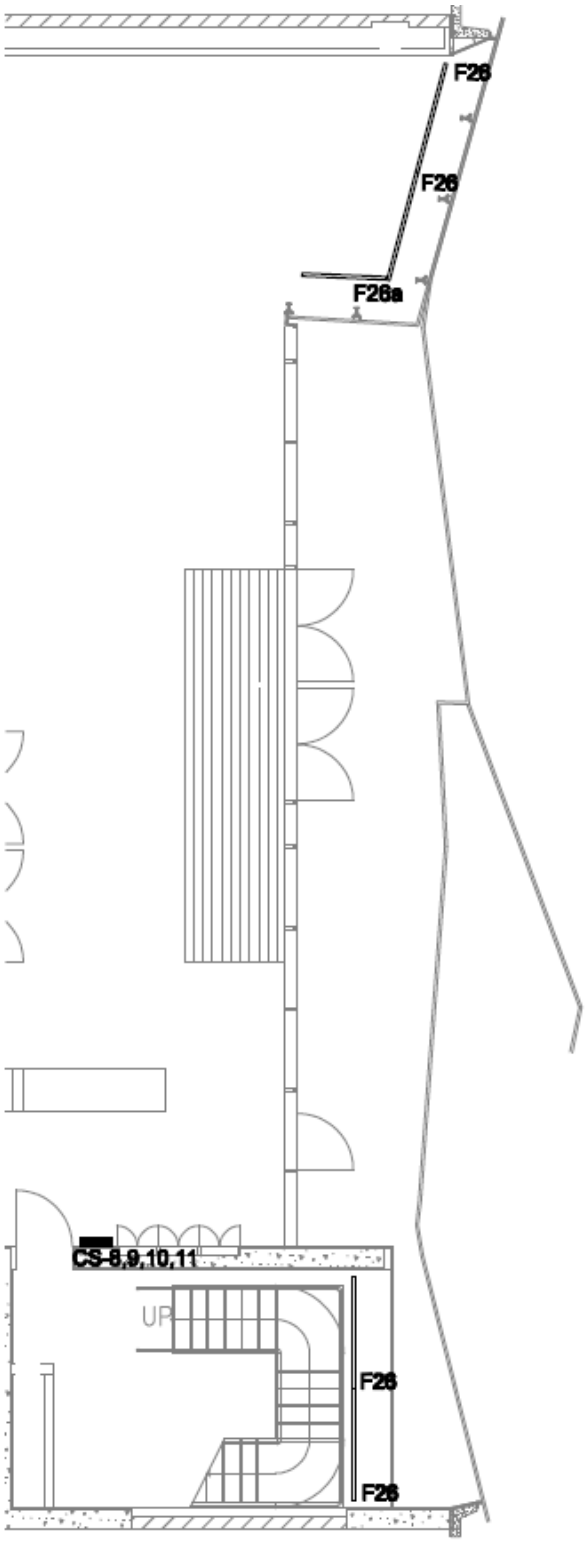
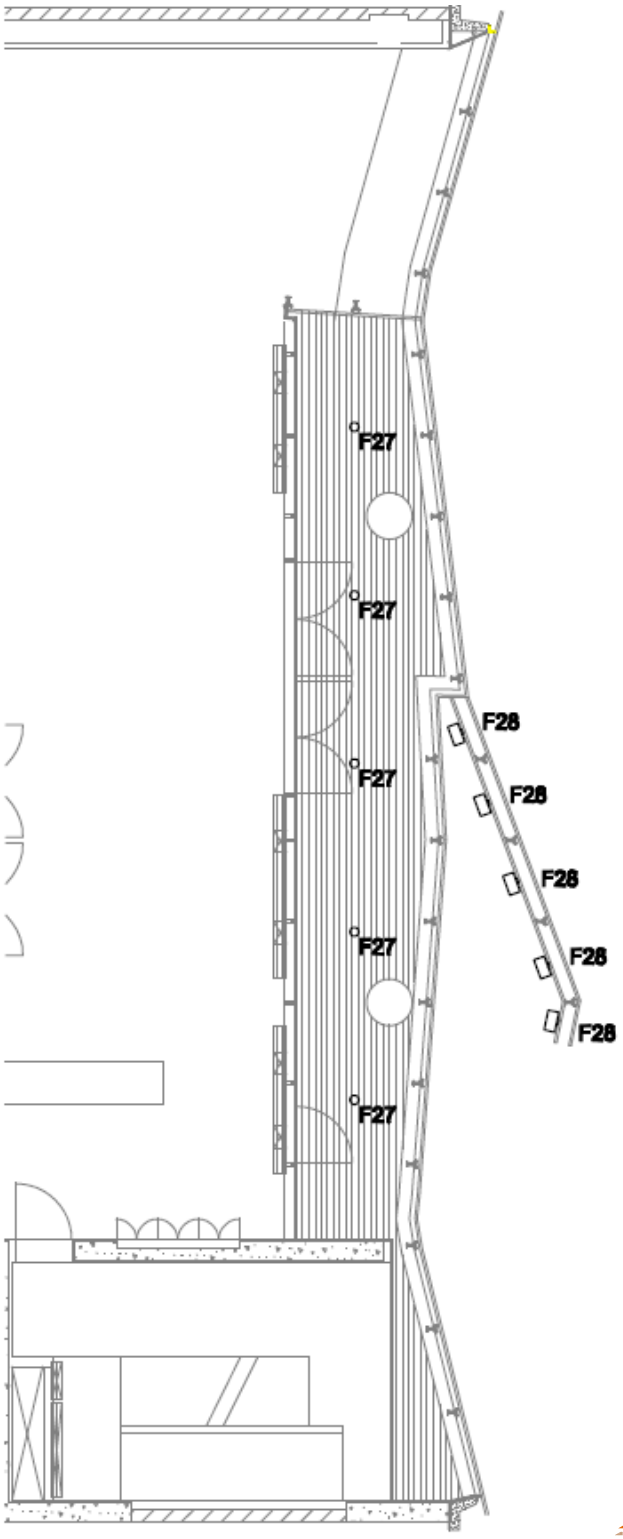



FIGURE 7: LIGHTING FLOOR PLAN (LEFT)




LIGHTING REFLECTED CEILING PLAN (RIGHT)

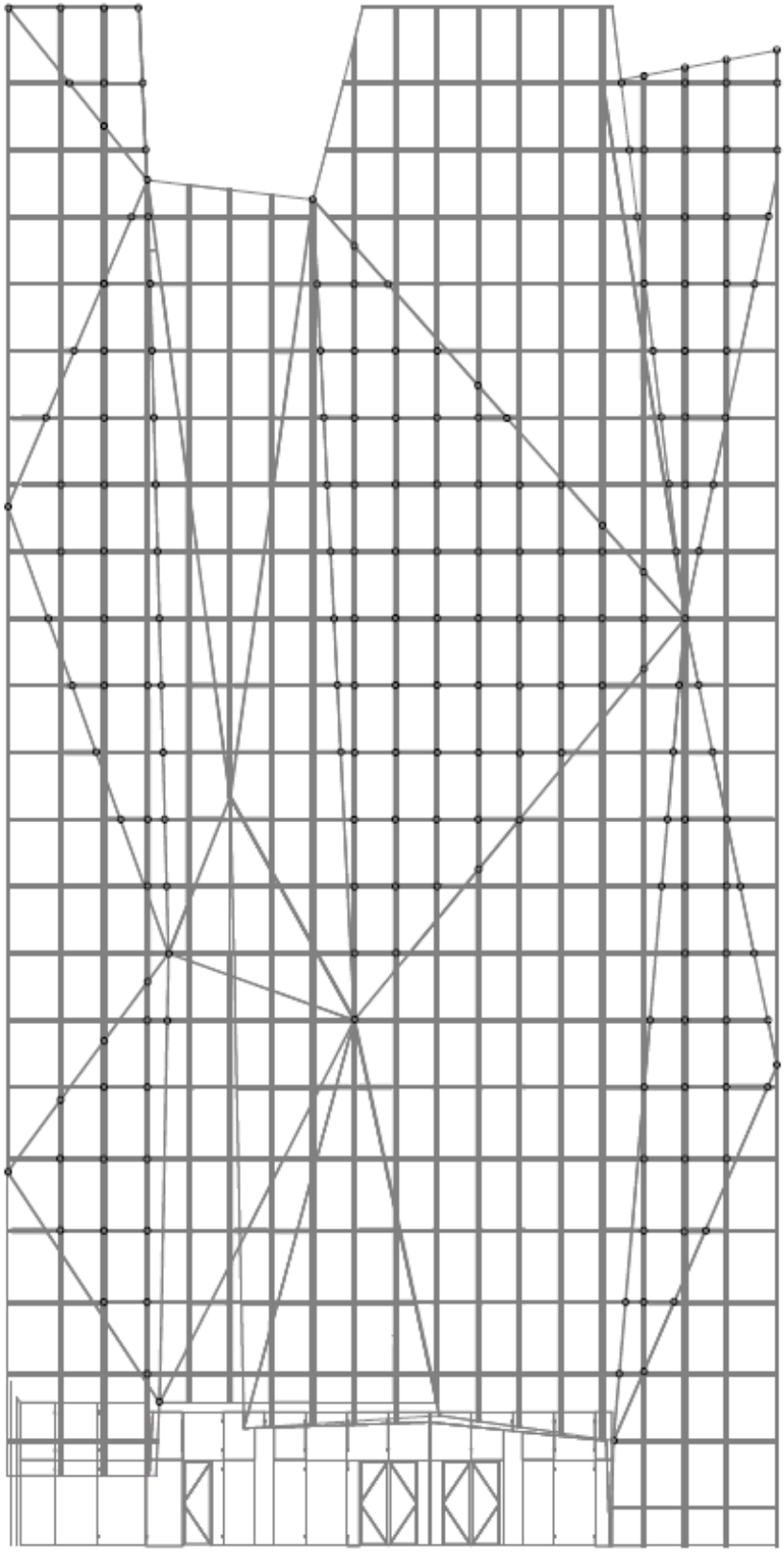


FIGURE 8: BUILDING ELEVATION - LOCATIONS FOR FIXTURE TYPE F29

## Visual Environment / Visual Performance

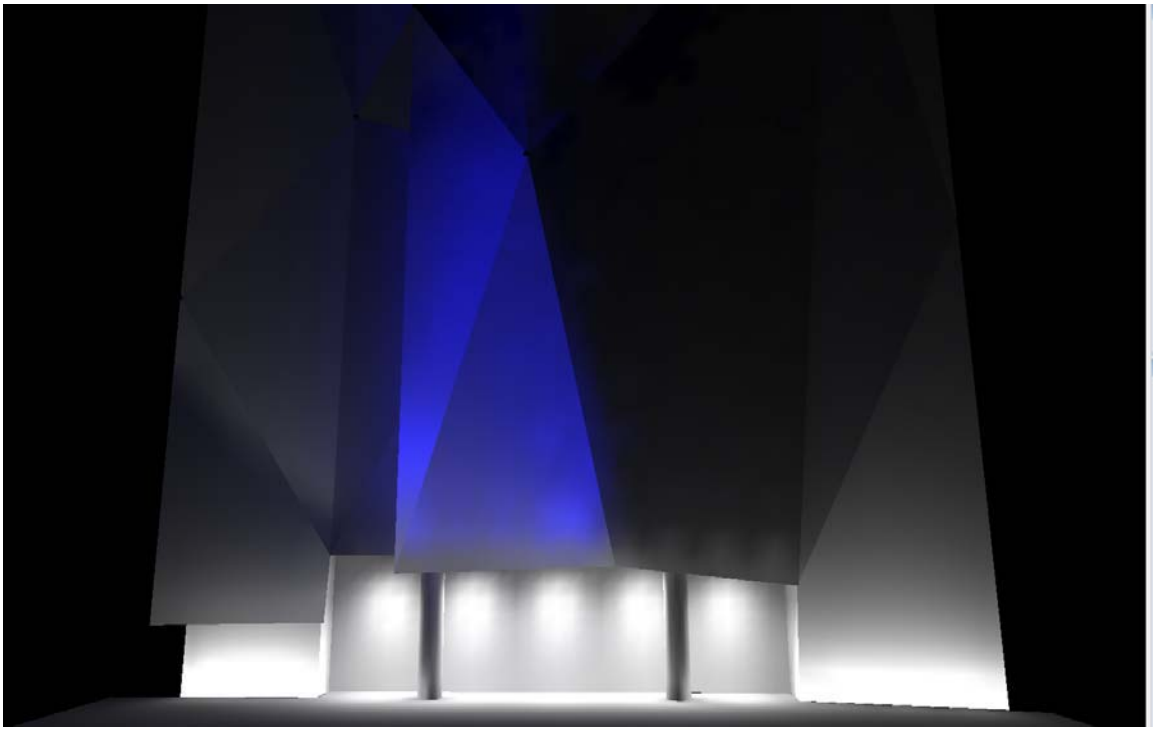


FIGURE 9: BUILDING ENTRANCE – PARTIAL ELEVATION*

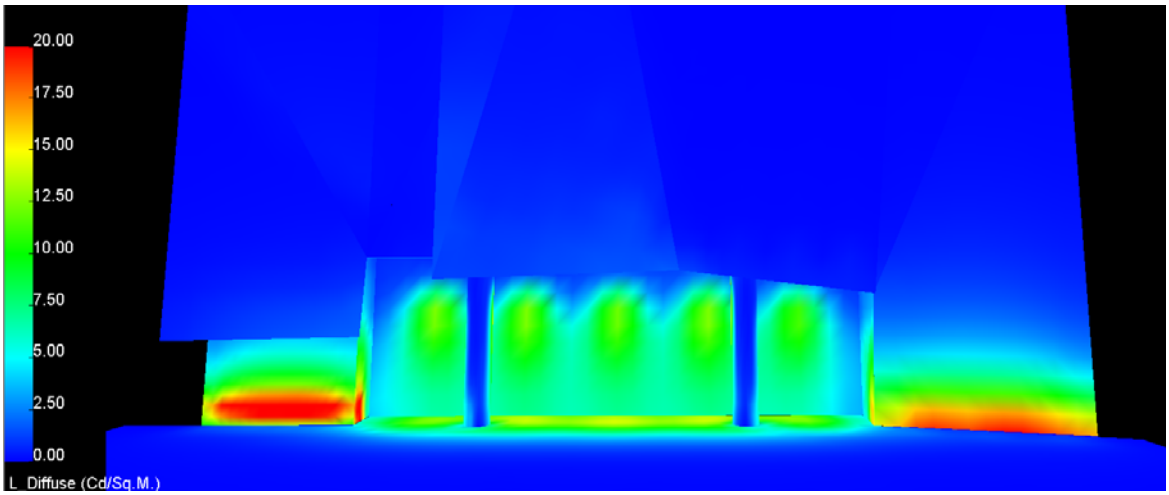
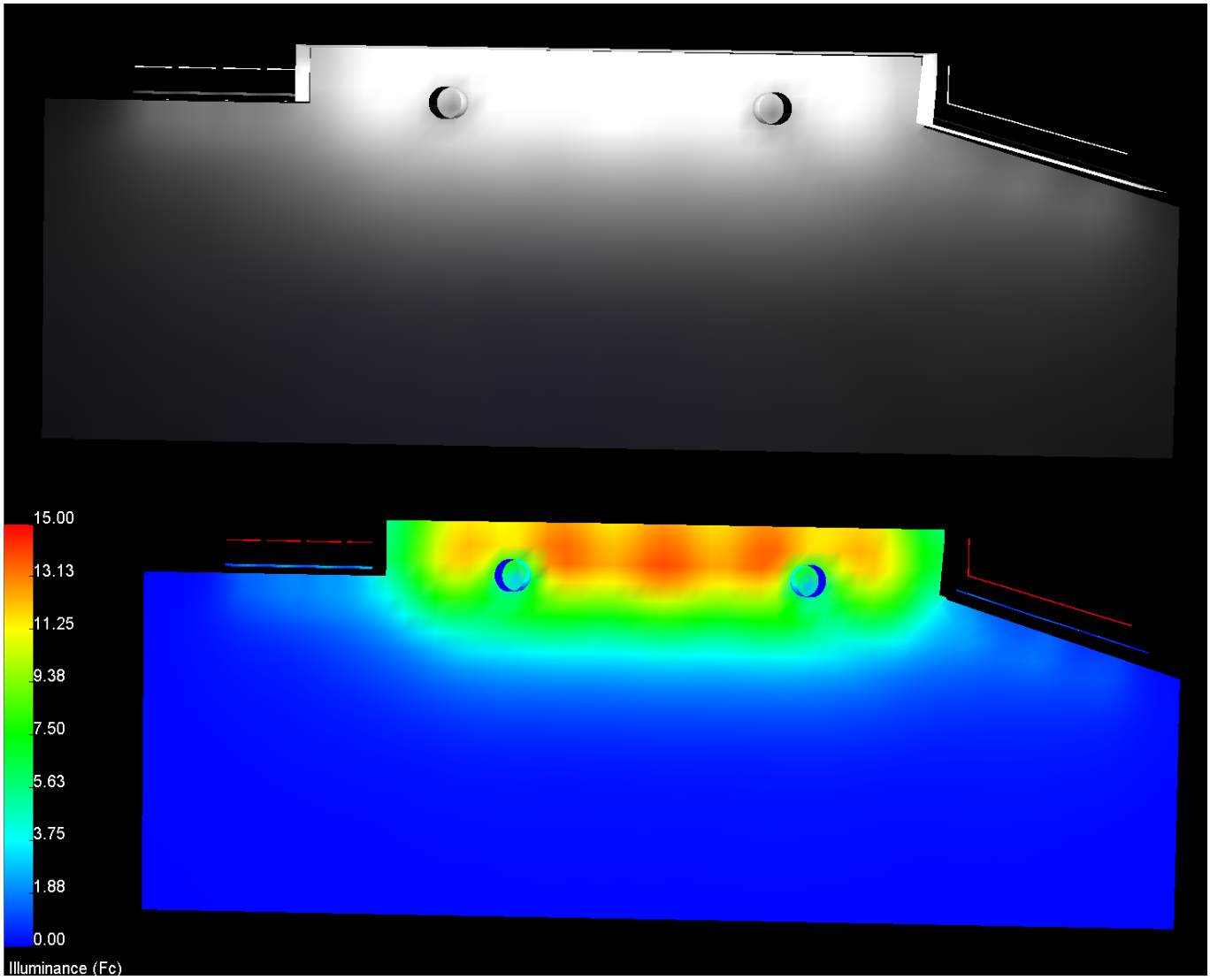
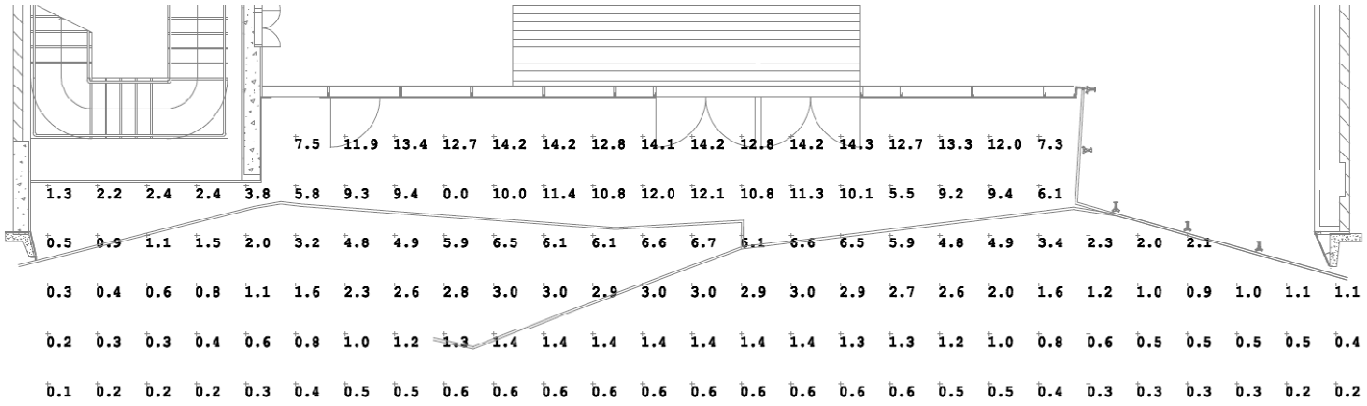



FIGURE 10: BUILDING ENTRANCE – PARTIAL ELEVATION (PSEUDO COLOR)*

*Remark – The actual material for the glass curtain wall is fritted glass. To simplify the model, the surfaces are modeled as a diffused material with the transmittance level of .5




| Calculation Summary | | | | | | | |
|---|---|---|---|---|---|---|---|
| Label | CalcType | Units | Avg | Max | Min | Avg/Min | Max/Min |
| z-floor_1_Ground | Illuminance | Fc | 5.01 | 14.4 | 0.5 | 10.02 | 28.80 |

FIGURE 11: BUILDING ENTRANCE IN PLAN AND CALCULATION SUMMARY

# Electrical Design: Façade / Exterior

## Electrical Design Objectives/criteria

The new electrical system combines façade/exterior lighting circuits onto one panelboard. The load from panelboard L1 is reduced from the replacement to the energy efficient lighting loads. Three circuits are added to balance the three phases of the panelboard L1. The panelboard is rated for three phase 208/120V system. All luminaires in this space are connected to SoftSwitch panel (LSP-2) and controlled from the control station behind the security desk in the vestibule. Refer to control diagrams in the appendix C.

**Original Panelboard (L1)**

PANELBOARD SCHEDULE

Designation: 0L-1
Voltage: 208/120V, 3PH, 4W
Fed From: 0G-1

Main Type: 100 MB
Bus Amps: 100 Amps

AVAILABLE FAULT CURRENT: 42,000 AMPS

| CCT No. | Load Description | Load A | Load B | Load C | C/B Size | C/B Size | Load A | Load B | Load C | Load Description | CCT No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | L01, L09, L29 | 1120 | | | 20A | 20A | 980 | | | 101,103,104,108 | 2 |
| 3 | L02,L03,L05,L06,L10 | | 1050 | | 20A | 20A | | 1090 | | 106,112 | 4 |
| 5 | L11,L13 | | | 1260 | 20A | 20A | | | 800 | 102,107,109 | 6 |
| 7 | L12,L14,L29 | 420 | | | 20A | 20A | 1200 | | | GIFT SHOP 114 - (12) B (SW-2) | 8 |
| 9 | L07,L08,L27 | | 270 | | 20A | 20A | | 900 | | GIFT SHOP 114 - (9) B (SW-2) | 10 |
| 11 | GIFT SHOP (SW-1) | | | 1100 | 20A | 20A | | | 300 | GIFT SHOP 114 - (6) D1 (SW-5) | 12 |
| 13 | GIFT SHOP (SW-1) | 1100 | | | 20A | 20A | 400 | | | GIFT SHOP 114 - (8) B (SW-4) | 14 |
| 15 | GIFT SHOP (SW-1) | | 1100 | | 20A | 20A | | 560 | | 117 (SECURITY DESK - L34a) | 16 |
| 17 | SPARE | | | | 20A | 20A | | | 600 | GIFT SHOP 114 - LV JB (SW-7) | 18 |
| 19 | L04 | 560 | | | 20A | 20A | 600 | | | GIFT SHOP 114 - LV JB (SW-7) | 20 |
| 21 | 2nd Fl BOH | | 770 | | 20A | 20A | | 600 | | GIFT SHOP 114 - LV JB (SW-6) | 22 |
| 23 | SPARE | | | | 20A | 20A | | | 600 | GIFT SHOP 114 - LV JB (SW-6) | 24 |
| 25 | 219 | 480 | | | 20A | 20A | 600 | | | GIFT SHOP 114 - LV JB (SW-8) | 26 |
| 27 | SPARE | | | | 20A | 20A | | | | | 28 |
| 29 | 2nd Fl BOH | | | 300 | 20A | 20A | | | 350 | 115 (COVE) | 30 |
| 31 | GIFT SHOP (SW-3) | 1100 | | | 20A | 20A | 375 | | | 118,119,120,121 | 32 |
| 33 | GIFT SHOP (SW-3) | | 1100 | | 20A | 20A | | | | | 34 |
| 35 | GIFT SHOP (SW-3) | | | 1100 | 20A | 20A | | | | | 36 |
| 37 | GIFT SHOP (SW-3) | 1100 | | | 20A | 20A | | | | | 38 |
| 39 | GIFT SHOP (SW-3) | | 1100 | | 20A | 20A | | | | | 40 |
| 41 | | | | | 20A | 20A | | | | | 42 |
| | Total: | 5880 | 5390 | 3760 | | | 4155 | 3150 | 2650 | | |

Branch circuit to be redesigned

| | | | | | |
|---|---|---|---|---|---|
| Total Phase A | 10035 | va | Panel Total: | 25 | kVA |
| Total Phase B | 8540 | va | Demand Total: | 31 | kVA |
| Total Phase C | 6410 | va | Demand | 87 | Amps |

**Original Panelboard (0L-2)**

PANELBOARD SCHEDULE

Designation: 0L-2 | Main Type: 100 MB
Voltage: 208/120V, 3PH, 4W | Bus Amps: 100 Amps
Fed From: 0G-1

AVAILABLE FAULT CURRENT: 42,000 AMPS

| CCT No. | Load Description | Load A | Load B | Load C | C/B Size | C/B Size | Load A | Load B | Load C | Load Description | CCT No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3RD FLOOR FAÇADE | 200 | | | 20A | 20A | 900 | | | 217 - TRACK | 2 |
| 3 | 3RD FLOOR FAÇADE | | 350 | | 20A | 20A | | 900 | | 217 - TRACK | 4 |
| 5 | 115/113 ELEV LOBBY - L5 - 14 | | | 700 | 20A | 20A | | | 900 | 217 - TRACK | 6 |
| 7 | 117 FOYER - L5 - 16 | 800 | | | 20A | 20A | 900 | | | 217 - TRACK | 8 |
| 9 | 117 FOYER - L5 - 20 | | 1000 | | 20A | 20A | | 900 | | 217 - TRACK | 10 |
| 11 | 117 SECURITY DESK - L5 - 7 | | | 350 | 20A | 20A | | | 900 | 217 - TRACK | 12 |
| 13 | 122 ENTRY - L5 - 9 | 450 | | | 20A | 20A | 750 | | | 2ND FLOOR FAÇADE | 14 |
| 15 | 2nd Fl Elevator Lobby Lighting | | 800 | | 20A | 20A | | 750 | | 2ND FLOOR FAÇADE | 16 |
| 17 | 2nd Fl Auditorium Lobby Lighting | | | 450 | 20A | 20A | | | 750 | 3RD FLOOR FAÇADE | 18 |
| 19 | 309 ELEV LOBBY - L5 - 13 | 650 | | | 20A | 20A | 750 | | | 3RD FLOOR FAÇADE | 20 |
| 21 | 117 FOYER - L5 - 6 | | | | 20A | 20A | | 750 | | 3RD FLOOR FAÇADE | 22 |
| 23 | | | | | 20A | 20A | | | 600 | FAÇADE L8 | 24 |
| | Total: | 2100 | 2150 | 1500 | | | 3300 | 3300 | 3150 | | |

Redesigned Branch Circuit

| | | | | | |
|---|---|---|---|---|---|
| Total Phase A | 5400 | va | Panel Total: | 16 | kVA |
| Total Phase B | 5450 | va | Demand Total: | 19 | kVA |
| Total Phase C | 4650 | va | Demand | 54 | Amps |

**New Panelboard (L1)**

PANELBOARD SCHEDULE

Designation: L1 | Main Type 100 MB
Voltage: 208/120V, 3PH, 4W | Bus Amps 100 Amps
Fed From: 0G-1

AVAILABLE FAULT CURRENT: 42,000 AMPS

| CCT No. | Load Description | Load A | Load B | Load C | C/B Size | C/B Size | Load A | Load B | Load C | Load Description | CCT No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | L01, L09, L29 | 1120 | | | 20A | 20A | 980 | | | 101,103,104,108 | 2 |
| 3 | L02,L03,L05,L06,L10 | | 1050 | | 20A | 20A | | 1090 | | 106,112 | 4 |
| 5 | L11,L13 | | | 1260 | 20A | 20A | | | 800 | 102,107,109 | 6 |
| 7 | L12,L14,L29 | 420 | | | 20A | 20A | 345 | | | GIFT SHOP 114 - (15) Fixture Type B | 8 |
| 9 | L07,L08,L27 | | 270 | | 20A | 20A | | 345 | | GIFT SHOP 114 - (15) Fixture Type B | 10 |
| 11 | GIFT SHOP 114 - (5) Fixture Type A | | | 115 | 20A | 20A | | | 300 | GIFT SHOP 114 - (6) D1 (SW-5) | 12 |
| 13 | GIFT SHOP 114 - (5) Fixture Type A | 115 | | | 20A | 20A | | | | | 14 |
| 15 | GIFT SHOP 114 - (5) Fixture Type A | | 115 | | 20A | 20A | | 560 | | 117 (SECURITY DESK - L34a) | 16 |
| 17 | SPARE | | | | 20A | 20A | | | 600 | GIFT SHOP 114 - LV JB (SW-7) | 18 |
| 19 | L04 | 560 | | | 20A | 20A | 600 | | | GIFT SHOP 114 - LV JB (SW-7) | 20 |
| 21 | 2nd Fl BOH | | 770 | | 20A | 20A | | 600 | | GIFT SHOP 114 - LV JB (SW-6) | 22 |
| 23 | SPARE | | | | 20A | 20A | | | 600 | GIFT SHOP 114 - LV JB (SW-6) | 24 |
| 25 | 219 | 480 | | | 20A | 20A | 600 | | | GIFT SHOP 114 - LV JB (SW-8) | 26 |
| 27 | SPARE | | | | 20A | 20A | | | | | 28 |
| 29 | 2nd Fl BOH | | | 300 | 20A | 20A | | | | | 30 |
| 31 | GIFT SHOP 114 - (5) Fixture Type A | 115 | | | 20A | 20A | 375 | | | 118,119,120,121 | 32 |
| 33 | GIFT SHOP 114 - (5) Fixture Type A | | 115 | | 20A | 20A | | 220 | | FIRST FLOOR EXTERIOR LIGHTING (5)F27 | 34 |
| 35 | GIFT SHOP 114 - (5) Fixture Type A | | | 115 | 20A | 20A | | | 792 | FAÇADE LED MARKER LIGHTS F29 | 36 |
| 37 | GIFT SHOP 114 - (5) Fixture Type A | 115 | | | 20A | 20A | | | | | 38 |
| 39 | GIFT SHOP 114 - (6) Fixture Type A | | 138 | | 20A | 20A | | 250 | | FAÇADE CANOPY LIGHTING (5) F28 | 40 |
| 41 | FIRST FLOOR FAÇADE LIGHTING F26 | | | 342 | 20A | 20A | | | | | 42 |
| | Total: | 2925 | 2458 | 2132 | | | 2900 | 3065 | 3092 | | |

Redesigned Branch Circuit
Depth Topic 1 - Reduced Lighting Load

| | | | | | |
|---|---|---|---|---|---|
| Total Phase A | 5825 | va | Panel Total: | 17 | kVA |
| Total Phase B | 5523 | va | Demand Total: | 19 | kVA |
| Total Phase C | 5224 | va | Demand | 52 | Amps |

## Feeder Sizing

**Panel L1** : Phase Conductor : 52 Amps x 1.25 = 65 Amps – 8 AWG CU THWN 75°C
Ground Conductor : 100 Amps – 8 AWG CU

## Lighting Design: Foyer / Elevator Lobby

**Description:**

A magnificent atrium extends three-stories, with a unique sculptural wall treatment echoing the facets of the building's glass front. A grand glass and terrazzo staircase extends down from the Spertus Café and the Feinberg Theater.

**Requirement met:** A circulation space

**Area:** 3400 Sq.ft. (projected area)

**Dimension:** Approx 56'-0" x 64'-0"

**Plan:**

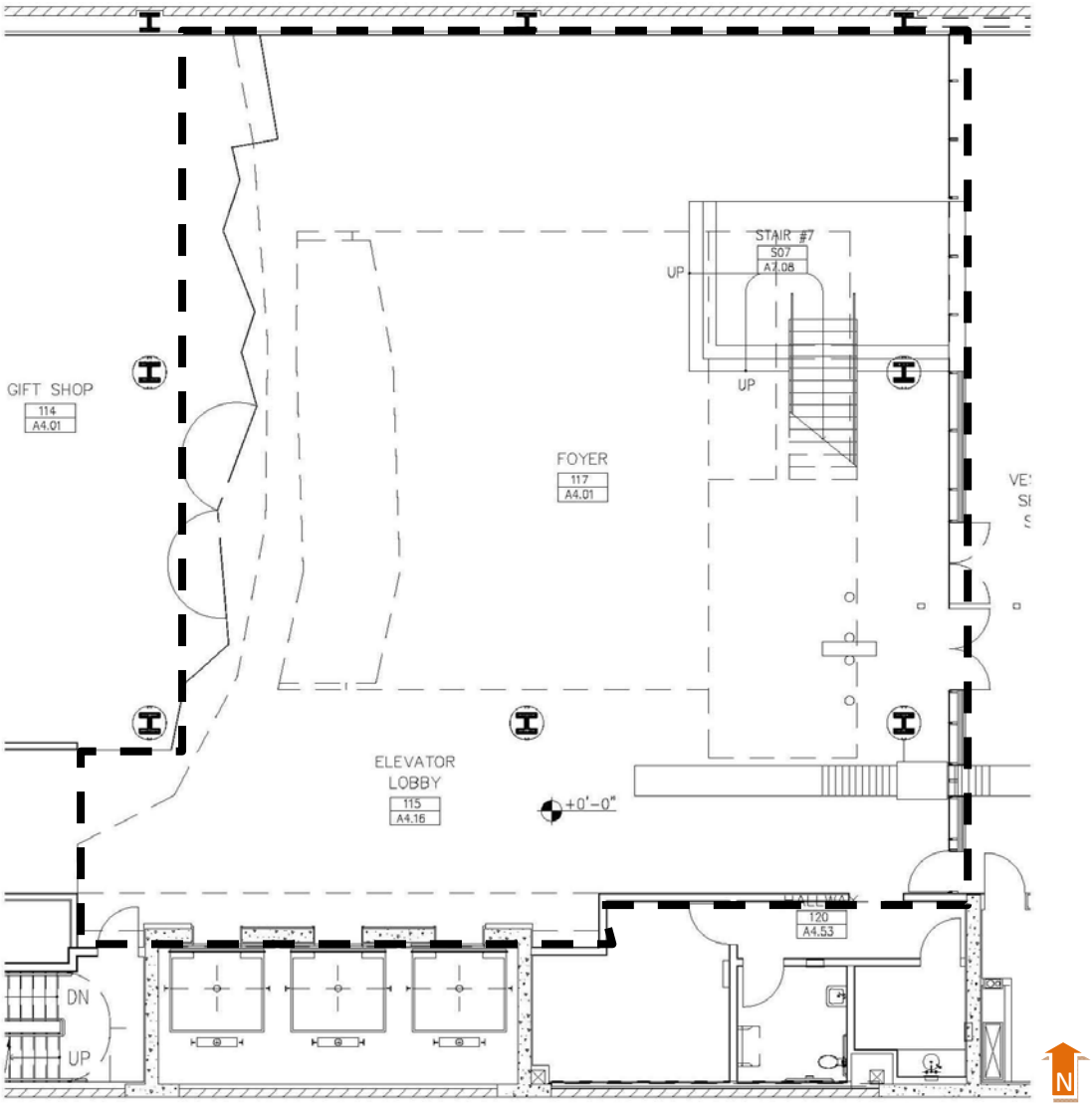



FIGURE 12: LOBBY FIRST FLOORPLAN

Redesign Space

**Surface Materials:**

| Surface | Material | Reflectance |
|---|---|---|
| **Floor** | Concrete slab | .3 |
| **Ceiling** | White painted gypsum wall board | .8 |
| **Wall** | White painted gypsum wall board | .7 |
| **Sculpture Wall** | White painted gypsum wall board | .7 |
| **Stairs (Railing)** | Clear glass railing | n/a |
| **Stairs (Steps/Platform)** | Terrazzo, light gray finish with glass railing | .3 |

**Activities/Tasks:**

- Visitor services desk
- Congregation
- Circulation ( to elevators, stairs, gift shop, and theater)
- Private events
- Wall of names of supporters

## Design Consideration / Criteria

**IESNA Lighting Design Guide**

- **Office – Lobby, Lounge, and Reception Area**

Appearance of Space and Luminaires

- According to IESNA design guide, this topic is a very important issue. The interior architecture of the space speaks for itself through clean lines and the use of modern materials including glass, metal, and terrazzo floor. Although the sculpture wall, which is a focal point of the space, has a very interesting geometrical form, it is painted with a very neutral white finish. The appearance of the luminaires should implement the interior architecture by being simple and not interrupting the focal point of the space. Most importantly, the beauty of this form is in how it is rendered with light.

Color Appearance (and color contrast)

- Color Appearance is an important design issue (IESNA). Color appearance of the space should provide warm and welcoming atmosphere. Color correlated temperature should be around 3500 K to provide somewhat warm to neutral color appearance. Good color rendering light source should be implemented to compliment people skin tones. Since all the material surfaces other than glass railing are painted in white, the use of color light should be considered to create visual interest and flexibility for private events that may occur in the space.

Daylight integration and control

- The daylight integration issue is somewhat important in this space (IESNA). Although the space is not directly adjacent to the exterior curtain wall, there is some daylight contribution from level one and two. Since the façade is east facing, the space may gained some direct sunlight penetration in the morning depending on time of year. Photocensor and dimming control system may be useful to help adjust light output accordingly.

Direct Glare

- Direct glare from the light sources and luminaires is an important issue in this space (IESNA) because it can potentially causes discomfort glare. In order to reduce direct glare from a single high intensity light source, multiple smaller light source that provide less light intensity should be substituted. To reduce direct glare from the luminaire, comfort diffused reflector and glare shield should be specified.

Light Distribution on Surfaces

- In order to illuminate the sculpture wall while maintaining its three dimensional appearance, faces adjacent to one another should have different luminance level to create higher contrast level. The faces that are lit should be uniformly illuminated to enhance the contour lines of the sculpture.

- Since all wall surfaces are painted in white, unwanted beam distributions or patterns are noticeable if not properly aimed or located.

Light Distribution on Task Plane (Uniformity)

- The task plane of the space is the floor of the main lobby or atrium. Lighting level on theses areas should be fairly uniform to avoid hot spots or distract people's attention from the architecture features of the space. Light level on terrazzo steps should also be fairly uniform, and perhaps higher light level in this area to emphasize and highlight the stairs.

Luminances of Room Surfaces

- Luminances of room surfaces are important to create visual hierarchy in the space. Although the sculpture wall is the focal point of the space and required to produce higher luminance level, the north wall of the space should be illuminated as well. Luminance level on north wall does not only create a scene of spaciousness, but also define the perimeter of the space.

Modeling of Faces and Objects

- Facial modeling is an important issue (IESNA) because of activities conducted in the space. To provide good facial modeling, it requires a combination of key light and fill light (direct and indirect components light). Since all the wall surfaces are white, reflected light may be bouncing off these surfaces as fill light. Good color rendering light sources should be specified to compliment people skin tones.

Points of Interest

- Point of Interest should be highlighted by lighting to create a focal point of the space and also to prevent boredom. The sculpture wall must be illuminated with highest luminance level.

- The other point of interest in this space is Spertus logo behind the information desk. These sign should be uniformly illuminated. They also act as a backdrop for people in front of them.

Shadows

- As mentioned before, in order to create three-dimensional look for the sculpture. Different luminance levels on adjacent surfaces should be appearance. In this particular case, if the sculpture is lit from above, soft shadows are created automatically because surfaces are not on the same plane.

Surface Characteristics

- All wall surfaces are gypsum wall board painted in white eggshell finish. Due to its high reflectance property of selected paint, high luminance level can be easily achieved. The space may seem brighter than it actually is.

System Control and Flexibility

- Flexibility in control system is not critical in this space because it is mainly used for lobby and circulation. The space occasionally used for private social events; thus, control system should allow some level of flexibility.

Special Considerations

- Task light should be provided for the visitor service desk for adequate light level for reading and writing.
- Energy consideration is important because the space is the main circulation of the building. Efficient light source that has high efficacy like Metal Halide should be considered.
- Long lamp life is also an important issue from maintenance perspective for such a high ceiling space.
- The elevator lobby is opened up to the atrium and can be seen from all levels. Lighting in this area should provide directional circulation especially in vertical direction.

Energy Considerations

- Energy Code Requirements – ASHRAE 90.1-2004 – Space by space method
    - **1.3w/sq ft.** for lobby

Illuminance (Horizontal)

- 10 fc (IESNA Handbook design guide – Lobby, lounges, and reception areas)

Illuminance (Vertical)

- 3 fc (IESNA Handbook design guide – Lobby, lounges, and reception areas)

## Lighting Redesign

### Lighting Solutions:

The same lighting design concept from the façade with a different interpretation is applied to the lobby area to create a cohesive transition spaces. Another interpretation to the 'Star of David' is the meaningful reciprocal significance of many things including good vs. evil and physical vs. spiritual. Lighting is used to convey these ideas through different lighting techniques and the use of light and shadow. For instance, a unique sculpture wall, which is a focal point in the space, is illuminated to express the concept of light and shadow. In order to create an emphasis on the interior architecture of the space, applying integrated lighting system with minimal appearance is one of the key considerations that are carried throughout the spaces. Energy consideration is also important in such a large space with limited energy allowance by code. Since the lobby space may be rented out for a private party after business hours, proposed lighting scheme will capable to provide flexibility and to create dramatic lighting effect.

- **General Illumination**
  General ambient light in the atrium space is provided by 70 watts T6 recessed Ceramic Metal Halide with wide flood distribution located on the third level ceiling plan. They are located in such a way that light can reach onto the first and second floor, and the luminaires can be accessed for maintenance from the third floor. General illumination for the elevator lobby area on both second and third is provided by 20 watts T4.5 Ceramic Metal Halide recessed downlight with wide flood distribution. The fact that T6 and T4 lamps have different sockets helps avoid confusion during lamp replacement, and they only have to stock two different lamp types with different wattages. 50 watts PAR30 halogen recessed downlight with flood distribution is specified for the lobby area of the first level to provide flexibility and dimming capability.

- **Accent Lighting**
  The elevator walls on all three levels are grazed by the linear fluorescent wall-slots to create a sense of navigation in the vertical direction. The sculpture wall is illuminated by high output linear LED fixtures surface mounted in the cutout architectural niche in the ceiling. The depth of floor slaps between 1$^{st}$ - 2$^{nd}$ floor and 2$^{nd}$ – 3$^{rd}$ floor are accented with RGB linear LED surface mounted in the architectural cove (Refer to page 31 for detail). The effect of the color dynamics will create a dramatic outcome in the overall design. The color changing effect can be programmed to activate periodically throughout the day to add interests and playfulness in the space. The white light will then be used for the rest of the time. By the stairs landing, there is a line LED linear source tracing the underside of the concrete steps/bench (Refer to page 31 for detail). The technique is used to navigate and direct people to the stairs that lead to the cafeteria and the theater.

## Controls:

Lutron Grafik Eye control system is specified to control the lobby lighting. The dimmable fixtures include linear fluorescent wall slot (fixture type F5) and halogen recessed downlight (fixture type F7). Lutron fluorescent dimming ballast (Hi-lume) must be provided for fixture type F5. The linear LED fixture (Fixture Type F8) is connected to the DMX controller which is powered by the Lutron processor. All the zones listed below will be controlled from the control station behind the reception desk by the entrance. The system is also connected to timeclock device to turn on and off lights at appropriate time settings. Refer to Appendix C for Control diagrams.

**Lobby Summary Load Schedule**

| Lutron Zone | Customer Zone | Zone/Circuit Description | Customer Circuit # | Voltage | Load Type | Actual Load (W/VA) |
|---|---|---|---|---|---|---|
| A1-1 | Zone 1 | Elevator Wall-Slot | L2/21 | 120V | FL - Hi-Lume | 297 |
| A1-1 | Zone 1 | Elevator Wall-Slot | L2/22 | 120V | FL - Hi-Lume | 297 |
| A1-1 | Zone 1 | Elevator Wall-Slot | L3/7 | 120V | FL - Hi-Lume | 297 |
| A1-2 | Zone 2 | First Floor Halogen Downlight | L2/7 | 120V | Incandescent | 800 |
| A1-2 | Zone 2 | First Floor Halogen Downlight | L2/9 | 120V | Incandescent | 700 |
| A1-3 | Zone 3 | Second Floor CMH Downlight | L2/15 | 120V | Non-Dim | 437 |
| A1-4 | Zone 4 | Third Floor CMH Downlight | L2/19 | 120V | Non-Dim | 406 |
| A1-5 | Zone 5 | Third Floor CMH 70WATTS | L3/11 | 120V | Non-Dim | 864 |
| A1-6 | Zone 6 | Sculpture Wall LED | L3/15 | 120V | Non-Dim | 766 |
| A1-7 | Zone 7 | Atrium - Floor Depth LED | L2/23 | 120V | Non-Dim | 792 |
| A1-8 | Zone 8 | Above Sculpture Wall LED | L3/13 | 120V | Non-Dim | 288 |
| A2-1 | Zone 9 | First Floor CMD | L2/5 | 120V | Non-Dim | 94 |

## Summary Performance Evaluation:

The lobby atrium lighting design successfully reinforces architectural forms and concepts. An adequate average illuminance level (10 fc) is provided at the ground on every level. The sculpture wall is illuminated in such a way that there are both illuminated and non-illuminated faces. Vertical wall and illuminance are appropriately addressed on the elevator walls. Through the use of efficient light sources, the general illumination is provided by a quality white light while conserving energy consumption. The overall energy consumption in this space is .74 Watt/Sq.ft. which is almost half of the maximum code requirement (1.3 Watt/Sq.ft.).

## Lighting Schedule

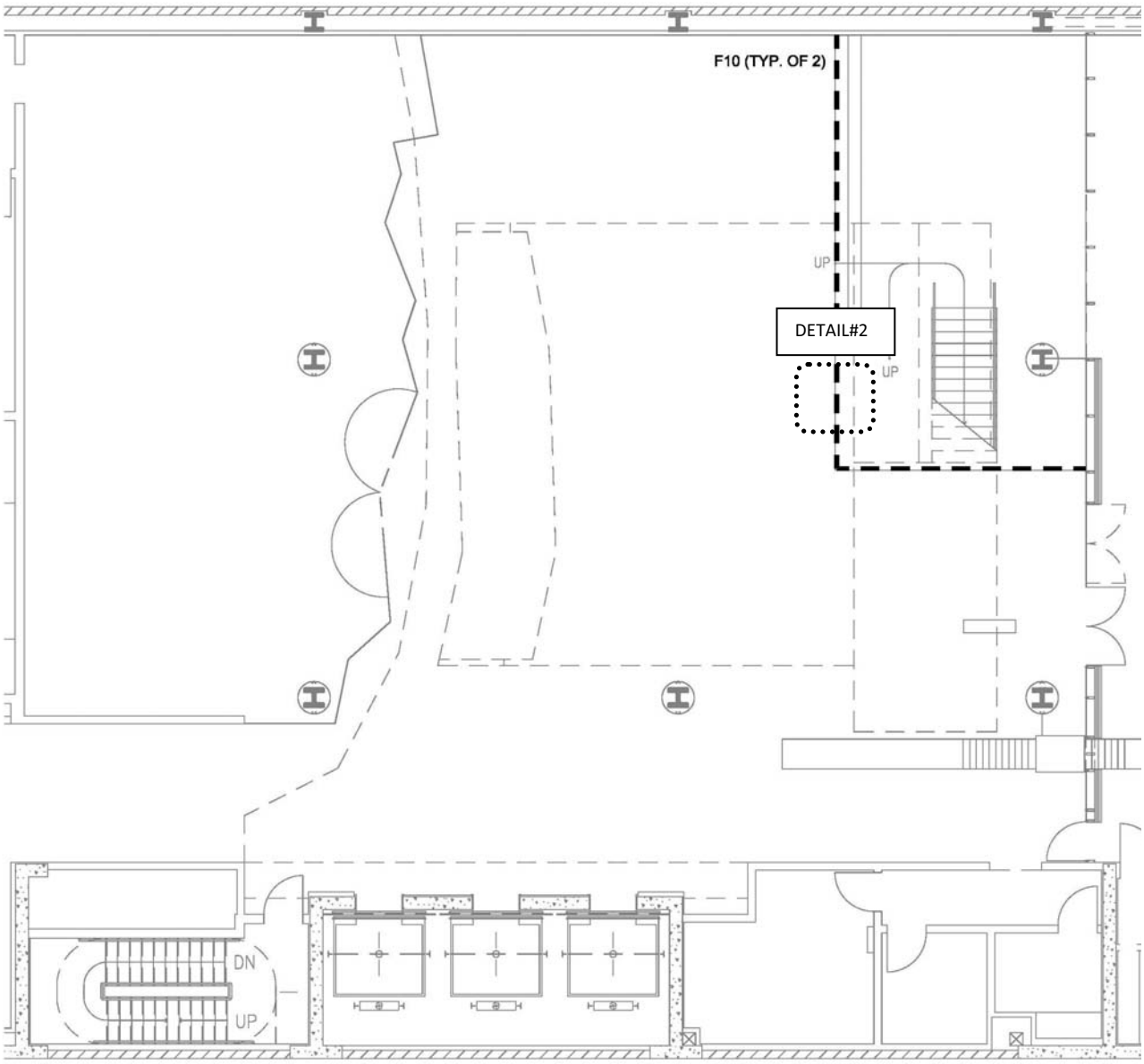
Refer to Appendix A for a complete schedule.

| Type | Manufacturer | CatalogNumber | Description | Electrical | Wattage |
|---|---|---|---|---|---|
| F1 | Amerlux | SD4-20-T4-E-SD-W-120-WF | 5" recessed wide flood distribution metal halide downlight with 1-20W T4 / T4.5 single-ended G8.5 base lamp. Optics: glass lens , anodized aluminum reflector. | Integral electronic ballast | 26 |
| F2 | Amerlux | SD4-20-T4-E-SD-W-120-NF | 5" recessed narrow flood distribution metal halide downlight with 1-20W T4 / T4.5 single-ended G8.5 base lamp. Optics: glass lens , anodized aluminum reflector. | Integral electronic ballast | 26 |
| F3 | Amerlux | SD4-70-T6-E-SD-W-120-WF | 5" recessed wide flood distribution metal halide downlight with 1-70W T6 single-ended base lamp. Optics: glass lens , anodized aluminum reflector. | Integral electronic ballast | 80 |
| F4 | Amerlux | SD4-70-T6-E-SD-W-120-NF | 5" recessed narrow floor distribution metal halide downlight with 1-70W T6 single-ended base lamp. Optics: glass lens , anodized aluminum reflector. | Integral electronic ballast | 80 |
| F5 | Litecontrol | 20-1-4-T5-CWM-LP/ELB-120 | 4' Nominal length T5 Fluorescent Linear Wall-Slot. The luminaire shall create a continuous recessed slot at the junction of the wall and ceiling that is 9" wide by 9" deep. The fixture system shall consist of 3 components: 1. A white, extruded aluminum fixture support rail shall provide continuous support and true alignment of fixtures and components. Rail shall be designed to provide reveal and compensate for irregularities in wall construction. Galvanized spline keys are included for continuous alignment. 2. The plenum cover/wall bracket shall be a one-piece assembly of 20-gauge steel and heavy-gauge steel brackets with leveling screws to provide adjustment. The plenum cover shall have a continuous hook- and-lock attachment to the wall rail and horizontal adjustment. 3. The fixture housing shall be of 20-gauge steel and shall attach to the plenum cover. The reflector system shall consist of a curved reflector of die-formed .025" thick specular aluminum, precisely shaped to project maximum lumens at 30°, and straight reflector portions of steel, finished in high-reflectance white for uniform distribution. The fixture housing shall incorporate an extruded aluminum luminance control deflector/ceiling trim. | Lutron Dimming Ballast 1% Dimming Hi-lume | 33 |

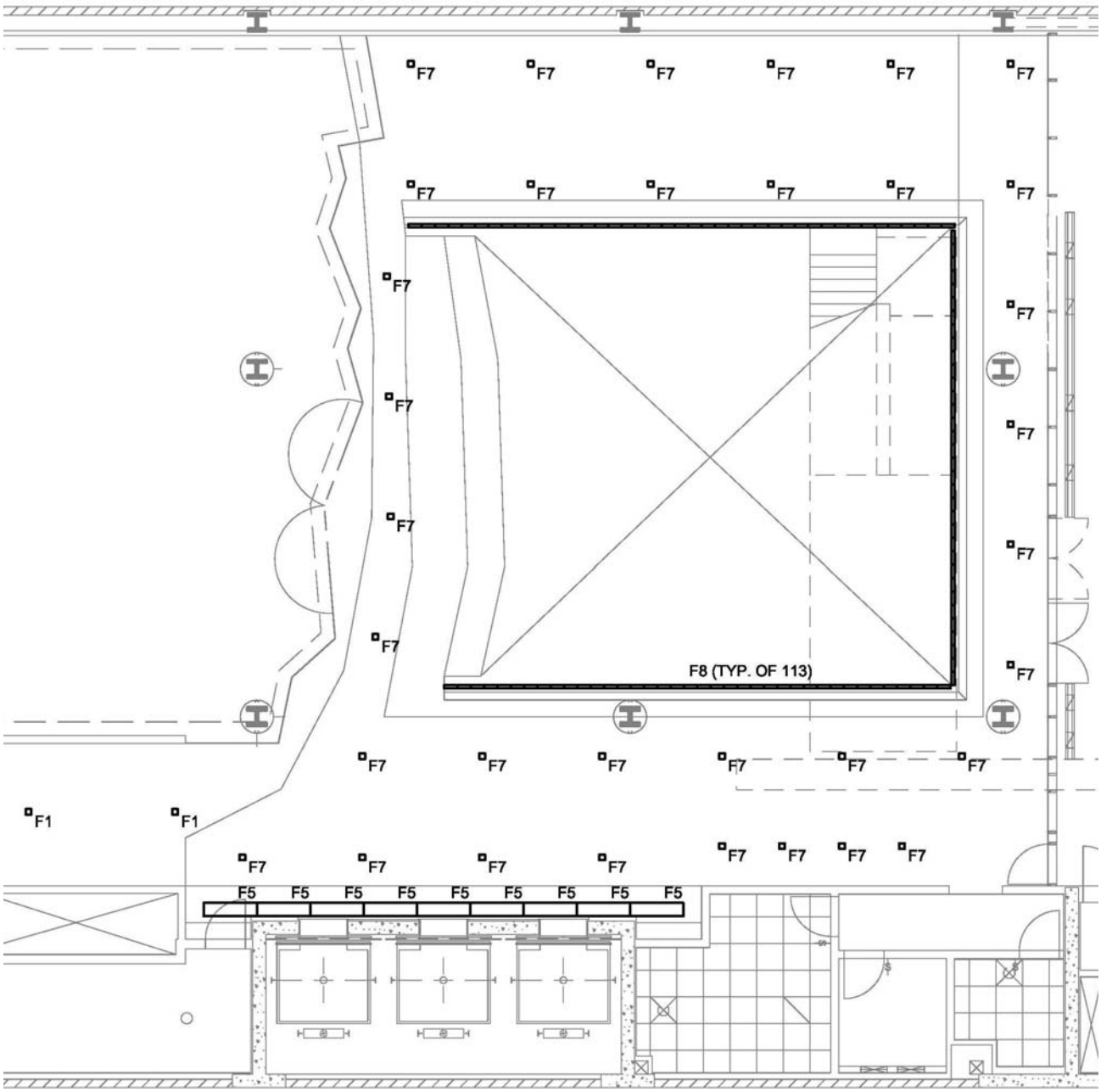
| Type | Manufacturer | CatalogNumber | Description | Electrical | Wattage |
|---|---|---|---|---|---|
| F7 | Kurt Versen | H8420 | 5" recessed directional downlight with PAR-30 lamp. Optics: anodized aluminum reflector. The lamp assembly rotates 360°. Angulation is 40° for PAR-16 and PAR-20. PAR-30 tilts to 35° maximum. All lock in any selected position. A sturdy steel housing protects all internal components and is vented for air flow cooling. The trim is stabilized to prevent racking. It is held to the ceiling by constant tension stainless steel springs. Maximum ceiling thickness 7/8". Top or bottom service. | n/a | 50 |
| F8 | Color Kinetics | 101-000066-00 | Compact linear fixture that generates saturated color and dynamic effects in alcoves, accent areas, and other interior spaces. The fixture is available with a wide (120º x 120º) or medium (100º x 40º) beam. An integrated rotating mount and optional mounting track provide precise positioning, and end-to-end connections ensure a simple installation. Integral mounting bracket with 180º rotation. Optibin® technology ensures uniform light quality. 24 VDC input power. End-to-end connectors. Two standard lengths: 6 in (152 mm) and 12 in (305 mm). Chromasic® technology provides precise and cost-efficient digital control | Provide Color Kinetics 60 Watts Power and Data Supply: Product# SPDS-60CA 24V See Drawing for Quantity | 3 watts/linear foot |
| F9 | Color Kinetics | 910503700278 | 4' linear LED with 10˚x 60˚ beam angle. Linear lighting fixture optimized for surface grazing and wall-washing applications requiring high-quality white light. Featuring Powercore® technology, eW Graze Powercore processes power directly from line voltage, eliminating the need for low-voltage, external power supplies. Tailor light output to specific applications. eW Graze Powercore offers superior beam quality for striation-free saturation as close as 6 in (152 mm) from fixture placement. With a 60º horizontal beam angle, eW Graze Powercore accommodates end-to-end or incremental placement without visible light scalloping between fixtures. Supports new applications for white light. Long-life LEDs (50,000 hours at 50% lumen maintenance) significantly reduce or eliminate maintenance problems, allowing the use of white lighting in spaces where bulb maintenance may be limited or unfeasible. Versatile installation options. Constant torque, locking hinges offer simple position control from various angles, without special tools. The low-profile extruded aluminum housing accommodates installation within wide-ranging architectural niches. | n/a | 58 |
| F10 | Sylvania | LNRFLXTP/LM10A/W3-727 27.5FT | Linear LED strip on flexible printed circuit board with self-adhesive back for easy installation. Contour configurations and three dimensional assembly possible. OSRAM Power TOPLED® delivers high luminous flux -Size of entire module (LxWxH)27.5 ft x 0.4 in. x 0.10 in. Conveniently field cut with scissors. Electrical connectors, mounting tracks and optical diffusers available for easy installation. Long life: Up to 100,000 hours depending on color. White modules service life is up to 50,000 hours when Tc point is maintained at or below 40°C. Available in various colors: red, true green, blue, yellow and white. Optimal operation with OPTOTRONIC 24Vdc power supplies 120° beam angle. Minimal heat generation. No UV or IR radiation. | Provide (2) 50 Watts Sylvania Power Supply: 51508 | 100 |

## Lighting Plans

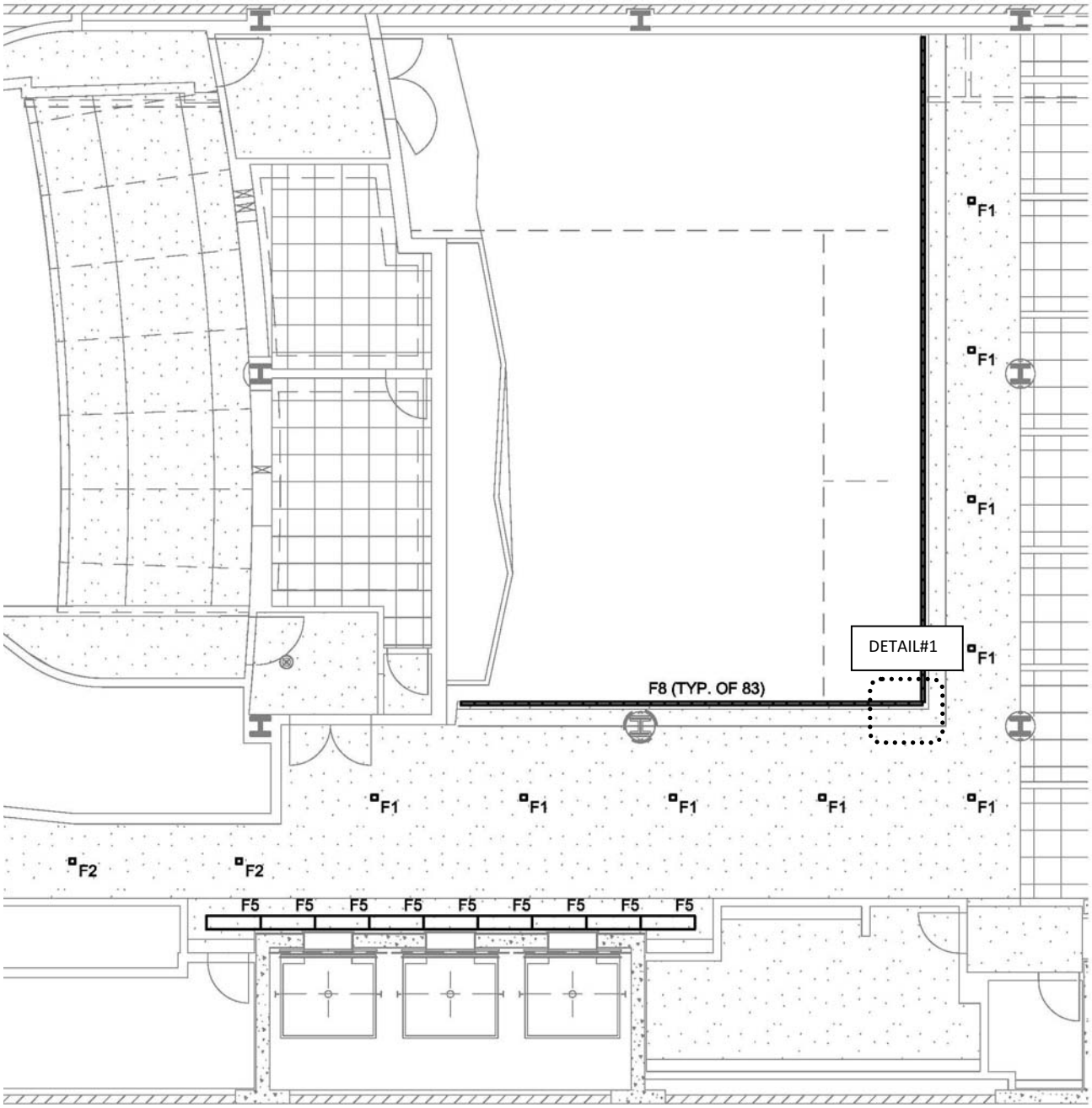
### First Floor Lighting Plan



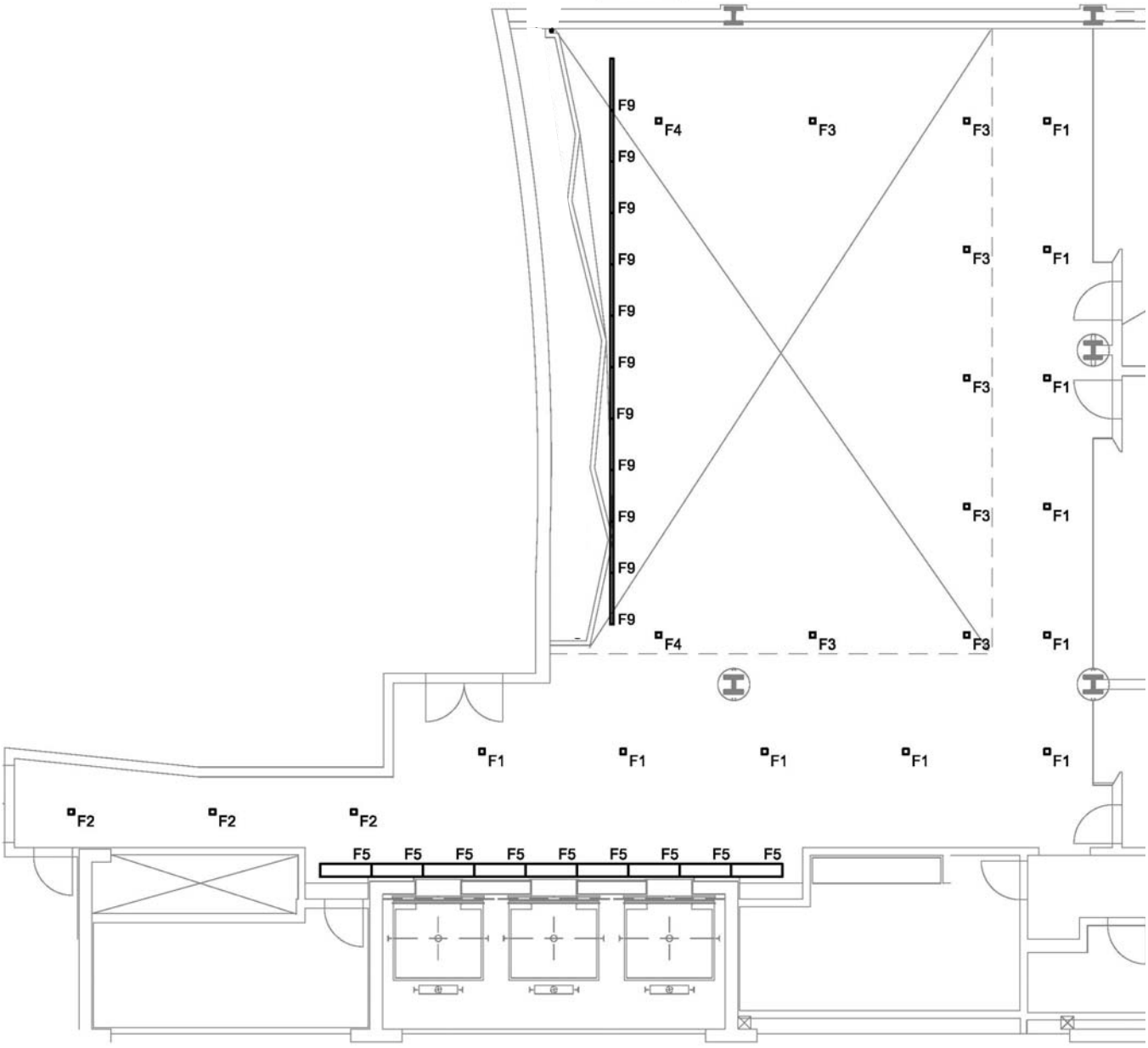
**First Level Lighting Ceiling Plan**



**Second Level Lighting Ceiling Plan**



**Third Level Lighting Ceiling Plan**



**Mounting Details:**

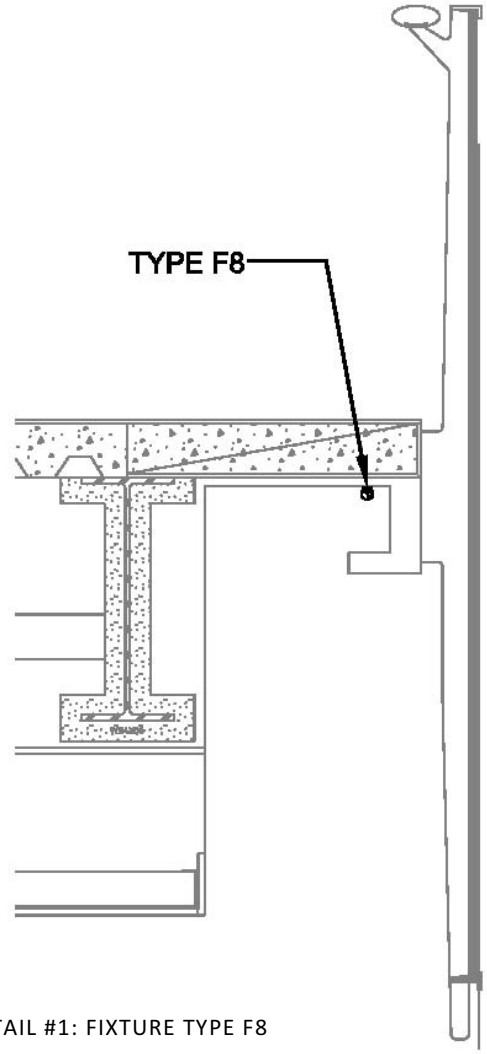



FIGURE 13: DETAIL #1: FIXTURE TYPE F8

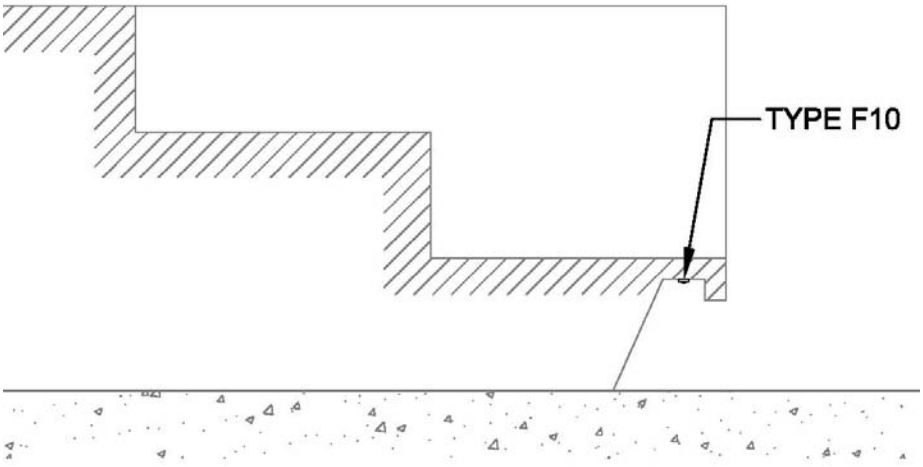



FIGURE 14: DETAIL #2: FIXTURE TYPE F10

## Visual Quality / Visual Performance

FIGURE 15: LOBBY CROSS-SECTION – LOOKING TOWARD ELEVATOR LOBBY

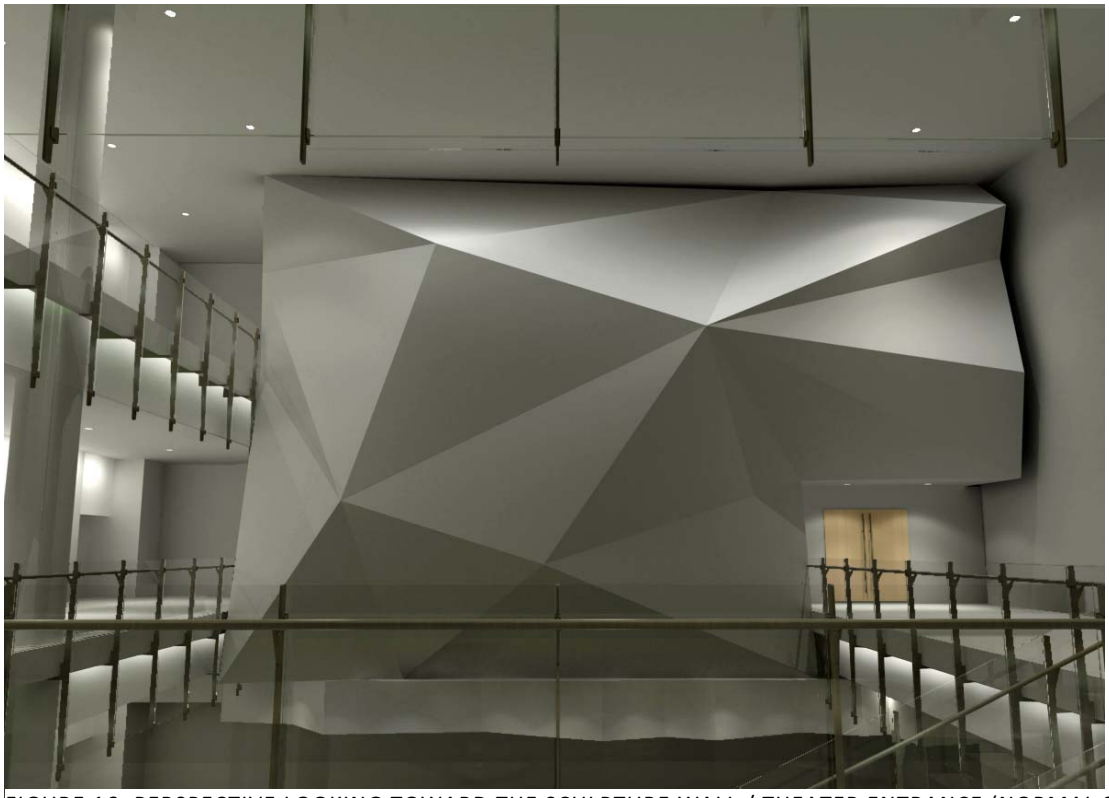


FIGURE 16: PERSPECTIVE LOOKING TOWARD THE SCULPTURE WALL / THEATER ENTRANCE (NORMAL SCENE) (3DMAX STUDIO)

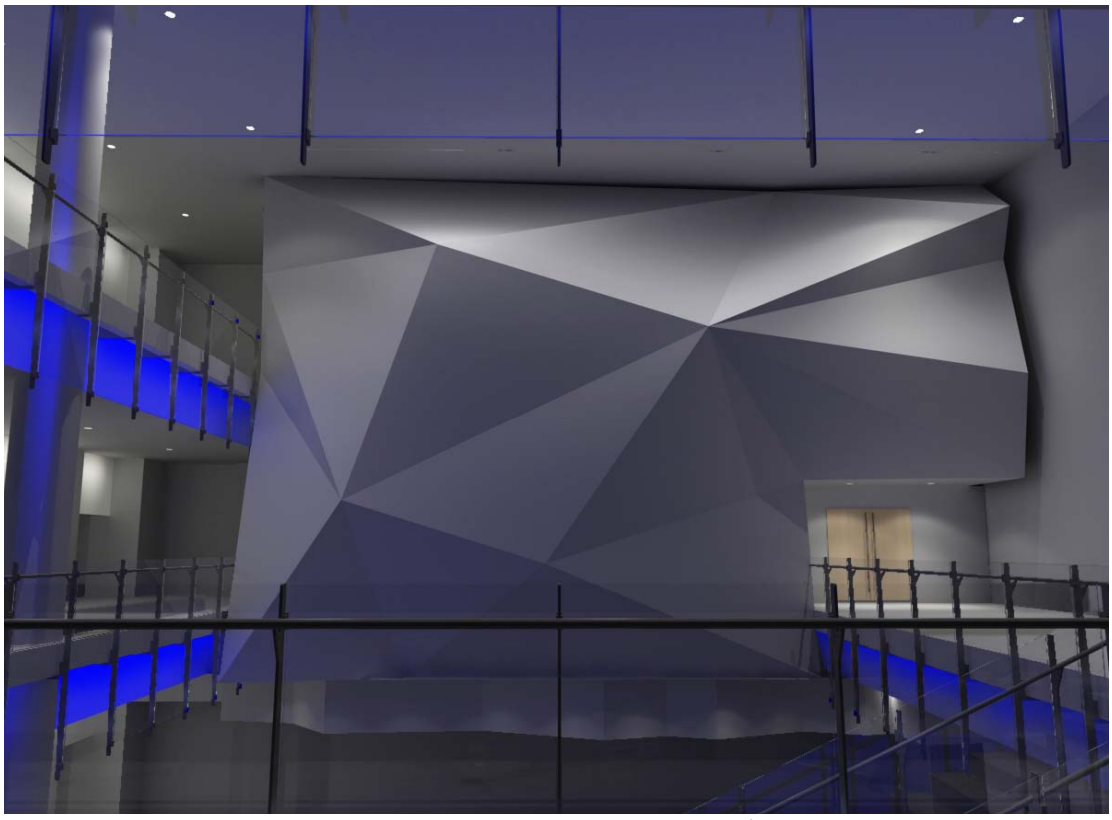


FIGURE 17: PERSPECTIVE LOOKING TOWARD THE SCULPTURE WALL / THEATER ENTRANCE (ENTERTAINMENT SCENE) (3DMAX STUDIO)

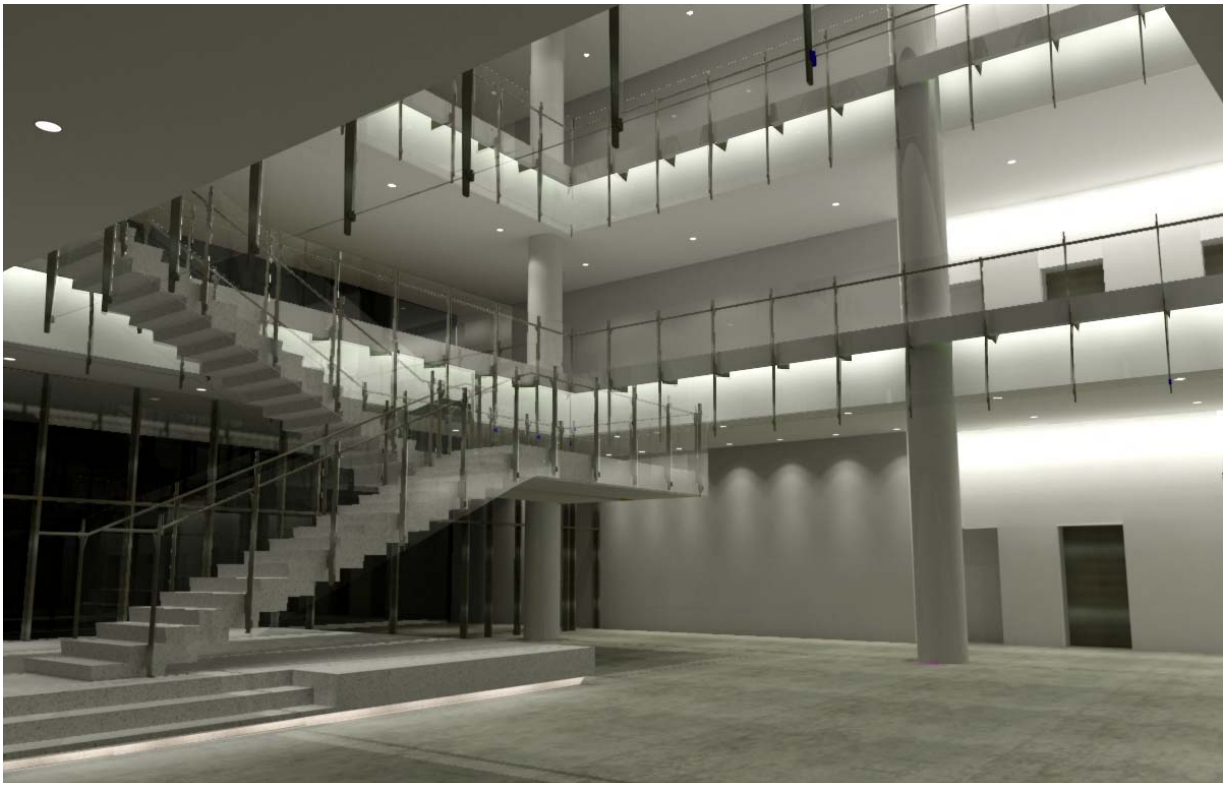


FIGURE 18: PERSPECTIVE LOOKING TOWARD THE STAIRS / BUILDING ENTRANCE (NORMAL SCENE) (3DMAX STUDIO)

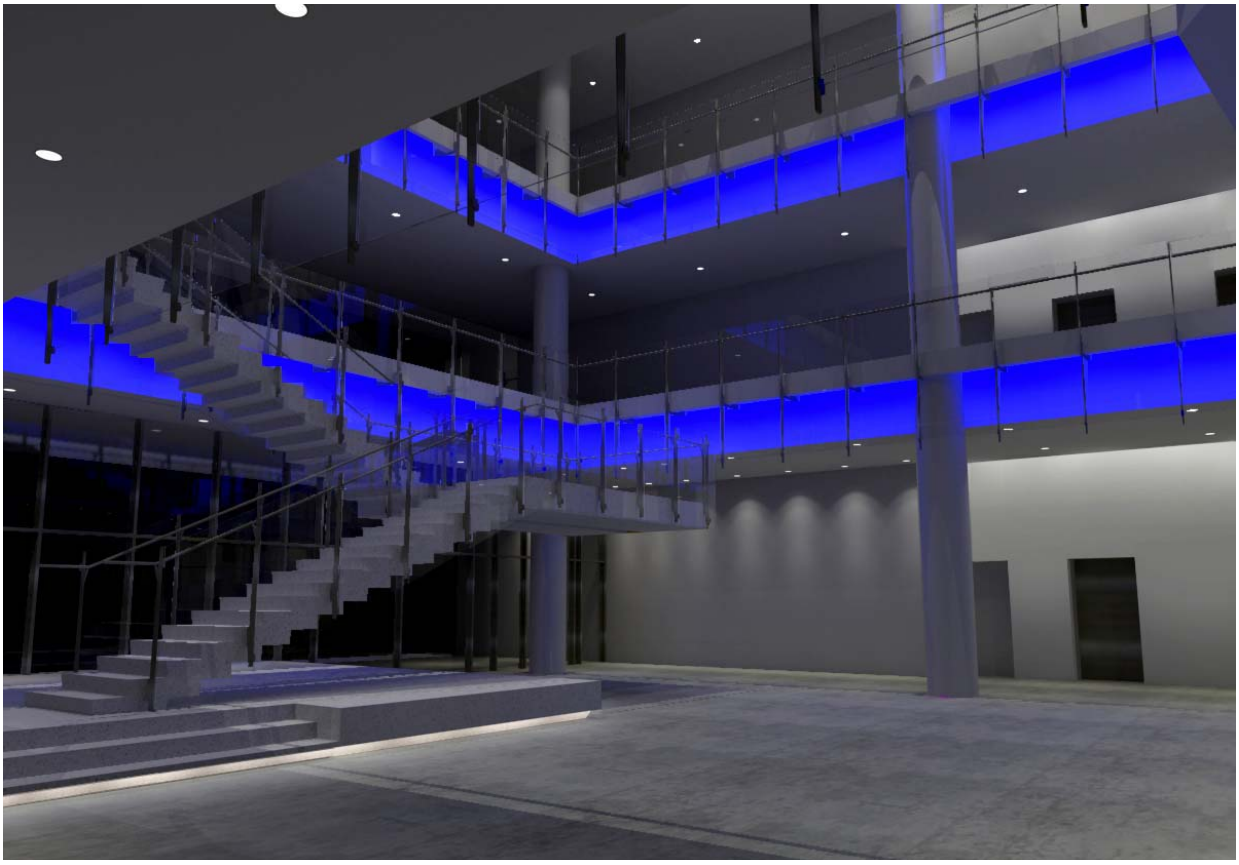


FIGURE 19: PERSPECTIVE LOOKING TOWARD THE STAIRS / BUILDING ENTRANCE (ENTERTAINMENT SCENE) (3DMAX STUDIO)

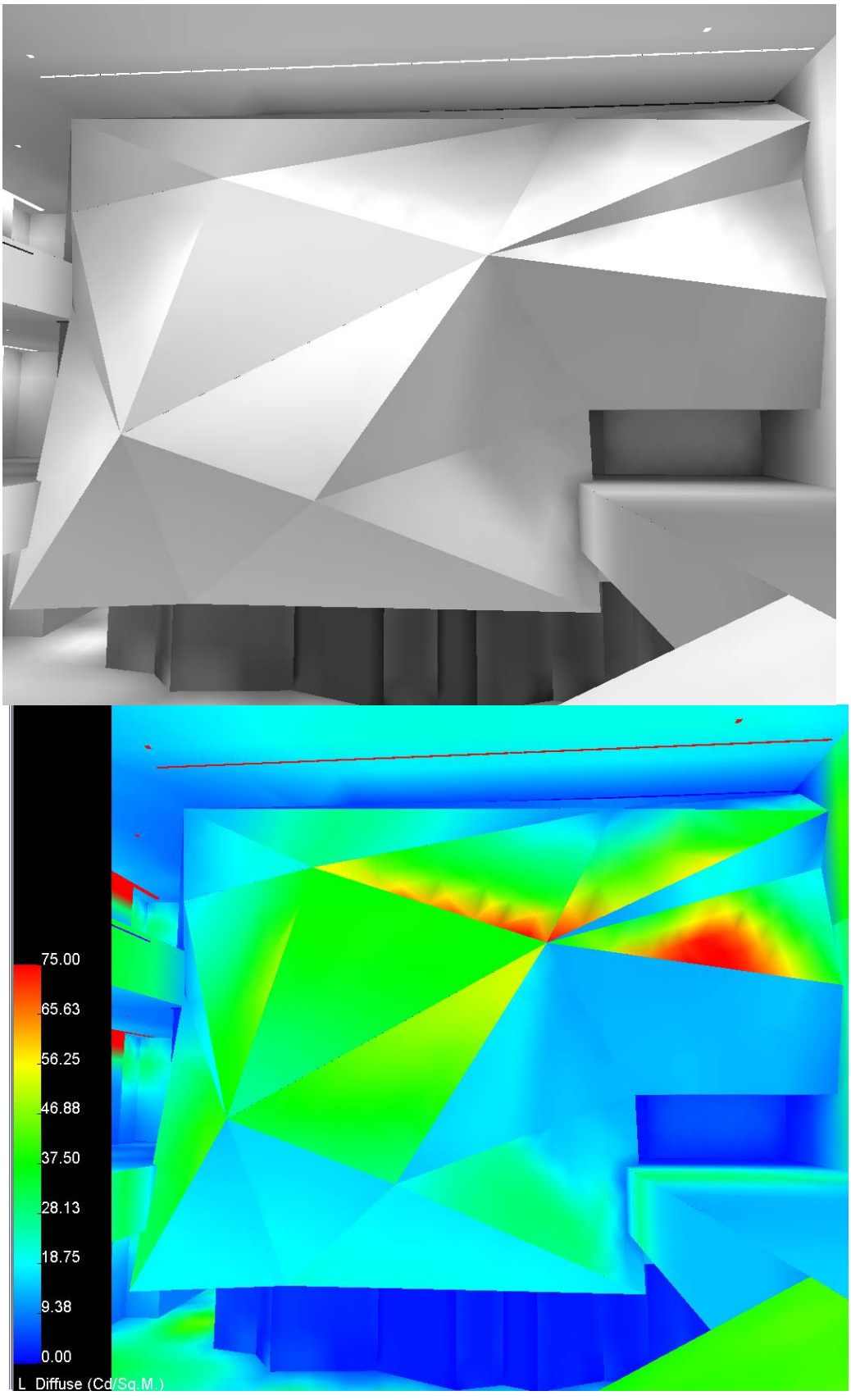



FIGURE 20: SCULPTURE WALL PERSPECTIVE AND PSEUDO COLOR IMAGE (AGI32)

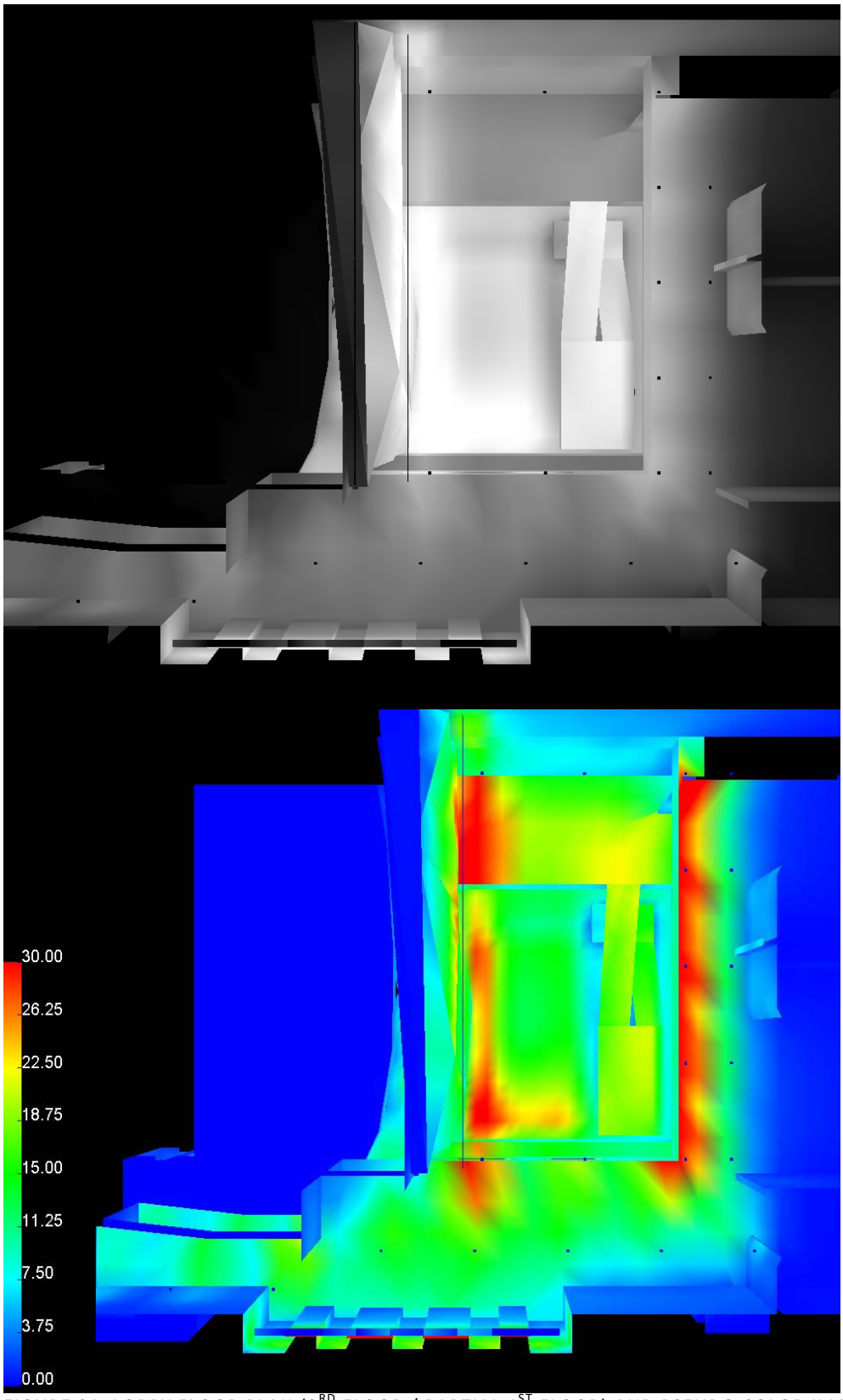
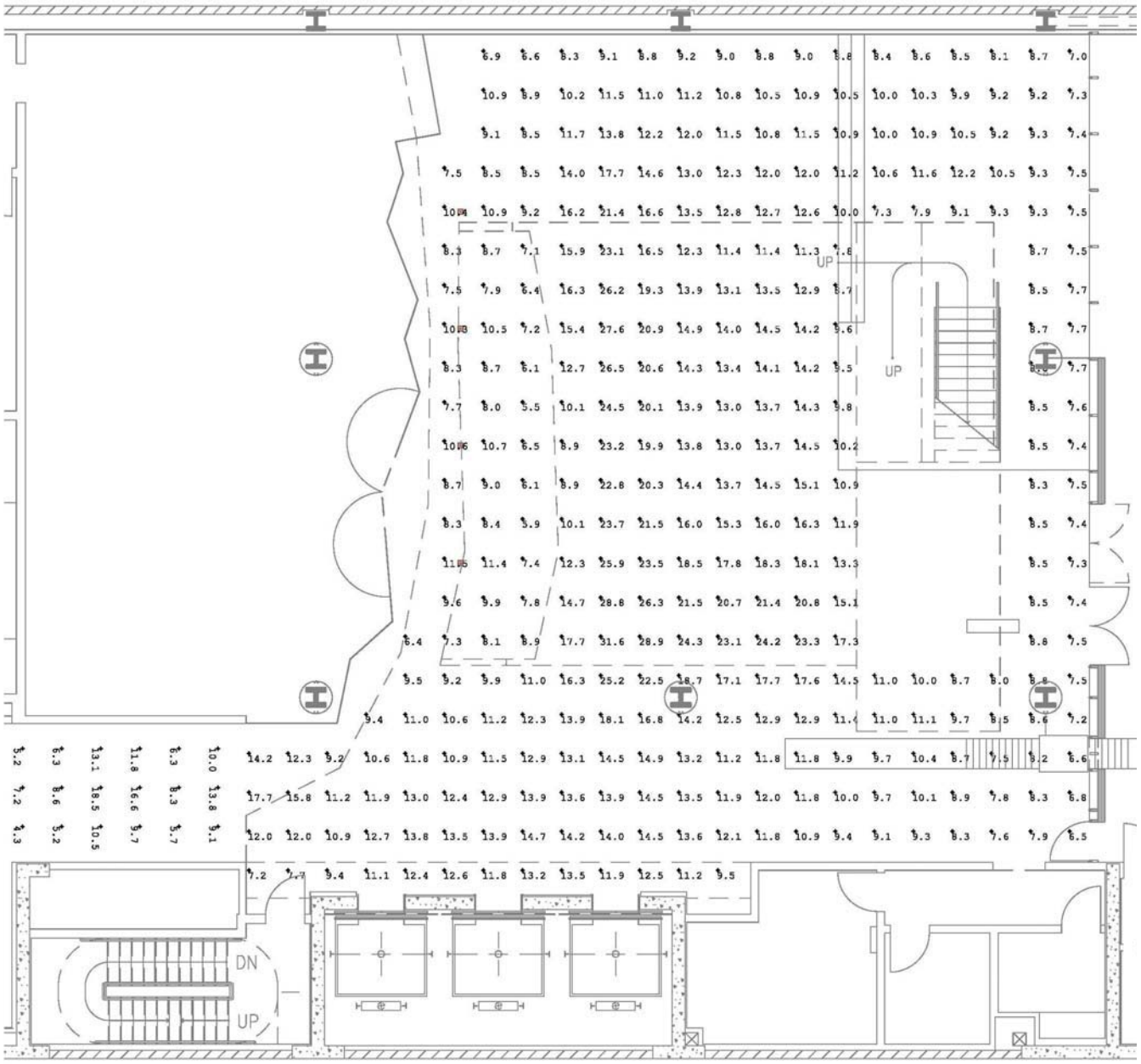



FIGURE 21: LOBBY FLOOR PLAN (3RD FLOOR / PARTIAL 1ST FLOOR) AND PSEUDO COLOR IMAGE (AGI32)

**First Floor Calculation Grid**




| Calculation Summary | | | | | | | |
|---|---|---|---|---|---|---|---|
| Label | CalcType | Units | Avg | Max | Min | Avg/Min | Max/Min |
| Landing 2_Top_1 | Illuminance | Fc | 19.59 | 21.1 | 17.9 | 1.09 | 1.18 |
| Stair 2_Planar | Illuminance | Fc | 18.68 | 20.4 | 17.0 | 1.10 | 1.20 |
| Stair 1_Planar | Illuminance | Fc | 15.82 | 17.9 | 15.0 | 1.05 | 1.19 |
| First Floor [Floor]_Floor | Illuminance | Fc | 12.19 | 31.6 | 5.5 | 2.22 | 5.75 |
| Third Floor [Floor] | Illuminance | Fc | 15.42 | 39.2 | 3.0 | 5.14 | 13.07 |
| Second Floor [Floor] | Illuminance | Fc | 12.65 | 36.0 | 2.4 | 5.27 | 15.00 |
| First Floor [Off Elevator Lobby] | Illuminance | Fc | 9.49 | 18.5 | 3.3 | 2.88 | 5.61 |
| Third Floor [Off Elevator Lobby] | Illuminance | Fc | 9.62 | 17.4 | 4.4 | 2.19 | 3.95 |
| Second Floor[Off Elevator Lobby] | Illuminance | Fc | 9.32 | 17.8 | 3.7 | 2.52 | 4.81 |

## Light Loss Factor Calculation: (General Illumination)

### TYPE F1 and F2

5" Square Recessed Downlight with 20 watts T4 Ceramic Metal Halide

- Lamp Lumen Depreciation – MC20TC/U/G8.5/830 Sylvania
  - LLD = maintained / initial = 1,275 / 1,700 = **.75**
- Luminaire Dirt Depreciation
  - Maintain category – IV
  - Degree of dirt condition – Clean
  - Cleaning cycle – 12 months
  - LDD = **.88**
- Room Surface Dirt Depreciation
  - Room cavity ratio = 5x12x(65+63) / (65X63) = 1.9
  - Degree of dirt condition – Clean
  - Cleaning cycle – 12 months
  - Expected dirt depreciation = 12%
  - Luminaire distribution type = Direct
  - RSDD = **.98**
- Ballast Factor = **1.0**

**LLF = .75 X .88 X .98 X 1.0 = .65**

### TYPE F3 and F4

5" Square Recessed Downlight with 70 watts T6 Ceramic Metal Halide

- Lamp Lumen Depreciation – MC70T6/U/G12/930 Sylvania
  - LLD = maintained / initial = 5,040 / 6,300 = **.80**
- Luminaire Dirt Depreciation
  - Maintain category – IV
  - Degree of dirt condition – Clean
  - Cleaning cycle – 12 months
  - LDD = **.88**
- Room Surface Dirt Depreciation
  - Room cavity ratio = 5x12x(65+63) / (65X63) = 1.9
  - Degree of dirt condition – Clean
  - Cleaning cycle – 12 months
  - Expected dirt depreciation = 12%
  - Luminaire distribution type = Direct
  - RSDD = **.98**
- Ballast Factor = **1.0**

**LLF = .80 X .88 X .98 X 1.0 = .69**

**TYPE F5**

4' Nominal length T5 Fluorescent Linear Wall-Slot

- Lamp Lumen Depreciation - FP28/835/ECO Sylvania
  - LLD = maintained / initial = 2697 / 2900 = **.93**
- Luminaire Dirt Depreciation
  - Maintain category – IV
  - Degree of dirt condition – Clean
  - Cleaning cycle – 12 months
  - LDD = **.88**
- Ballast Factor = **1.04**
- Room Surface Dirt Depreciation
  - Room cavity ratio = 5x12x(65+63) / (65X63) = 1.9
  - Degree of dirt condition – Clean
  - Cleaning cycle – 12 months
  - Expected dirt depreciation = 12%
  - Luminaire distribution type = Direct
  - RSDD = **.98**

**LLF = .93 X .88 X 1.04 X .98 = .83**

**TYPE F7**

5" Square Recessed Downlight with 50 watts PAR30

- Lamp Lumen Depreciation – 50PAR30/CAPIR/FL40 Sylvania
  - LLD = maintained / initial = 825 / 900 = **.92**
- Luminaire Dirt Depreciation
  - Maintain category – IV
  - Degree of dirt condition – Clean
  - Cleaning cycle – 12 months
  - LDD = **.88**
- Room Surface Dirt Depreciation
  - Room cavity ratio = 5x12x(65+63) / (65X63) = 1.9
  - Degree of dirt condition – Clean
  - Cleaning cycle – 12 months
  - Expected dirt depreciation = 12%
  - Luminaire distribution type = Direct
  - RSDD = **.98**

**LLF = .92 X .88 X .98 = .79**

**Energy Calculation:** ASHRAE/Standard 90.1 2004 : Space by space method

The total energy consumption for lobby lighting is 5,542 watts which is .74 Watt/Sq.ft. This number is almost half of the allowable energy consumption by code for lobby spaces (1.3 Watt/Sq.ft.).

| Space Type | Area ($ft.^2$) | Fixt. Type | Fixture Description | Watts / Fixture | Fixture Quantity | Total Watts | Actual Watts | Base $W/ft^2$ | Allow Watts |
|---|---|---|---|---|---|---|---|---|---|
| Lobby | 7,502 | F3,F4 | T6 CMH Recessed Downlight | 79 | 9 | 711 | 5541.8 | 1.3 | 9752 |
| | | F1,F2 | T4 CMH Recessed Downlight | 26 | 28 | 728 | | | |
| | | F5 | 4' T5 Fluorescent Wall Slot | 32 | 27 | 864 | | | |
| | | F7 | PAR30 Recessed Downlight | 50 | 34 | 1700 | | | |
| | | F8 | Linear LED (accent) | 3 | 262 | 786 | | | |
| | | F9 | Linear LED (wall grazer) | 58 | 10 | 580 | | | |
| | | F10 | Flexible LED | 86.4 | 2 | 172.8 | | | |

# Electrical Design: Foyer / Elevator Lobby

## Electrical Design Objectives/criteria

The new electrical system utilizes 12 circuits from three different panelboards including panel L1, L2, and L3. These panels are dedicated for lighting loads; therefore, 1.25 multiply factor is applied to demand load when sizing phase conductors for feeder. The panelboards are rated for three phase 208/120V system. All lighting loads are running on 120V single phase expect linear LED fixtures (fixture type F8 and type10). Power supplies are required for these two fixture types. The 12 circuits are divided into 10 control zones. All the dimmable luminaires are connected dimming panel (LDP-1) while non-dimming luminaires are connected to SoftSwitch panel (LSP-1). The control station (CS-1) is located on the first floor behind the reception desk. Refer to control diagrams in the appendix C.

**Original Panelboard (L1)**

PANELBOARD SCHEDULE

Designation: 0L-1 | Main Type: 100 MB
Voltage: 208/120V, 3PH, 4W | Bus Amps: 100 Amps
Fed From: 0G-1

AVAILABLE FAULT CURRENT: 42,000 AMPS

| CCT No. | Load Description | Load A | Load B | Load C | C/B Size | C/B Size | Load A | Load B | Load C | Load Description | CCT No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | L01, L09, L29 | 1120 | | | 20A | 20A | 980 | | | 101,103,104,108 | 2 |
| 3 | L02,L03,L05,L06,L10 | | 1050 | | 20A | 20A | | 1090 | | 106,112 | 4 |
| 5 | L11,L13 | | | 1260 | 20A | 20A | | | 800 | 102,107,109 | 6 |
| 7 | L12,L14,L29 | 420 | | | 20A | 20A | 1200 | | | GIFT SHOP 114 - (12) B (SW-2) | 8 |
| 9 | L07,L08,L27 | | 270 | | 20A | 20A | | 900 | | GIFT SHOP 114 - (9) B (SW-2) | 10 |
| 11 | GIFT SHOP (SW-1) | | | 1100 | 20A | 20A | | | 300 | GIFT SHOP 114 - (6) D1 (SW-5) | 12 |
| 13 | GIFT SHOP (SW-1) | 1100 | | | 20A | 20A | 400 | | | GIFT SHOP 114 - (8) B (SW-4) | 14 |
| 15 | GIFT SHOP (SW-1) | | 1100 | | 20A | 20A | | 560 | | 117 (SECURITY DESK - L34a) | 16 |
| 17 | SPARE | | | | 20A | 20A | | | 600 | GIFT SHOP 114 - LV JB (SW-7) | 18 |
| 19 | L04 | 560 | | | 20A | 20A | 600 | | | GIFT SHOP 114 - LV JB (SW-7) | 20 |
| 21 | 2nd Fl BOH | | 770 | | 20A | 20A | | 600 | | GIFT SHOP 114 - LV JB (SW-6) | 22 |
| 23 | SPARE | | | | 20A | 20A | | | 600 | GIFT SHOP 114 - LV JB (SW-6) | 24 |
| 25 | 219 | 480 | | | 20A | 20A | 600 | | | GIFT SHOP 114 - LV JB (SW-8) | 26 |
| 27 | SPARE | | | | 20A | 20A | | | | | 28 |
| 29 | 2nd Fl BOH | | | 300 | 20A | 20A | | | 350 | 115 (COVE) | 30 |
| 31 | GIFT SHOP (SW-3) | 1100 | | | 20A | 20A | 375 | | | 118,119,120,121 | 32 |
| 33 | GIFT SHOP (SW-3) | | 1100 | | 20A | 20A | | | | | 34 |
| 35 | GIFT SHOP (SW-3) | | | 1100 | 20A | 20A | | | | | 36 |
| 37 | GIFT SHOP (SW-3) | 1100 | | | 20A | 20A | | | | | 38 |
| 39 | GIFT SHOP (SW-3) | | 1100 | | 20A | 20A | | | | | 40 |
| 41 | | | | | 20A | 20A | | | | | 42 |
| | Total: | 5880 | 5390 | 3760 | | | 4155 | 3150 | 2650 | | |

Branch circuit to be redesigned

| | | | | | |
|---|---|---|---|---|---|
| Total Phase A | 10035 | va | Panel Total: | 25 | kVA |
| Total Phase B | 8540 | va | Demand Total: | 31 | kVA |
| Total Phase C | 6410 | va | Demand | 87 | Amps |

**Original Panelboard (L2)**

PANELBOARD SCHEDULE

Designation: 0L-2
Voltage: 208/120V, 3PH, 4W
Fed From: 0G-1

Main Type: 100 MB
Bus Amps: 100 Amps

AVAILABLE FAULT CURRENT: 42,000 AMPS

| CCT No. | Load Description | Load A | Load B | Load C | C/B Size | C/B Size | Load A | Load B | Load C | Load Description | CCT No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3RD FLOOR FAÇADE | 200 | | | 20A | 20A | 900 | | | 217 - TRACK | 2 |
| 3 | 3RD FLOOR FAÇADE | | 350 | | 20A | 20A | | 900 | | 217 - TRACK | 4 |
| 5 | 115/113 ELEV LOBBY - L5 - 14 | | | 700 | 20A | 20A | | | 900 | 217 - TRACK | 6 |
| 7 | 117 FOYER - L5 - 16 | 800 | | | 20A | 20A | 900 | | | 217 - TRACK | 8 |
| 9 | 117 FOYER - L5 - 20 | | 1000 | | 20A | 20A | | 900 | | 217 - TRACK | 10 |
| 11 | 117 SECURITY DESK - L5 - 7 | | | 350 | 20A | 20A | | | 900 | 217 - TRACK | 12 |
| 13 | 122 ENTRY - L5 - 9 | 450 | | | 20A | 20A | 750 | | | 2ND FLOOR FAÇADE | 14 |
| 15 | 2nd Fl Elevator Lobby Lighting | | 800 | | 20A | 20A | | 750 | | 2ND FLOOR FAÇADE | 16 |
| 17 | 2nd Fl Auditorium Lobby Lighting | | | 450 | 20A | 20A | | | 750 | 3RD FLOOR FAÇADE | 18 |
| 19 | 309 ELEV LOBBY - L5 - 13 | 650 | | | 20A | 20A | 750 | | | 3RD FLOOR FAÇADE | 20 |
| 21 | 117 FOYER - L5 - 6 | | | | 20A | 20A | | 750 | | 3RD FLOOR FAÇADE | 22 |
| 23 | | | | | 20A | 20A | | | 600 | FAÇADE L8 | 24 |
| | Total: | 2100 | 2150 | 1500 | | | 3300 | 3300 | 3150 | | |

Branch circuit to be redesigned

| | | | | | |
|---|---|---|---|---|---|
| Total Phase A: | 5400 | va | Panel Total: | 16 | kVA |
| Total Phase B: | 5450 | va | Demand Total: | 19 | kVA |
| Total Phase C: | 4650 | va | Demand | 54 | Amps |

**Original Panelboard (L3)**

PANELBOARD SCHEDULE

Designation: 3L-1
Voltage: 208/120V, 3PH, 4W
Fed From: 3G-1

Main Type: 100 MB
Bus Amps: 100 Amps

AVAILABLE FAULT CURRENT: 22,000 AMPS

| CCT No. | Load Description | Load A | Load B | Load C | C/B Size | C/B Size | Load A | Load B | Load C | Load Description | CCT No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 301 (DRESSING TABLE) | 1275 | | | 20A | 20A | 1050 | | | 402,403,405,406 | 2 |
| 3 | 302,306 | | 540 | | 20A | 20A | | 600 | | 401 | 4 |
| 5 | 307,311,312 | | | 1035 | 20A | 20A | | | 1500 | 408 | 6 |
| 7 | 309 (COVE) | 350 | | | 20A | 20A | 600 | | | 404 | 8 |
| 9 | SPARE | | | | 20A | 20A | | 600 | | 413 | 10 |
| 11 | 309 L32s | | | 1500 | 20A | 20A | | | 600 | 413 (TRACK LIGHTING) | 12 |
| 13 | 309 L32s | 1250 | | | 20A | 20A | 380 | | | 407,416 | 14 |
| 15 | 309 L31s | | 425 | | 20A | 20A | | 350 | | 416 (COVE) | 16 |
| 17 | 309 L31s | | | 425 | 20A | 20A | | | 280 | 406,411 | 18 |
| 19 | 309 L31s | 425 | | | 20A | 20A | 1000 | | | 412,421,422 | 20 |
| 21 | 309 L31s | | 425 | | 20A | 20A | | 1270 | | 414 | 22 |
| 23 | 309 L31s | | | 425 | 20A | 20A | | | | SPARE | 24 |
| 25 | 309 L31s | 375 | | | 20A | 20A | | | | SPARE | 26 |
| 27 | 313 L22s | | 840 | | 20A | 20A | | 510 | | 417,418,419,420 | 28 |
| 29 | 314 L22s | | | 840 | 20A | 20A | | | 150 | 412, L21s | 30 |
| 31 | 315 | 280 | | | 20A | 20A | | | | | 32 |
| 33 | | | | | 20A | 20A | | | | | 34 |
| 35 | | | | | 20A | 20A | | | | | 36 |
| 37 | | | | | 20A | 20A | | | | | 38 |
| 39 | | | | | 20A | 20A | | | | | 40 |
| 41 | | | | | 20A | 20A | | | | | 42 |
| | Total: | 3955 | 2230 | 4225 | | | 3030 | 3330 | 2530 | | |

Branch circuit to be redesigned

| | | | | | |
|---|---|---|---|---|---|
| Total Phase A: | 6985 | va | Panel Total: | 19 | kVA |
| Total Phase B: | 5560 | va | Demand Total: | 24 | kVA |
| Total Phase C: | 6755 | va | Demand | 67 | Amps |

**New Panelboard (L1)**

PANELBOARD SCHEDULE

Designation: L1 — Main Type: 100 MB
Voltage: 208/120V, 3PH, 4W — Bus Amps: 100 Amps
Fed From: 0G-1

AVAILABLE FAULT CURRENT: 42,000 AMPS

| CCT No. | Load Description | Load A | Load B | Load C | C/B Size | C/B Size | Load A | Load B | Load C | Load Description | CCT No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | L01, L09, L29 | 1120 | | | 20A | 20A | 980 | | | 101,103,104,108 | 2 |
| 3 | L02,L03,L05,L06,L10 | | 1050 | | 20A | 20A | | 1090 | | 106,112 | 4 |
| 5 | L11,L13 | | | 1260 | 20A | 20A | | | 800 | 102,107,109 | 6 |
| 7 | L12,L14,L29 | 420 | | | 20A | 20A | 345 | | | GIFT SHOP 114 - (15) Fixture Type B | 8 |
| 9 | L07,L08,L27 | | 270 | | 20A | 20A | | 345 | | GIFT SHOP 114 - (15) Fixture Type B | 10 |
| 11 | GIFT SHOP 114 - (5) Fixture Type A | | | 115 | 20A | 20A | | | 300 | GIFT SHOP 114 - (6) D1 (SW-5) | 12 |
| 13 | GIFT SHOP 114 - (5) Fixture Type A | 115 | | | 20A | 20A | | | | | 14 |
| 15 | GIFT SHOP 114 - (5) Fixture Type A | | 115 | | 20A | 20A | | 560 | | 117 (SECURITY DESK - L34a) | 16 |
| 17 | SPARE | | | | 20A | 20A | | | 600 | GIFT SHOP 114 - LV JB (SW-7) | 18 |
| 19 | L04 | 560 | | | 20A | 20A | 600 | | | GIFT SHOP 114 - LV JB (SW-7) | 20 |
| 21 | 2nd Fl BOH | | 770 | | 20A | 20A | | 600 | | GIFT SHOP 114 - LV JB (SW-6) | 22 |
| 23 | SPARE | | | | 20A | 20A | | | 600 | GIFT SHOP 114 - LV JB (SW-6) | 24 |
| 25 | 219 | 480 | | | 20A | 20A | 600 | | | GIFT SHOP 114 - LV JB (SW-8) | 26 |
| 27 | SPARE | | | | 20A | 20A | | | | | 28 |
| 29 | 2nd Fl BOH | | | 300 | 20A | 20A | | | | | 30 |
| 31 | GIFT SHOP 114 - (5) Fixture Type A | 115 | | | 20A | 20A | 375 | | | 118,119,120,121 | 32 |
| 33 | GIFT SHOP 114 - (5) Fixture Type A | | 115 | | 20A | 20A | | | | | 34 |
| 35 | GIFT SHOP 114 - (5) Fixture Type A | | | 115 | 20A | 20A | | | | | 36 |
| 37 | GIFT SHOP 114 - (5) Fixture Type A | 115 | | | 20A | 20A | | | | | 38 |
| 39 | GIFT SHOP 114 - (6) Fixture Type A | | 138 | | 20A | 20A | | | | | 40 |
| 41 | | | | | 20A | 20A | | | | | 42 |
| | Total: | 2925 | 2458 | 1790 | | | 2900 | 2595 | 2300 | | |

| | | | | | |
|---|---|---|---|---|---|
| Total Phase A | 5825 | va | Panel Total: | 15 | kVA |
| Total Phase B | 5053 | va | Demand Total: | 17 | kVA |
| Total Phase C | 4090 | va | Demand | 47 | Amps |

Redesigned Branch Circuit
Depth Topic 1 - Reduced Lighting Load

**New Panelboard (L2)**

PANELBOARD SCHEDULE

Designation: L2 — Main Type: 100 MB
Voltage: 208/120V, 3PH, 4W — Bus Amps: 100 Amps
Fed From: 0G-1

AVAILABLE FAULT CURRENT: 42,000 AMPS

| CCT No. | Load Description | Load A | Load B | Load C | C/B Size | C/B Size | Load A | Load B | Load C | Load Description | CCT No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3RD FLOOR FAÇADE | 200 | | | 20A | 20A | 144 | | | 217 - TRACK (6) CFL | 2 |
| 3 | 3RD FLOOR FAÇADE | | 350 | | 20A | 20A | | 144 | | 217 - TRACK (6) CFL | 4 |
| 5 | 116 FOYER - (4) F7, (2) F1 | | | 269 | 20A | 20A | | | 144 | 217 - TRACK (6) CFL | 6 |
| 7 | 117 FOYER - (15) F7 | 750 | | | 20A | 20A | 144 | | | 217 - TRACK (6) CFL | 8 |
| 9 | 117 FOYER - (15) F7 | | 750 | | 20A | 20A | | 144 | | 217 - TRACK (6) CFL | 10 |
| 11 | 117 SECURITY DESK - L5 - 7 | | | 350 | 20A | 20A | | | 144 | 217 - TRACK (6) CFL | 12 |
| 13 | 122 ENTRY - L5 - 9 | 450 | | | 20A | 20A | 336 | | | 2ND FLOOR FAÇADE (14) CFL | 14 |
| 15 | 216 ELEV LOBBY - F1, F2 | | 322 | | 20A | 20A | | 312 | | 2ND FLOOR FAÇADE (13) CFL | 16 |
| 17 | 2nd Fl Auditorium Lobby Lighting | | | 450 | 20A | 20A | | | 432 | 3RD FLOOR FAÇADE (18) CFL | 18 |
| 19 | 309 ELEV LOBBY - F1, F2 | 299 | | | 20A | 20A | 432 | | | 3RD FLOOR FAÇADE (18) CFL | 20 |
| 21 | 115 FOYER (9) F5 | | 297 | | 20A | 20A | | 297 | | 216 FOYER (9) F5 | 22 |
| 23 | 216, 309 ELEV LOBBY - F8 Power Supply (11) | | | 660 | 20A | 20A | | | 600 | FAÇADE L8 | 24 |
| | Total: | 1699 | 1719 | 1729 | | | 1056 | 897 | 1320 | | |

| | | | | | |
|---|---|---|---|---|---|
| Total Phase A: | 2755 | va | Panel Total: | 8 | kVA |
| Total Phase B: | 2616 | va | Demand Total: | 10 | kVA |
| Total Phase C: | 3049 | va | Demand | 27 | Amps |

Redesigned Branch Circuit
Depth Topic 1 - Reduced Lighting Load

**New Panelboard (L3)**

PANELBOARD SCHEDULE

Designation: L3
Voltage: 208/120V, 3PH, 4W
Fed From: 3G-1

Main Type: 100 MB
Bus Amps: 100 Amps

AVAILABLE FAULT CURRENT: 22,000 AMPS

| CCT No. | Load Description | Load A | Load B | Load C | C/B Size | C/B Size | Load A | Load B | Load C | Load Description | CCT No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 301 (DRESSING TABLE) | 1275 | | | 20A | 20A | 1050 | | | 402,403,405,406 | 2 |
| 3 | 302,306 | | 540 | | 20A | 20A | | 600 | | 401 | 4 |
| 5 | 307,311,312 | | | 1035 | 20A | 20A | | | 1500 | 408 | 6 |
| 7 | 309 ELEV LOBBY (9) F5 | 297 | | | 20A | 20A | 600 | | | 404 | 8 |
| 9 | SPARE | | | | 20A | 20A | | 600 | | 413 | 10 |
| 11 | 309, ELEV LOBBY (6) F3, (2) F4 | | | 632 | 20A | 20A | | | 600 | 413 (TRACK LIGHTING) | 12 |
| 13 | 309 Power Supply (5), F8 (Sculpture wall) | 300 | | | 20A | 20A | 380 | | | 407,416 | 14 |
| 15 | 309 ELEV LOBBY (11) F9 | | 638 | | 20A | 20A | | 350 | | 416 (COVE) | 16 |
| 17 | | | | | 20A | 20A | | | 280 | 406,411 | 18 |
| 19 | | | | | 20A | 20A | 1000 | | | 412,421,422 | 20 |
| 21 | | | | | 20A | 20A | | 1270 | | 414 | 22 |
| 23 | | | | | 20A | 20A | | | | SPARE | 24 |
| 25 | | | | | 20A | 20A | | | | SPARE | 26 |
| 27 | 313 L22s | | 840 | | 20A | 20A | | 510 | | 417,418,419,420 | 28 |
| 29 | 314 L22s | | | 840 | 20A | 20A | | | 150 | 412, L21s | 30 |
| 31 | 315 | 280 | | | 20A | 20A | | | | | 32 |
| 33 | | | | | 20A | 20A | | | | | 34 |
| 35 | | | | | 20A | 20A | | | | | 36 |
| 37 | | | | | 20A | 20A | | | | | 38 |
| 39 | | | | | 20A | 20A | | | | | 40 |
| 41 | | | | | 20A | 20A | | | | | 42 |
| | Total: | 2152 | 2018 | 2507 | | | 3030 | 3330 | 2530 | | |

Total Phase A: 5182 va
Total Phase B: 5348 va
Total Phase C: 5037 va

Panel Total: 16 kVA
Demand Total: 18 kVA
Demand 49 Amps

Redesigned Branch Circuit
Depth Topic 1 - Reduced Lighting Load

## Feeder Sizing

**Panel L1** : Phase Conductor : 47 Amps x 1.25 = 58.75 Amps – 8 AWG CU THWN 75$^{o}$C
Ground Conductor : 100 Amps – 8 AWG CU

**Panel L2** : Phase Conductor : 27 Amps x 1.25 = 33.75 Amps – 12 AWG CU THWN 75$^{o}$C
Ground Conductor : 100 Amps – 8 AWG CU

**Panel L3** : Phase Conductor : 49 Amps x 1.25 = 61.25 Amps – 8 AWG CU THWN 75$^{o}$C
Ground Conductor : 100 Amps – 8 AWG CU

**FEEDER SCHEDULE**

| FROM | TO | # OF SET | CONDUIT (PER SET) | | CONDUCTORS (PER SET) | | | | | | | | | SIZE OF OVER CURRENT PROTECTION | FRAME OR SWITCH SIZE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | PHASE CONDUCTORS | | | NEUTRAL CONDUCTORS | | | GROUND | | | | |
| | | | SIZE | TYPE | No | SIZE | TYPE | No | SIZE | TYPE | No | SIZE | TYPE | | |
| 0G-1 | L1 | 1 | .75" | EMT | 3 | 8AWG | CU THWN | 1 | 8AWG | CU THWN | 1 | 8AWG | CU THWN | 100 | 100A3P |
| 0G-1 | L2 | 1 | .75" | EMT | 3 | 12AWG | CU THWN | 1 | 12AWG | CU THWN | 1 | 8AWG | CU THWN | 100 | 100A3P |
| 3G-1 | L3 | 1 | .75" | EMT | 3 | 8AWG | CU THWN | 1 | 8AWG | CU THWN | 1 | 8AWG | CU THWN | 100 | 100A3P |

FIGURE 22: PANELBOARD L1, L2, L3 FEEDER SCHEDULE

## Lighting Design: Feinberg Theater

**Description:**

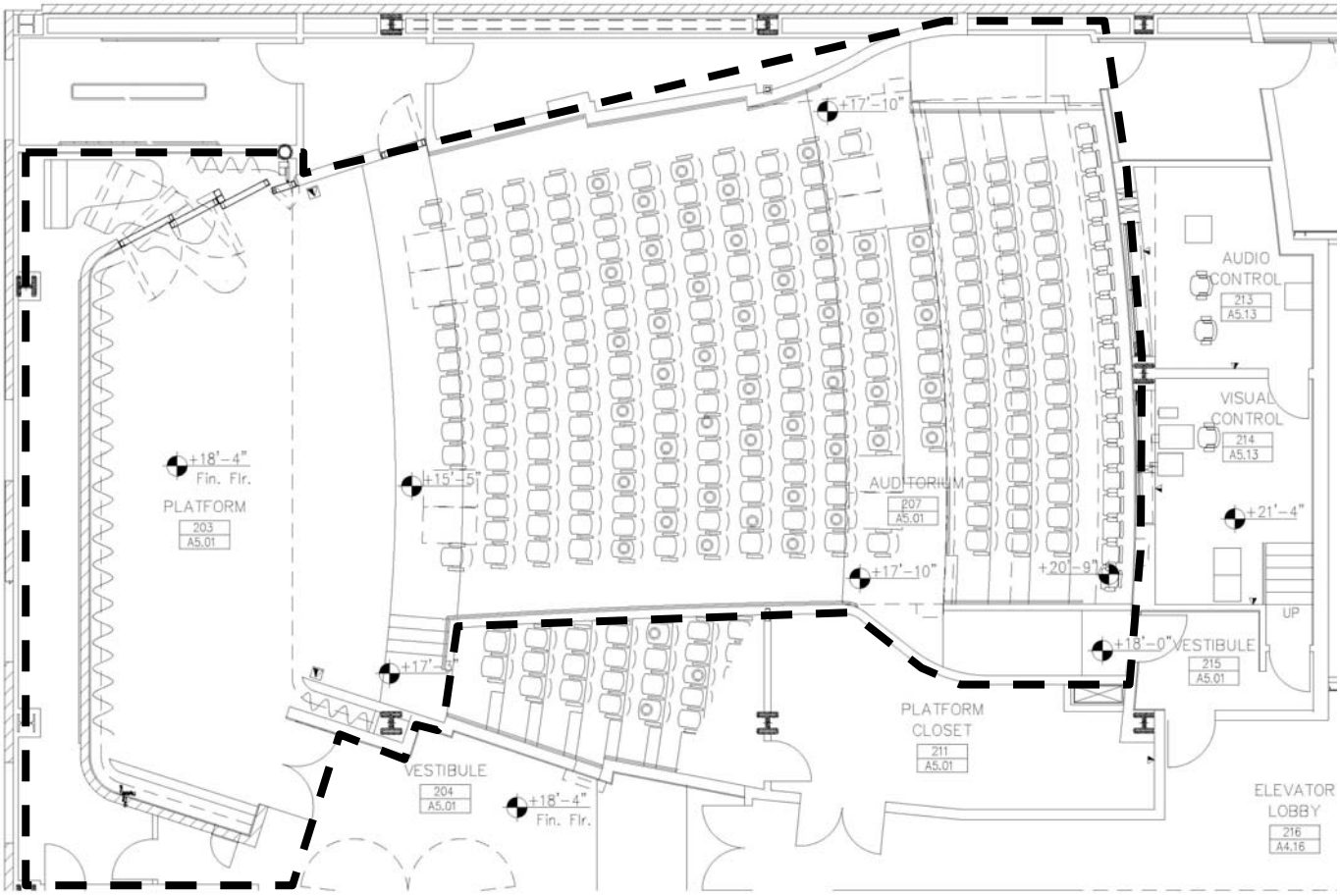
Feinberg Theater is specially designed for lectures, live performances, and film, with a proscenium stage, viewer-friendly tiered seating, a wrap-around mezzanine and balcony, and state-of-the-art acoustics. It can seat up to 400 people. Possible breadth topic for this space is a study of acoustics system.

**Requirement met:** A special purpose space

**Area:** approx. 4,700 Sq.ft. (total of both levels)

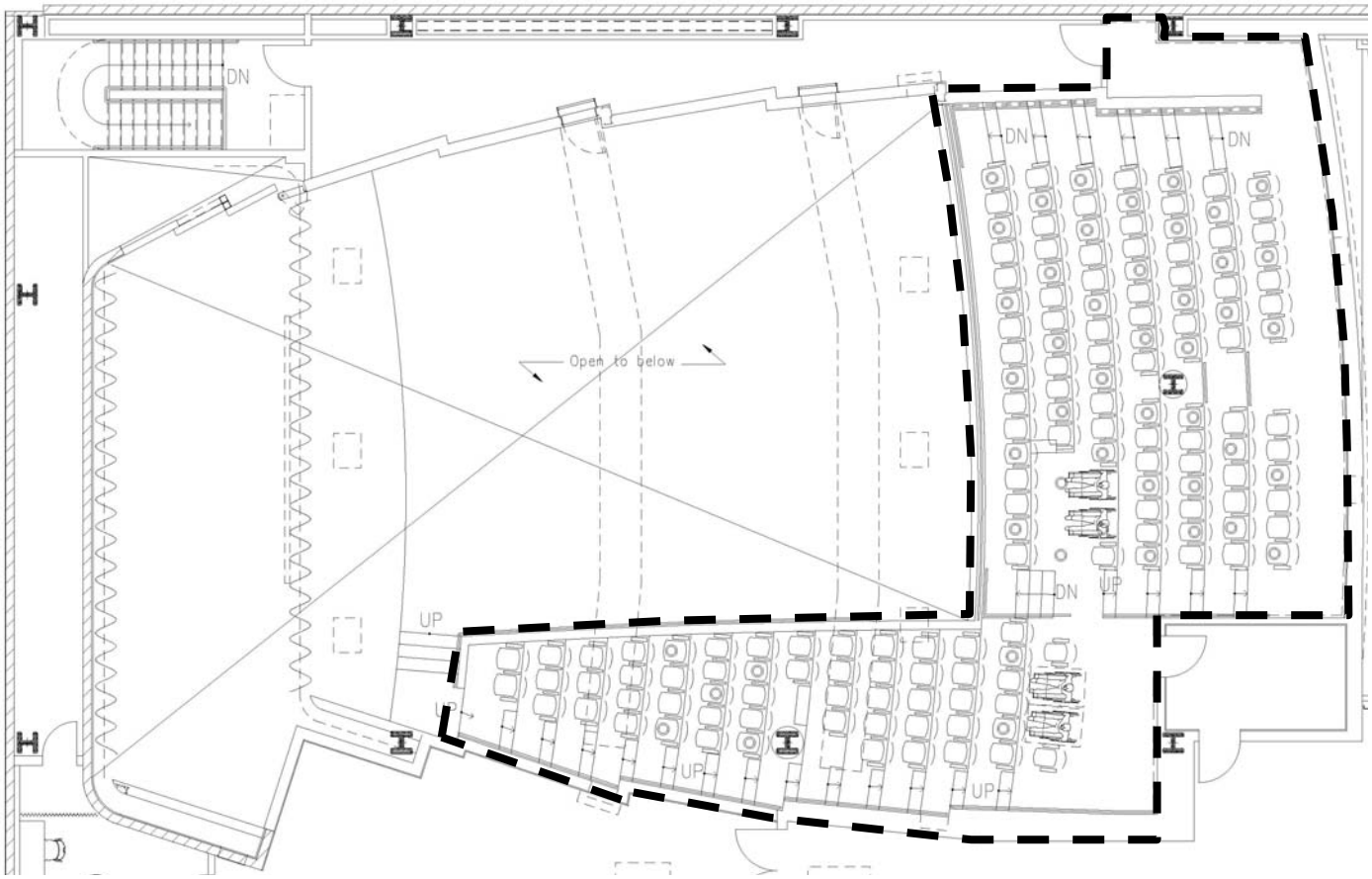
**Dimension:** Approx 58’-0” x 82’-0”

**Plan:**
Main level



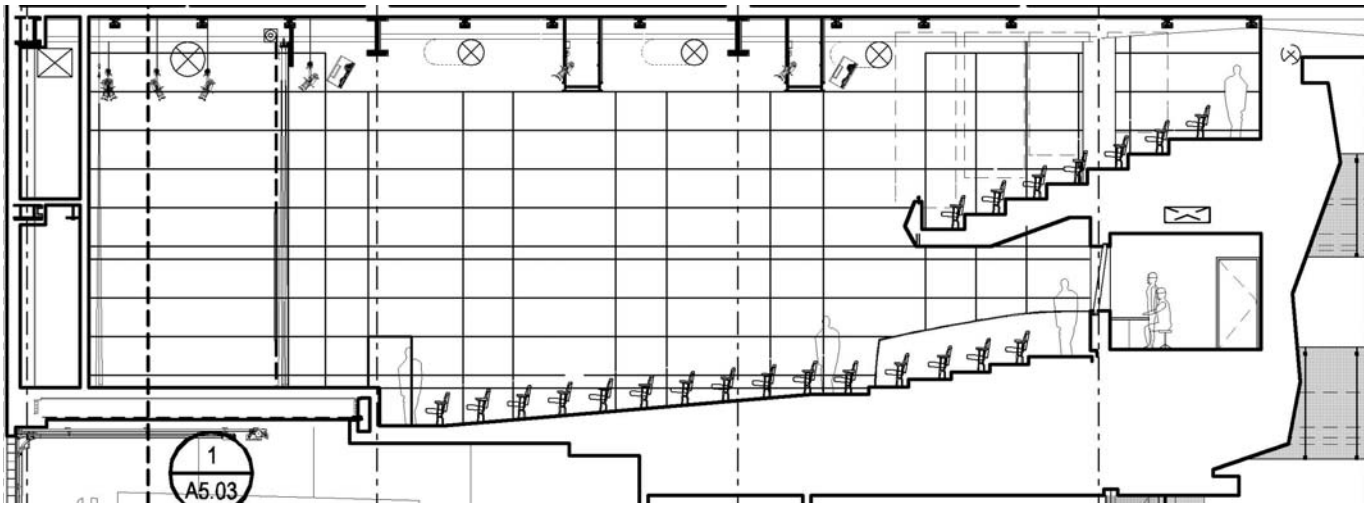

Redesign Space

Balcony level




**Proposed Space**

**Section:**



**Materials:**

| Surface | Material | Reflectance |
|---|---|---|
| **Floor** | Carpet Broadloom, color Dove Gray | .4 |
| **Stage Floor** | Resilient wood floor assembly (Northern hard maple tounge and groove flooring) | .4 |
| **Ceiling** | Exposed Ceiling | .6 |
| **Wall (side wall, front portion)** | Grey painted gypsum wall board | .5 |
| **Acoustic Wall (side wall, rear portion)** | Medium density fiberboard with perforated 5/8” fire retardant treated MDF | .5 |
| **Acoustic Wall (back wall)** | 1” thick fiberglass panels | .5 |
| **Stage Curtain (side)** | Dark red curtain | .3 |
| **Stage Curtain (back)** | Medium Gray curtain | .4 |
| **Seating** | Yellow (Ochre) fabric with light colored natural wood back | .7 |

**Activities/Tasks:**

- Lectures
- Live performances
- Films

## Design Consideration / Criteria

Color Appearance (and color contrast)

- Color Appearance is an important design issue. Good color rendering light source should be implemented to compliment people skin tones for house lighting. Color correlation temperature should be warm to neutral (3000-3500 K) to complement with golden yellow color of seating fabric.

Direct Glare

- Direct glare from light sources is an important design issue in a theater space. Direct glare does not only create discomfort glare, but also can distract the audience's attention. To reduce direct glare from the luminaire, comfort diffused reflector and glare shield should be specified especially for steplight.

Light Distribution on Task Plane (Uniformity)

- Task plane for house lighting is seating area. The seating area should have diffuse, uniform, and comfortable illumination.
- Luminaire should provide medium - wide distribution to provide uniform lighting and avoid hot spots depending on the mounting height.

Luminances of Room Surfaces

- Although the focal point of the space is the stage, side walls should be uniformly illuminated to define the perimeter and promote the scene of spaciousness.

Modeling of Faces and Objects

- Facial modeling is particularly important for the performer or speaker on the stage. Good modeling of faces can be done by providing lighting from multiple directions.

Points of Interest

- The focal point of this space is the stage. Curtains around and behind the stage can be created as a point of interest.

Shadows

- Shadows on performers should be avoided by providing key light from different angles and locations.

System Control and Flexibility

- The general house lighting should be under dimmer control, preferably from several stations, such as the stage lighting control board, the projection booth, and the staff entrance. There should be transfer capabilities, however, so that the lighting is not accidently turned on during performances (IESNA Ch.15-8).
- Selected lighting system circuits may be dedicated for cleaning and rehearsals.
- "Panic" switches independent of dimmers and switches should be provided to allow an operator to bring on selected lights on the house in case of emergency (IESNA Ch.15-8).

Special Considerations

- Foyer area (IESNA Ch.15-8)
  - Restful, subdued atmosphere is desirable.
  - Wall lighting and accents on statuary, paintings, posters, and plants are important in developing atmosphere.
  - Lighting must not spill into the auditorium
  - Before and after performances, the following levels are recommended:
    - 5 fc for motion picture theater
    - 15 fc for live production theatres
    - Since this particular theatre will be used for both purposes, 10 fc should be provided to compromise the differences.
- Seating area (IESNA Ch.15-8)
  - Diffuse, comfortable illumination is desirable.
- Stage Lighting (IESNA Ch.15-9)
  - Intensity of light
    - Precise, consistent dimmer control is essential for establishing and maintaining various intensity levels.
    - Vertical illuminances of 200 fc or higher are required to highlight selected performances.
  - Distribution of light
    - Stage lighting calls for wide variety of luminaire types and mounting positions.
    - Luminance ratios on the stage should not exceed 100:1
  - Color
    - Color is used to accent, enhance, distort, and motivate the scene.
    - Color should be controlled means of lamp selection, dimmers, and filters.
    - A tonal quality can be obtained by the additive mixture of two or more sources
    - Color rendering index used in stage lighting should not be less than 80.
  - Lighting location
    - Two basic locations are:
      - In front of the proscenium opening, including the auditorium ceiling and side walls.
      - Behind the proscenium opening, including pipes for attaching tormentor (side) lights, overhead cyclorama or top lights
    - A typical multipurpose stage can be divided into smaller lighting areas (10-12 ft. in diameter). In this particular theater, we have approximate 40’x20’ stage. Therefore, we can have two rows of four lighting areas, for a total of 8 lighting areas. Each lighting area should have four sets of luminaires

Lamp maintenance consideration

- Location of luminaires has to be accessible for the purpose of lamp replacement
- Long lamp life should be specified

Energy Consideration

- Energy Code Requirements – ASHRAE 90.1-2004 – Space by space method
    - **2.6w/sq ft.** for audience/seating area in performing arts theater

Illuminance (Horizontal)

- Seating area: 10-20 fc when performances are not taking place (IESNA recommendation – Ch.15-8)
- 30 fc (IESNA Reading – Handwritten tasks - #2 pencil and softer leads)
- Although IESNA design guide recommends 10-20 fc on horizontal workplane for theater seating areas, 30fc should be able to achieve by the system to provide adequate light level for reading and writing.

Illuminance (Vertical)

- 3 fc (IESNA Offices – Lobby, lounges, and reception areas)

# Lighting Redesign

## Lighting Solutions:

The overall lighting design goal for the theater is to provide flexible lighting systems that produce quality light as well as to enhance the interior architecture in the space. The idea of rhythm and pattern of light are applied to not only define a space, but also accent the architectural features. The ceiling panel is designed as a part of breadth study to integrate lighting systems by providing space to recess lights and to hide theatrical fixtures and catwalks. It is not only a place holder for recessed luminaires, but also performs as a luminaire itself. The rhythm of gradient light is created on the panels to provide a sense of spaciousness as well as to provide indirect/diffused light in the space. These panels will also improve acoustical performance and overall aesthetic appearance of the interior architecture. The coordination study for the ceiling system is shown in the detail

**General Illumination**

General illumination is provided by the two systems of downlight including compact fluorescent downlight and halogen downlight. The two systems combine will provide adequate illuminance level for reading/writing tasks (30fc). However, only the halogen downlight system is needed for pre-show and post-show purposes. The halogen downlight system provides flexibility for dimming and fading effects. The ceiling panels are glazed by linear fluorescent cove fixtures to create gradient of light on the panels as well as to provide indirect light in the space. Indirect/direct linear fluorescent wall mounted is specified on the back wall of the balcony level to create the same effect on the ceiling panels. The fixture also provides vertical illuminance to define the back wall. The same technique is applied to the seating area under the balcony by linear fluorescent cove fixtures.

**Accent/Navigation**

To emphasize the verticality and accent the shape of the theater, color changing LED cove fixture is specified in the vertical cove along the perimeter walls. This system also helps for navigation along the perimeter path and steps to the balcony level. Appropriate colors can be set through DMX control system to create coherent color scheme with the shows or performances. The LED step lights are located along the perimeter path and along the steps to the balcony seating to provide adequate illuminance level for navigation and path of emergency egress.

**Stage Lighting**

There are two lighting systems provided on the stage area as a part of house lighting system. One is pendant mounted compact fluorescent to provide general illumination for stage setting or cleaning up. The other system is halogen track system. It will be used to highlight the texture and color of the front curtain before the shows or performances. It can also be used to substitute the theatrical fixtures as front lighting for simple shows and lectures.

Theatrical light fixtures will be specified by the theater consultant. Mounting locations for theatrical light fixtures can be found in the lighting detail drawing from appendix D and in the ceiling coordination study drawing from appendix H.

## Controls:

All house lighting and theatrical lighting are connected to dimming rack and controlled by the control stations and the control console in the control room. Diagram below shows riser diagram for specified control system.

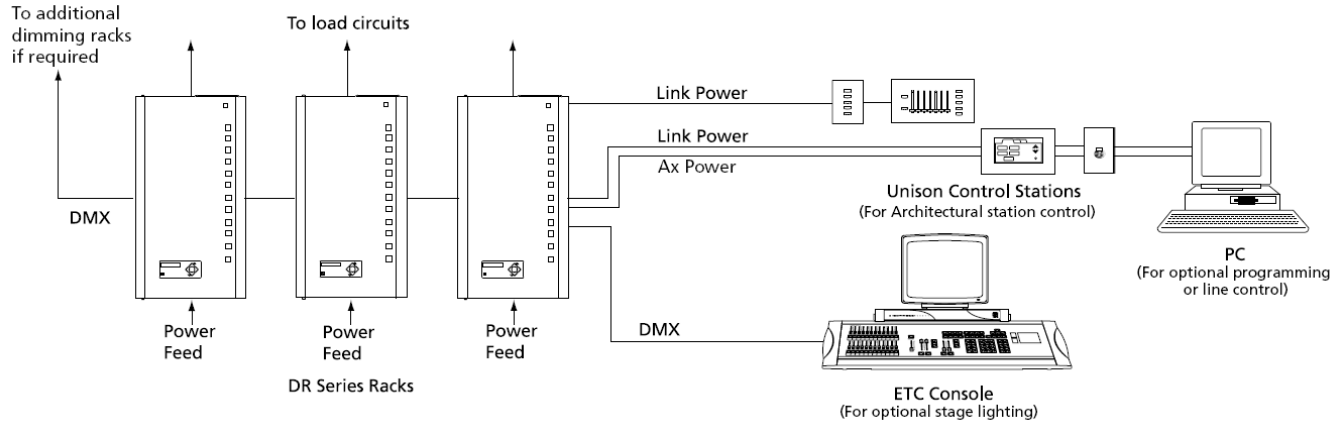



FIGURE 23: UNISON DIMMING AND CONTROL RISER BY ELECTRONIC THEATER CONTROLS, INC.

The overall control system includes the three main components: distribution, dimming, and controls. Distribution system includes power distribution boxes that provide electricity from the dimmers to the fixtures and network DMX node. The dimming system contains the control processor (main processor for the dimming rack), and the dimming rack itself. Lastly, the control system consists of the architectural control devices (for houselights, work lights, and lobby lights) and the console which is used to adjust and play back lighting looks.

## Summary Performance Evaluation:

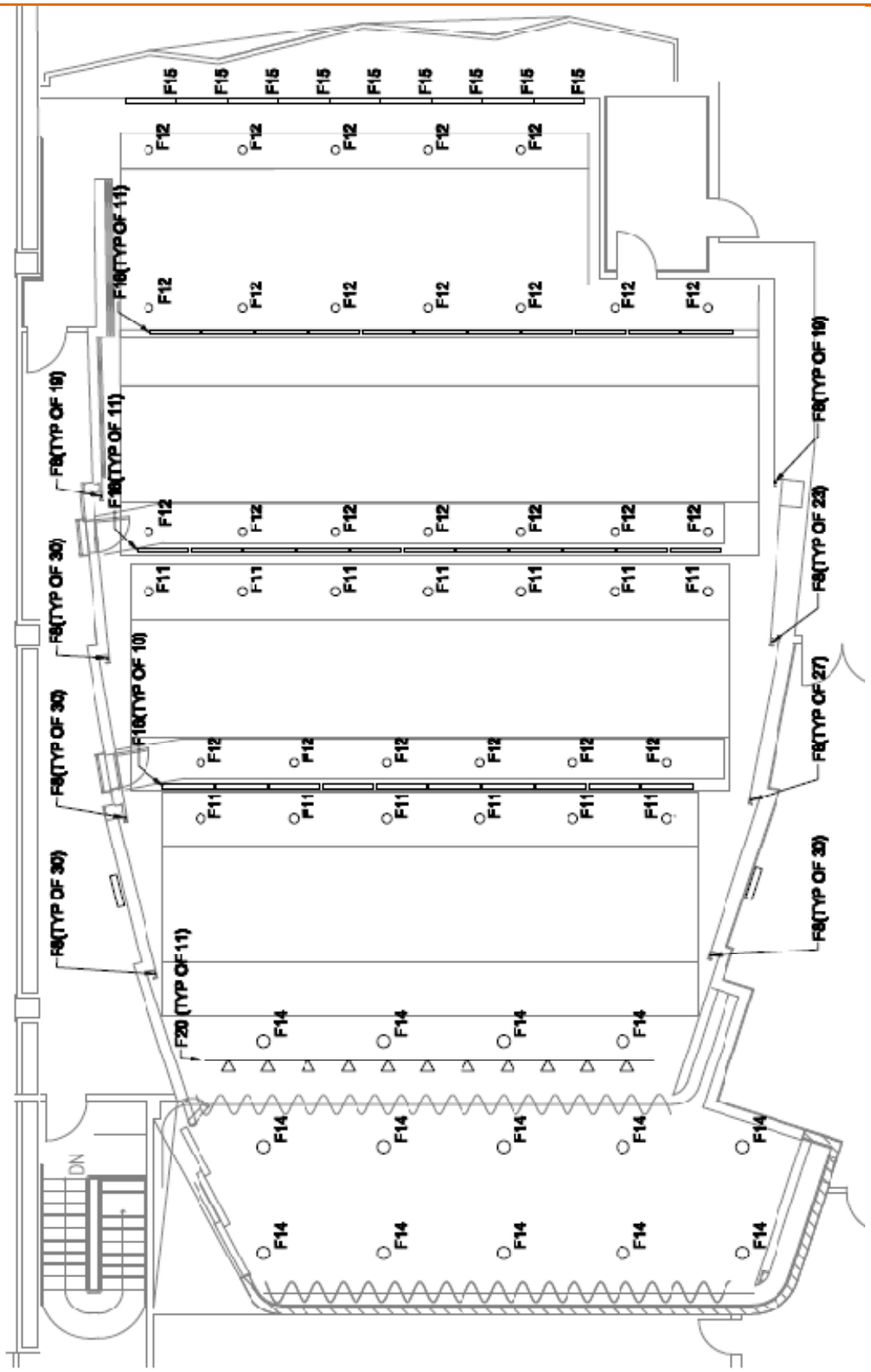
The Feinburg theater house lighting design offers integrated, energy efficient, and flexible system. Different targeted illuminance levels can be achieved from different presets. The uniformity ratio is an issue in some areas including the balcony seating level due to the limitations of mounting heights and locations. The total energy consumption is 9,968 watts (2.26 watts/Sq.ft.) which is 1,472 watts below the maximum code requirement.

## Lighting Schedule

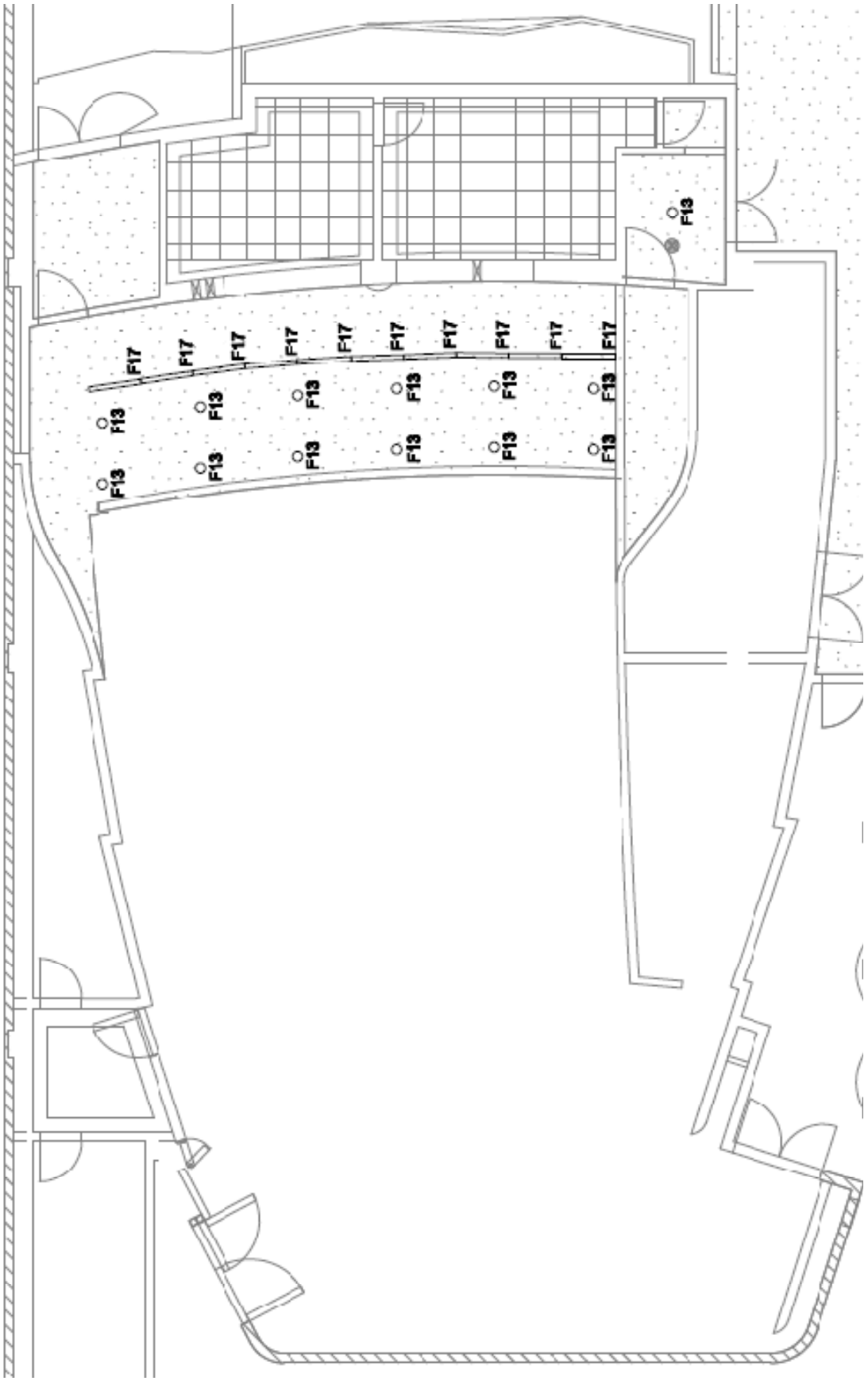
Refer to Appendix A for a complete schedule.

| Type | Manufacturer | CatalogNumber | Description | Electrical | Wattage |
|---|---|---|---|---|---|
| F8 | Color Kinetics | 101-000066-00 | Compact linear fixture that generates saturated color and dynamic effects in alcoves, accent areas, and other interior spaces. The fixture is available with a wide (120º x 120º) or medium (100º x 40º) beam. An integrated rotating mount and optional mounting track provide precise positioning, and end-to-end connections ensure a simple installation. Integral mounting bracket with 180º rotation. Optibin® technology ensures uniform light quality. 24 VDC input power. End-to-end connectors. Two standard lengths: 6 in (152 mm) and 12 in (305 mm). Chromasic® technology provides precise and cost-efficient digital control | Provide Color Kinetics 480 Watts Power and Data Supply: Product# sPDS-480ca 24V See Drawing for Quantity | 3 watts/linear foot |
| F11 | Kurt Versen | P909 | 8" recessed compact fluorescent downlight with 2-CFTR42W lamps. Optics: anodized aluminum reflector. | Integral electronic ballast | 81 |
| F12 | Kurt Versen | C7311 PAR-38 HAL | 7" recessed halogen accent light with 1-PAR38 250W max lamp. Optics: anodized aluminum reflector. | n/a | 100 |
| F13 | Kurt Versen | C7310 PAR-30 | 6" recessed halogen accent light with 1-PAR30S 75W max lamp. Optics: anodized aluminum reflector. | n/a | 75 |
| F14 | Lightolier | CS8242HUCL 42W | 9" surface-mounted compact fluorescent downlight with 2-CFTR42W lamps. Optics: anodized aluminum parabolic reflector. | Integral electronic 120V/277V ballast | |
| F15 | Focal Point | FMEW-PA-1T5-1C-120-S-WM-20 | Wall-mounted fluorescent up/downlight with 1-F28T5 (48in) lamp (in cross-section). Optics: acrylic diffuser , anodized aluminum reflector. | Lutron Dimming Ballast 10% Dimming Eco-10 2-lamp ballast | 66 |
| F16 | Elliptipar | F305-T354-S-00-T-00-0 | Specular extruded aluminum reflector. Stainless steel lampholder/ support brackets. Aluminum sidearm with mounting tab. Extruded aluminum ballast/wireway channel cover. Conduit entry (one each end, conduit and connector by others). Extruded aluminum ballast/ wireway compartment | Lutron Dimming Ballast 10% Dimming Eco-10 2-lamp ballast | 132 |
| F17 | Elliptipar | F305-T328-S-00-T-00-0 | Specular extruded aluminum reflector. Stainless steel lampholder/support brackets. Aluminum sidearm with mounting tab. Extruded aluminum ballast/wireway channel cover. Conduit entry (one each end, conduit and connector by others). Extruded aluminum ballast/ wireway compartment | Lutron Dimming Ballast 10% Dimming Eco-10 2-lamp ballast | 66 |
| F18 | Winona Lighting | LED-STEP03-3-L-001/HO-DM24V-BAL-X-STD | Recessed LED step light. | Integral transformer | 6 |
| F19 | Kurt Versen | P932 | 7" recessed compact fluorescent downlight with 1-CFTR42W lamp. Optics: anodized aluminum ellipsoidal reflector. | Lutron Dimming Ballast 5% Dimming Compact SE | 47 |
| F20 | Lighting Services Inc | 200-3G-CC-WL-FD-B 38HAL | 6" track-mounted halogen accent light with 1-PAR38 200W max lamp. Optics: glare shield. | n/a | 100 |

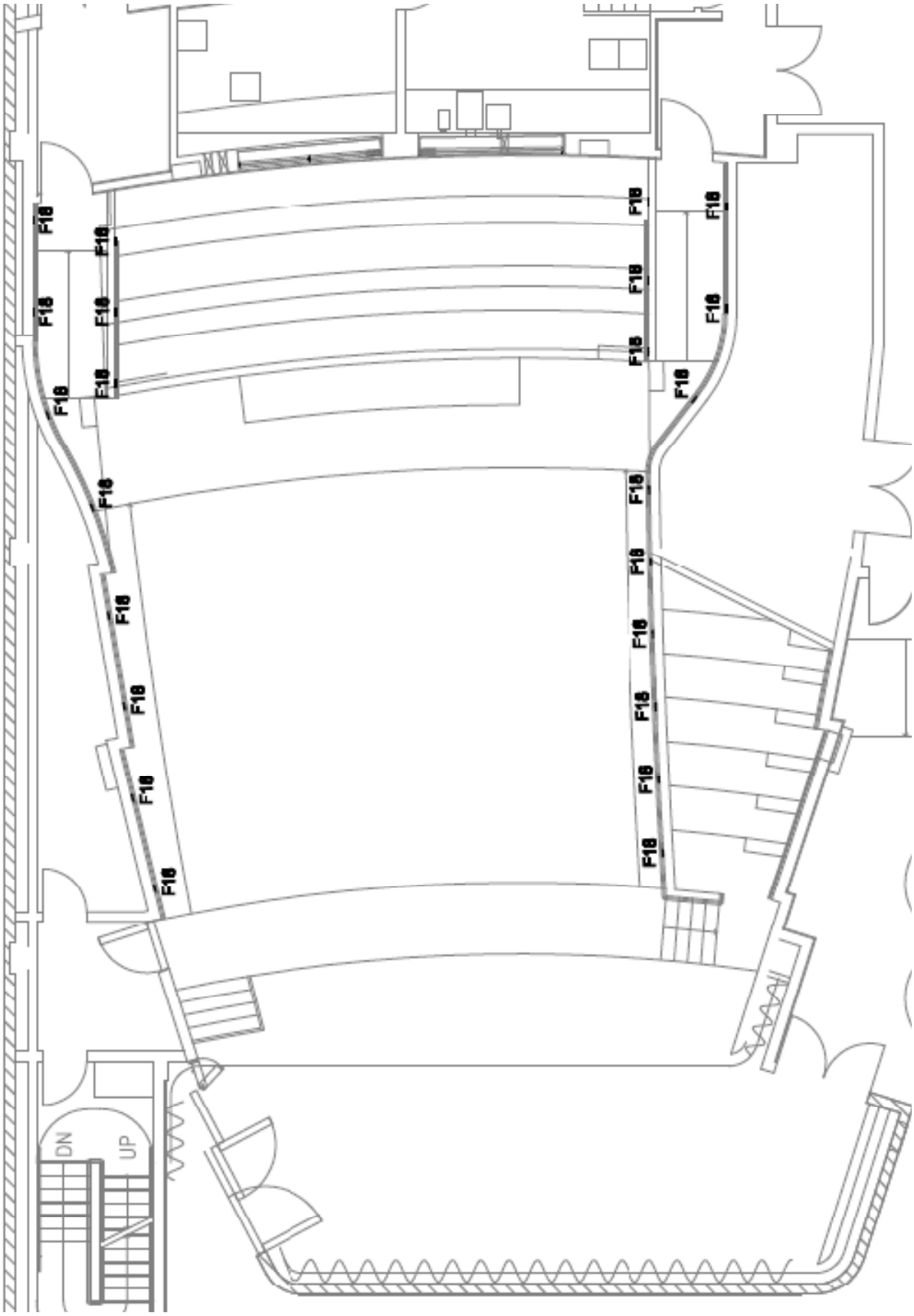
## Lighting Plans




Lighting Reflected Ceiling Plan

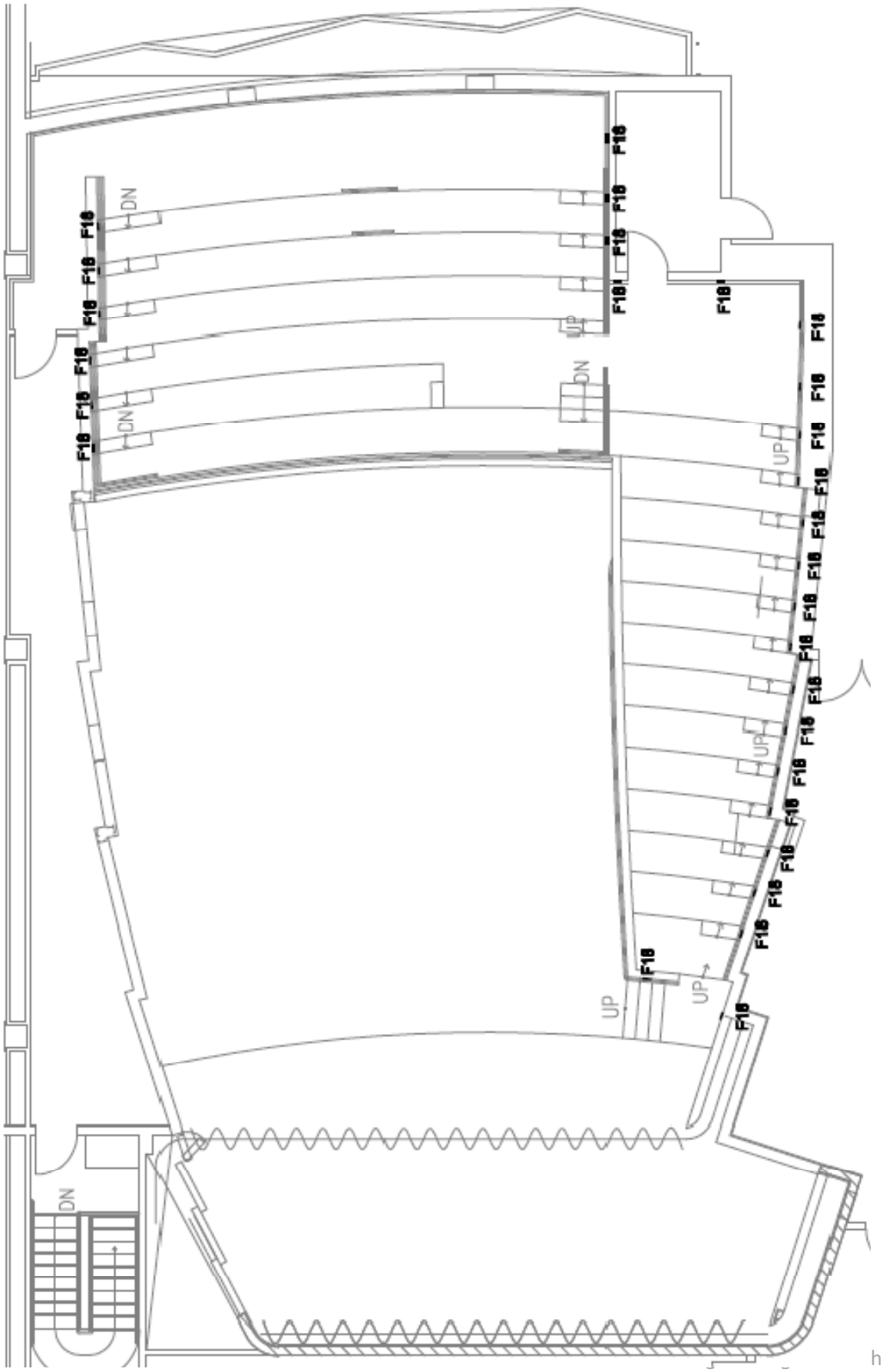



Lighting Reflected Ceiling Plan – Under Balcony




Lighting Floor Plan – Main Level

Lighting Floor Plan – Balcony Level




hesis
Kanis Glaewketgarn

## Presets

### Pre-show Mode

Pre-show mode is used before the lectures, performances, or movies. Target illuminance on the horizontal workplane (ground) is 10-20 FC (IESNA recommendation – Ch.15-8). This scene is achieved by a combination of different lighting systems including top lighting (downlight), side lighting (vertical coves), and uplighting (ceiling coves). Pre-show mode does not only provide adequate illuminance level for the occupants to navigate to their seats and socialize with one another before a lecture or performance, it also reinforces and defines the architecture of the space. The chart below shows dimming level or light output of each fixture type to create achieve target illuminance level and desired lighting effects.

| Type | F11 | F12 | F13 | F14 | F15 | F16 | F17 | F18 | F19 | F20 |
|---|---|---|---|---|---|---|---|---|---|---|
| Light Level | off | 100% | 50% | 50% | 50% | 50% | 50% | 100% | 75% | 60% |

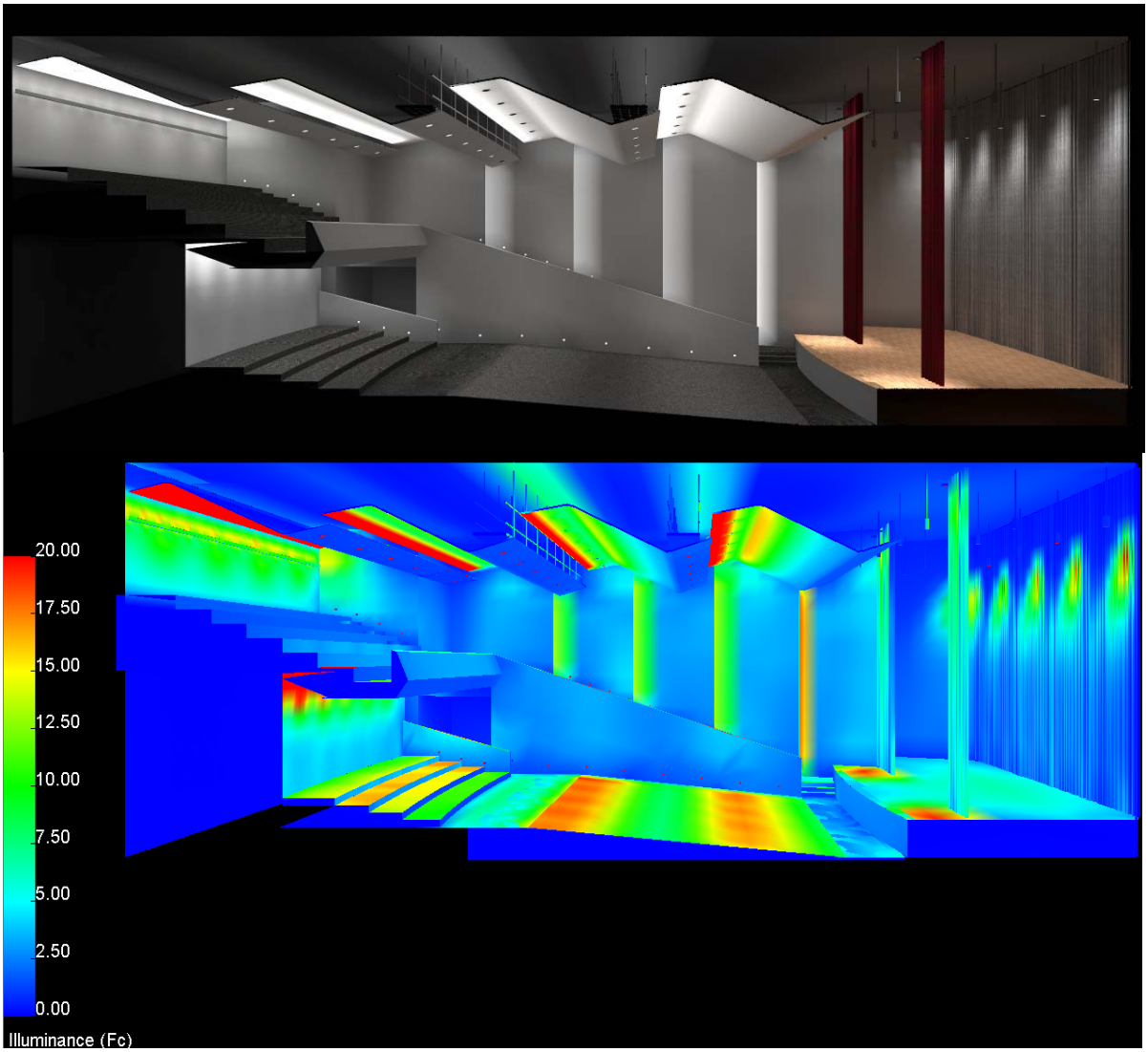



FIGURE 24: SECTION – PRE-SHOW MODE

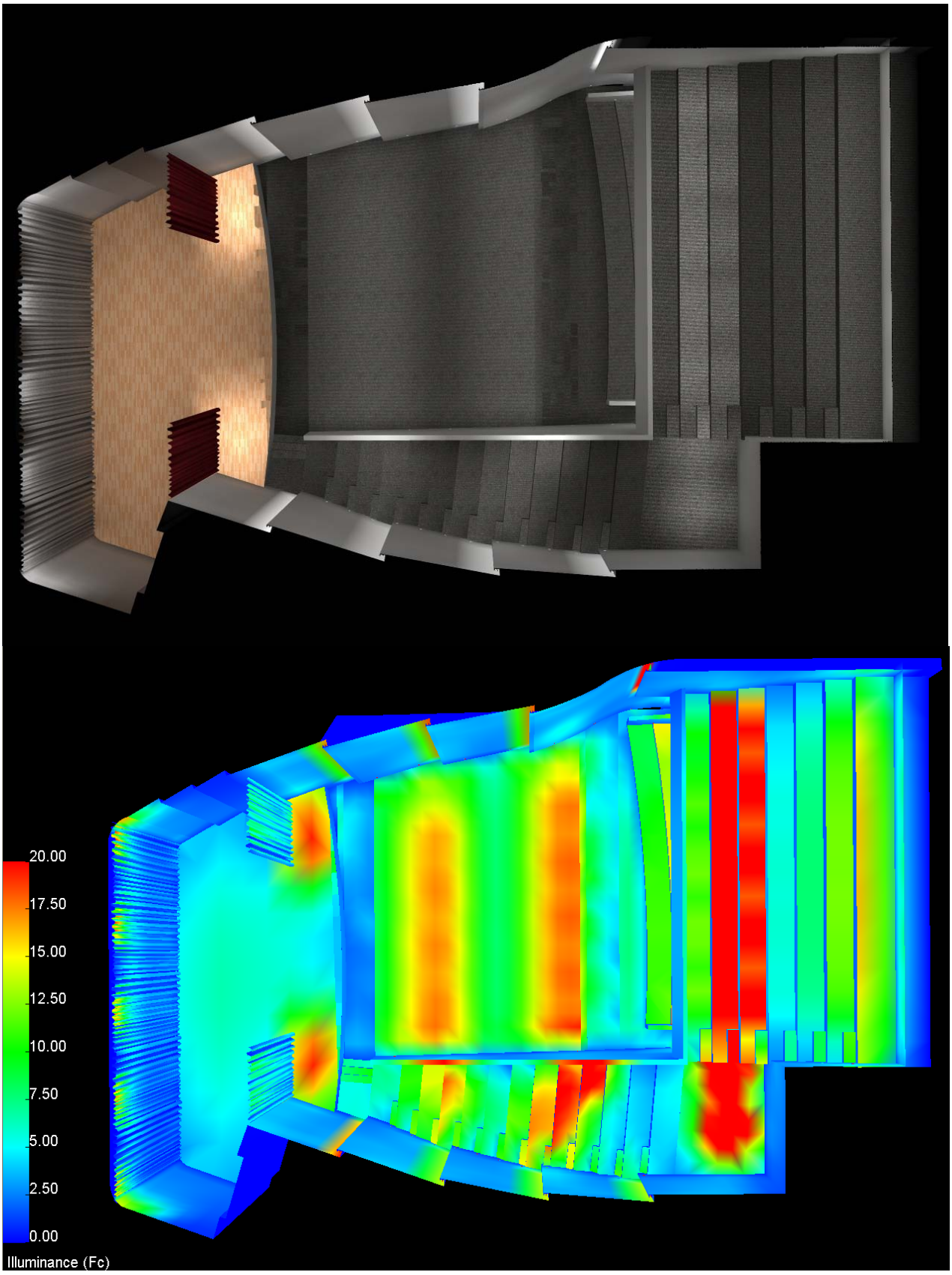



FIGURE 25: FLOORPLAN – PRE-SHOW MODE

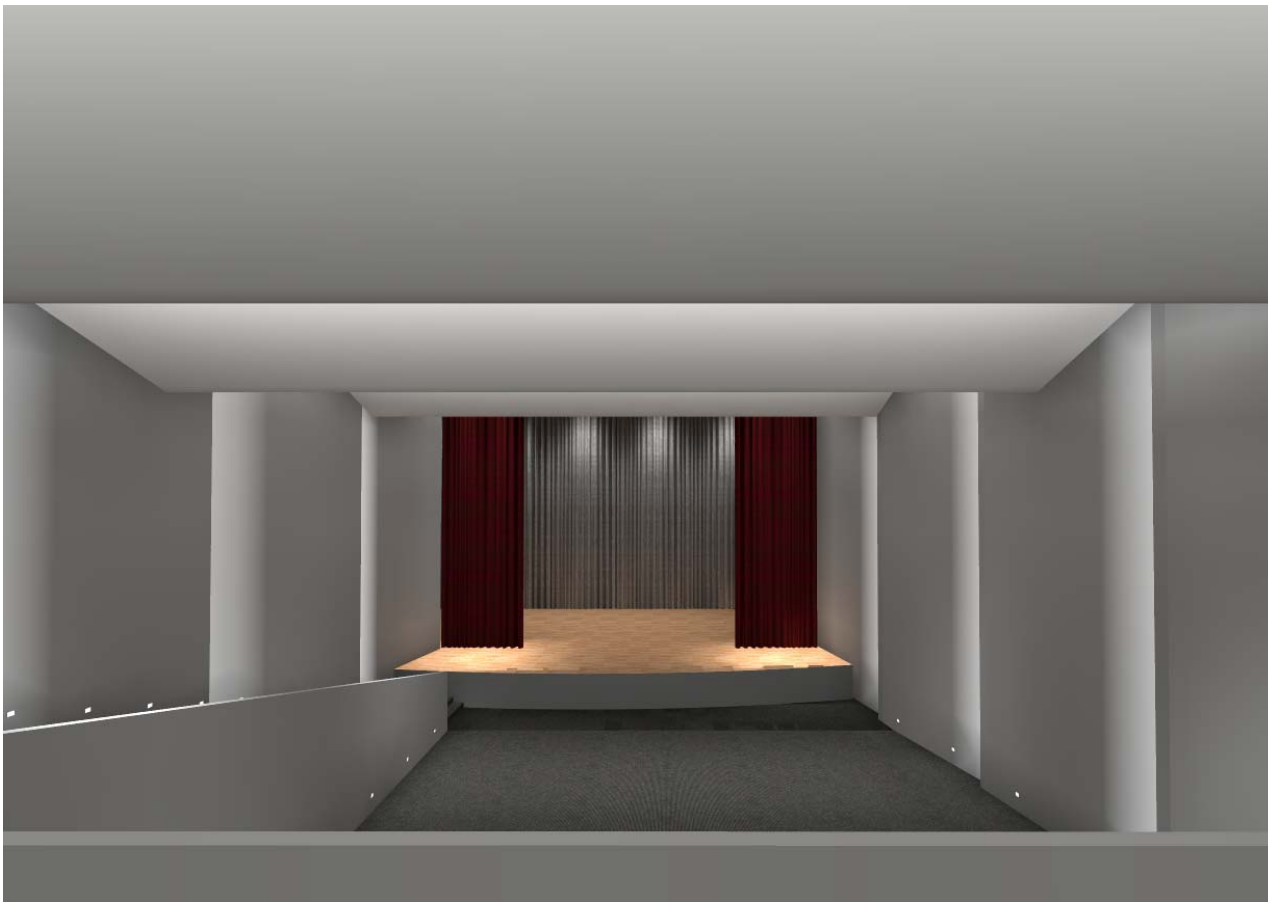


FIGURE 26: PERSPECTIVE: FROM BALCONY LEVEL

## Calculation Summary: Pre-show Mode

| Calculation Summary | | | | | | | |
|---|---|---|---|---|---|---|---|
| Label | CalcType | Units | Avg | Max | Min | Avg/Min | Max/Min |
| Balcony Floor_2_Balcony Floor_2 | Illuminance | Fc | 22.98 | 37.6 | 7.1 | 3.24 | 5.30 |
| Balcony Floor_1_Balcony Floor_1 | Illuminance | Fc | 28.65 | 44.4 | 0.0 | N.A. | N.A. |
| Balcony Floor_3_Balcony Floor_3 | Illuminance | Fc | 5.73 | 9.1 | 1.7 | 3.37 | 5.35 |
| Balcony Floor_4_Balcony Floor_4 | Illuminance | Fc | 8.39 | 9.8 | 2.1 | 4.00 | 4.67 |
| Balcony Floor_5_Balcony Floor_5 | Illuminance | Fc | 12.04 | 14.1 | 3.2 | 3.76 | 4.41 |
| Under Balcony 1_Under Balcony 1 | Illuminance | Fc | 10.38 | 11.3 | 8.7 | 1.19 | 1.30 |
| Z-Floor_4_Under Balcony 2 | Illuminance | Fc | 14.66 | 16.6 | 13.1 | 1.12 | 1.27 |
| Z-Floor_2_Under Balcony 3 | Illuminance | Fc | 16.23 | 17.4 | 15.4 | 1.05 | 1.13 |
| Z-Floor_3_Under Balcony 4 | Illuminance | Fc | 12.46 | 14.7 | 10.4 | 1.20 | 1.41 |
| Stage Floor | Illuminance | Fc | 7.15 | 34.1 | 2.7 | 2.65 | 12.63 |
| Z-Floor_1_Main Seating Area Floo | Illuminance | Fc | 12.80 | 19.0 | 6.4 | 2.00 | 2.97 |

FIGURE 27: CALCULATION SUMMARY: PRE-SHOW MODE

### Show-time Mode

Show-time mode is used during the shows or performances. Only step lights and vertical cove lights are on in this mode. The two systems provide adequate illuminance level for navigation and path of emergency egress. The vertical coves can be turned off if dark space is desired. The chart below shows dimming level or light output of each fixture type to create achieve target illuminance level and desired lighting effects.

| Type | F8 | F11 | F12 | F13 | F14 | F15 | F16 | F17 | F18 | F19 | F20 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Light Level | 10% | off | off | off | off | off | off | off | 100% | off | vary |

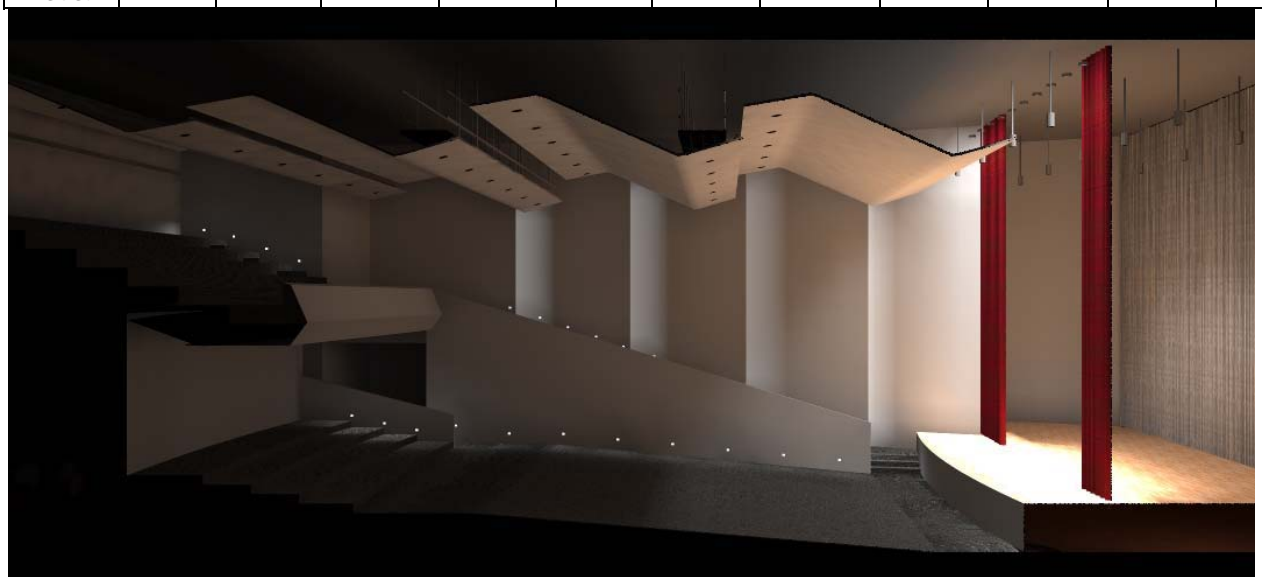


FIGURE 28: SECTION – SHOW-TIME MODE

FIGURE 29: PERSPECTIVE FROM BALCONY LEVEL – SHOW-TIME MODE

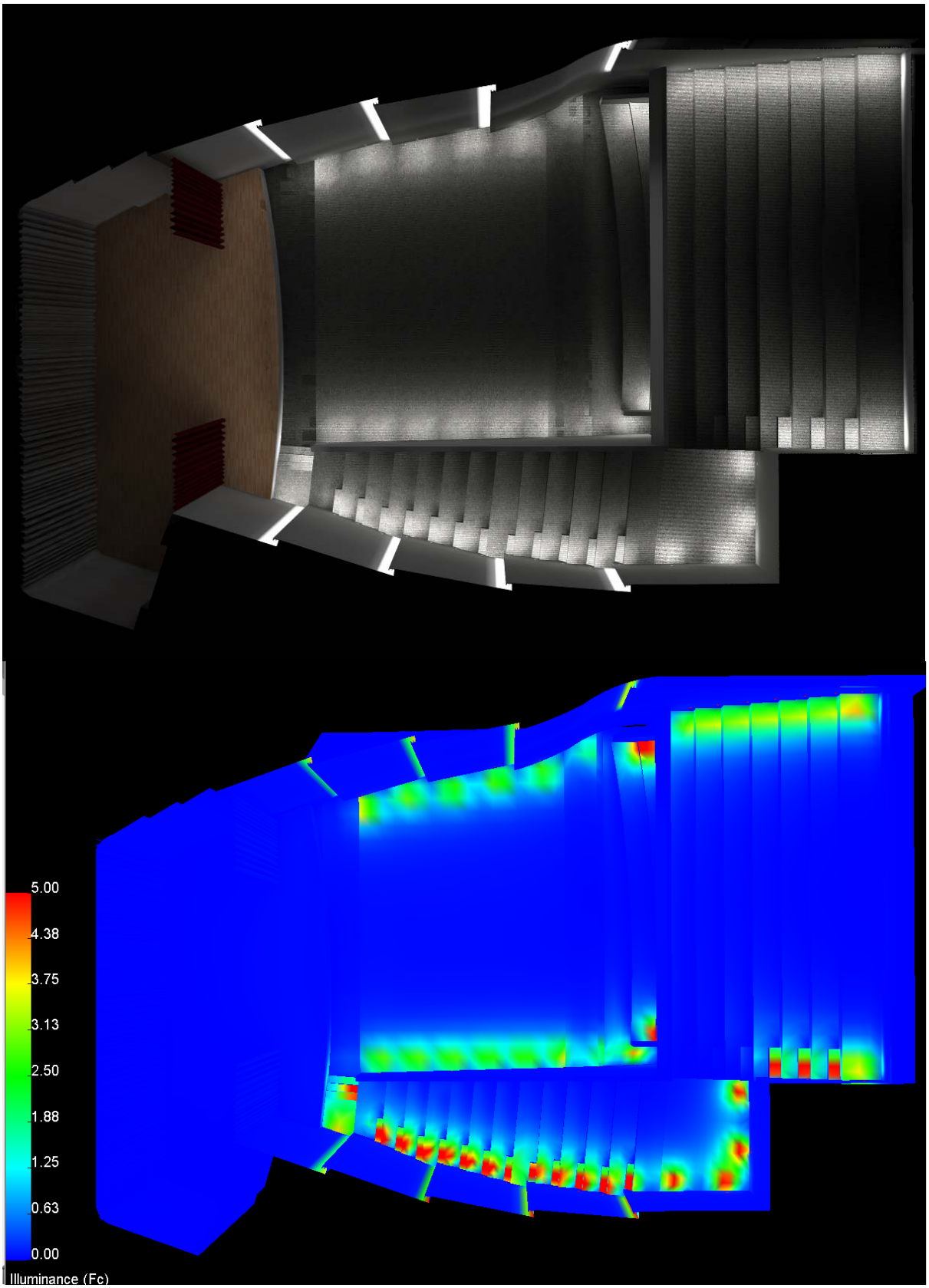



FIGURE 30: FLOOR PLAN: SHOW-TIME MODE

### Writing/Reading/Lecture Mode

This lighting scene utilizes every lighting system in the space at full output to provide adequate illuminace level for writing, reading, lecturing and cleaning up (30 fc). The chart below shows dimming level or light output of each fixture type to create achieve target illuminance level and desired lighting effects.

| Type | F8 | F11 | F12 | F13 | F14 | F15 | F16 | F17 | F18 | F19 | F20 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Light Level | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |

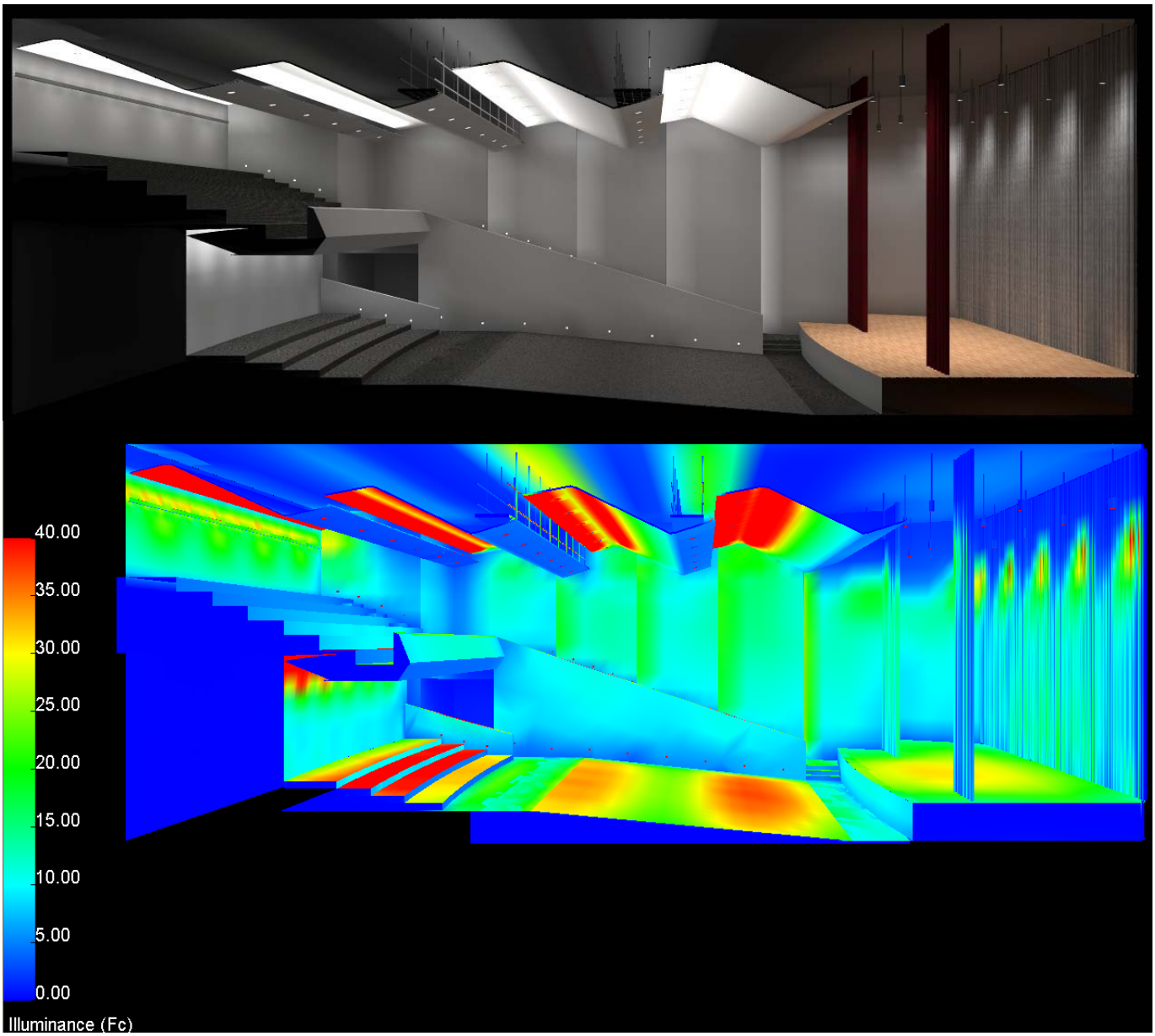



FIGURE 31: SECTION – ALL ON MODE

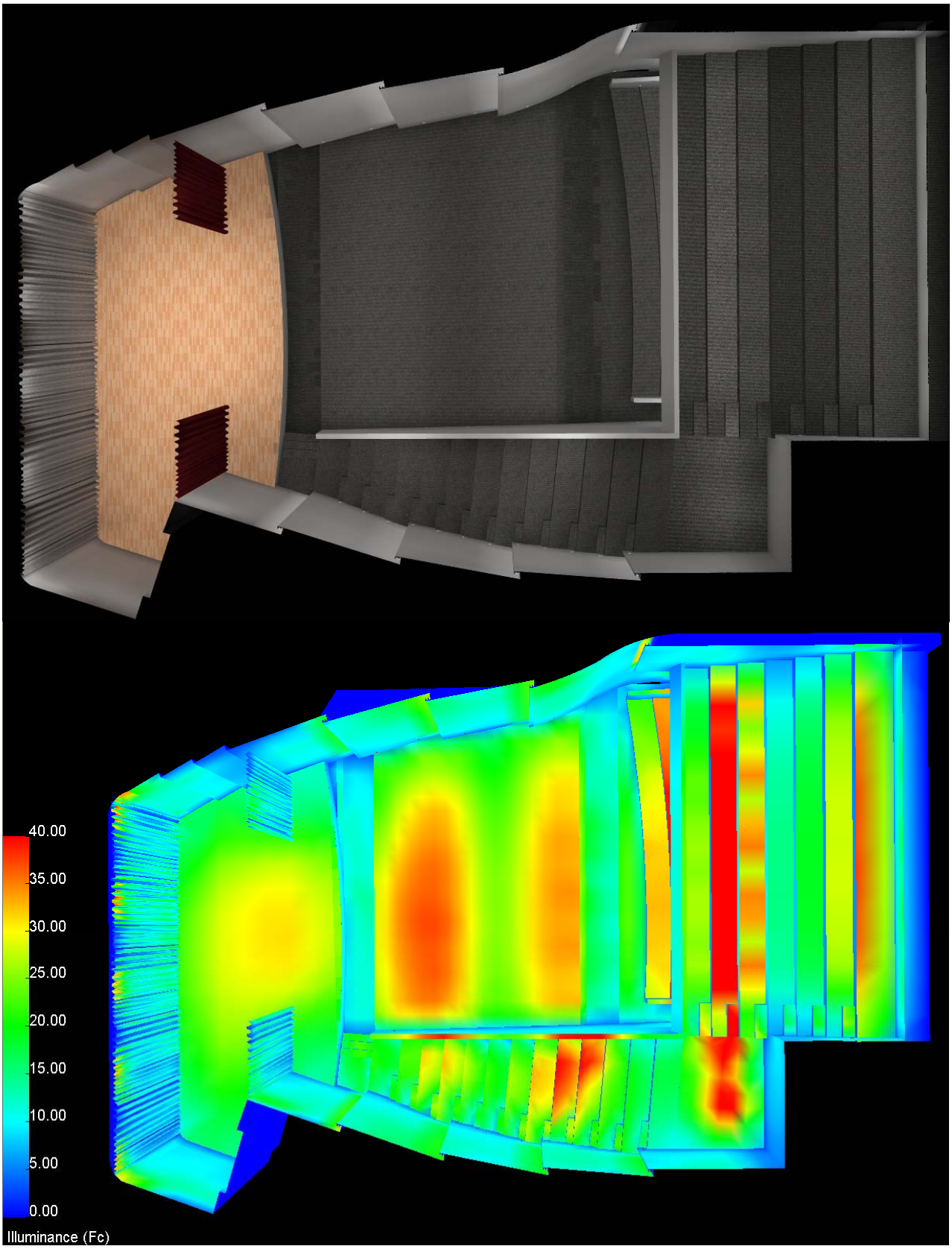



FIGURE 32: FLOOR PLAN – ALL ON MODE

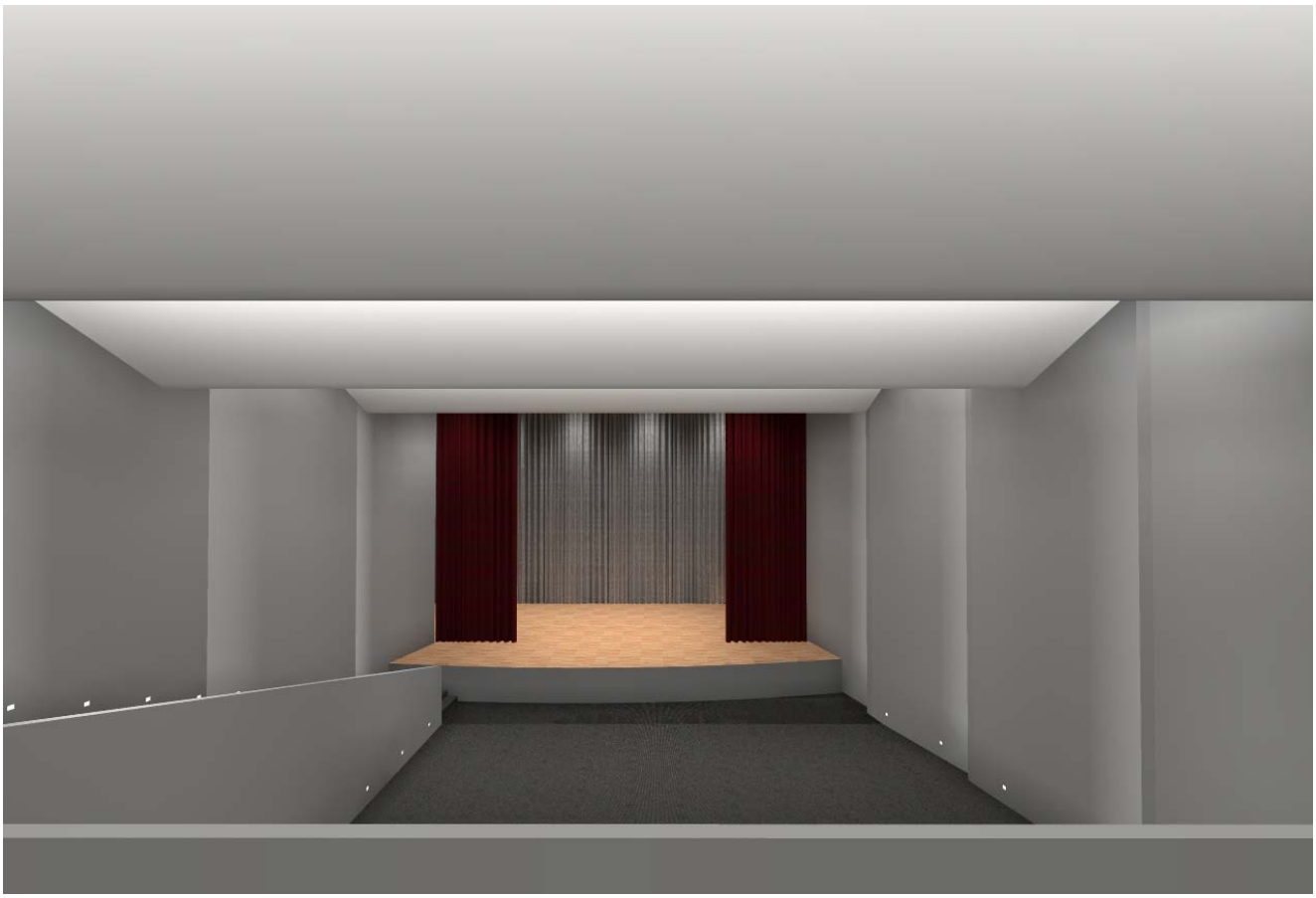


FIGURE 33: PERSPECTIVE FROM THE BALCONY LEVEL – ALL ON MODE

## Calculation Summary: All on Mode

| Calculation Summary | | | | | | | |
|---|---|---|---|---|---|---|---|
| Label | CalcType | Units | Avg | Max | Min | Avg/Min | Max/Min |
| Balcony Floor_2_Balcony Floor_2 | Illuminance | Fc | 34.14 | 50.5 | 13.1 | 2.61 | 3.85 |
| Balcony Floor_1_Balcony Floor_1 | Illuminance | Fc | 40.02 | 58.8 | 0.0 | N.A. | N.A. |
| Balcony Floor_3_Balcony Floor_3 | Illuminance | Fc | 14.54 | 21.0 | 4.5 | 3.23 | 4.67 |
| Balcony Floor_4_Balcony Floor_4 | Illuminance | Fc | 19.76 | 23.2 | 4.8 | 4.12 | 4.83 |
| Balcony Floor_5_Balcony Floor_5 | Illuminance | Fc | 27.51 | 32.3 | 6.7 | 4.11 | 4.82 |
| Under Balcony 1_Under Balcony 1 | Illuminance | Fc | 29.63 | 32.8 | 22.7 | 1.31 | 1.44 |
| Z-Floor_4_Under Balcony 2 | Illuminance | Fc | 38.92 | 41.2 | 34.0 | 1.14 | 1.21 |
| Z-Floor_2_Under Balcony 3 | Illuminance | Fc | 41.43 | 43.1 | 39.7 | 1.04 | 1.09 |
| Z-Floor_3_Under Balcony 4 | Illuminance | Fc | 30.44 | 35.8 | 24.5 | 1.24 | 1.46 |
| Stage Floor | Illuminance | Fc | 25.52 | 35.2 | 11.6 | 2.20 | 3.03 |
| Z-Floor_1_Main Seating Area Floo | Illuminance | Fc | 28.73 | 37.3 | 13.6 | 2.11 | 2.74 |

FIGURE 34: CALCULATION SUMMARY: ALL ON MODE

## Light Loss Factor Calculation

### TYPE F11, 14, 19

Compact Fluorescent Recessed Downlight

- Lamp Lumen Depreciation – CF42DT/E/IN/830/ECO
  - LLD = maintained / initial = 2751 / 3200 = **.85**
- Luminaire Dirt Depreciation
  - Maintain category – IV
  - Degree of dirt condition – Clean
  - Cleaning cycle – 24 months
  - LDD = **.89**
- Room Surface Dirt Depreciation
  - Room cavity ratio = 5x22.5x(53.5+46) / (53.5X46) = 4.55
  - Degree of dirt condition – Clean
  - Cleaning cycle – 24 months
  - Expected dirt depreciation = 17%
  - Luminaire distribution type = Direct
  - RSDD = .**95**
- Ballast Factor = **1.0**

**LLF = .85 X .89 X .95 X 1.0 = .72**

### TYPE F12, 20

PAR38 Recessed Downlight

- Lamp Lumen Depreciation – 100PAR/CAPIR/FL40
  - LLD = maintained / initial = 1800 / 2070 = **.87**
- Luminaire Dirt Depreciation
  - Maintain category – IV
  - Degree of dirt condition – Clean
  - Cleaning cycle – 24 months
  - LDD = **.89**
- Room Surface Dirt Depreciation
  - Room cavity ratio = 5x22.5x(53.5+46) / (53.5X46) = 4.55
  - Degree of dirt condition – Clean
  - Cleaning cycle – 24 months
  - Expected dirt depreciation = 17%
  - Luminaire distribution type = Direct
  - RSDD = .**95**

**LLF = .87 X .89 X .95 = .74**

**TYPE F13**

PAR30 Recessed Downlight

- Lamp Lumen Depreciation – 75PAR30/HAL/FL40
  - LLD = maintained / initial = 950 / 1130 = **.84**
- Luminaire Dirt Depreciation
  - Maintain category – IV
  - Degree of dirt condition – Clean
  - Cleaning cycle – 24 months
  - LDD = **.89**
- Room Surface Dirt Depreciation
  - Room cavity ratio = 5x22.5x(53.5+46) / (53.5X46) = 4.55
  - Degree of dirt condition – Clean
  - Cleaning cycle – 24 months
  - Expected dirt depreciation = 17%
  - Luminaire distribution type = Direct
  - RSDD = **.95**

**LLF = .84 X .89 X .95 = .71**

**TYPE F15, 17**

Linear Fluorescent Wall Mounted

- Lamp Lumen Depreciation – FP28/830/ECO
  - LLD = maintained / initial = 2697 / 2900 = **.93**
- Luminaire Dirt Depreciation
  - Maintain category – II
  - Degree of dirt condition – Clean
  - Cleaning cycle – 24 months
  - LDD = **.89**
- Room Surface Dirt Depreciation
  - Room cavity ratio = 5x22.5x(53.5+46) / (53.5X46) = 4.55
  - Degree of dirt condition – Clean
  - Cleaning cycle – 24 months
  - Expected dirt depreciation = 17%
  - Luminaire distribution type = Direct
  - RSDD = **.95**
- Ballast Factor = **1.0**

**LLF = .93 X .89 X .95 X 1.0 = .79**

**TYPE F16**

Linear Fluorescent Cove Fixture

- Lamp Lumen Depreciation – FP54/830/HO/ECO
  - LLD = maintained / initial = 4650 / 5000 = **.93**
- Luminaire Dirt Depreciation
  - Maintain category – II
  - Degree of dirt condition – Clean
  - Cleaning cycle – 24 months
  - LDD = **.89**
- Room Surface Dirt Depreciation
  - Room cavity ratio = 5x22.5x(53.5+46) / (53.5X46) = 4.55
  - Degree of dirt condition – Clean
  - Cleaning cycle – 24 months
  - Expected dirt depreciation = 17%
  - Luminaire distribution type = Direct
  - RSDD = .**95**
- Ballast Factor = **1.0**

**LLF = .93 X .89 X .95 X 1.0 = .79**

**Energy Calculation:** ASHRAE/Standard 90.1 2004 : Space by space method

The total energy consumption is 9,968 watts (2.26 watts/Sq.ft.) which is 1,472 watts below the maximum code requirement.

| Room Name | Space Type | Area ($ft.^2$) | Fixt. Type | Fixture Description | Watts / Fixture | Fixture Qty | Total Watts | Total Watts / Room | Base $W/ft.^2$ | Total Watts / Room |
|---|---|---|---|---|---|---|---|---|---|---|
| Feinberg Theater | Audience / Seating For Performing Arts Theater | 4,400 | F11 | Compact Fluorescent Downlight | 81 | 10 | 810 | 9968 | 2.6 | 11440 |
| | | | F12 | PAR38 Recessed Downlight | 100 | 20 | 2000 | | | |
| | | | F16 | Linear Fluorescent Cove | 132 | 16 | 2112 | | | |
| | | | F14 | Compact Fluorescent Cylinder | 81 | 14 | 1134 | | | |
| | | | F8 | Linear LED (accent) | 3 | 238 | 714 | | | |
| | | | F13 | PAR30 Recessed Downlight | 75 | 14 | 1050 | | | |
| | | | F15 | Linear Fluorescent Wall Mounted | 66 | 5 | 330 | | | |
| | | | F17 | Linear Fluorescent Cove | 66 | 5 | 330 | | | |
| | | | F18 | LED Step Light | 3 | 51 | 153 | | | |
| | | | F19 | Compact Fluorescent Downlight | 47 | 5 | 235 | | | |
| | | | F20 | Halogen Track Heads | 100 | 11 | 1100 | | | |

## Electrical Design: Feinburg Theater

An actual panelboard schedule for the theater is not available from the engineer of the project, Environmental Systems Design. However, Schuler Shook Theater Consultant issued schedule with dimming assignments. According to the electrical one-line diagram E0.12, panel 2S-1 feeds power to all the lights in the theater.

### House Lights

| LOCATION | Fixture Quantity | Type | Wattage | Total | Works 20A | House 20A | Orchestra 20A | Platform 20A | DIMMER From: | To: | Circuit Name |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Main Floor Entry Aisles | 6 | SA | 100W | 600W | | 1 | | | 127 | 127 | HL-2 |
| Not Used | | | | | | 1 | | | 128 | 128 | HL-4 |
| Balcony Downlights - Row 4 - Center | 2 | SC | 575W | 1150W | | 1 | | | 129 | 129 | HL-8 |
| Balcony Downlights - Row 4 - Sides | 2 | SC | 575W | 1150W | | 1 | | | 130 | 130 | HL-9 |
| Balcony Downlights - Row 4 - Sides | 2 | SC | 575W | 1150W | | 1 | | | 131 | 131 | HL-11 |
| Balcony Downlights - Row 2 - Center | 3 | SC | 575W | 1725W | | 1 | | | 132 | 132 | HL-10 |
| Balcony Downlights - Row 2 - Sides | 2 | SC | 575W | 1150W | | 1 | | | 133 | 133 | HL-13 |
| Balcony Downlights - Row 1 - Center | 3 | SC | 575W | 1725W | | 1 | | | 134 | 134 | HL-14 |
| Balcony Downlights - Row 1 - Sides | 2 | SC | 575W | 1150W | | 1 | | | 135 | 135 | HL-15 |
| FOH Catwalk #2 - Northeast | 2 | SC | 575W | 1150W | | 1 | | | 136 | 136 | HL-16 |
| FOH Catwalk #2 - East Center | 3 | SC | 575W | 1725W | | 1 | | | 137 | 137 | HL-17 |
| FOH Catwalk #2 - Northwest | 2 | SC-1 | 575W | 1150W | | 1 | | | 138 | 138 | HL-18 |
| FOH Catwalk #2 - West Center | 3 | SC-1 | 575W | 1725W | | 1 | | | 139 | 139 | HL-19 |
| FOH Catwalk #1 - Northeast | 2 | SC-1 | 575W | 1150W | | 1 | | | 140 | 140 | HL-20 |
| FOH Catwalk #1 - East Center | 3 | SC-1 | 575W | 1725W | | 1 | | | 141 | 141 | HL-21 |
| FOH Catwalk #1 - West Center | 3 | SC-1 | 575W | 1725W | | 1 | | | 142 | 142 | HL-22 |
| Stage Edge Pipe North | 2 | SC-2 | 575W | 1150W | | 1 | | | 143 | 143 | HL-23 |
| Stage Edge Pipe South | 2 | SC-2 | 575W | 1150W | | 1 | | | 144 | 144 | HL-24 |
| Balcony Downlights - Row 2 - South | 2 | SC | 575W | 1150W | | 1 | | | 145 | 145 | HL-25 |
| Balcony Downlights - Row 1 - South | 2 | SC | 575W | 1150W | | 1 | | | 146 | 146 | HL-26 |
| FOH Catwalk #2 - Southeast | 2 | SC | 575W | 1150W | | 1 | | | 147 | 147 | HL-27 |
| FOH Catwalk #2 - Southwest | 2 | SC | 575W | 1150W | | 1 | | | 148 | 148 | HL-28 |
| FOH Catwalk #1 - Southeast | 2 | SC | 575W | 1150W | | 1 | | | 149 | 149 | HL-29 |
| FOH Catwalk #1 - Southwest | 2 | SC | 575W | 1150W | | 1 | | | 150 | 150 | HL-30 |

### Orchestra Lights

| LOCATION | Fixture Quantity | Type | Wattage | Total | Works 20A | House 20A | Orchestra 20A | Platform 20A | DIMMER From: | To: | Circuit Name |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1st Electric - North | 2 | SC-2 | 575W | 1150W | | | 1 | | 151 | 151 | OL-1 |
| 1st Electric - Center | 3 | SC-2 | 575W | 1725W | | | 1 | | 152 | 152 | OL-2 |
| 1st Electric - South | 3 | SC-2 | 575W | 1725W | | | 1 | | 153 | 153 | OL-3 |
| 2nd Electric - North | 2 | SC-2 | 575W | 1150W | | | 1 | | 154 | 154 | OL-4 |
| 2nd Electric - Center | 2 | SC-2 | 575W | 1150W | | | 1 | | 155 | 155 | OL-5 |
| 2nd Electric - South | 3 | SC-2 | 575W | 1725W | | | 1 | | 156 | 156 | OL-6 |
| 3rd Electric - North | 3 | SC-2 | 575W | 1725W | | | 1 | | 157 | 157 | OL-7 |
| 3rd Electric - Center | 2 | SC-2 | 575W | 1150W | | | 1 | | 158 | 158 | OL-8 |
| 3rd Electric - South | 3 | SC-2 | 575W | 1725W | | | 1 | | 159 | 159 | OL-9 |
| 1st Catwalk | 3 | SL | 575W | 1725W | | | 1 | | 160 | 160 | OL-10 |

## Production Lights

| LOCATION | Fixture Quantity | Type | Wattage | Total | Works 20A | House 20A | Orchestra 20A | Platform 20A | DIMMER From: | DIMMER To: | Circuit Name |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1st Catwalk North | 2 | SL | 575W | 1150W | | | | 1 | 161 | 161 | PL-1 |
| 1st Catwalk Center | 2 | SL | 575W | 1150W | | | | 1 | 162 | 162 | PL-2 |
| 1st Catwalk South | 2 | SL | 575W | 1150W | | | | 1 | 163 | 163 | PL-3 |
| 2nd Catwalk North | 2 | SL-2 | 575W | 1150W | | | | 1 | 164 | 164 | PL-4 |
| 2nd Catwalk North | 1 | SL-2 | 575W | 575W | | | | 1 | 165 | 165 | PL-5 |
| 2nd Catwalk Center | 2 | SL-2 | 575W | 1150W | | | | 1 | 166 | 166 | PL-6 |
| 2nd Catwalk Center | 1 | SL-2 | 575W | 575W | | | | 1 | 167 | 167 | PL-7 |
| 2nd Catwalk South | 2 | SL-2 | 575W | 1150W | | | | 1 | 168 | 168 | PL-8 |
| 2nd Catwalk South | 1 | SL-2 | 575W | 575W | | | | 1 | 169 | 169 | PL-9 |
| 1st Electric South | 1 | SL-1 | 575W | 575W | | | | 1 | 170 | 170 | PL-10 |
| 1st Electric North | 1 | SL-1 | 575W | 575W | | | | 1 | 171 | 171 | PL-11 |
| 2nd Electric South | 1 | SL-1 | 575W | 575W | | | | 1 | 172 | 172 | PL-12 |
| 2nd Electric North | 1 | SL-1 | 575W | 575W | | | | 1 | 173 | 173 | PL-13 |

**HOUSELIGHTS**

| Location | Fixture Quantity | Type | Wattage | Total | Works 20A | House 20A | Orchestra 20A | Platform 20A | DIMMER From | To | Circuit Name |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Main Floor (CFL) | 13 | F11 | 81 | 1053 | | 1 | | | 1 | 1 | HL-1 |
| Main Floor (Halogen) | 13 | F12 | 100 | 1300 | | 1 | | | 2 | 2 | HL-2 |
| Main Floor (Halogen) | 12 | F13 | 100 | 1200 | | 1 | | | 3 | 3 | HL-3 |
| Main Floor (Fluorescent) | 21 | F16 | 66 | 1386 | | 1 | | | 4 | 4 | HL-4 |
| Balcony (Fluorescent) | 10 | F15 | 66 | 660 | | 1 | | | 5 | 5 | HL-5 |
| Underbalcony Downlight | 13 | F13 | 75 | 975 | | 1 | | | 6 | 6 | HL-6 |
| Underbalcony Cove | 10 | F17 | 66 | 660 | | 1 | | | 7 | 7 | HL-7 |
| Vertical Coves (Power Supply) | 2 | F8 | 480 | 960 | | 1 | | | 8 | 8 | HL-8 |
| Step lights | 51 | F18 | 6 | 306 | | 1 | | | 9 | 9 | HL-9 |

**PLATFORM LIGHTS**

| Location | Fixture Quantity | Type | Wattage | Total | Works 20A | House 20A | Orchestra 20A | Platform 20A | DIMMER From | To | Circuit Name |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Front Stage | 11 | F20 | 100 | 1100 | | | | 1 | 10 | 10 | PL-1 |

**WORKLIGHTS**

| Location | Fixture Quantity | Type | Wattage | Total | Works 20A | House 20A | Orchestra 20A | Platform 20A | DIMMER From | To | Circuit Name |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Stage | 14 | F14 | 46 | 644 | 1 | | | | 11 | 11 | WL-1 |

## Lighting Design: Open Office

**Description:**

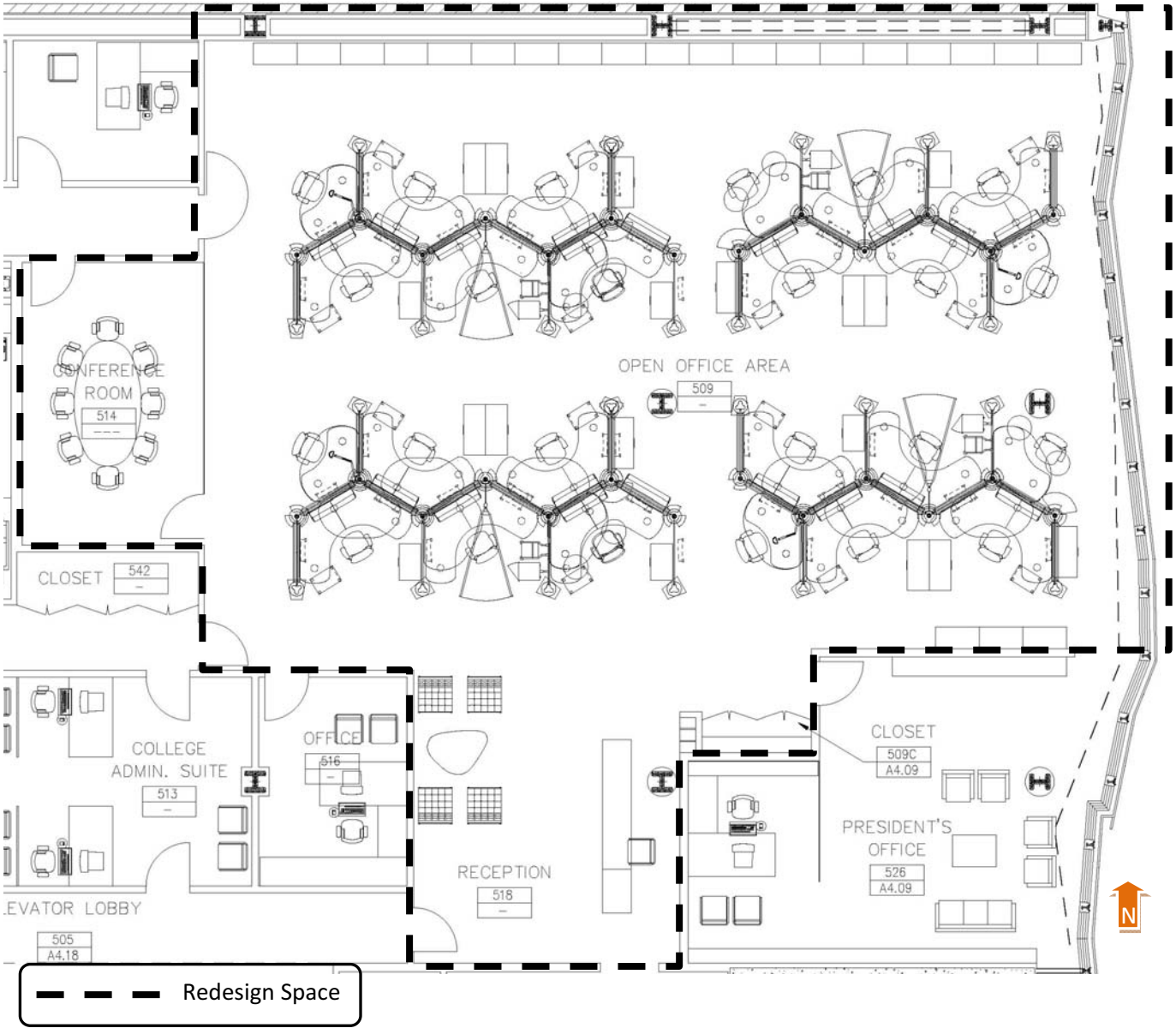
Open office area on 5th floor of Spertus College consists of an open space predominately for computer usage, a small conference room, and a reception area. As part of the Masters study , Daylighting analysis is conducted in the open office area.

**Requirement met:** A large work space

**Area:** 3,450 Sq.ft.

**Dimension:** Approx 43'-0" x 63'-0"

**Plan:**



**Materials:**

| Surface | Material | Reflectance |
|---|---|---|
| **Floor** | Concrete slab | .3 |
| **Ceiling** | Acoustical ceiling tile: Armstrong Optima open plan, 2'x2' panels with Square Tegular edge profile. Ceiling system consists of E-W running 6" nominal slots spaced 8'-8" o.c. for light fixtures and air supply diffusers. | .8 |
| **Wall** | White painted gypsum wall board | .7 |
| **Conference Room wall (adjacent to open office)** | Full height interior glass wall set into recessed aluminum channels top and bottom. All vertical glass to glass joints to be sealed with Rhoda clear silicones | n/a |

**Activities/Tasks:**

- Reception and waiting area
- Open space for computer usage
- Small conference room
- Circulation to President's Office

## Design Consideration / Criteria

Appearance of Space and Luminaires

- Since the glass curtain wall is one of the walls for the open office area, the lighting system on the ceiling can be seen from the street level. It is important to ensure the consistency of luminaires' appearances with other spaces attached to the curtain wall.

Color Appearance (and color contrast)

- Color Appearance is an important design issue (IESNA). Good Color rendering light source should be implemented to compliment people skin tones. Color correlation temperature (CCT) produced by light source should be neutral (3500 K) to transition daylight contribution into the space. It also helps stimulate work activities and environment.

Daylight integration and control

- It is important to integrate daylight into the space due to large area of glazing. Direct glare and direct sun penetration could potentially be a problem in the morning depending on time of year. Dimming control system should be integrated to save energy. Shading devices or blinds with different transmittance levels should be considered to prevent direct sunlight penetration.

Direct Glare

- This deign issue is considered very important by IESNA design guide.
- In term of sun light direct glare, this is an important issue and can be avoided by shading devices. Direct glare from the luminaires could potentially be a problem. It can cause visual discomfort and reflected glare on the computer screen.
- One of the ways to reduce direct glare in the intensive VDT space is to employ direct/indirect or indirect fixture. To reduce direct glare from the luminaire, comfort diffused reflector, louvers, or glare shield should be specified.

Reflected Glare

- This deign issue is considered very important by IESNA design guide.
- Reflected glare can be reduced by the use of matte surfaces and by carrying out the procedures for reducing veiling reflections on the task
- Large area low-luminance luminaires or indirect luminaires can be used when specular surfaces cannot be avoided.

Light Distribution on Surfaces

- The north and south wall of the space should be uniformly illuminated. It does not only help create the sense of spaciousness, but also reduce contract level between the curtain wall and side walls.

Light Distribution on Task Plane (Uniformity)

- In order create the impression of visual clarity, high uniform light level should be provided, mostly overhead (direct) lighting.
- Non-uniform perimeter lighting is crucial to allow the eyes to stretch and prevent fatigue.

Luminances of Room Surfaces

- This deign issue is considered very important by IESNA design guide.
- Luminances near each task and in other parts of the office interior within the field of view should be balance with the task luminance.

| Tasks | Luminance Ratio |
|---|---|
| **Between paper task and adjacent VDT screen** | 3:1 |
| **Between task and adjacent dark surrounding** | 3:1 |
| **Between task and remote (non adjacent) Surface** | 10:1 |

- The maximum allowable ceiling luminance should not exceed 850 cd/m^2.
- The smooth gradient should be provided between the high and low luminance level.

Modeling of Faces and Objects

- Facial modeling is an important issue (IESNA). To provide good facial modeling, a combination of key light and fill light is required (direct and indirect components light).

Points of Interest

- There is currently no point of interest in the space. However it can be created by providing lighting that exceeds recommended luminance ratio stated above in some area.
- Another possibility is to provide different lighting system for the adjacent areas (reception and conference). Since both areas are transparent and connected the open office. Creating interesting and innovative lighting system for these two areas would help an open office from being uninteresting.

Shadows

- Shadows are minimized if the light arrives at the task from many directions, helped by high-reflectance matte finishes on room surfaces.

Source/Task/Eye/Geometry

- Luminaires should be located at the appropriate distance and angle from the VDT screens.

Sparkle/Desirable Reflected Highlights

- Sparkle/Desirable Reflected Highlights can be created in reception area to provide visual interest to the space.

Surface Characteristics

- All wall surfaces are gypsum wall board painted in white eggshell finish. Due to its high reflectance property of selected paint, high luminance level can be easily achieved. The space may seem brighter than it actually is.

Task lighting

- Task lighting integrated to the furniture system should be considered to reduce level of ambient in the space and save some energy.

Illuminance (Horizontal)

- 30 fc (IESNA Offices – Open plan office – Intensive VDT use)

Illuminance (Vertical)

- 5 fc (IESNA Offices – Open plan office – Intensive VDT use)

**Special Considerations by Areas**

*Reception Area*

- Visual Environment
  - The lighting should be restful and yet provide enough illumination for reading
  - Relaxation impression (Steffy)
    - Create a less formal setting and more casual space
    - Relaxation impression is best enhanced with non-uniform luminance and peripheral emphasis through accent of selective walls, wallslots, consistent accent lighting, and sconces.
- Visual Performance
  - Task
    - **10fc** on horizontal surfaces for general ambient and **3fc** on vertical surfaces (offices – lobbies, lounges, and reception areas – IESNA lighting design guide)
    - **30fc** on horizontal tasks at seating area for reading (reading – glossy magazines – IESNA lighting design guide)
    - **30fc** on horizontal workplane at reception desk (reading – printed tasks – 8 and 10 point style – IESNA lighting design guide)

*Conference Room*

- Visual Environment
  - Visual Clarity (Steffy) to provide occupants ability to perceive distinctions of architecture, interior detail, features, objects, and other people's features.
  - Spaciousness Impression (Steffy) to provide perception of spatial volume.
  - Two or more lighting systems should be planned to provide flexibility for this range:
    - A general lighting system in which the control of illuminance is provided by switches or dimmers.
    - A supplement lighting system consisting of downlighting with dimmer controls for slide projection and other low-level illumination requirements.
    - A perimeter or wall-wash lighting system controlled with dimmers for better visual appeal and for wall-mounted presentations.
- Visual Performance
  - Video Presentation
    - Less than **5fc** on front screen projection systems (DG-17)
    - **10fc** for writing on work plane (Category C – Working spaces where simple visual tasks are performed – IESNA ch.10)
  - Face to Face Conference
    - **5fc** average vertical illuminance on faces (IESNA design guide for meeting in the conference room)
    - **20-40fc** average illuminance on 60% reflectance walls (target 30fc at eye height) (DG-17)
    - **1.5:1** max:min uniformity ratio across all faces (DG-17)
    - **30-50fc** for writing on work plane (IESNA)

Energy Considerations

- Energy Code Requirements – ASHRAE 90.1-2004 – Space by space method
  - Open Office Area
    - Standard 90.1 – **1.1w/sq ft.** for open plan office
    - Additional **1.0w/sq ft.** for decorative
    - Additional **.35w/sq ft.** for VDT compliance fixtures
  - Conference Room
    - Standard 90.1 – **1.3w/sq ft.** for conference room
    - Additional **1.0w/sq ft.** for decorative
    - Additional **.35w/sq ft.** for VDT compliance fixtures
  - Reception Area
    - Standard 90.1 – **1.2w/sq ft.** for lounge/recreation

## Lighting Redesign

### Lighting Solutions:

The 'Star of David' lighting concept and the idea of unique shapes that echo the facets of the building's glass front are reappearing in the lighting design of this open office through decorative luminaires. In order to create a cohesive design for all three areas in this space, appearances of luminaire are very important. Light level is also important to create transitional path from one area to another.

**Reception Area**

To create a warm and welcoming environment, recessed halogen downlight is specified in the reception area. This particular fixture does not only provide adequate illuminance level for the general illumination, it also provides color effects through the use of indirect light from the LEDs within the fixture itself. The use colors help reinforces the impression of relaxation. Other than the recessed downlights, there are three wall mounted decorative luminaires on the left wall near the seating area. These triangular pieces do not only create a focal point, but also provide some side lighting to enhance facial modeling in the seating area.

**Open Office**

The direct/indirect suspended luminaire is specified for the open office area. Adequate illuminance level is achieved on the workplane mostly from the direct component of the luminaire. However, the indirect component adds a nice illuminance plane on the ceiling to create a sense of spaciousness. They are oriented parallel to the curtain wall for the purpose of daylight harvesting.

**Conference Room**

The main source of lighting in the conference room comes from the direct/indirect suspended central piece. This luminaire is designed and manufactured by Artemide. It does not only provide direct light on the conference table top and on people's faces, but it also provide light on the ceiling. The fixture itself is a focal point of the room because of its shape and glowing effect. There are recessed compact fluorescent wall-washers on all three walls of the conference room. They do not only help define the shape of the space and create a sense of spaciousness, but also provide vertical illumination for pin-ups or presentation materials.

## Controls:

All the luminaires in the three spaces are connected to LCP SpecGrade dimming panel (LDP-2). There are total of three master controls, each has four presets, off, and fine-tuning of light levels with master raise/lower. One is located in the reception area near the reception desk. The other two are located near the entrance and exit of the conference room. In addition, there are three other switches with one scene and all off located near all the entrances and exits. The system is also connected to occupancy censor. Refer to Appendix C for Control diagrams.

**Open Office LCP Dimming Panel Load Schedule**

**Panel Name:** Panel Unit 1
**Lutron Model No.:** LCP8-1204ML-20
**Panel Address / Location:** 1 /

| Area/Room | Customer Circuit # | Lutron Circuit # | Circuit Description | Load Type | Actual Load (W/VA) | Max. Load (W/VA) | BRKR Size | Phase |
|---|---|---|---|---|---|---|---|---|
| Open Office | L4/23 | 1 | FIXTURE TYPE F21 | Electronic LV | 1449 | 2000 | 20A-1P | A |
| Open Office | L4/19 | 2 | FIXTURE TYPE F21 | Electronic LV | 966 | 2000 | 20A-1P | B |
| Open Office | L4/29 | 3 | FIXTURE TYPE F21 | Electronic LV | 426 | 2000 | 20A-1P | C |
| Open Office | L4/18 | 4 | FIXTURE TYPE F21 | Electronic LV | 290 | 2000 | 20A-1P | A |
| Open Office | L4/11 | 5 | FIXTURE TYPE F21 | Electronic LV | 294 | 2000 | 20A-1P | B |
| Open Office | L4/12 | 6 | FIXTURE TYPE F21 | Electronic LV | 202 | 2000 | 20A-1P | C |
| | | 7 | Spare | | 0 | 2000 | 20A-1P | |
| | | 8 | Spare | | 0 | 2000 | 20A-1P | |

120/208V, 3Ø-4 Wire Main Lugs LCP SpecGrade Dimming Panel containing 1 20A-1Pole branch breaker rated at 10,000AIC for each of the 8 dimming circuits. Max input feed = 175A

**Feed Type:** Normal

**Phase A:** 1739 W/VA
**Phase B:** 1260 W/VA
**Phase C:** 628 W/VA

## Summary Performance Evaluation:

Simple and effecting lighting design solutions are utilized in the reception area, open office, and the conference room. A combination of halogen downlights and decorative fluorescent wall sconces creates a transitional space to all the fluorescent areas including the open office and the conference room. Adequate illuminance level is provided on the reception desk workplane (avg of 49 fc) and seating area. Although the fluorescent decorative wall sconces are not factored in the calculation, average of 5 fc is already achieved from the downlight system. Higher illuminance levels at the reception desk and on the wall near the decorative fixtures create a peripheral emphasis that enhances relaxation impression. Uniform illuminance level is also achieved on the tasks throughout the open office. Although there is no dedicated luminaires for vertical or wall illumination, the direct/indirect pendants do a good job of illuminating the vertical walls and defining the perimeter of the space. The conference room lighting design offers simple but elegant design solutions. An average illuminance of 48 fc is provided on the conference table and 20 fc on the vertical walls.

## Lighting Schedule

Refer to Appendix A for a complete schedule.

| Type | Manufacturer | CatalogNumber | Description | Electrical | Wattage |
|---|---|---|---|---|---|
| F21 | Zumtobel | CS-1545/2545-T-CO-DH120-CO/DO | Suspended fluorescent up/downlight with 1-F54T5/HO (48in) lamp (in cross-section). Optics: straight louver , opal acrylic diffuser , anodized aluminum reflector 79% up/21% down. | Lutron Dimming Ballast 1% Dimming Hi-lume | 69 |
| F22 | Kurt Versen | H8453 26W | 5" recessed compact fluorescent wallwasher with 1-CFTR32W lamp. Optics: glass spread lens , anodized aluminum reflector , single. | Lutron Dimming Ballast 1% Dimming Hi-lume | 32 |
| F23 | Pure Lighting | AH3-ASE3-RGB | 3" recessed halogen accent light with 1-MR16 37W max lamp. Optics: glare shield , prismatic lens. | Integral magnetic transformer | 37 |
| F24 | Artemide | Mouette Suspension Asymmetrical | Textured opal white wing shaped diffuser constructed of a single piece of polypropylene produced by using rotoform molding technology. Available in two verisons: asymmetrical and symmetrical. Diffuser support in white powder coated steel. Suspension cables and support ends in stainless steel with griplock connectors, height adjustable at installation. Center electrical feed with thermoplastic molded canopy. Mounting to standard electrical junction boxes. | Integral electronic 120V/277V ballast | 176 |
| F25 | Modular Lighting | 11340101 | Fluorescent decorative wall mounted fixture. | Integral electronic 120V/277V ballast | 28 |

## Lighting Plans

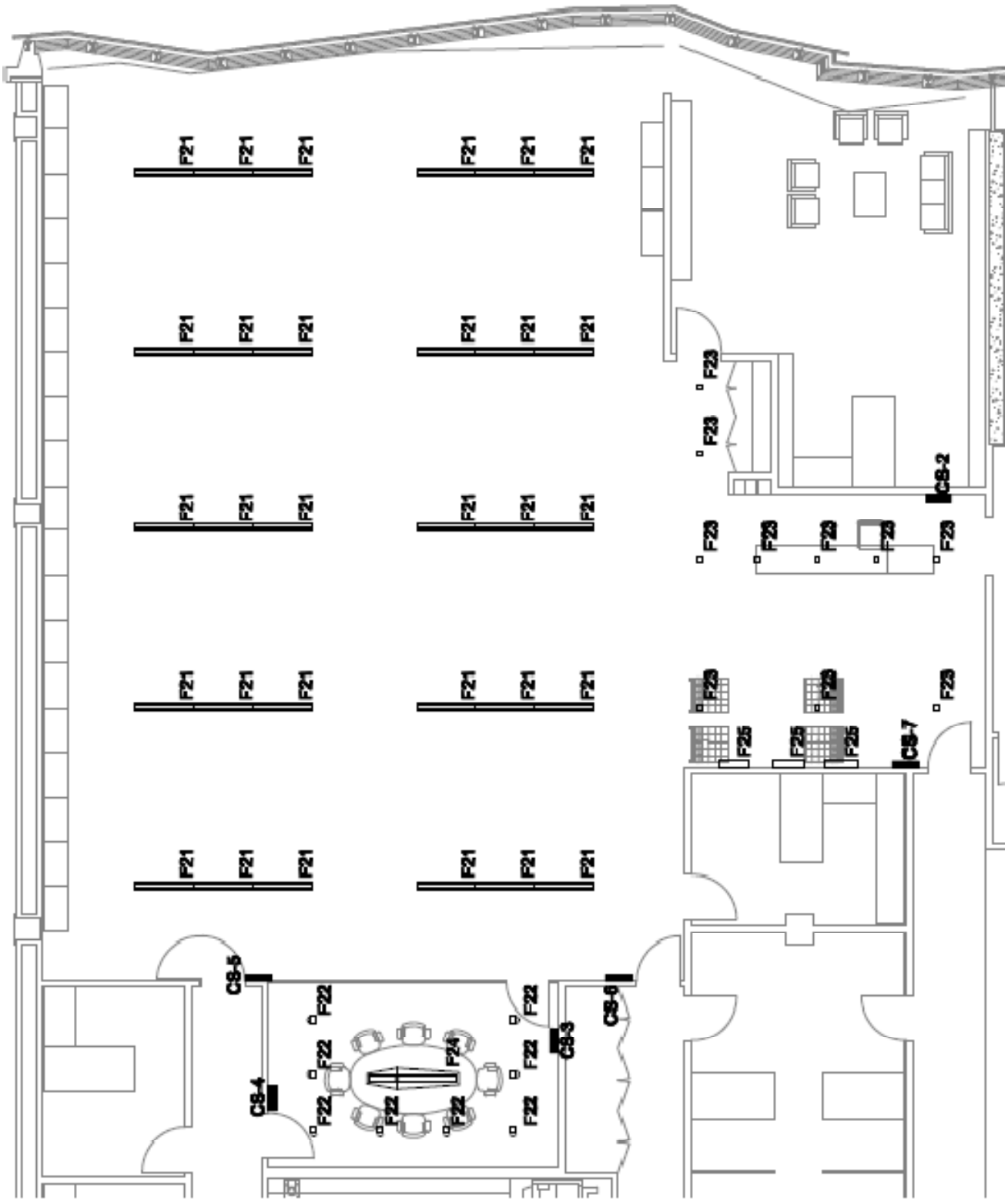



FIGURE 35: OPEN OFFICE LIGHTING PLAN

## Visual Quality / Visual Performance

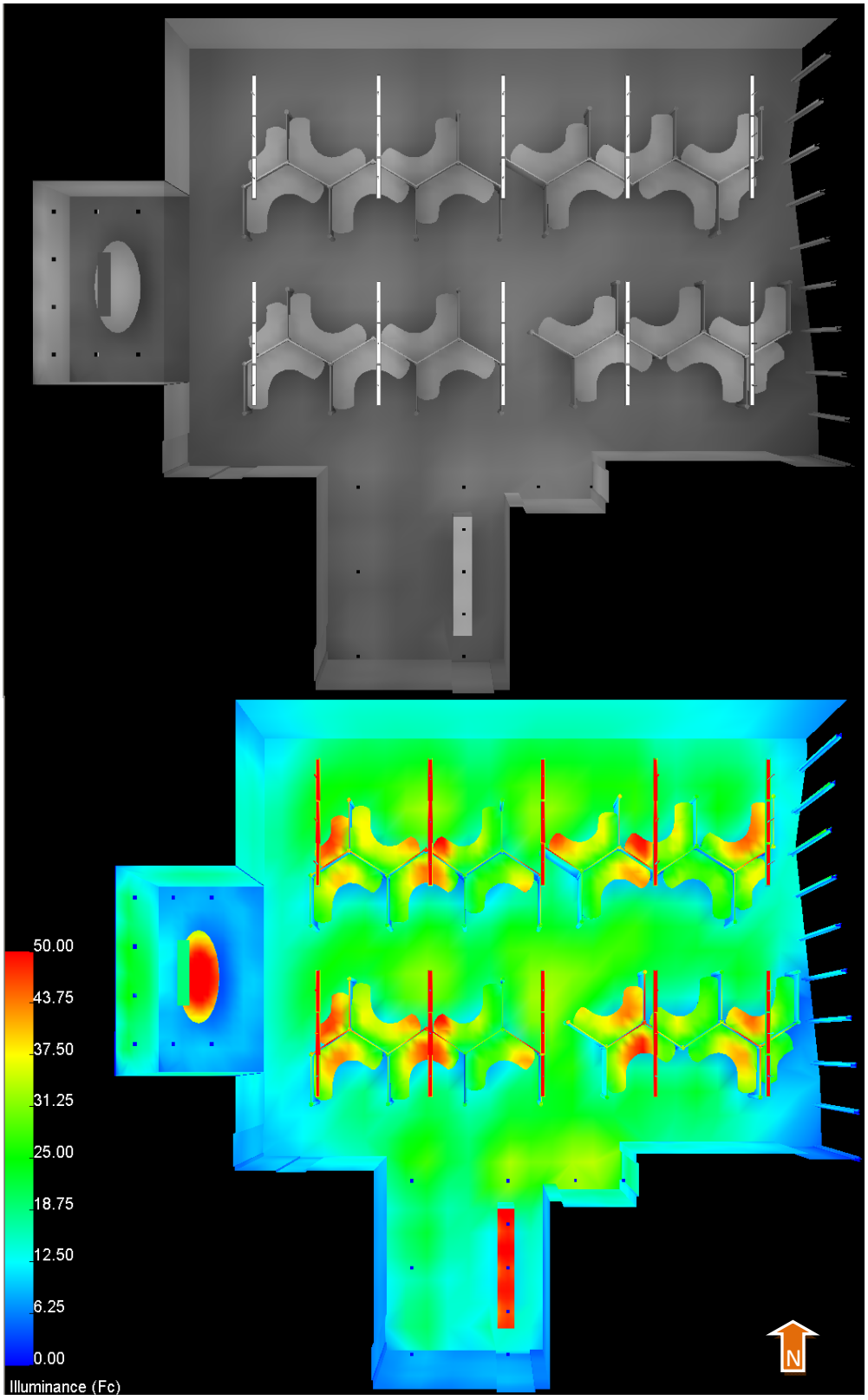



FIGURE 36: FLOOR PLAN – OPEN OFFICE

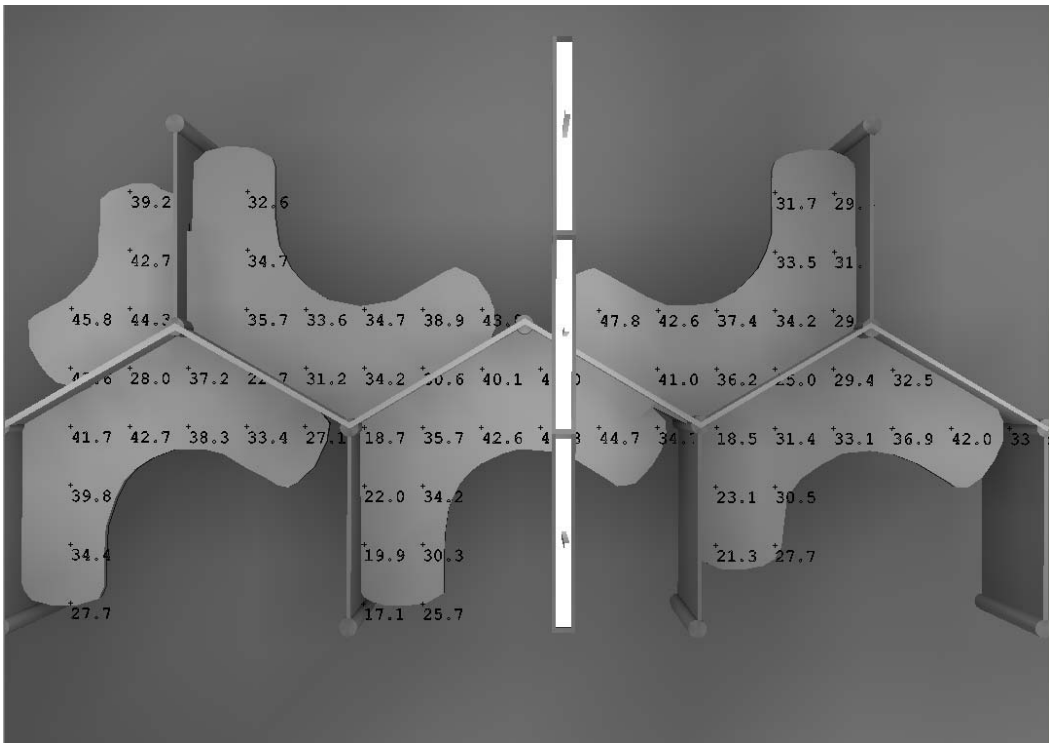



FIGURE 37: TYPICAL WORKSTATION – ILLUMINANCE GRID ON THE WORKPLANE

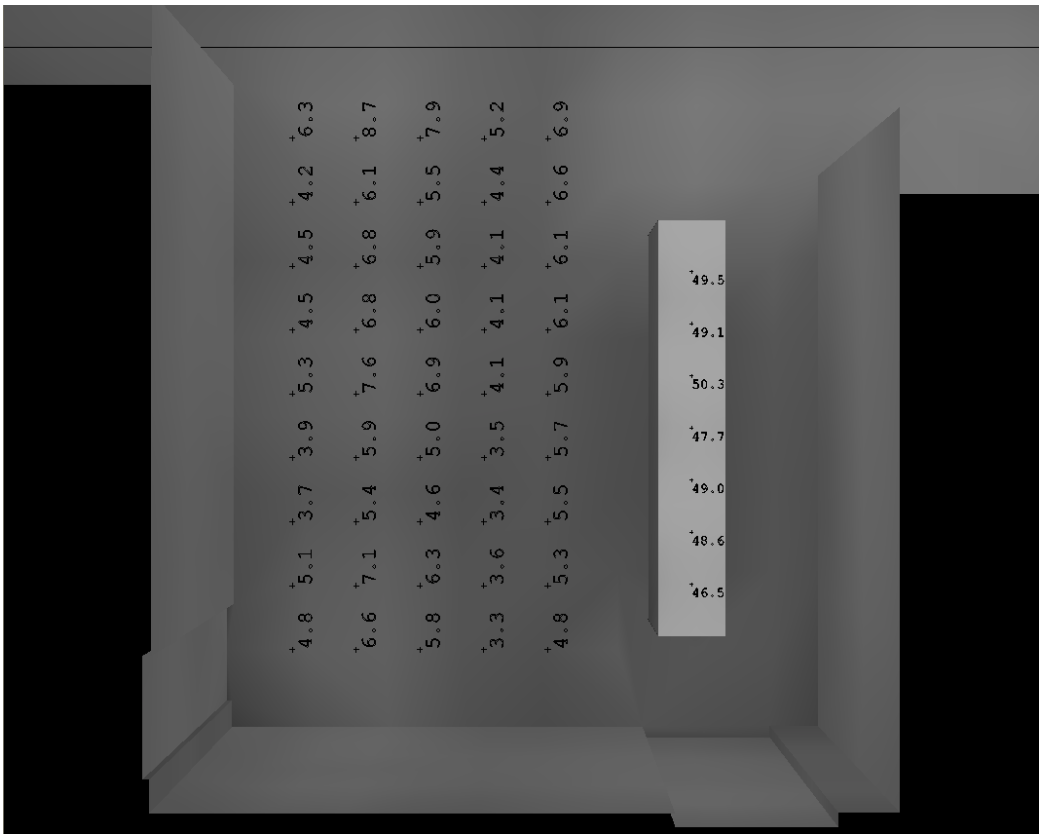



FIGURE 38: RECEPTION AREA – ILLUMINANCE GRID ON THE GROUND / RECEPTION DESK

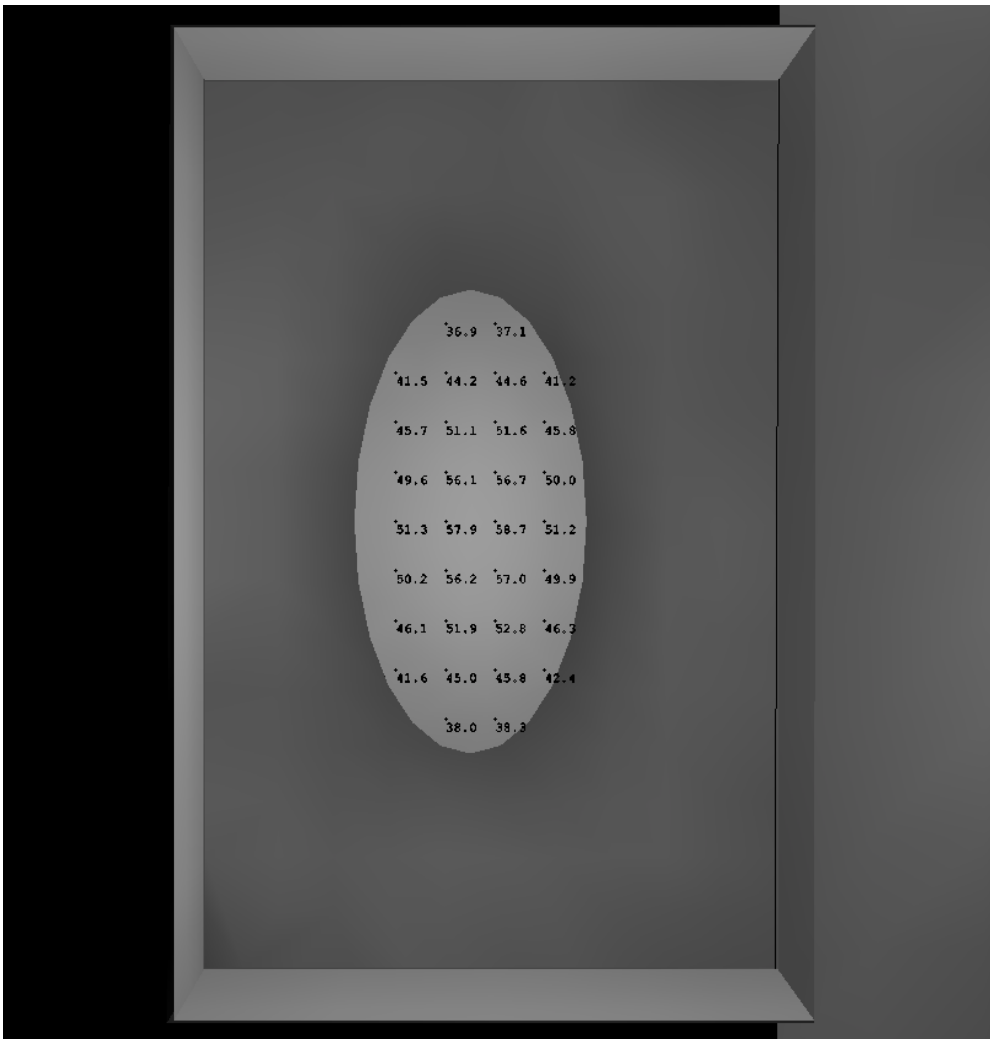



FIGURE 39: CONFERENCE ROOM – ILLUMINANCE GRID ON THE CONFERENCE TABLE

**Calculation Summary: Open Office/Reception Area/Conference Room**

| Calculation Summary | | | | | | | |
|---|---|---|---|---|---|---|---|
| Label | CalcType | Units | Avg | Max | Min | Avg/Min | Max/Min |
| Workplane | Illuminance | Fc | 32.78 | 48.7 | 0.1 | 327.80 | 487.00 |
| Conference Table_Top | Illuminance | Fc | 47.90 | 58.7 | 36.9 | 1.30 | 1.59 |
| Workplane_1 | Illuminance | Fc | 5.46 | 8.7 | 3.3 | 1.65 | 2.64 |
| Object_Reception Desk Top | Illuminance | Fc | 48.67 | 50.3 | 46.5 | 1.05 | 1.08 |

FIGURE 40: CALCULATION SUMMARY: OPEN OFFICE/RECEPTION AREA/CONFERENCE ROOM

## Light Loss Factor Calculation

### TYPE F21, 24

Linear Fluorescent Direct/Indirect Pendant

- Lamp Lumen Depreciation – FP54/830/HO/ECO
  - LLD = maintained / initial = 4650 / 5000 = **.93**
- Luminaire Dirt Depreciation
  - Maintain category – II
  - Degree of dirt condition – Clean
  - Cleaning cycle – 24 months
  - LDD = **.89**
- Room Surface Dirt Depreciation
  - Room cavity ratio = 5x7.5x(48.5+42) / (48.5X42) = 1.6
  - Degree of dirt condition – Clean
  - Cleaning cycle – 12 months
  - Expected dirt depreciation = 12%
  - Luminaire distribution type = Direct/Indirect
  - RSDD = .**98**
- Ballast Factor = **1.0**

**LLF = .93 X .89 X .98 X 1.0 = .81**

### TYPE F22

Compact Fluorescent Recessed Downlight

- Lamp Lumen Depreciation – CF26DT/E/IN/830/ECO
  - LLD = maintained / initial = 1548 / 1800 = **.86**
- Luminaire Dirt Depreciation
  - Maintain category – IV
  - Degree of dirt condition – Clean
  - Cleaning cycle – 24 months
  - LDD = **.89**
- Room Surface Dirt Depreciation
  - Room cavity ratio = 5x7.5x(48.5+42) / (48.5X42) = 1.6
  - Degree of dirt condition – Clean
  - Cleaning cycle – 12 months
  - Expected dirt depreciation = 12%
  - Luminaire distribution type = Direct
  - RSDD = .**98**
- Ballast Factor = **1.0**

**LLF = .86 X .89 X .98 X 1.0 = .75**

**TYPE F23**

Low Voltage Recessed Downlight

- Lamp Lumen Depreciation – 37MR16/IR/FL35/C 12V
  - LLD = maintained / initial = not given = **.85** (assumption)
- Luminaire Dirt Depreciation
  - Maintain category – IV
  - Degree of dirt condition – Clean
  - Cleaning cycle – 24 months
  - LDD = **.89**
- Room Surface Dirt Depreciation
  - Room cavity ratio = 5x7.5x(48.5+42) / (48.5X42) = 1.6
  - Degree of dirt condition – Clean
  - Cleaning cycle – 12 months
  - Expected dirt depreciation = 12%
  - Luminaire distribution type = Direct
  - RSDD = .**98**

**LLF = .85 X .89 X .98 X = .74**

**Energy Calculation:** ASHRAE/Standard 90.1 2004 : Space by space method

| Room Name | Space Type | Area ($ft.^2$) | Fixt. Type | Fixture Description | Watts / Fixture | Fixture Qty | Total Watts | Actual Watts | Base $W/ft.^2$ | Allow Watts | Decorative Watts Used | Energy Code Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Open Office | Office - Open plan | 2,751 | F21 | Direct/indirect Suspened Pendant | 69 | 30 | 2070 | 2070 | 1.1 | 3026 | n/a | Passed |
| | | | | | | | | | | | | |
| Reception | Lounge/Recreation | 389 | F23 | Recessed Halogen Downlight | 40 | 10 | 400 | 670 | 1.2 | 467 | 203 | Passed w/ décor't Allowanace |
| | | | F25 | Fluorescent Wall-Mounted | 90 | 3 | 270 | | | | | |
| | | | | | | | | | | | | |
| Conference Rm | Conference Room | 265 | F22 | Recessed CFL Downlight | 32 | 8 | 256 | 432 | 1.3 | 345 | 87 | Passed w/ décor't Allowanace |
| | | | F24 | Direct/indirect Suspened Pendant | 176 | 1 | 176 | | | | | |
| | | | | | | | 0 | | | | | |

# Electrical Design: Open Office

## Electrical Design Objectives/criteria

Existing lighting systems, which are primary linear fluorescent and low-voltage halogen, utilize eight (8) circuits from panelboard 5L-1. The panelboard supplies 120 volt power for both the 5th floor and the 6th floor lighting loads. The redesign lighting systems utilize efficient light sources including T5 high output linear fluorescent, compact fluorescent, and halogen. As a result, lighting load decreases. Six circuits are utilized to supply the entire lighting load in the all the spaces. The two out of six circuits are dedicated for the linear fluorescent pendants in the open office area. The other four circuits are dedicated for the conference room and the reception area. Although the phases in panelboard L4 are not quite balanced, they are more balanced compared to the existing panelboard. All the luminaires in the three spaces are connected to LCP SpecGrade dimming panel (LDP-2) and controlled from control stations by the reception desk, exits, and entrances (see drawing for exact locations). Refer to Appendix C for Control diagrams.

**Original Panelboard (L4)**

PANELBOARD SCHEDULE

Designation: 5L-1 | Main Type: 100 MB
Voltage: 208/120V, 3PH, 4W | Bus Amps: 100 Amps
Fed From: 5G-1

AVAILABLE FAULT CURRENT: 22,000 AMPS

| CCT No. | Load Description | Load A | Load B | Load C | C/B Size | C/B Size | Load A | Load B | Load C | Load Description | CCT No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 501,532 | 1260 | | | 20A | 20A | 770 | | | 602,605 | 2 |
| 3 | 504 | | 840 | | 20A | 20A | | 980 | | 601 (DAYLIGHT HARVESTING) | 4 |
| 5 | 529 | | | 140 | 20A | 20A | | | 980 | 601 (DAYLIGHT HARVESTING) | 6 |
| 7 | 506,507,519,528,530,537,538 | 1120 | | | 20A | 20A | 450 | | | | 8 |
| 9 | 508,510,531,533,534 | | 1200 | | 20A | 20A | | 280 | | 603,604 | 10 |
| 11 | 514 | | | 280 | 20A | 20A | | | | | 12 |
| 13 | 511,512,513,516 | 960 | | | 20A | 20A | | | | | 14 |
| 15 | 502,503,539 | | 825 | | 20A | 20A | | | | | 16 |
| 17 | 505 | | | 490 | 20A | 20A | | | | | 18 |
| 19 | 509 L22s | 1120 | | | 20A | 20A | | | | | 20 |
| 21 | 509 L22s | | 560 | | 20A | 20A | | | | | 22 |
| 23 | 509 L22s | | | 1120 | 20A | 20A | | | | | 24 |
| 25 | 509 L5s | 950 | | | 20A | 20A | | | | | 26 |
| 27 | 509 L5s | | 900 | | 20A | 20A | | | | | 28 |
| 29 | 518 | | | 340 | 20A | 20A | | | | | 30 |
| 31 | 528 | 420 | | | 20A | 20A | | | | | 32 |
| 33 | | | | | 20A | 20A | | | | | 34 |
| 35 | | | | | 20A | 20A | | | | | 36 |
| 37 | | | | | 20A | 20A | | | | | 38 |
| 39 | | | | | 20A | 20A | | | | | 40 |
| 41 | | | | | 20A | 20A | | | | | 42 |
| | Total: | 5830 | 4325 | 2370 | | | 1220 | 1260 | 980 | | |

Redesigned Branch Circuit

| | | | | | |
|---|---|---|---|---|---|
| Total Phase A | 7050 va | Panel Total: | 16 | kVA |
| Total Phase B | 5585 va | Demand Total: | 20 | kVA |
| Total Phase C | 3350 va | Demand | 56 | Amps |

**New Panelboard (L4)**

PANELBOARD SCHEDULE

Designation: L4 (L5-1) Main Type 100 MB
Voltage: 208/120V, 3PH, 4W Bus Amps 100 Amps
Fed From: 5G-1

AVAILABLE FAULT CURRENT: 22,000 AMPS

| CCT No. | Load Description | Load A | Load B | Load C | C/B Size | C/B Size | Load A | Load B | Load C | Load Description | CCT No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 501,532 | 1260 | | | 20A | 20A | 770 | | | 602,605 | 2 |
| 3 | 504 | | 840 | | 20A | 20A | | 980 | | 601 (DAYLIGHT HARVESTING) | 4 |
| 5 | 529 | | | 140 | 20A | 20A | | | 980 | 601 (DAYLIGHT HARVESTING) | 6 |
| 7 | 506,507,519,528,530,537,538 | 1120 | | | 20A | 20A | 450 | | | | 8 |
| 9 | 508,510,531,533,534 | | 1200 | | 20A | 20A | | 280 | | 603,604 | 10 |
| 11 | 514 (8) F22 & (1) F24 | | | 256 | 20A | 20A | | | 176 | 514 (1) F24 | 12 |
| 13 | 511,512,513,516 | 960 | | | 20A | 20A | | | | | 14 |
| 15 | 502,503,539 | | 825 | | 20A | 20A | | | | | 16 |
| 17 | 505 | | | 490 | 20A | 20A | | | 252 | 518 (3) F25 | 18 |
| 19 | 509 (12) F21 | 840 | | | 20A | 20A | | | | | 20 |
| 21 | | | | | 20A | 20A | | | | | 22 |
| 23 | 509 (18) F21 | | | 1260 | 20A | 20A | | | | | 24 |
| 25 | | | | | 20A | 20A | | | | | 26 |
| 27 | | | | | 20A | 20A | | | | | 28 |
| 29 | 518 (10) F23 | | | 370 | 20A | 20A | | | | | 30 |
| 31 | | | | | 20A | 20A | | | | | 32 |
| 33 | | | | | 20A | 20A | | | | | 34 |
| 35 | | | | | 20A | 20A | | | | | 36 |
| 37 | | | | | 20A | 20A | | | | | 38 |
| 39 | | | | | 20A | 20A | | | | | 40 |
| 41 | | | | | 20A | 20A | | | | | 42 |
| | Total: | 4180 | 2865 | 2516 | | | 1220 | 1260 | 1408 | | |

Total Phase A 5400 va Panel Total: 13 kVA
Total Phase B 4125 va Demand Total: 17 kVA
Total Phase C 3924 va Demand 47 Amps

Branch Circuit Redesign
Depth Topic 1 - Reduced Lighting Load

## Feeder Sizing

**Panel L4** : Phase Conductor : 47 Amps x 1.25 = 58.75 Amps – 8 AWG CU THWN 75$^{o}$C
Ground Conductor: 100 Amps – 8 AWG CU

**FEEDER SCHEDULE**

| FROM | TO | # OF SET | CONDUIT (PER SET) | | CONDUCTORS (PER SET) | | | | | | | | | SIZE OF OVER CURRENT PROTECTION | FRAME OR SWITCH SIZE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | PHASE CONDUCTORS | | | NEUTRAL CONDUCTORS | | | GROUND CONDUCTORS | | | | |
| | | | SIZE | TYPE | No | SIZE | TYPE | No | SIZE | TYPE | No | SIZE | TYPE | | |
| 5G-1 | L4 | 1 | .75" | EMT | 3 | 8AWG | CU THWN | 1 | 8AWG | CU THWN | 1 | 8AWG | CU THWN | 100 | 100A3P |

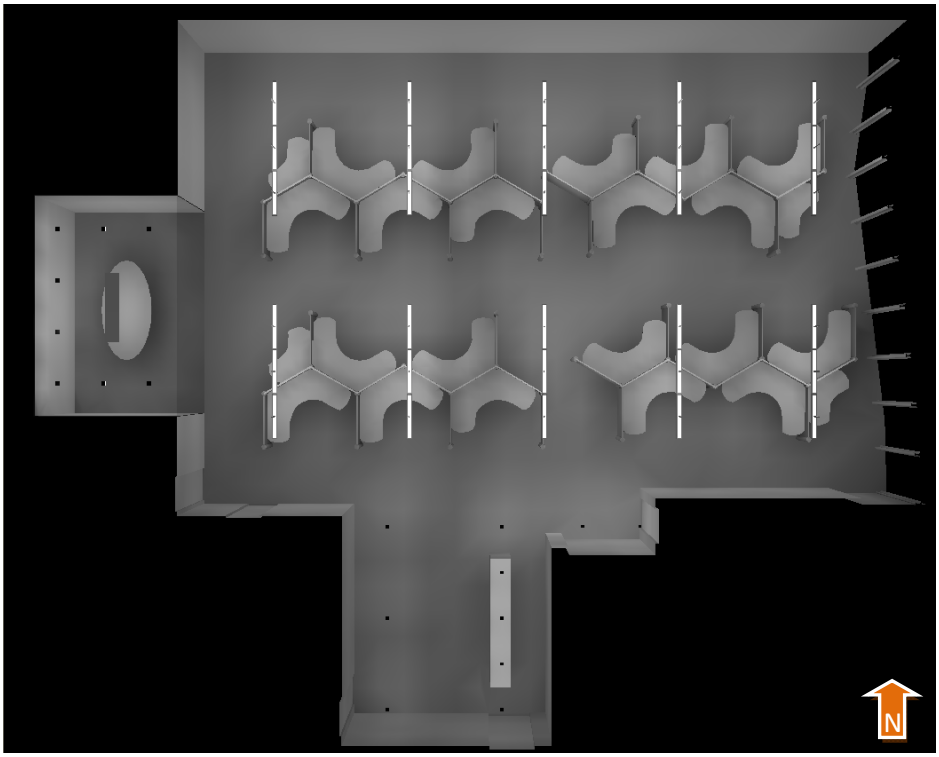
## Daylighting Study: Open Office

### Overview

To maximize the energy saving from daylight harvesting in the open office, an analysis is conducted to identity the best control (dimming) configuration that suits the room orientation and the available daylight in the space. The analysis shows that one row dimming is the best option because it saves more energy throughout the year.

### Constrains

Chicago is located at 41°59'N latitude and 87°54'W longitude. The open office faces directly east toward the Lake Michigan with no view of any obstacle. The glass curtain wall is 40% fritted with ceramic dots. Assume that visible light transmittance level through this material is 50%. Solar shades are available to block the morning sun from clear sky condition. The transmittance for the shades is 20%. Therefore, the total transmittance of the fritted glass behind the solar shade is 10%. The electric lighting is the open office area is fixture type F21, direct/indirect suspended pendant. There are total of five (5) rows of six (6) light fixtures. Fixture type 21 utilizes linear fluorescent 54WT5HO. The voltage is regulated controlled by Lutron Hi-lume dimming ballast.




### Analysis

The analysis focuses on identifying the dimming configuration that would save the most energy. The initial investigation suggests three possible options including one-row dimming, two-row dimming, and one-row on/off. One-row dimming option would dim the first row of six (6) fixtures of fixture type F21 from the glass curtain wall. Two-row dimming option would dim the first two rows of twelve (12) fixtures of fixture type F21 all together. And one-row on/off option would switch the first row of fixture type F21. The analysis is conducted at noon on the following dates: January 21, March21, and December21. Both overcast and clear sky condition is investigated on each day. The solar shades are down during the clear sky condition to reduce level or contrast and glare.

The critical points are located for all twelve scenarios in order to identify the dimming levels. The dimming levels are then used to calculate energy saving. The tables below show the comparison between one-row and two-rows dimming on three different days and two sky conditions. The analysis illustrated that one-row dimming has twice an average % saving over the two-rows dimming option. The fact that one-row dimming option is more effective is because of the available sunlight in the space. It allows the first row to dim much more than the two rows combined.

| | January 21st | | | |
|---|---|---|---|---|
| | 1-row dimming (6 fixtures) | | 2-rows dimming (12 fixtures) | |
| | Clear | Overcast | Clear | Overcast |
| Dimming Level | 0.636 | 0.479 | 0.901 | 0.906 |
| Watts Saving | 119 | 171 | 65 | 62 |
| % Saving | 6 | 9 | 3 | 3 |
| Avg % Saving | 7.8 | | 3.4 | |
| Preferred Option | ✓ | | × | |

| | March 21st | | | |
|---|---|---|---|---|
| | 1-row dimming (6 fixtures) | | 2-rows dimming (12 fixtures) | |
| | Clear | Overcast | Clear | Overcast |
| Dimming Level | 0.627 | 0.186 | 0.901 | 0.856 |
| Watts Saving | 122 | 266 | 65 | 94 |
| % Saving | 7 | 14 | 3 | 5 |
| Avg % Saving | 10.4 | | 4.3 | |
| Preferred Option | ✓ | | × | |

| | May 21st | | | |
|---|---|---|---|---|
| | 1-row dimming (6 fixtures) | | 2-rows dimming (12 fixtures) | |
| | Clear | Overcast | Clear | Overcast |
| Dimming Level | 0.666 | 0 | 0.913 | 0.819 |
| Watts Saving | 109 | 327 | 57 | 118 |
| % Saving | 6 | 18 | 3 | 6 |
| Avg % Saving | 11.7 | | 4.7 | |
| Preferred Option | ✓ | | × | |

FIGURE 41: ENERGY SAVING SUMMERY

## Sample Energy Saving Calculation

- 54W T5HO
- Ballast power to light output data.
  - Maximum light = 100% (Ballast Factor) at 62 watts
  - Minimum light = 1% at 8 watts.

<10% THD Electronic T5 HO Fluorescent Dimming Systems

| Item Number | Description | Input Voltage (VAC) | Input Current (AMPS) | Lamp[1] Type | Rated[2,3] Lumens (lm) | No. of Lamps | Ballast[3] Factor (BF) | System[3] Lumens | Input[3] Wattage (W) | System Efficacy (lm/W) |
|---|---|---|---|---|---|---|---|---|---|---|
| 49671 | QT1x54/120PHO-DIM | 120 | 0.54 | FP54T5HO | 5000 | 1 | 1.00<br>0.01 | 5000<br>50 | 62<br>8 | 81 |
| 49672 | QT1x54/277PHO-DIM | 277 | 0.23 | FP54T5HO | 5000 | 1 | 1.00<br>0.01 | 5000<br>50 | 61<br>8 | 82 |
| 49673 | QT2x54/120PHO-DIM | 120 | 1.07 | FP54T5HO | 5000 | 2 | 1.00<br>0.01 | 10000<br>100 | 120<br>18 | 83 |
| 49674 | QT2x54/277PHO-DIM | 277 | 0.45 | FP54T5HO | 5000 | 2 | 1.00<br>0.01 | 10000<br>100 | 117<br>18 | 85 |

**1-Row Dimming – January 21st at Noon – Clear sky condition**

- If 64% output is based on full light output (1.0 ballast factor), this corresponds to 0.64 x 1.0 = 0.64 BF
- (.64 -.01)/(1.0 -.01) x (62 - 8) + 8 = 42.4 W
- Energy consumed = 42.4 W/fixture x 6 fixtures = 254 W
- Energy saving = (62 W x 6 fixture) – 254 W = 119
- % Saving = 119 / (62 x 30) = **6.4%**

**2-Rows Dimming – January 21st at Noon – Clear sky condition**

- If 90% output is based on full light output (1.0 ballast factor), this corresponds to 0.90 x 1.0 = 0.90 BF
- (.90 -.01)/(1.0 -.01) x (62 - 8) + 8 = 56.5 W
- Energy consumed = 56.5 W/fixture x 12 fixtures = 678 W
- Energy saving = (62 W x 12 fixture) – 678 W = 65
- % Saving = 65 / (62 x 30) = **3.4%**

All electric lights on

| | -14.2 | -11.2 | -8.2 | -5.2 | -2.2 | 0.8 | 3.8 | 6.8 | 9.8 | 12.8 | 15.8 | 18.8 | 21.8 | 24.8 | 27.8 | 30.8 | 33.8 | 36.8 | 39.8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55.3 | 19.8 | 21.4 | 20.7 | 21.2 | 22.7 | 23.3 | 22.1 | 22.1 | 23.3 | 23.5 | 21.9 | 21.6 | 22.4 | 22.4 | 20.5 | 19.5 | 19.2 | 17.5 | 13.3 |
| 52.3 | 29.8 | 32.4 | 28.7 | 28.7 | 33.4 | 34.8 | 30.3 | 29.8 | 33.9 | 34.9 | 30.1 | 29.2 | 32.9 | 33.9 | 28.7 | 27 | 29.3 | 28 | 19.4 |
| 49.3 | 41.4 | 45.6 | 37.5 | 36.9 | 45.9 | 48.5 | 39.5 | 38.3 | 46.4 | 48.7 | 39.2 | 37.5 | 45.3 | 47.7 | 38 | 35.3 | 41.4 | 40.8 | 26.4 |
| 46.3 | 47.1 | 52.2 | 42.4 | 41.6 | 52.6 | 55.7 | 44.8 | 43.3 | 53.2 | 55.8 | 44.4 | 42.4 | 52 | 54.9 | 43.2 | 40.2 | 47.8 | 47.4 | 30.4 |
| 43.3 | 44.9 | 50.5 | 41.6 | 41.1 | 51.6 | 54.6 | 44.3 | 43 | 52.3 | 54.9 | 44 | 42.2 | 51.2 | 54 | 42.8 | 39.8 | 46.9 | 46.3 | 30 |
| 40.3 | 36.4 | 41.6 | 36.3 | 36.6 | 44 | 46.2 | 39.3 | 38.6 | 44.9 | 46.6 | 39.2 | 38 | 43.8 | 45.6 | 37.9 | 35.5 | 39.6 | 38.2 | 25.9 |
| 37.3 | 28.7 | 33 | 31.5 | 32.5 | 36.7 | 38 | 34.7 | 34.6 | 37.7 | 38.5 | 34.7 | 34.2 | 36.9 | 37.5 | 33.3 | 31.6 | 32.6 | 30.4 | 22.2 |
| 34.3 | 29.8 | 34.4 | 32.1 | 33.1 | 38 | 39.5 | 35.5 | 35.3 | 39.1 | 40.1 | 35.6 | 34.9 | 38.3 | 39.2 | 34.2 | 32.5 | 34.1 | 32.1 | 23.1 |
| 31.3 | 37.6 | 43.5 | 37.1 | 37.4 | 46 | 48.7 | 40.5 | 39.6 | 47.1 | 49.2 | 40.5 | 39.1 | 46.3 | 48.6 | 39.6 | 37.1 | 42.3 | 41.3 | 27.5 |
| 28.3 | 43.2 | 49.7 | 40.8 | 40.5 | 51.5 | 54.7 | 43.9 | 42.5 | 52.4 | 55.1 | 43.9 | 42.1 | 51.7 | 54.9 | 43.5 | 40.5 | 48.1 | 47.6 | 30.7 |
| 25.3 | 42.4 | 48.5 | 39.4 | 38.9 | 49.7 | 52.7 | 42 | 40.6 | 50.4 | 53.1 | 42.2 | 40.4 | 50.1 | 53.4 | 42.2 | 39.3 | 46.9 | 46.4 | 29.9 |
| 22.3 | 34.7 | 39.2 | 32.7 | 32.4 | 40.2 | 42.3 | 34.5 | 33.5 | 40.7 | 42.7 | 34.8 | 33.7 | 40.9 | 43.5 | 35.4 | 33.3 | 38.4 | 37.5 | 24.7 |
| 19.3 | 22.8 | 25.5 | 23.6 | 23.7 | 26.7 | 27.5 | 24.2 | 24 | 26.9 | 27.9 | 24.7 | 24.4 | 27.8 | 29.7 | 26.4 | 25.2 | 26.5 | 24.8 | 17.5 |

Illuminance (fc) contribution from first row of Luminaires (dimmed zone)

| | -14.2 | -11.2 | -8.2 | -5.2 | -2.2 | 0.8 | 3.8 | 6.8 | 9.8 | 12.8 | 15.8 | 18.8 | 21.8 | 24.8 | 27.8 | 30.8 | 33.8 | 36.8 | 39.8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55.3 | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 | 0.5 | 0.6 | 0.8 | 1 | 1.3 | 1.8 | 2.4 | 3.3 | 4.6 | 6.6 | 9.3 | 12 | 12.4 | 9.6 |
| 52.3 | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 | 0.5 | 0.6 | 0.8 | 1.1 | 1.4 | 1.9 | 2.6 | 3.7 | 5.5 | 8.6 | 13.9 | 20.8 | 22.3 | 15.4 |
| 49.3 | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 | 0.5 | 0.7 | 0.9 | 1.1 | 1.5 | 2 | 2.8 | 4.1 | 6.4 | 10.7 | 19.2 | 31.6 | 34.5 | 22.2 |
| 46.3 | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 | 0.5 | 0.7 | 0.9 | 1.2 | 1.5 | 2.1 | 3 | 4.4 | 7 | 12.1 | 22.2 | 37.2 | 40.6 | 26 |
| 43.3 | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 | 0.5 | 0.7 | 0.9 | 1.2 | 1.6 | 2.2 | 3.1 | 4.6 | 7.2 | 12.1 | 21.9 | 36.1 | 39.4 | 25.4 |
| 40.3 | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 | 0.5 | 0.7 | 0.9 | 1.2 | 1.6 | 2.2 | 3.1 | 4.6 | 7 | 11.3 | 18.8 | 29 | 31.3 | 21.3 |
| 37.3 | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 | 0.5 | 0.7 | 0.9 | 1.2 | 1.6 | 2.2 | 3.1 | 4.6 | 6.8 | 10.5 | 16.1 | 22.3 | 23.5 | 17.6 |
| 34.3 | 0.2 | 0.2 | 0.2 | 0.3 | 0.4 | 0.5 | 0.7 | 0.9 | 1.2 | 1.6 | 2.2 | 3.1 | 4.6 | 6.9 | 10.7 | 16.7 | 23.8 | 25.2 | 18.4 |
| 31.3 | 0.1 | 0.2 | 0.2 | 0.3 | 0.4 | 0.5 | 0.7 | 0.9 | 1.2 | 1.6 | 2.2 | 3.1 | 4.6 | 7.1 | 11.6 | 20 | 31.7 | 34.4 | 22.9 |
| 28.3 | 0.1 | 0.2 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.8 | 1.1 | 1.5 | 2.1 | 3 | 4.5 | 7.2 | 12.3 | 22.4 | 37.3 | 40.7 | 26.2 |
| 25.3 | 0.2 | 0.2 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.8 | 1 | 1.4 | 2 | 2.8 | 4.3 | 6.9 | 11.9 | 21.9 | 36.5 | 39.8 | 25.5 |
| 22.3 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 | 0.6 | 0.7 | 0.9 | 1.3 | 1.8 | 2.6 | 3.9 | 6.2 | 10.3 | 18 | 29 | 31.4 | 20.6 |
| 19.3 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 | 0.5 | 0.6 | 0.8 | 1.1 | 1.5 | 2.2 | 3.3 | 5.2 | 8.2 | 12.9 | 18.3 | 19.3 | 13.8 |

Illuminance (fc) contribution from first two rows of Luminaires (dimmed zone)

| | -14.2 | -11.2 | -8.2 | -5.2 | -2.2 | 0.8 | 3.8 | 6.8 | 9.8 | 12.8 | 15.8 | 18.8 | 21.8 | 24.8 | 27.8 | 30.8 | 33.8 | 36.8 | 39.8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55.3 | 0.7 | 0.8 | 0.9 | 1.1 | 1.4 | 1.8 | 2.4 | 3.1 | 4.3 | 5.9 | 8.3 | 11.6 | 15.3 | 17.3 | 16.8 | 16.7 | 17.1 | 16 | 12.1 |
| 52.3 | 0.7 | 0.8 | 1 | 1.2 | 1.5 | 1.9 | 2.5 | 3.4 | 4.7 | 6.9 | 10.4 | 16.4 | 24.6 | 28.2 | 24.7 | 24 | 27.1 | 26.4 | 18.2 |
| 49.3 | 0.7 | 0.8 | 1 | 1.2 | 1.5 | 2 | 2.7 | 3.6 | 5.2 | 7.8 | 12.6 | 21.8 | 35.7 | 41.4 | 33.6 | 32.2 | 39.1 | 39.1 | 25.2 |
| 46.3 | 0.7 | 0.8 | 1 | 1.2 | 1.6 | 2 | 2.8 | 3.8 | 5.5 | 8.5 | 14 | 24.9 | 41.6 | 48.3 | 38.7 | 36.9 | 45.5 | 45.7 | 29.2 |
| 43.3 | 0.7 | 0.8 | 1 | 1.2 | 1.6 | 2.1 | 2.8 | 3.9 | 5.7 | 8.7 | 14.1 | 24.6 | 40.6 | 47.1 | 38.2 | 36.5 | 44.5 | 44.5 | 28.7 |
| 40.3 | 0.6 | 0.8 | 1 | 1.2 | 1.6 | 2.1 | 2.9 | 4 | 5.7 | 8.5 | 13.3 | 21.7 | 33.6 | 38.8 | 33.1 | 32.2 | 37.1 | 36.4 | 24.6 |
| 37.3 | 0.6 | 0.7 | 0.9 | 1.2 | 1.6 | 2.1 | 2.9 | 4 | 5.7 | 8.3 | 12.5 | 19.1 | 26.9 | 30.8 | 28.5 | 28.3 | 30.1 | 28.6 | 20.9 |
| 34.3 | 0.5 | 0.7 | 0.9 | 1.2 | 1.6 | 2.1 | 2.8 | 3.9 | 5.6 | 8.3 | 12.6 | 19.6 | 28.4 | 32.5 | 29.6 | 29.1 | 31.6 | 30.3 | 21.8 |
| 31.3 | 0.5 | 0.7 | 0.9 | 1.2 | 1.5 | 2 | 2.7 | 3.8 | 5.6 | 8.4 | 13.4 | 22.7 | 36.1 | 41.9 | 35 | 33.8 | 39.9 | 39.6 | 26.3 |
| 28.3 | 0.5 | 0.7 | 0.9 | 1.1 | 1.4 | 1.9 | 2.6 | 3.7 | 5.4 | 8.4 | 14 | 24.9 | 41.5 | 48.3 | 39 | 37.3 | 45.7 | 45.9 | 29.5 |
| 25.3 | 0.5 | 0.7 | 0.8 | 1.1 | 1.4 | 1.8 | 2.5 | 3.4 | 5.1 | 7.9 | 13.3 | 24 | 40.4 | 47.1 | 37.9 | 36.3 | 44.7 | 44.8 | 28.7 |
| 22.3 | 0.5 | 0.6 | 0.8 | 1 | 1.3 | 1.7 | 2.3 | 3.1 | 4.5 | 7 | 11.3 | 19.7 | 32.2 | 37.8 | 31.4 | 30.3 | 36.2 | 35.9 | 23.5 |
| 19.3 | 0.5 | 0.6 | 0.8 | 1 | 1.2 | 1.5 | 2 | 2.7 | 3.9 | 5.7 | 8.7 | 13.7 | 20.6 | 24.5 | 22.6 | 22.4 | 24.4 | 23.3 | 16.4 |

## 1-Row Dimming Analysis

March 21 at Noon – Overcast

Dimming levels – Critical point

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55.3 | -4 | -3 | -2 | -1.33 | -2.75 | -1.6 | -1 | -1.13 | -0.7 | -0.92 | -0.78 | -0.58 | -0.7 | -0.57 | -0.52 | -0.71 | -1.22 | -2.99 | -9.23 |
| 52.3 | -4 | -2 | -2.33 | -1.33 | -1.5 | -1.4 | -0.83 | -1 | -0.91 | -0.93 | -0.68 | -0.69 | -0.51 | -0.44 | -0.36 | -0.34 | -0.55 | -1.7 | -6.52 |
| 49.3 | -3 | -3.5 | -1.33 | -1.67 | -1.5 | -1.2 | -0.86 | -0.78 | -0.82 | -0.67 | -0.65 | -0.57 | -0.54 | -0.38 | -0.21 | -0.09 | -0.13 | -0.91 | -4.59 |
| 46.3 | -3 | -2 | -1.67 | -2 | -1.75 | -1.4 | -0.86 | -0.89 | -0.75 | -0.87 | -0.71 | -0.6 | -0.48 | -0.34 | -0.17 | 0.005 | -0.01 | -0.69 | -3.89 |
| 43.3 | -3 | -2 | -1.67 | -1.67 | -1.5 | -1.2 | -1 | -0.89 | -0.83 | -0.75 | -0.73 | -0.58 | -0.48 | -0.33 | -0.17 | -0.04 | -0.06 | -0.73 | -3.89 |
| 40.3 | -2 | -2 | -1.67 | -1.67 | -1.25 | -1.2 | -1.14 | -1 | -0.75 | -0.75 | -0.73 | -0.61 | -0.52 | -0.4 | -0.27 | -0.2 | -0.29 | -1.12 | -4.67 |
| 37.3 | -2.5 | -2.5 | -1.67 | -1.67 | -1.25 | -1.2 | -1.14 | -0.89 | -0.83 | -0.81 | -0.68 | -0.61 | -0.5 | -0.44 | -0.36 | -0.38 | -0.62 | -1.7 | -5.58 |
| 34.3 | -2.5 | -2 | -2.5 | -1.67 | -1.25 | -1.4 | -1 | -0.89 | -0.75 | -0.75 | -0.64 | -0.61 | -0.48 | -0.41 | -0.31 | -0.28 | -0.46 | -1.39 | -4.92 |
| 31.3 | -4 | -2 | -3 | -1.67 | -1.5 | -1.2 | -0.86 | -0.89 | -0.75 | -0.69 | -0.68 | -0.58 | -0.43 | -0.31 | -0.16 | -0.03 | -0.05 | -0.67 | -3.46 |
| 28.3 | -5 | -2 | -2.5 | -1.67 | -1.5 | -1.2 | -1.17 | -1 | -0.82 | -0.73 | -0.67 | -0.53 | -0.4 | -0.22 | -0.03 | 0.129 | 0.147 | -0.33 | -2.69 |
| 25.3 | -2.5 | -2 | -2.5 | -1.67 | -1.25 | -1.2 | -1.17 | -1 | -0.9 | -0.71 | -0.6 | -0.5 | -0.35 | -0.17 | 0.017 | 0.169 | 0.186 | -0.29 | -2.6 |
| 22.3 | -1.5 | -1.5 | -2 | -1.33 | -2 | -1.5 | -1.17 | -1.14 | -0.89 | -0.85 | -0.61 | -0.46 | -0.31 | -0.16 | -0.02 | 0.111 | 0.066 | -0.54 | -3.28 |
| 19.3 | -2 | -1.5 | -3 | -1.67 | -1.67 | -1.5 | -1.2 | -1.17 | -1 | -0.82 | -0.73 | -0.5 | -0.33 | -0.15 | -0.05 | -0.02 | -0.2 | -1.15 | -5.2 |

## 2-Row Dimming Analysis

March 21 at Noon – Overcast

Dimming levels – Critical point

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55.3 | -0.43 | -0.13 | 0 | 0.364 | -0.07 | 0.278 | 0.5 | 0.452 | 0.581 | 0.576 | 0.602 | 0.672 | 0.634 | 0.584 | 0.405 | 0.048 | -0.56 | -2.09 | -7.12 |
| 52.3 | -0.43 | 0.25 | 0 | 0.333 | 0.267 | 0.368 | 0.52 | 0.529 | 0.574 | 0.594 | 0.683 | 0.732 | 0.772 | 0.72 | 0.526 | 0.225 | -0.19 | -1.28 | -5.36 |
| 49.3 | -0.14 | -0.13 | 0.3 | 0.333 | 0.333 | 0.4 | 0.519 | 0.556 | 0.596 | 0.692 | 0.738 | 0.794 | 0.824 | 0.787 | 0.616 | 0.348 | 0.084 | -0.69 | -3.92 |
| 46.3 | -0.29 | 0.25 | 0.1 | 0.25 | 0.25 | 0.4 | 0.5 | 0.553 | 0.618 | 0.671 | 0.743 | 0.807 | 0.841 | 0.803 | 0.636 | 0.401 | 0.174 | -0.5 | -3.36 |
| 43.3 | -0.29 | 0.25 | 0.2 | 0.25 | 0.375 | 0.429 | 0.536 | 0.564 | 0.614 | 0.667 | 0.73 | 0.801 | 0.833 | 0.798 | 0.626 | 0.381 | 0.142 | -0.53 | -3.33 |
| 40.3 | 0 | 0.25 | 0.2 | 0.333 | 0.438 | 0.429 | 0.483 | 0.55 | 0.614 | 0.671 | 0.714 | 0.77 | 0.792 | 0.745 | 0.568 | 0.298 | -0.01 | -0.82 | -3.91 |
| 37.3 | -0.17 | 0 | 0.222 | 0.333 | 0.438 | 0.476 | 0.483 | 0.55 | 0.614 | 0.651 | 0.696 | 0.733 | 0.743 | 0.679 | 0.502 | 0.212 | -0.2 | -1.22 | -4.54 |
| 34.3 | -0.2 | 0.143 | 0.111 | 0.333 | 0.375 | 0.429 | 0.5 | 0.564 | 0.625 | 0.663 | 0.714 | 0.745 | 0.757 | 0.702 | 0.527 | 0.265 | -0.1 | -0.98 | -4 |
| 31.3 | -0.2 | 0.143 | 0.111 | 0.25 | 0.333 | 0.45 | 0.556 | 0.579 | 0.625 | 0.679 | 0.731 | 0.784 | 0.817 | 0.778 | 0.617 | 0.393 | 0.163 | -0.45 | -2.89 |
| 28.3 | -0.2 | 0.143 | 0.111 | 0.273 | 0.357 | 0.474 | 0.5 | 0.568 | 0.63 | 0.69 | 0.75 | 0.815 | 0.848 | 0.818 | 0.674 | 0.477 | 0.306 | -0.18 | -2.28 |
| 25.3 | -0.2 | 0.143 | 0.125 | 0.273 | 0.357 | 0.389 | 0.48 | 0.559 | 0.608 | 0.696 | 0.759 | 0.821 | 0.856 | 0.828 | 0.691 | 0.499 | 0.333 | -0.15 | -2.2 |
| 22.3 | 0 | 0.333 | 0.125 | 0.3 | 0.308 | 0.412 | 0.435 | 0.516 | 0.622 | 0.657 | 0.752 | 0.807 | 0.842 | 0.807 | 0.666 | 0.472 | 0.251 | -0.35 | -2.75 |
| 19.3 | 0 | 0.167 | 0 | 0.2 | 0.333 | 0.333 | 0.45 | 0.519 | 0.564 | 0.632 | 0.701 | 0.759 | 0.782 | 0.751 | 0.619 | 0.415 | 0.098 | -0.78 | -4.21 |

## 1-Row Dimming Analysis

March 21 at Noon – Clear sky

Dimming levels – Critical point

| | -14.2 | -11.2 | -8.2 | -5.2 | -2.2 | 0.8 | 3.8 | 6.8 | 9.8 | 12.8 | 15.8 | 18.8 | 21.8 | 24.8 | 27.8 | 30.8 | 33.8 | 36.8 | 39.8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55.3 | -2.5 | -2 | -1.67 | -1 | -1.75 | -1.2 | -0.83 | -0.87 | -0.6 | -0.69 | -0.61 | -0.46 | -0.45 | -0.33 | -0.23 | -0.2 | -0.33 | -0.9 | -2.79 |
| 52.3 | -2.5 | -1.5 | -1.67 | -1 | -1 | -1 | -0.83 | -0.75 | -0.64 | -0.64 | -0.53 | -0.42 | -0.3 | -0.18 | -0.01 | 0.144 | 0.178 | -0.13 | -1.47 |
| 49.3 | -2 | -2.5 | -1 | -1.33 | -1 | -1 | -0.71 | -0.67 | -0.64 | -0.47 | -0.4 | -0.32 | -0.22 | -0.05 | 0.159 | 0.344 | 0.446 | 0.258 | -0.72 |
| 46.3 | -2 | -1.5 | -1.33 | -1.33 | -1.25 | -1 | -0.71 | -0.67 | -0.58 | -0.6 | -0.43 | -0.27 | -0.14 | 0.029 | 0.231 | 0.441 | 0.532 | 0.377 | -0.45 |
| 43.3 | -2 | -1.5 | -1.33 | -1.33 | -1.25 | -1 | -0.71 | -0.67 | -0.58 | -0.5 | -0.41 | -0.23 | -0.09 | 0.069 | 0.248 | 0.434 | 0.521 | 0.376 | -0.41 |
| 40.3 | -2 | -1.5 | -1.33 | -1.33 | -1 | -1 | -0.86 | -0.78 | -0.5 | -0.44 | -0.36 | -0.23 | -0.09 | 0.043 | 0.212 | 0.362 | 0.434 | 0.256 | -0.61 |
| 37.3 | -2 | -2 | -1.33 | -1.33 | -1 | -1 | -0.86 | -0.67 | -0.58 | -0.5 | -0.32 | -0.19 | -0.07 | 0.044 | 0.181 | 0.273 | 0.287 | 0.051 | -0.84 |
| 34.3 | -2 | -1.5 | -2 | -1.33 | -1 | -1 | -0.71 | -0.56 | -0.5 | -0.38 | -0.27 | -0.16 | -0.02 | 0.087 | 0.224 | 0.335 | 0.353 | 0.147 | -0.7 |
| 31.3 | -3 | -1.5 | -2.5 | -1.33 | -1 | -0.8 | -0.57 | -0.56 | -0.42 | -0.31 | -0.27 | -0.13 | 0.022 | 0.169 | 0.31 | 0.46 | 0.53 | 0.39 | -0.32 |
| 28.3 | -4 | -1.5 | -2 | -1 | -1.25 | -0.8 | -0.67 | -0.63 | -0.45 | -0.33 | -0.24 | -0.07 | 0.067 | 0.222 | 0.39 | 0.549 | 0.614 | 0.499 | -0.14 |
| 25.3 | -2 | -1.5 | -1.5 | -1.33 | -1 | -1 | -0.83 | -0.63 | -0.5 | -0.36 | -0.2 | -0.07 | 0.093 | 0.246 | 0.42 | 0.562 | 0.627 | 0.497 | -0.15 |
| 22.3 | -1.5 | -1 | -1.5 | -1 | -1.33 | -1 | -0.83 | -0.86 | -0.56 | -0.46 | -0.22 | -0.08 | 0.077 | 0.226 | 0.369 | 0.517 | 0.562 | 0.389 | -0.45 |
| 19.3 | -2 | -1.5 | -2 | -1.33 | -1.33 | -1.25 | -1 | -0.83 | -0.63 | -0.45 | -0.33 | -0.14 | 0.03 | 0.173 | 0.305 | 0.411 | 0.415 | 0.145 | -1.16 |

## 2-Row Dimming Analysis

March 21 at Noon – Clear sky

Dimming levels – Critical point

| | -14.2 | -11.2 | -8.2 | -5.2 | -2.2 | 0.8 | 3.8 | 6.8 | 9.8 | 12.8 | 15.8 | 18.8 | 21.8 | 24.8 | 27.8 | 30.8 | 33.8 | 36.8 | 39.8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55.3 | 0 | 0.25 | 0.222 | 0.455 | 0.286 | 0.389 | 0.542 | 0.548 | 0.605 | 0.61 | 0.651 | 0.707 | 0.693 | 0.647 | 0.518 | 0.329 | 0.07 | -0.47 | -2.01 |
| 52.3 | 0 | 0.25 | 0.2 | 0.417 | 0.4 | 0.474 | 0.56 | 0.559 | 0.617 | 0.652 | 0.721 | 0.774 | 0.805 | 0.77 | 0.644 | 0.504 | 0.369 | 0.045 | -1.1 |
| 49.3 | 0.143 | 0.125 | 0.4 | 0.417 | 0.467 | 0.5 | 0.556 | 0.611 | 0.635 | 0.718 | 0.77 | 0.826 | 0.857 | 0.838 | 0.732 | 0.609 | 0.55 | 0.345 | -0.52 |
| 46.3 | 0.143 | 0.375 | 0.3 | 0.417 | 0.375 | 0.5 | 0.571 | 0.605 | 0.655 | 0.718 | 0.786 | 0.847 | 0.877 | 0.857 | 0.76 | 0.664 | 0.615 | 0.444 | -0.29 |
| 43.3 | 0.143 | 0.375 | 0.3 | 0.417 | 0.438 | 0.524 | 0.571 | 0.615 | 0.667 | 0.724 | 0.78 | 0.846 | 0.874 | 0.86 | 0.759 | 0.66 | 0.611 | 0.449 | -0.25 |
| 40.3 | 0.167 | 0.25 | 0.3 | 0.417 | 0.5 | 0.524 | 0.552 | 0.6 | 0.667 | 0.729 | 0.767 | 0.825 | 0.848 | 0.827 | 0.734 | 0.624 | 0.555 | 0.36 | -0.39 |
| 37.3 | 0 | 0.143 | 0.333 | 0.417 | 0.5 | 0.524 | 0.552 | 0.625 | 0.667 | 0.711 | 0.768 | 0.801 | 0.822 | 0.789 | 0.698 | 0.583 | 0.472 | 0.22 | -0.55 |
| 34.3 | 0 | 0.286 | 0.222 | 0.417 | 0.5 | 0.524 | 0.571 | 0.641 | 0.696 | 0.735 | 0.786 | 0.816 | 0.831 | 0.806 | 0.716 | 0.615 | 0.513 | 0.29 | -0.43 |
| 31.3 | 0 | 0.286 | 0.222 | 0.417 | 0.467 | 0.55 | 0.63 | 0.658 | 0.696 | 0.75 | 0.791 | 0.846 | 0.875 | 0.859 | 0.771 | 0.68 | 0.627 | 0.47 | -0.15 |
| 28.3 | 0 | 0.286 | 0.222 | 0.455 | 0.429 | 0.526 | 0.577 | 0.622 | 0.704 | 0.762 | 0.814 | 0.867 | 0.896 | 0.884 | 0.808 | 0.727 | 0.685 | 0.556 | -0.01 |
| 25.3 | 0 | 0.286 | 0.25 | 0.364 | 0.429 | 0.5 | 0.56 | 0.647 | 0.686 | 0.759 | 0.82 | 0.871 | 0.901 | 0.89 | 0.818 | 0.736 | 0.694 | 0.551 | -0.03 |
| 22.3 | 0.2 | 0.333 | 0.25 | 0.4 | 0.385 | 0.471 | 0.522 | 0.581 | 0.689 | 0.729 | 0.814 | 0.858 | 0.891 | 0.873 | 0.793 | 0.713 | 0.652 | 0.465 | -0.27 |
| 19.3 | 0 | 0.333 | 0.125 | 0.3 | 0.417 | 0.467 | 0.5 | 0.593 | 0.641 | 0.719 | 0.77 | 0.825 | 0.84 | 0.824 | 0.748 | 0.656 | 0.561 | 0.292 | -0.82 |

## 1-Row Dimming Analysis

January 21 at Noon – Overcast

Dimming levels – Critical point

| | -14.2 | -11.2 | -8.2 | -5.2 | -2.2 | 0.8 | 3.8 | 6.8 | 9.8 | 12.8 | 15.8 | 18.8 | 21.8 | 24.8 | 27.8 | 30.8 | 33.8 | 36.8 | 39.8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55.3 | -2 | -1.5 | -1 | -0.33 | -1.5 | -0.8 | -0.17 | -0.37 | -0.1 | -0.23 | -0.17 | -0.04 | -0.09 | -0.02 | 0.015 | -0.1 | -0.42 | -1.56 | -5.54 |
| 52.3 | -2 | -1 | -1 | -0.33 | -0.75 | -0.6 | -0.17 | -0.25 | -0.27 | -0.21 | -0.11 | -0.08 | 0.027 | 0.073 | 0.128 | 0.144 | 0.01 | -0.73 | -3.81 |
| 49.3 | -1.5 | -1.5 | -0.67 | -0.67 | -0.5 | -0.4 | -0.14 | -0.22 | -0.18 | -0.07 | -0.05 | 0 | 0.024 | 0.125 | 0.234 | 0.302 | 0.275 | -0.23 | -2.58 |
| 46.3 | -1.5 | -1 | -0.67 | -1 | -0.75 | -0.6 | -0.14 | -0.22 | -0.17 | -0.2 | -0.1 | -0.03 | 0.068 | 0.143 | 0.248 | 0.365 | 0.355 | -0.08 | -2.13 |
| 43.3 | -1.5 | -1 | -0.67 | -0.67 | -0.5 | -0.4 | -0.29 | -0.22 | -0.17 | -0.13 | -0.14 | 0 | 0.043 | 0.153 | 0.248 | 0.338 | 0.324 | -0.11 | -2.13 |
| 40.3 | -1 | -0.5 | -0.67 | -0.67 | -0.5 | -0.4 | -0.29 | -0.22 | -0.17 | -0.12 | -0.09 | -0.03 | 0.022 | 0.1 | 0.186 | 0.234 | 0.176 | -0.35 | -2.63 |
| 37.3 | -1 | -1.5 | -0.67 | -0.67 | -0.5 | -0.4 | -0.43 | -0.22 | -0.17 | -0.19 | -0.09 | -0.03 | 0.043 | 0.074 | 0.124 | 0.118 | -0.04 | -0.73 | -3.22 |
| 34.3 | -1 | -1 | -1.5 | -0.67 | -0.5 | -0.4 | -0.29 | -0.22 | -0.17 | -0.12 | -0.05 | -0.03 | 0.043 | 0.101 | 0.159 | 0.18 | 0.063 | -0.53 | -2.79 |
| 31.3 | -2 | -1 | -1.5 | -0.67 | -0.5 | -0.4 | -0.14 | -0.22 | -0.17 | -0.06 | -0.09 | -0.03 | 0.065 | 0.155 | 0.259 | 0.345 | 0.325 | -0.07 | -1.86 |
| 28.3 | -3 | -1 | -1 | -0.67 | -0.75 | -0.4 | -0.33 | -0.25 | -0.09 | -0.13 | -0.05 | 0 | 0.111 | 0.222 | 0.333 | 0.442 | 0.456 | 0.15 | -1.37 |
| 25.3 | -1.5 | -1 | -1 | -0.67 | -0.5 | -0.4 | -0.33 | -0.25 | -0.2 | -0.14 | 0 | 0.036 | 0.14 | 0.261 | 0.37 | 0.466 | 0.479 | 0.171 | -1.3 |
| 22.3 | -0.5 | -0.5 | -1 | -0.67 | -0.67 | -0.5 | -0.33 | -0.43 | -0.22 | -0.15 | 0 | 0.038 | 0.154 | 0.242 | 0.35 | 0.433 | 0.4 | 0.013 | -1.74 |
| 19.3 | -1 | -1 | -1.5 | -0.67 | -0.67 | -0.5 | -0.4 | -0.33 | -0.25 | -0.18 | -0.07 | 0.045 | 0.152 | 0.25 | 0.329 | 0.349 | 0.23 | -0.37 | -2.96 |

## 2-Row Dimming Analysis

January 21 at Noon – Overcast

Dimming levels – Critical point

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55.3 | 0.143 | 0.375 | 0.444 | 0.636 | 0.357 | 0.556 | 0.667 | 0.645 | 0.744 | 0.729 | 0.747 | 0.793 | 0.765 | 0.734 | 0.619 | 0.389 | 0.006 | -0.98 | -4.19 |
| 52.3 | 0.143 | 0.5 | 0.3 | 0.583 | 0.533 | 0.579 | 0.72 | 0.706 | 0.723 | 0.739 | 0.798 | 0.829 | 0.854 | 0.819 | 0.696 | 0.504 | 0.24 | -0.46 | -3.07 |
| 49.3 | 0.286 | 0.25 | 0.5 | 0.583 | 0.6 | 0.6 | 0.667 | 0.722 | 0.731 | 0.808 | 0.833 | 0.867 | 0.885 | 0.865 | 0.756 | 0.584 | 0.414 | -0.08 | -2.15 |
| 46.3 | 0.286 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.679 | 0.711 | 0.764 | 0.788 | 0.836 | 0.876 | 0.899 | 0.874 | 0.765 | 0.618 | 0.47 | 0.037 | -1.79 |
| 43.3 | 0.143 | 0.5 | 0.5 | 0.5 | 0.562 | 0.667 | 0.714 | 0.718 | 0.754 | 0.793 | 0.823 | 0.874 | 0.892 | 0.87 | 0.759 | 0.603 | 0.449 | 0.02 | -1.77 |
| 40.3 | 0.333 | 0.5 | 0.4 | 0.583 | 0.625 | 0.667 | 0.655 | 0.7 | 0.754 | 0.788 | 0.812 | 0.853 | 0.866 | 0.838 | 0.725 | 0.55 | 0.356 | -0.16 | -2.14 |
| 37.3 | 0.333 | 0.429 | 0.444 | 0.583 | 0.625 | 0.667 | 0.655 | 0.7 | 0.737 | 0.771 | 0.808 | 0.827 | 0.836 | 0.795 | 0.681 | 0.495 | 0.229 | -0.42 | -2.55 |
| 34.3 | 0.4 | 0.429 | 0.444 | 0.583 | 0.625 | 0.619 | 0.679 | 0.744 | 0.768 | 0.783 | 0.817 | 0.837 | 0.845 | 0.809 | 0.696 | 0.529 | 0.294 | -0.27 | -2.2 |
| 31.3 | 0.2 | 0.429 | 0.333 | 0.5 | 0.6 | 0.65 | 0.704 | 0.737 | 0.75 | 0.798 | 0.828 | 0.859 | 0.884 | 0.857 | 0.754 | 0.612 | 0.464 | 0.073 | -1.49 |
| 28.3 | 0.2 | 0.429 | 0.444 | 0.545 | 0.571 | 0.684 | 0.692 | 0.703 | 0.759 | 0.798 | 0.836 | 0.88 | 0.901 | 0.884 | 0.79 | 0.665 | 0.556 | 0.244 | -1.1 |
| 25.3 | 0.2 | 0.429 | 0.5 | 0.455 | 0.571 | 0.611 | 0.64 | 0.706 | 0.745 | 0.81 | 0.85 | 0.883 | 0.906 | 0.89 | 0.802 | 0.678 | 0.573 | 0.263 | -1.05 |
| 22.3 | 0.4 | 0.667 | 0.5 | 0.5 | 0.538 | 0.588 | 0.652 | 0.677 | 0.756 | 0.786 | 0.841 | 0.878 | 0.901 | 0.876 | 0.787 | 0.663 | 0.519 | 0.136 | -1.4 |
| 19.3 | 0.4 | 0.5 | 0.375 | 0.5 | 0.583 | 0.6 | 0.65 | 0.704 | 0.718 | 0.772 | 0.805 | 0.847 | 0.859 | 0.841 | 0.757 | 0.625 | 0.422 | -0.14 | -2.34 |

## 1-Row Dimming Analysis

January 21 at Noon – Clear sky

Dimming levels – Critical point

| | -14.2 | -11.2 | -8.2 | -5.2 | -2.2 | 0.8 | 3.8 | 6.8 | 9.8 | 12.8 | 15.8 | 18.8 | 21.8 | 24.8 | 27.8 | 30.8 | 33.8 | 36.8 | 39.8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55.3 | -2 | -2 | -1.33 | -1 | -1.5 | -1.2 | -0.83 | -0.87 | -0.7 | -0.77 | -0.67 | -0.54 | -0.55 | -0.46 | -0.38 | -0.41 | -0.61 | -1.46 | -4.97 |
| 52.3 | -2.5 | -2 | -1.67 | -1.33 | -1.25 | -1 | -0.83 | -0.87 | -0.73 | -0.71 | -0.58 | -0.5 | -0.41 | -0.31 | -0.15 | 0 | 0.019 | -0.38 | -1.98 |
| 49.3 | -2 | -2.5 | -1.33 | -1.33 | -1.25 | -1 | -0.86 | -0.78 | -0.73 | -0.53 | -0.5 | -0.43 | -0.32 | -0.14 | 0.065 | 0.266 | 0.373 | 0.171 | -0.82 |
| 46.3 | -2 | -1.5 | -1.33 | -1.33 | -1.25 | -1.2 | -0.71 | -0.67 | -0.67 | -0.67 | -0.52 | -0.33 | -0.23 | -0.03 | 0.174 | 0.401 | 0.5 | 0.355 | -0.41 |
| 43.3 | -2 | -1.5 | -1.33 | -1.67 | -1.25 | -1 | -0.71 | -0.67 | -0.67 | -0.56 | -0.45 | -0.29 | -0.15 | 0.028 | 0.215 | 0.411 | 0.512 | 0.383 | -0.31 |
| 40.3 | -2 | -1.5 | -1.33 | -1.33 | -1 | -1 | -0.86 | -0.78 | -0.58 | -0.5 | -0.41 | -0.29 | -0.13 | 0.029 | 0.195 | 0.356 | 0.438 | 0.281 | -0.46 |
| 37.3 | -2 | -2 | -1.33 | -1.33 | -1 | -1 | -0.86 | -0.67 | -0.58 | -0.5 | -0.36 | -0.23 | -0.09 | 0.044 | 0.181 | 0.28 | 0.305 | 0.094 | -0.66 |
| 34.3 | -2 | -1.5 | -2.5 | -1.33 | -1 | -1 | -0.71 | -0.67 | -0.5 | -0.44 | -0.27 | -0.19 | -0.04 | 0.087 | 0.224 | 0.347 | 0.37 | 0.179 | -0.55 |
| 31.3 | -4 | -1.5 | -2.5 | -1.33 | -1.25 | -0.8 | -0.57 | -0.56 | -0.5 | -0.37 | -0.32 | -0.16 | 0.022 | 0.169 | 0.319 | 0.475 | 0.543 | 0.41 | -0.23 |
| 28.3 | -4 | -1.5 | -2 | -1.33 | -1.25 | -1 | -0.83 | -0.63 | -0.55 | -0.4 | -0.29 | -0.1 | 0.044 | 0.222 | 0.398 | 0.558 | 0.622 | 0.509 | -0.08 |
| 25.3 | -2 | -1.5 | -2 | -1.33 | -1.25 | -1 | -0.83 | -0.75 | -0.6 | -0.43 | -0.25 | -0.11 | 0.07 | 0.246 | 0.42 | 0.566 | 0.636 | 0.505 | -0.12 |
| 22.3 | -1.5 | -1.5 | -2 | -1.33 | -1.67 | -1.25 | -0.83 | -1 | -0.67 | -0.54 | -0.28 | -0.12 | 0.051 | 0.21 | 0.369 | 0.517 | 0.572 | 0.401 | -0.43 |
| 19.3 | -1.5 | -1.5 | -2.5 | -1.67 | -1.67 | -1.25 | -1.2 | -0.83 | -0.75 | -0.55 | -0.4 | -0.18 | -0.03 | 0.135 | 0.28 | 0.395 | 0.421 | 0.176 | -1.11 |

## 2-Row Dimming Analysis

January 21 at Noon – Clear sky

Dimming levels – Critical point

| | -14.2 | -11.2 | -8.2 | -5.2 | -2.2 | 0.8 | 3.8 | 6.8 | 9.8 | 12.8 | 15.8 | 18.8 | 21.8 | 24.8 | 27.8 | 30.8 | 33.8 | 36.8 | 39.8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55.3 | 0.143 | 0.25 | 0.222 | 0.455 | 0.286 | 0.389 | 0.5 | 0.516 | 0.581 | 0.61 | 0.639 | 0.681 | 0.673 | 0.613 | 0.458 | 0.216 | -0.13 | -0.91 | -3.74 |
| 52.3 | 0 | 0.25 | 0.2 | 0.417 | 0.4 | 0.421 | 0.52 | 0.529 | 0.596 | 0.638 | 0.712 | 0.762 | 0.789 | 0.745 | 0.599 | 0.421 | 0.247 | -0.16 | -1.52 |
| 49.3 | 0.143 | 0.125 | 0.3 | 0.333 | 0.4 | 0.45 | 0.519 | 0.583 | 0.615 | 0.705 | 0.762 | 0.817 | 0.849 | 0.824 | 0.702 | 0.562 | 0.494 | 0.271 | -0.6 |
| 46.3 | 0.143 | 0.25 | 0.3 | 0.333 | 0.375 | 0.45 | 0.536 | 0.605 | 0.655 | 0.694 | 0.771 | 0.839 | 0.87 | 0.849 | 0.744 | 0.64 | 0.589 | 0.425 | -0.26 |
| 43.3 | 0.143 | 0.25 | 0.3 | 0.333 | 0.438 | 0.476 | 0.571 | 0.615 | 0.649 | 0.713 | 0.773 | 0.837 | 0.869 | 0.854 | 0.751 | 0.649 | 0.604 | 0.456 | -0.16 |
| 40.3 | 0 | 0.25 | 0.3 | 0.417 | 0.5 | 0.476 | 0.517 | 0.575 | 0.667 | 0.718 | 0.759 | 0.816 | 0.845 | 0.822 | 0.728 | 0.624 | 0.561 | 0.382 | -0.26 |
| 37.3 | 0 | 0.143 | 0.222 | 0.333 | 0.438 | 0.524 | 0.517 | 0.6 | 0.649 | 0.711 | 0.76 | 0.796 | 0.818 | 0.786 | 0.698 | 0.59 | 0.482 | 0.255 | -0.4 |
| 34.3 | -0.2 | 0.143 | 0.111 | 0.333 | 0.438 | 0.476 | 0.571 | 0.641 | 0.679 | 0.723 | 0.778 | 0.811 | 0.831 | 0.806 | 0.72 | 0.622 | 0.525 | 0.32 | -0.31 |
| 31.3 | 0 | 0.286 | 0.111 | 0.333 | 0.4 | 0.55 | 0.593 | 0.632 | 0.679 | 0.75 | 0.791 | 0.841 | 0.875 | 0.859 | 0.774 | 0.689 | 0.637 | 0.485 | -0.07 |
| 28.3 | -0.2 | 0.143 | 0.222 | 0.364 | 0.357 | 0.526 | 0.577 | 0.622 | 0.704 | 0.75 | 0.807 | 0.867 | 0.896 | 0.886 | 0.81 | 0.732 | 0.691 | 0.562 | 0.041 |
| 25.3 | -0.2 | 0.143 | 0.25 | 0.273 | 0.357 | 0.444 | 0.52 | 0.618 | 0.686 | 0.759 | 0.82 | 0.871 | 0.901 | 0.89 | 0.818 | 0.738 | 0.7 | 0.558 | 0.003 |
| 22.3 | 0 | 0.333 | 0.25 | 0.3 | 0.308 | 0.412 | 0.522 | 0.548 | 0.667 | 0.714 | 0.805 | 0.858 | 0.888 | 0.87 | 0.793 | 0.713 | 0.66 | 0.476 | -0.26 |
| 19.3 | 0 | 0.167 | 0.125 | 0.2 | 0.333 | 0.4 | 0.45 | 0.556 | 0.615 | 0.702 | 0.759 | 0.818 | 0.835 | 0.816 | 0.739 | 0.652 | 0.561 | 0.318 | -0.77 |

## 1-Row Dimming Analysis

May 21 at Noon – Overcast

Dimming levels – Critical point

| | -14.2 | -11.2 | -8.2 | -5.2 | -2.2 | 0.8 | 3.8 | 6.8 | 9.8 | 12.8 | 15.8 | 18.8 | 21.8 | 24.8 | 27.8 | 30.8 | 33.8 | 36.8 | 39.8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55.3 | -5 | -4.5 | -2.67 | -2 | -3.75 | -2.4 | -1.5 | -1.75 | -1.2 | -1.38 | -1.28 | -1 | -1.15 | -0.98 | -0.91 | -1.15 | -1.79 | -4.02 | -11.9 |
| 52.3 | -5.5 | -3 | -3 | -2 | -2.25 | -2 | -1.5 | -1.5 | -1.36 | -1.43 | -1.16 | -1.12 | -0.89 | -0.8 | -0.71 | -0.68 | -0.95 | -2.4 | -8.47 |
| 49.3 | -4 | -4.5 | -2 | -2.33 | -2 | -1.8 | -1.43 | -1.33 | -1.36 | -1.07 | -1.05 | -1 | -0.93 | -0.73 | -0.51 | -0.38 | -0.43 | -1.41 | -6.04 |
| 46.3 | -4.5 | -2.5 | -2.67 | -2.67 | -2.5 | -2 | -1.43 | -1.44 | -1.25 | -1.33 | -1.14 | -1 | -0.86 | -0.69 | -0.47 | -0.25 | -0.27 | -1.13 | -5.16 |
| 43.3 | -4 | -3 | -2.33 | -2.67 | -2 | -1.8 | -1.43 | -1.33 | -1.25 | -1.25 | -1.18 | -1 | -0.87 | -0.68 | -0.48 | -0.3 | -0.33 | -1.18 | -5.17 |
| 40.3 | -3 | -2.5 | -2.33 | -2.33 | -2 | -2 | -1.57 | -1.44 | -1.25 | -1.25 | -1.18 | -1.06 | -0.91 | -0.76 | -0.59 | -0.51 | -0.62 | -1.66 | -6.14 |
| 37.3 | -3 | -3 | -2.33 | -2.33 | -2 | -1.8 | -1.57 | -1.44 | -1.33 | -1.25 | -1.14 | -1.03 | -0.89 | -0.81 | -0.71 | -0.74 | -1.04 | -2.4 | -7.28 |
| 34.3 | -3 | -3 | -3.5 | -2.33 | -2 | -2 | -1.57 | -1.33 | -1.25 | -1.19 | -1.09 | -1.03 | -0.87 | -0.75 | -0.64 | -0.62 | -0.84 | -2 | -6.45 |
| 31.3 | -6 | -2.5 | -4 | -2.33 | -2 | -1.8 | -1.43 | -1.33 | -1.25 | -1.13 | -1.14 | -0.97 | -0.8 | -0.65 | -0.46 | -0.29 | -0.32 | -1.1 | -4.62 |
| 28.3 | -6 | -3 | -3.5 | -2.33 | -2.25 | -1.8 | -1.67 | -1.5 | -1.27 | -1.2 | -1.1 | -0.93 | -0.76 | -0.54 | -0.3 | -0.09 | -0.07 | -0.67 | -3.65 |
| 25.3 | -3 | -2.5 | -3 | -2.33 | -2 | -1.8 | -1.67 | -1.5 | -1.4 | -1.21 | -1 | -0.89 | -0.7 | -0.48 | -0.24 | -0.05 | -0.02 | -0.63 | -3.53 |
| 22.3 | -2.5 | -2 | -3 | -2 | -2.67 | -2 | -1.67 | -1.71 | -1.44 | -1.31 | -1 | -0.85 | -0.67 | -0.47 | -0.28 | -0.12 | -0.18 | -0.94 | -4.39 |
| 19.3 | -2.5 | -2.5 | -4 | -2.33 | -2.33 | -2.25 | -1.8 | -1.83 | -1.63 | -1.36 | -1.13 | -0.91 | -0.7 | -0.46 | -0.33 | -0.28 | -0.51 | -1.7 | -6.8 |

## 2-Row Dimming Analysis

May 21 at Noon – Overcast

Dimming levels – Critical point

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55.3 | -0.71 | -0.38 | -0.22 | 0.182 | -0.29 | 0.111 | 0.375 | 0.323 | 0.465 | 0.458 | 0.506 | 0.586 | 0.542 | 0.48 | 0.25 | -0.2 | -0.96 | -2.89 | -9.21 |
| 52.3 | -0.86 | 0 | -0.3 | 0.167 | 0.133 | 0.211 | 0.4 | 0.412 | 0.447 | 0.493 | 0.606 | 0.665 | 0.711 | 0.649 | 0.405 | 0.025 | -0.49 | -1.88 | -7.01 |
| 49.3 | -0.43 | -0.37 | 0.1 | 0.167 | 0.2 | 0.25 | 0.37 | 0.444 | 0.5 | 0.603 | 0.667 | 0.743 | 0.776 | 0.732 | 0.518 | 0.18 | -0.15 | -1.13 | -5.2 |
| 46.3 | -0.57 | 0 | -0.1 | 0.083 | 0.125 | 0.25 | 0.393 | 0.421 | 0.527 | 0.588 | 0.679 | 0.759 | 0.8 | 0.754 | 0.543 | 0.247 | -0.04 | -0.89 | -4.49 |
| 43.3 | -0.57 | 0 | 0 | 0.083 | 0.188 | 0.333 | 0.393 | 0.462 | 0.526 | 0.586 | 0.66 | 0.748 | 0.788 | 0.745 | 0.529 | 0.219 | -0.08 | -0.93 | -4.46 |
| 40.3 | -0.33 | 0 | 0 | 0.167 | 0.25 | 0.286 | 0.345 | 0.425 | 0.526 | 0.576 | 0.639 | 0.705 | 0.738 | 0.68 | 0.456 | 0.118 | -0.27 | -1.29 | -5.18 |
| 37.3 | -0.33 | -0.14 | 0 | 0.167 | 0.25 | 0.286 | 0.345 | 0.45 | 0.509 | 0.554 | 0.624 | 0.665 | 0.677 | 0.597 | 0.368 | 0.011 | -0.51 | -1.79 | -5.97 |
| 34.3 | -0.4 | -0.14 | -0.11 | 0.083 | 0.25 | 0.286 | 0.393 | 0.462 | 0.518 | 0.578 | 0.635 | 0.679 | 0.697 | 0.628 | 0.405 | 0.072 | -0.39 | -1.5 | -5.29 |
| 31.3 | -0.4 | 0 | -0.11 | 0.083 | 0.2 | 0.3 | 0.407 | 0.474 | 0.518 | 0.595 | 0.657 | 0.727 | 0.77 | 0.721 | 0.517 | 0.237 | -0.05 | -0.82 | -3.89 |
| 28.3 | -0.6 | -0.14 | -0.11 | 0.091 | 0.143 | 0.316 | 0.385 | 0.432 | 0.537 | 0.607 | 0.686 | 0.767 | 0.81 | 0.77 | 0.59 | 0.34 | 0.127 | -0.49 | -3.13 |
| 25.3 | -0.6 | -0.14 | 0 | 0.091 | 0.143 | 0.222 | 0.36 | 0.441 | 0.529 | 0.62 | 0.699 | 0.775 | 0.819 | 0.783 | 0.609 | 0.369 | 0.161 | -0.45 | -3.02 |
| 22.3 | -0.2 | 0 | -0.12 | 0.1 | 0.077 | 0.235 | 0.304 | 0.387 | 0.511 | 0.571 | 0.681 | 0.756 | 0.801 | 0.759 | 0.58 | 0.337 | 0.058 | -0.7 | -3.72 |
| 19.3 | -0.4 | -0.17 | -0.37 | 0 | 0.083 | 0.2 | 0.3 | 0.37 | 0.436 | 0.544 | 0.621 | 0.701 | 0.728 | 0.69 | 0.518 | 0.263 | -0.14 | -1.24 | -5.56 |

## 1-Row Dimming Analysis

May 21 at Noon – Clear sky

Dimming levels – Critical point

| | -14.2 | -11.2 | -8.2 | -5.2 | -2.2 | 0.8 | 3.8 | 6.8 | 9.8 | 12.8 | 15.8 | 18.8 | 21.8 | 24.8 | 27.8 | 30.8 | 33.8 | 36.8 | 39.8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55.3 | -2.5 | -2 | -1.33 | -0.67 | -1.75 | -1 | -0.5 | -0.63 | -0.3 | -0.46 | -0.33 | -0.12 | -0.18 | -0.04 | 0.061 | 0.075 | -0.03 | -0.52 | -2.2 |
| 52.3 | -2.5 | -1.5 | -1.33 | -0.67 | -0.75 | -0.8 | -0.5 | -0.5 | -0.45 | -0.36 | -0.21 | -0.12 | 0 | 0.091 | 0.209 | 0.338 | 0.351 | 0.072 | -1.15 |
| 49.3 | -2 | -2 | -1 | -1 | -0.75 | -0.8 | -0.43 | -0.33 | -0.36 | -0.2 | -0.1 | -0.04 | 0.024 | 0.172 | 0.346 | 0.484 | 0.557 | 0.383 | -0.54 |
| 46.3 | -2 | -1 | -1 | -1 | -1 | -0.8 | -0.43 | -0.44 | -0.33 | -0.33 | -0.14 | -0.03 | 0.091 | 0.229 | 0.388 | 0.554 | 0.618 | 0.475 | -0.3 |
| 43.3 | -2 | -1 | -1 | -1 | -0.75 | -0.6 | -0.43 | -0.33 | -0.33 | -0.25 | -0.14 | 0 | 0.109 | 0.25 | 0.397 | 0.539 | 0.604 | 0.467 | -0.28 |
| 40.3 | -1.5 | -1 | -1 | -1 | -0.75 | -0.6 | -0.57 | -0.44 | -0.25 | -0.19 | -0.14 | 0 | 0.087 | 0.214 | 0.354 | 0.473 | 0.524 | 0.351 | -0.47 |
| 37.3 | -1.5 | -1.5 | -1 | -1 | -0.75 | -0.6 | -0.57 | -0.44 | -0.33 | -0.25 | -0.09 | 0 | 0.109 | 0.206 | 0.314 | 0.385 | 0.39 | 0.162 | -0.7 |
| 34.3 | -1.5 | -1.5 | -2 | -1 | -0.75 | -0.6 | -0.43 | -0.33 | -0.25 | -0.19 | -0.05 | 0.032 | 0.13 | 0.232 | 0.336 | 0.425 | 0.437 | 0.238 | -0.57 |
| 31.3 | -3 | -1 | -2 | -1 | -0.75 | -0.4 | -0.29 | -0.33 | -0.25 | -0.12 | -0.09 | 0.032 | 0.152 | 0.282 | 0.405 | 0.53 | 0.587 | 0.453 | -0.22 |
| 28.3 | -3 | -1 | -1.5 | -0.67 | -1 | -0.6 | -0.5 | -0.37 | -0.18 | -0.13 | -0.1 | 0.067 | 0.178 | 0.319 | 0.472 | 0.603 | 0.657 | 0.553 | -0.05 |
| 25.3 | -1.5 | -1 | -1.5 | -1 | -0.75 | -0.6 | -0.5 | -0.37 | -0.3 | -0.14 | -0.05 | 0.071 | 0.209 | 0.348 | 0.487 | 0.607 | 0.666 | 0.55 | -0.05 |
| 22.3 | -1 | -1 | -1.5 | -0.67 | -1 | -0.75 | -0.5 | -0.57 | -0.33 | -0.31 | -0.06 | 0.077 | 0.205 | 0.323 | 0.447 | 0.567 | 0.603 | 0.449 | -0.3 |
| 19.3 | -2 | -1 | -2 | -1 | -1 | -0.75 | -0.6 | -0.5 | -0.38 | -0.18 | -0.13 | 0.045 | 0.152 | 0.288 | 0.402 | 0.473 | 0.47 | 0.212 | -0.92 |

## 2-Row Dimming Analysis

May 21 at Noon – Clear sky

Dimming levels – Critical point

| | -14.2 | -11.2 | -8.2 | -5.2 | -2.2 | 0.8 | 3.8 | 6.8 | 9.8 | 12.8 | 15.8 | 18.8 | 21.8 | 24.8 | 27.8 | 30.8 | 33.8 | 36.8 | 39.8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55.3 | 0 | 0.25 | 0.222 | 0.545 | 0.214 | 0.444 | 0.583 | 0.581 | 0.674 | 0.678 | 0.711 | 0.767 | 0.745 | 0.723 | 0.631 | 0.485 | 0.281 | -0.18 | -1.55 |
| 52.3 | 0 | 0.375 | 0.3 | 0.5 | 0.467 | 0.526 | 0.64 | 0.647 | 0.681 | 0.71 | 0.779 | 0.823 | 0.846 | 0.823 | 0.725 | 0.613 | 0.502 | 0.216 | -0.82 |
| 49.3 | 0.143 | 0.25 | 0.4 | 0.5 | 0.533 | 0.55 | 0.63 | 0.667 | 0.712 | 0.782 | 0.817 | 0.862 | 0.888 | 0.872 | 0.789 | 0.689 | 0.639 | 0.458 | -0.35 |
| 46.3 | 0.143 | 0.375 | 0.4 | 0.5 | 0.5 | 0.55 | 0.643 | 0.684 | 0.727 | 0.765 | 0.829 | 0.876 | 0.901 | 0.886 | 0.809 | 0.732 | 0.686 | 0.532 | -0.16 |
| 43.3 | 0.143 | 0.375 | 0.4 | 0.5 | 0.5 | 0.571 | 0.643 | 0.692 | 0.719 | 0.77 | 0.823 | 0.878 | 0.899 | 0.887 | 0.806 | 0.726 | 0.679 | 0.53 | -0.13 |
| 40.3 | 0.167 | 0.375 | 0.4 | 0.5 | 0.562 | 0.571 | 0.621 | 0.65 | 0.737 | 0.776 | 0.812 | 0.853 | 0.875 | 0.858 | 0.782 | 0.689 | 0.625 | 0.445 | -0.27 |
| 37.3 | 0.167 | 0.286 | 0.444 | 0.5 | 0.563 | 0.619 | 0.621 | 0.675 | 0.719 | 0.759 | 0.808 | 0.832 | 0.851 | 0.821 | 0.747 | 0.647 | 0.548 | 0.311 | -0.44 |
| 34.3 | 0.2 | 0.429 | 0.333 | 0.5 | 0.562 | 0.571 | 0.643 | 0.692 | 0.732 | 0.771 | 0.817 | 0.847 | 0.859 | 0.837 | 0.76 | 0.67 | 0.576 | 0.366 | -0.33 |
| 31.3 | 0.2 | 0.429 | 0.333 | 0.5 | 0.533 | 0.65 | 0.704 | 0.711 | 0.732 | 0.786 | 0.821 | 0.868 | 0.895 | 0.878 | 0.803 | 0.722 | 0.672 | 0.525 | -0.06 |
| 28.3 | 0.2 | 0.286 | 0.333 | 0.545 | 0.5 | 0.632 | 0.654 | 0.676 | 0.759 | 0.798 | 0.836 | 0.888 | 0.911 | 0.899 | 0.833 | 0.759 | 0.72 | 0.601 | 0.071 |
| 25.3 | 0 | 0.286 | 0.375 | 0.455 | 0.5 | 0.556 | 0.64 | 0.676 | 0.725 | 0.797 | 0.85 | 0.888 | 0.913 | 0.902 | 0.839 | 0.763 | 0.725 | 0.598 | 0.066 |
| 22.3 | 0.4 | 0.5 | 0.375 | 0.5 | 0.462 | 0.529 | 0.609 | 0.645 | 0.733 | 0.757 | 0.841 | 0.878 | 0.904 | 0.889 | 0.818 | 0.743 | 0.682 | 0.518 | -0.14 |
| 19.3 | 0 | 0.333 | 0.25 | 0.4 | 0.5 | 0.533 | 0.6 | 0.667 | 0.692 | 0.754 | 0.805 | 0.847 | 0.864 | 0.849 | 0.783 | 0.696 | 0.602 | 0.348 | -0.62 |

## Electrical Depth One: Energy Efficient Loads

Some parts of the building, including the area next to the façade on every level and the gift shop, utilize inefficient light source such as tungsten halogen. This investigation will not only reduce operating cost of electricity and lamps replacement in the long run, but also allow for smaller equipment sizes; hence, the initial cost is reduced. Proposed luminaires and light sources are carefully specified to maintain the integrity of the original lighting design. Compact fluorescent downlight is chosen to replace MR-16 halogen downlight to maintain relatively the same light output and dimming capability. High efficacy T4.5 ceramic metal halide source is specifies for the gift shop to replace PAR30 track head. Ceramic metal halide sources are generally produce high intensity light which is desirable in retail setting. These changes affect total of seven lighting panelboards which result in modification for the feeders and the conduits.

### Fixture L5 Replacement

| | Fixture Type | Description | Input Watts | Lumens (initial) | Spacing Criterion | Efficiency | Dimmable |
|---|---|---|---|---|---|---|---|
| Existing | L5 | 4" Recessed MR-16 Downlight | 50 | 880 | .4 | 93.9 | YES |
| Proposing | L5 ALT | 6" Recessed T(T4) Compact Fluorescent | 24 | 1250 | .7 | 51.8 | YES |

### Gift Shop, Fixture A and B Replacement

| | Fixture Type | Description | Input Watts | Lumens (initial) | Spacing Criterion | Efficiency | Dimmable |
|---|---|---|---|---|---|---|---|
| Existing | A | PAR30 Track head | 50 | 660 | n/a | n/a | YES |
| Proposing | A ALT | T4.5 Ceramic Metal Halide Track head | 23 | 1700 | n/a | 55 | NO |
| Existing | B | Recessed 2 lamps PAR30 Adjustable Downlight | 100 | 1320 | n/a | n/a | YES |
| Proposing | B ALT | T4.5 Ceramic Metal Halide Adjustable Recessed Downlight | 23 | 1700 | n/a | n/a | NO |

## Panelboard Schedule

The following panelboards have been modified with more energy efficient loads. Highlighted in green is the circuit with energy efficient lighting load. Summary is shown at the bottom of the panelboard schedule to illustrate the total energy saving from the particular panel.

PANELBOARD SCHEDULE

Designation: **L1** Main Type: 100 MB
Voltage: 208/120V, 3PH, 4W Bus Amps: 100 Amps
Fed From: 0G-1

AVAILABLE FAULT CURRENT: 42,000 AMPS

| CCT No. | Load Description | Load A | Load B | Load C | C/B Size | C/B Size | Load A | Load B | Load C | Load Description | CCT No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | L01, L09, L29 | 1120 | | | 20A | 20A | 980 | | | 101,103,104,108 | 2 |
| 3 | L02,L03,L05,L06,L10 | | 1050 | | 20A | 20A | | 1090 | | 106,112 | 4 |
| 5 | L11,L13 | | | 1260 | 20A | 20A | | | 800 | 102,107,109 | 6 |
| 7 | L12,L14,L29 | 420 | | | 20A | 20A | 345 | | | GIFT SHOP 114 - (15) Fixture Type B ALT | 8 |
| 9 | L07,L08,L27 | | 270 | | 20A | 20A | | 345 | | GIFT SHOP 114 - (15) Fixture Type B ALT | 10 |
| 11 | GIFT SHOP 114 - (5) Fixture Type A ALT | | | 115 | 20A | 20A | | | 300 | GIFT SHOP 114 - (6) D1 (SW-5) | 12 |
| 13 | GIFT SHOP 114 - (5) Fixture Type A ALT | 115 | | | 20A | 20A | | | | | 14 |
| 15 | GIFT SHOP 114 - (5) Fixture Type A ALT | | 115 | | 20A | 20A | | 560 | | 117 (SECURITY DESK - L34a) | 16 |
| 17 | SPARE | | | | 20A | 20A | | | 600 | GIFT SHOP 114 - LV JB (SW-7) | 18 |
| 19 | L04 | 560 | | | 20A | 20A | 600 | | | GIFT SHOP 114 - LV JB (SW-7) | 20 |
| 21 | 2nd Fl BOH | | 770 | | 20A | 20A | | 600 | | GIFT SHOP 114 - LV JB (SW-6) | 22 |
| 23 | SPARE | | | | 20A | 20A | | | 600 | GIFT SHOP 114 - LV JB (SW-6) | 24 |
| 25 | 219 | 480 | | | 20A | 20A | 600 | | | GIFT SHOP 114 - LV JB (SW-8) | 26 |
| 27 | SPARE | | | | 20A | 20A | | | | | 28 |
| 29 | 2nd Fl BOH | | | 300 | 20A | 20A | | | | | 30 |
| 31 | GIFT SHOP 114 - (5) Fixture Type A ALT | 115 | | | 20A | 20A | 375 | | | 118,119,120,121 | 32 |
| 33 | GIFT SHOP 114 - (5) Fixture Type A ALT | | 115 | | 20A | 20A | | | | | 34 |
| 35 | GIFT SHOP 114 - (5) Fixture Type A ALT | | | 115 | 20A | 20A | | | | | 36 |
| 37 | GIFT SHOP 114 - (5) Fixture Type A ALT | 115 | | | 20A | 20A | | | | | 38 |
| 39 | GIFT SHOP 114 - (6) Fixture Type A ALT | | 138 | | 20A | 20A | | | | | 40 |
| 41 | | | | | 20A | 20A | | | | | 42 |
| | Total: | 2925 | 2458 | 1790 | | | 2900 | 2595 | 2300 | | |

| | | | | | |
|---|---|---|---|---|---|
| Total Phase A | 5825 | va | Panel Total: | 15 | kVA |
| Total Phase B | 5053 | va | Demand Total: | 17 | kVA |
| Total Phase C | 4090 | va | New Lighting Demand | 47 | Amps |
| | | | Original Lighting Demand | 87 | Amps |
| Lighting load | 15 | kVA | Total Energy Saving | **40** | Amps |

Redesigned Branch Circuit
Depth Topic 1 - Reduced Lighting Load

PANELBOARD SCHEDULE

Designation: **L2** Main Type: 100 MB
Voltage: 208/120V, 3PH, 4W Bus Amps: 100 Amps
Fed From: 0G-1

AVAILABLE FAULT CURRENT: 42,000 AMPS

| CCT No. | Load Description | Load A | Load B | Load C | C/B Size | C/B Size | Load A | Load B | Load C | Load Description | CCT No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3RD FLOOR FAÇADE | 200 | | | 20A | 20A | 144 | | | 217 - TRACK (6) CFL | 2 |
| 3 | 3RD FLOOR FAÇADE | | 350 | | 20A | 20A | | 144 | | 217 - TRACK (6) CFL | 4 |
| 5 | 116 FOYER - (4) F7, (2) F1 | | | 269 | 20A | 20A | | | 144 | 217 - TRACK (6) CFL | 6 |
| 7 | 117 FOYER - (15) F7 | 750 | | | 20A | 20A | 144 | | | 217 - TRACK (6) CFL | 8 |
| 9 | 117 FOYER - (15) F7 | | 750 | | 20A | 20A | | 144 | | 217 - TRACK (6) CFL | 10 |
| 11 | 117 SECURITY DESK - L5 - 7 | | | 350 | 20A | 20A | | | 144 | 217 - TRACK (6) CFL | 12 |
| 13 | 122 ENTRY - L5 - 9 | 450 | | | 20A | 20A | 336 | | | 2ND FLOOR FAÇADE (14) CFL | 14 |
| 15 | 216 ELEV LOBBY - F1, F2 | | 322 | | 20A | 20A | | 312 | | 2ND FLOOR FAÇADE (13) CFL | 16 |
| 17 | 2nd Fl Auditorium Lobby Lighting | | | 450 | 20A | 20A | | | 432 | 3RD FLOOR FAÇADE (18) CFL | 18 |
| 19 | 309 ELEV LOBBY - F1, F2 | 299 | | | 20A | 20A | 432 | | | 3RD FLOOR FAÇADE (18) CFL | 20 |
| 21 | 115 FOYER (9) F5 | | 297 | | 20A | 20A | | 297 | | 216 FOYER (9) F5 | 22 |
| 23 | 216, 309 ELEV LOBBY - F8 Power Supply (11) | | | 660 | 20A | 20A | | | 600 | FAÇADE L8 | 24 |
| | Total: | 1699 | 1719 | 1729 | | | 1056 | 897 | 1320 | | |

| | | | | | |
|---|---|---|---|---|---|
| Total Phase A: | 2755 | va | Panel Total: | 8 | kVA |
| Total Phase B: | 2616 | va | Demand Total: | 10 | kVA |
| Total Phase C: | 3049 | va | Demand | 27 | Amps |
| | | | Original Lighting Demand | 54 | Amps |
| Lighting load | 8 | kVA | Total Energy Saving | **27** | Amps |

Redesigned Branch Circuit
Depth Topic 1 - Reduced Lighting Load

PANELBOARD SCHEDULE

Designation: **L3** Main Type: 100 MB
Voltage: 208/120V, 3PH, 4W Bus Amps: 100 Amps
Fed From: 3G-1

AVAILABLE FAULT CURRENT: 22,000 AMPS

| CCT No. | Load Description | Load A | Load B | Load C | C/B Size | C/B Size | Load A | Load B | Load C | Load Description | CCT No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 301 (DRESSING TABLE) | 1275 | | | 20A | 20A | 1050 | | | 402,403,405,406 | 2 |
| 3 | 302,306 | | 540 | | 20A | 20A | | 600 | | 401 | 4 |
| 5 | 307,311,312 | | | 1035 | 20A | 20A | | | 1500 | 408 | 6 |
| 7 | 309 ELEV LOBBY (9) F5 | 297 | | | 20A | 20A | 600 | | | 404 | 8 |
| 9 | SPARE | | | | 20A | 20A | | 600 | | 413 | 10 |
| 11 | 309, ELEV LOBBY (6) F3, (2) F4 | | | 632 | 20A | 20A | | | 600 | 413 (TRACK LIGHTING) | 12 |
| 13 | 309 Power Supply (5), F8 (Sculpture wall) | 300 | | | 20A | 20A | 380 | | | 407,416 | 14 |
| 15 | 309 ELEV LOBBY (11) F9 | | 638 | | 20A | 20A | | 350 | | 416 (COVE) | 16 |
| 17 | | | | | 20A | 20A | | | 280 | 406,411 | 18 |
| 19 | | | | | 20A | 20A | 1000 | | | 412,421,422 | 20 |
| 21 | | | | | 20A | 20A | | 1270 | | 414 | 22 |
| 23 | | | | | 20A | 20A | | | | SPARE | 24 |
| 25 | | | | | 20A | 20A | | | | SPARE | 26 |
| 27 | 313 L22s | | 840 | | 20A | 20A | | 510 | | 417,418,419,420 | 28 |
| 29 | 314 L22s | | | 840 | 20A | 20A | | | 150 | 412, L21s | 30 |
| 31 | 315 | 280 | | | 20A | 20A | | | | | 32 |
| 33 | | | | | 20A | 20A | | | | | 34 |
| 35 | | | | | 20A | 20A | | | | | 36 |
| 37 | | | | | 20A | 20A | | | | | 38 |
| 39 | | | | | 20A | 20A | | | | | 40 |
| 41 | | | | | 20A | 20A | | | | | 42 |
| | Total: | 2152 | 2018 | 2507 | | | 3030 | 3330 | 2530 | | |

| | | | | |
|---|---|---|---|---|
| Total Phase A: | 5182 | va | Panel Total: | 16 kVA |
| Total Phase B: | 5348 | va | Demand Total: | 18 kVA |
| Total Phase C: | 5037 | va | Demand | 49 Amps |
| | | | Original Lighting Demand | 67 Amps |
| Lighting load | 16 | kVA | Total Energy Saving | **18** Amps |

Redesigned Branch Circuit
Depth Topic 1 - Reduced Lighting Load

PANELBOARD SCHEDULE

Designation: **5L-2** Main Type: 100 MB
Voltage: 208/120V, 3PH, 4W Bus Amps: 100 Amps
Fed From: 5G-1

AVAILABLE FAULT CURRENT: 22,000 AMPS

| CCT No. | Load Description | Load A | Load B | Load C | C/B Size | C/B Size | Load A | Load B | Load C | Load Description | CCT No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 423 (FUTURE) | 450 | | | 20A | 20A | 432 | | | 423 (18) CFL | 2 |
| 3 | 423 (FUTURE) | | 450 | | 20A | 20A | | 336 | | 423 (14) CFL | 4 |
| 5 | 423 (FUTURE) | | | 450 | 20A | 20A | | | 360 | 5TH FLOOR FAÇADE (15) CFL | 6 |
| 7 | 423 (FUTURE) | 450 | | | 20A | 20A | 408 | | | 5TH FLOOR FAÇADE (17) CFL | 8 |
| 9 | 423 (FUTURE) | | 450 | | 20A | 20A | | 600 | | 6TH FLOOR FAÇADE (25) CFL | 10 |
| 11 | 423 (FUTURE) | | | 450 | 20A | 20A | | | 456 | 6TH FLOOR FAÇADE (19) CFL | 12 |
| 13 | 423 (FUTURE) | 450 | | | 20A | 20A | 432 | | | 7TH FLOOR FAÇADE (18) CFL | 14 |
| 15 | 423 (FUTURE) | | 450 | | 20A | 20A | | 528 | | 7TH FLOOR FAÇADE (22) CFL | 16 |
| 17 | 423 (FUTURE) | | | 450 | 20A | 20A | | | 528 | 8TH FLOOR FAÇADE (22) CFL | 18 |
| 19 | 423 (FUTURE) | 450 | | | 20A | 20A | 504 | | | 8TH FLOOR FAÇADE (21) CFL | 20 |
| 21 | 423 (FUTURE) | | 450 | | 20A | 20A | | | | 7TH FLOOR FAÇADE | 22 |
| 23 | 423 (FUTURE) | | | 450 | 20A | 20A | | | | 7TH FLOOR FAÇADE | 24 |
| 25 | 423 (FUTURE) | 450 | | | 20A | 20A | | | | 7TH FLOOR FAÇADE | 26 |
| 27 | 423 (FUTURE) | | 450 | | 20A | 20A | | | | 6TH FLOOR FAÇADE | 28 |
| 29 | | | | | 20A | 20A | | | | | 30 |
| 31 | | | | | 20A | 20A | | | | | 32 |
| 33 | | | | | 20A | 20A | | | | | 34 |
| 35 | | | | | 20A | 20A | | | | | 36 |
| 37 | | | | | 20A | 20A | | | | | 38 |
| 39 | | | | | 20A | 20A | | | | | 40 |
| 41 | | | | | 20A | 20A | | | | | 42 |
| | Total: | 2250 | 2250 | 1800 | | | 1776 | 1464 | 1344 | | |

| | | | | |
|---|---|---|---|---|
| Total Phase A | 4026 | va | Panel Total: | 11 kVA |
| Total Phase B | 3714 | va | Demand Total: | 12 kVA |
| Total Phase C | 3144 | va | Demand | 34 Amps |
| | | | Original Lighting Demand | 68 Amps |
| Lighting load | 11 | kVA | Total Energy Saving | **34** Amps |

Branch Circuit Redesign
Depth Topic 1 - Reduced Lighting Load

PANELBOARD SCHEDULE

Designation: **9L-4** Main Type: 100 MB
Voltage: 208/120V, 3PH, 4W Bus Amps: 100 Amps
Fed From: 9G-1

AVAILABLE FAULT CURRENT: 22,000 AMPS

| CCT No. | Load Description | Load A | Load B | Load C | C/B Size | C/B Size | Load A | Load B | Load C | Load Description | CCT No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | SPARE | | | | 20A | 20A | 360 | | | 907 (15) CFL | 2 |
| 3 | 907 (14) CFL | | 336 | | 20A | 20A | | 312 | | 907 (13) CFL | 4 |
| 5 | 907 (12) CFL | | | 288 | 20A | 20A | | | 525 | 907 TRACK | 6 |
| 7 | 907 (18) CFL | 432 | | | 20A | 20A | 525 | | | 907 TRACK | 8 |
| 9 | 907 (18) CFL | | 432 | | 20A | 20A | | 525 | | 907 TRACK | 10 |
| 11 | SPARE | | | | 20A | 20A | | | 525 | 907 TRACK | 12 |
| 13 | SPARE | | | | 20A | 20A | 525 | | | 907 TRACK | 14 |
| 15 | SPARE | | | | 20A | 20A | | 525 | | 907 TRACK | 16 |
| 17 | SPARE | | | | 20A | 20A | | | 525 | 907 TRACK | 18 |
| 19 | SPARE | | | | 20A | 20A | 525 | | | 907 TRACK | 20 |
| 21 | SPARE | | | | 20A | 20A | | | | SPARE | 22 |
| 23 | SPARE | | | | 20A | 20A | | | | SPARE | 24 |
| | Total: | 432 | 768 | 288 | | | 1935 | 1362 | 1575 | | |

| | | | | |
|---|---|---|---|---|
| Total Phase A | 2367 va | Panel Total: | 6 | kVA |
| Total Phase B | 2130 va | Demand Total: | 7 | kVA |
| Total Phase C | 1863 va | Demand | 20 | Amps |
| | | Original Lighting Demand | 30 | Amps |
| Lighting load | 6 kVA | Total Energy Saving | **10** | Amps |

Branch Circuit Redesign
Depth Topic 1 - Reduced Lighting Load

PANELBOARD SCHEDULE

Designation: **9L-7** Main Type: 100 MB
Voltage: 208/120V, 3PH, 4W Bus Amps: 100 Amps
Fed From: 9G-1

AVAILABLE FAULT CURRENT: 22,000 AMPS

| CCT No. | Load Description | Load A | Load B | Load C | C/B Size | C/B Size | Load A | Load B | Load C | Load Description | CCT No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1001 TRACK | 425 | | | 20A | 20A | 425 | | | 1001 TRACK - ATRIUM | 2 |
| 3 | 1001 TRACK | | 425 | | 20A | 20A | | 425 | | 1001 TRACK - ATRIUM | 4 |
| 5 | 1001 TRACK | | | 425 | 20A | 20A | | | 425 | 1001 TRACK - ATRIUM | 6 |
| 7 | 1001 TRACK | 425 | | | 20A | 20A | 425 | | | 1001 TRACK - ATRIUM | 8 |
| 9 | 1001 TRACK | | 425 | | 20A | 20A | | 425 | | 1001 TRACK - ATRIUM | 10 |
| 11 | 1001 TRACK | | | 425 | 20A | 20A | | | 425 | 1001 TRACK - ATRIUM | 12 |
| 13 | 1007 (22) CFL | 528 | | | 20A | 20A | 425 | | | 1001 TRACK - ATRIUM | 14 |
| 15 | 1007 (8) CFL | | 192 | | 20A | 20A | | 425 | | 1001 TRACK - ATRIUM | 16 |
| 17 | 1007 (17) CFL | | | 408 | 20A | 20A | | | 425 | 1001 TRACK - ATRIUM | 18 |
| 19 | SPARE | | | | 20A | 20A | 425 | | | 1001 TRACK - ATRIUM | 20 |
| 21 | SPARE | | | | 20A | 20A | | 425 | | 1001 TRACK - ATRIUM | 22 |
| 23 | SPARE | | | | 20A | 20A | | | 425 | 1001 TRACK - ATRIUM | 24 |
| | Total: | 1378 | 1042 | 1258 | | | 1700 | 1700 | 1700 | | |

| | | | | |
|---|---|---|---|---|
| Total Phase A | 3078 va | Panel Total: | 9 | kVA |
| Total Phase B | 2742 va | Demand Total: | 10 | kVA |
| Total Phase C | 2958 va | Demand | 28 | Amps |
| | | Original Lighting Demand | 35 | Amps |
| Lighting load | 9 kVA | Total Energy Saving | **7** | Amps |

Branch Circuit Redesign
Depth Topic 1 - Reduced Lighting Load

PANELBOARD SCHEDULE

Designation: **9L-9** Main Type: 100 MB
Voltage: 208/120V, 3PH, 4W Bus Amps: 100 Amps
Fed From: 9G-1

AVAILABLE FAULT CURRENT: 22,000 AMPS

| CCT No. | Load Description | Load A | Load B | Load C | C/B Size | C/B Size | Load A | Load B | Load C | Load Description | CCT No. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | SPARE | | | | 20A | 20A | 408 | | | 10TH FLR FAÇADE (17) CFL | 2 |
| 3 | SPARE | | | | 20A | 20A | | 425 | | 1010 TRACK | 4 |
| 5 | SPARE | | | | 20A | 20A | | | 425 | 1010 TRACK | 6 |
| 7 | SPARE | | | | 20A | 20A | 425 | | | 1010 TRACK | 8 |
| 9 | SPARE | | | | 20A | 20A | | 425 | | 1010 TRACK | 10 |
| 11 | SPARE | | | | 20A | 20A | | | 425 | 1010 TRACK | 12 |
| 13 | SPARE | | | | 20A | 20A | 425 | | | 1010 TRACK | 14 |
| 15 | SPARE | | | | 20A | 20A | | 425 | | 1010 TRACK | 16 |
| 17 | SPARE | | | | 20A | 20A | | | 425 | 1010 TRACK | 18 |
| 19 | SPARE | | | | 20A | 20A | 425 | | | 1010 TRACK | 20 |
| 21 | SPARE | | | | 20A | 20A | | 425 | | 1010 TRACK | 22 |
| 23 | SPARE | | | | 20A | 20A | | | | SPARE | 24 |
| | Total: | 0 | 0 | 0 | | | 1683 | 1700 | 1275 | | |

| | | | | |
|---|---|---|---|---|
| Total Phase A | 1683 va | Panel Total: | 5 | kVA |
| Total Phase B | 1700 va | Demand Total: | 5 | kVA |
| Total Phase C | 1275 va | Demand | 15 | Amps |
| | | Original Lighting Demand | 17 | Amps |
| Lighting load | 5 kVA | Total Energy Saving | **2** | Amps |

Branch Circuit Redesign
Depth Topic 1 - Reduced Lighting Load

## Cost and Energy Saving Analysis

According to the electrical power plans, there are electrical rooms on every other floor in the building. In each of the electrical room, the lighting panelboards that feed the new energy efficient lighting loads are located approximately 16 feet away from the general panelboards. Therefore, this number is used to calculate the total cost saving from downsizing the feeders from general panelboard to the lighting panelboard. The table below shows a summary of total costs of each options and the total initial cost saving from switching to the energy efficient lighting loads. However this investigative does not take the initial costs of the luminaires and lamps into account.

| | COST/UNIT (LINEAR FOOT) | QUANTITY (LINEAR FOOT) | TOTAL COST |
|---|---|---|---|
| ORIGINAL DESIGN | 437.92 | 16 | 7006.72 |
| ENERGY EFFICIENT LOADS | 290.71 | 16 | 4651.36 |
| | **TOTAL SAVING ($)** | | **2355.36** |

FIGURE 42: INITIAL COST SAVING SUMMARY FROM DOWNSIZING PANELBOARD FEEDERS

## Original design feeder schedul

**FEEDER SCHEDULE**

| FROM | TO | # OF SET | CONDUIT (PER SET) | | CONDUCTORS (PER SET) | | | | | | | | | SIZE OF OVER CURRENT PROTECTION | FRAME OR SWITCH SIZE | COST/UNIT INCL OVERHEAD / PROFIT | | COST / UNIT (1 CONDUIT + 4 WIRES) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | PHASE CONDUCTORS | | | NEUTRAL CONDUCTORS | | | GROUND | | | | | CONDUIT | WIRE | |
| | | | SIZE | TYPE | No | SIZE | TYPE | No | SIZE | TYPE | No | SIZE | TYPE | | | | | |
| 0G-1 | 0L-1 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 6AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| 0G-1 | 0L-2 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 6AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| 3G-1 | 3L-1 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 6AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| 5G-1 | 5L-1 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 6AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| 5G-1 | 5L-2 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 6AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| 5G-1 | 5L-3 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 6AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| 7G-1 | 7L-1 | 1 | 2" | EMT | 3 | 2/0AWG | CU THWN | 1 | 2/0AWG | CU THWN | 1 | 6AWG | CU THWN | 150 | 100A3P | 11.45 | 5.18 | 32.17 |
| 9G-1 | 9L-1 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 6AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| 9G-1 | 9L-2 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 6AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| 9G-1 | 9L-3 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 6AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| 9G-1 | 9L-4 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 6AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| 9G-1 | 9L-5 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 6AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| 9G-1 | 9L-6 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 6AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| 9G-1 | 9L-7 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 6AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| 9G-1 | 9L-8 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 6AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| 9G-1 | 9L-9 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 6AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| | | | | | | | | | | | | | | | **TOTAL COST/UNIT ($)** | | | **437.92** |

## Feeder schedule for energy efficient lighting loads

**FEEDER SCHEDULE**

| FROM | TO | # OF SET | CONDUIT (PER SET) | | CONDUCTORS (PER SET) | | | | | | | | | SIZE OF OVER CURRENT PROTECTION | FRAME OR SWITCH SIZE | COST/UNIT INCL OVERHEAD / PROFIT | | COST / UNIT (1 CONDUIT + 4 WIRES) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | PHASE CONDUCTORS | | | NEUTRAL CONDUCTORS | | | GROUND | | | | | CONDUIT | WIRE | |
| | | | SIZE | TYPE | No | SIZE | TYPE | No | SIZE | TYPE | No | SIZE | TYPE | | | | | |
| 0G-1 | 0L-1 | 1 | .75" | EMT | 3 | 8AWG | CU THWN | 1 | 8AWG | CU THWN | 1 | 8AWG | CU THWN | 100 | 100A3P | 4.93 | 1.09 | 9.29 |
| 0G-1 | 0L-2 | 1 | .75" | EMT | 3 | 12AWG | CU THWN | 1 | 12AWG | CU THWN | 1 | 8AWG | CU THWN | 100 | 100A3P | 4.93 | 0.625 | 7.43 |
| 3G-1 | 3L-1 | 1 | .75" | EMT | 3 | 8AWG | CU THWN | 1 | 8AWG | CU THWN | 1 | 8AWG | CU THWN | 100 | 100A3P | 4.93 | 1.09 | 9.29 |
| 5G-1 | 5L-1 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 8AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| 5G-1 | 5L-2 | 1 | .75" | EMT | 3 | 10AWG | CU THWN | 1 | 10AWG | CU THWN | 1 | 8AWG | CU THWN | 100 | 100A3P | 4.93 | 0.765 | 7.99 |
| 5G-1 | 5L-3 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 8AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| 7G-1 | 7L-1 | 1 | 1.25" | EMT | 3 | 3AWG | CU THWN | 1 | 3AWG | CU THWN | 1 | 8AWG | CU THWN | 150 | 100A3P | 9.6 | 2.1 | 18 |
| 9G-1 | 9L-1 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 8AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| 9G-1 | 9L-2 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 8AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| 9G-1 | 9L-3 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 8AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| 9G-1 | 9L-4 | 1 | .75" | EMT | 3 | 12AWG | CU THWN | 1 | 12AWG | CU THWN | 1 | 8AWG | CU THWN | 100 | 100A3P | 4.93 | 0.625 | 7.43 |
| 9G-1 | 9L-5 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 8AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| 9G-1 | 9L-6 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 8AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| 9G-1 | 9L-7 | 1 | .75" | EMT | 3 | 10AWG | CU THWN | 1 | 10AWG | CU THWN | 1 | 8AWG | CU THWN | 100 | 100A3P | 4.93 | 0.765 | 7.99 |
| 9G-1 | 9L-8 | 1 | 2" | EMT | 3 | 1AWG | CU THWN | 1 | 1AWG | CU THWN | 1 | 8AWG | CU THWN | 100 | 100A3P | 11.45 | 3.9 | 27.05 |
| 9G-1 | 9L-9 | 1 | .75" | EMT | 3 | 14AWG | CU THWN | 1 | 14AWG | CU THWN | 1 | 8AWG | CU THWN | 100 | 100A3P | 4.93 | 0.49 | 6.89 |
| | | | | | | | | | | | | | | | **TOTAL COST/UNIT ($)** | | | **290.71** |

| PANELBOARD | AMPS SAVING |
|---|---|
| L1 | 40 |
| L2 | 27 |
| L3 | 18 |
| 5L-2 | 34 |
| 9L-4 | 10 |
| 9L-7 | 7 |
| 9L-9 | 2 |
| **TOTAL AMPS SAVING** | 138 |
| **TOTAL VA SAVING** | 16560 |
| 14 hrs/day, 365 days/year @ $0.095 /KW hr | |
| **TOTAL ANNUAL ENERGY (KW hr) SAVING** | 84621.6 |
| **TOTAL ANNUAL ENERGY COST SAVING ($)** | **8039.05** |

## Analysis

By utilizing energy efficient light sources, total electricity of 84,621 Kw-hr can be saved annually, which is the saving of $8,039 of electricity bill every year. Again, the initial costs of the luminaires and lamps are not taken into account. However, the saving from the operating costs shows that the initial costs of the luminaires and lamps would have a very short payback period. Therefore, it is recommended to switch to the suggested luminaires with the energy efficient light sources.

## Electrical Depth Two: Efficient Transformers

The efficient transformers will be investigated and compared to existing transformers in the building. An efficient transformer usually costs more than a typical transformer. However, potential saving may come from long term operating costs. The payback periods will be identified to determine whether or not it would make economic sense to specify these efficient transformers.

In this study, an efficient transformer from Powersmiths will be compared with a status quo transformer. Powersmiths transformers are running at 98.8% efficient during normal operating hours and at 98.4% efficient during non-operating hours. There are total of six transformers in this building. Four of them are connected to the emergency power distribution system. And the other two are connected to normal power distribution system.

| INDIVIDUAL TRANSFORMER SCHEDULE | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Tag** | **Primary Voltage** | **Secondary Voltage** | **Size (kVA)** | **Type** | **Temp. Rise** | **Taps** | **Mounting** |
| **T-EM1** | 480 | 208/120 | 75 | Dry | 90°C in a 40°C ambient | (2)2.5% | Pad on floor |
| **T-EM2** | 480 | 208/120 | 75 | Dry | 90°C in a 40°C ambient | (2)2.5% | Pad on floor |
| **T-EM3** | 480 | 240/120 | 9 | Dry | 90°C in a 40°C ambient | (2) 5% | Pad on floor |
| **T-EM4** | 480 | 240/120 | 2 | Dry | 90°C in a 40°C ambient | (2) 5% | Pad on floor |
| **T-C1** | 208 | 208/120 | 30 | Isolation | N/A | N/A | Isolation Pad |
| **T-C2** | 208 | 208/120 | 45 | Isolation | N/A | N/A | Isolation Pad |

### Assumptions:

A few assumptions related to building operating cycle are made in order to quantify annual load of these transformers. Although this building is a private building, some parts of the building are opened to the public on both weekdays and weekends during business hours and beyond. The private sections of the building including offices will be used only on the weekdays during business hours. As a result, duration of equipment operating is assumed to be 14 hrs/ day for 365 days/ year. Assumption for the load during normal operating hours is 40%, and for the load outside operating hours is 10%.

To determine, percentage of load during normal operating hours, the types of load on each of the transformers were investigated. Two 75 kVA transformers (T-EM1 and T-EM2) are connected to the life safety generator and the emergency service entrance on one end and to the automatic transfer switches on other. These particular transformers will be utilized only when the emergency generator is running. Therefore, it is appropriate to assume that these transformers employ minimal load during normal operating hours.

### Initial Costs:

The initial costs of the existing transformers are obtained from RS Means 2009 - Facilities Construction Cost Data 24th edition. Prices listing below include overhead and profit from distributors and installers.

| Tag | Size (kVA) | Type | Cost ($) | RS Means 2009 |
|---|---|---|---|---|
| **T-EM1** | 75 | Dry | 6,825 | 26 22 13.10 Transformer, Dry-Type |
| **T-EM2** | 75 | Dry | 6,825 | 26 22 13.10 Transformer, Dry-Type |
| **T-EM3** | 9 | Dry | n/a | 26 22 13.10 Transformer, Dry-Type |
| **T-EM4** | 2 | Dry | n/a | 26 22 13.10 Transformer, Dry-Type |
| **T-C1** | 30 | Isolation | 6,850 | 26 22 13.30 Isolating Transformer |
| **T-C2** | 45 | Isolation | 9,900 | 26 22 13.30 Isolating Transformer |
| | | **Total** | **$ 30,400** | |

The initial costs for Powersmiths efficient transformers are not available. As a result, they are assumed to cost 200% more than a typical transformer.

| | |
|---|---|
| **Total Initial Cost for Efficient Transformers** | **$ 30,400 x 2.0 = 60,800** |

### Analysis:

The benefit of utilizing an efficient transformer is saving from the operating cost, which comes from minimizing transformer losses and costs associated with A/C. Although the initial costs for the efficient transformers are higher than a typical transformer, annual operating saving can add up really quickly and pay off for itself at no time. After inputting all the data in the EPS for LEED calculator from Powersmiths, it is clear that switching all the transformers in the building to the efficient transformers would be an appropriate option. Payback period on total cost is estimated at around nine years. That means after the 9th year, the owner will start making some saving comparing to using a typical transformer. That saving will add up to $112,918 after twenty years and $257,590 after thirty-two years.

| | | | |
|---|---|---|---|
| Payback on total cost | **8.81** | **years** | current kWh rate: **$0.095** |
| Cost of Energy Savings | **$ 0.031** | **/kWh** | |
| Cost - Benefit Ratio | **3.0** | **times less to save a kWh than to buy a kWh** | |

| | Annual Operating Cost | Life Cycle Operating Cost & Savings | |
|---|---|---|---|
| | | **20 years** | **32 years** |
| Status Quo Transformers | $4,195 | $151,524 | $345,658 |
| Powersmiths Transformers | $1,069 | $38,606 | $88,069 |
| **Savings with Powersmiths** | **$3,126** | **$112,918** | **$257,590** |

## Calculations:

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**ESP for LEED Calculator™**

*Energy Savings Payback Calculator*

| | |
|---|---|
| **Project Description** | **Mellenium Science Complex** |
| **Date** | **13-Feb-09** |

***Data Entry***

**Transformers on Project**

| QTY | kVA |
|---|---|
| 1 | 30 |
| 1 | 45 |
| 2 | 75 |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

| | |
|---|---|
| **Available Full Load kW** | **225** |
| Average kVA (calc) | **56** |
| equipment operating hrs/ day | **14** |
| equipment operating days/yr | **365** |
| Load during normal operating hours | **40%** |
| Load outside operating hours | **10%** |

| | Calc Load kW | Calc Annual kWh |
|---|---|---|
| | 90 | 459,900 |
| | 23 | 82,125 |
| **Total Annual Load kWh:** | | **542,025** |

**Annual Cost to Operate Load Only**

| | | |
|---|---|---|
| kWh rate | **$ 0.095** | Annual Consumption: $ 51,492 |
| demand rate ($/kW/mo) ex. $10.00 | **$10.00** | Annual Demand: $ 10,800 |
| | | **Total Cost to run load** **$ 62,292** |

***Annual Cost of Status Quo Transformer Losses & Associated Air Conditioning (A/C) burden***

| | | | |
|---|---|---|---|
| Nameplate Linear efficiency (normal op hrs) | **96.5%** | % electronics or current THD | **30.0%** |
| Calculated operating efficiency | 95.5% | | |
| Transformer kW Losses (Normal Operation) | 4.3 kW | | |
| Status quo Efficiency (Outside op. hrs) | **94.0%** | | |
| Transformer kW Losses (Outside op. hrs) | 1.4 kW | | |
| Annual addititional kWh from transformers | 27,165 kWh | | |
| **Annual Cost of Transformer Losses** | $ 3,095 | | |
| A/C System Performance (kW/ton) | **1.25** | | |
| Additional Tons of Cooling (on peak) | 1.22 tons | | |
| Annual addititional kWh from A/C | 9,647 kWh | | |
| **Annual Cost of Associated A/C** | $ 1,099 | | |

**Summary with Status Quo Transformer**

| | |
|---|---|
| Annual Cost of feeding Building Load | $ 62,292 |
| Annual Cost of Transformer Losses | $ 3,095 |
| Annual Cost of Associated A/C | $ 1,099 |
| **Electrical Bill (Status Quo Transformer)** | **$ 66,487** |

IMPORTANT: By using the ESP Calculator™, you are agreeing the TERMS OF USE section on page 3

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POWERSMITHS

Page 2

# ESP for LEED Calculator™

*Energy Savings Payback Calculator*

Toll Free : 1-800-747-9627 or (905) 791-1493

## Using Powersmiths instead of status quo transformers

| | | |
|---|---|---|
| Powersmiths Efficiency (Normal Operation) | 98.8% | |
| Powersmiths kW Losses (Normal Operation) | 1.1 | kW |
| Powersmiths Efficiency (Outside op. hrs) | 98.4% | |
| Transformer kW Losses (Outside op. hrs) | 0.4 | kW |
| Annual addititional kWh from transformers | 6,921 | kWh |
| **Annual Cost of Powersmiths Losses** | $ 789 | |
| Additional Tons of Cooling (on peak) | 0.31 | tons |
| Annual addititional kWh from A/C | 2,458 | kWh |
| **Annual Cost of Associated A/C** | $ 280 | |

## Comparing Status Quo & Powersmiths

| | Status Quo | Powersmiths | |
|---|---|---|---|
| Annual Cost of feeding Building Load | $ 62,292 | $ 62,292 | |
| Annual Cost of Transformer Losses | $ 3,095 | $ 789 | |
| Annual Cost of Associated A/C | $ 1,099 | $ 280 | **Reduction** |
| **Annual estimated Electrical Bill** | $ 66,487 | $ 63,361 | **5%** |

| | | |
|---|---|---|
| **Peak kW reduction (normal op hours)** | **4.3** | **kW** |
| **Annual kWh reduction** | **27,433** | **kWh** |
| **Reduction in Air Conditioning Load (on peak)** | **0.91** | **tons** |

## Cost Analysis (calc)

| | |
|---|---|
| Energy Cost Escalation (above inflation) | 3.0% |
| Annual Power Quality Benefit | $ - |

| | Annual Operating Cost | Life Cycle Operating Cost & Savings | |
|---|---|---|---|
| | | 20 years | 32 years |
| Status Quo Transformers | $4,195 | $151,524 | $345,658 |
| Powersmiths Transformers | $1,069 | $38,606 | $88,069 |
| ***Savings with Powersmiths*** | **$3,126** | **$112,918** | **$257,590** |

## Cost

| | Cost |
|---|---|
| Powersmiths Transformers | $60,800 |
| Status Quo Transformers | $33,250 |

## Payback on total cost

| | | | |
|---|---|---|---|
| | 8.81 | years | current kWh rate: |
| **Cost of Energy Savings** | $ 0.031 | /kWh | $0.095 |
| **Cost - Benefit Ratio** | 3.0 | times less to save a kWh than to buy a kWh | |

## Leasing Option

| | 60 Month Term | 48 Month Term | 36 Month Term |
|---|---|---|---|
| ***Total Annual Leasing Payments*** | **$15,373** | **$18,751** | **$23,858** |
| ***Net Annual Cost with savings*** | $12,247 | $15,625 | $20,732 |

## Summary of Environmental Benefits

| Annual Reduction in Greenhouse Gases (per EPA) | Equivalence |
|---|---|
| 20 tons of CO2 | 4 Acres trees planted |
| 66 tons of Coal | 3 Car Emissions |
| 159 kgs of SO2 | 3 homes heated |
| 68 kgs of NOx | |

IMPORTANT: By using the ESP Calculator™, you are agreeing the TERMS OF USE section on page 3

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Page 3

**ESP for LEED Calculator™**
*Energy Savings Payback Calculator*

**Status Quo Transformer (Normal Operation)**

Enter the average efficiency of the transformers. While NEMA TP1 is legislated minimum efficiency, it only applies at a single 35% load point, and under ideal linear load profile. Since most transformers are much less loaded than 35%, be sure to use lower efficiency to reflect load level.

**Status Quo Transformer (Outside Op. hours)**

Transformer efficiency is typically lower than normal when lightly loaded (86-89% when 10-15% loaded for most sizes)

**% electronics or Current THD**

IEEE Std 1100 and other industry references document transformer losses can more than double when feeding electronics when installled compared to ideal linear load in a manufacturer's factory test.

**Transformer Operating Losses**

Transformer Losses = kW load/net efficiency - kW load.

**A/C Performance (kW/ton)**

Varies widely depending on age and technology of cooling system. As low as 0.5 to over 2kW/ton (1.25-1.5 is often tp)

Unlike most substation transformers that are vented to the exterior, most building distribution transformers are ventilated within the building, and their heat losses therefore add to the cooling load.

**Powersmiths Efficiency (Normal Operation) & (Outside Op. hours)**

Available on Powersmiths product data sheet

**Energy Cost escalation (above inflation)**

It is well recognized that energy rates are increasing much faster than inflation. Enter the % over inflation

**Annual Power Quality Benefit**

Savings attributable to reduced downtime, equipment locks & failures associated with poor power quality

**Cost**

Cost of transformers. Enter dollar figure for transformers under consideration. If the interest is to look at the justification for replacing existing transformers, enter $0 in the conventional transformer cost field.

**Energy Operating Cost**

Energy OPERATING COST (normal op) = (transformer + cooling) kW losses x kWh rate x hrs/day x days/yr + demand charge
Demand charge is not included in the calculation of losses outside normal hours to be conservative.

**Return on Investment (ROI)**

ROI on Incremental Cost is based on dividing the Incremental Investment in Powersmiths by the Annual Savings
ROI on Total Transformer Cost is based on dividing the Total Transformer Cost by the Annual Savings

**Cost of Energy Savings**

In its simplest form, the cost of energy savings represents the cost to save a kWh as opposed to paying for it according to the prevailing kWh rate.
The equation is: Cost of Energy Savings = (Incremental Product Cost / Lifetime kWh saved)

**Leasing**

Powersmiths Leasing has many benefits, including avoiding the use of capital, offsetting monthly leasing payment with the reduction in monthly energy bill from using Powersmiths

**Environmental Benefits**

Conversion rates from kWh to emission reduction and equivalent benefits are published by the EPA, and reflect environmental benefits derived from reduced emissions associated with reduced power generation.

**TERMS OF USE**

Power Quality Institute has used its best efforts in developing the ESP Calculator ™ with the intent of providing an easy to use and useful calculation tool. However, data entered and assumptions made may not accurately reflect all variables that apply in a given facility. The results are therefore estimates only and may differ from actual measurements. The user is responsible for evaluating the suitability and accuracy of the ESP Calculator ™. The Power Quality Institute and Powersmiths International Corp. make no representations or warranties with respect to the accuracy or completeness of the estimates generated by the ESP Calculator ™ and specifically disclaim any implied warranties of merchantability or fitness for any particular purpose and shall in no event be liable for any loss of profit or any other commercial damage, including, but not limited to special, incidental, consequential or other damages.

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 doc#807-000440-115-A03 ***17-Jan-09***

# Protective Device Coordination Study and Fault Current Analysis

## Fault Current Analysis

The fault current calculation will be analyzed along the path to the panel board 0L-2. This path starts from the service entrance switchboard GSWB-1 to the main distribution panel 0G-1, and to the panelboard 0L-2. A partial single-line diagram below shows the path for fault current analysis. Refer to appendix F for the complete single-line diagram.

The results of the analysis show that the current designed system at the transformer secondary has smaller fault current protection than that required by the calculations. The utility secondary requires at least 41,675 AIC, but the specified equipment is rated at 40,000 AIC. Standard breaker rated at 65,000 AIC should be replaced the specified equipment at this location.

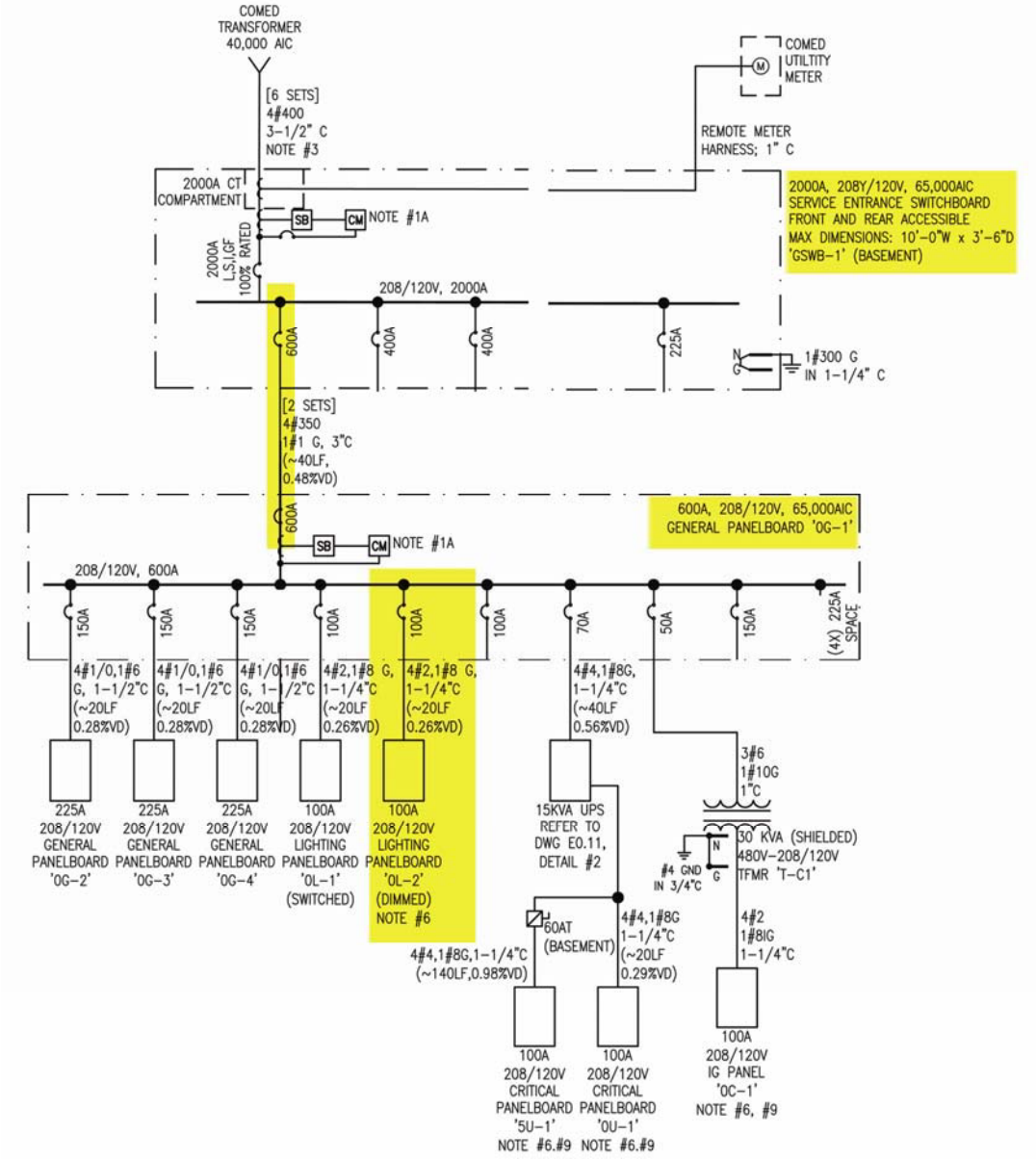



FIGURE 43: SINGLE-LINE DIAGRAM FOR THE PATH OF FAULT CURRENT ANALYSIS

| Summary Results of Fault Current | | | |
|---|---|---|---|
| **Point** | **Location** | **Available Fault (A)** | **Standard Breaker Rating (A)** |
| A | Utility Company Secondary | 41,674 | 65,000 |
| B | Switchboard (GSWB-1) | 33,725 | 42,000 |
| C | Distribution Panel (0G-1) | 27,552 | 42,000 |
| D | End Use Panel (0L-2) | 17,182 | 22,000 |

| Fault Current Analysis (Per Unit Method) | | | | | | |
|---|---|---|---|---|---|---|
| **Utility Transformer Primary Side** | | | | | | |
| | System Voltage KV | = 0.208 | | | | |
| | Base KVA | = 10000 | | | | |
| | Utility Company Available Fault | = 100000000 | | | | |
| **Utility Primary** | | | **ΣX** | **ΣR** | **ΣZ** | **$I_{sc}$ (A)** |
| | X(p.u.) = KVAbase / Utility S.C. KVA | = 0.0001 | | | | |
| | R(p.u.) | = 0 | | | | |
| **Transformer Secondary** | | | | | | |
| %Z = 5.00 | X(p.u.) = %X * KVAbase / 100 * KVAxfrmr | = 0.5946667 | 0.594667 | 0.3 | 0.666054 | **41674.14** |
| X/R = 1.98 | R(p.u.) = %R * KVAbase / 100 * KVAxfrmr | = 0.3 | | | | |
| %X = 4.46 | | | | | | |
| %R = 2.25 | | | | | | |
| kVA = 750 | | | | | | |
| **Switchboard GSWB-1** | | | | | | |
| Wire = 400 | X = (L/1000) * XL * (1/Sets) | = 0.12835 | 0.723017 | 0.39326 | 0.82305 | **33724.83** |
| Length = 68 | R = (L/1000) * R * (1/Sets) | = 0.09326 | | | | |
| Sets = 6 | | | | | | |
| XL = 0.0490 | | | | | | |
| R = 0.0356 | | | | | | |
| **Panelboard 0G-1** | | | | | | |
| Wire = 350 | X = (L/1000) * XL * (1/Sets) | = 0.14764 | 0.870657 | 0.50684 | 1.007438 | **27552.3** |
| Length = 26 | R = (L/1000) * R * (1/Sets) | = 0.11358 | | | | |
| Sets = 2 | | | | | | |
| XL = 0.0491 | | | | | | |
| R = 0.0378 | | | | | | |
| **Panelboard 0L-2** | | | | | | |
| Wire = 2 | X = (L/1000) * XL * (1/Sets) | = 0.20282 | 1.073477 | 1.20719 | 1.61544 | **17182.4** |
| Length = 15 | R = (L/1000) * R * (1/Sets) | = 0.70035 | | | | |
| Sets = 1 | | | | | | |
| XL = 0.0585 | | | | | | |
| R = 0.202 | | | | | | |

## Coordination Study Analysis

After overlaying and analyzing the overcurrent time delay curves for a 20A, 100A, and 600A circuit breaker, there is some overlap. The 100A circuit breaker starts to overlap the 20A circuit breaker with its lower limit starting at 550A and 4 sec and continues to 600A and 0.03 sec. The 20A lower limit remains ahead of the lower limit of the 100A circuit breaker until it hits 600A and .03 sec. This means that the 100A circuit breaker will trip before the 20A breaker starting at 600A and .03 sec.

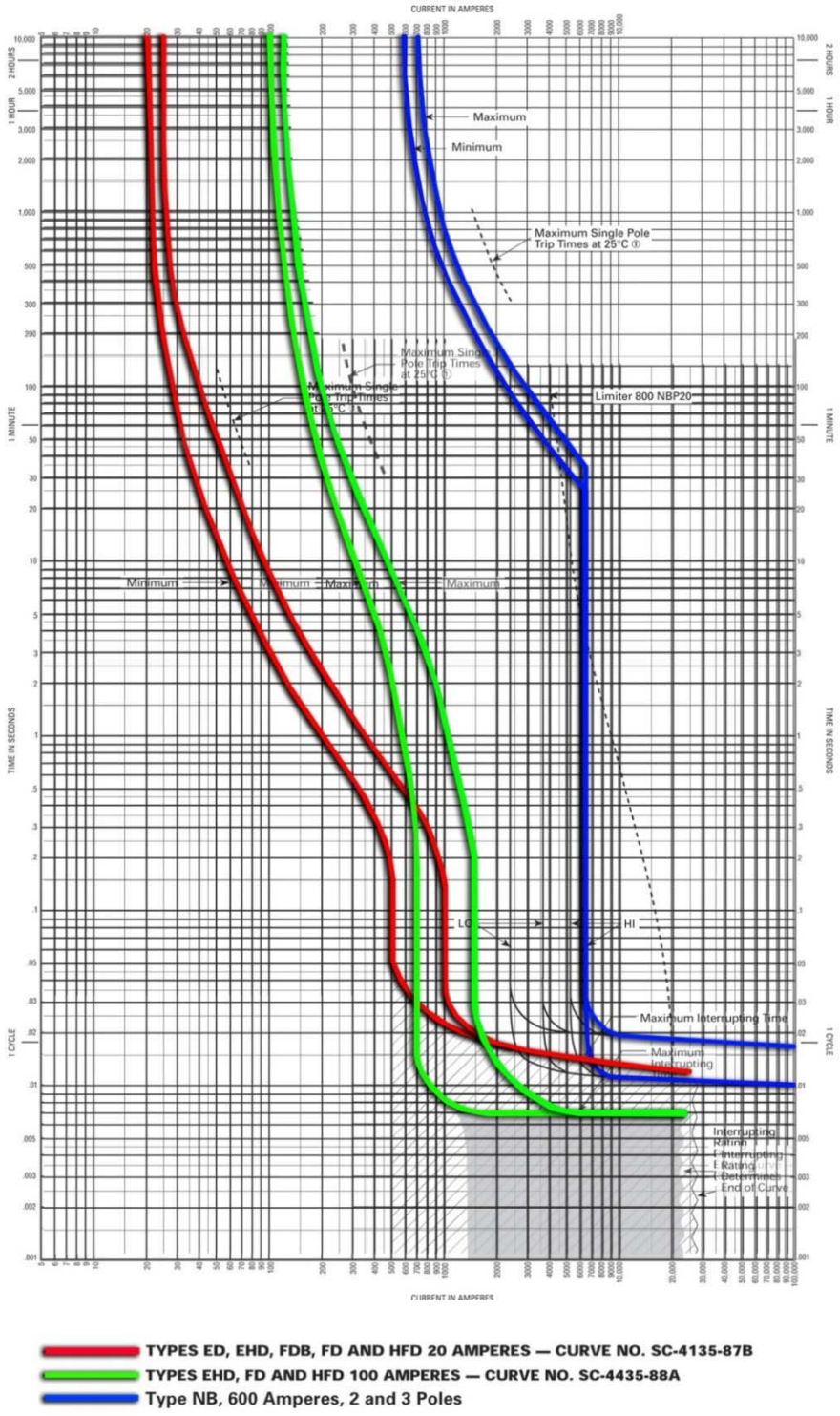



FIGURE 44: OVERCURRENT TIME DELAY CURVES FOR A 20A, 100A, AND 600A CIRCUIT BREAKER

## Breadth Topic One: Analysis and Redesign of Feinberg Theater Acoustics

### Overview

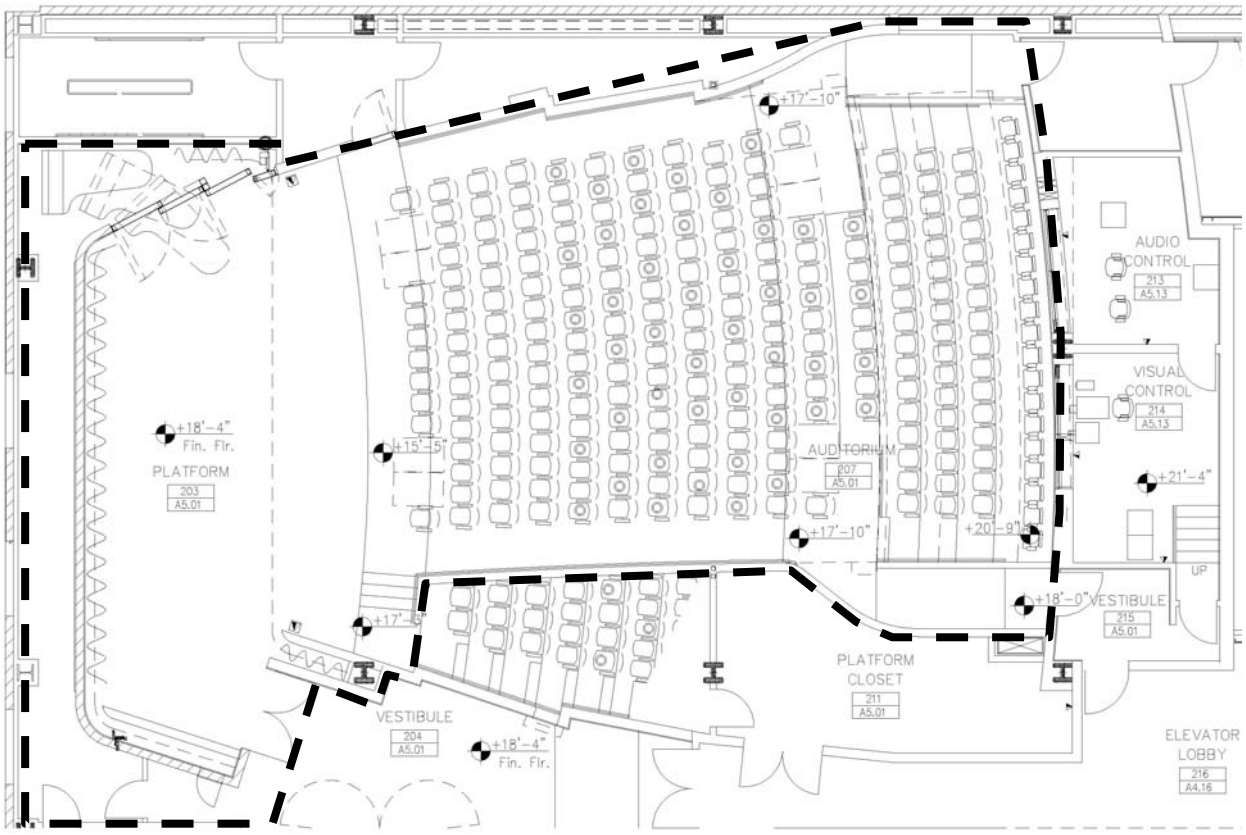
The Feinberg Theater is a multifunction facility including live performance, film, community events, and lectures. Acoustical criterions and characteristics will be defined and used as a design guideline. Reverberation time and STC analysis will be performed for the Feinberg Theater. Ceiling panels will be proposed to not only improve acoustical performance, but also to better integrate lighting system and mechanical system to the space. Analysis of this alteration will be performed to ensure acoustical performance.

#### Space Overview – Existing Condition:

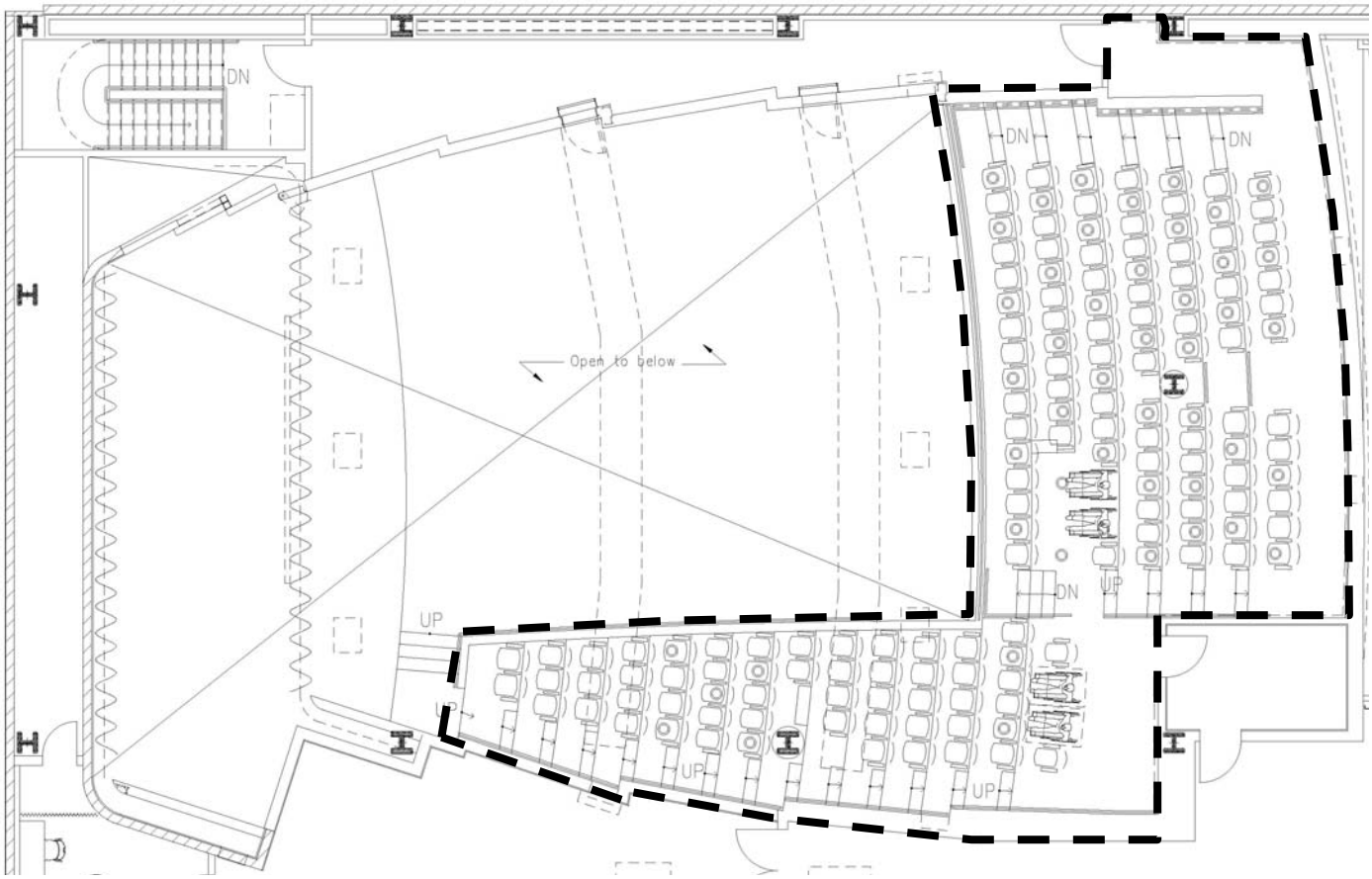
**Area:** approx. 4,700 Sq.ft. (total of both levels)

**Dimension:** Approx 58'-0" x 82'-0"

**Plan:**
Main level



Balcony level




**Section:**

## Design Criterions

A multipurpose auditorium of this type, which serves many functions, must be designed with compromise reverberation time. A short reverberation time is desirable for speech activities, and a long reverberation time is preferred for instrumental music and chorus. Therefore, a mid-frequency reverberation of 1.7 at 500 Hz is selected for the space. 1.3 and 0.8 multiplier are applied to reverberation times at 125 and 4000 Hz respectively. It is also important to distribute sound energy throughout the theater and adsorb sound energy to control echoes by employing the appropriate materials at the right locations.

| | Frequency (Hz) | | |
|---|---|---|---|
| | 125 | 500 | 4000 |
| Target | 2.21 | 1.7 | 1.36 |

## Acoustical Analysis – Existing Design

The result after performing an initial acoustical analysis using reverberation times indicates that there are some areas of improvement to the acoustical performance in the space. The reverberation times at 500 and 4000 Hz are lower than preferred reverberation times. According to **RT (sec) = (0.05V)/ΣA** equation, in order to increase these two reverberation times without expanding the space volume is to decrease the ΣA. One of the major contributions to ΣA at 500 and 4000 Hz comes from sprayed cellulose fiber on exposed structure. Acoustical wall panels on the side and back walls are also another area where some slight adjustments should be made.

### Existing Design – Comparison of the Actual and Optimum Reverberation Times (Nodes at 125, 500, and 4000 Hz)

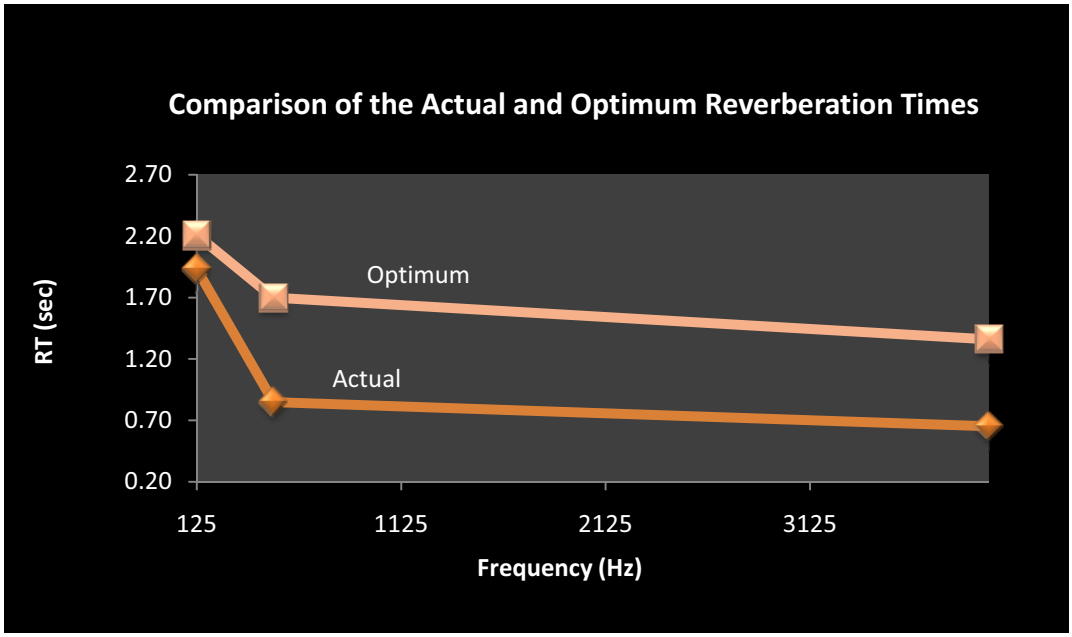



FIGURE 45: COMPARISON OF THE ACTUAL AND OPTIMUM REVERBERATION TIMES – EXISTING CONDITION

| Original Design - Reverberation Time (without Ceiling Panels) | | | | | | |
|---|---|---|---|---|---|---|
| **Surface Element** | **Area (Sq.Ft.)** | **Material** | | **Frequency (Hz)** | | |
| | | | | **125** | **500** | **4000** |
| Audience Floor | 1,450 | Carpet | α | 0.01 | 0.06 | 0.45 |
| | | | Sα (sabins) | 14.50 | 87.00 | 652.50 |
| Stage Floor | 950 | Resilient poured-in-place concrete | α | 0.01 | 0.02 | 0.02 |
| | | | Sα (sabins) | 9.50 | 19.00 | 19.00 |
| Exposed Ceiling | 4,215 | Sprayed cellulose fiber (25mm(1") on solid backing) | α | 0.08 | 0.75 | 0.76 |
| | | | Sα (sabins) | 337.20 | 3161.25 | 3203.40 |
| Front & Side Walls | 7,350 | Gypsum Wallboard | α | 0.14 | 0.06 | 0.04 |
| | | | Sα (sabins) | 1029.00 | 441.00 | 294.00 |
| Sloped Balcony Soffit | 1,150 | Gypsum Wallboard | α | 0.14 | 0.06 | 0.04 |
| | | | Sα (sabins) | 161.00 | 69.00 | 46.00 |
| A/V Room Windows | 80 | Glass | α | 0.18 | 0.04 | 0.02 |
| | | | Sα (sabins) | 14.40 | 3.20 | 1.60 |
| Acoutical Walls (Back and Side) | 1,800 | 1" thick Fiberglass Panels 6-7 pcf. | α | 0.20 | 0.33 | 0.33 |
| | | | Sα (sabins) | 360.00 | 594.00 | 594.00 |
| Stage Drapery (Against Back Wall) | 2,250 | Drapery (14 oz/yd2, 476 g/m2, flat against wall) | α | 0.05 | 0.13 | 0.36 |
| | | | Sα (sabins) | 112.50 | 292.50 | 810.00 |
| Stage Drapery (Pleated) | 900 | Drapery (18 oz/yd2, 612 g/m2, pleated 50%) | α | 0.14 | 0.53 | 0.60 |
| | | | Sα (sabins) | 126.00 | 477.00 | 540.00 |
| Air | | | m | 0.00 | 0.00 | 8.00 |
| | | | mV (sabians) | 0.00 | 0.00 | 970.40 |
| Seats (Fully Occupied) | 2,500 | Fabric-Upholsterd | α | 0.39 | 0.80 | 0.87 |
| | | | Sα (sabins) | 975.00 | 2000.00 | 2175.00 |
| **Total absorption, ΣA (sabins) fully occupied room** | | | | **3139.1** | **7144.0** | **9305.9** |
| **RT (sec) = (0.05V)/ΣA** | | | | **1.93** | **0.85** | **0.65** |
| Optimum RT500 = 1.7 | | | | 2.21 | 1.7 | 1.36 |

## Design Solutions

To appropriately address the problem with the reverberation times, a series of Z shape smooth plaster ceiling panel is introduced in the space. These panels do not only correct the reverberation times by adding more reflective surfaces in the space, but also help distributing sound energy throughout the theater. These panels will also be used to integrate lighting and mechanical systems in the space. To further improve the reverberation time, the acoustical panels on the side wall are eliminated. These panels will only on the back walls on both main and balcony level.

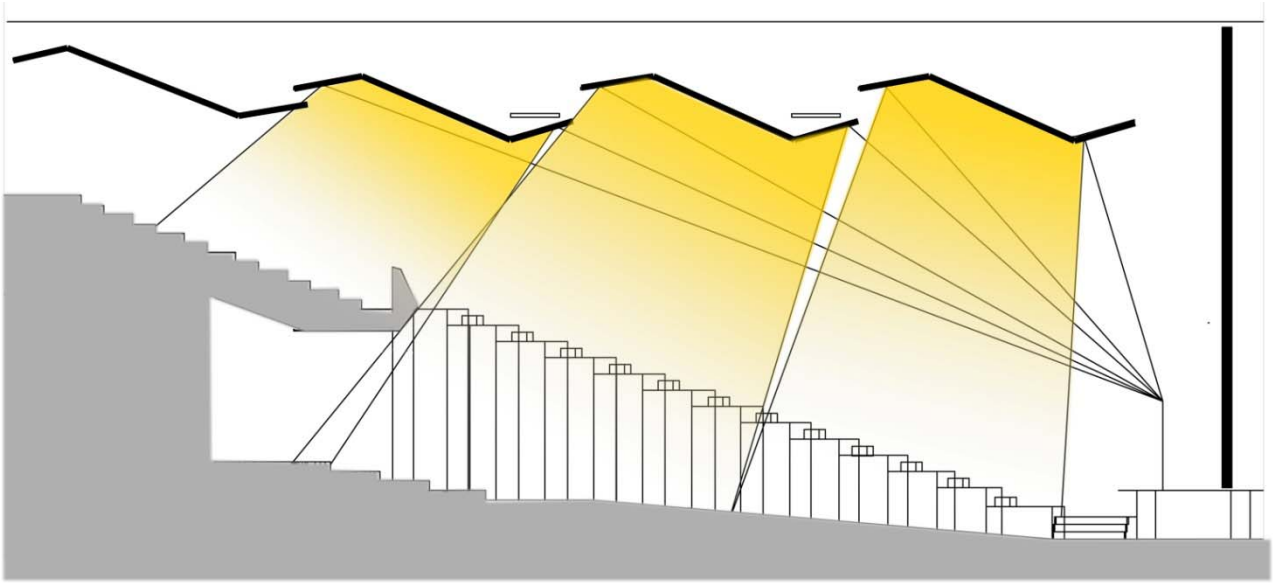


FIGURE 46: RAY STUDY DIAGRAM

FIGURE 47: SECTION PERSPECTIVE

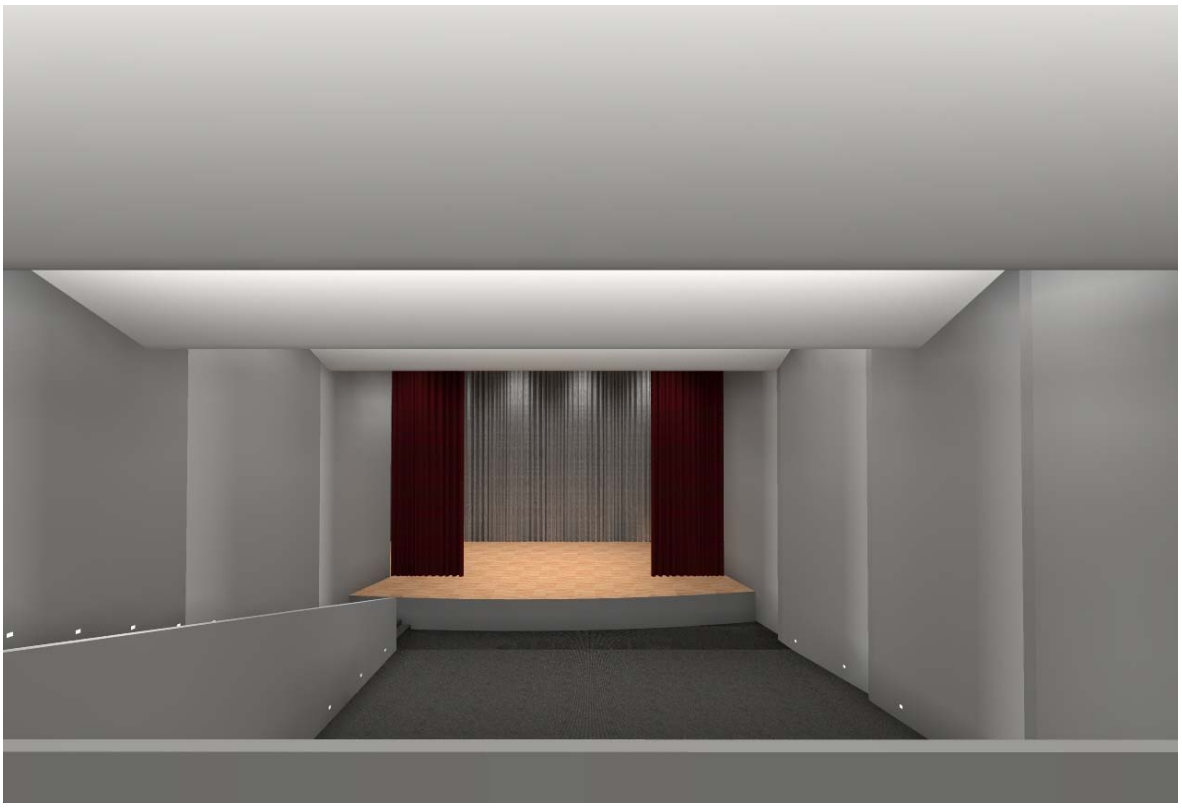


FIGURE 48: PERSPECTIVE FROM THE BALCONY

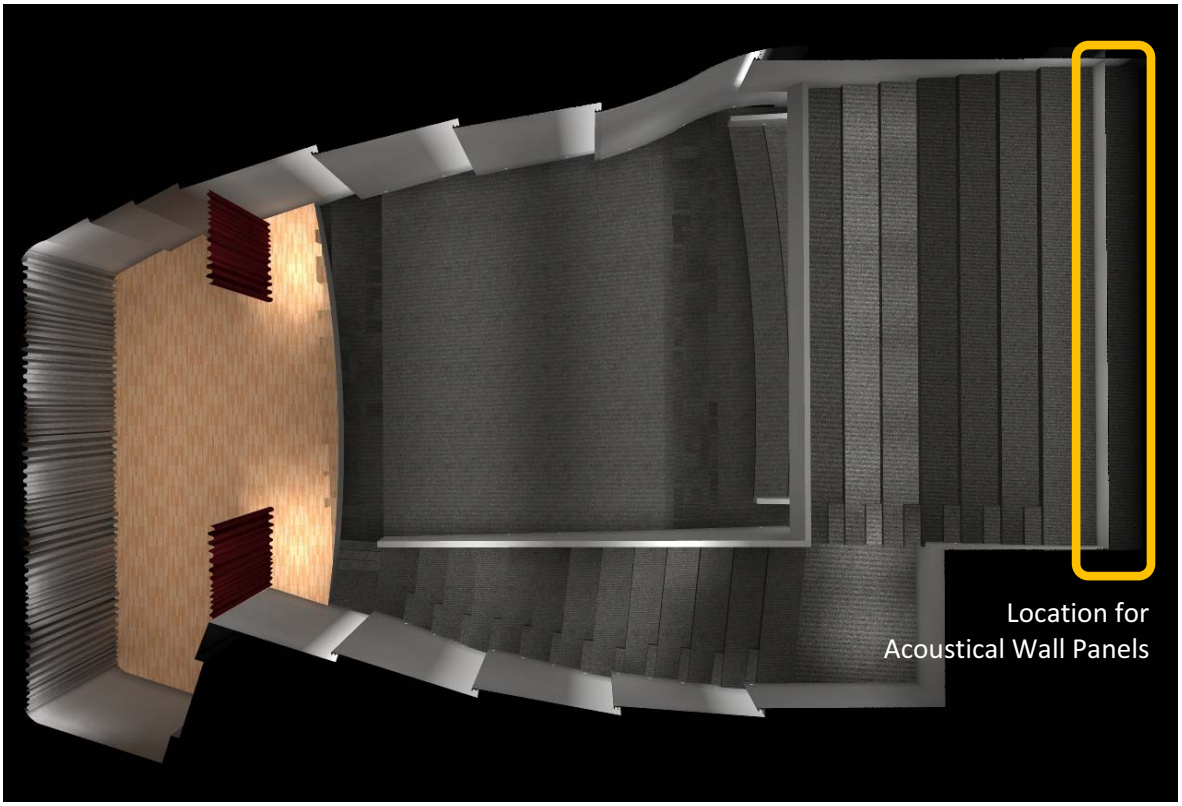



FIGURE 49: LOCATION FOR ACOUSTICAL WALL PANELS

**Proposed Design – Comparison of the Actual and Optimum Reverberation Times (Nodes at 125, 500, and 4000 Hz)**

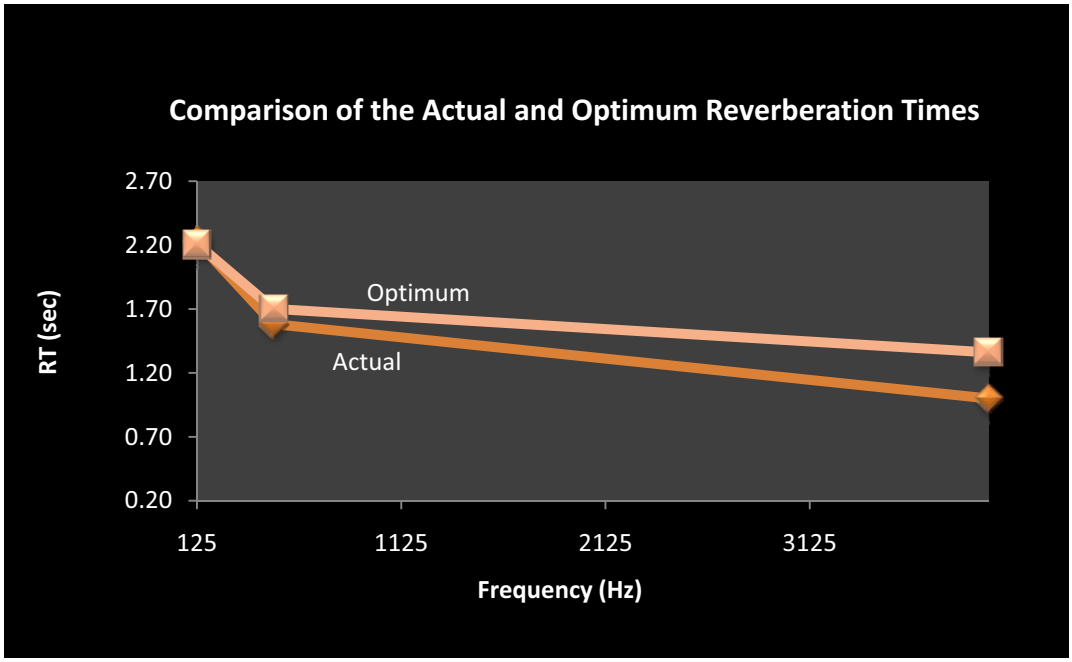



FIGURE 50: COMPARISON OF THE ACTUAL AND OPTIMUM REVERBERATION TIMES – PROPOSED DESIGN

| Proposed Design - Reverberation Time (with Ceiling Panels) | | | | | | |
|---|---|---|---|---|---|---|
| **Surface Element** | **Area (Sq.Ft.)** | **Material** | | **Frequency (Hz)** | | |
| | | | | **125** | **500** | **4000** |
| Aisles | 1,450 | Carpet | α | 0.01 | 0.06 | 0.45 |
| | | | Sα (sabins) | 14.50 | 87.00 | 652.50 |
| Stage Floor | 950 | Resilient poured-in-place concrete | α | 0.01 | 0.02 | 0.02 |
| | | | Sα (sabins) | 9.50 | 19.00 | 19.00 |
| Ceiling Panels | 3,100 | Plaster (smooth) on solid material | α | 0.01 | 0.02 | 0.05 |
| | | | Sα (sabins) | 40.30 | 62.00 | 155.00 |
| Front & Side Walls | 7,350 | Gypsum Wallboard | α | 0.14 | 0.06 | 0.04 |
| | | | Sα (sabins) | 1029.00 | 441.00 | 294.00 |
| Sloped Balcony Soffit | 1,150 | Gypsum Wallboard | α | 0.14 | 0.06 | 0.04 |
| | | | Sα (sabins) | 161.00 | 69.00 | 46.00 |
| A/V Room Windows | 80 | Glass | α | 0.18 | 0.04 | 0.02 |
| | | | Sα (sabins) | 14.40 | 3.20 | 1.60 |
| Acoutical Walls (Back and Side) | 1,800 | 1" thick Fiberglass Panels 6-7 pcf. | α | 0.20 | 0.33 | 0.33 |
| | | | Sα (sabins) | 260.00 | 429.00 | 429.00 |
| Stage Drapery (Against Back Wall) | 2,250 | Drapery (14 oz/yd2, 476 g/m2, flat against wall) | α | 0.04 | 0.11 | 0.35 |
| | | | Sα (sabins) | 90.00 | 247.50 | 787.50 |
| Stage Drapery (Pleated) | 900 | Drapery (18 oz/yd2, 612 g/m2, pleated 50%) | α | 0.14 | 0.53 | 0.60 |
| | | | Sα (sabins) | 126.00 | 477.00 | 540.00 |
| Air | | | m | 0.00 | 0.00 | 8.00 |
| | | | mV (sabians) | 0.00 | 0.00 | 970.40 |
| Seats (Fully Occupied) | 2,500 | Fabric-Upholsterd | α | 0.39 | 0.80 | 0.87 |
| | | | Sα (sabins) | 975.00 | 2000.00 | 2175.00 |
| **Total absorption, ΣA (sabins) fully occupied room** | | | | **2719.7** | **3834.7** | **6070.0** |
| **RT (sec) = (0.05V)/ΣA** | | | | **2.23** | **1.58** | **1.00** |
| Optimum $RT_{500}$ = 1.7 | | | | 2.21 | 1.7 | 1.36 |

# Breadth Topic Two: Design Integration

## Overview

The purpose of design integration breadth study is to ensure that the lighting systems, mechanical systems, and acoustical equipments are integrated and will be working together properly. The existing ceiling in this space is exposed and sprayed with fireproof cellulose. The proposed acoustical panels are the place holders for the architectural house lighting, theatrical lighting, and mechanical supply system. The physical shapes, sizes, material, and locations of the panels are specified in the acoustics breadth study section.

## Air-distribution system

The main air-distribution system for the Feinberg Theater comprises of the overhead supply air diffusers and the under-floor return system. The supply diffusers are fed by the 24" diameter circular duct. There are total of twenty-four (24) Inlets (diffusers) that extend out of the three main supply ducts. Each of the supply diffuser provides 300 CFM or .14160 $m^3$/s of air into the space. The volumetric flow for the round under-floor air returns grille is rated at 80 CFM or .0378 $m^3$/s.

Air velocity criteria are determined by the air-distribution performance index (ADPI) to provide comfortable environment as well as to avoid draft near the occupied zone. ADPI suggests that high percentage of people are comfortable where the effective draft temperature is between -3F (-1.7C) and +2F (1.1C) and the air velocity is less than 70ft/min (.36 m/s).

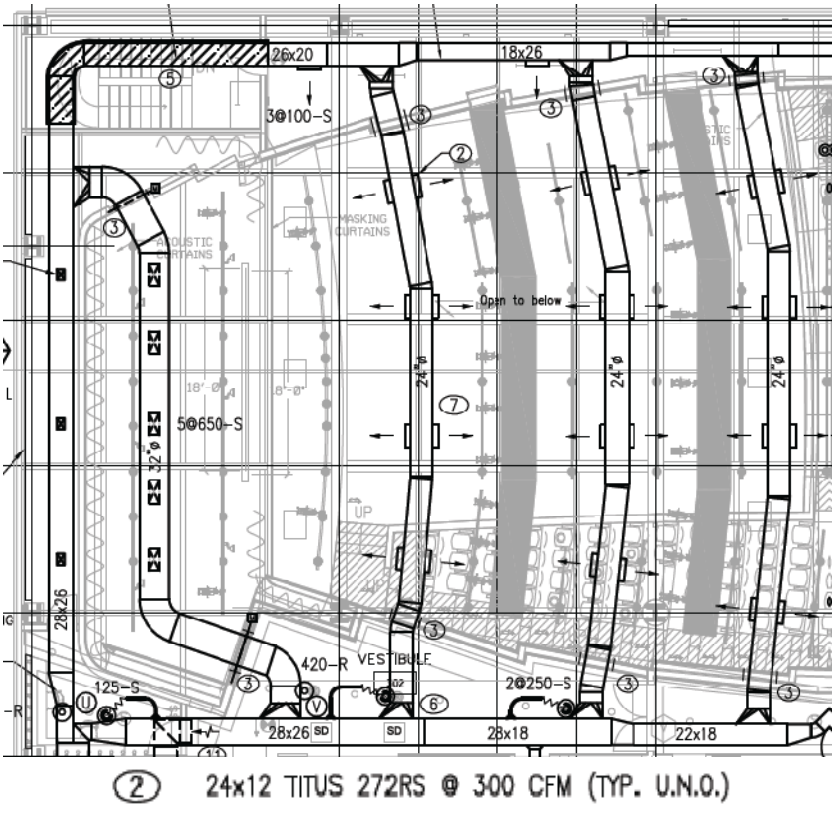



FIGURE 51: AIR SUPPLY DISTRIBUTION SYSTEM

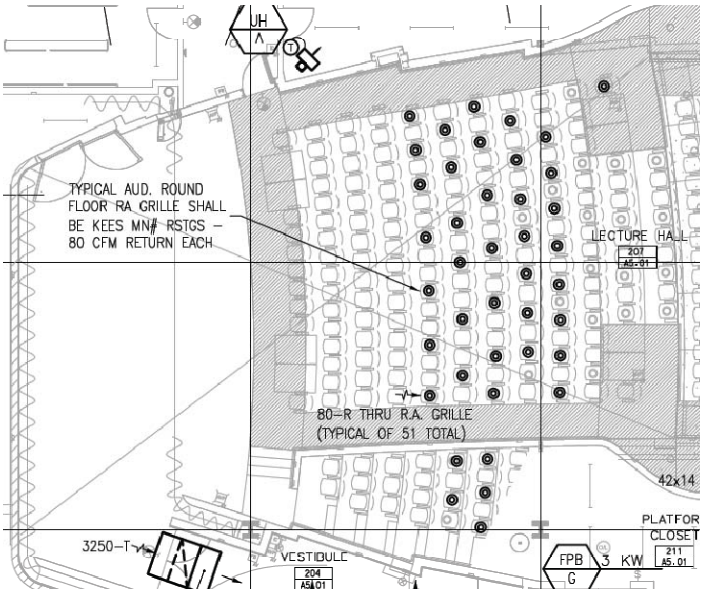



FIGURE 52: LOCATIONS OF UNDERFLOOR AIR RETURN GRILLES

## Phoenics VR Model Analysis

Phoenics VR model is constructed to simulate air-distribution pattern and to determine air velocity near the occupied zone. The model is also used to study the interaction between the air from the diffusers and the proposed ceiling panels. The ceiling panels are simplified from the original shape for the purpose of modeling. The probe is located at the red dot (30 inches above the ground) to measure the air velocity at the seated occupant. The result shows that the velocity at the censor is .0581 m/s (11.46 ft/min) which is less than the maximum velocity recommended by ADPI (.36 m/s or 70 ft/min).

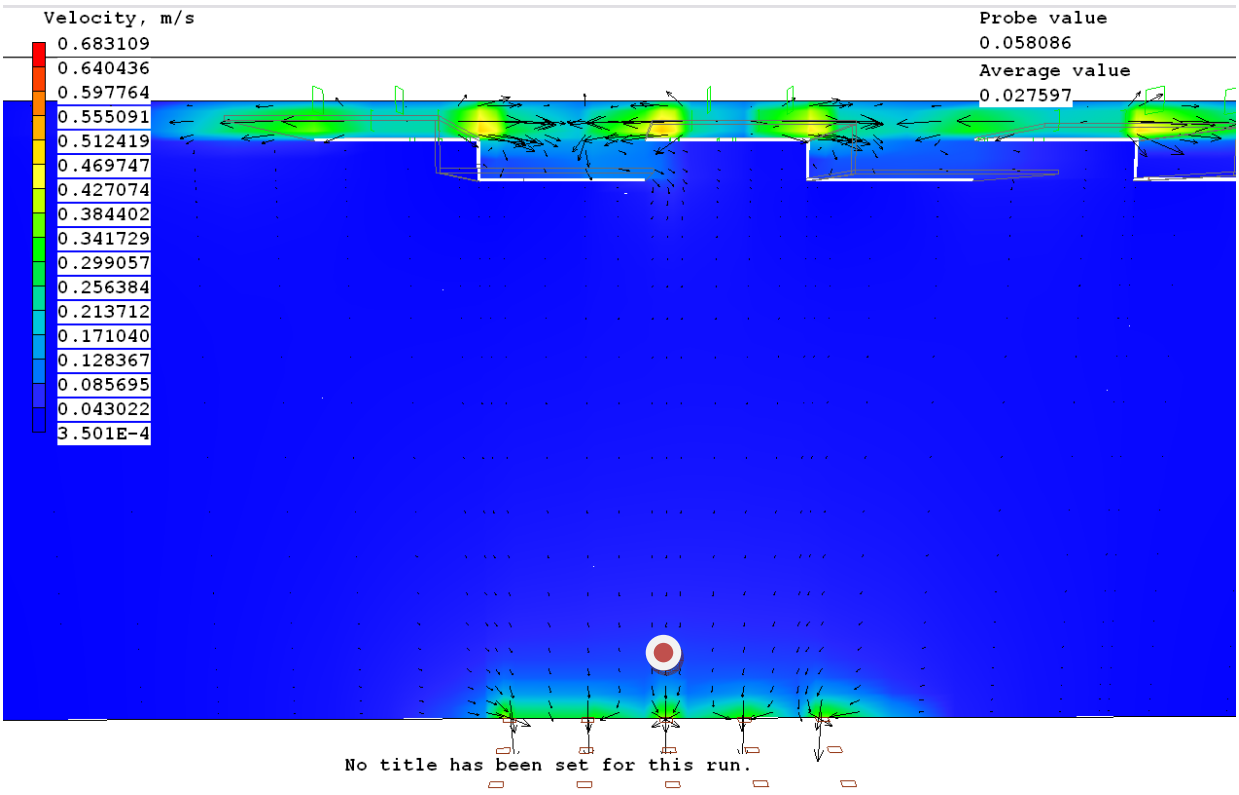



FIGURE 53: CROSS SECTION OF THE THEATER SHOWS VECTORS OF AIR VELOCITY

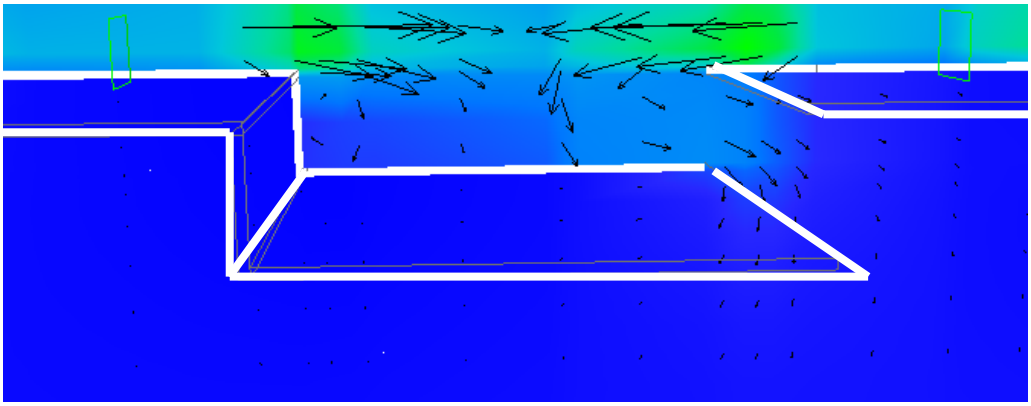


FIGURE 54: THE DIAGRAM BELOW SHOWS THE VECTORS OF AIR VELOCITY TRAVELING FROM THE DIFFUSERS BYPASSING THE CEILING PANELS.

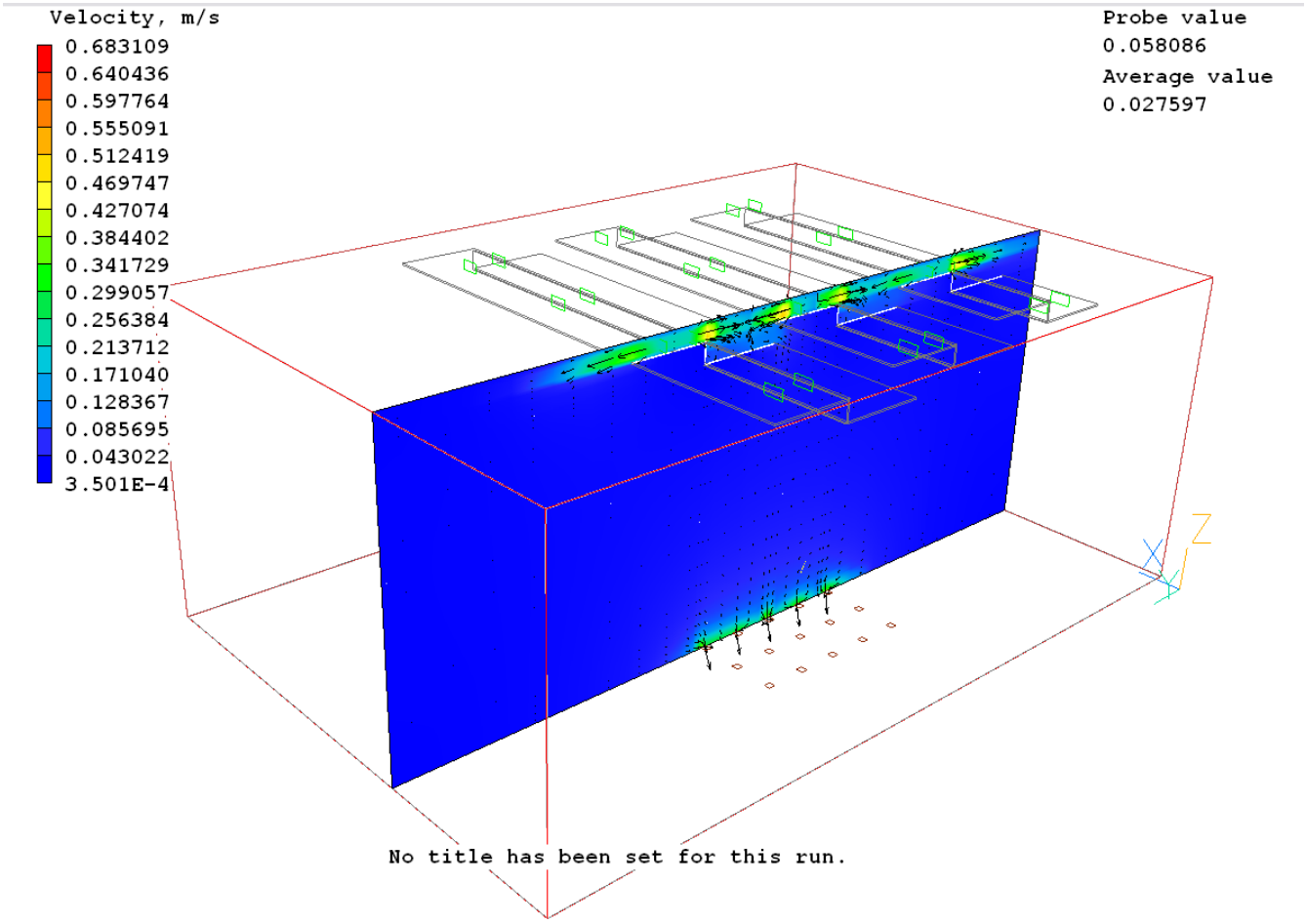



FIGURE 55: ISOMETRIC VIEW OF PHOENICS VR MODEL

## Coordination Study

Other than looking at the interaction between the air distribution system and the proposed design ceiling panels, the coordination study is conducted to better integrate the architectural lighting system, theatrical lighting system, ceiling panels, and air supply ductwork/diffusers. A proper distance is specified between each of the ceiling panels to allow the clearance for the theatrical light fixtures. The recessed downlights (fixture type F11 and F12) are strategically located so that they are accessible from the catwalk for the purpose of lamp replacement. The linear fluorescent cove (fixture type F16) is located to in such a way to maximize its distribution to wash the ceiling panel. It can also be access from the catwalk for lamp replacement. Refer to appendix H for a full drawing.

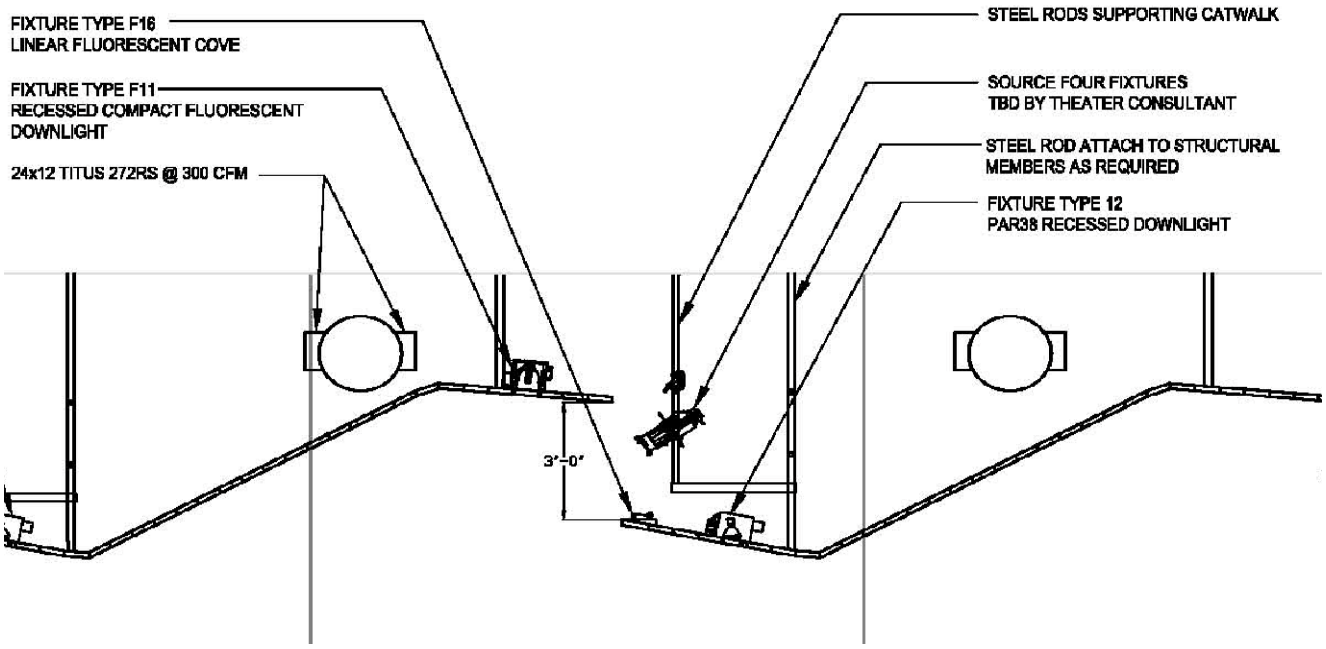
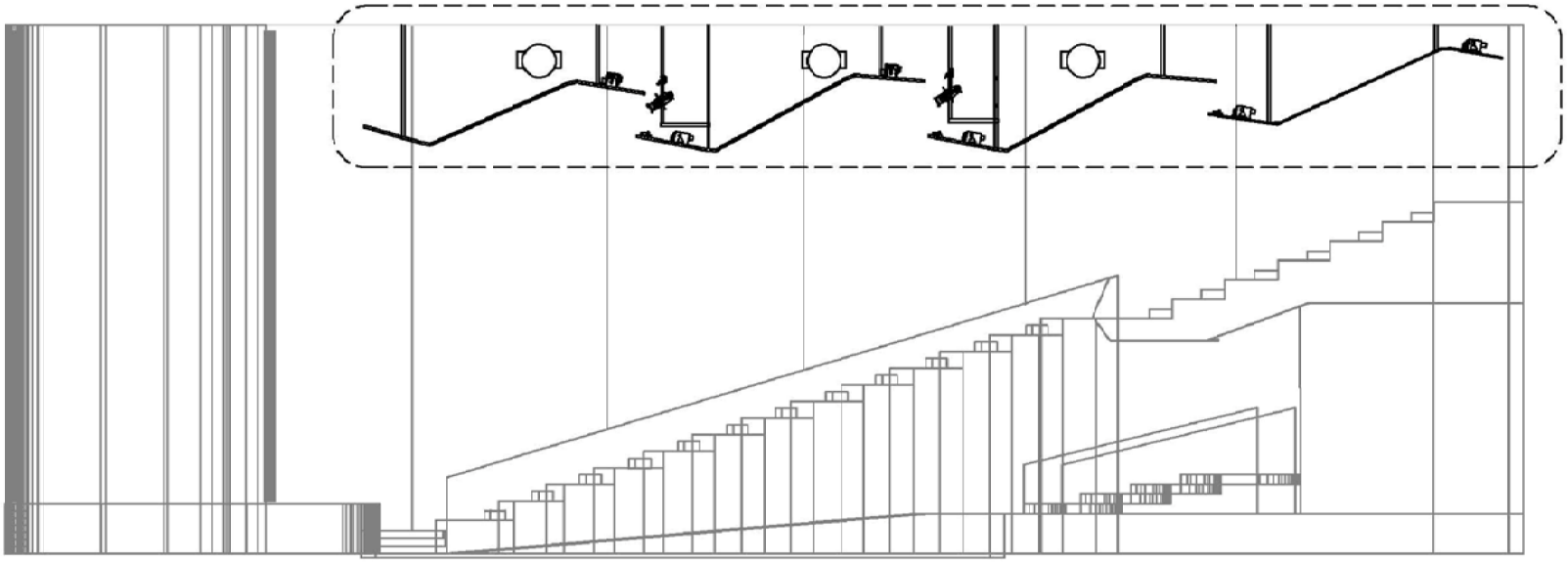
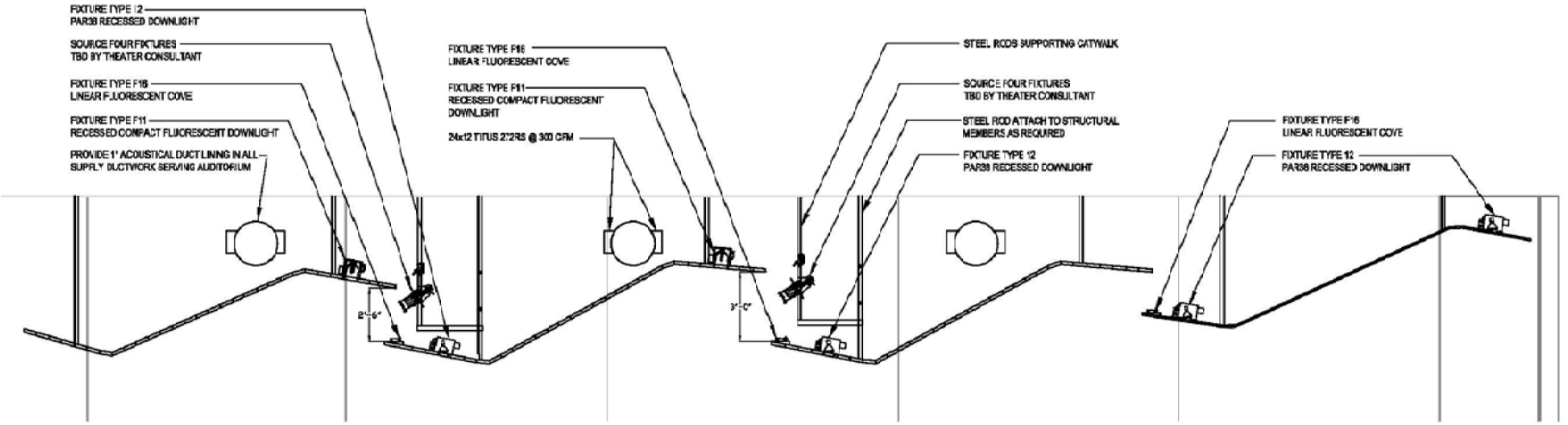



FIGURE 56: CEILING PANEL COORDINATION DRAWING



① FEINBURG THEATER - SECTION SCALE: $\frac{1}{8}$" = 1'-0"




② COORDINATION DRAWING SCALE: $\frac{3}{16}$" = 1'-0"