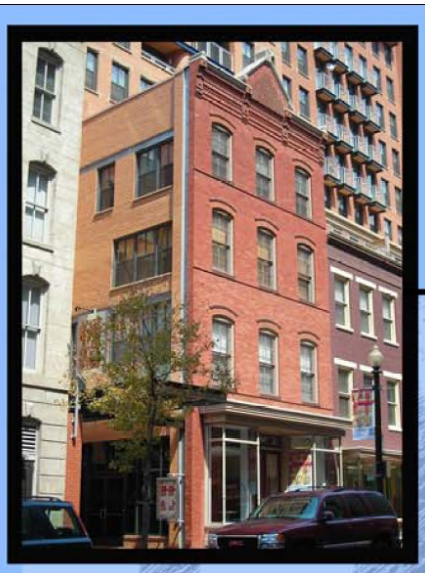
Woolly Mammoth Theatre
Washington DC

Kate Feato
Lighting/Electrical Option
Spring 2007
Lighting Advisor: Dr. Mistrick
Electrical Advisor: Professor Dannerth



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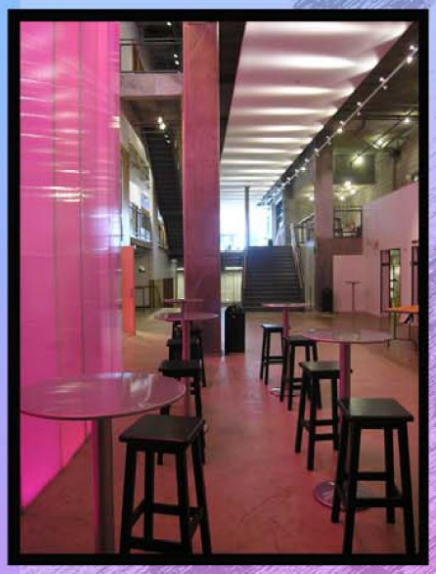
Project Team
Owner: Woolly Mammoth Theatre Company
Architect: Mcinturff Achitects
General Contractor: Davis Construction
Structural Engineer: Tadger-Cohm-Edelson
MEP Engineer: GHT Chartered
Architectural Lighting: C.M. Kling & Assoc. Inc

Project Information
Location: 641 D Street NW Washington DC
Occupancy: 265 seat courtyard style theater with associated support spaces
Size: 31,608 SF
Number of Stories: 3
Dates of Construction: 4.1.04 - 4.26.05
Project Cost: $8 Million
Delivery Method: Design-Bid-Building



Mechanical
The space has ten air handling units ranging from 11,250 cfm to 625 cfm. There are 14 fans ranging from 33,000 cfm to 500 cfm. There are six electric heating coils running at 208 volts varying from 8200 cfm to 1200 cfm.

Electrical
All panelboards are run at 208/120 volt. There are (2) 2000A switchboards. One is servicing all mechanical equipment and motors, while the other is servicing the lighting/dimming and general equipment. There is one transformer used for two fused disconnect switches, which control the audio visual equipment.

Lighting
The lighting has an industrial theme. The fixtures used are simple and edgy. Black, white and aluminum track is used to accentuate walls throughout the lobby. Industrial luminaires and bare par lamps are placed in the theatre and office suite. There is a 22' high light wall, which is lit with bare pars shining down behind semi-translucent laminate panels. 90% of the fixtures in the space are halogen incandescent.

Structural
The building shell was a provided CMU structural cavity with historic brick facade. Floors are metal decking with concrete fill supported by steel joists. Structural steel reinforced concrete beams and columns run throughout the space.

www.arche.psu.edu/thesis/eportfolio/2007/portfolios/kmf213

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Executive Summary

The Woolly Mammoth Theatre Company's mission is to make new, edgy and provocative productions. This sets the stage for the theatre's theme of a 'transparent theatrical laboratory". All of the spaces which are normally hidden from patrons, including rehearsal halls, classrooms, offices and other support spaces, are open to be seen. This will give the patrons a "behind-the-scenes" look at making a live theater production. Throughout the space this theme is portrayed through the lighting, style of architecture and the finishes.

The first part of this report will consist of an in-depth study of the lighting design for the building. The overall lighting concept in the building must enhance the architectural concept. New designs are proposed for four spaces; the canopy, the lobby, the theatre and the office suite. Included in this study are conceptual design, luminaire selection, lamp and ballast selection, fixture placement and the necessary calculations.

An analysis of the building's electrical system is the next section of this report. The electrical redesign of the four newly designed lighting spaces was performed, including the electrical and control plans, and all wire and panel sizing. A complex control system was specified for the flexibility of the canopy and lobby spaces. Also provided in this section is a study of the copper versus aluminum wiring. This study shows the price of aluminum is cheaper, but it is still not feasible to change all the wiring in a building to aluminum. A comparison analysis of screw base and pin base compact fluorescents was performed as well. The advantages and disadvantages of the both were described.

The next part of the report is an analysis of the hydronic heating systems. Hydronic heating systems have many advantages over electric resistive heating systems. Hydronic systems were thoroughly researched and the advantages were described. Next the existing electric heating system for the Woolly Mammoth Theatre was analyzed for initial cost and energy consumption cost throughout a year. A new hydronic heating system was then designed for the space, including sizing of all necessary equipment. This system was analyzed for initial cost and energy consumption cost throughout a year and compared to the existing system. From this information a payback period of about six weeks was found. The hydronic heating system has many benefits over the existing heating system and has the opportunity to save the theatre company a lot of money over the course of the theatre's life.

The last analysis is an acoustic analysis of the theatre space. The theatre space is the most important space acoustically. Patrons come to the Woolly Mammoth Theatre to view productions, and expect good quality. A reverberation time calculation was done to check the existing materials in the theatre. This reverberation time was found to be slightly too high for the ideal situation of the theatre. An acoustical redesign was performed and the reverberation was then taken with the new materials. This reverberations time was the ideal time for the theatre. From this it is easy to see that material absorption is very important in the theatre environment and the change of one material in a space

The Woolly Mammoth Theatre is a very unique and complex space. It has specific design needs which must be taken into account in every aspect of the building. This report provided the integration of architecture, energy consumption, and aesthetics into many of the building systems.

Building Statistics

- **Building Name:** Woolly Mammoth Theater
- **Location and Site:** 641 D Street, NW Washington DC
- **Building Occupant Name:** Woolly Mammoth Theater Company
- **Occupancy:** 265 Seat Theater with Associated Support Spaces
- **Size:** 31,608 SF
- **Number of Stories:** 3
- **Project Team:**
    - Owner: Woolly Mammoth Theater Company
        - http://www.woollymammoth.net/
    - Architect: Mcinturff Architects
        - http://mcinturffarchitects.com/
    - General Contractor: Davis Construction
        - http://www.davisconstruction.com/
    - Structural Engineer: Tadger-Cohn-Edelson
    - MEP Engineer: GHT Chartered
    - Life Safety Consultant: Rolf Jensen & Associates
    - Theater Consultant: Theatre Projects Consultants
        - http://www.tpcworld.com/
    - Acoustic and Audio-Visual Consultant: Acoustic Dimensions
        - http://www.acousticdimensions.com/
    - Architectural Lighting: C.M. Kling & Associates
        - http://www.cmkling.com/
- **Dates of Construction:** April 1, 2004 – April 26, 2005
- **Overall Project Cost:** 8 Million (Does not include concrete shell or historical façade which were provided)
- **Project Delivery Method:** Design-Bid-Build- Hard Bid

Construction:

The concrete shell of the building was provided to the theatre. It was a contribution that valued $4.5 million. The theatre project itself totaled a cost of $8 million. The delivery method was a design-bid-build with a hard bid. Construction started in April of 2004 and lasted a little over a year.

Structural:

The building shell was a provided CMU structural cavity with historic brick facade. Floors are metal decking with concrete fill supported by steel joists. Structural steel reinforced concrete beams and columns run throughout the space. The balcony and tech room in the theatre are on a cantilevered concrete slab.

Mechanical:

The theatre's mechanical system was designed to be totally silent. This was done by using open ended ducts that shoot air horizontally out and down from the catwalk level. No diffusers were used. This enhanced the acoustical quality and intimacy of the theatre. The space has ten air handling units ranging from 11,250 cfm to 625 cfm. There are 14 fans ranging from 33,000 cfm to 500 cfm. There are six electric heating coils running at 208 volts varying from 8200 cfm to 1200 cfm. The mechanical equipment is located sporadically throughout the building in small mechanical closets.

Lighting:

The lighting has an industrial theme. The fixtures used are simple and edgy. Black, white and aluminum track is used to accentuate walls throughout the lobby. Industrial luminaires and bare par lamps are placed in the theatre, circulation areas and office suite. Self ballasted compact fluorescents were used in many of the industrial jelly jars fixtures for a more efficient solution than incandescent. There is a 22' high light wall, which is lit with bare pars shining down behind semi-translucent laminate panels. 90% of the fixtures in the space are halogen incandescent. In the "working" spaces such as the shop, costume rooms and office suites fluorescent pendants were an efficient solution.

Electrical:

All panelboards are run at 208/120 volt. There are (2) 2000A switchboards. One is servicing all mechanical equipment and motors, while the other is servicing the lighting/dimming and general equipment. There is one transformer used for two fused disconnect switches, which control the audio visual equipment.

Transportation:

There is one passenger elevator for patrons in the theatre. The elevator goes from the lower level of the lobby to the street level, and up to the vestibule of the office area. The elevator is 27 KVA and protected by a 150 A circuit breaker. There is one freight elevator located in the shop. This elevator is 36 KVA and protected by a 200 A circuit breaker.

Telecommunications and Audio Visual:

The complete sound, communications and video system is split in four groups based on the different levels and type of audio visual signals. The four groups are microphone and other sensitive wiring; line level wiring; loudspeaker and control wiring; and telephone, video, control and digital systems. The theatre needed a very flexible sound system to meet its unique needs. Because of the budget restraints, the focus on the design was on infrastructure. This will give the theatre company the opportunity to expand the system in the future.

Acoustics:

The primary challenge was that the theatre is built into a residential development. Outdoor spaces and residences are located directly above the theatre, a parking garage below and a loading dock adjacent. Complete room in room construction was not feasible.

Architecture:

The theater is part of a 12 story mixed use facility including 420 condominiums and street level retail. The exterior façade and concrete shell were provided, leaving the interior to be designed by the theater company. The idea for it was to produce a "transparent theatrical laboratory". All of the spaces normally hidden from the view of patrons (rehearsal halls, classrooms, offices and support areas) are open for them to see and truly understand the "behind-the-scenes" of making a production. The interior has a rough edgy feel, using unfinished concrete and unrefined joints throughout the space.

National Codes:

- Boca Building Code 1996 Edition
- Title 12 DCMR 1999 Edition
- Accessibility- ANSI A 117 1986 Edition
- BOCA Fire Prevention 1996 Edition

Zoning:

- Downtown Development District- Permits incentives and requirements for Downtown sub-areas to a maximum FAR of 6.0 to 10.0, and a maximum height of one hundred-thirty (130) feet. This district is mapped in combination with other districts.
- Central Business District- The downtown core comprising the retail and office centers for the District of Columbia and the metropolitan area, and allows office, retail, housing and mixed uses to a maximum lot occupancy of 100%, a maximum FAR of 8.5 to 10.0, a maximum height of 110 feet and 130 on 110-foot adjoining streets.

Lighting Depth

Lighting Depth

The Woolly Mammoth Theatre Company is a very unique group. They have a mission to provide new and edgy productions to the community. Therefore, when designing their first permanent facility, the "personality" of the building must go along with who they are. The architectural concept for the building is a 'transparent theatrical laboratory". Throughout the building, spaces normally hidden from patrons, including rehearsal halls, classrooms, offices and other support spaces are open to be seen. This will give the patrons a "behind-the-scenes" look at making a live theater production.

The lighting concept in the Woolly Mammoth Theatre must enhance the architectural theme. The lighting design concept throughout the building will be to make the spaces **Come Alive**. The finishes in the space are very grim, being white painted walls, concrete floors and ceilings, and concrete block walls. There are only a few select colors in each space. The lighting design will add pizzazz to the spaces, making them new, edgy and provocative as the theatre company's productions are. The lighting design will highlight the architectural elements and make them stand out. All of the redesigned spaces will come alive in their own way.

There is a hierarchy of the spaces throughout the building. Three public spaces were redesigned, and one private space. The public versus private space design criteria is very different. The lobby is the most important public space in the redesign. It is the most edgy and eye-catching. The next public space is the entrance. It foreshadows for patrons what is to come inside the building. The last public space is the theatre space. The house lighting was redesigned. It is the most subdued public space because in the theatre itself, the production is what is important and should not be outdone. The private space that was redesigned was the office suite. This space is only for the employees of the theatre. The office will come alive in a softer way.

Color

Awake

Dynamic

Vibrant

Flashy

Energetic

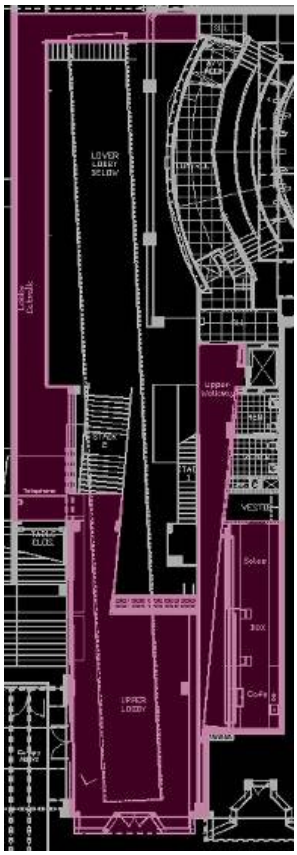
Hi-Tech

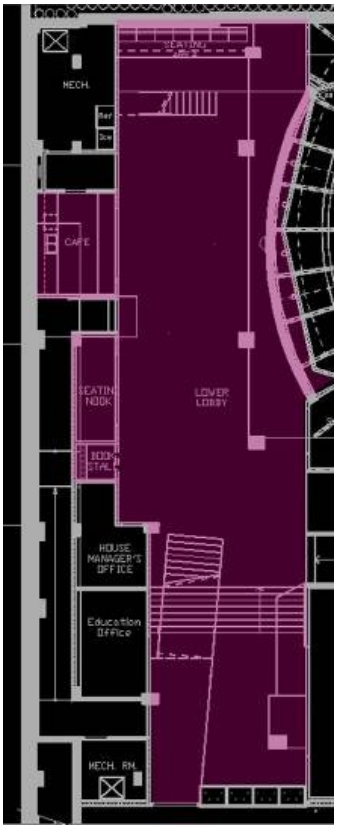
Lobby

Space Overview

As patrons enter the lobby, they are in for a huge surprise. The theater is said to get lost in the cityscape; but once you are inside everything becomes clear. Entering from street level, patrons come in on the second floor. The lobby has a tunnel like feel, extending 130' back and varying widths between 20'-40'. The finishes are unfinished, looking industrial and edgy. There are only a few key colors in the space. On this level there are a ticket booth and café. There is a long balcony, referred to as the "lobby catwalk", descending the entire length of the space where seating is available and art is on display. Also extending the length of the space is a white gypsum board ceiling panel. This helps to draw the eye to the back of the space.

Moving further into the space, stairs will take patrons down to the first level where the lobby is a double-heighted space. The stairs and bridges are cleverly placed to invite movement between the first and second levels of the lobby. On this level there are seating areas, a book stall, a café and the entrances to the orchestra seating. When inside the space, there is no mistake where the theater is. A 22' high curved polycarbonate wall stands between the lobby and theater. This semi-translucent wall has a layer of mylar behind it.





Materials in the Space

- concrete slab ceiling- clear finish — reflectance = 20%
- white painted gypsum wall board ceiling panel — reflectance = 90%
- concrete slab floor- clear satin finish — reflectance = 35%
- masonry block walls- clear finish — reflectance = 25%
- white painted gypsum walls — reflectance = 95%
- polycarbonate translucent wall- ice color
- wood paneling on ticket booth and both café fronts
- plastic laminate counter tops
- blue painted gypsum walls around ticket booth — reflectance = 65%
- orange painted gypsum wall at entry seating area — reflectance = 65%

Glazing

- 2 sided glazing system with vertical joints
  ½" thick clear laminated glazing
- Multi-walled structured polycarbonate glazing
  Polygal: translucent extruded polycarbonate sheet with internal ribbing and smooth flat exterior surface, Color Ice

Daylighting

Above the two story high lightwall, the curve continues with glass. This curved third story glass wall (wall to the office suite) faces an exterior glass façade wall, with a gap of three to eight feet. This gap is open to the lobby space. This technique provides daylight to shine through the third story glass façade and down into the lobby during the daytime. A daylight study was not performed because all of the direct sunlight entering the lobby space hits the light wall. The daylighting does provide ambient light for the daytime, and therefore the theatre company can dim the lighting during those hours.

Design Criteria

General

In this lobby many tasks will be taking place. Tickets, programs and souvenirs will be bought; and snacks will be eaten. The lobby will provide a space for patrons to wait before and after performances. Glare should be completely avoided.

Color rendering and facial modeling are all very important in the lobby. Patrons will be spending time in this space and should look beautiful. There should be points of visual interest and sparkle in the room. This will lead the eye through the space and keep patrons interested.

Illuminance and Luminance Values

According to the IESNA, between 15 and 20 footcandles of horizontal illuminance is desirable for lobbies and foyers in theaters of live productions. The artwork and posters in the space should range from 70 to 350 cd/m^2, depending on surrounding brightness.

Power Density

According to Ashrea 90.1 (2004), using the space by space method for a lobby of a performing arts building, 3.3 W/SF are allowed.

Schematic Design/Design Intent

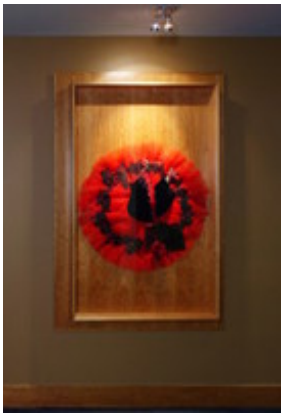
Design Goals

- Color
- Sparkle
- Rhythmic - Invites Movement and Flow
- Most Exciting Space

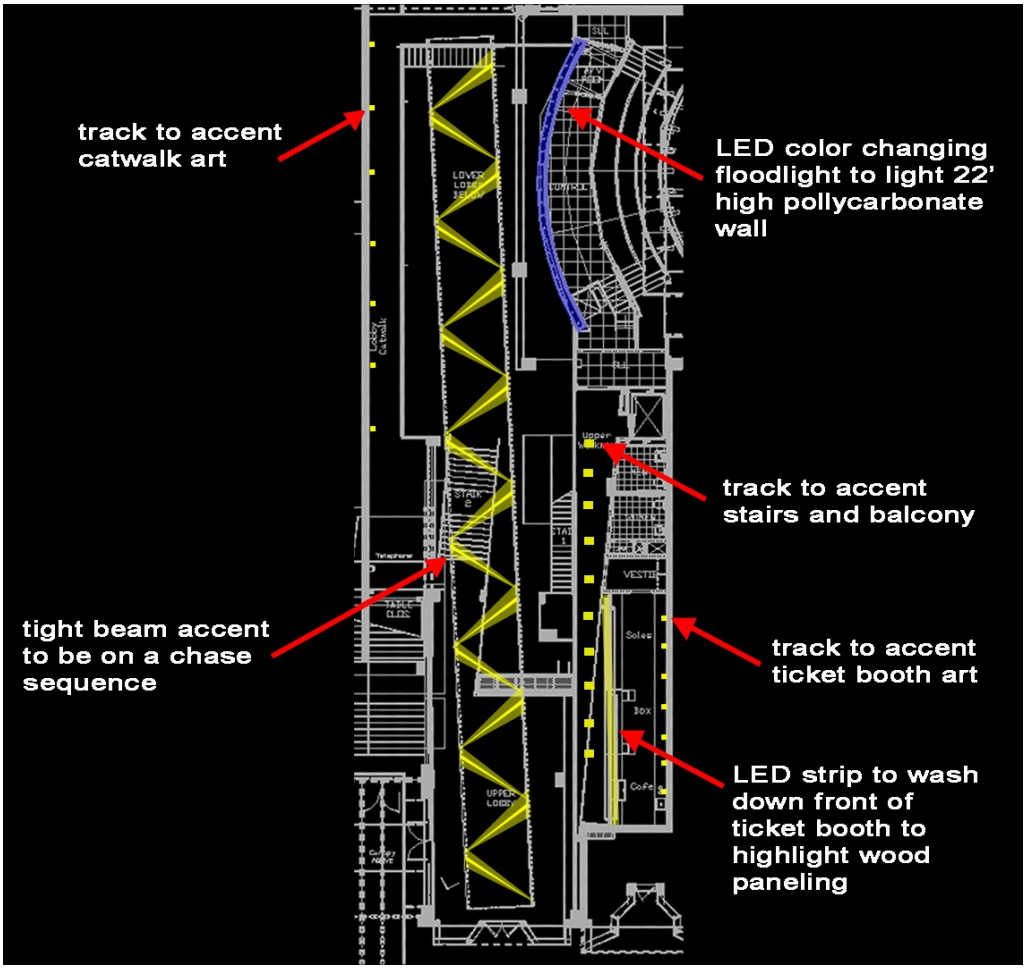
The lobby of the Woolly Mammoth Theatre will be the first interior space patrons will see. The appearance should be pleasing to the eye, feeling inviting and exhilarating. Its edgy design will draw people into the space. Because the majority of the finishes are white and unfinished concrete, colored light will help the space come alive. This light will spread throughout the space giving the lobby a glow of color. The lobby's main character comes from its architecture: the way the stairs are placed, the balconies over looking the lower floor, the small nooks and book stalls, and the gypsum panel extending into the space. These architectural features will be highlighted and be made to sparkle wherever possible.

The architecture also lends itself to movement, and therefore the lighting will keep with that theme. The lighting should be very rhythmic, which will encourage flow and movement. The space will have brightness patterns that attract the eye, as well as influence flow through the space. There should be many layers of light throughout the space, with visual clues as to where to go. This will guide patrons through the tunnel-like dimensions. This space will be the height of experience for the theatre, until the patrons actually see the performance in the theatre.

Concept Photos

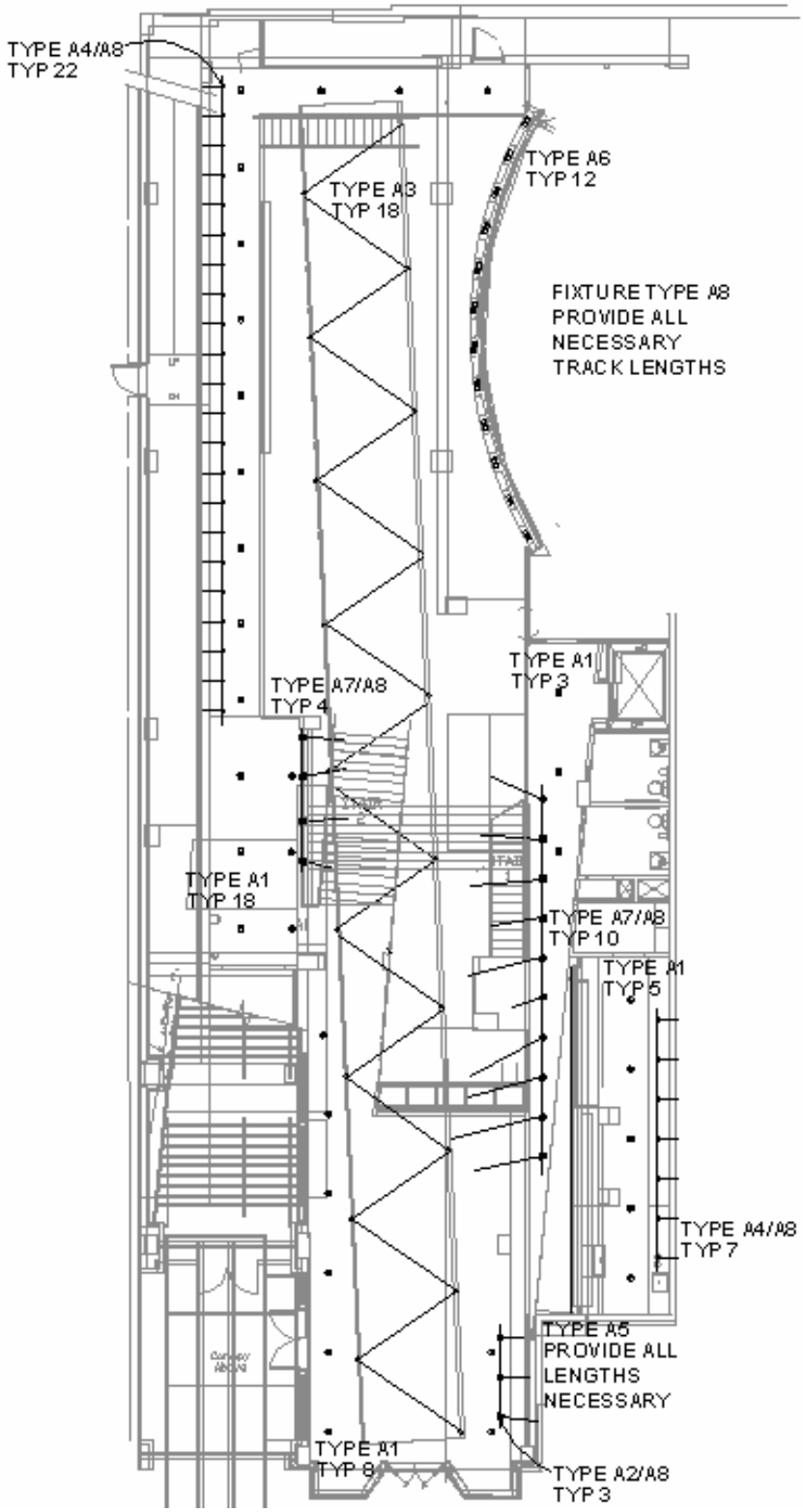


Concept Diagram

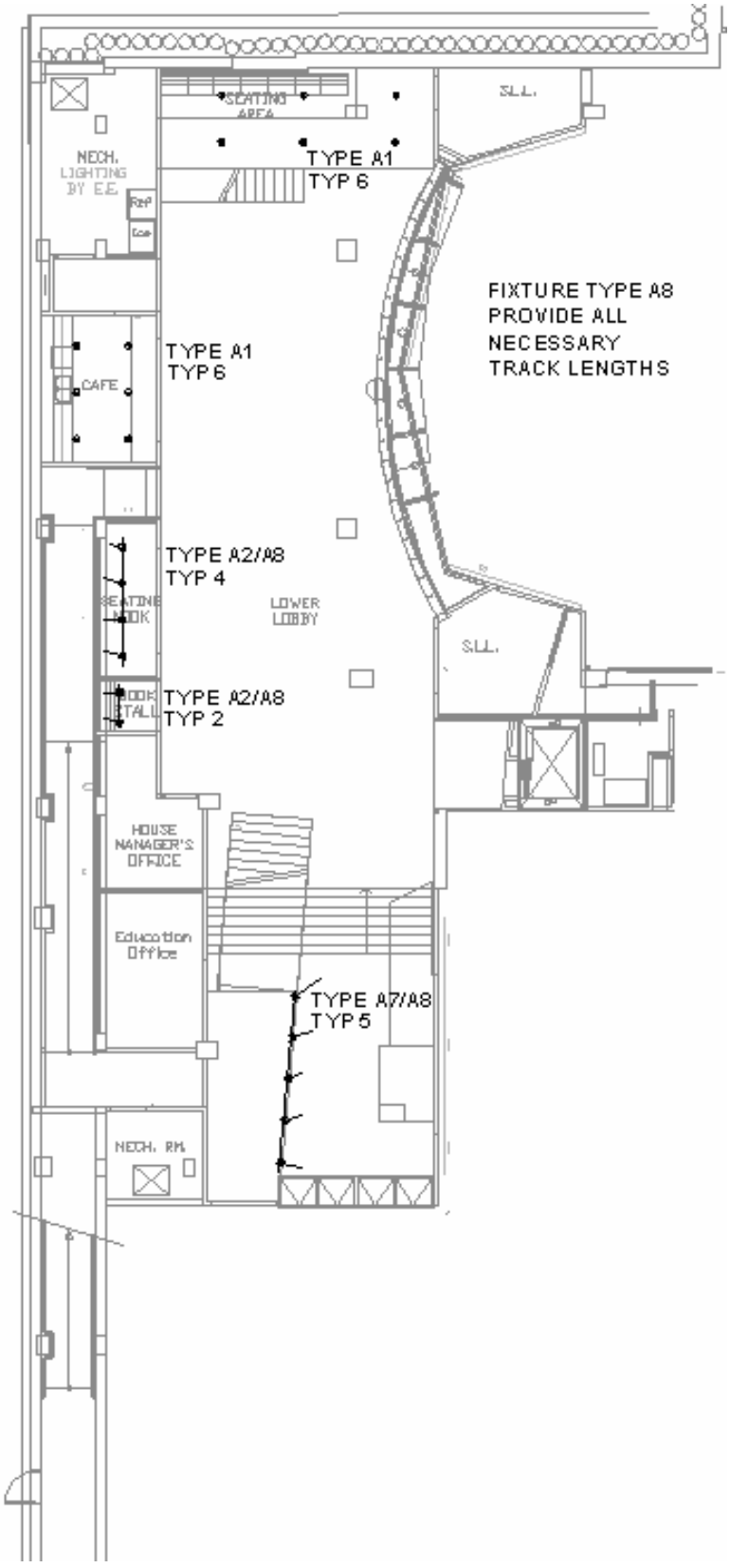


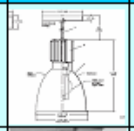
Final Design

Second Floor (Street Level) Lighting Plan



First Floor Lighting Plan



LOBBY LUMINAIRE SCHEDULE						
FIXTURE TYPE	PICTURE	DESCRIPTION	LAMP	MANUFACTURER	CATALOG NUMBER	NOTES
A1		CFL PENDANT	SYLVANIA CF32DT/E/IN/835/ECO	LIGHTOLIER	406U2-416SR	LOCATION: LOBBY DESIGN A
A2		PAR TRACK FIXTURE	SYLVANIA 50PAR36/HAL/WFL30	LSI	236-00-S	LOCATION: LOBBY DESIGN A
A3		GYPSUM PANEL MONO POINT FIXTURE	GE Q71MR16/C/NSP15	LSI	260-5E	LOCATION: LOBBY DESIGN A
A4		ART ACCENT TRACK FIXTURE	GE Q50MR16/C/FL40	LSI	260-00	LOCATION: LOBBY DESIGN A
A5		LED STRIP	1 WHITE LEDS INCLUDED	ARDEE	WW2A LAMPING PR SERIES MOUNTING	LOCATION: LOBBY DESIGN A
A6		LED COLOR CHANGING FLOOD LIGHT	36 RGB LEDS INLCUDED	COLOR KINETICS	COLORBLAST 12 116-000012-02	LOCATION: LOBBY DESIGN A
A7		PAR TRACK FIXTURE	SYLVANIA 100PAR38/CAP/IP/FL40	LSI	290-00	LOCATION: LOBBY DESIGN A
A8		TRACK	N/A	LSI	LSI 120/250V TRACK SILVER FINISH	LOCATION: LOBBY DESIGN A

Fixture, lamp and ballast cut-sheets can be found in Appendix A.

Light Loss Factors							
Fixture	Cleaning Interval	Category	BF	LLD	LDD	RSDD	LLF
A1	12 months (clean)	IV	1.00	0.86	0.94	0.97	0.78
A2	12 months (clean)	IV	1.00	0.90	0.94	0.97	0.82
A3	12 months (clean)	IV	1.00	0.90	0.94	0.97	0.82
A4	12 months (clean)	IV	1.00	0.90	0.94	0.97	0.82
A5	12 months (clean)	IV	1.00	1.00	0.94	0.97	0.91
A6	12 months (clean)	IV	1.00	1.00	0.94	0.97	0.91
A7	12 months (clean)	IV	1.00	0.90	0.94	0.97	0.82
RCR Calculated to be 3.1 Space Assumed to be Very Clean							

The cleaning interval for the lobby was assumed to be 12 months since the building is owned and maintained by the theatre company directly. The space was assumed to be a clean environment because there are no surrounding spaces where adhesive or ambient dirt would be generated.

Power Density					
Fixture	Quantity	Wattage	Total Wattage	SF	W/SF
A1	46	39	1794		
A2	9	50	450		
A3	18	71	1278		
A4	29	50	1450		
A5	230	1	230		
A6	12	50	600		
A7	19	100	1900		
			7702	5182	**1.49**

Using the input wattages for the specified ballast and lamps, the power density for the lobby is 1.49 W/SF. This is significantly under the 3.3 W/SF allowed for the lobby of a performing arts building.

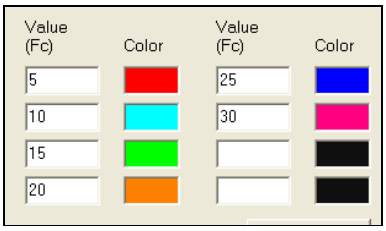
Calculation Grids

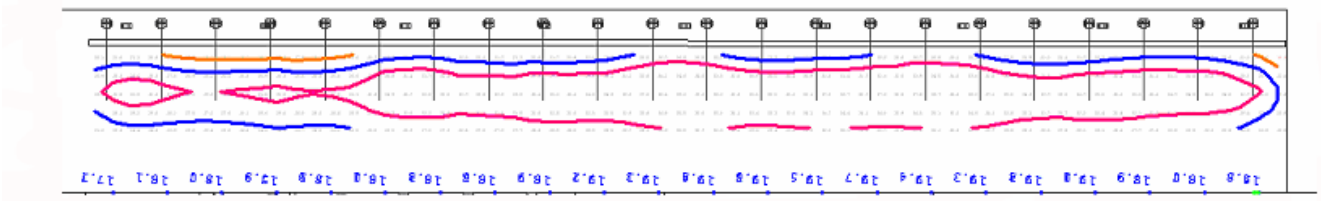
Value (Fc)	Color	Value (Fc)	Color
5		25	
10		30	
15			
20			

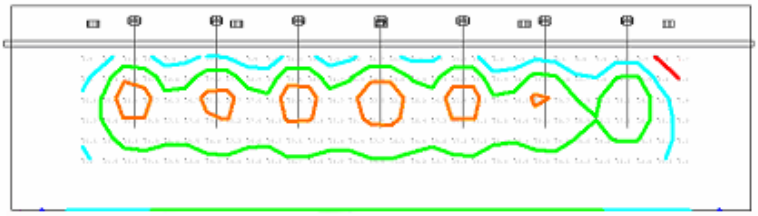
Numeric Summary						
Label	CalcType	Units	Avg	Max	Min	Avg/Min
Lower Level B_Floor	Illuminance	Fc	17.36	32.1	10.5	1.65
Lower Level_Floor	Illuminance	Fc	17.47	29.4	5.0	3.49
Upper Level_Floor	Illuminance	Fc	14.86	28.1	4.8	3.10

The average illuminance of the second floor (street level) of the lobby is 15 fc, with a maximum of 28 fc and a minimum of 5 fc. The area with the lowest light levels, about 10 fc, is directly near the entrance. This is acceptable because the entrance wall and front façade are both glass. Therefore during the day, daylight will illuminate this area. During the evening, the canopy lighting will illuminate this area. The balcony catwalk has an even distribution of 17 fc. The second floor should be slightly dimmer than the first, because there should be more contrast with the accenting of the art and gypsum panel.

The first floor illuminance is slightly higher than the second floor, having an average of 17 fc. Having the first floor illuminance level higher will encourage patrons too look up at the gypsum panel and art running through the space.







Numeric Summary						
Label	CalcType	Units	Avg	Max	Min	Avg/Min
Catwalk_Art	Illuminance	Fc	29.07	39.2	16.2	1.79
Ticket Booth_Art	Illuminance	Fc	14.62	23.0	2.7	5.41

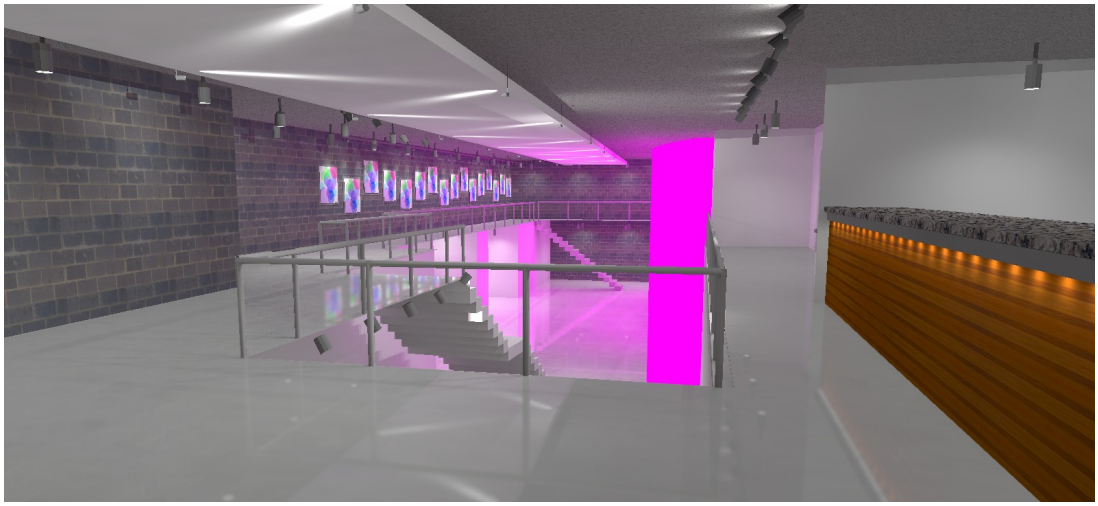
The catwalk are has an average of 30 fc, with a very even distribution of 1.79 average to minimum fc. This is important because the art of the catwalk is not constant. The even distribution will let the theatre company place any type or size art display on the wall. The ticket booth art has a lower illuminance average of 15 fc, because the ticket booth floor has a lower illuminance than the catwalk floor. The art lighting is not completely evenly distributed. There are seven permanent pictures hanging on the wall, each fixture is accent one picture. These pictures are never removed, and therefore each one can be highlighted more dramatically.

Control

The lobby lighting will be on a standard theatrical dimming rack controlled by an architectural interface. The lobby lighting will be zoned according to type of fixture and area of the room. All lobby fixtures will be controlled by this system. The accent fixtures lighting the gypsum ceiling panel will be on a chase sequence (first fixture will fade to a higher level, then second, then third and so on). The sequence will run slow, being subtle. This will make the space have a dynamic feel and will guide patrons into the tunnel like room. The LED floodlights lighting the polycarbonate wall will be color changing, so they can be set on one color, or a color changing sequence. When they are color changing, the sequence will be very slow, so it does not compete with the accents on the gypsum panel.

The lobby will have many different lighting scenes for different circumstances. Four typical preset scenes useful to the theatre company would be night performance, day performance, day ambient and night ambient. These presets could also be altered for specific needs of the event as well.

Renderings



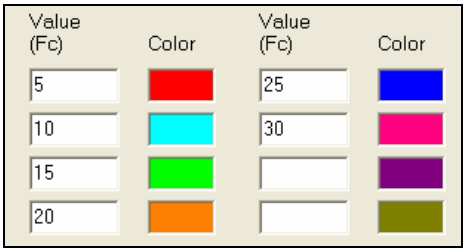
Conclusion

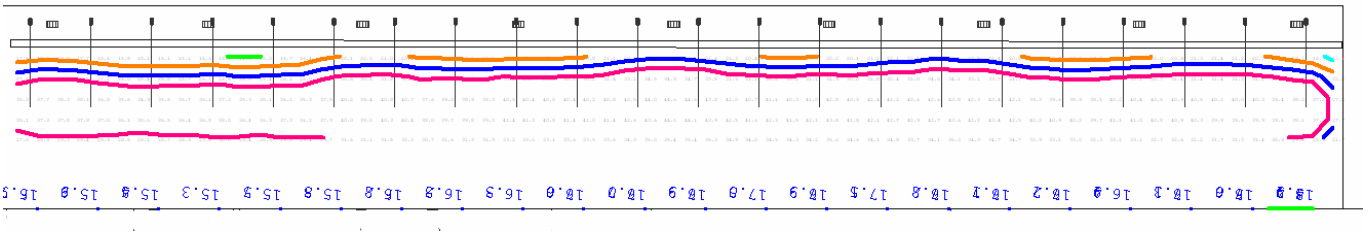
The lobby is an architecturally complex space. The lighting design must work with the architecture to enhance the space. The suspended gypsum panel is one of the most important features in the lobby. The accent lighting on the stark white panel will guide patrons into the space. Once led to the back of the lobby, patrons will see the 22' high light-wall. The panel and this wall are completely contrasting, adding dimension to the space. The panel is white, long and narrow, straight, and unevenly lit with accents. The light wall is robust, colored, curved and evenly distributed. These two elements are very prominent and define the space. The track used throughout the space highlights many unique features of the architecture including stairways, walls, balconies and artwork. The orange accent wall and the wood paneling on the ticket booth were lit to draw attention to their color and texture. The new design for the lobby is aesthetically pleasing, as well as fulfills the design criteria and its purpose. The lobby is a very exciting space, and with the new lighting design the space comes alive.

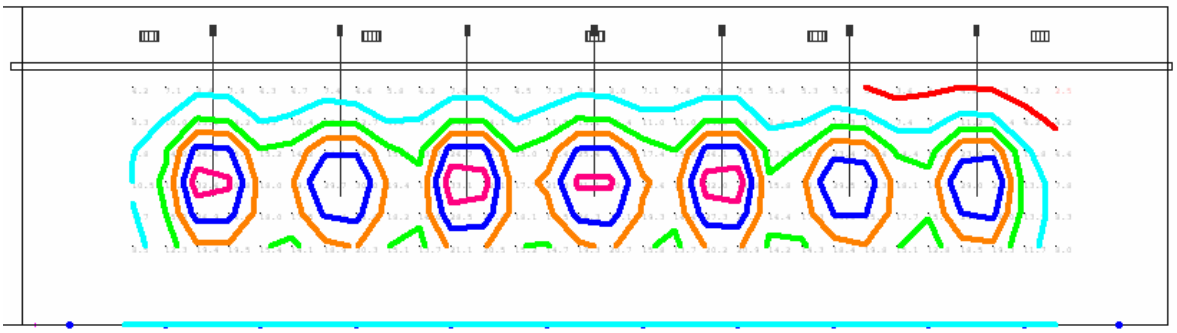
Lobby Design 2

In the second design for the lobby, the track fixtures accenting the catwalk and the ticket book art were changed from 50 W MR16 fixtures to 35 W LED fixtures. The LED fixture is fixture type A8. The fixture cut-sheet can be found in Appendix A. The design will be critiqued on performance and cost/efficiency.

Performance







Numeric Summary						
Label	CalcType	Units	Avg	Max	Min	Avg/Min
Catwalk_Art	Illuminance	Fc	32.11	44.6	13.7	2.34
Ticket Booth_Art	Illuminance	Fc	16.17	33.1	2.5	6.47

The average illuminance on both the catwalk art and the ticket booth art is only about 1 fc to 2 fc higher using the LED fixture. This is because the LED fixture's rated lumens are 100 lumens more that the MR16 fixture. Due to this fact, the LED fixture could actually be compared with a 71 W MR16. The LED fixture provides a very even distribution on the catwalk art, and a diverse distribution on the ticket booth art, just as the MR16 fixture does. The LED fixture has 100% lumen maintenance, whereas the MR16 only has 90%. The CCT and CRI of both fixtures are equivalent.

Efficiency and Cost

The rated lamp life for the LEDs is 50,000 hours. This is much longer than the lamp life of 6,000 hours for the MR16. The wattage of the LED fixture is also less, 35W compared to the 50 W for the MR16. Below is a calculation of the money saved on electricity with the new design, using the LED track versus the MR16 track.

* Average number of hours on per year:	2496
* Electric cost per kilowatt hour:	0.08

Lamp 1

Lamp name:	MR16
* Watts (fixture watts/# of lamps):	50
* Cost (including disposal cost):	$ 7
* Life in hours:	6000
* Cost of labor to replace lamp:	$ 0
Mean lumens:	900

Lamp 2

Lamp name:	LED
* Watts (fixture watts/# of lamps):	35
* Cost (including disposal cost):	$ 0
* Life in hours:	50000
* Cost of labor to replace lamp:	$ 0
Mean lumens:	1000

CALCULATE

Results

	Lamp 1	Lamp 2
Lamp name:	MR16	LED
Cost over lamp life:	$31	$140
Cost per 1,000 hours:	$5.17	$2.8
Cost per year:	$12.9	$6.99
Cost per million lumen hours:	$5.74	$2.8

Savings with Lamp 2: $5.91 /year

According to this energy analysis, every LED fixture saves about $6.00 per year. For the lobby design there are 29 fixtures. This would give a total savings of $174 per year. This does not take into account the initial cost of the fixture (at least $200 more than the MR 16 fixture).

In the calculation below, the initial cost of the LED fixture is taken into account, and a payback is generated for the new system.

* Required

* Number of fixtures:	29
* Average number of hours on per year:	2496
* Your electric cost per kilowatt hour:	$ .08
* Watts per fixture used in current system:	50
* Watts per fixture used in proposed system:	35
Cost to upgrade each fixture*:	$ 200

CALCULATE

Results

Cost of Electricity			Energy Savings (with proposed system)		
Current system:	$289.54	per year	Each fixture:	$3	per year
Proposed system:	$202.68	per year	Total:	$86.86	per year

Using only your energy savings, you will get your full investment back in **800 months (66.67 yr.)**

In this calculation, the efficiency of the fixture does not outweigh the extra cost. A payback of 67 years is too long of a payback. If there were more fixtures being replaced in the space, or if the MR16 fixtures were using 71 W lamps, the benefits would have been greater.

Conclusion

LEDs are the newest technology in lighting design. They are getting better and better every day, with more options for fixtures, brighter lamps and better dimming solutions. Yet they are not the best solution in every case. In this design, the LEDs would save a small amount of money on electricity, but the payback of the initial cost is probably longer than the system will even be installed. Therefore the LEDs should not be used. The reliable, cheap and versatile MR16 should be kept for the track lighting of the catwalk and ticket booth artwork.

Canopy

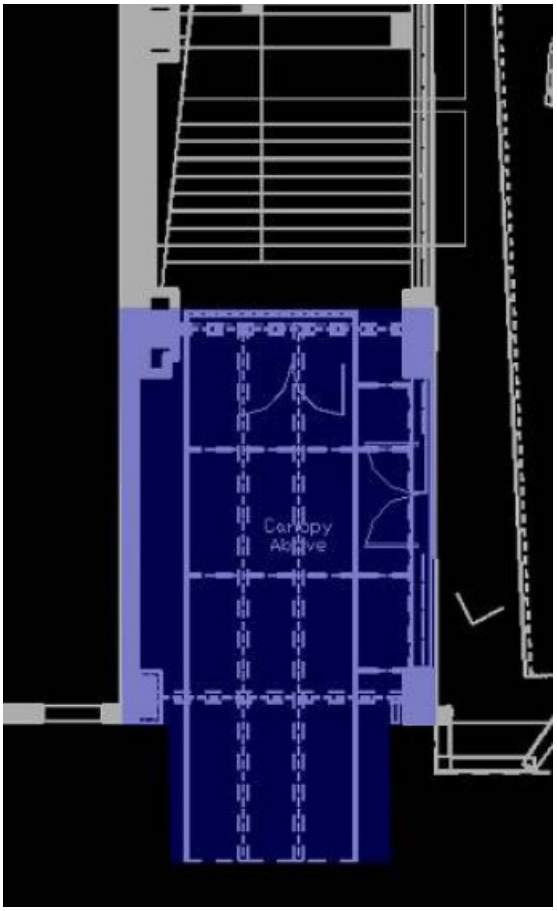
Space Overview

The Woolly Mammoth Theatre sits on a busy street in downtown DC. It has a historic brick façade facing this street and remains very low-key. The doors to this storefront remain closed. To enter the theatre, patrons must go around the corner.

The alley does have a canopy to make it more apparent. The canopy is made of black steel columns/beams and a plastic glazing panel. There is also an area to hang advertisements for upcoming shows. Yet this canopy is not glitzy or glamorous. It has an industrial feel, which will prevail throughout the space.

The canopy will direct patrons to the entrance of the theatre. The appearance of the luminaires will foreshadow what will be seen throughout the building. There should be accent lighting on the wall of the adjacent building where posters are being displayed. This area should have sparkle and be eye-catching. The steel and glass surfaces should appear to be beautiful.

The majority of the theatre company's shows are in the evening hours. The theater should blend in to the cityscape during the "work day". Once it becomes dusk, the full view of the theatre should become apparent from the outside.



Materials in the space

- black steel structure — reflectance = 20%
- brick walkway — reflectance = 35%
- brick and glass façade of theatre on one side
- brick adjacent building facade

Glazing

- polycarbonate panel
  Polygal: translucent extruded polycarbonate sheet with internal ribbing and smooth flat exterior surface, Color Ice

Horizontal Illuminance

According to IESNA Handbook there should be 5 footcandles of horizontal illuminance on the ground. There should also be at least 3 footcandles of vertical illuminance.

Power Density

According to the ASHREA 90.1 (2004), using the Space- By- Space method, the power density allowed for an entrance canopy is 1.25 W/SF.

Schematic Design/Design Intent

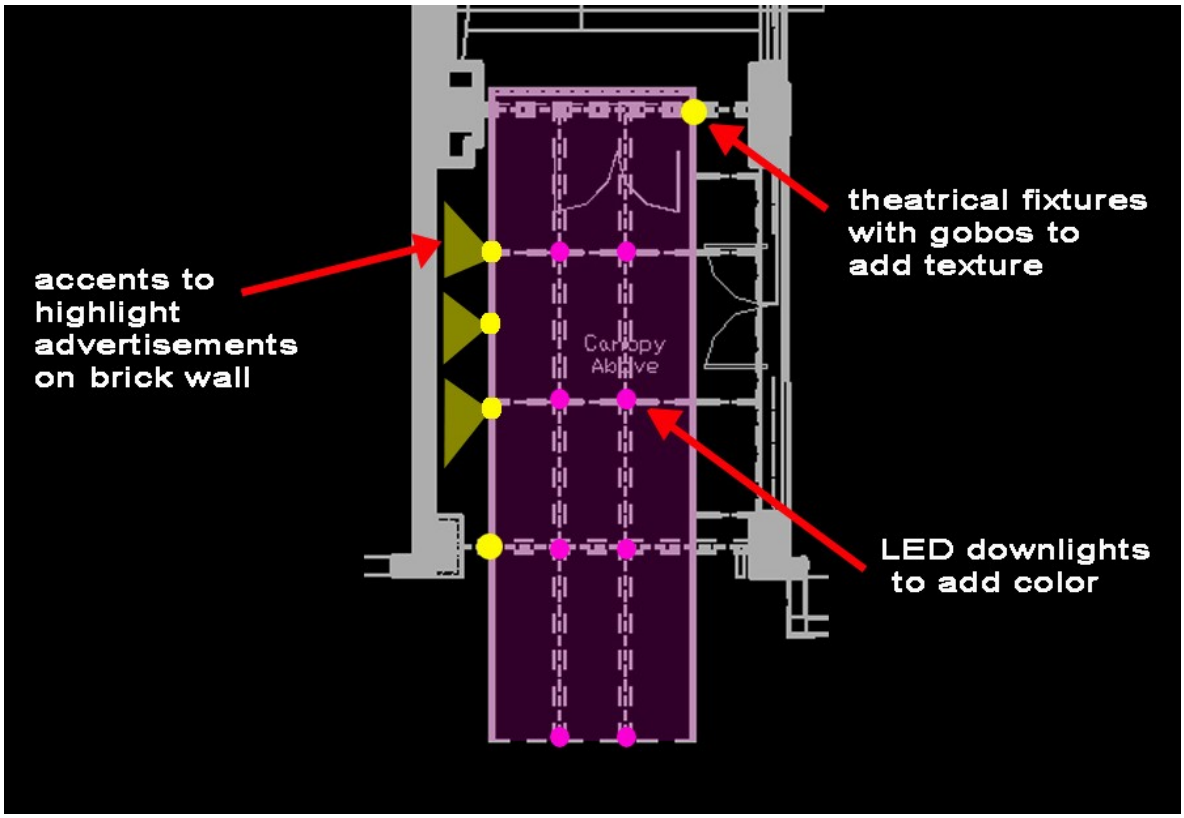
Design Goals

- Eye-catching
- Peeks Interest
- Depth
- Foreshadow What Is Inside

The entrance to the Woolly Mammoth Theatre is located in an alleyway. To make the canopy eye-catching during hours of operation, color and texture were used. The RGB LED downlights will be able to be a variety of colors. This will peek the interest of on-lookers. They will want to know what is inside the building. The two theatrical fixtures will be very close to white light. They will have gobos to add texture to the canopy floor. The layering of light will give the space depth. All of these features will foreshadow the color and texture to be seen once entering the building.

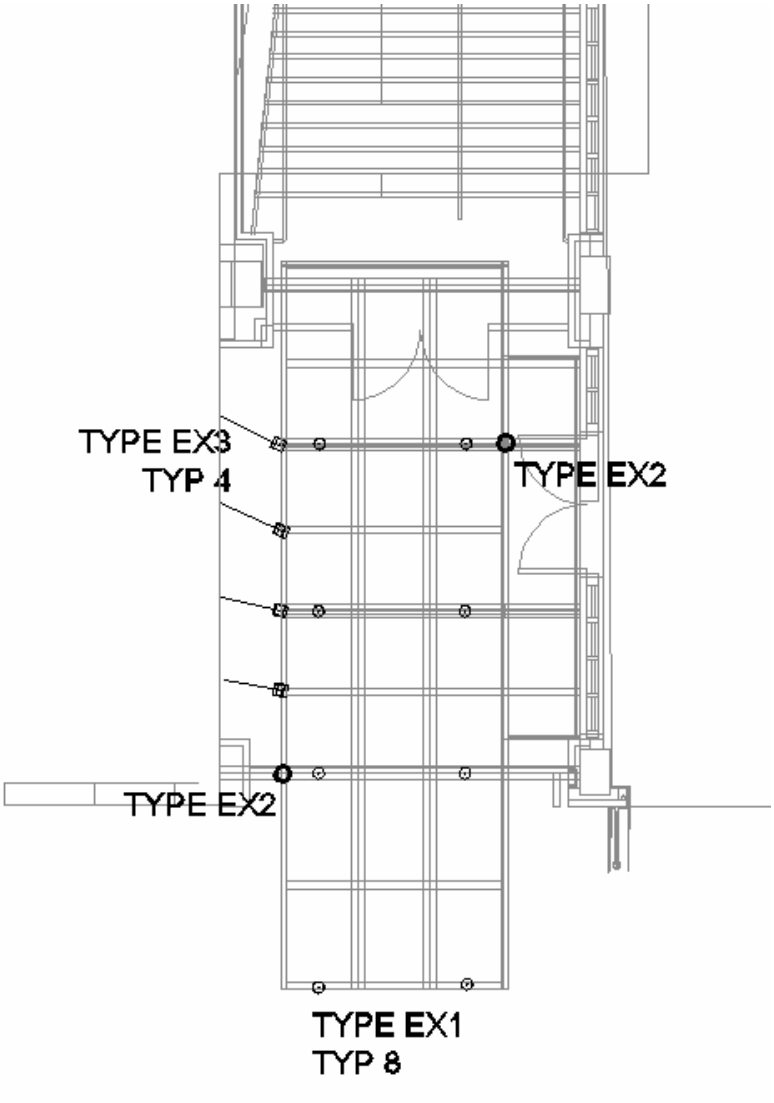
Concept Photos

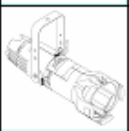
Concept Diagram



Final Design

Lighting Plan



CANOPY LUMINAIRE SCHEDULE						
FIXTURE TYPE	PICTURE	DESCRIPTION	LAMP	MANUFACTURER	CATALOG NUMBER	NOTES
EX1		RGB LED SPOTLIGHT	31 LUXEON HIGH LUX LEDS	TIR	DES-30-RGB-BLK-DMK	LOCATION: CANOPY
EX2		THEATRICAL FIXTURE PROVIDE WITH SPECIFIED GOBO	SYLVANIA HPL375	ETC	426J-400PH-M	LOCATION: CANOPY
EX2A		ROSCO	N/A	ROSCO	DOT BREAKUP 77053-0660	LOCATION: CANOPY
EX3		YOKE MOUNTED HALOGEN CYLINDER	SYLVANIA 50PAR30CAPIRNFL25	LSI	FB-30-B	LOCATION: CANOPY

All fixture, lamp and ballast cut-sheets can be found in Appendix A.

Light Loss Factors							
Fixture	Cleaning Interval	Category	BF	LLD	LDD	RSDD	LLF
EX1	12 months (medium)	IV	1.00	1.00	0.89	0.94	0.84
EX2	12 months (medium)	IV	1.00	0.90	0.89	0.94	0.75
EX3	12 months (medium)	IV	1.00	1.00	0.89	0.94	0.84
RCR Calculated to be 5.6 Space Assumed to be Clean							

The cleaning interval for the canopy was assumed to be 12 months since the building is owned and maintained by the theatre company directly. The space was assumed to be a medium environment. The canopy is an exterior space, but is in between two large buildings in an alley. Therefore the amount of dirt would generated is not high.

Power Density					
Fixture	Quantity	Wattage	Total Wattage	SF	W/SF
EX1	8	35	280		
EX2	2	375	750		
			1030	550	**1.87**
EX3	4	50	200	550	**0.36**

Using the input wattages for the specified ballast and lamps, the power density for the canopy is 1.87 W/SF. This is slightly over the allowed 1.25 W/SF. Taking into account the power allowances of the other redesigned spaces, all of which were significantly under the allowed power density, the canopy being over is acceptable. Fixture type EX3 is an exception in the power density calculation because it is an integral part of advertising.

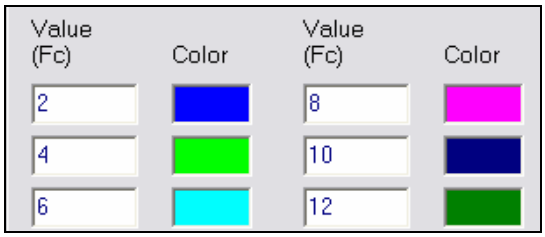
Calculation Grids

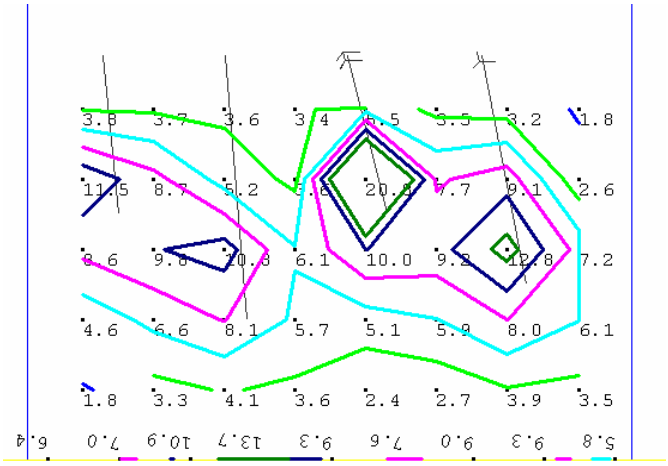
Value (Fc)	Color	Value (Fc)	Color
2		8	
4		10	
6		12	

Numeric Summary						
Label	CalcType	Units	Avg	Max	Min	Avg/Min
Wall	Illuminance	Fc	6.19	20.8	1.8	3.44
Ground	Illuminance	Fc	6.24	13.7	2.0	3.12

The average illuminance of the canopy floor is 6 fc, which fulfills the suggested value of 5 fc. The lighting is evenly distributed over the canopy floor with a average to minimum fc ratio of 3.12. This is ideal because the colored light should be as even as possible to give the canopy space a glowing feel. The theatrical fixtures with gobos were not taken into account in this calculation. They will add light to the space, but will be used strictly for texture.

Advertisements on Brick Facade



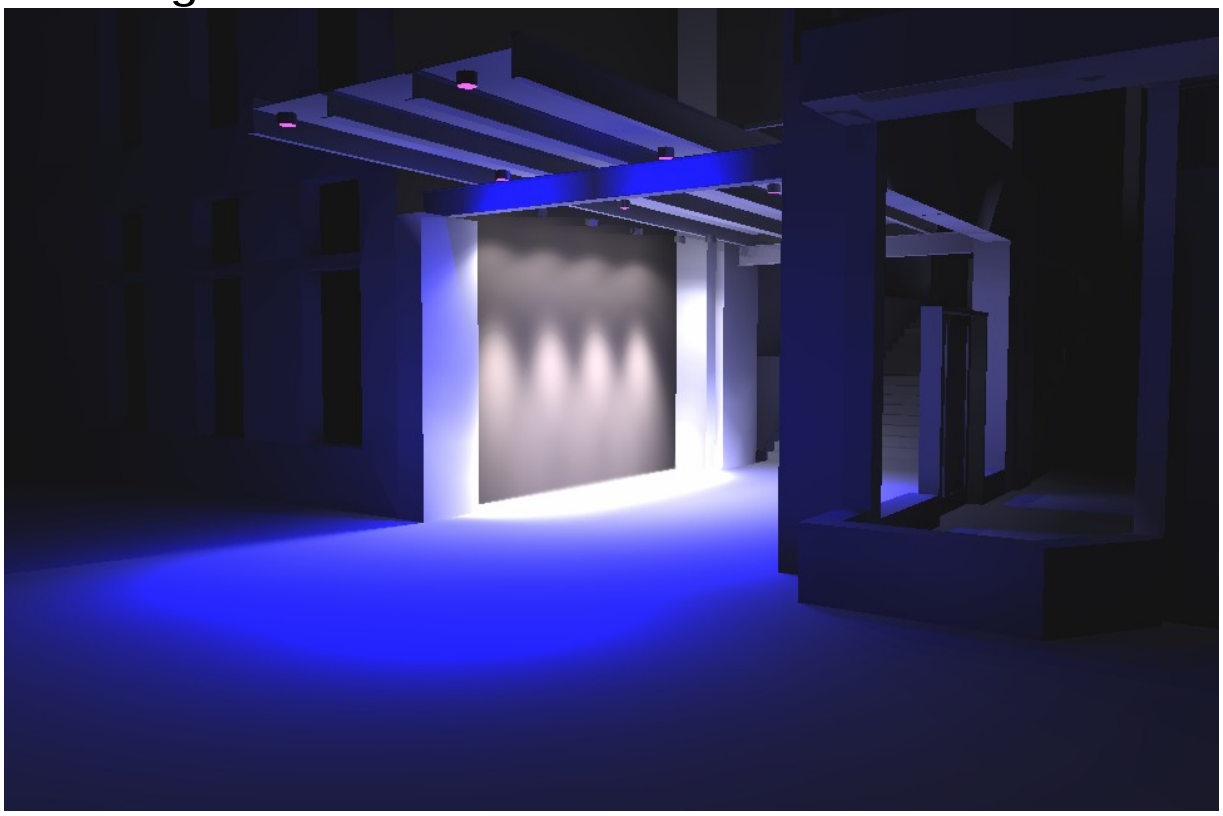


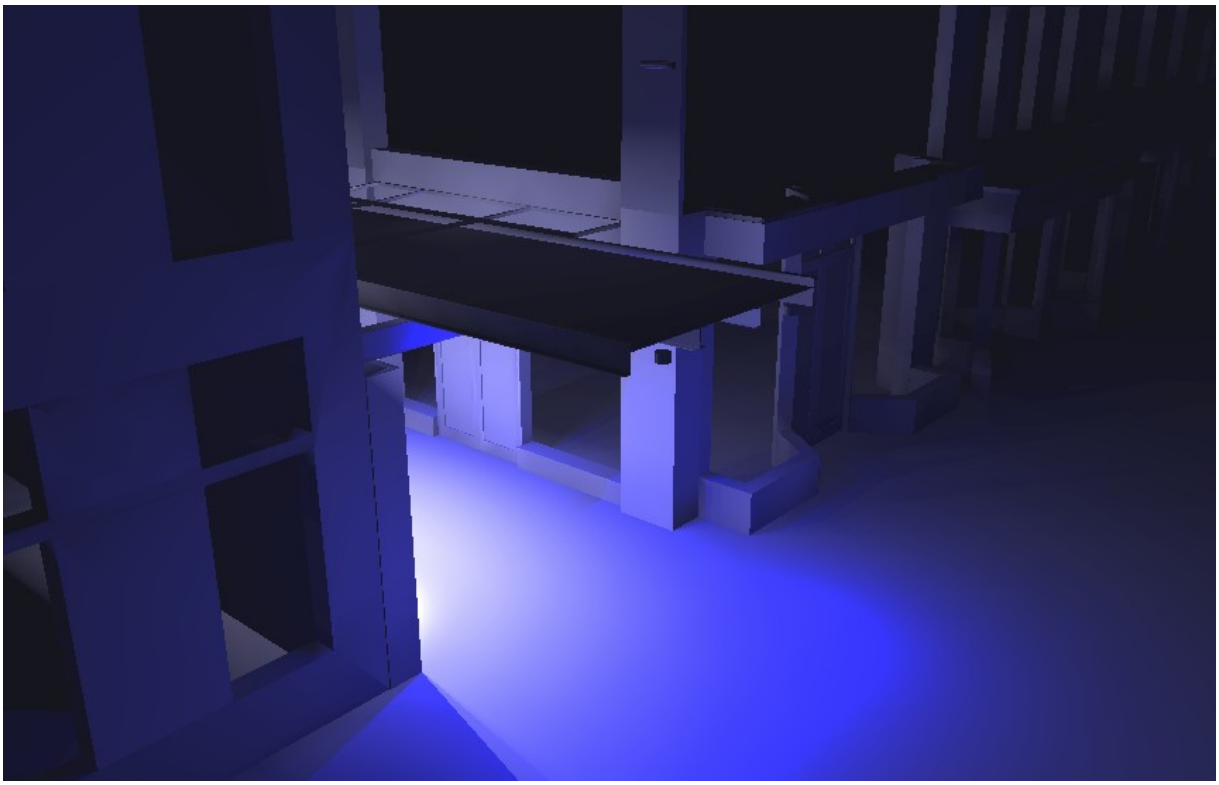
The aiming of the accents on the brick façade is adjustable, and can be changed with the size of the advertisement. In this calculation the accents were arbitrarily aimed as if there were two advertisements. This façade has significantly more illuminance than the canopy area itself. This will direct the patron's attention to the advertisement.

Control

The canopy lighting will be controlled by the same system as the lobby. This will allow the LED fixtures to be color changing on a sequence. Also the accents for the advertisements and the theatrical fixtures can be dimmed. The exterior zones will not be on during the day, unless it is a very dark day. If necessary the advertisement lighting can be used to add light to the space during daytime hours. All the exterior fixtures will be turned on at dusk.

Renderings





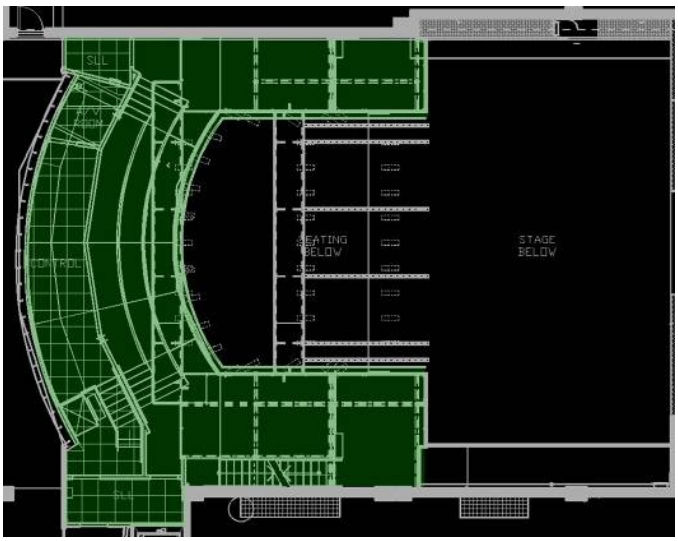
Conclusions

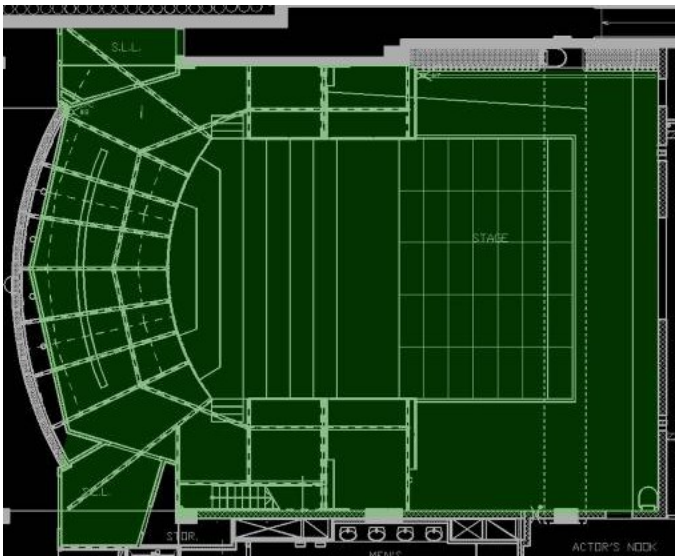
The canopy of the Woolly Mammoth Theatre is located in an alley off of the main road. This adds to the mystery of the theatre, because it is almost lost in the cityscape. During the day the theatre will blend in with the surrounding buildings, but at night the space will come alive. The lighting design for the canopy is edgy, using high-tech fixtures and control. Color and texture are used to grab the attention of outsiders. The space shows people a glimpse of what can be seen inside the building. The new design for this space fulfills the design criteria as well as embraces the lighting design concept.

Theatre

Space Overview

Entering the theatre through the main entrance on the orchestra floor, there is no grand entrance. The doors are awkwardly placed behind a concrete column. The theme of the theatre is to be intimate and edgy. It is a 6,000 SF space with seating on two levels, 187 orchestra and 78 balcony plus standing room. The theatre has a courtyard configuration designed to connect the audience and actors in this cozy setting. The space is high and deep, making it very flexible. The main finish throughout the theatre is black. The only color in the space is the maple seat backs, the wood slats on the balcony fronts and the red accent wall at the back of the theatre.





Materials in the Space

- concrete slab ceiling- clear finish — reflectance = 20%
- concrete block walls- clear finish — reflectance = 20%
- concrete block walls- black stained finish — reflectance = 10%
- concrete wall- clear finish — reflectance = 20%
- concrete wall- black stained finish — reflectance = 10%
- red painted gypsum wall — reflectance = 30%
- concrete slab floor- clear satin finish — reflectance = 30%
- carpet- dark gray — reflectance = 10%
- light wood paneling on balcony fronts
- black upholstered seats
- black metal catwalks
- metal railings

Design Criteria

General

Before and after a performance, the theatre house lighting will be on. This lighting should be diffuse and comfortable. In this time patrons will be entering and exiting the theatre, finding their seats, reading programs and waiting for the performance to begin.

The lighting should have some accenting or visual interest, as patrons may be waiting lengths of time in their seats. The space should appear to be at a high quality in appearance. Color rendering and facial modeling are very important to achieve this.

The general lighting should be on dimming control. Also “panic” switches independent of dimmers and switches should be provided to bring on selected house lights in case of an emergency. Emergency house lighting, exit lighting, and aisle lighting are all necessary.

Illuminance and Luminance Values

A minimum of 10 to 20 footcandles should be maintained throughout the seating area when a performance is not taking place. Higher illuminances of 30 footcandles are required to perform visual tasks, such as rehearsals, cleaning and maintenance of the space. During performances emergency light levels must be 0.2 footcandles.

Power Density

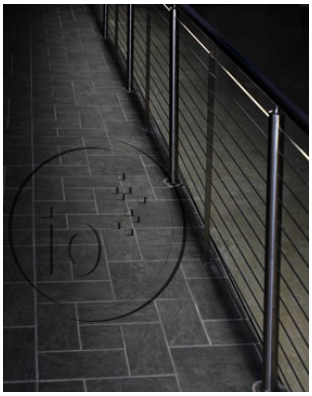
According to Ashrea 90.1 the power density for an audience/seating area in a performance space is 1.8 watts/sq. ft.

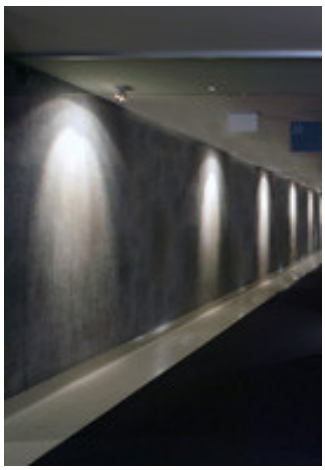
Schematic Design/Design Intent

- Intimate
- Subdued
- Sparkle

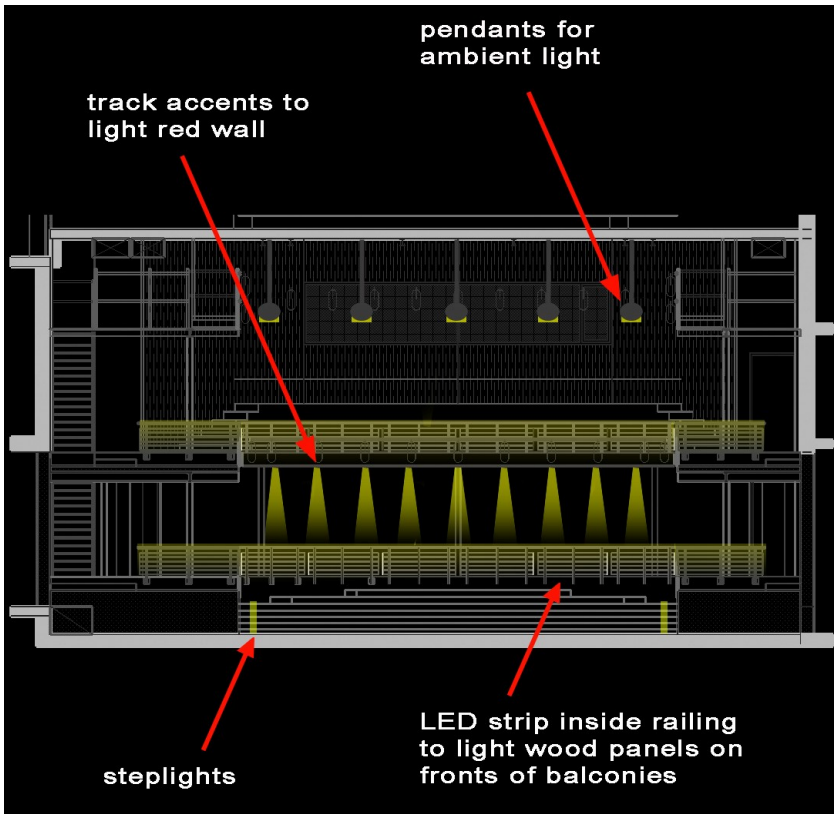
The lighting for the theatre must come alive in a different way than the previously discussed spaces. The main function of the theatre is to hold the performance. For that reason the lighting before and after the show should not compete with the show itself. The house lighting should prepare the audience for the production. Staying with the architectural concept of the theatre, the lighting should enhance the intimate feeling of the theatre. Sparkle should be added to the space. This will be accomplished by expressing the equipment and the actual theatre mechanics to enhance the space and add sparkle. The lighting of the theatre will be subtle, yet still make the space come alive.

Concept Photos



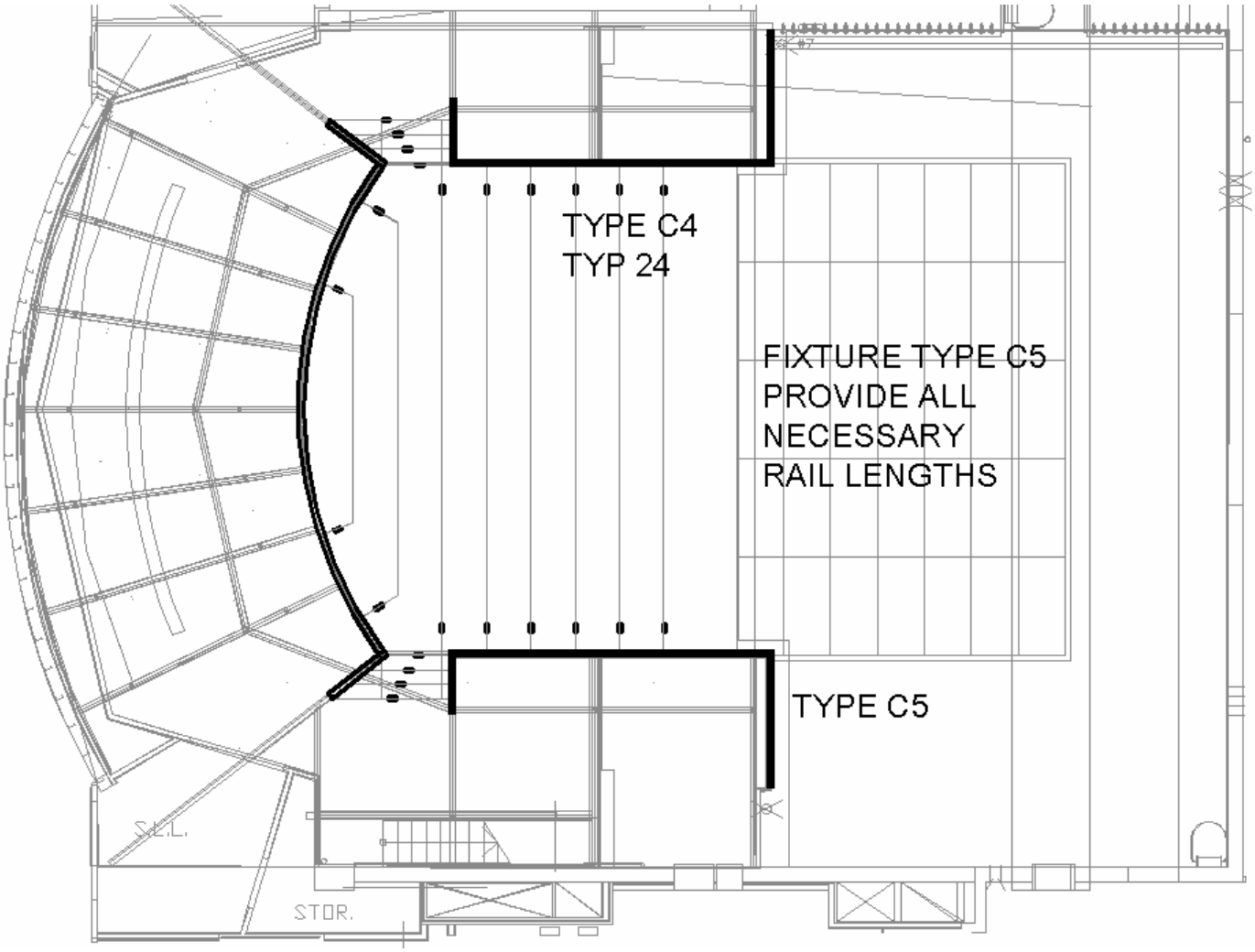


Concept Diagram

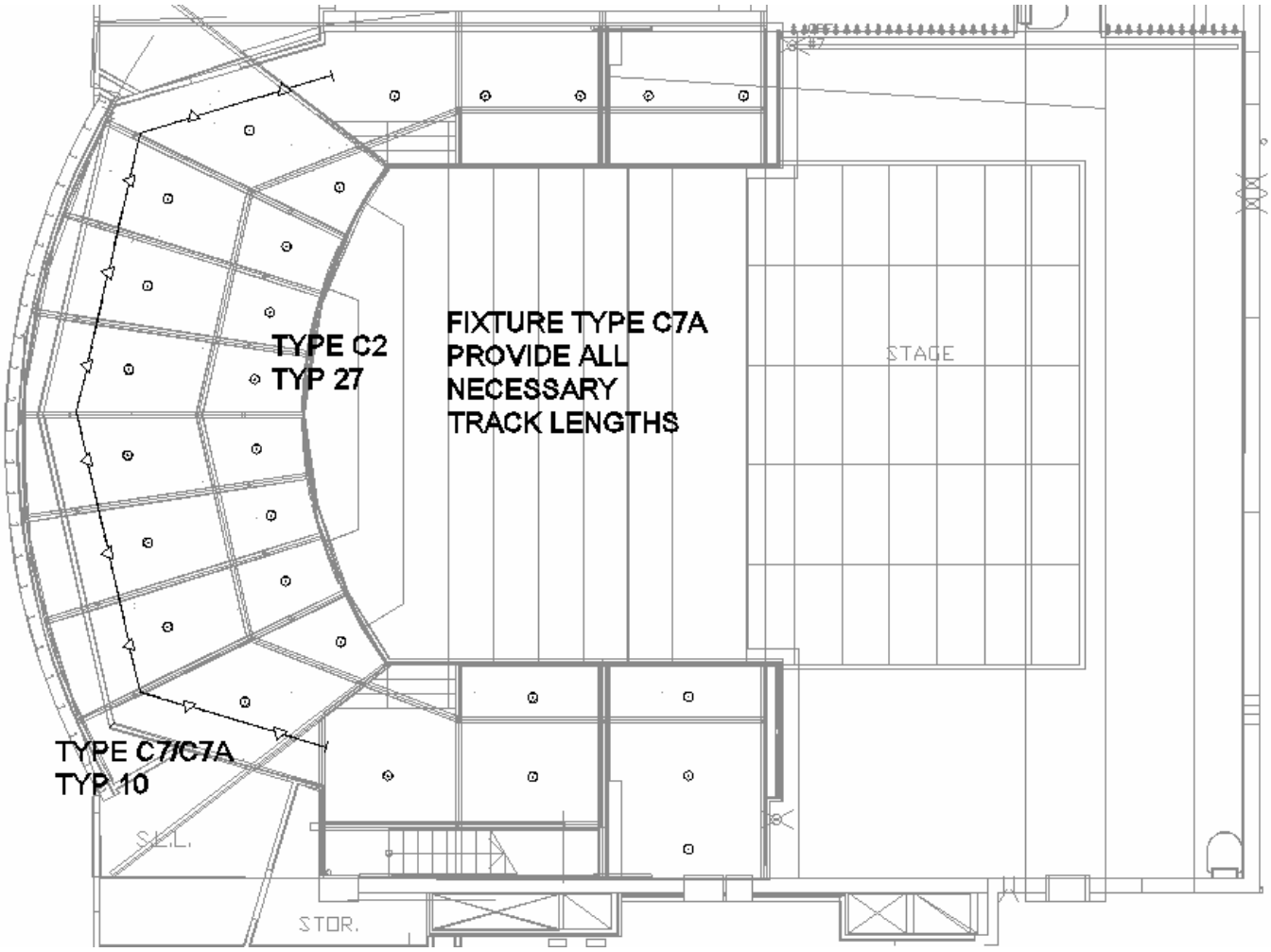


Final Design

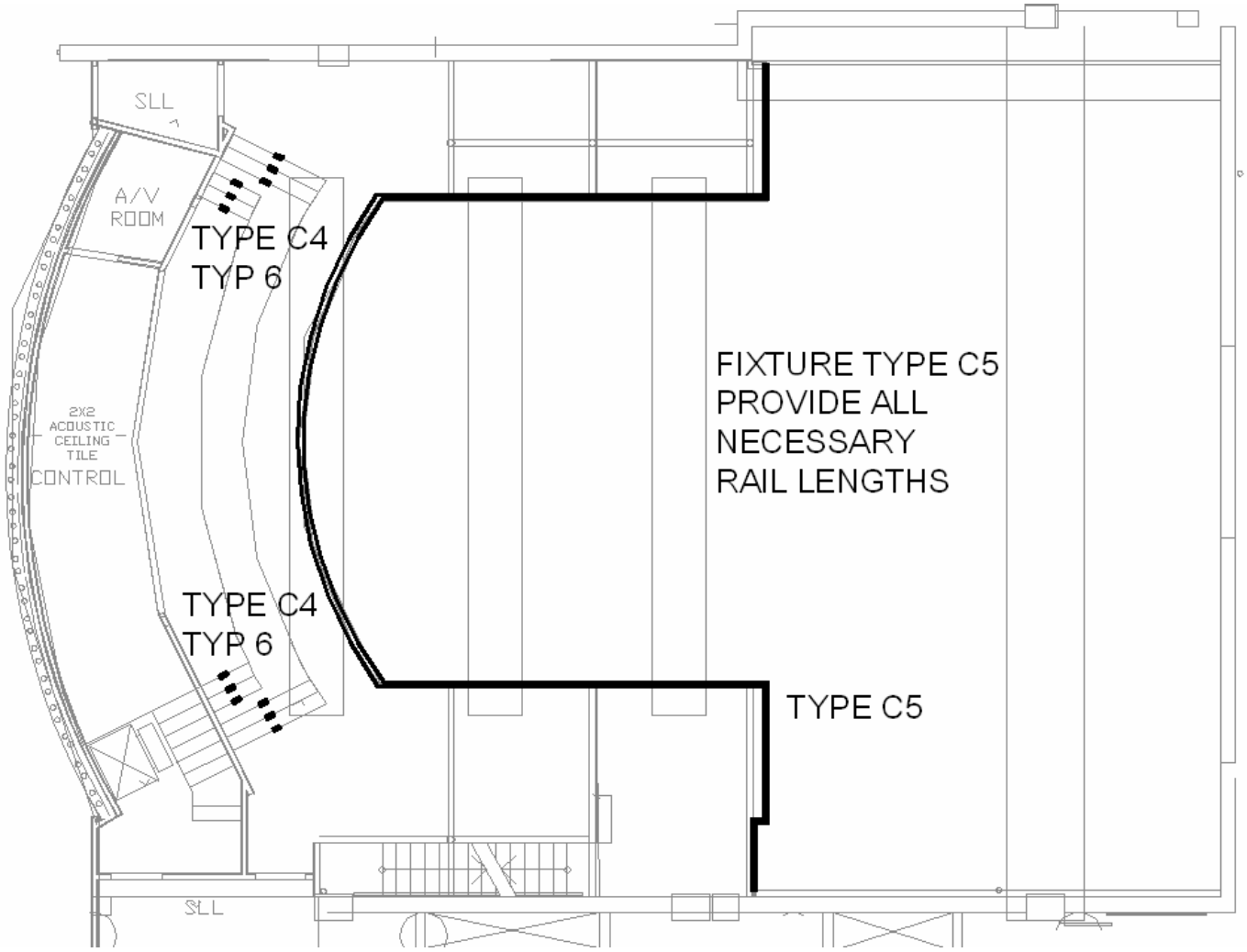
Orchestra Level Lighting Plan



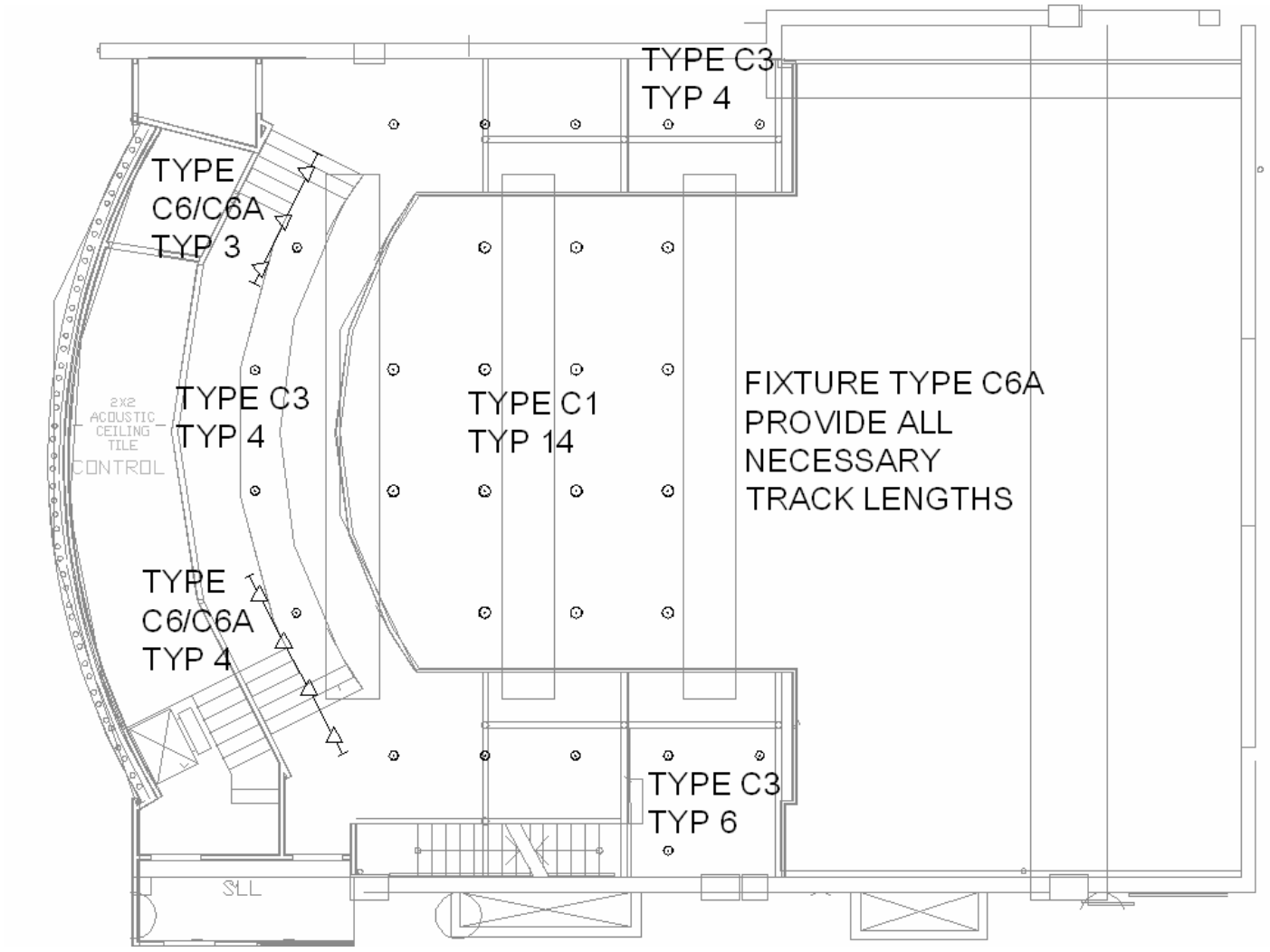
Orchestra Level Lighting RCP

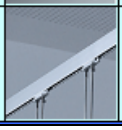


Balcony Plan



Balcony Level RCP



THEATRE LUMINAIRE SCHEDULE						
FIXTURE TYPE	PICTURE	DESCRIPTION	LAMP	MANUFACTURER	CATALOG NUMBER	NOTES
C1		LARGE CFL PENDANT	SYLVANIA CF42DT/E/IN/835/ECO	DELRAY	7713342	LOCATION: THEATRE
C2		CFL SURACE CYLINDER	SYLVANIA CF32DT/E/IN/835/ECO	KURT VERSEN	P913-DM	LOCATION: THEATRE
C3		CFL PENDANT CYLINDER	SYLVANIA CF42DT/E/IN/835/ECO	KURT VERSEN	P914-DM-ES 6' STEM	LOCATION: THEATRE
C4		STEPLIGHT	SYLVANIA 20T4Q/CL/AX	LUMIERE	1201-LA	LOCATION: THEATRE
C5		RAILING LIGHT	LED 2W/FT	IO LIGHTING	LUXRAIL PROVIDE ALL NECESSARY LENGTHS	LOCATION: THEATRE
C6		SUSPENDED TRACK FIXTURE	SYLVANIA 120PAR38/HAL/NFL25	ERCO	7746.000 BLACK	LOCATION: THEATRE
C6A		TRACK	N/A	ERCO	ERCO 2- CIRCUIT TRACK PROVIDE ALL NECESSARY LENGTHS	LOCATION: THEATRE
C7		ACCENT WALL TRACK	GE Q50MR16/C/FL40	BUSCHFELD DESIGN	SHOP V-15 35703	LOCATION: THEATRE
C7A		TRACK	N/A	BUSCHFELD DESIGN	SHOPT V-15 PROVIDE ALL NECESSARY LENGTHS	LOCATION: THEATRE

All fixture, lamp and ballast cut-sheets can be found in Appendix A.

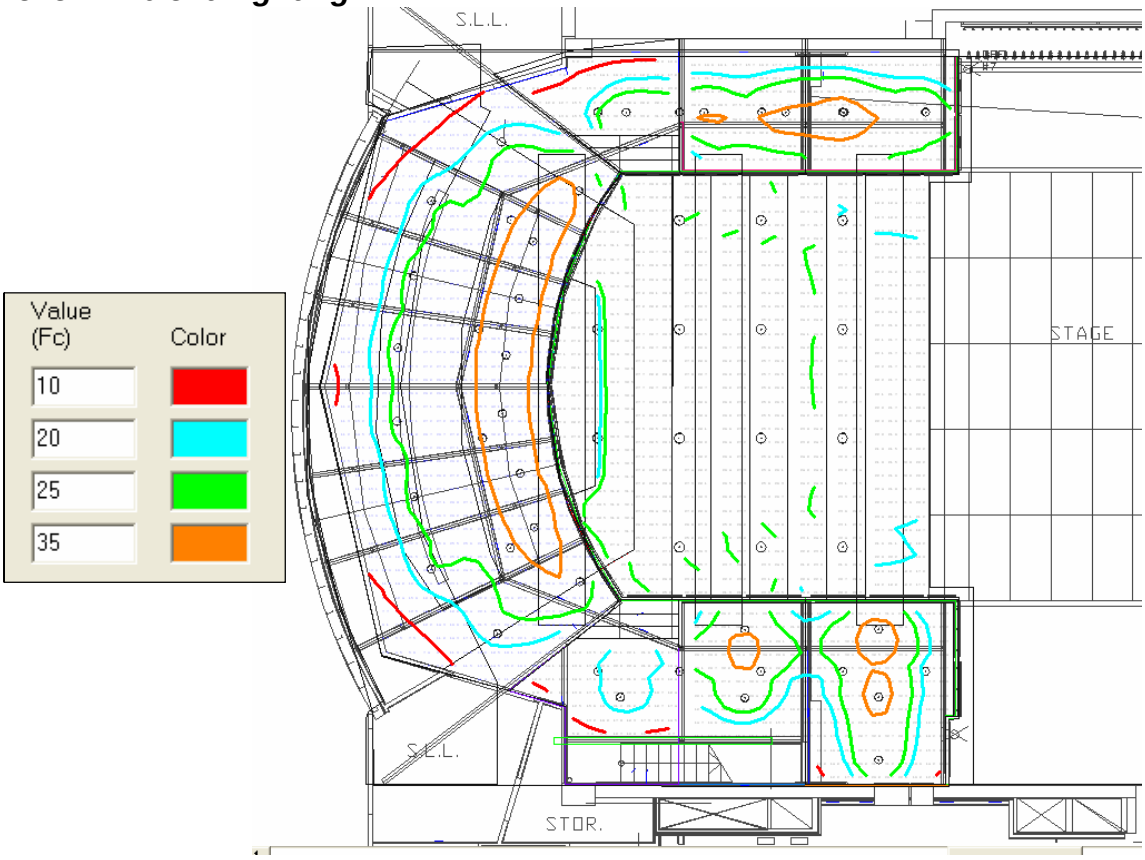
Light Loss Factors							
Fixture	**Cleaning Interval**	**Category**	**BF**	**LLD**	**LDD**	**RSDD**	**LLF**
C1	12 months (clean)	IV	1.00	0.86	0.95	0.97	0.79
C2	12 months (clean)	IV	1.00	0.86	0.95	0.97	0.79
C3	12 months (clean)	IV	1.00	0.86	0.95	0.97	0.79
C4	12 months (clean)	IV	1.00	0.90	0.95	0.97	0.83
C5	12 months (clean)	IV	1.00	1.00	0.95	0.97	0.92
C6	12 months (clean)	IV	1.00	0.90	0.95	0.97	0.83
C7	12 months (clean)	IV	1.00	0.90	0.95	0.97	0.83
RCR Calculated to be 4.1		**Space Assumed to be Very Clean**					

The cleaning interval for the lobby was assumed to be 12 months since the building is owned and maintained by the theatre company directly. The space was assumed to be a clean environment because there are no surrounding spaces where adhesive or ambient dirt would be generated.

Power Density					
Fixture	**Quantity**	**Wattage**	**Total Wattage**	**SF**	**W/SF**
C1	14	148	2072		
C2	27	39	1053		
C3	15	50	750		
C4	24	20	480		
C5	240	2	480		
C6	7	120	840		
C7	10	50	500		
			6175	6000	**1.03**

Using the input wattages for the specified ballast and lamps, the power density for the lobby is 1.03 W/SF. This is under the 1.8 W/SF allowed for audience seating areas of a performing arts building.

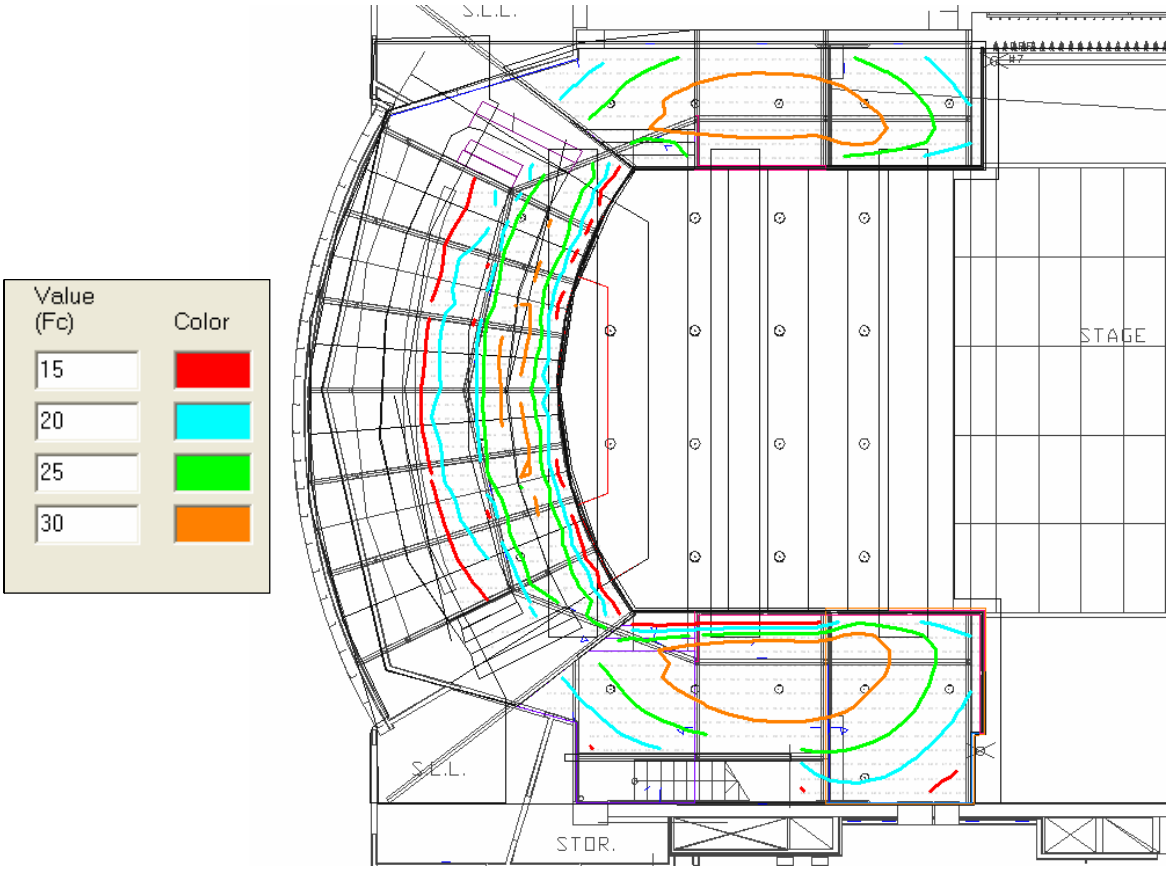
Calculation Grids
Orchestra Level Ambient Lighting



Numeric Summary						
Label	CalcType	Units	Avg	Max	Min	Avg/Min
First Floor_Row K, L, M	Illuminance	Fc	25.26	43.3	6.8	3.71
First Floor_Row C	Illuminance	Fc	23.76	25.6	19.8	1.20
First Floor_Row A	Illuminance	Fc	20.68	24.0	16.5	1.25
First Floor_Row B	Illuminance	Fc	22.75	24.4	19.8	1.15
First Floor_Row D	Illuminance	Fc	25.33	27.0	21.9	1.16
First Floor_Row E	Illuminance	Fc	25.88	27.8	21.3	1.22
First Floor_Row F	Illuminance	Fc	27.01	28.8	22.8	1.18
First Floor_Row J	Illuminance	Fc	28.27	30.9	25.1	1.13
First Floor_Row H	Illuminance	Fc	27.29	32.7	16.5	1.65
First Floor_Row G	Illuminance	Fc	27.88	30.5	20.8	1.34
First Floor_North Entrance	Illuminance	Fc	18.43	34.6	5.2	3.54
First Floor_South Entrance	Illuminance	Fc	16.19	22.6	5.8	2.79
First Floor_North Boxes	Illuminance	Fc	26.82	42.8	10.6	2.53
First Floor_South Boxes	Illuminance	Fc	24.37	39.8	8.3	2.94

The average illuminance on the orchestra level floor is between 25 and 30 fc in the seating areas. The entrance areas have an average illumination of 17 fc. These illumination levels satisfy the design criteria requirements. Before and after performances, the lighting will be dimmed to an average of 10 to 15 fc. The lighting will be on 100% when cleaning the theatre, and during rehearsals. The orchestra level has a very diffuse illumination across the space. The largest average to minimum fc ratio is 3.71, which is still an even distribution to the eye. This calculation did not take into account accent lighting.

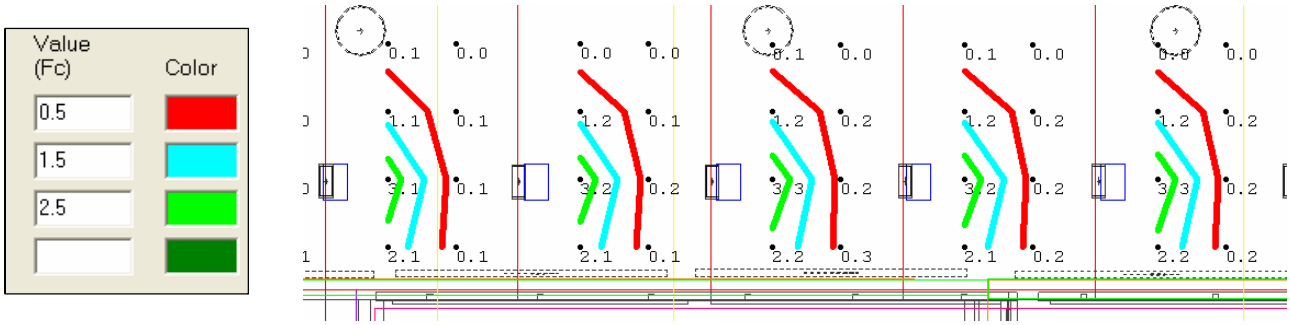
Balcony Level Ambient Lighting



Numeric Summary						
Label	CalcType	Units	Avg	Max	Min	Avg/Min
Balcony_Row B	Illuminance	Fc	23.41	30.6	6.1	3.84
Balcony_Row C	Illuminance	Fc	17.68	23.7	8.5	2.08
Balcony_Row A	Illuminance	Fc	23.17	32.4	10.0	2.32
Balcony_North Entrance and Boxes	Illuminance	Fc	26.71	34.6	15.5	1.72
Balcony_South Entrance and Boxes	Illuminance	Fc	25.12	34.6	11.9	2.11

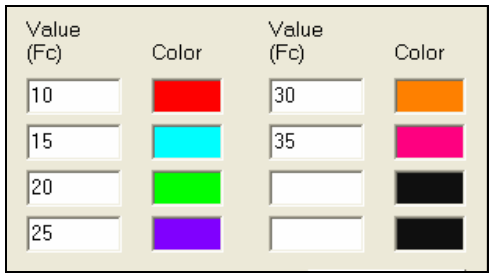
The average illuminance on the balcony level floor is between 23 and 26 fc. These illumination levels satisfy the design criteria requirements. Before and after performances, the lighting will be dimmed to an average of 10 to 15 fc. The lighting will be on 100% when cleaning the theatre, and during rehearsals. The balcony level has a very diffuse illumination across the space. The largest average to minimum fc ratio is 3.84, which is still an even distribution to the eye. This calculation did not take into account accent lighting. Therefore the average illumination of Row C will be higher.

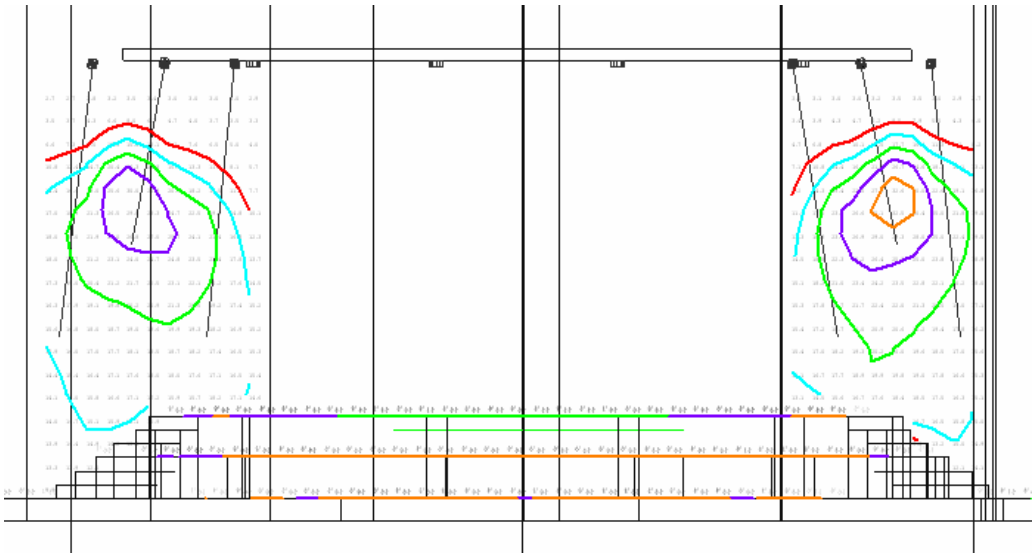
Aisle: Step lighting



The step lights in the aisle will be on during performances. They provide the necessary 0.2 fc illumination for emergency lighting.

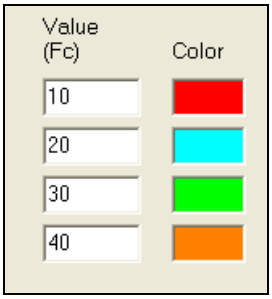
Balcony Level: Back Wall Metal Acoustical Baffles

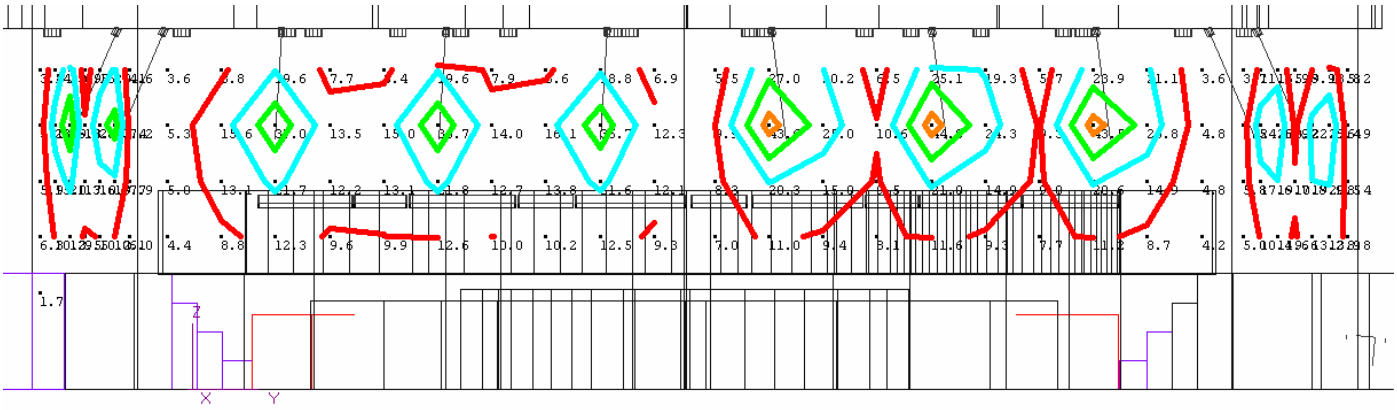




The back wall of the balcony level is metal acoustical baffle. The finish has a high quality look, and therefore is accented with track. This adds layering of light to the space, which add depth. The wall has an uneven distribution to keep with the concept of intimate. The track fixtures are on the theatrical control system and can be dimmed.

Orchestra Level: Back Red Wall





The back wall of the orchestra level is a red painted gypsum board wall. Track is run along the wall to add small scallops of light. The track is spaced far enough apart so the wall is not uniformly lit. This accenting adds subtle visual interest and sparkle to the space. The track also gives an intimate feeling to the space.

Renderings

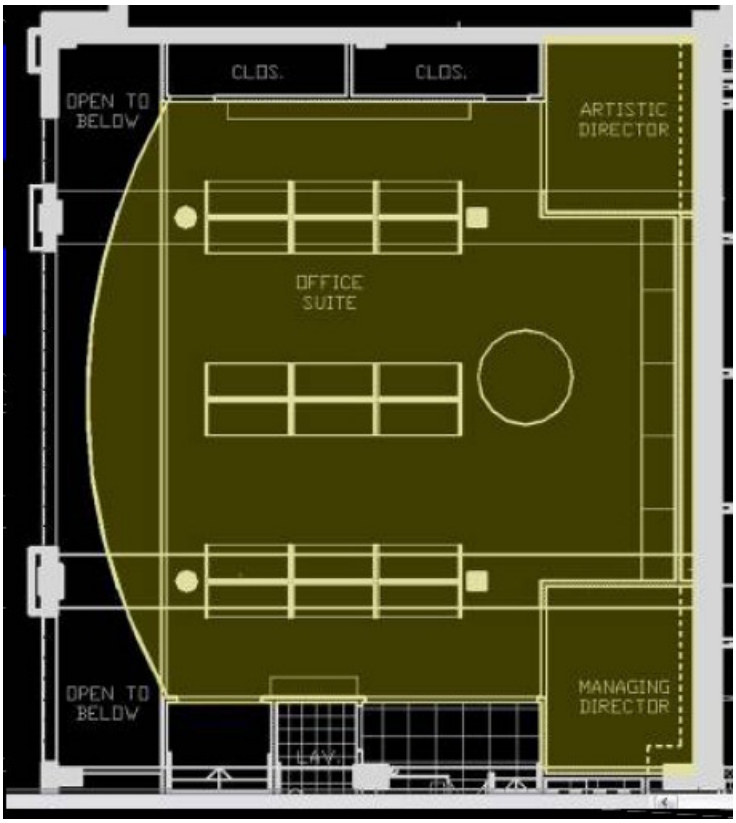
Conclusion

The theatre's architecture lends itself to an intimate atmosphere. The courtyard configuration establishes a strong connection with the audience and actors. The lighting of the theatre must not disrupt that connection. The lighting must also be subtle, so it does not compete with the production. In keeping with these goals, the theatre comes alive in a different way than the lobby and canopy. A low level of diffuse ambient light is provided for circulation needs. Track is used to accent the back walls of the orchestra and balcony levels, which both have finishes that are high quality and add visual interest. The metal acoustical baffles, when accented, add sparkle by highlighting the theatre mechanics. The wood panels on the fronts of the balconies are lit with a LED railing light, accenting the beautiful wood finish and bringing the focus away from the outer walls. This also keeps the space intimate. The lighting design parallels with the architectural concept of the theatre space, therefore enhancing the theatre environment.

Office

Space Overview

The office has an open plan with two private offices for the artistic director and the managing director. There are movable cubicles set up in three sections. It is a comfortable environment for the key personnel of the theatre to do work. The space is rather small but has a spacious feel. This was achieved by using glass for the surrounding interior walls connecting the office to the vestibule, hub area and exterior.



Material in the Space

- concrete slab ceiling- clear finish — reflectance = 20%
- orange painted gypsum walls — reflectance = 55%
- carpet- medium gray — reflectance = 25%
- cubicle partitions- light — reflectance = 60%

Glazing

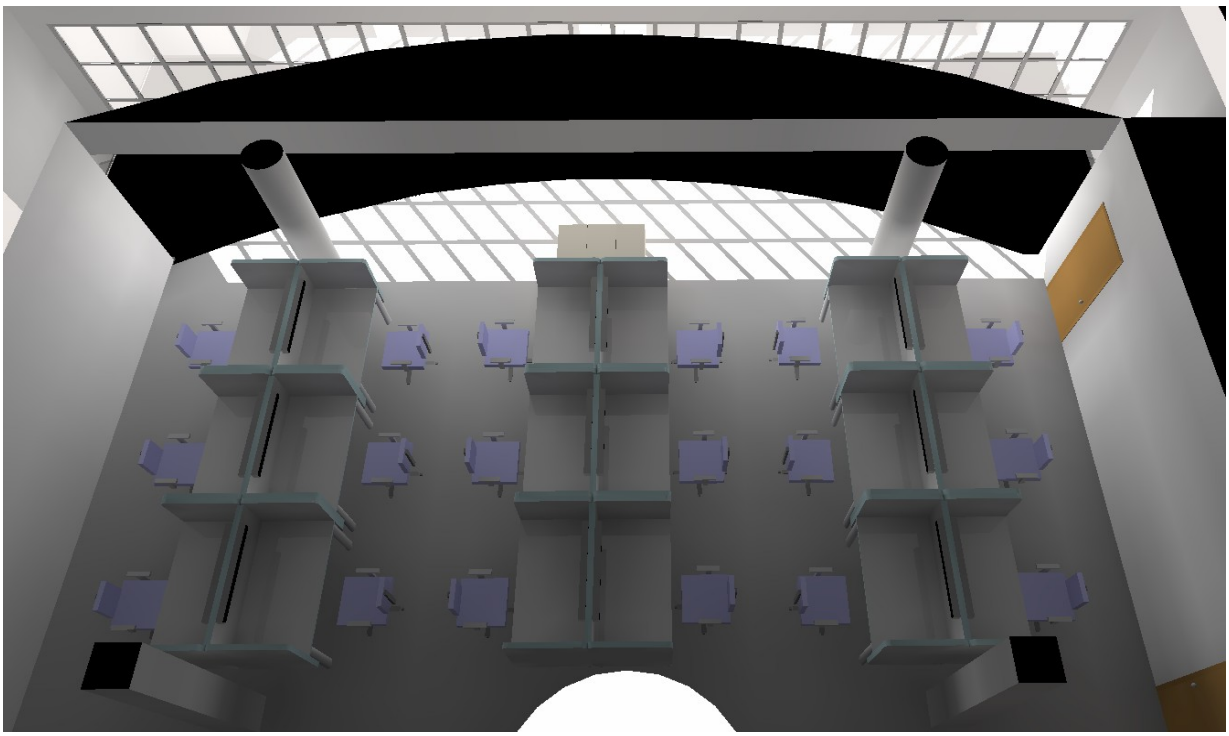
- ½" tempered glass — transmittance = 80%
- 3/8" clear laminated glazing faceted wall — transmittance = 80%

Daylighting Study

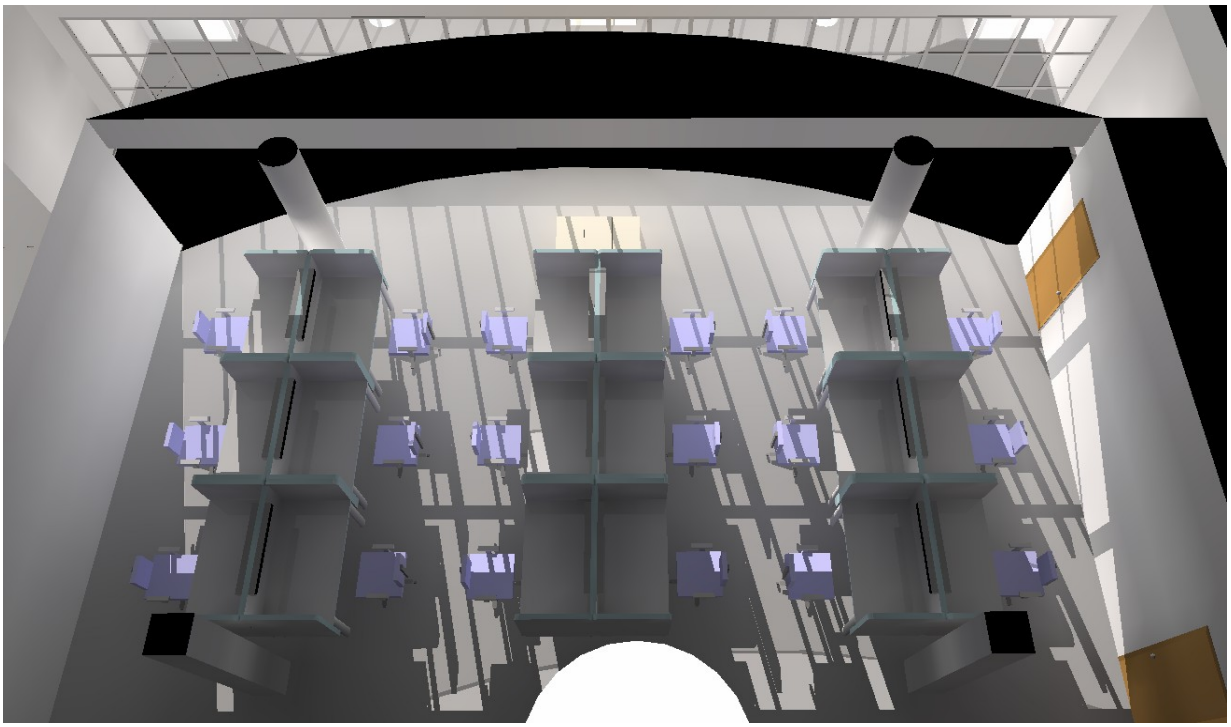
A daylighting study was conducted for the days of June 21, December 21 and March 21. These three dates are when the sky is at its highest point, its lowest point, and in the middle. The office has a full glazed wall facing west. The curved wall is 3/8" thick clear laminated glazing faceted wall. This wall is adjacent to another glass wall. The straight wall is ½" thick tempered glass. The office also has one diffuse skylight dome in the other half of the office area. This dome provides ambient lighting to the office with no direct sunlight entering the space.

The daylighting analysis was studied for two criteria, direct light hitting the work plane and ambient light levels. It is very important direct daylight does not hit the task surface in the office space. This will cause poor visibility and discomfort. Yet direct sun when used cautiously, where non-critical task occur can be a good design feature. Patterns of light and shadows from the sun add a dynamic feature to the space. They give the occupants a sense of well-being, time and orientation.

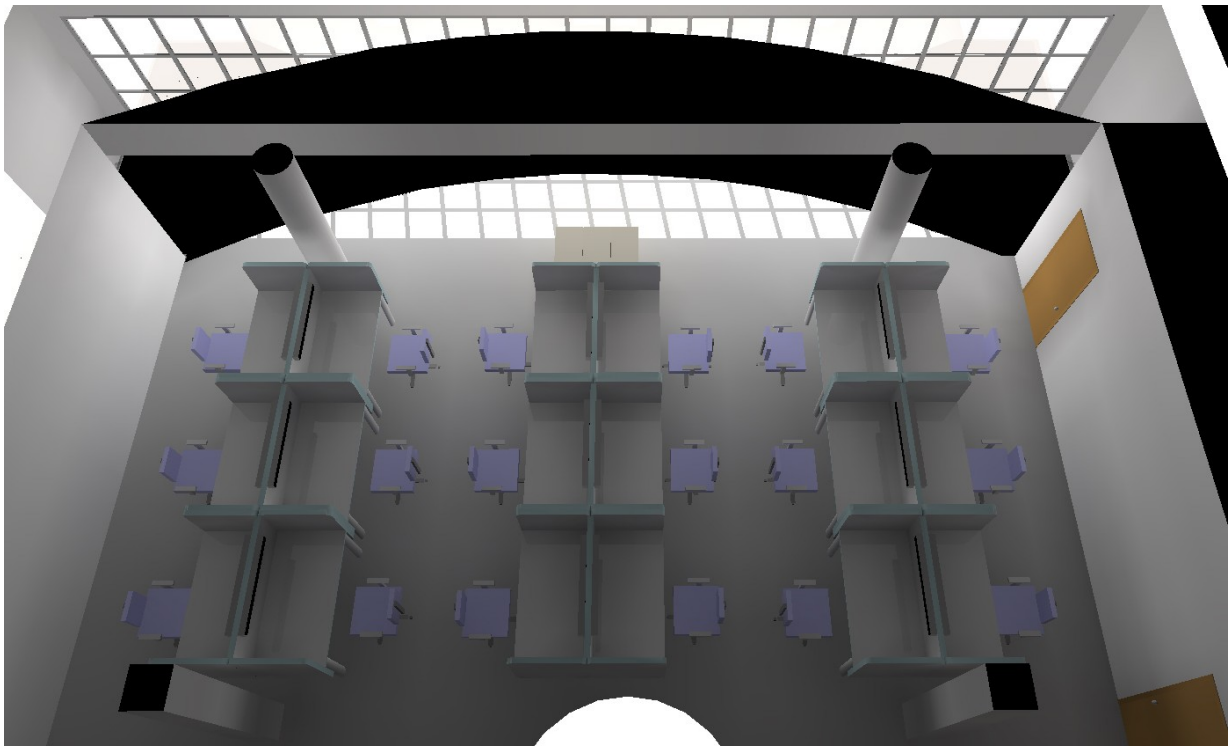
Direct Glare
March 21 3:00 PM



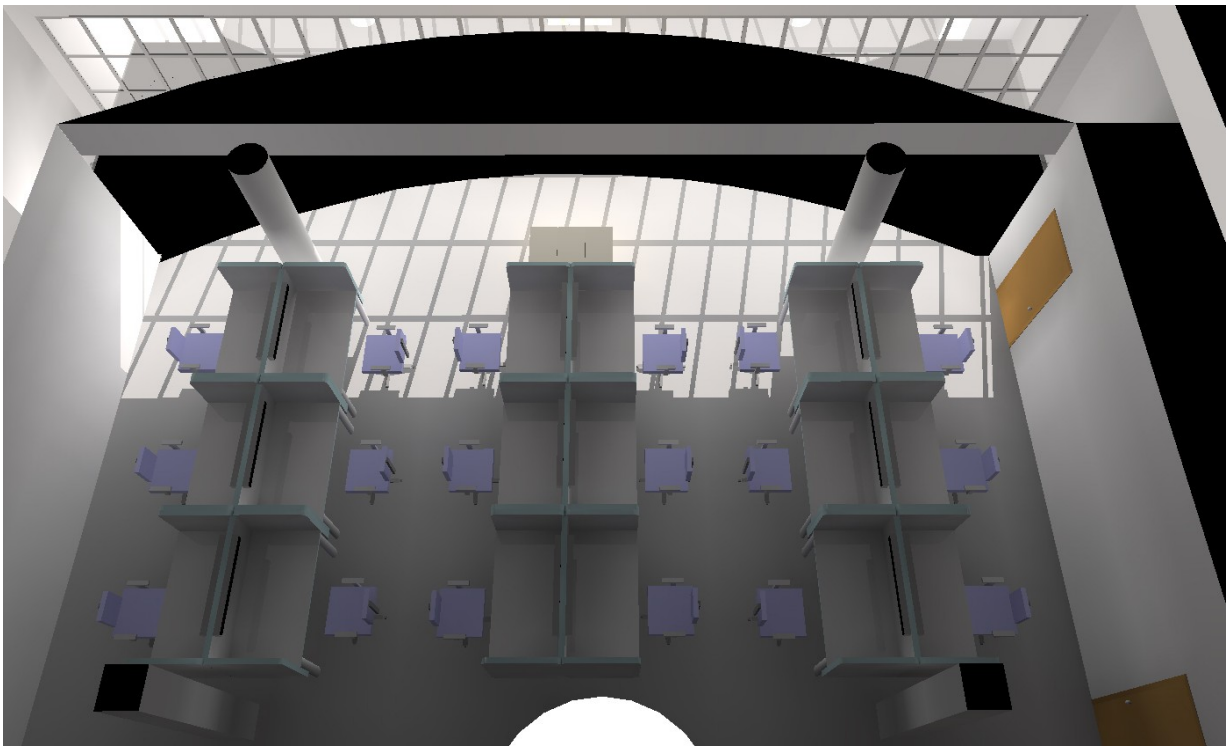
March 21 5:00 PM



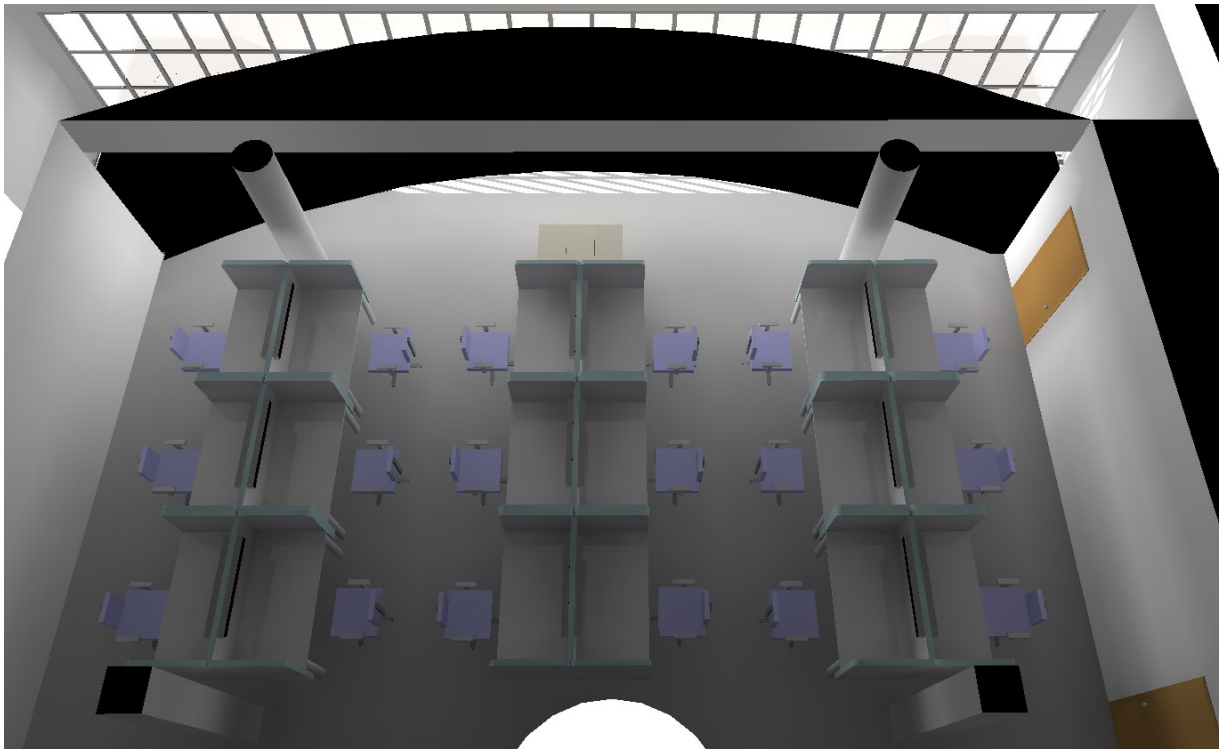
June 21 3:00 PM



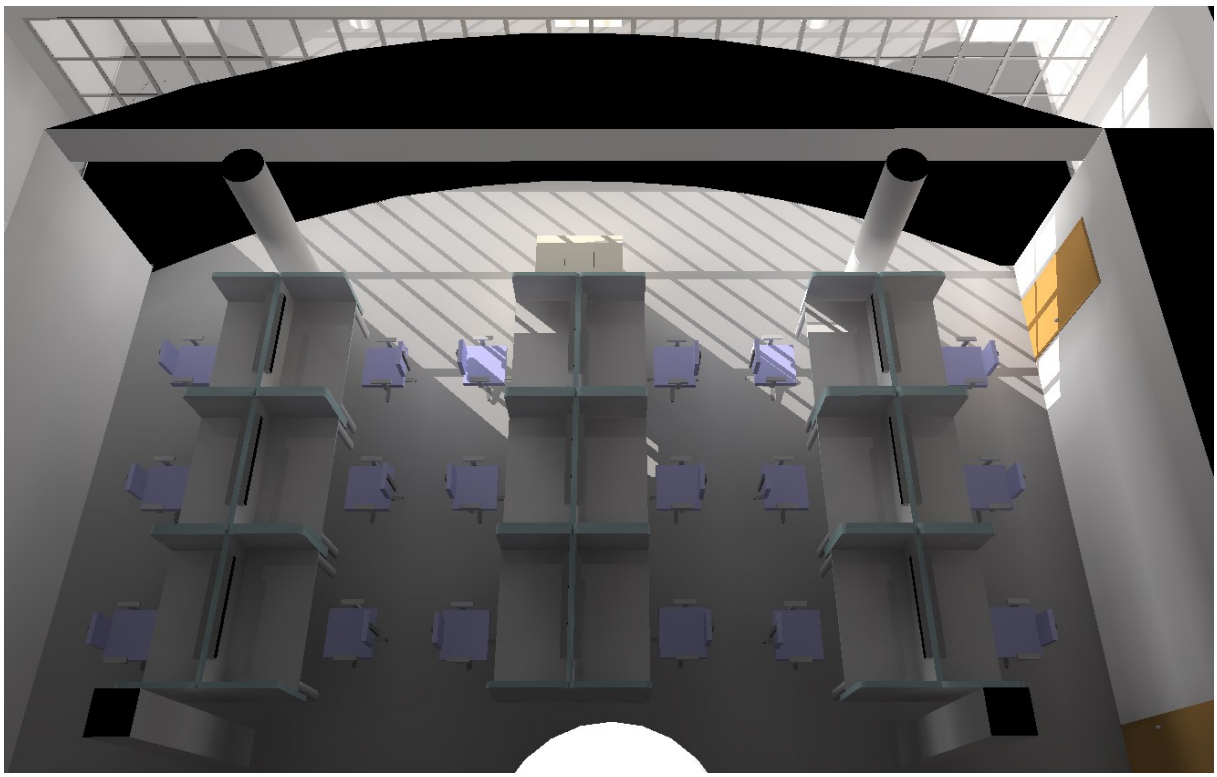
June 21 5:00 PM



December 21 1:00 PM



December 21 3:00 PM



As seen in the previous renderings, direct glare is not a major problem in the office suite. The furniture layout of the cubicles was well thought out. The walls of the cubicles closest to the glazing block the direct glare most of the time. The few instances that the direct sunlight does hit the task surface, it did not cover much area. The direct sunlight did add a dynamic effect to the office suite, adding patterns and shadows from the mullions.

The daylight in the office suite provided a large amount of ambient light to the space. The problem is the light provided is not evenly distributed. The desks closest to the window receive daylight in most conditions. The daylight does not reach far into the space during most months out of the year. The skylight provides low levels of diffuse light to the space.

Conclusion

With the current furniture layout, direct glare is not a problem in the office suite. The direct sunlight does add a dynamic aspect to the space. Therefore the glazing does not need to be altered from the current glazing, clear with 80% transmittance. Daylight does provide a sufficient amount of light into the office suite. Yet the majority of the light is not evenly distributed over the task surface. Also only the cubicles closest to the glazing have enough illumination. It would be possible to specify a dimming system for this office suite, but it was not necessary for the space. When personal cubicles are universally controlled and dimmed, many people are unhappy. After speaking with the employees of the Woolly Mammoth Theatre Company, they did not want to install a dimming system. They workers wanted a very bright work environment. Therefore the office suite is not dimmed.

Design Criteria

General

The lighting in the office should be very comfortable. The work surfaces should be uniformly lit. In the office there is intermittent use of VDTs. Direct and reflected glare should be avoided completely. It is important to avoid having direct sunlight hit the work surface, creating glare. Also the luminances of surfaces and contrast must be carefully analyzed. The open plan office has moveable cubicles, and therefore the lighting should be flexible.

Illuminance and Luminance Values

According to the IESNA Lighting Handbook the illuminance on the work plane for an open office with intense VDT work should be 30 footcandles. The vertical illuminance should be 5 footcandles. When using VDTs, the luminance ratio of screen to paper task should be 3:1. For screen to far background the luminance ratio should be 10:1.

Power Density

According to Ashrea 90.1, the Space- By- Space Method, the power density allowed in an open plan office is 1.1 W/SF.

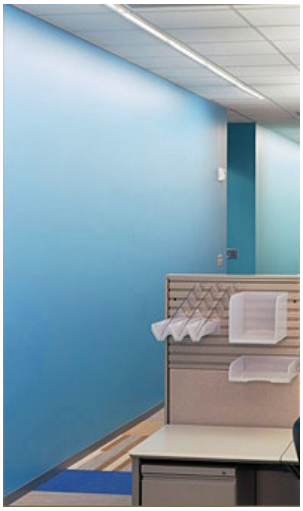
Schematic Design/ Design Intent

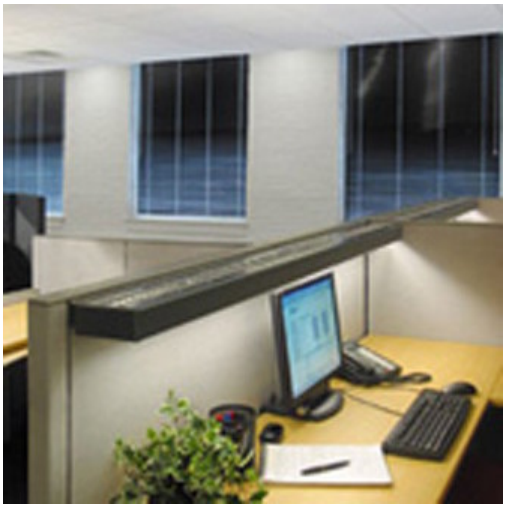
Design Goals

- Spacious
- Comfortable
- Energetic

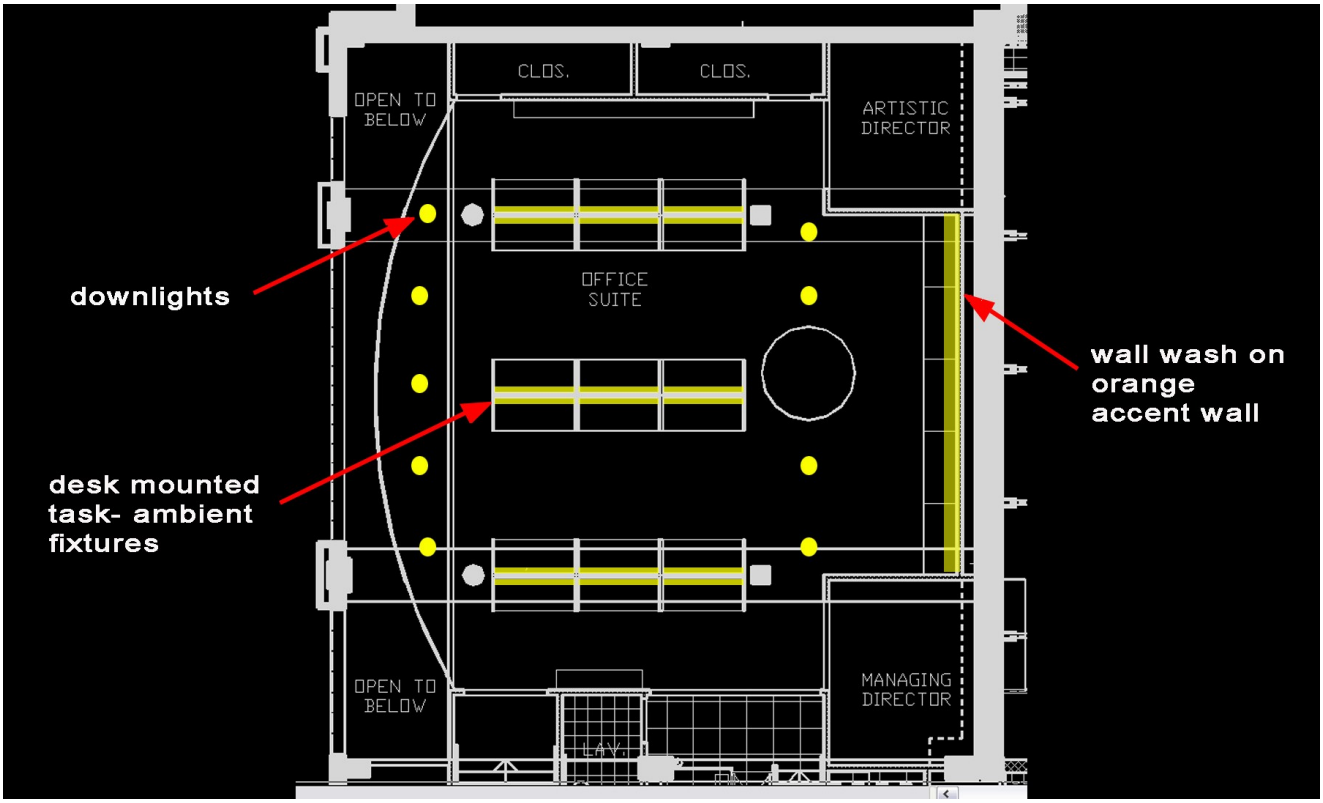
These goals were achieved in the office space by using many techniques. The office is small in square footage, and rather cramped with cubicles throughout it. Two of the four walls are made of glass, which helps to expand the feeling of the space. In the lighting of the space, the orange accent wall is washed with light. This will keep the space feeling spacious. To keep the office comfortable for the employees, direct and reflected glare must be avoided completely. This was accomplished by using a desk mounted fixture with direct and indirect light. The energetic feeling was achieved by using indirect light to stop the “cave” effect. Also there are differing light levels away from task areas to give depth.

Concept Photos



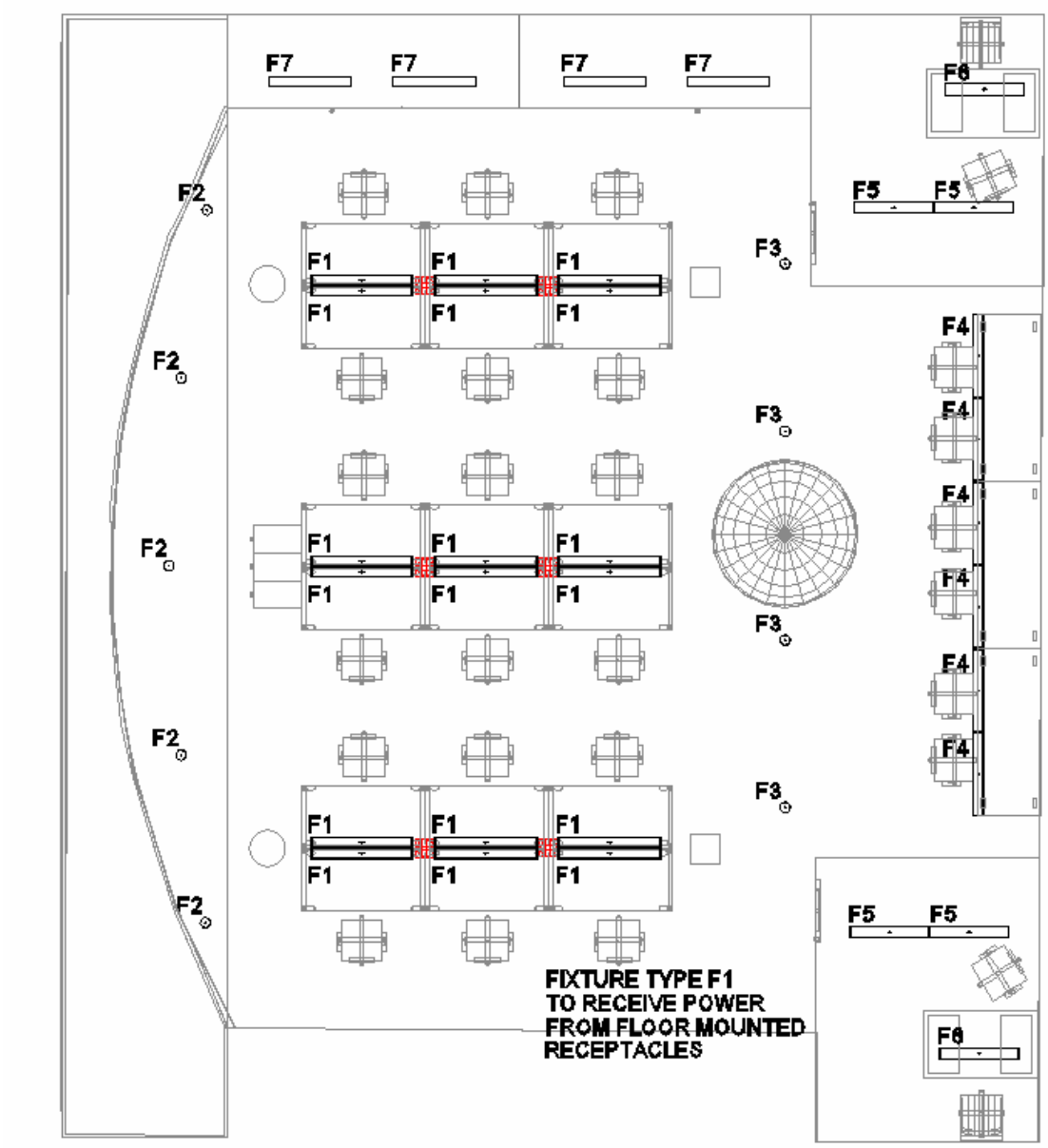


Concept Diagram

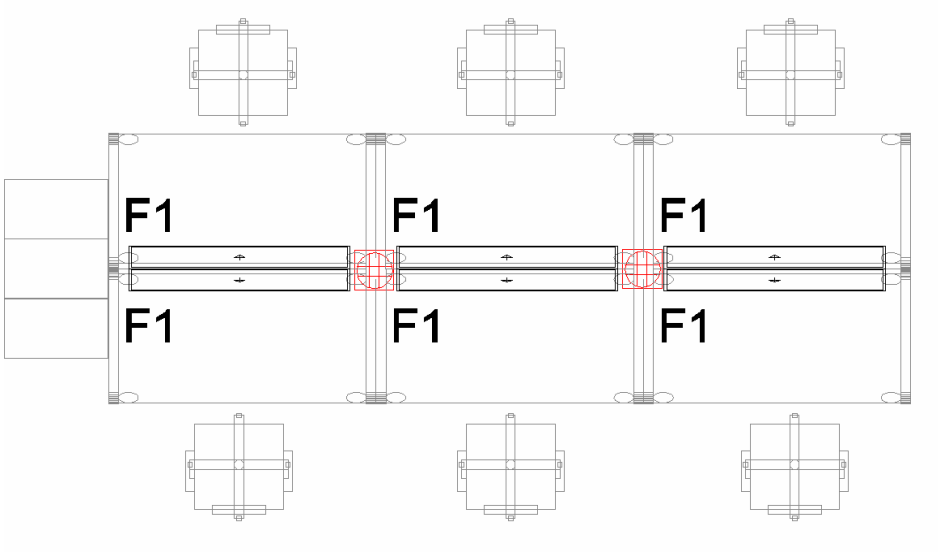


Final Design

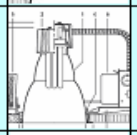
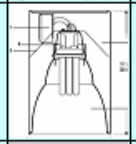
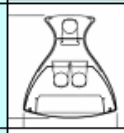
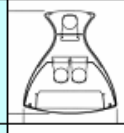
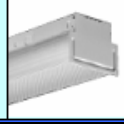
Lighting Plan



Luminaire Detail



Fixture Type F1 task- ambient fixtures will are plug in fixtures. They will receive power from the floor mounted receptacles showed in red.

OFFICE LUMINAIRE SCHEDULE						
FIXTURE TYPE	PICTURE	DESCRIPTION	LAMP	MANUFACTURER	CATALOG NUMBER	NOTES
F1		DESK MOUNTED TASK AMBIENT FLUORESCENT	SYLVANIA FP35/835/ECO	TAMBIENT	STYLE L201	LOCATION: OFFICE
F2		RECESSED DOWNLIGHT	SYLVANIA CF26DT/E/IN/835/ECO	LIGHTOLIER	8021-CCLP	LOCATION: OFFICE
F3		SURFACE MOUNTED COMPACT FLUORESCENT CYLINDER	SYLVANIA CF26DT/E/IN/835/ ECO	LIGHTOLIER	CS6132	LOCATION: OFFICE
F4		SURFACE MOUNTED FLUORESCENT WALL WASH	SYLVANIA FP28/835/ECO	ELLIPTIPAR	F144-T128-S-22-T-00-0	LOCATION: OFFICE
F5		SURFACE MOUNTED FLUORESCENT DIRECT PENDANT	SYLVANIA (2) FP54/835/HO/ECO	METALUMEN	C6B4NXUK	LOCATION: OFFICE
F6		SURFACE MOUNTED FLUORESCENT DIRECT PENDANT	SYLVANIA (1) FP54/835/HO/ECO	METALUMEN	C6A4NXUK	LOCATION: OFFICE
F7		CLOSET FLUORESCENT STRIP	SYLVANIA FO32/835/ECO	LIGHTOLIER	JS4C132	LOCATION: OFFICE

Fixture, lamp and ballast cut-sheets can be found in Appendix A.

Light Loss Factors							
Fixture	**Cleaning Interval**	**Category**	**BF**	**LLD**	**LDD**	**RSDD**	**LLF**
F1	12 months (clean)	II	1.01	0.93	0.98	0.89	0.82
F2	12 months (clean)	IV	1.10	0.86	0.94	0.96	0.85
F3	12 months (clean)	IV	1.10	0.86	0.94	0.96	0.85
F4	12 months (clean)	IV	1.04	0.93	0.94	0.96	0.87
F5	12 months (clean)	IV	0.99	0.93	0.94	0.96	0.83
F6	12 months (clean)	IV	0.99	0.93	0.94	0.96	0.83
F7	12 months (clean)	IV	0.92	0.92	0.94	0.96	0.76
RCR Calculated to be 2.2 Space Assumed to be Very Clean							

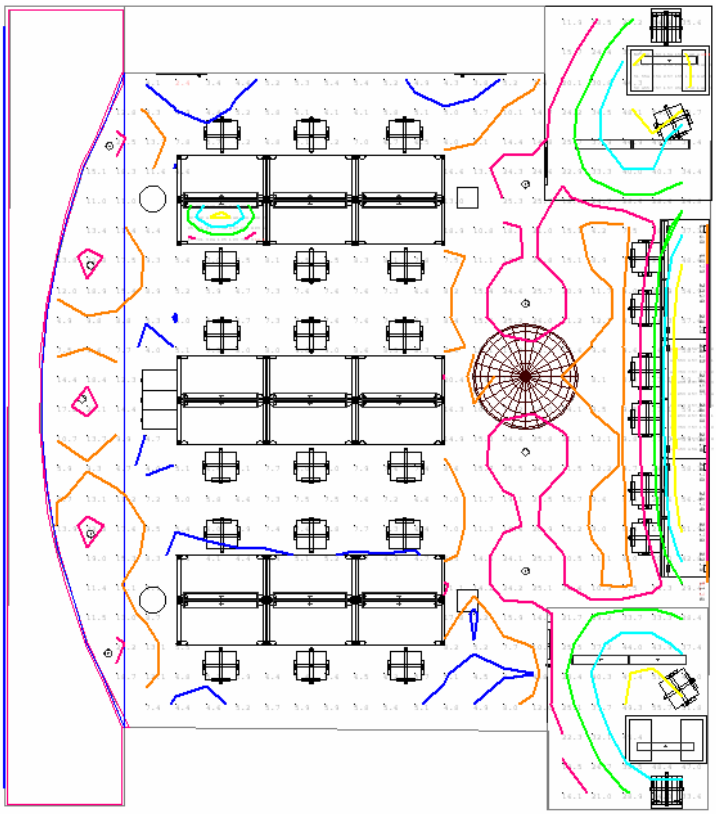
The cleaning interval for the office suite was assumed to be 12 months since the building is owned and maintained by the theatre company. The space was assumed to be a clean environment. The office suite is small area on the third floor on the theatre. It is not near any spaces that would generate large amounts of dirt.

Power Density					
Fixture	**Quantity**	**Wattage**	**Total Wattage**	**SF**	**W/SF**
F1	18	41	738		
F2	5	29	145		
F3	4	29	116		
F4	6	33	198		
F5	4	62	248		
F6	2	118	236		
F7	4	32	128		
			1809	2145	**0.84**

Using the input wattages for the specified ballast and lamps, the power density for the lobby is 0.84 W/SF. This is under the allowed 1.1 W/SF allowed for an open office.

Calculation Grids

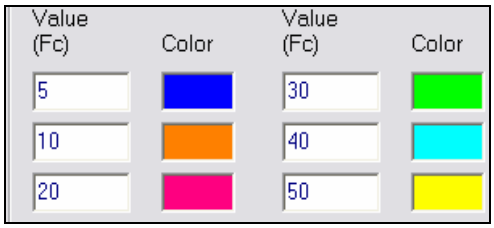
Value (Fc)	Color	Value (Fc)	Color
5		30	
10		40	
20		50	

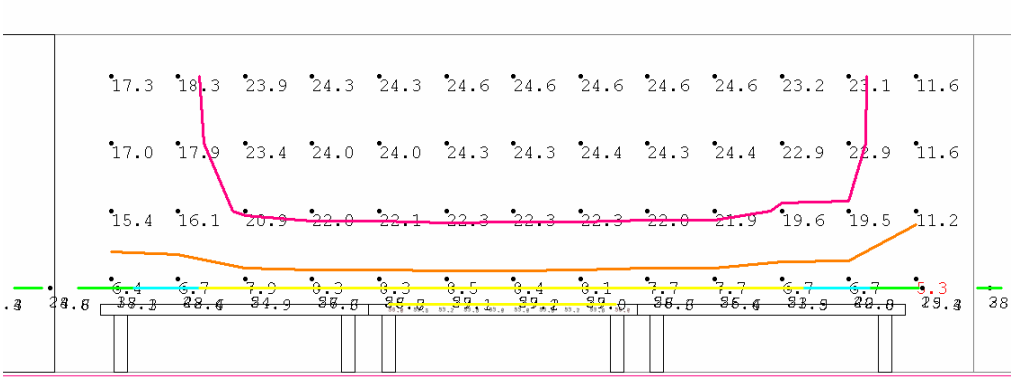


Numeric Summary						
Label	CalcType	Units	Avg	Max	Min	Avg/Min
Orange Wall	Illuminance	Fc	17.86	24.6	5.3	3.37
Office_Desk	Illuminance	Fc	52.89	57.4	45.4	1.16
Office_Cubicle	Illuminance	Fc	33.08	52.5	14.4	2.30
Private Office_Desk	Illuminance	Fc	51.87	57.1	43.1	1.20
Workplane	Illuminance	Fc	16.07	59.2	2.4	6.70

The average illuminance of the work plane is 16 fc. This is an ideal level for the areas that are not work surfaces. The average to minimum fc ratio is 6.7. The office having slightly different levels of light in the space will make the space comfortable and add visual interest for the employees. Due to the task component of the task-ambient fixtures on each cubicle, the average cubicle illuminance is 33 fc, very evenly distributed with a 2.30 average to minimum fc ratio. The ambient component of the task-ambient fixtures used will illuminate the ceiling, to make the space feel energetic and not like a cave. The fixtures also eliminate direct and reflected glare because the source is mounted on each cubicle. Another advantage of the task-ambient fixtures is they are mounted to the cubicles, and therefore can move with the cubicle if the office is rearranged or more cubicles are added.

Orange Accent Wall



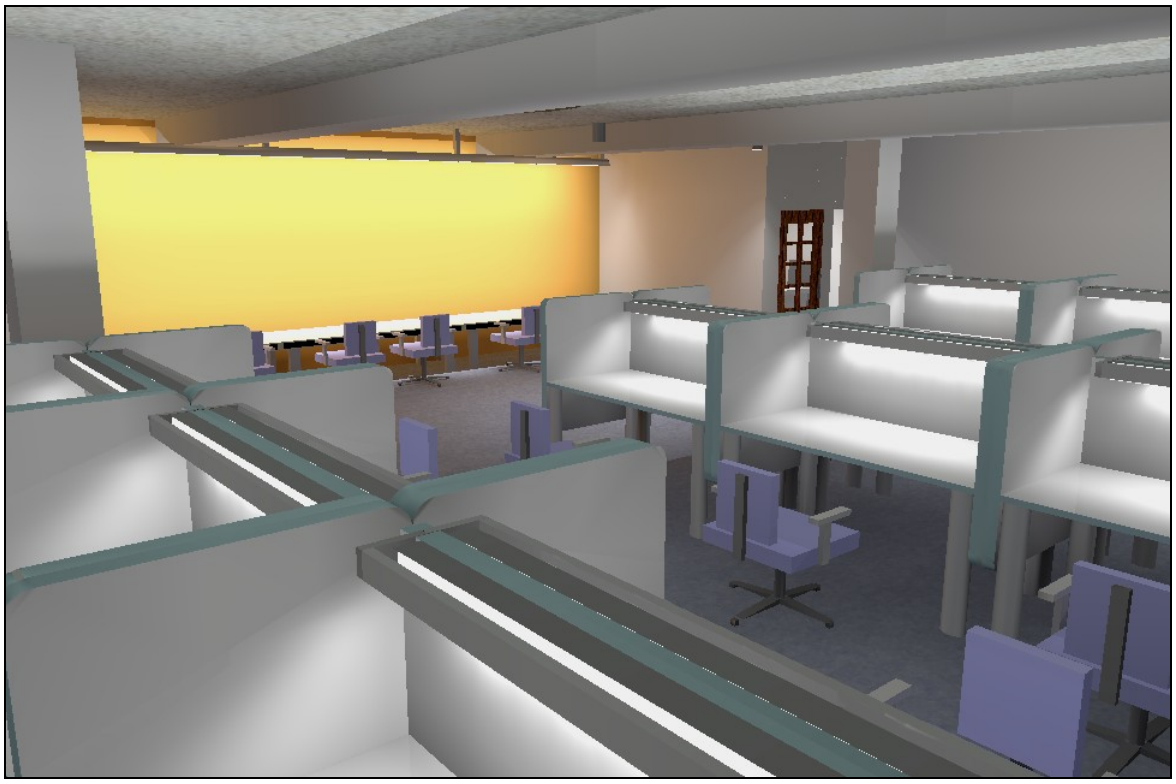


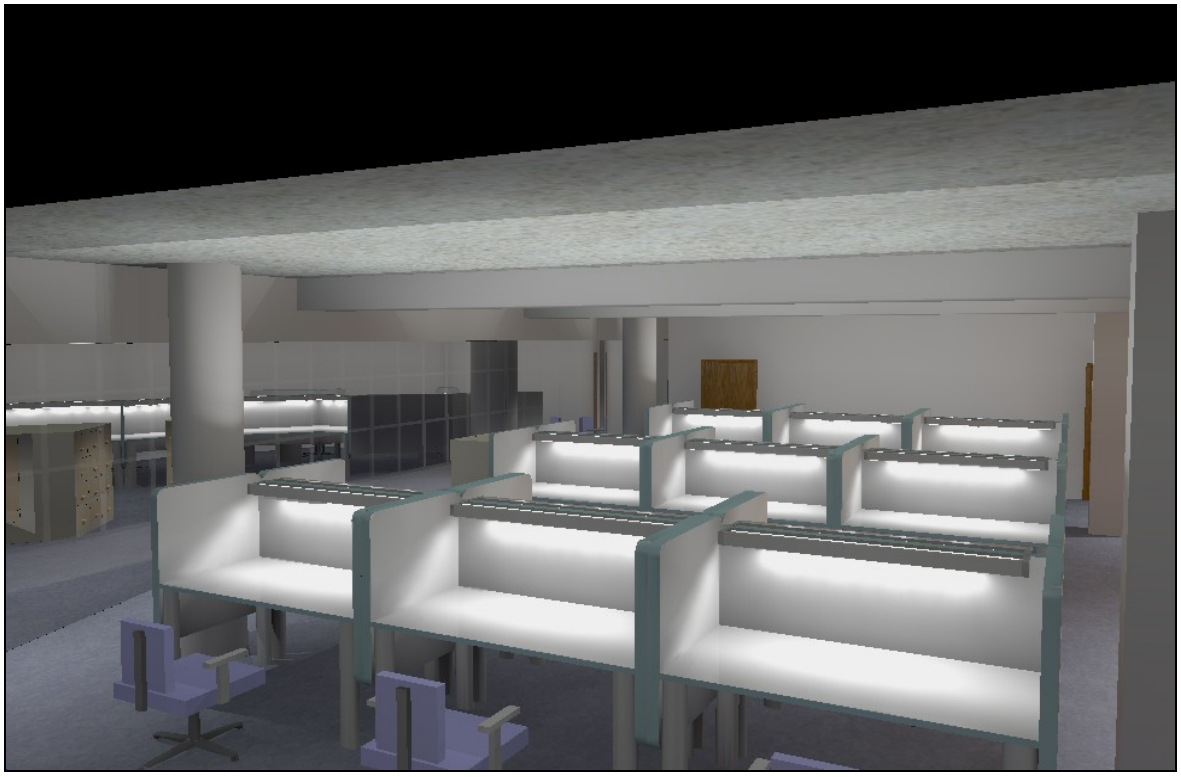
The orange accent wall has an average illuminance of 18 fc, with an average to minimum fc ratio of 3.37. The wall is evenly distributed, giving the office a spacious feel while highlighting the spectacular color of the wall.

Control

The office suite will be standard switched control. Dimming of the design was unnecessary. The zones of fixtures are switched separately, giving the office suite some control. During most days the recessed downlights adjacent to the glass wall will not need to be on. The cylinders near the skylight will also not be needed on a number of days. All of the cubicle lights will be switched together. This is because if they are separately switched, the ambient component of light would be a very uneven distribution on the ceiling, having some lights on and some off. Also, after speaking with employees in the space office, they all agreed they would like a very bright environment. This environment will be an energetic space that leads to productivity.

Renderings





Conclusion

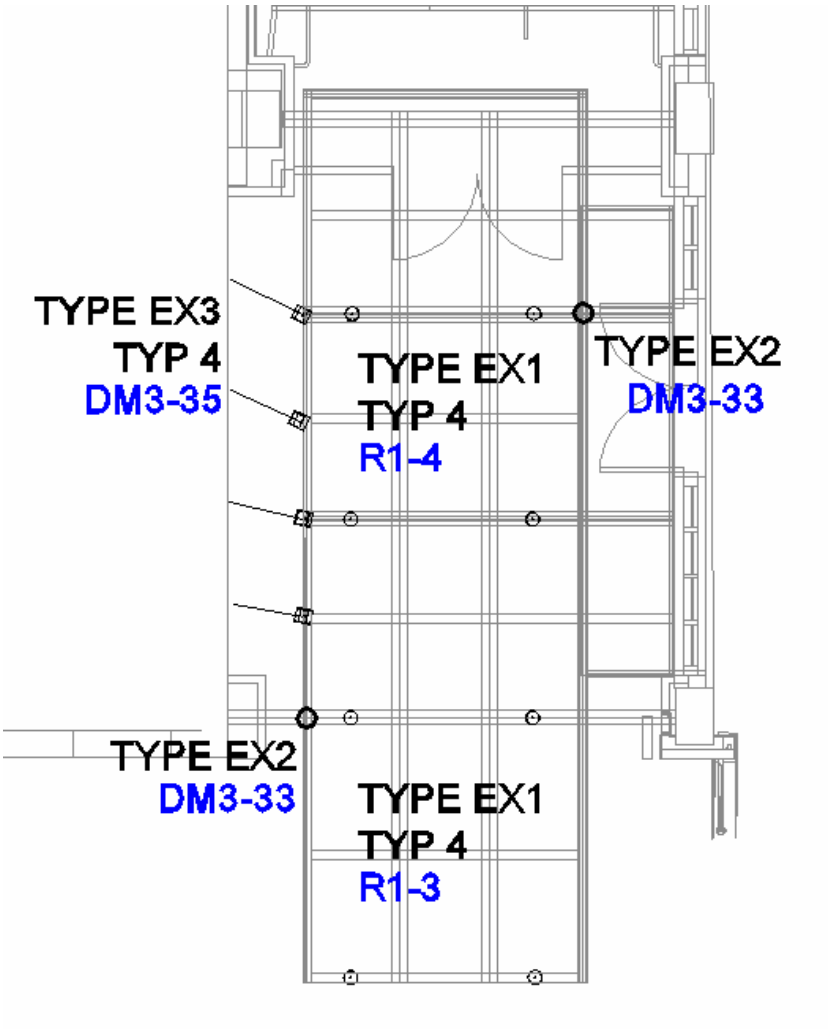
The office suite is a private space for the employees at the Woolly Mammoth Theatre. The workers spend long hours each week performing their duties in the space. Due to this, the lighting must be designed for comfort. The office should feel spacious and energetic, to encourage production in the space. All employees in the office suite use VDTs. The task-ambient light used in the design eliminates reflected and direct glare from the ceiling. This fixture also makes the design flexible with the movable cubicles. The task component provides the necessary illumination on the work surface, and the ambient component provides illumination on the ceiling to brighten the space. The wall washers accent the vibrant orange wall and give an energetic feel to the space. The office suite is controlled by standard switching, but zoned with the ability to switch areas off separately. The lighting design for the office is feasible, and

Electrical Depth

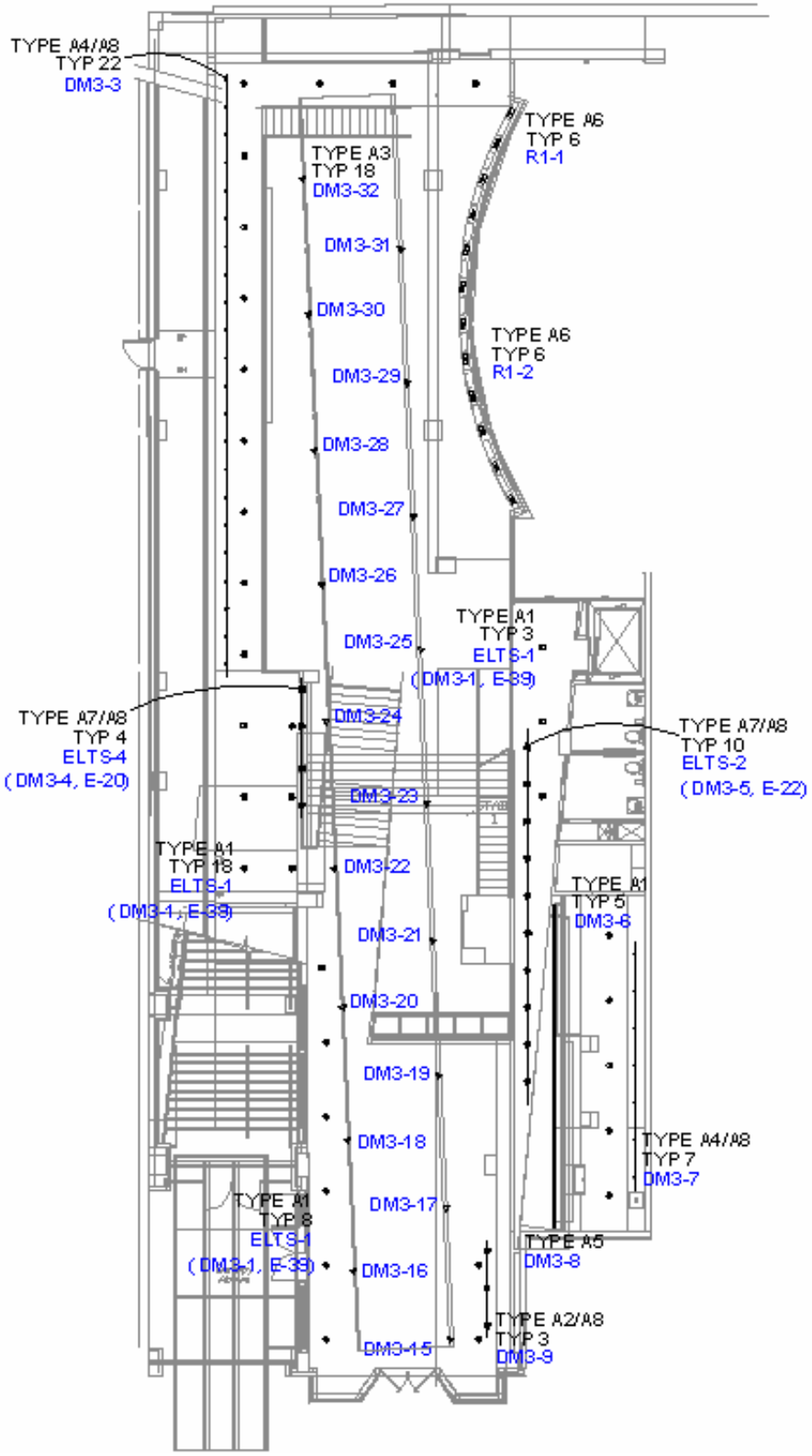
Electrical Depth

Electrical and Control Plans

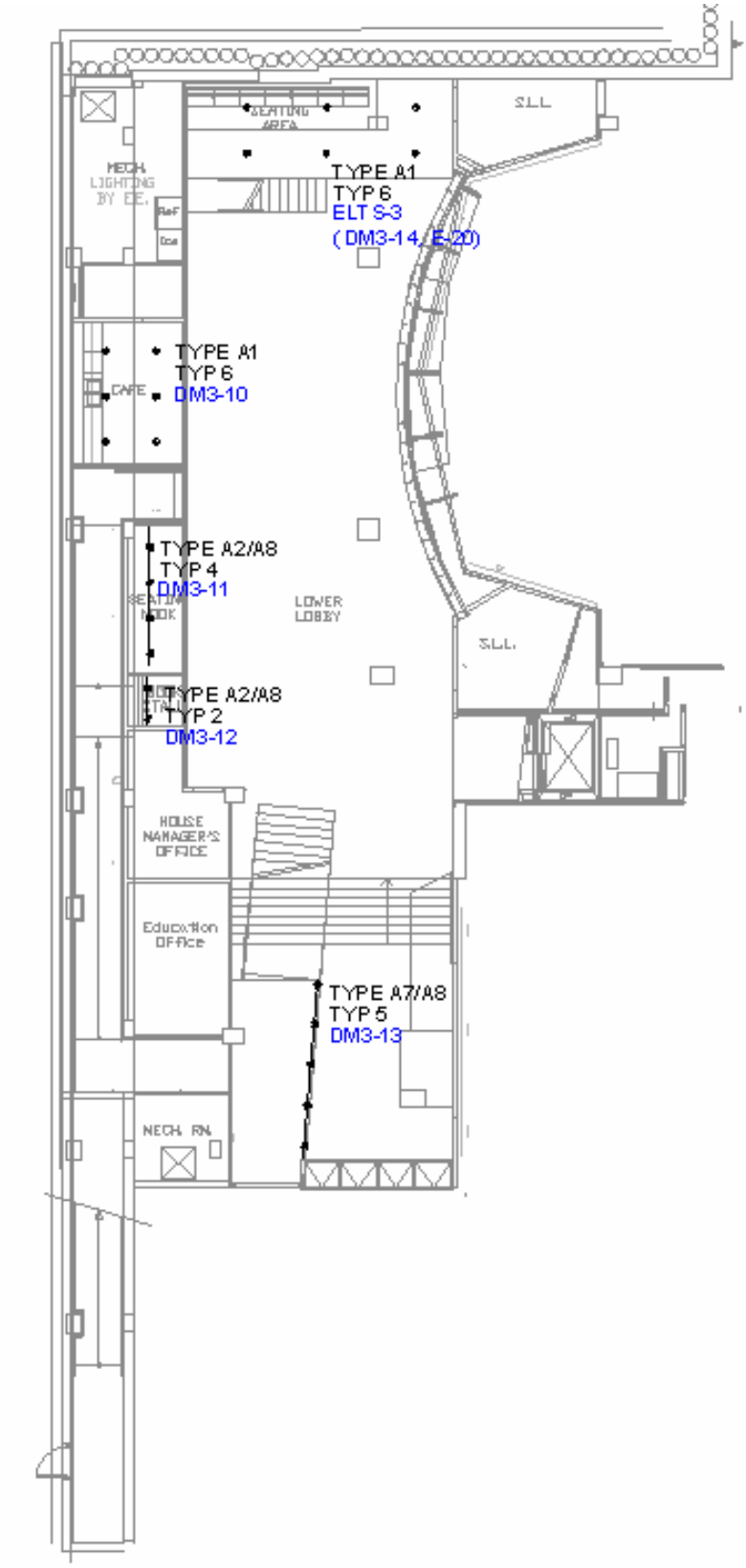
Canopy



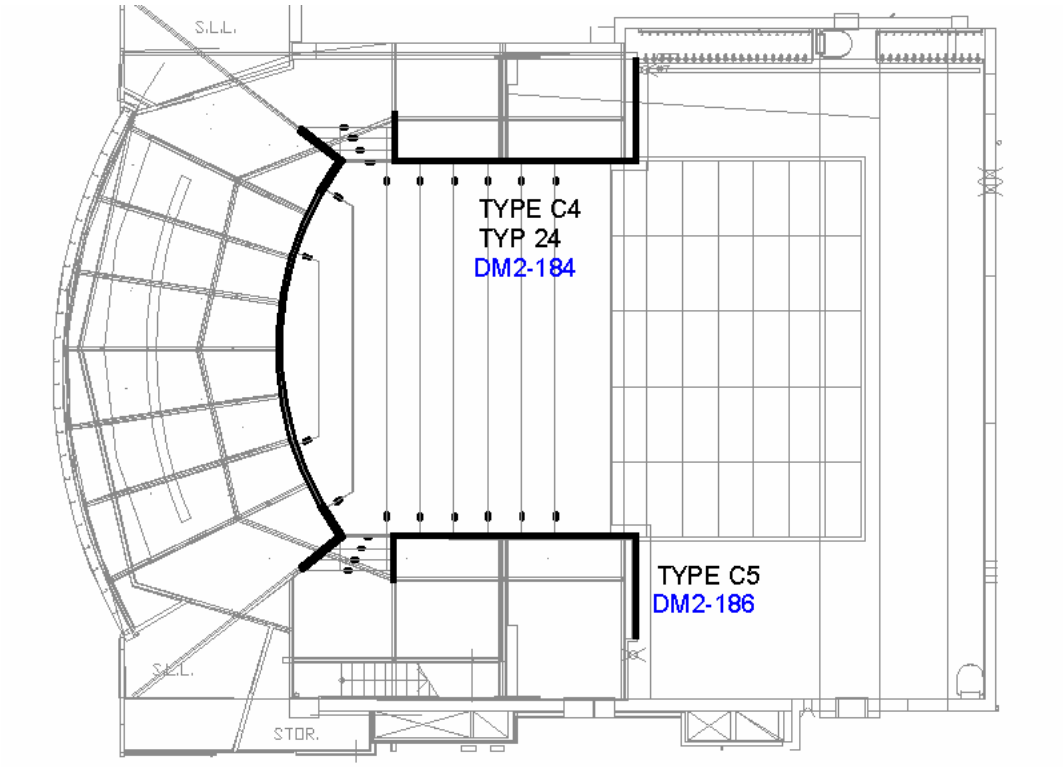
Lobby
Second Floor (Street Level) Plan



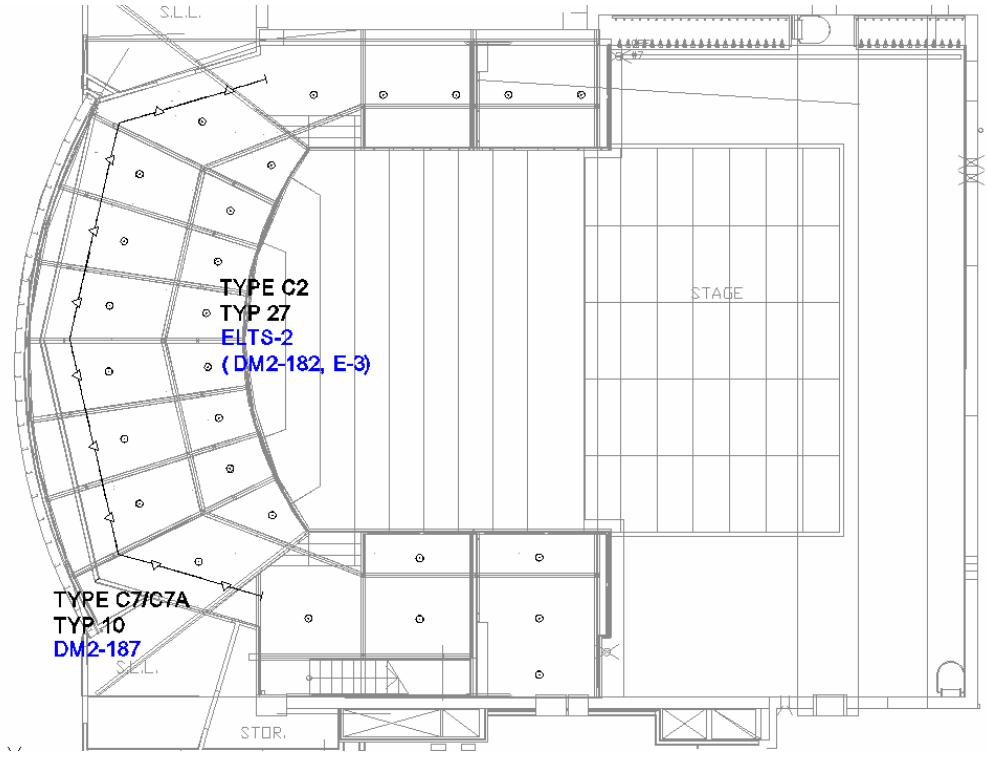
First Floor Plan



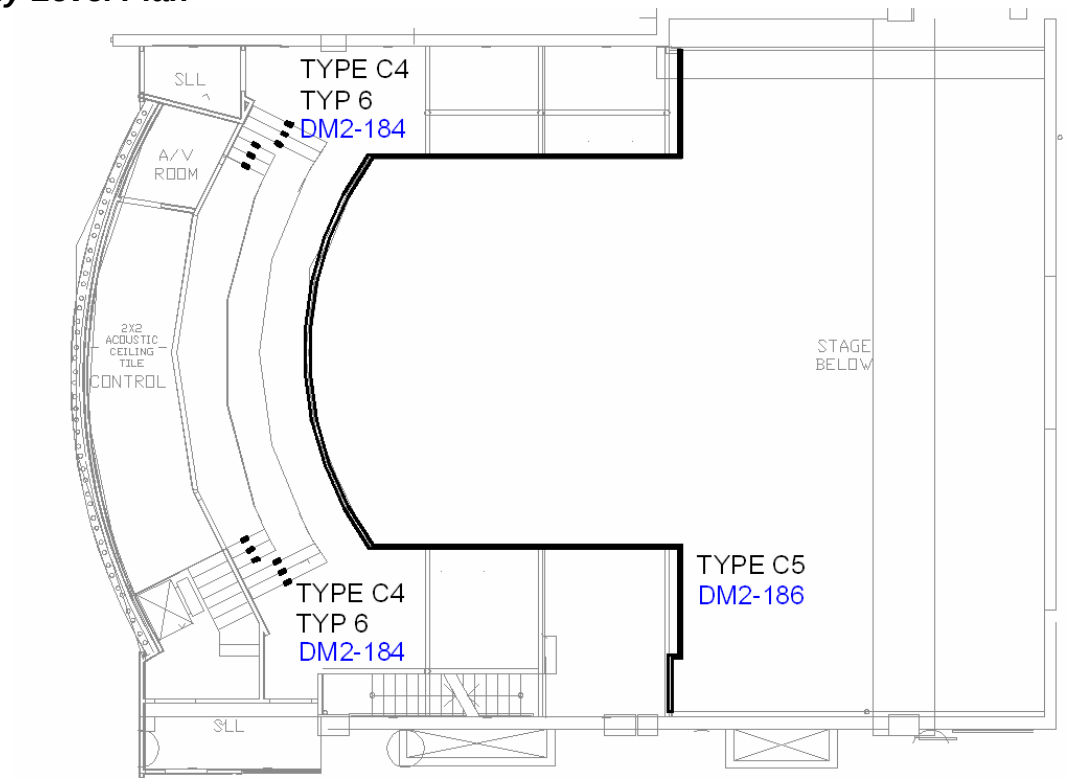
Theatre
Orchestra Level Plan



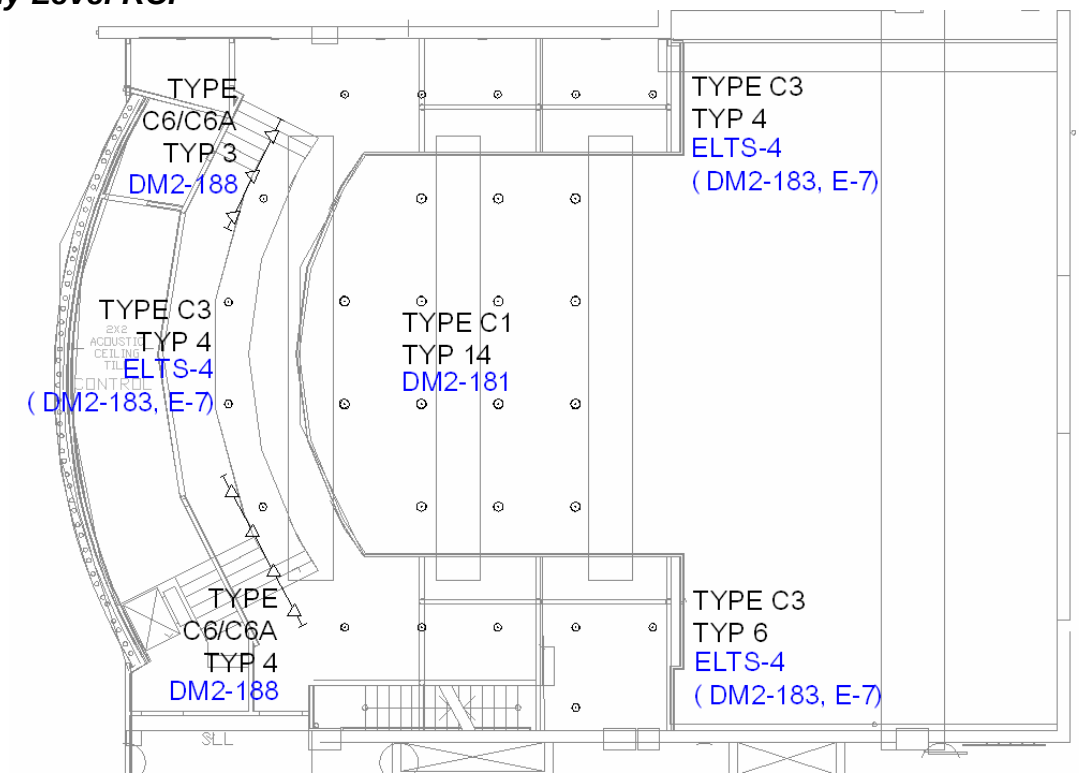
Orchestra Level RCP



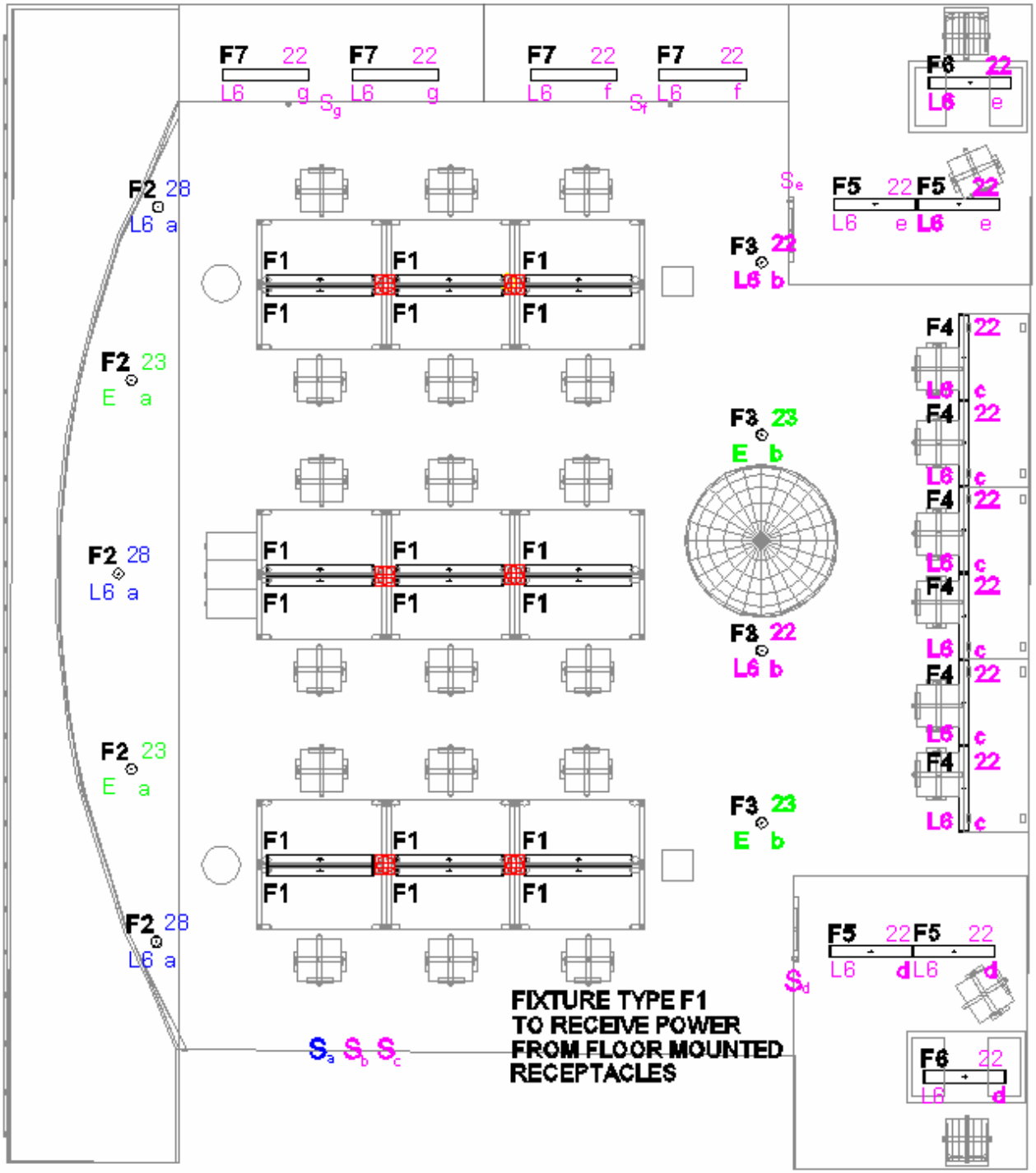
Balcony Level Plan



Balcony Level RCP



Office


F7 22 L6 g
F7 22 L6 g
F7 22 L6 f
F7 22 L6 f
F6 22 L6 e
F5 22 L6 e
F5 22 L6 e
F2 28 L6 a
F2 23 E a
F2 28 L6 a
F2 23 E a
F2 28 L6 a
F1
F3 22 L6 b
F3 23 E b
F3 22 L6 b
F3 23 E b
F4 22 L6 c
F5 22 L6 d
F5 22 L6 d
F6 22 L6 d
FIXTURE TYPE F1
TO RECEIVE POWER
FROM FLOOR MOUNTED
RECEPTACLES

Panelboards

Existing Panel M3

PANELBOARD SCHEDULE

VOLTAGE: 208Y/120V,3PH,4W
SIZE/TYPE BUS: 225A
SIZE/TYPE MAIN: 225A/3P C/B

PANEL TAG: M3
PANEL LOCATION: xx
PANEL MOUNTING: SURFACE

MIN. C/B AIC: 85K
OPTIONS:

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
RECEPTACLE		160	20A/1P	1	*			2	20A/1P	1000		AHU-5
RECEPTACLE		320	20A/1P	3		*		4	20A/1P	1000		AHU-5
RECEPTACLE		320	20A/1P	5			*	6	20A/1P	1000		AHU-5
RECEPTACLE		160	20A/1P	7	*			8	20A/1P	1000		REFRIGERATOR
RECEPTACLE		160	20A/1P	9		*		10	20A/1P	400		ICEMAKER
RECEPTACLE		160	20A/1P	11			*	12	20A/1P	475		LIGHTS
RECEPTACLE		640	20A/1P	13	*			14	20A/1P	400		TRACK LIGHTS
RECEPTACLE		640	20A/1P	15		*		16	20A/1P	300		TRACK LIGHTS
RECEPTACLE		800	20A/1P	17			*	18	20A/1P	190		LIGHTS
RECEPTACLE		160	20A/1P	19	*			20	20A/1P	400		TRACK LIGHTS
DISPLAY LIGHTS		300	20A/1P	21		*		22	20A/1P	190		LIGHTS
RECEPTACLE		160	20A/1P	23			*	24	20A/1P	600		SUMP PUMP
RECEPTACLE		320	20A/1P	25	*			26	20A/1P	0		SPARE
RECEPTACLE		320	20A/1P	27		*		28	20A/1P	0		SPARE
RECEPTACLE		320	20A/1P	29			*	30	20A/1P	1000		BASEBOARD HEATER
RECEPTACLE		320	20A/1P	31	*			32	20A/1P	1000		BASEBOARD HEATER
SPARE		0	20A/1P	33		*		34	20A/1P	1000		BASEBOARD HEATER
SPARE		0	20A/1P	35			*	36	20A/1P	1000		BASEBOARD HEATER
SPARE		0	20A/1P	37	*			38	20A/1P	1000		BASEBOARD HEATER
SPARE		0	20A/1P	39		*		40	20A/1P	1000		BASEBOARD HEATER
SPARE		0	20A/1P	41			*	42	20A/1P	1000		BASEBOARD HEATER

CONNECTED LOAD (KW) - A	6.56	TOTAL DESIGN LOAD (KW)	20.96
CONNECTED LOAD (KW) - B	5.63	POWER FACTOR	0.95
CONNECTED LOAD (KW) - C	7.03	TOTAL DESIGN LOAD (AMPS)	61

New Panel M3

PANELBOARD SCHEDULE

VOLTAGE: 208Y/120V,3PH,4W
SIZE/TYPE BUS: 225A
SIZE/TYPE MAIN: 225A/3P C/B

PANEL TAG: M3
PANEL LOCATION: xx
PANEL MOUNTING: SURFACE

MIN. C/B AIC: 85K
OPTIONS:

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
RECEPTACLE		160	20A/1P	1	*			2	20A/1P	1000		AHU-5
RECEPTACLE		320	20A/1P	3		*		4	20A/1P	1000		AHU-5
RECEPTACLE		320	20A/1P	5			*	6	20A/1P	1000		AHU-5
RECEPTACLE		160	20A/1P	7	*			8	20A/1P	1000		REFRIGERATOR
RECEPTACLE		160	20A/1P	9		*		10	20A/1P	400		ICEMAKER
RECEPTACLE		160	20A/1P	11			*	12	20A/1P	0		SPARE
RECEPTACLE		640	20A/1P	13	*			14	20A/1P	0		SPARE
RECEPTACLE		640	20A/1P	15		*		16	20A/1P	0		SPARE
RECEPTACLE		800	20A/1P	17			*	18	20A/1P	0		SPARE
RECEPTACLE		160	20A/1P	19	*			20	20A/1P	400		TRACK LIGHTS
SPARE		0	20A/1P	21		*		22	20A/1P	190		LIGHTS
RECEPTACLE		160	20A/1P	23			*	24	20A/1P	600		SUMP PUMP
RECEPTACLE		320	20A/1P	25	*			26	20A/1P	0		SPARE
RECEPTACLE		320	20A/1P	27		*		28	20A/1P	0		SPARE
RECEPTACLE		320	20A/1P	29			*	30	20A/1P	1000		BASEBOARD HEATER
RECEPTACLE		320	20A/1P	31	*			32	20A/1P	1000		BASEBOARD HEATER
SPARE		0	20A/1P	33		*		34	20A/1P	1000		BASEBOARD HEATER
SPARE		0	20A/1P	35			*	36	20A/1P	1000		BASEBOARD HEATER
SPARE		0	20A/1P	37	*			38	20A/1P	1000		BASEBOARD HEATER
SPARE		0	20A/1P	39		*		40	20A/1P	1000		BASEBOARD HEATER
SPARE		0	20A/1P	41			*	42	20A/1P	1000		BASEBOARD HEATER

CONNECTED LOAD (KW) - A	6.16	TOTAL DESIGN LOAD (KW)	19.23
CONNECTED LOAD (KW) - B	5.03	POWER FACTOR	0.95
CONNECTED LOAD (KW) - C	6.36	TOTAL DESIGN LOAD (AMPS)	56

Panel M3 Sizing

Note: All wires to be sized 75 degrees C, THWN, CU wire
Design Load: 56 Amps
Circuit Breaker Size: 60 Amps
Feeder Size: #8 AWG
Neutral: #8 AWG
Ground: #10 AWG
Conduit Size: 1 inch

Existing Panel L5

PANELBOARD SCHEDULE

VOLTAGE: 208Y/120V,3PH,4W
SIZE/TYPE BUS: 225A
SIZE/TYPE MAIN: 225A/3P C/B

PANEL TAG: L5 SECTION A
PANEL LOCATION: xx
PANEL MOUNTING: RECESSED

MIN. C/B AIC: 85K
OPTIONS: DOUBLE SECTION PANEL WITH CABLE TIES BETWEEN MAIN LUGS

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
RECEPTACLE	0	800	20A/1P	1	*			2	20A/1P	1425	0	WH-1
RECEPTACLE	0	800	20A/1P	3		*		4	20A/1P	1425	0	WH-1
RECEPTACLE	0	320	20A/1P	5			*	6	20A/1P	1425	0	WH-1
RECEPTACLE	0	640	20A/1P	7	*			8	20A/1P	1300	0	LIFT
RECEPTACLE	0	320	20A/1P	9		*		10	20A/1P	320	0	RECEPTACLE
RECEPTACLE	0	320	20A/1P	11			*	12	20A/1P	190	0	LIGHTS
RECEPTACLE	0	320	20A/1P	13	*			14	20A/1P	0	0	SPARE
RECEPTACLE	0	640	20A/1P	15		*		16	20A/1P	700	0	TRACK LIGHTS
RECEPTACLE	0	320	20A/1P	17			*	18	20A/1P	300	0	TRACK LIGHTS
RECEPTACLE	0	320	20A/1P	19	*			20	20A/1P	500	0	TRACK LIGHTS
RECEPTACLE	0	320	20A/1P	21		*		22	20A/1P	0	0	SPARE
RECEPTACLE	0	160	20A/1P	23			*	24	20A/1P	0	0	SPARE
RECEPTACLE	0	160	20A/1P	25	*			26	20A/1P	160	0	RECEPTACLE
RECEPTACLE	0	160	20A/1P	27		*		28	20A/1P	160	0	RECEPTACLE
RECEPTACLE	0	160	20A/1P	29			*	30	20A/1P	160	0	RECEPTACLE
RECEPTACLE	0	160	20A/1P	31	*			32	20A/1P	100	0	CARD READER
RECEPTACLE	0	800	20A/1P	33		*		34	20A/1P	100	0	PROCESSOR PANEL
REFRIGERATOR	0	800	20A/1P	35			*	36	20A/1P	0	0	SPARE
REFRIGERATOR	0	800	20A/1P	37	*			38	20A/1P	0	0	SPARE
RECEPTACLE	0	160	20A/1P	39		*		40	20A/1P	0	0	SPARE
COUNTER LIGHTS	0	190	20A/1P	41			*	42	20A/1P	0	0	SPARE

CONNECTED LOAD (KW) - A	6.69	TOTAL DESIGN LOAD (KW)	17.61
CONNECTED LOAD (KW) - B	5.91	POWER FACTOR	0.90
CONNECTED LOAD (KW) - C	4.35	TOTAL DESIGN LOAD (AMPS)	54

PANELBOARD SCHEDULE

VOLTAGE: 208Y/120V,3PH,4W
SIZE/TYPE BUS: 225A
SIZE/TYPE MAIN: 225A/3P C/B

PANEL TAG: L5 SECTION B
PANEL LOCATION: xx
PANEL MOUNTING: RECESSED

MIN. C/B AIC: 85K
OPTIONS: DOUBLE SECTION PANEL WITH CABLE TIES BETWEEN MAIN LUGS

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
TRACK UP	1000	500	20A/1P	43	*			44	20A/1P	1000	1500	PERF. LTS
TRACK UP	1000	500	20A/1P	45		*		46	20A/1P	1000	1500	PERF. LTS
TRACK UP	400	500	20A/1P	47			*	48	20A/1P	500	1500	TRACK
TRACK DOWN	800	500	20A/1P	49	*			50	20A/1P	0	1300	LIGHT-WALL
TRACK DOWN	400	500	20A/1P	51		*		52	20A/1P	800	400	LIGHT-WALL
TRACK DOWN	400	500	20A/1P	53			*	54	20A/1P	800	200	LIGHT-WALL
TRACK	400	800	20A/1P	55	*			56	20A/1P	800		LIGHT-WALL
TRACK	800	800	20A/1P	57		*		58	20A/1P	800	700	LIGHT-WALL
SPARE	400	0	20A/1P	59			*	60	20A/1P	800	300	LIGHT-WALL
SPARE	0	0	20A/1P	61	*			62	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	63		*		64	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	65			*	66	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	67	*			68	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	69		*		70	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	71			*	72	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	73	*			74	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	75		*		76	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	77			*	78	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	79	*			80	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	81		*		82	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	83			*	84	20A/1P	0	0	SPARE

CONNECTED LOAD (KW) - A	3.60	TOTAL DESIGN LOAD (KW)	10.66
CONNECTED LOAD (KW) - B	4.40	POWER FACTOR	1.00
CONNECTED LOAD (KW) - C	3.10	TOTAL DESIGN LOAD (AMPS)	30

New Panel L5

PANELBOARD SCHEDULE

VOLTAGE: 208Y/120V,3PH,4W
SIZE/TYPE BUS: 225A
SIZE/TYPE MAIN: 225A/3P C/B

PANEL TAG: L5 SECTION A
PANEL LOCATION: xx
PANEL MOUNTING: RECESSED

MIN. C/B AIC: 85K
OPTIONS:

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
RECEPTACLE	0	800	20A/1P	1	*			2	20A/1P	1425	0	WH-1
RECEPTACLE	0	800	20A/1P	3		*		4	20A/1P	1425	0	WH-1
RECEPTACLE	0	320	20A/1P	5			*	6	20A/1P	1425	0	WH-1
RECEPTACLE	0	640	20A/1P	7	*			8	20A/1P	1300	0	LIFT
RECEPTACLE	0	320	20A/1P	9		*		10	20A/1P	320	0	RECEPTACLE
RECEPTACLE	0	320	20A/1P	11			*	12	20A/1P	1000	0	PERF. LTS
RECEPTACLE	0	320	20A/1P	13	*			14	20A/1P	0	0	SPARE
RECEPTACLE	0	640	20A/1P	15		*		16	20A/1P	1000	0	PERF. LTS
RECEPTACLE	0	320	20A/1P	17			*	18	20A/1P	300	0	LIGHTWALL
RECEPTACLE	0	320	20A/1P	19	*			20	20A/1P	300	0	LIGHTWALL
RECEPTACLE	0	320	20A/1P	21		*		22	20A/1P	140	0	CANOPY
RECEPTACLE	0	160	20A/1P	23			*	24	20A/1P	140	0	CANOPY
RECEPTACLE	0	160	20A/1P	25	*			26	20A/1P	160	0	RECEPTACLE
RECEPTACLE	0	160	20A/1P	27		*		28	20A/1P	160	0	RECEPTACLE
RECEPTACLE	0	160	20A/1P	29			*	30	20A/1P	160	0	RECEPTACLE
RECEPTACLE	0	160	20A/1P	31	*			32	20A/1P	100	0	CARD READER
RECEPTACLE	0	800	20A/1P	33		*		34	20A/1P	100	0	PROCESSOR PANEL
REFRIGERATOR	0	800	20A/1P	35			*	36	20A/1P	0	0	SPARE
REFRIGERATOR	0	800	20A/1P	37	*			38	20A/1P	2978	0	DIM 3
RECEPTACLE	0	160	20A/1P	39		*		40	20A/1P	2977	0	DIM 3
COUNTER LIGHTS	0	190	20A/1P	41			*	42	20A/1P	2977	0	DIM 3

CONNECTED LOAD (KW) - A	9.46	TOTAL DESIGN LOAD (KW)	29.76
CONNECTED LOAD (KW) - B	9.32	POWER FACTOR	0.94
CONNECTED LOAD (KW) - C	8.27	TOTAL DESIGN LOAD (AMPS)	88

All loads were removed from Panel L5 Section B. Therefore it was removed from the system.

PANELBOARD SCHEDULE

VOLTAGE: 208Y/120V,3PH,4W
SIZE/TYPE BUS: 225A
SIZE/TYPE MAIN: 225A/3P C/B

PANEL TAG: L5 SECTION B
PANEL LOCATION: xx
PANEL MOUNTING: RECESSED

MIN. C/B AIC: 85K
OPTIONS: DOUBLE SECTION PANEL WITH CABLE TIES BETWEEN MAIN LUGS

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
SPARE	0	0	20A/1P	43	*			44	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	45		*		46	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	47			*	48	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	49	*			50	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	51		*		52	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	53			*	54	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	55	*			56	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	57		*		58	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	59			*	60	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	61	*			62	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	63		*		64	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	65			*	66	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	67	*			68	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	69		*		70	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	71			*	72	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	73	*			74	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	75		*		76	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	77			*	78	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	79	*			80	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	81		*		82	20A/1P	0	0	SPARE
SPARE	0	0	20A/1P	83			*	84	20A/1P	0	0	SPARE

CONNECTED LOAD (KW) - A	0.00	TOTAL DESIGN LOAD (KW)	0.00
CONNECTED LOAD (KW) - B	0.00	POWER FACTOR	
CONNECTED LOAD (KW) - C	0.00	TOTAL DESIGN LOAD (AMPS)	0

Panel L5 Sizing

Note: All wires to be sized 75 degrees C, THWN, CU wire
Design Load: 88 Amps
Circuit Breaker Size: 90 Amps
Feeder Size: #4 AWG
Neutral: #4 AWG
Ground: #8 AWG
Conduit Size: (4) #4 AWG, (1) #8 AWG

(4) * 0.0824 + 0.0366 = 0.03662 inches squared
40% * 1.526” = 0.614” > 0.03662”
Conduit to be 1 ¼” RMC

Emergency Lighting Transfer Switch Panel

EMERGENCY LIGHTING TRANSFER SWITCH (ELTS) PANEL - LOBBY		
20 AMP RATED, 4-WIRE INPUT, 2-POLE TRANSFER, 2-WIRE OUTPUT		
ALT #	**NORMAL/RELAY/DIMMING CKT**	**EMERGENC CKT**
1	DM3-1	E-39
2	DM3-5	E-22
3	DM3-14	E-37
4	DM3-4	E-20
5	SPARE	
6	SPARE	
7	SPARE	
8	SPARE	
9	SPARE	
10	SPARE	
11	SPARE	
12	SPARE	

New Panel DM3

LOBBY/CANOPY DIMMER SCHEDULE DM3 SCHEDULE						
ZONE. NO	**CKT NO.**	**FIXTURE TYPE**	**DESCRIPTION**	**WATTS/ FIXTURE**	**QTY.**	**LOAD (W)**
1	**1**	A1	CFL PENDANTS	39	29	1,131
2	**2**		SPARE			
3	**3**	A4	TRACK- CATWALK	50	22	1,100
4	**4**	A7	TRACK- MAIN STAIRS	100	4	400
5	**5**	A7	TRACK- MAIN STAIRS	100	10	1,000
6	**6**	A1	CFL PENDANTS- TICKET BOOTH	39	5	195
7	**7**	A4	TRACK- TICKET BOOTH	50	7	350
8	**8**	A5	LED STRIP- TICKET BOOTH	1	230	230
9	**9**	A2	TRACK- ENTRANCE WALL	50	3	150
10	**10**	A1	CFL PENDANTS- CAFÉ	39	6	234
11	**11**	A2	TRACK- SEATING NOOK	50	4	200
12	**12**	A2	TRACK- BOOK STALL	50	2	100
13	**13**	A7	TRACK- UNDER MAIN STAIRS	100	5	500
14	**14**	A1	CFL PENDANTS- SEATING AREA	39	6	234
15	**15**	A3	ACCENT- GYPSUM PANEL	71	1	71
16	**16**	A3	ACCENT- GYPSUM PANEL	71	1	71
17	**17**	A3	ACCENT- GYPSUM PANEL	71	1	71
18	**18**	A3	ACCENT- GYPSUM PANEL	71	1	71
19	**19**	A3	ACCENT- GYPSUM PANEL	71	1	71
20	**20**	A3	ACCENT- GYPSUM PANEL	71	1	71
21	**21**	A3	ACCENT- GYPSUM PANEL	71	1	71
22	**22**	A3	ACCENT- GYPSUM PANEL	71	1	71
23	**23**	A3	ACCENT- GYPSUM PANEL	71	1	71
24	**24**	A3	ACCENT- GYPSUM PANEL	71	1	71
25	**25**	A3	ACCENT- GYPSUM PANEL	71	1	71
26	**26**	A3	ACCENT- GYPSUM PANEL	71	1	71
27	**27**	A3	ACCENT- GYPSUM PANEL	71	1	71
28	**28**	A3	ACCENT- GYPSUM PANEL	71	1	71
29	**29**	A3	ACCENT- GYPSUM PANEL	71	1	71
30	**30**	A3	ACCENT- GYPSUM PANEL	71	1	71
31	**31**	A3	ACCENT- GYPSUM PANEL	71	1	71
32	**32**	A3	ACCENT- GYPSUM PANEL	71	1	71
33	**33**	EX2	SOURCE 4 JR- CANOPY	375	2	750

34	**34**		SPARE			
35	**35**	EX3	CYLINDER ACCENT- CANOPY	50	4	200
36			SPARE			
37			SPARE			
38			SPARE			
39			SPARE			
40			SPARE			
41			SPARE			
42			SPARE			
43			SPARE			
44			SPARE			
45			SPARE			
46			SPARE			
47			SPARE			
48			SPARE			
				TOTAL LOAD (W)		**8,052**

Panel DM3 Sizing

Note: All wires to be sized 75 degrees C, THWN, CU wire
Design Load: 23 Amps
Circuit Breaker Size: 30 Amps
Feeder Size: #10 AWG
Neutral: #10 AWG
Ground: #10 AWG
Conduit Size: ¾ “

New Relay R1

RELAY R1 PANEL SCHEDULE			
ATS #	**AMPACITY**	**ZONE (DMX 512 CONTROL)**	**FROM CKT**
1	20 A	LIGHTWALL	L5-18
2	20 A	LIGHTWALL	L5-20
3	20 A	CANOPY	L5-22
4	20 A	CANOPY	L5-24
5	20 A	SPARE	
6	20 A	SPARE	
7	20 A	SPARE	
8	20 A	SPARE	
9	20 A	SPARE	
10	20 A	SPARE	
11	20 A	SPARE	
12	20 A	SPARE	
13	20 A	SPARE	
14	20 A	SPARE	
15	20 A	SPARE	
16	20 A	SPARE	
17	20 A	SPARE	
18	20 A	SPARE	
19	20 A	SPARE	
20	20 A	SPARE	
21	20 A	SPARE	
22	20 A	SPARE	
23	20 A	SPARE	
24	20 A	SPARE	

Existing Emergency Lighting Transfer Switch Panel

EMERGENCY LIGHTING TRANSFER SWITCH (ELTS) PANEL- THEATRE		
20 AMP RATED, 4-WIRE INPUT, 2-POLE TRANSFER, 2-WIRE OUTPUT		
ALT #	**NORMAL/RELAY/DIMMING CKT**	**EMERGENCY CKT**
1	SPARE	SPARE
2	DM2-183	E-3
3	DM2-184	E-5
4	DM2-185	E-7
5	SPARE	SPARE
6	T1-2	E-11
7	T1-6	E-13
8	R-13	E-19
9	R-12	E-21
10	R-16	E-27
11	T1-14	E-24
12	SPARE	SPARE
13	SPARE	SPARE
14	SPARE	SPARE
15	SPARE	SPARE
16	SPARE	SPARE
17	SPARE	SPARE
18	SPARE	SPARE
19	SPARE	
20	SPARE	
21	SPARE	
22	SPARE	
23	SPARE	
24	SPARE	
25	SPARE	

New Emergency Lighting Transfer Switch Panel

EMERGENCY LIGHTING TRANSFER SWITCH (ELTS) PANEL-THEATRE		
20 AMP RATED, 4-WIRE INPUT, 2-POLE TRANSFER, 2-WIRE OUTPUT		
ALT #	**NORMAL/RELAY/DIMMING CKT**	**EMERGENCY CKT**
1	SPARE	SPARE
2	DM2-182	E-3
3	DM2-184	E-5
4	DM2-183	E-7
5	SPARE	SPARE
6	T1-2	E-11
7	T1-6	E-13
8	R-13	E-19
9	R-12	E-21
10	R-16	E-27
11	T1-14	E-24
12	SPARE	SPARE
13	SPARE	SPARE
14	SPARE	SPARE
15	SPARE	SPARE
16	SPARE	SPARE
17	SPARE	SPARE
18	SPARE	SPARE
19	SPARE	
20	SPARE	
21	SPARE	
22	SPARE	
23	SPARE	
24	SPARE	
25	SPARE	

Existing Panel DM2

THEATER DIMMER PANEL DM2 SCHEDULE		
DIMMER #	**DIMMING MODULE**	**ZONE (512 CONTROL)**
181	2.4 KW	BACK WALL 1ST FLR. LIGHTS
182	2.4 KW	BACK WALL 1ST FLR. LIGHTS
183	2.4 KW	UNDER BALCONY 1ST FLR LIGHTS
184	2.4 KW	SLL AND STAIR LIGHTS
185	2.4 KW	2ND FLR LIGHTS
186	2.4 KW	BACK WALL 2ND FLR. LIGHTS
187	2.4 KW	HOUSE LIGHTS
188	2.4 KW	HOUSE LIGHTS

New Panel Dim2

THEATER DIMMER PANEL DM2 SCHEDULE					
ZONE. NO	**FIXTURE TYPE**	**DESCRIPTION**	**WATTS/ FIXTURE**	**QTY.**	**LOAD (W)**
181	C1	CFL PENDANTS	148	7	1,036
181	C1	CFL PENDANTS	148	7	1,036
182	C2	CFL CYLINDERS- FIRST FLOOR	39	27	1,053
183	C3	CFL PENDANT CYLINDERS- BALCONY FLOOR	50	15	750
184	B, B1, B2	SLL AND STAIR LIGHTS			650
185	C4	STEPLIGHTS	20	24	480
186	C5	LED RAILING	2	240	480
187	C7	TRACK- BACK WALL 1ST FLR.	50	10	500
188	C6	SUSPENDED TRACK- BACK WALL 2ND FLR.	120	7	840

Feeders for Panel DM2 could not be sized due to the unknown loads of Zone No. 1 - 180.

Existing Panel L6

PANELBOARD SCHEDULE

VOLTAGE: 208Y/120V,3PH,4W
SIZE/TYPE BUS: 225A
SIZE/TYPE MAIN: 225A/3P C/B

PANEL TAG: L6
PANEL LOCATION: SECOND LEVEL
PANEL MOUNTING: SURFACE

MIN. C/B AIC: 85K
OPTIONS:

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
SYSTEMS FURN		800	20A/1P	1	*			2	20A/1P	320		RECEPTACLE
SYSTEMS FURN		800	20A/1P	3		*		4	20A/1P	320		RECEPTACLE
SYSTEMS FURN		800	20A/1P	5			*	6	20A/1P	320		RECEPTACLE
SYSTEMS FURN		800	20A/1P	7	*			8	20A/1P	320		RECEPTACLE
SYSTEMS FURN		800	20A/1P	9		*		10	20A/1P	320		RECEPTACLE
SYSTEMS FURN		800	20A/1P	11			*	12	20A/1P	320		RECEPTACLE
SYSTEMS FURN		800	20A/1P	13	*			14	20A/1P	0		SPARE
SYSTEMS FURN		800	20A/1P	15		*		16	20A/1P	0		SPARE
SYSTEMS FURN		800	20A/1P	17			*	18	20A/1P	0		SPARE
RECEPTACLE		160	20A/1P	19	*			20	20A/1P	400		DISPOSAL
RECEPTACLE		160	20A/1P	21		*		22	20A/1P	1520		LIGHTS
RECEPTACLE		160	20A/1P	23			*	24	20A/1P	1520		LIGHTS
RECEPTACLE		160	20A/1P	25	*			26	20A/1P	760		LIGHTS
RECEPTACLE		160	20A/1P	27		*		28	20A/1P	0		SPARE
RECEPTACLE		960	20A/1P	29			*	30	20A/1P	1100		TRACK LIGHTS
RECEPTACLE		800	20A/1P	31	*			32	20A/1P	320		RECEPTACLE
RECEPTACLE		320	20A/1P	33		*		34	20A/1P	320		RECEPTACLE
RECEPTACLE		800	20A/1P	35			*	36	20A/1P	100		CHAIR LIFT
RECEPTACLE		960	20A/1P	37	*			38	20A/1P	100		CARD READER
RECEPTACLE		800	20A/1P	39		*		40	20A/1P	400		F-5
RECEPTACLE		320	20A/1P	41			*	42	20A/1P	0		SPARE

CONNECTED LOAD (KW) - A	6.70	TOTAL DESIGN LOAD (KW)	22.71
CONNECTED LOAD (KW) - B	6.72	POWER FACTOR	0.92
CONNECTED LOAD (KW) - C	8.00	TOTAL DESIGN LOAD (AMPS)	69

New Panel L6

PANELBOARD SCHEDULE

VOLTAGE: 208Y/120V,3PH,4W
SIZE/TYPE BUS: 225A
SIZE/TYPE MAIN: 225A/3P C/B

PANEL TAG: L6
PANEL LOCATION: SECOND FLOOR
PANEL MOUNTING: SURFACE

MIN. C/B AIC: 85K
OPTIONS:

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
SYSTEMS FURN		800	20A/1P	1	*			2	20A/1P	320		RECEPTACLE
SYSTEMS FURN		800	20A/1P	3		*		4	20A/1P	320		RECEPTACLE
SYSTEMS FURN		800	20A/1P	5			*	6	20A/1P	320		RECEPTACLE
SYSTEMS FURN		800	20A/1P	7	*			8	20A/1P	320		RECEPTACLE
SYSTEMS FURN		800	20A/1P	9		*		10	20A/1P	320		RECEPTACLE
SYSTEMS FURN		800	20A/1P	11			*	12	20A/1P	320		RECEPTACLE
SYSTEMS FURN		800	20A/1P	13	*			14	20A/1P	864	OFFICE	QUAD RECEPTACLE
SYSTEMS FURN		800	20A/1P	15		*		16	20A/1P	864	OFFICE	QUAD RECEPTACLE
SYSTEMS FURN		800	20A/1P	17			*	18	20A/1P	0		SPARE
RECEPTACLE		160	20A/1P	19	*			20	20A/1P	400		DISPOSABLE
RECEPTACLE		160	20A/1P	21		*		22	20A/1P	926	OFFICE	OFFICE LIGHTS
RECEPTACLE		160	20A/1P	23			*	24	20A/1P	1520		LIGHTS
RECEPTACLE		160	20A/1P	25	*			26	20A/1P	760		LIGHTS
RECEPTACLE		160	20A/1P	27		*		28	20A/1P	664	OFFICE	OFFICE LIGHTS
RECEPTACLE		960	20A/1P	29			*	30	20A/1P	1100		TRACK LIGHTS
RECEPTACLE		800	20A/1P	31	*			32	20A/1P	320		RECEPTACLE
RECEPTACLE		320	20A/1P	33		*		34	20A/1P	320		RECEPTACLE
RECEPTACLE		800	20A/1P	35			*	36	20A/1P	100		CHAIR LIFT
RECEPTACLE		960	20A/1P	37	*			38	20A/1P	100		CARD READER
RECEPTACLE		800	20A/1P	39		*		40	20A/1P	400		F-5
RECEPTACLE		320	20A/1P	41			*	42	20A/1P	0		QUAD RECEPTACLE

CONNECTED LOAD (KW) - A	7.56	TOTAL DESIGN LOAD (KW)	23.76
CONNECTED LOAD (KW) - B	7.65	POWER FACTOR	0.91
CONNECTED LOAD (KW) - C	8.00	TOTAL DESIGN LOAD (AMPS)	73

Panel L6 Sizing

Note: All wires to be sized 75 degrees C, THWN, CU wire
Design Load: 73 Amps
Circuit Breaker Size: 80 Amps
Feeder Size: #6 AWG
Neutral: #6 AWG
Ground: #8 AWG
Conduit Size: 1 ¼"

Emergency Lighting Panelboards

Existing Panel E

PANELBOARD SCHEDULE

VOLTAGE: 208Y/120V,3PH,4W
SIZE/TYPE BUS: 225A
SIZE/TYPE MAIN: 225A/3P C/B

PANEL TAG: E
PANEL LOCATION: SHOP
PANEL MOUNTING: SURFACE

MIN. C/B AIC: MATCHING EXISTING ATS
OPTIONS:

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
FACP		200	20A/1P	1	*			2	20A/1P	200		ELEV TROUGH
THEATER LIGHTS		300	20A/1P	3		*		4	20A/1P	1000		ELEV PIT
THEATER LIGHTS		1900	20A/1P	5			*	6	20A/1P	200		EXIT SIGNS
THEATER LIGHTS		1900	20A/1P	7	*			8	20A/1P	100		LIGHT
SPARE		0	20A/1P	9		*		10	20A/1P	200		EXIST SIGNS
ONTROL RM LIGHT		500	20A/1P	11			*	12	20A/1P	200		EXIT SIGNS
LIGHTS		300	20A/1P	13	*			14	20A/1P	200		FREIGHT ELEV TROUGH
LIGHTS		900	20A/1P	15		*		16	20A/1P	100		FREIGHT ELEV LIGHT
LIGHTS-1ST FL		600	20A/1P	17			*	18	20A/1P	1000		FREIGHT ELEV PIT
THEATER LIGHTS		300	20A/1P	19	*			20	20A/1P	400		TRACK LIGHTS
THEATER LIGHTS		200	20A/1P	21		*		22	20A/1P	1000		TRACK LIGHTS
LIGHTS OFFICE		500	20A/1P	23			*	24	20A/1P	0		STEP LIGHTS
LIGHTS OFFICE		300	20A/1P	25	*			26	20A/1P	0		SPARE
LIGHTS SLL		300	20A/1P	27		*		28	20A/1P	0		SPARE
LIGHTS CORR		1200	20A/1P	29			*	30	20A/1P	0		SPARE
LIGHTS CORR		1200	20A/1P	31	*			32	20A/1P	0		SPARE
LIGHTS-1ST FL		1500	20A/1P	33		*		34	20A/1P	0		SPARE
LIGHTS CORR		300	20A/1P	35			*	36	20A/1P	0		SPARE
LIGHTS-1ST FL		1300	20A/1P	37	*			38	20A/1P	4000		SPACE
LIGHTS-2ND FL		500	20A/1P	39		*		40	20A/1P	4000		SPACE
LIGHTS TRACK		700	20A/1P	41			*	42	20A/1P	4000		SPACE

CONNECTED LOAD (KW) - A	10.40	TOTAL DESIGN LOAD (KW)	18.74
CONNECTED LOAD (KW) - B	10.00	POWER FACTOR	1.00
CONNECTED LOAD (KW) - C	11.10	TOTAL DESIGN LOAD (AMPS)	52

New Panel E

PANELBOARD SCHEDULE

VOLTAGE: 208Y/120V,3PH,4W
SIZE/TYPE BUS: 225A
SIZE/TYPE MAIN: 225A/3P C/B

PANEL TAG: E
PANEL LOCATION: SHOP
PANEL MOUNTING: SURFACE

MIN. C/B AIC: MATCHING EXISTING ATS
OPTIONS:

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
FACP		200	20A/1P	1	*			2	20A/1P	200		ELEV TROUGH
THEATER LIGHTS		300	20A/1P	3		*		4	20A/1P	1000		ELEV PIT
THEATER LIGHTS		1900	20A/1P	5			*	6	20A/1P	200		EXIT SIGNS
THEATER LIGHTS		1900	20A/1P	7	*			8	20A/1P	100		LIGHT
SPARE		0	20A/1P	9		*		10	20A/1P	200		EXIT SIGNS
CONTROL RM LIGHTS		500	20A/1P	11			*	12	20A/1P	200		EXIT SIGNS
LIGHTS		300	20A/1P	13	*			14	20A/1P	200		FREIGHT ELEV TROUGH
SPARE		0	20A/1P	15		*		16	20A/1P	100		FREIGHT ELEV LIGHT
LIGHTS-1ST FL		600	20A/1P	17			*	18	20A/1P	1000		FREIGHT ELEV PIT
THEATER LIGHTS		300	20A/1P	19	*			20	20A/1P	400		TRACK LIGHTS
THEATER LIGHTS		200	20A/1P	21		*		22	20A/1P	1000		TRACK LIGHTS
LIGHTS OFFICE		205	20A/1P	23			*	24	20A/1P	0		SPARE
LIGHTS OFFICE		300	20A/1P	25	*			26	20A/1P	0		SPARE
LIGHTS SLL		300	20A/1P	27		*		28	20A/1P	0		SPARE
LIGHTS CORR		1200	20A/1P	29			*	30	20A/1P	0		SPARE
LIGHTS CORR		1200	20A/1P	31	*			32	20A/1P	0		SPARE
LIGHTS-1ST FL		1500	20A/1P	33		*		34	20A/1P	0		SPARE
LIGHTS CORR		300	20A/1P	35			*	36	20A/1P	0		SPARE
LIGHTS-1ST FL		234	20A/1P	37	*			38	20A/1P	4000		SPACE
LIGHTS-2ND FL		1131	20A/1P	39		*		40	20A/1P	4000		SPACE
LIGHTS TRACK		700	20A/1P	41			*	42	20A/1P	4000		SPACE

CONNECTED LOAD (KW) - A	9.33	TOTAL DESIGN LOAD (KW)	10.93
CONNECTED LOAD (KW) - B	9.73	POWER FACTOR	1.00
CONNECTED LOAD (KW) - C	10.81	TOTAL DESIGN LOAD (AMPS)	30

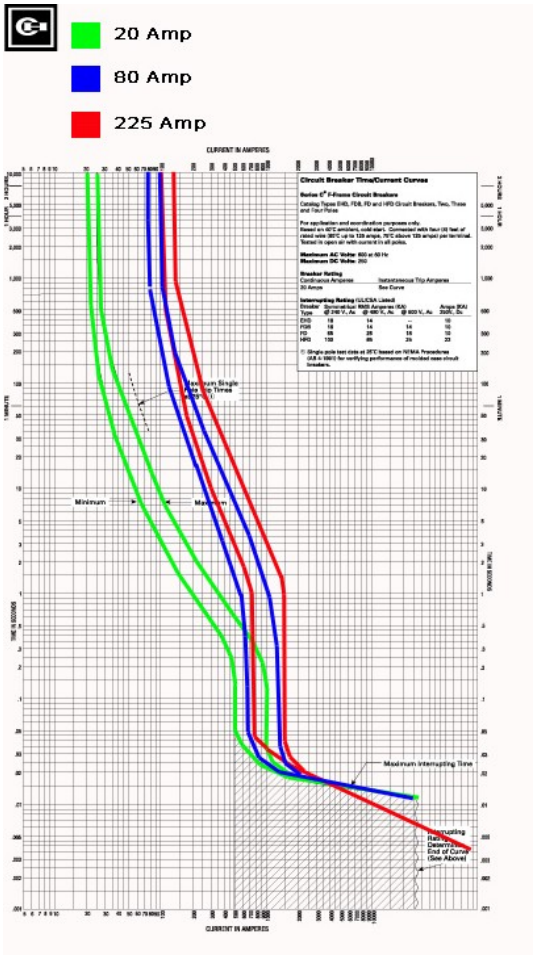
Panel E Sizing

Note: All wires to be sized 75 degrees C, THWN, CU wire
Design Load: 30 Amps
Circuit Breaker Size: 30 Amps
Feeder Size: #10 AWG
Neutral: #10 AWG
Ground: #10 AWG
Conduit Size: ¾”

Note: Voltage drop calculations did not need to be calculated for new design panels. All panels are located in electrical closets in the corresponding rooms. Therefore the distance of the runs was not long.

Device Coordination Study

All circuit breaker cut-sheets can be found in Appendix B-1



Conclusion

This diagram above shows three devices from the electrical system, a 20 A circuit breaker from a branch circuit and the 80 A circuit breaker from panel L6 and a 225 A circuit breaker from switchboard S1. The three devices are coordinated because the 20 A breaker will trip before the 80 A breaker, and the 80 A breaker will trip before the 225 A breaker.

Short Circuit

The utility for the Woolly Mammoth Theatre was contacted in order to obtain the existing information on short circuit current. The information was unavailable. Therefore the short circuit current calculation could not be carried out.

Copper versus Aluminum Wiring

FEEDER SCHEDULE					
FEEDER	**SERVING**	**SERVING FROM**	**WIRE**	**CONDUIT**	**GROUND**
1	L4	S1	4 #5000 KCMIL	3- 1/2 "	1 #3
2	M3, M2	S1	4 #5000 KCMIL	3- 1/2 "	1 #3
3	L5	S1	4 #4/0	2- 1/2"	1 #4
4	TP, 100 A AUDIO	S1	3 #250 KCMIL	2- 1/2"	1 #4
5	T1	S1	4 #1	1- 1/2"	1 #8
6	T	S1	4 #5000 KCMIL	3- 1/2 "	1 #3
7	DM1	S1	(2) 3 #400 KCMIL, 2 #400 KCMIL N	3- 1/2 "	1 #2
8	DM2	S1	(2) 3 #400 KCMIL, 2 #400 KCMIL N	3- 1/2 "	1 #2
9	M1	S2	4 #5000 KCMIL	3- 1/2 "	1 #3
10	CH-1	S2	(2) 3 #250 KCMIL	2- 1/2"	1 #1
11	ELEVATOR	S2	3 #1	1- 1/2"	1 #6
12	FREIGHT ELEVATOR	S2	3 #1/0	1- 1/2"	1 #6
13	WH	S2	3 #3/0	2"	1 #6
14	WH	S2	3 #3/0	2"	1 #6
15	PB	S2	4 #5000 KCMIL	3- 1/2 "	1 #3

COPPER TO ALUMINUM WIRING SIZING AND COST ANALYSIS											
FEEDER NUMBER	OCPD (AMPS)	COPPER WIRING								LENGTH (FT)	PRICE
		WIRE SIZE (AWG OR KCMIL)				PRICE PER LINEAR FOOT					
		CONDUCTORS	NEUTRAL	GROUND	CONDUIT	CONDUCTORS	NEUTRAL	GROUND	CONDUIT		
1	400	3 #500	1 #500	1 #3	3-1/2 "	$4.20	$4.20	$0.50	$19.65	120	$4,434.00
2	400	3 #500	1 #500	1 #3	3-1/2 "	$4.20	$4.20	$0.50	$19.65	140	$5,173.00
3	225	3 #4/0	1 #4/0	1 #4	2-1/2"	$1.81	$1.81	$0.41	$11.20	160	$3,015.20
4	250	3 #250		1 #4	2-1/2"	$2.16		$0.41	$11.20	65	$1,175.53
5	225	3 #1	1 #1	1 #8	1-1/2"	$0.80	$0.80	$0.80	$5.20	20	$184.00
6	400	3 #500	1 #500	1 #3	3-1/2 "	$4.20	$4.20	$0.50	$19.65	20	$739.00
7	600	(2) 3 #400	2 #400	1 #2	3-1/2 "	$3.40	$3.40	$0.63	$19.65	20	$949.60
8	600	(2) 3 #400	2 #400	1 #2	3-1/2 "	$3.40	$3.40	$0.63	$19.65	20	$949.60
9	400	3 #500	1 #500	1 #3	3-1/2 "	$4.20	$4.20	$0.50	$19.65	200	$7,390.00
10	550	(2) 3 #250		1 #1	2-1/2"	$2.16		$0.80	$11.20	25	$624.00
11	150	3 #1		1 #6	1-1/2"	$0.80		$0.27	$5.20	190	$1,494.35
12	200	3 #3/0		1 #6	1-1/2"	$0.94		$0.27	$7.10	160	$1,629.60
13	200	3 #3/0		1 #6	2"	$0.94		$0.27	$7.10	15	$152.78
14	200	3 #3/0		1 #6	2"	$0.94		$0.27	$7.10	20	$203.70
15	400	3 #500	1 #500	1 #3	3-1/2 "	$4.20	$4.20	$0.50	$19.65	115	$4,249.25
								TOTAL PRICE			$32,363.60

FEEDER NUMBER	OCPD (AMPS)	ALUMINUM WIRING								LENGTH (FT)	PRICE
		WIRE SIZE (AWG OR KCMIL)				PRICE PER LINEAR FOOT					
		CONDUCTORS	NEUTRAL	GROUND	CONDUIT	CONDUCTORS	NEUTRAL	GROUND	CONDUIT		
1	400	(2) 3 #4/0	2 #4/0	1 #1	3"	$1.00	$1.00	$0.51	$15.20	120	$2,840.40
2	400	(2) 3 #4/0	2 #4/0	1 #1	3"	$1.00	$1.00	$0.51	$15.20	140	$3,313.80
3	225	3 #250	1 #250	1 #2	3"	$1.22	$1.22	$0.35	$15.20	160	$3,268.80
4	250	3 #350		1 #2	3"	$1.71		$0.35	$15.20	65	$1,344.20
5	225	3 #250	1 #250	1 #2	3"	$1.22	$1.22	$0.35	$15.20	20	$104.60
6	400	(2) 3 #4/0	2 #4/0	1 #1	3"	$1.00	$1.00	$0.51	$15.20	20	$473.40
7	600	(2) 3 #400	2 #400	1 #2/0	5"	$2.00	$2.00	$0.72	$44.00	20	$1,214.40
8	600	(2) 3 #400	2 #400	1 #2/0	5"	$2.00	$2.00	$0.72	$44.00	20	$1,214.40
9	400	(2) 3 #4/0	2 #4/0	1 #1	3"	$1.00	$1.00	$0.51	$15.20	200	$1,694.00
10	550	(2) 3 #400		1 #2/0	3-1/2"	$2.00		$0.72	$19.65	25	$809.25
11	150	3 #2/0		1 #4	2"	$0.72		$0.26	$7.10	190	$1,807.85
12	200	3 #4/0		1 #4	2"	$1.00		$0.26	$7.10	160	$1,654.40
13	200	3 #4/0		1 #4	2"	$1.00		$0.26	$7.10	15	$155.10
14	200	3 #4/0		1 #4	2"	$1.00		$0.26	$7.10	20	$206.80
15	400	(2) 3 #4/0	2 #4/0	1 #1	3"	$1.00	$1.00	$0.51	$15.20	115	$2,722.05
								TOTAL PRICE			$22,823.45

Characteristics of Copper and Aluminum

CHARACTERISTICS	COPPER	ALUMINUM
Tensile strength (lb/in^2).	55,000	25,000
Tensile strength for same conductivity (lb).	55,000	40,000
Weight for same conductivity (lb).	100	48
Cross section for same conductivity (C.M.).	100	160
Specific resistance (Ω/mil ft).	10.6	17

Copper and aluminum are the two most commonly used conductors. Copper has the highest conductivity of all engineering metals. The ampacity of copper conductors is about 1.6 times that of aluminum conductors of the same size, because of the coppers higher conductivity. This means that copper wire is smaller than all equivalent ampacity aluminum cables. Smaller wire means it is easier and less expensive to install. The smaller diameter and less stiffness of the insulation allow flexibility and require less effort to bend into position during installation. Copper is hard and stronger than aluminum, which means it is more resistive to abuse during installation. Copper connections run cooler than the aluminum equivalent meaning that copper connections will have a longer life.

On a first look basis aluminum cable can be cheaper than copper cable. But the life-cycle cost, including cable life, cost of installation, materials, maintenance, repairs and possible replacement must be considered. Also the potential liability of poor performance must be taken into account. The most important aspect is “life”. The longest life has the lowest total cost and will provide the greatest value. The problem comes with predicting the life of an aluminum wire, because the predicting would be from short-term accelerated laboratory tests. The life of a copper wire is predicted through actual field performance.

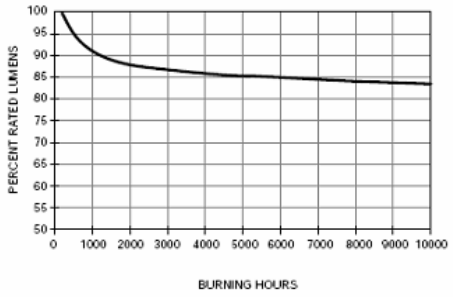
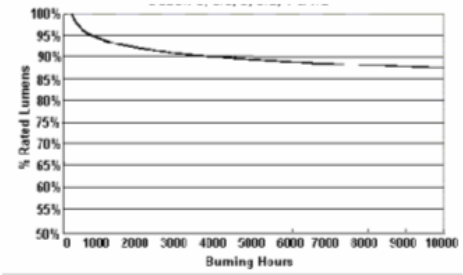
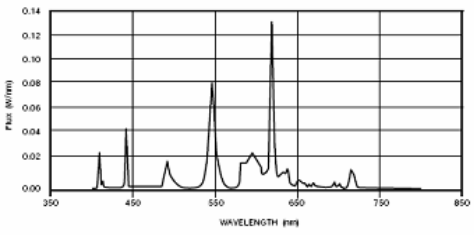
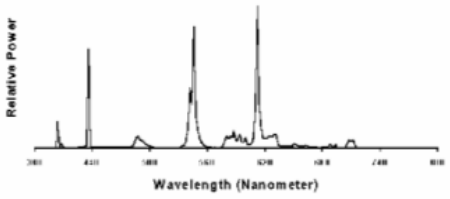
Conclusion

Commercial wiring is a long-term asset and is critical to the investment and performance that directly affects the profitability of a building. When weighing the advantages of copper and aluminum, copper is the better choice. Aluminum has a lower initial cost, but the many disadvantages outweigh the cost savings. Copper has unparalleled reliability for over a century, and should not be replaced by aluminum.

Compact Fluorescent Comparison

The following analysis is a comparison between screw base compact fluorescents and pin base compact fluorescents. The lamp and ballast cut-sheets can be found in Appendix B-2.

Statistics

CFL Comparison		
	Screw Base	**Pin Base**
Ballast	Integral	Remote
Wattage	23 W	26 W
Life	10,000 hr	12,000 hr
CRI	82	82
CCT	3000 K	3000 K
Initial Lumens at 25 C	1450	1710
Mean Lumens at 25 C	1160	1470
Maximum Overall Length	5.875"	6.5"
Lumen Maintenance Curve		
Spectral Power Distribution Curve		

As seen above, the two lamps are very similar in statistical information. The important difference in the two types of lamps is the ballast. Screw base CFLs are self ballasted, having the ballast inside the lamp. This makes it usable in retrofit applications where incandescent lamps were used. Pin base CFLs need a separate ballast to work properly. Therefore pin base CFLs only work in CFL fixtures made specifically for the pin based lamp.

Screw base compact fluorescents have been known to be finicky. This is due to their self-ballasting component. Ballast failure is a random process that can be compared with the standard failure profile for any electronic device. There is an initial small peak of failures, followed by a drop and steady increase over lamp life. The life of all electronics largely depends on the operating temperature. For every 10°C temperature rise, typical the life of the electronic is cut in half. This is why the quoted lamp life of CFLs is at 25°C. The average life of electronics is greater than this, so at this temperature most electronics will not fail due to failure of the electronics. A specific application of this is when screw base CFLs are run base-up. This results in hotter electronics and a shorter average life. Also when they are used in enclosed fixtures, the ambient temperature will rise dramatically due to the ballast.

There are also other problems with screw base compact fluorescents, noted by lighting designers in the industry. The screw base CFLs may not always fit in the luminaire. This is because the CFL is larger than a standard incandescent lamp, due to the ballast portion. Also if the lamp is viewable there may be a shadow due to the ballast compartment, depending where the base is in relation to the shade. The screw base CFL can only be run at 120 volts. Therefore it can not be used in many applications were voltages other than 120 volts are used. When re-lamping occurs, if the fixture is a screw base there is a good chance maintenance will re-lamp with an incandescent. This will drastically effect the power consumption in a building. If the luminaire is pin based, there can be no mistake of the lamp type to re-lamp with. Ecologically, when lamp life is taken into account the screw base CFL produces more waste going into the environment.

The main application for screw base compact fluorescents is for retrofit. When a screw base CFL is compared to an incandescent lamp, the CFL is much more efficient and will save the consumer money. Studies show that CFLs can save a consumer up to 66% on their energy bill and will last ten times longer than standard incandescent fixtures. In commercial applications, screw base CFLs are rarely specified in a new design. This is where the pin base CFLs are ideal. These CFLs are used when compact fluorescents are chosen for a design from the beginning.

Cost Comparison

Simple Life-Cycle Cost Estimator

Compare the life-cycle costs for two different lamps.

Enter the following information and click "calculate."
Your results will display below.

* Required

* Average number of hours on per year:	2912
* Electric cost per kilowatt hour:	0.10

Lamp 1

Lamp name:	Screw Base
* Watts (fixture watts/# of lamps):	23
* Cost (including disposal cost):	$ 10
* Life in hours:	6500
* Cost of labor to replace lamp:	$ 0
Mean lumens:	1160

Lamp 2

Lamp name:	Pin Base
* Watts (fixture watts/# of lamps):	26
* Cost (including disposal cost):	$ 3
* Life in hours:	12000
* Cost of labor to replace lamp:	$ 0
Mean lumens:	1470

CALCULATE

Results

	Lamp 1	Lamp 2
Lamp name:	Screw Base	Pin Base
Cost over lamp life:	$24.95	$34.2
Cost per 1,000 hours:	$3.84	$2.85
Cost per year:	$11.18	$8.3
Cost per million lumen hours:	$3.31	$1.94

Savings with Lamp 2: $2.88 /year

A cost comparison has been done of a screw base luminaire and lamp, versus a pin base luminaire, lamp and ballast. The luminaires are assumed to be used an average of 2912 hours per year. The electric cost per kilowatt hour is $0.10. The screw base CFL is assumed to only last 2/3 of its life.

According to the study, $2.88 per lamp will be saved per year. Now we will assume we have 25 luminaires. That is a savings of $72 per year, which is a savings of $1440 over twenty years. Yet ballast and luminaire cost have not been taken into account. Each ballast costs on average $30.00 and each luminaire will cost on average $20 more (to have pin-base). This is an initial cost of $1250. Therefore over the twenty year space, only $190 will be saved. With the pin base system, the lamp gives off more lumens, and consequently less luminaires will be needed. Or if the same number of luminaires were used, they could be dimmed to extend lamp life further.

Conclusion

In commercial applications, pin base compact fluorescents are almost always specified. This is due to reliability, voltage consideration, aesthetics, performance and cost. The screw base compact fluorescent should only be used in the application it was produced for, retrofit. The screw base CFL is a better option in many cases than an incandescent lamp. When it is used in the wrong application, its lamp life is shortened and it can be unreliable.

Mechanical Breadth

Mechanical Breadth

Research

A hydronic system is the ideal solution for the heating system in many commercial buildings, including the Woolly Mammoth Theatre. This type of heating system provides many advantages over other systems that would benefit a theatre such as yours, including comfort, efficiency (which will result in lower operating costs), versatility, noise reduction, and reliability. All of these aspects are very important in a theater environment and should be taken into account when the heating system is designed for the Woolly Mammoth Theatre.

Comfort

There are many reasons why a hydronic heating system works so well, and these are closely related to the way the system works. A building needs a heating system so the occupants are comfortable in the space year round, including the frigid winter and the milder spring and fall seasons. Occupants are uncomfortable when they are not warm enough or are in a drafty room. When it is cold outside, a building loses heat to the exterior via conduction, convection and radiation. Many factors effect how quickly a space loses heat to the outside, including the amount of insulation in the walls and ceiling, the amount of glazing, how cold it is outside compared to inside, and how strong the wind is blowing. Also, heat moves from warmer objects to colder ones. As a building loses heat to the cold air, the occupants lose heat to the building and the colder objects in it (walls, windows, etc.). The heating system in a building must replace the cold being lost to the outdoors and at the same time not be drafty or create hot/cold spots in the building. (Bell & Gossett)

A hydronic system works to create a comfortable environment according to the previous provisions. In a hydronic heating system, boiler heated water is transported through pipes quietly and efficiently to radiators, baseboard convectors or radiant floors to heat up this equipment. In each space these warm surfaces are created. The occupants, as well as surrounding cold walls and ceilings, are then sent heat by the warm objects. (Energy)

In a hydronic system, there is no air blowing around the room. Therefore there is almost no draft to make people feel uncomfortable. In addition, because a hydronic system is heating objects and people through radiating surfaces rather than hot air, the air does not dry out as much. A hydronic system makes it easier to maintain a comfortable humidity level during the winter season, and does not overheat the air. Another plus in this type of system is the thermostat can be set at a lower temperature for each zone, and the room will still feel comfortable. (Bell & Gossett)

Figure 1.0a is the ideal situation for heating in a space. The thick vertical line represents the temperature at a range of locations between the ceiling and floor. Notice from this diagram that the line is rather flat from ceiling to floor, with the temperature being slightly warmer at the floor and slightly cooler at the ceiling. This situation will optimize occupant comfort. Figure 1.0b is the diagram representing a space heated by a hydronic

system. Hydronic systems offer a very even heating of a space because they use mostly radiant heating rather than convective heating. This diagram has a temperature line very closely matched to the ideal situation diagram. (Bell & Gossett)

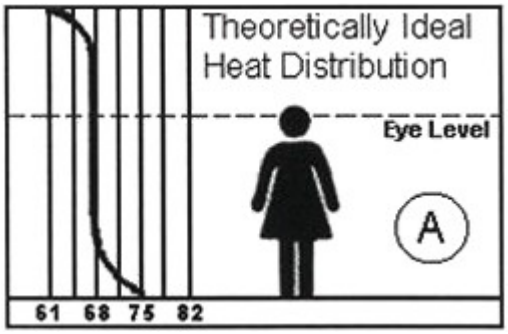


Figure 1.0a Ideal Heating System

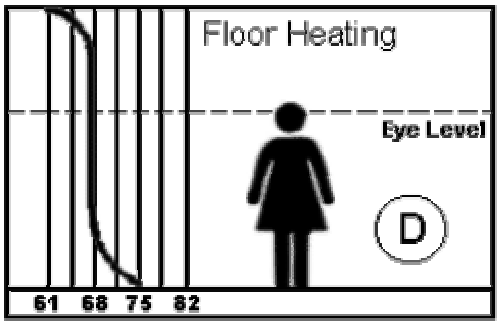


Figure 1.0b Hydronic Heating System

Efficiency

A hydronic system is more efficient than other systems. This is because water is a better carrier of heat than air. Water conducts heat twenty times faster than air. Air is a good insulator, but is not the best heating medium. A given volume of water can hold almost 3,500 times as much heat as the same volume of air, for the same temperature rise in each material. Water can move a lot of heat (BTU's) from one place, where it is produced, to another place, where it is used very efficiently. Also a hydronic system is more efficient because there is no heat loss through cracks, around doors and windows as with an air system. It is a completely sealed system. This is because the heat is mostly being radiated into the space rather than blown into it. Fewer BTU's need to be produced to keep the space feeling comfortable, because of the lower heat loss. (Bell & Gossett) A more efficient system will dramatically save on the operating cost for the heating system. Buildings utilizing hydronic heating systems have a 30% *or more* savings on heating bills. (US)

Noise

One of the most important and appealing advantages of a hydronic heating system for the Woolly Mammoth Theatre is that the system is virtually silent. The boiler is located away from the space, so there is no mechanical equipment noise. A loud heating system is detrimental to a theater. In a theater setting, the space must be completely free of extraneous noises. During a performance, patrons should not hear any mechanical equipment working. It will take away from the intimate connection the actors have with the audience during a performance. (Hurlcon)

Versatility

Hydronic systems are very versatile systems. With a hydronic system, 40,000 BTU's can be moved through a ¾" copper pipe through walls and between floors quietly and efficiently. With an air system, an 8" by 14" duct would be necessary to move that many BTU's into a space. (Bell & Gossett) Therefore, using a hydronic system is a space saver. The required ductwork of an air system is many times larger than the piping for a hydronic system. (BC) In the Woolly Mammoth Theatre, because of the unfinished concrete spaces, a small copper pipe would be much more inconspicuous than a large duct running across the ceiling. A hydronic system will not draw attention to itself and will let the architectural impression be more prominent.

A hydronic system has the flexibility to run off of many different fuel sources. It can be powered by gas, oil, electricity or even solar energy. Also, the type of fuel source used can be changed by just buying a new boiler for the new fuel source of choice. This aspect is very appealing because the lifespan of a building is a long time. Over that time period, the price or availability of a specific fuel may change. When electricity is being used, in some geographical locations special heating or off-peak rates are available to consumers. This can bring the cost equal to or less expensive than the use of other fossil fuels. (Warmly)

Zoning the building is very simple when using a hydronic system. A building can be zoned by rooms, floors or any way the owner would like. (Bell & Gossett) Each zone is thermostatically controlled by valves that regulate the flow of hot water to control the temperature in each zone. Any or all zones may operate at one time. (Stein)

Reliability

Hydronic systems are very reliable. The majority of maintenance is on the pumps and boilers. Most pumps are maintenance free, using water to lubricate the bearings. This allows for a more quiet and efficient life span. Usually pumps have an estimated life span of ten years. Boilers do require routine maintenance. Many installers of boilers will offer a yearly maintenance package, which includes cleaning and general up-keep. Different types of boilers will require different maintenance. (Warmly)

Other Factors

Hydronic systems are environmentally clean systems. The boiler heats the water, and is then circulated. Being a closed system, the radiators and natural convectors provide clean natural heat to the space. There is no forced air circulation through ducts that accumulate dust and allergens and distribute them throughout the building. (Hydronic)

Hydronic systems are also very modular and expandable. Radiators can be added as the needs of the building change. Once a boiler of the appropriate size is installed, radiators/convectors are able to be added as needed. If an extension or renovation is done on the building, the new area must be plumbed and the radiators/convectors added as

required. In an air system, an expansion is much more extensive and complicated. (Hurlcon)

Electric Heating System versus Hydronic Heating System

Existing Electric Resistive Heating System

Electric Heating Coils

Equipment	kW	Cost	
DH-1	15	$360.00	
DH-2	50	$655.00	
DH-3	20	$550.00	
DH-4	10	$510.00	
DH-5	25	$690.00	
DH-6	10	$410.00	
	130	**$3,175.00**	**Total**

Energy Consumption

Pepco Rating Periods

On-Peak Period	12:00 Noon to 8:00 PM
Int-Peak Period	8:00 AM to 12:00 Noon 8:00 PM to 12:00 Midnight
Off- Peak Period	12:00 Midnight to 8:00 AM Saturdays, Sundays and Holidays
For a 7 day week	
On- Peak	40 hr
Int- Peak	40 hr
Off- Peak	88 hr

EXISTING SYSTEM- MONTHLY ELECTRIC COSTS

		Billing Months of June- October	kW	Billing Months of November- May	kW
			130		130
GENERATION					
kW-hr Charge	On Peak	$0.08682 per kW-h	$451.46	$0.06889 per kW-h	$358.23
	Intermediate	$0.06632 per kW-h	$344.86	$0.07239 per kW-h	$376.43
	Off Peak	$0.05645 per kW-h	$645.79	$0.05757 per kW-h	$658.60
kW Charge	On Peak	$0.84507 per kW	$109.86		
	Maximum	$0.30248 per kW	$39.32	$0.30248 per kW	$39.32
TRANSMISSION					
All kW-h		$0.00111 per kW-h	$24.24	$0.00111 per kW-h	$24.24
kW Charge	On Peak	$0.71000 per kW	$92.30		
	Maximum	$0.59000 per kW	$76.70	$0.59000 per kW	$76.70
DISTRIBUTION					
Customer Charge		$20.93000 per month	$20.93	$20.90000 per month	$20.90
All kW-h		$0.01029 per kW-h	$224.73	$0.01029 per kW-h	$224.73
kW Charge	Maximum	$4.80000 per kW	$624.00	$4.80000 per kW	$624.00
Delivery Tax		$0.00770 per kW-h	$168.17	$0.00770 per kW-h	$168.17
Public Space Occupancy Surcharge		$0.00154 per kW-h	$33.63	$0.00159 per kW-h	$34.73
Reliability Energy Trust Fund		$0.00065 per kW-h	$14.20	$0.00065 per kW-h	$14.20
Gneration Procurement Credit		$0.00002 per kW-h	$0.44	$0.00002 per kW-h	$0.44
SUB-TOTAL			$2,870.64		$2,620.68
Subtracting once monthly charges			$109.86 $39.32 $92.30 $76.70 $20.93 $624.00		$0.00 $39.32 $0.00 $76.70 $20.90 $624.00
Billing for average 7 day week less demand and peak charges			$1,907.53		$1,859.76
Billing for 1 month less demand and peak charges			$7,630.11		$7,439.04
Billing for 1 month of electrical service			**$8,593.22**		**$8,199.96**
Yearly Cost of Electrical Service				**$100,365.80**	

Note: Cyan Boxes Denote Standard Monthly Charge

New Hydronic Heating System
System Assumptions

The average house of 2,000 SQ FT uses 100,000 Btu/hr. The Woolly Mammoth Theatre is 32,000 SQ FT. This is equivalent to 16 houses. Therefore the assumed heating load is 1.6 million Btu/hr or 1600 MBH.

The existing cooling system is a hydronic cooling system. The pipes for the new hydronic heating system would be the same pipes if the system is a 2 pipe system, and parallel pipes if the system is a 4 pipe system. Therefore the existing information on pressure was used. The new system is assumed to have 30' of head loss, and be two pumps in parallel.

The return and supply air temperatures were estimated. The return air is assumed to be 140 degrees F, while the supply air is assumed to be 160 degrees F. This gives a delta T of 20 degrees.

Calculations

$$Q = \dot{m} * C_p \Delta T$$
$$\dot{m} = Q / (C_p \Delta T)$$

$$C_p = 1.0 \text{ Btu} / (\text{lbm}°\text{F})$$
$$\Delta T = 20° \text{ F}$$

$$\dot{m} = (1{,}600{,}000 \text{ Btu/hr}) / ((1.0 \text{ Btu/lbm}°\text{F})*(20° \text{ F}))$$
$$\dot{m} = 80{,}000 \text{ lb/hr} = 160 \text{ gpm}$$

Hydronic Heating Equipment Sizing and Cost

The energy use for the coil was assumed to be 65,000 Btus. All equipment cut-sheets can be found in Appendix C. All equipment price data from Costworks 2005. Assumptions on the equipment selection can be found in Appendix C.

Load: 1.6 million Btu/hr or 1600 MBH
Flow Rate: 160 gpm
Pump Head: 30'

New Hydronic System

Equipment	Btu	Cost	
Boiler	2,000,000	$12,300.00	
Coils	60,000	$425.00	
Pumps (2)	100,416	1200	
	2,160,416	**$13,925.00**	**Total**

MODIFIED SYSTEM- MONTHLY NATURAL GAS COSTS			
			Therms (100,000 Btu)
			21.60
SYSTEM			
Heating and/or Cooling	$17.00000	per month	$17.00
Non-heating and Non-cooling	$11.75000	per month	$11.75
MONTHLY			
January	$1.0957	per therm	$23.67
February	$1.0957	per therm	$23.67
March	$0.9833	per therm	$21.24
April	$0.9833	per therm	$21.24
May	$0.9390	per therm	$20.28
June	$0.7543	per therm	$16.29
July	$0.7543	per therm	$16.29
August	$0.7331	per therm	$15.83
September	$0.8568	per therm	$18.51
October	$0.8603	per therm	$18.58
November	$0.9512	per therm	$20.55
December	$1.0957	per therm	$23.67
DISTRIBUTION			
First 125 therms	$0.30930	per therm	$6.68
Next 875 therms	$0.25030	per therm	$0.00
Over 1,000 therms	$0.19030	per therm	$0.00
SUBTOTAL MONTHLY COSTS			$35.43
Monthly Costs Incurred Over a Year			$425.17
Yearly Cost of Electrical Service			**$664.99**

Initial Cost Difference $10,750.00
Energy Cost Difference $99700.00
Payback Period 0.12 of a year = about 6 weeks

Conclusion

The hydronic heating system is a more efficient system than the electric resistive heating system. It also has many other advantages including comfort, versatility and reliability. If the Woolly Mammoth Theatre were to install this type of system, the payback would be a short time of about 6 weeks. This is a very good payback period, showing that the system is a better choice than electric resistive heating.

Acoustical Breadth

Acoustical Breadth Study

The Woolly Mammoth Theatre is a live performance theatre. It is about 6000 SQ FT with 265 seats. The seating includes 187 orchestra seats and 78 balcony seats. Acoustics play a very important role in the function of the theatre. The theatre has been designed as a courtyard configuration to connect the audience with the actors in a close setting. The theatre company's goal is to produce live productions for the community. They value the connection between the actor and the audience, and therefore expect the theatre to be a very intimate atmosphere. Their goal is to produce intimate performances where the audience will forget they are in a large public atmosphere.

Reverberation time is defined as the time required for sound to decay 60 dB after the source has stopped. The recommended reverberation time for small theaters is between 1.2 to 1.4 seconds. Yet because of the theatre company's goal, the theater will be designed to have a reverberation time between small theaters and intimate drama. The reverberation time for intimate drama is between 0.9 and 1.1. Therefore the goal reverberation time for the Woolly Mammoth Theatre is 1.15 seconds.

Many different types of sound absorbing materials can be used to control reverberation to the ideal level. The larger a volume is, the longer the reverberation time will be. This is because sounds waves will have travel farther to hit room surfaces, than in a small room. Sound absorption is a great asset because the sound can me made to see like it is coming directly from the actual source, rather from all around the room.

The Sabine formula for reverberation will be used in this analysis:

T = 0.05 V/a
T = reverberation time (s)
V = room volume (CU FT)
a = total SQ FT of room absorption (sabins)

The Existing Design
Materials

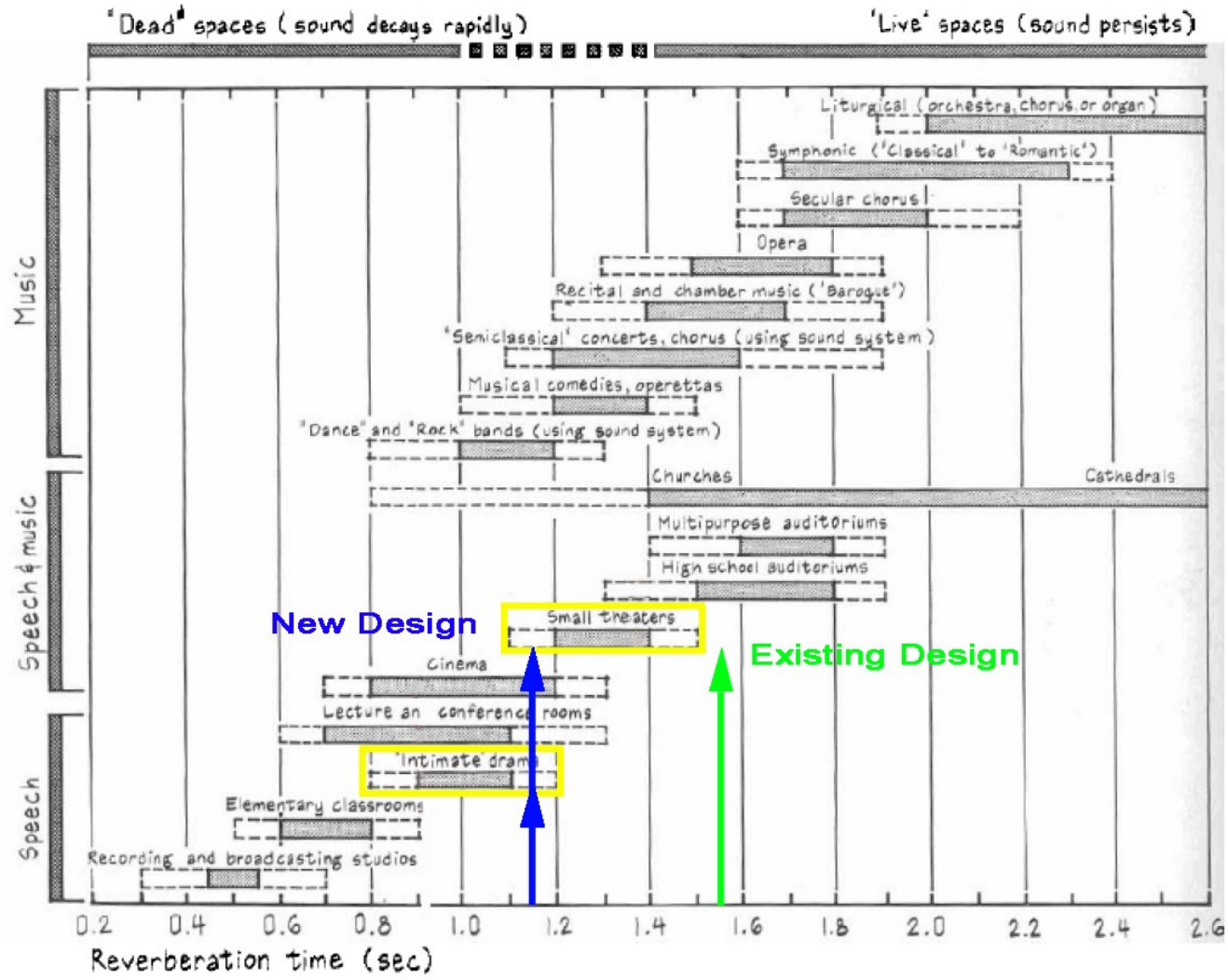
The existing design has many materials to be taken into account when doing a reverberation time calculation. The floors in the theatre are concrete in the seating areas, and the rest is heavy carpet on concrete. The stage is wood. There are many different wall materials throughout the space. The side walls are concrete block wall. The back wall of the first floor is a gypsum board wall, and the back wall of the balcony level is perforated metal acoustical wall baffles, with a control room window. The ceiling in the theatre is a concrete slab ceiling. The balcony railings and catwalks must also be taken into account. The railings of the balconies are wood paneled, and the catwalks are metal.

Acoustic Calculations

Sound Absorption Data For Materials														
Surface Type	Material Description	Surface Area (SF)	125 Hertz		250 Hertz		500 Hertz		1000 Hertz		2000 Hertz		4000 Hertz	
			alpha	sabins	alpha	sabins	alpha	sabins	alpha	sabins	alpha	sabins	alpha	sabins
Floor	Concrete slab floor-clear satin finish	1105	0.010	11.05	0.010	11.05	0.015	16.58	0.020	22.10	0.020	22.10	0.020	22.10
	Wood	921	0.150	138.15	0.110	101.31	0.100	92.10	0.070	64.47	0.060	55.26	0.070	64.47
	Heavy carpet on concrete	2089	0.020	41.78	0.060	125.34	0.140	292.46	0.370	772.93	0.600	1253.40	0.650	1357.85
Walls	Painted gypsum board	900	0.100	90.00	0.080	72.00	0.050	45.00	0.030	27.00	0.030	27.00	0.030	27.00
	Concrete block wall painted	3000	0.100	300.00	0.050	150.00	0.060	180.00	0.070	210.00	0.090	270.00	0.080	240.00
	Control room window	110	0.180	19.80	0.060	6.60	0.040	4.40	0.030	3.30	0.020	2.20	0.020	2.20
	Satin silver perforated metal accoustical wall baffles	682	0.700	477.40	0.860	586.52	0.740	504.68	0.880	600.16	0.950	647.90	0.860	586.52
Balcony Railing Fronts	Wood	286	0.150	42.90	0.110	31.46	0.100	28.60	0.070	20.02	0.060	17.16	0.070	20.02
Catwalks	Metal	400	0.050	20.00	0.100	40.00	0.100	40.00	0.100	40.00	0.070	28.00	0.020	8.00
Ceiling	Concrete slab ceiling-clear finish	2849	0.010	28.49	0.010	28.49	0.015	42.74	0.020	56.98	0.020	56.98	0.020	56.98
Audience	Audience in upholstered seats, per SF of floor area	1865	0.600	1119.00	0.740	1380.10	0.880	1641.20	0.960	1790.40	0.930	1734.45	0.850	1585.25
			Total Sabins	**2289**		**2533**		**2888**		**3607**		**4114**		**3970**

Reverberation Time Calculation						
	125 Hertz	250 Hertz	500 Hertz	1000 Hertz	2000 Hertz	4000 Hertz
Alpha Total Absorption (Sabins)	2288	2533	2888	3607	4114	3970
V Volume (CU FT)	100000	100000	100000	100000	100000	100000
T Reverberation Time (sec)	**2.18**	**1.97**	**1.73**	**1.39**	**1.22**	**1.26**

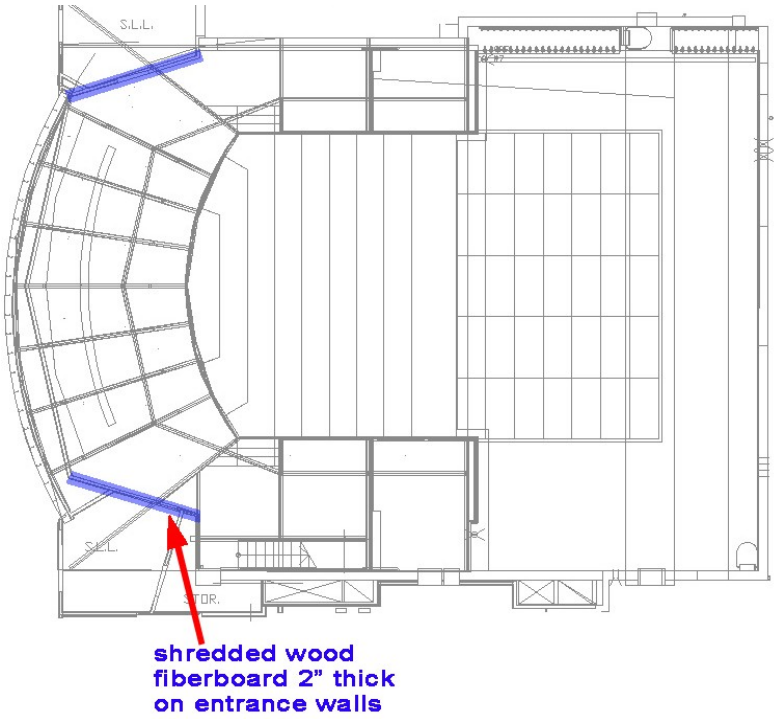
The average reverberation time between 500 and 1000 Hertz in the existing theater is 1.56 seconds. This is above the ideal reverberation time of the theater. Therefore, added absorptive material should be used in the space.


'Dead' spaces (sound decays rapidly)
'Live' spaces (sound persists)
Liturgical (orchestra, chorus or organ)
Symphonic ('Classical' to 'Romantic')
Secular chorus
Opera
Recital and chamber music ('Baroque')
'Semiclassical' concerts, chorus (using sound system)
Musical comedies, operettas
"Dance" and "Rock" bands (using sound system)
Churches
Cathedrals
Multipurpose auditoriums
High school auditoriums
Small theaters
Cinema
Lecture an conference rooms
'Intimate' drama
Elementary classrooms
Recording and broadcasting studios
Music
Speech & music
Speech
New Design
Existing Design
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
Reverberation time (sec)

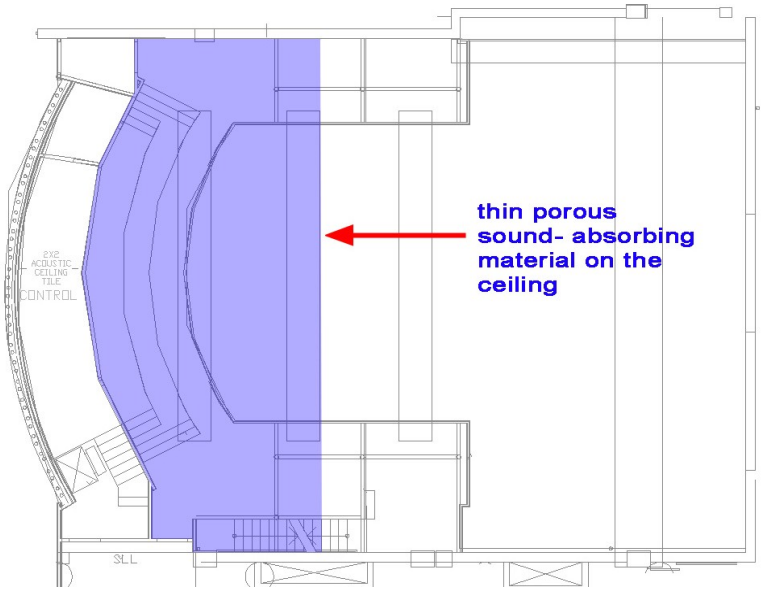
The New Design
Materials

The new acoustic design for the theatre has incorporated two new absorbing acoustical materials. In the new acoustic design for the theatre, two new sound-absorbing materials were incorporated to the existing design. On the orchestra level, the north and south entrance walls were covered with 2" thick fiberboard. Also a thin porous sound absorbing material was added to the back half of the theater's ceiling.

Orchestra Level Plan



Balcony Level



Sound Absorption Data For New Design Materials														
Surface Type	Material Description	Surface Area (SF)	125 Hertz		250 Hertz		500 Hertz		1000 Hertz		2000 Hertz		4000 Hertz	
			alpha	sabins	alpha	sabins	alpha	sabins	alpha	sabins	alpha	sabins	alpha	sabins
Floor	Concrete slab floor-clear satin finish	1105	0.010	11.05	0.010	11.05	0.015	16.58	0.020	22.10	0.020	22.10	0.020	22.10
	Wood	921	0.150	138.15	0.110	101.31	0.100	92.10	0.070	64.47	0.060	55.26	0.070	64.47
	Heavy carpet on concrete	2089	0.020	41.78	0.060	125.34	0.140	292.46	0.370	772.93	0.600	1253.40	0.650	1357.85
Walls	Painted gypsum board	900	0.100	90.00	0.080	72.00	0.050	45.00	0.030	27.00	0.030	27.00	0.030	27.00
	Concrete block wall painted	3000	0.100	300.00	0.050	150.00	0.060	180.00	0.070	210.00	0.090	270.00	0.080	240.00
	Control room window	110	0.180	19.80	0.060	6.60	0.040	4.40	0.030	3.30	0.020	2.20	0.020	2.20
	Satin silver perforated metal accoustical wall baffles	682	0.700	477.40	0.860	586.52	0.740	504.68	0.880	600.16	0.950	647.90	0.860	586.52
	Shredded Wood Fiberboard, 2in thick on concrete	340	0.150	51.00	0.260	88.40	0.620	210.80	0.940	319.60	0.640	217.60	0.920	312.80
Balcony Railing Fronts	Wood	286	0.150	42.90	0.110	31.46	0.100	28.60	0.070	20.02	0.060	17.16	0.070	20.02
Catwalks	Metal	400	0.050	20.00	0.100	40.00	0.100	40.00	0.100	40.00	0.070	28.00	0.020	8.00
Ceiling	Thin porous sound abosorbing material 3/4" thick	1100	0.10	110.00	0.60	660.00	0.80	880.00	0.82	902.00	0.78	858.00	0.60	660.00
	Concrete slab ceiling clear finish	1749	0.010	17.49	0.010	17.49	0.015	26.24	0.020	34.98	0.020	34.98	0.020	34.98
Audience	Audience in upholstered seats, per SF of floor area	1865	0.600	1119.00	0.740	1380.10	0.880	1641.20	0.960	1790.40	0.930	1734.45	0.850	1585.25
			Total Sabins	2439		3270		3962		4807		5168		4921

Reverberation Time Calculation						
	125 Hertz	250 Hertz	500 Hertz	1000 Hertz	2000 Hertz	4000 Hertz
Alpha Total Absorption (Sabins)	2439	3270	3962	4807	5168	4921
V Volume (CU FT)	100000	100000	100000	100000	100000	100000
T Reverberation Time (sec)	**2.05**	**1.53**	**1.26**	**1.04**	**0.97**	**1.02**

The average reverberation time between 500 and 1000 Hertz of the new design is 1.15 seconds. This is the ideal reverberation time for the Woolly Mammoth Theatre.

Conclusion

The primary concern in the theater is to have an ideal reverberation time, while keeping the aesthetic concept of an “unfinished” edgy space. The absorbent material was added to the ceiling, which is not in the main line of view in the theatre. Fiberboard was also added on the entrance walls in the back of the first floor. The absorbent materials were placed very carefully to not disturb the architectural concept of the theatre. The ceiling and the back entrance walls are inconspicuous places to add absorbent material. The added material lowered the reverberation time the ideal time of 1.15. This reverberation time falls in the high end of the RT for intimate drama and on the low end of the RT for small theatres.

Final Conclusions

The Woolly Mammoth was a very exciting space to analyze. Even though it was a relatively small building, each space was complex, well thought out and had many distinctive architectural elements. The unique client in this process was a key element as well. The Woolly Mammoth Theatre Company had a distinct vision for their first "home". This had to be kept in mind when designing the theatre.

In my lighting redesign, I have taken the new edgy and provocative personality of the theatre company and put it in the lighting design. Color, texture, and technology were used to make the spaces come alive. The unfinished industrial finishes now glow with color or are highlighted to sparkle. The concept fits perfectly into the architectural theme of a "transparent theatrical laboratory". The spaces have a high-tech, flashy, and dynamic feel to them. The new lighting design was then electrically redesigned. The lobby and canopy are now easily controlled by a dimming system. This will give the theatre company the flexibility and aesthetic quality they want. The lighting electrical system for the Woolly Mammoth Theatre enhances the space to a higher level of quality and aesthetics.

From this analysis, I have learned a great deal. I now understand more about the industry and how the process of designing and constructing a building comes together. Also the fact that each discipline's design affects other disciplines immensely. A design can't just be the right lighting, electrical or mechanical design; it must fit in with all of the building systems. All disciplines are working toward a similar end goal, to make the best building possible.

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