



**WOOLLY MAMMOTH  
THEATRE  
WASHINGTON DC**

**KATE FEATO  
SENIOR THESIS 2007  
PENNSYLVANIA STATE UNIVERSITY  
ARCHITECTURAL ENGINEERING  
LIGHTING/ELECTRICAL OPTION  
APRIL 18, 2007**



**Location:** Washington DC  
**Owner:** The Woolly Mammoth  
Theatre Company  
**Architect:** McInturff Architects  
**Size:** 31,600 SF  
**Total Stories:** 3  
**Cost:** \$8,000,000



Over view

Woolly Mammoth Theatre

## Lighting Depth

Canopy

Lobby

Theatre

Office

## Electrical Depth

Redesign of 4 spaces

CFL Comparison

CU to AL Analysis

## Acoustical Breadth

*Mechanical Breadth*

Conclusion

Outline

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Woolly Mammoth Theatre

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Woolly Mammoth Theatre

To C o m e A L I V E

Energetic

Hi-tech

Color

Awake

Vibrant

Dynamic

Flashy

Concept

Woolly Mammoth Theatre

## Lighting Depth

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## Acoustical Breadth

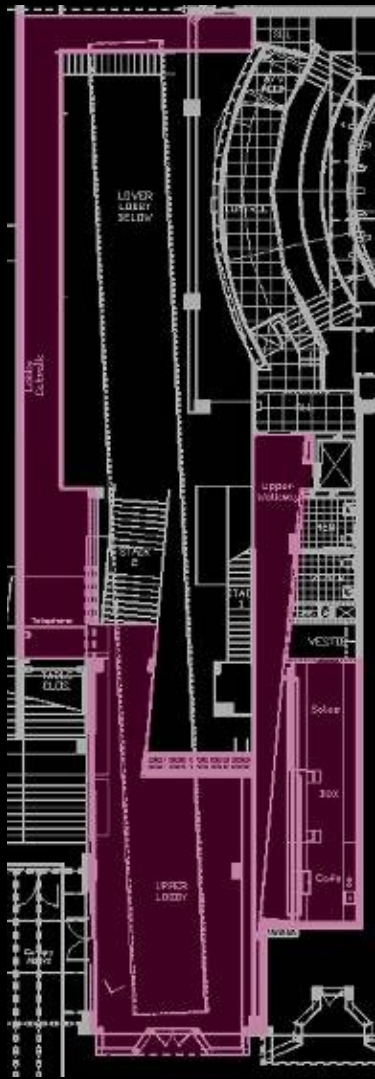
*Mechanical Breadth*

Conclusion

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Woolly Mammoth Theatre



Lobby

Overview

# Woolly Mammoth Theatre

## Design Goals:

- Sparkle
- Color
- Rhythm- Movement and Flow
- Accent Architectural Elements
- Flexible



## Design Criteria

- Accommodate relevant tasks
- 15-20 horizontal fc illuminance
- High quality color rendering
- Power allowance- 3.3 W/SF for a lobby of a performing arts building

Lobby

Design Goals  
and Criteria

Woolly Mammoth Theatre



track to accent  
catwalk art

LED color changing  
floodlight to light 22'  
high polycarbonate  
wall

tight beam accent  
to be on a chase  
sequence

track to accent  
stairs and balcony

track to accent  
ticket booth art

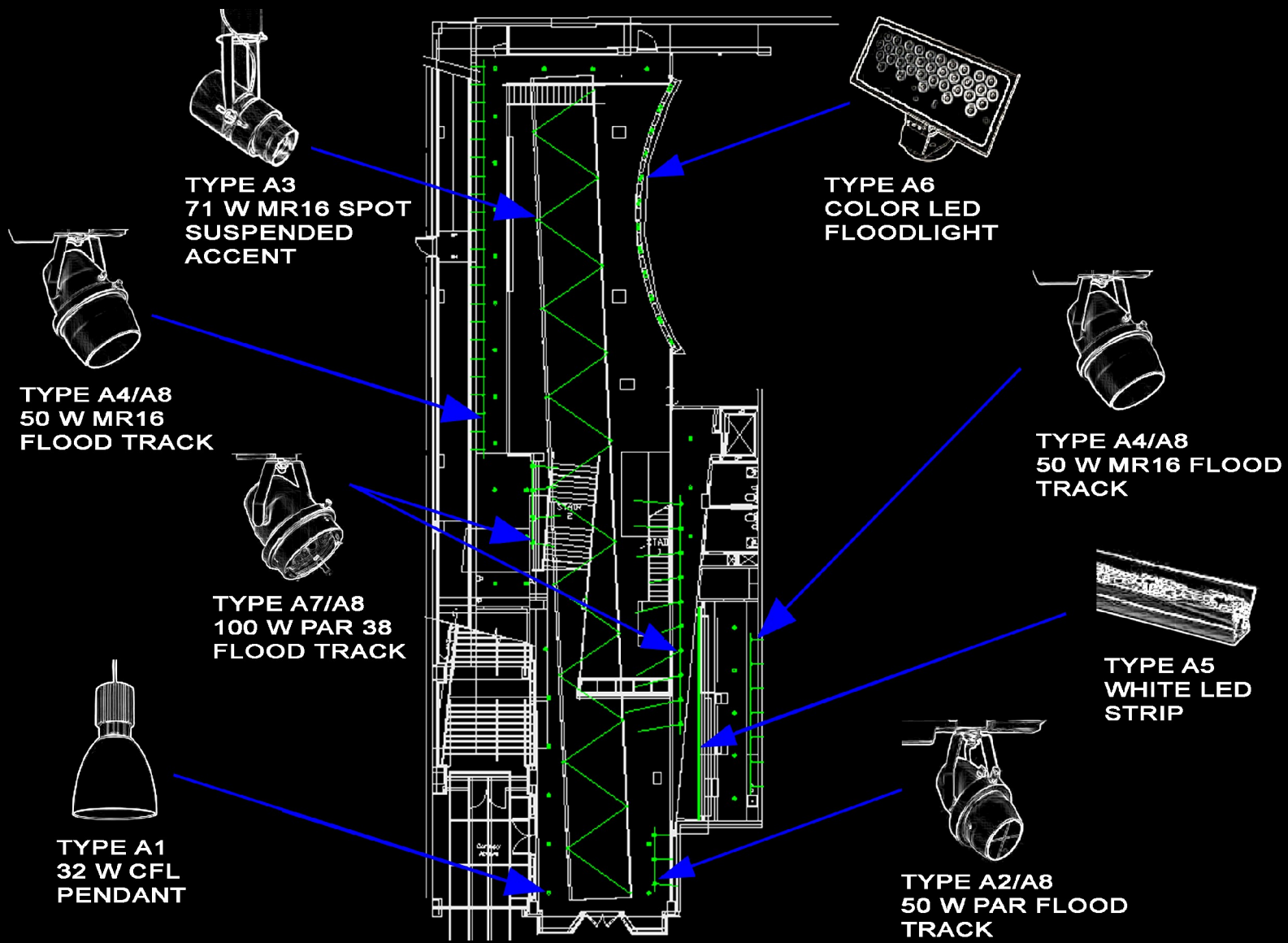
LED strip to wash  
down front of  
ticket booth to  
highlight wood  
paneling



Lobby

Schematic  
Design

Woolly Mammoth Theatre



Lobby

Second Floor  
Lighting Plan

Woolly Mammoth Theatre



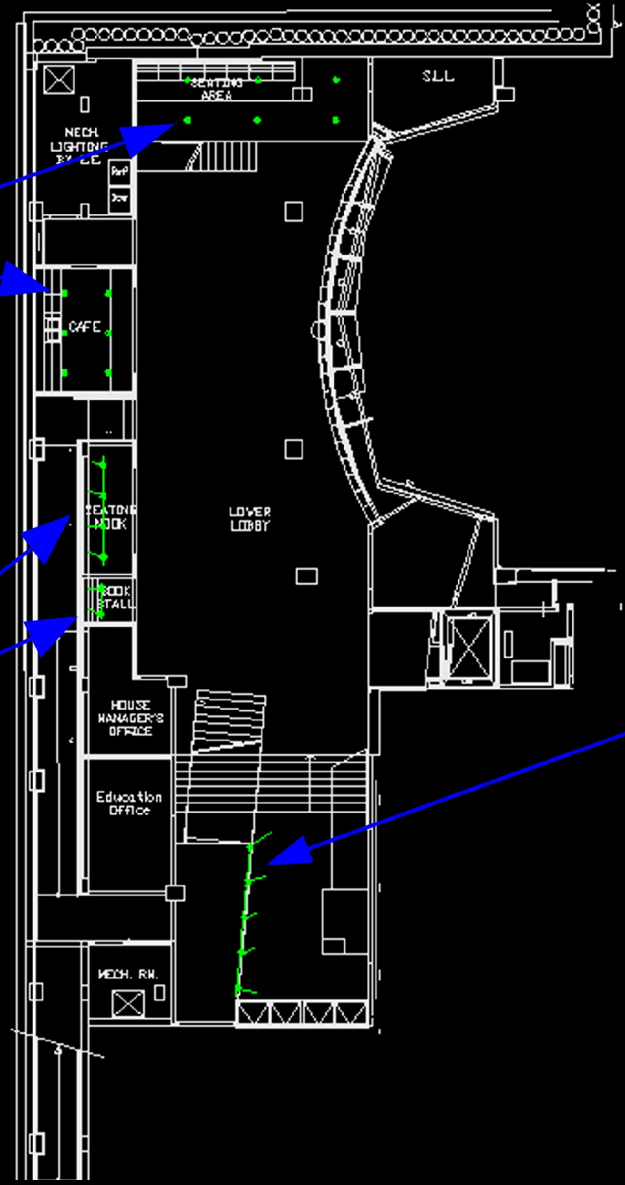
TYPE A1  
32 W CFL  
PENDANT



TYPE A4/A8  
50 W PAR TRACK



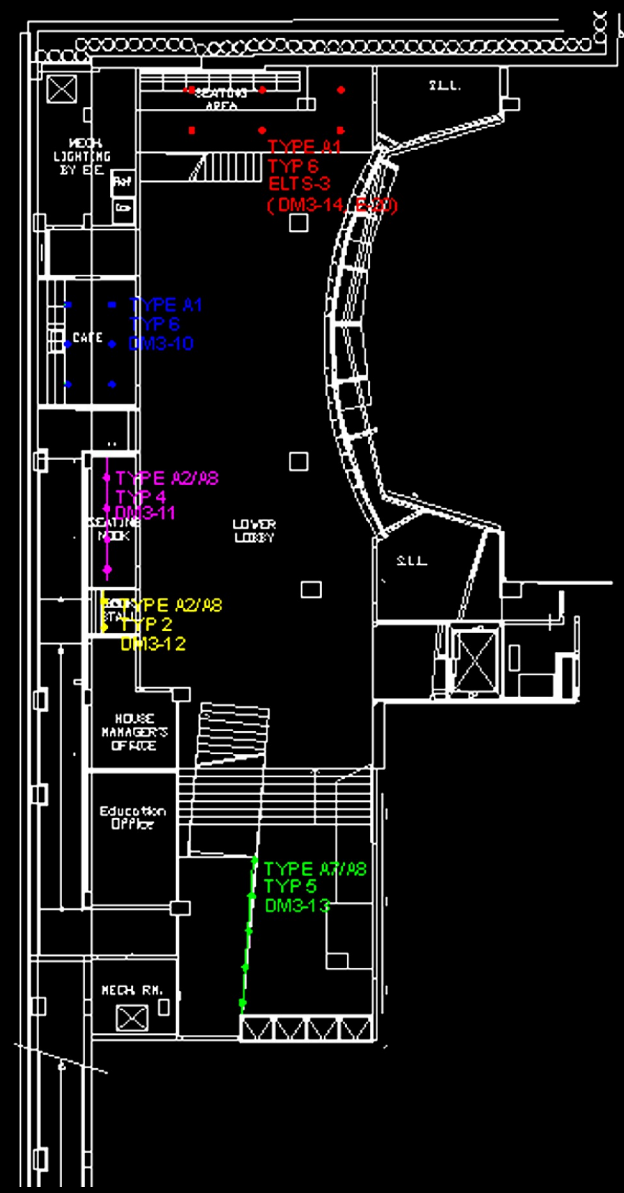
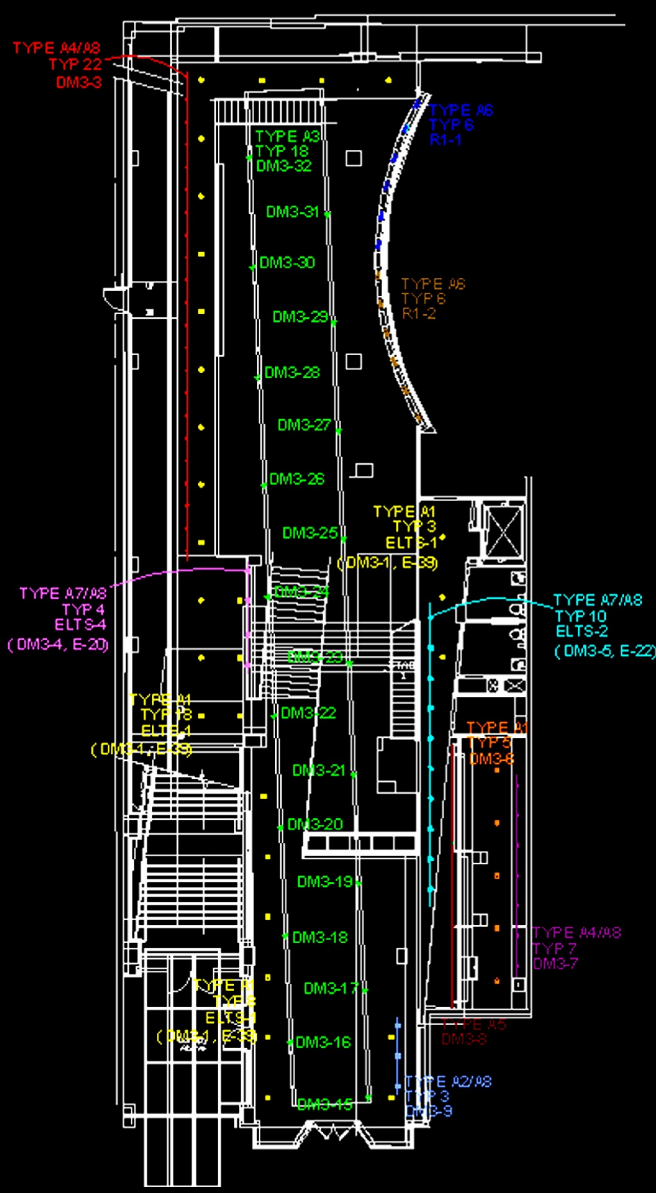
TYPE A7/A8  
100 W PAR 38  
TRACK



Lobby

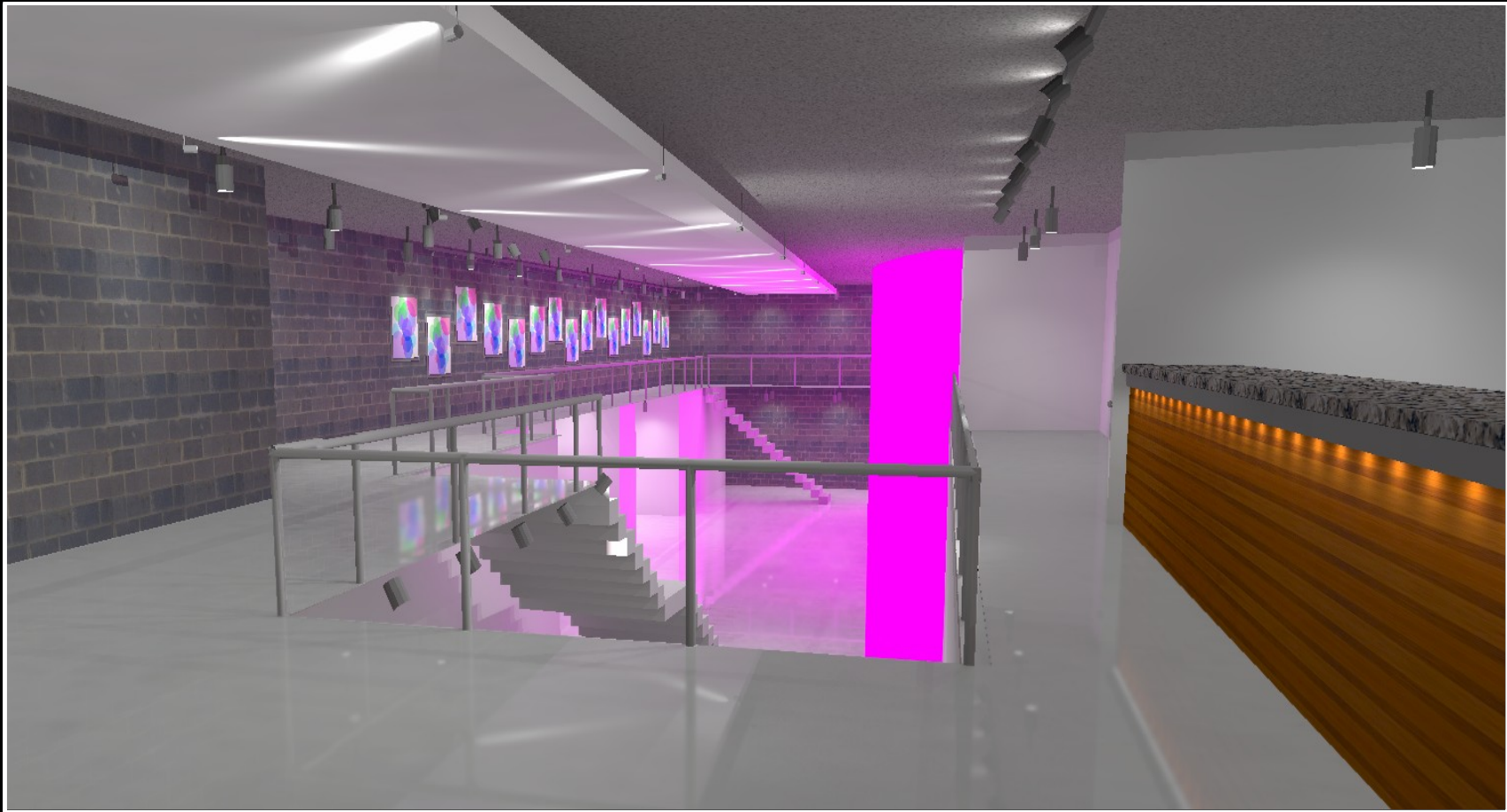
First Floor  
Lighting Plan

Woolly Mammoth Theatre



Lobby  
Control  
Plans

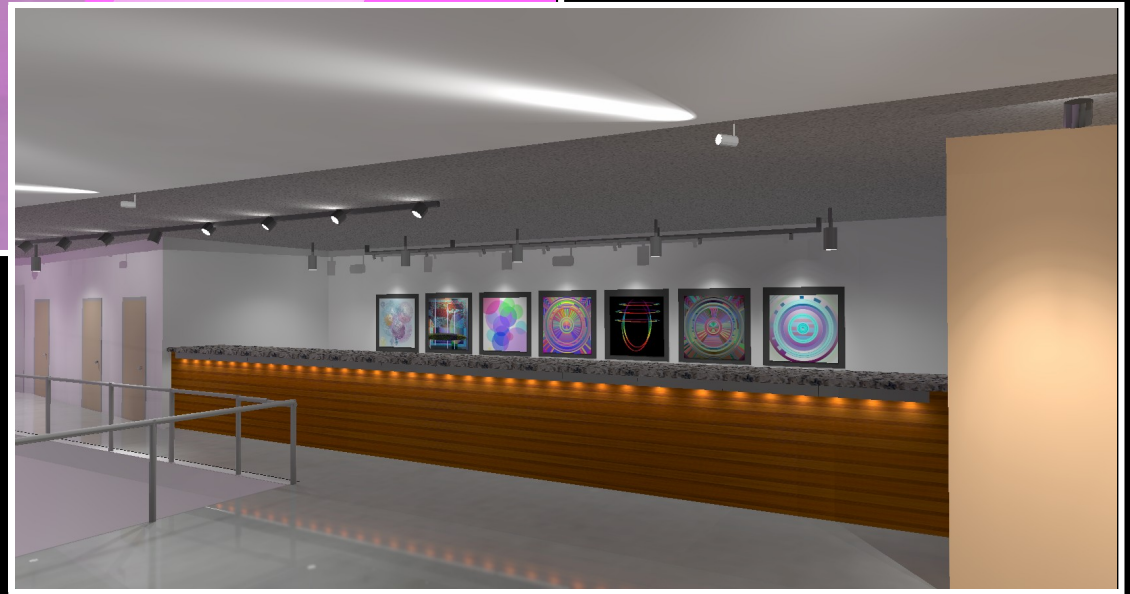
# Woolly Mammoth Theatre



Lobby

Renderings

Woolly Mammoth Theatre



Lobby

Renderings

Woolly Mammoth Theatre

The average illuminance of the floor on both levels is between 15 and 20 fc. ✓

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 power density is 1.49 W/SF, which is less than the allowed 3.3 W/SF. ✓

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

- Color ✓
- Sparkle ✓
- Movement and Flow ✓
- Accent Architecture ✓

Lobby

Conclusions

Woolly Mammoth Theatre

# Lighting Depth

Canopy

Lobby

Theatre

Office

## Electrical Depth

Redesign of 4 spaces

CFL Comparison

CU to AL Analysis

## Acoustical Breadth

*Mechanical Breadth*

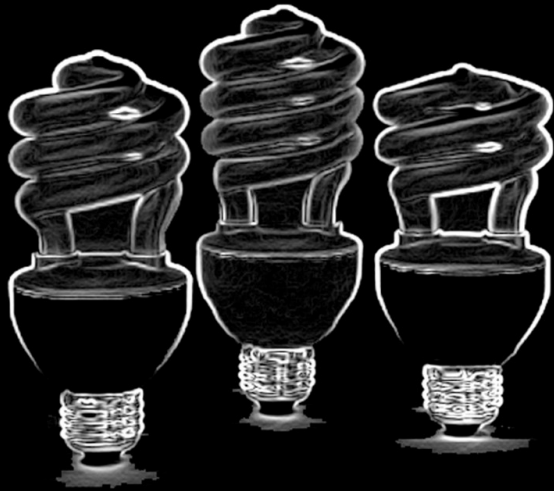
Conclusion

Outline

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Woolly Mammoth Theatre





**Screw Base**

**V  
e  
r  
s  
u  
s**

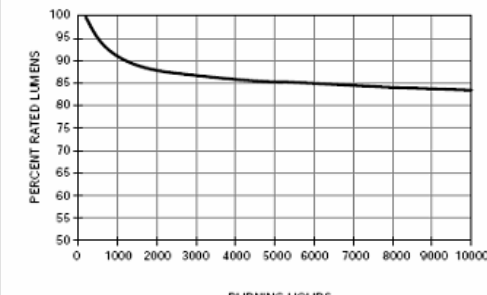
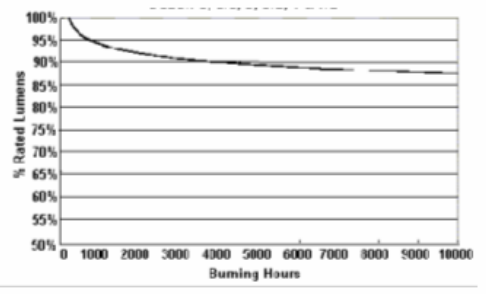
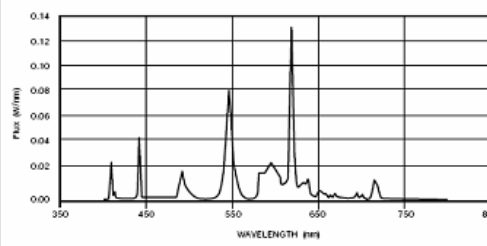
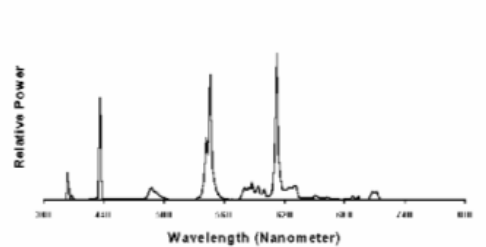


**Pin Base**

Electrical

CFL  
Comparison

Woolly Mammoth Theatre

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	 <p>A line graph showing the percentage of rated lumens over 10,000 burning hours for a screw base CFL. The y-axis is labeled 'PERCENT RATED LUMENS' and ranges from 50 to 100. The x-axis is labeled 'BURNING HOURS' and ranges from 0 to 10,000. The curve starts at 100% at 0 hours and drops to approximately 85% at 10,000 hours.</p>	 <p>A line graph showing the percentage of rated lumens over 10,000 burning hours for a pin base CFL. The y-axis is labeled '% Rated Lumens' and ranges from 50 to 100. The x-axis is labeled 'Burning Hours' and ranges from 0 to 10,000. The curve starts at 100% at 0 hours and drops to approximately 88% at 10,000 hours.</p>
Spectral Power Distribution Curve	 <p>A spectral power distribution graph for a screw base CFL. The y-axis is labeled 'Power (0/1mm)' and ranges from 0.00 to 0.14. The x-axis is labeled 'WAVELENGTH (nm)' and ranges from 350 to 850. The graph shows several sharp peaks, with the highest peak at approximately 580 nm.</p>	 <p>A spectral power distribution graph for a pin base CFL. The y-axis is labeled 'Relative Power' and ranges from 0.00 to 0.14. The x-axis is labeled 'Wavelength (Nanometer)' and ranges from 350 to 850. The graph shows several sharp peaks, with the highest peak at approximately 580 nm.</p>

Electrical

CFL Data  
Comparison

Woolly Mammoth Theatre

## Disadvantages of Screw Base

- Life Span
- Size
- Appearance
- Voltage
- Maintenance
- Power Density



Electrical

CFL  
Comparison

Woolly Mammoth Theatre

## Lamp

- \$2.88 saved per lamp x 25 fixtures = \$72 per year
- \$1440 saved over 20 years with pin based

## Extra Cost With Pin Base

- \$30 ballast and \$20 extra fixture cost
- Initial Cost \$1250

\$190 savings over 20 years

**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:

\* Electric cost per kilowatt hour:

**Lamp 1**

Lamp name:

\* Watts (fixture watts/# of lamps):

\* Cost (including disposal cost):

\* Life in hours:

\* Cost of labor to replace lamp:

Mean lumens:

**Lamp 2**

Lamp name:

\* Watts (fixture watts/# of lamps):

\* Cost (including disposal cost):

\* Life in hours:

\* Cost of labor to replace lamp:

Mean lumens:

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**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

Acoustical

CFL Cost  
Comparison

Woolly Mammoth Theatre

The disadvantages of specifying a screw base CFL in a commercial new design outweigh the advantages.

Screw base CFLs are good for retrofit applications where incandescents were used.

Electrical

Conclusions

Woolly Mammoth Theatre

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Woolly Mammoth Theatre

## Existing Conditions:

- 6000 SF
- 265 seats- 187 orchestra, 78 balcony
- Courtyard configuration



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)

Acoustical

Overview

Woolly Mammoth Theatre

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	1104.6	0.010	11.05	0.010	11.05	0.015	16.57	0.020	22.09	0.020	22.09	0.020	22.09
	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	285.5	0.150	42.83	0.110	31.41	0.100	28.55	0.070	19.99	0.060	17.13	0.070	19.99
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				2288		2533		2888		3607		4114		3970

Average RT between 500 Hz and 1000 HZ is 1.56 seconds.

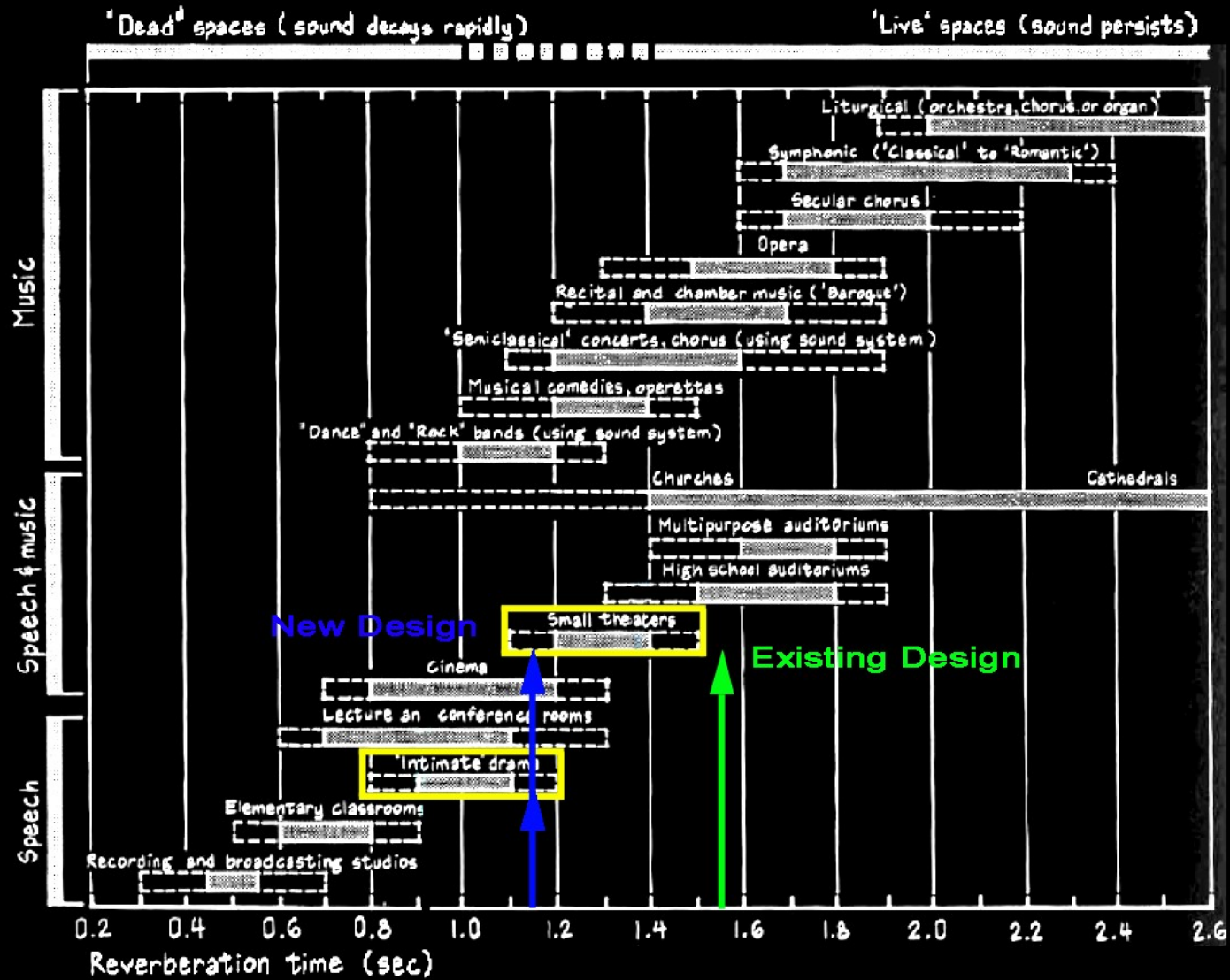
Reverberation Time Calculation						
	125 Hertz	250 He	500 He	1000 Hertz	2000 Hertz	4000 He
Alpha Total Absorption (Sabins)	2288	2533	2888	3607	4114	3970
V Volume (CU FT)	100000	100000	100000	100000	100000	100000
T Reverberation Time (sec)	2.18	1.97	1.73	1.39	1.22	1.26

Acoustical

Existing Condition Calculations

Woolly Mammoth Theatre

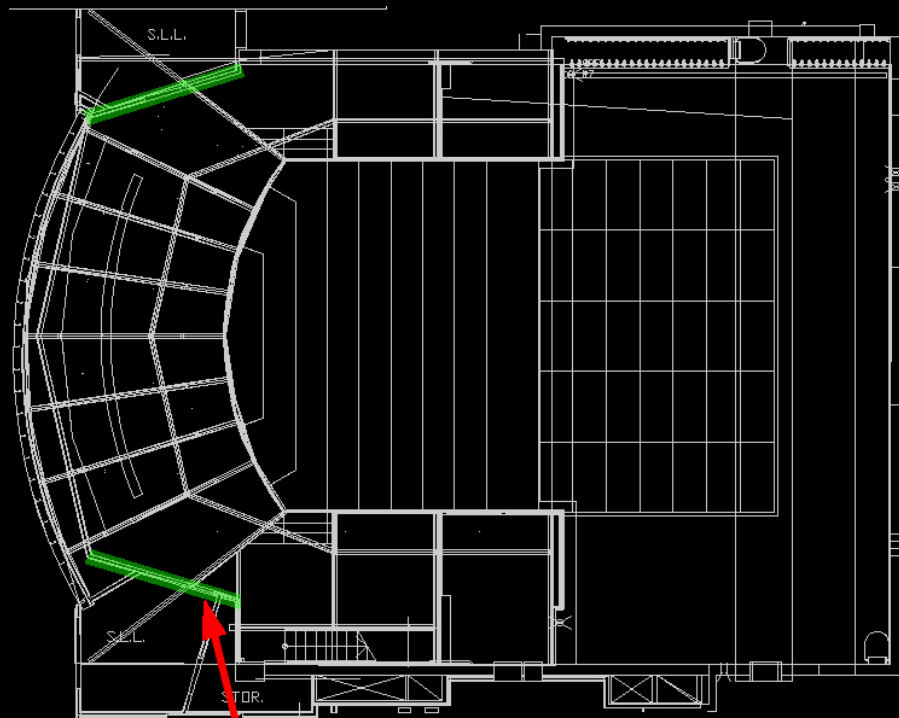




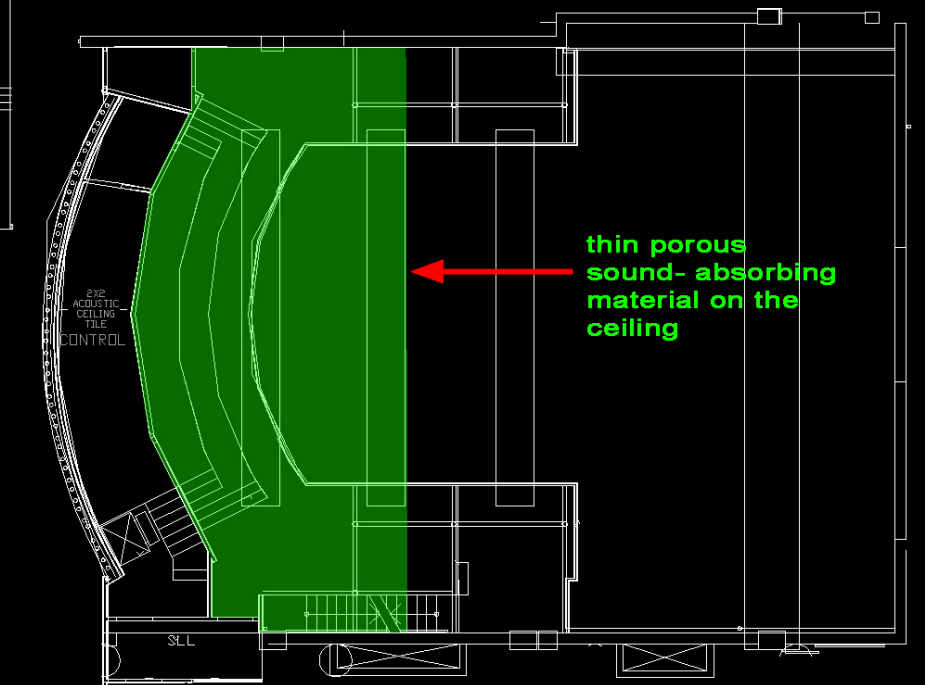
Acoustical

Reverberation  
times

Woolly Mammoth Theatre



shredded wood  
fiberboard 2" thick  
on entrance walls



thin porous  
sound- absorbing  
material on the  
ceiling

Acoustical

New Design  
Plans

Woolly Mammoth Theatre

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 absorbing 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
			<b>Total Sabins</b>	<b>2439</b>		<b>3270</b>		<b>3962</b>		<b>4807</b>		<b>5168</b>		<b>4921</b>

Average RT between 500 Hz and 1000 Hz is 1.15 seconds.

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

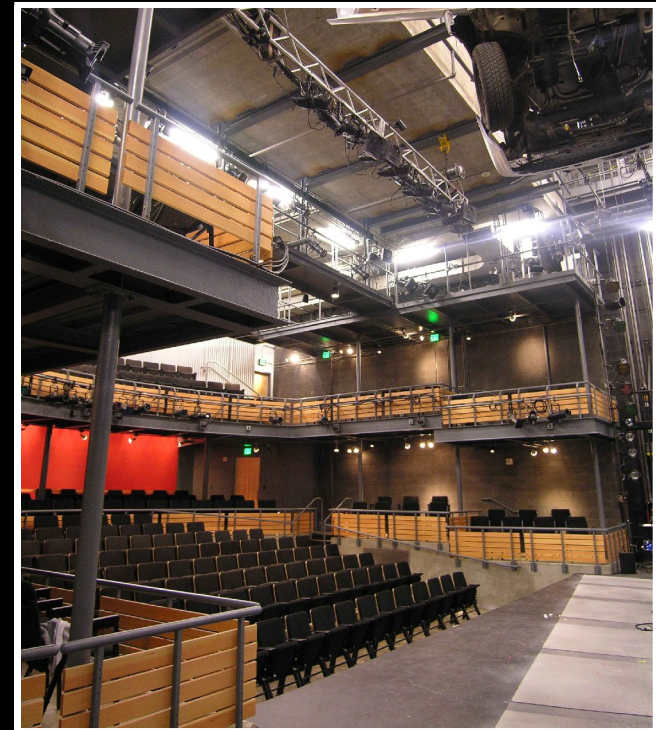
Acoustical

New Design Calculations

Woolly Mammoth Theatre

By adding absorptive material, the theatre's reverberation time decreased to an ideal RT.

The absorptive material in the theatre was added without changing the architecture or look of the space.



Acoustical

Conclusions

Woolly Mammoth Theatre

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Woolly Mammoth Theatre

## Lighting Depth

- implemented a flexible system in controls and fixture types
- provided a lighting design that incorporated the architecture of the building

## Electrical Depth

- determined pin base CFLs are better for specifying in a commercial application
- determined screw base CFLs are a more efficient source than incandescents, and should be used in retrofit applications

## Acoustical Breadth

- provided a solution to lower the reverberation time to make it more ideal for the Woolly Mammoth Theatre Company

Conclusion

Lighting Depth

Woolly Mammoth Theatre

Thank you to....

my friends and family

my fellow AE classmates

the faculty of the AE department

Conclusion

Acknowledgments

Woolly Mammoth Theatre



Conclusion

Comments and  
Questions

Woolly Mammoth Theatre



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