

Massachusetts

Architectural Engineering
Senior Thesis Project

Public Library

4.15.09

Lighting and Electrical

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Advisors: Dr. Mistrick and
Prof. Dannerth

Massachusetts Public Library

The Massachusetts Public Library was originally opened in 1889. In 1982, the building was listed as an **important landmark** on the National Register of Historic Places. Today it is being renovated as a **state-of-the-art public library facility**.



General Building Information

Size-

35,000 SF Renovation
70,000 SF Expansion
105,000 SF Total

Stories-

3 above grade (6 Total)

Building Occupant-

General Public

Dates of Construction-

January 2007 – April 2009

Scope of Work

Electrical Depth Study-
Energy analysis of transformers
Copper vs. Aluminum Feeders

Lighting Depth Study-
Redesign of lighting in four
spaces

Daylight Depth Study-
Analysis of energy savings with
dimming and on-off switching

Mechanical Breadth Study-
Calculation of cooling loads

Acoustical Breadth Study-
Reverberation time analysis



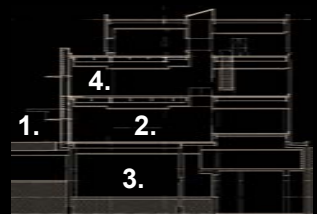
Massachusetts Public Library

1. Exterior Space-

2. Entry Lobby-

3. Meeting Room-

4. Stacks and Seating Area-



Electrical Depth

Energy Efficient Transformers



EXISTING TRANSFORMER SCHEDULE							
#REQ.	KVA	PHASE	PRIMARY	SECONDARY	CATALOG #	TEMP. RISE	Cost
1	3	3	480V	208Y/120V	3T2F	115C	1525
1	6	3	480V	208Y/120V	6T2F	115C	2025
1	9	3	480V	208Y/120V	9T2F	115C	2300
2	112.5	3	480V	208Y/120V	EE112T3H	115C	7300
1	15	3	480V	208Y/120V	EE153H	115C	3025
2	30	3	480V	208Y/120V	EE30T3H	115C	3600
2	45	3	480V	208Y/120V	EE45T3H	115C	4225

	Annual Operating Cost	Life Cycle Operating Cost & Savings	
		20 years	32 years
Status Quo Transformers	\$8,143	\$294,126	\$670,996
Powersmiths Transformers	\$2,249	\$81,256	\$185,362
Savings with Powersmiths	\$5,893	\$212,870	\$485,633
Cost			
Powersmiths Transformers	\$4,183		
Status Quo Transformers	\$27,888		
Payback on total cost			
		2.37 years	current kWh rate:
Cost of Energy Savings	\$ 0.009 /kWh		\$0.110
Cost - Benefit Ratio		12.4	times less to save a kWh than to buy a kWh
Leasing Option			
	60 Month Term	48 Month Term	36 Month Term
Total Annual Leasing Payments	\$10,577	\$12,901	\$16,415
Net Annual Cost with savings	\$4,684	\$7,008	\$10,522

Summary of Environmental Benefits

Annual Reduction in Greenhouse Gases (per EPA)		Equivalence	
36	tons of CO2	7	Acres trees planted
117	tons of Coal	5	Car Emissions
283	kgs of SO2	5	homes heated
122	kgs of NOx		

Massachusetts Public Library

Electrical Depth Study

Exterior Space-

Lighting Depth Study

Entry Lobby-

Lighting Depth Study

Meeting Room-

Lighting Depth Study

Acoustical Breadth Study

Stacks and Seating Area-

Lighting Depth Study

Daylighting Depth Study

Mechanical Breadth Study

Electrical Depth

Energy Efficient Transformers



Payback period of **2.37** years

In **32** years, the difference in **savings** would be **\$485,000**

Significant **reduction** in **Greenhouse Gases**

EXISTING TRANSFORMER SCHEDULE							
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1	3	3	480V	208Y/120V	3T2F	115C	1525
1	6	3	480V	208Y/120V	6T2F	115C	2025
1	9	3	480V	208Y/120V	9T2F	115C	2300
2	112.5	3	480V	208Y/120V	EE112T3H	115C	7300
1	15	3	480V	208Y/120V	EE153H	115C	3025
2	30	3	480V	208Y/120V	EE30T3H	115C	3600
2	45	3	480V	208Y/120V	EE45T3H	115C	4225

Massachusetts Public Library

Electrical Depth Study

Exterior Space-

Lighting Depth Study

Entry Lobby-

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Meeting Room-

Lighting Depth Study

Acoustical Breadth Study

Stacks and Seating Area-

Lighting Depth Study

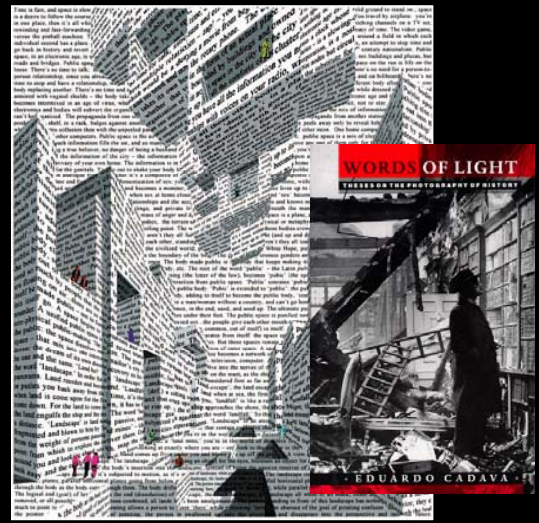
Daylighting Depth Study

Mechanical Breadth Study

Inspiration

Words of Light

- Appearance**
Compliment and accentuate the architectural style
- Hierarchy**
Use light to guide occupants
- Transparency/Flow**
Connection between spaces
- Color Temperature**
Warm color temperature to match the interior finishes



Massachusetts Public Library

Electrical Depth Study

Exterior Space-
Lighting Depth Study

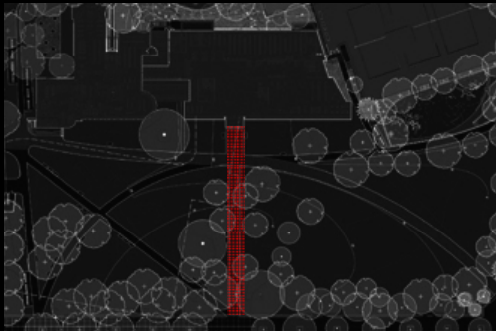
Entry Lobby-
Lighting Depth Study

Meeting Room-
Lighting Depth Study
Acoustical Breadth Study

Stacks and Seating Area-
Lighting Depth Study
Daylighting Depth Study
Mechanical Breadth Study

Exterior Space

Ground plane | Floor plan



Massachusetts Public Library

Electrical Depth Study

Exterior Space-
Lighting Depth Study

Entry Lobby-
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Acoustical Breadth Study

Stacks and Seating Area-
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Mechanical Breadth Study

Exterior Space

Design Concepts

Visual Hierarchy-

- Main Entrance
- Pathway Light

Impression-

- Way-finding
- Safety

Key Features-

- Linearity of Building

Illuminance/Distribution-

- Vertical illuminance of Faces- 0.3 fc
- Horizontal illuminance of Ground - 1.0 fc

Controls/Energy-

- Time Clock



Massachusetts Public Library

Electrical Depth Study

Exterior Space-

- Lighting Depth Study

Entry Lobby-

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Meeting Room-

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Stacks and Seating Area-

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Exterior Space

Ground plane | Lighting plan



Massachusetts Public Library

Electrical Depth Study

Exterior Space-
Lighting Depth Study

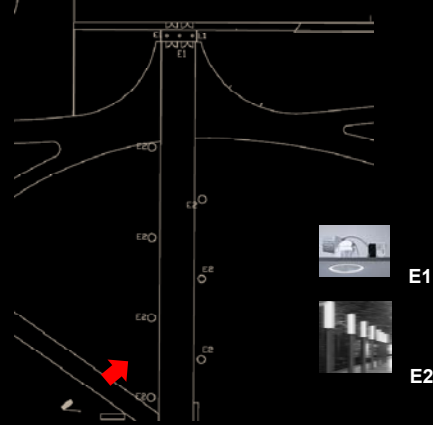
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Exterior Space

Ground plane | Lighting plan



E1



E2



Description	Allowable/Target	Actual
Vertical Illuminance of Faces	0.3 fc	0.82 fc
Horizontal illuminance of Ground	1.0 fc	1.41 fc
Power Density	0.2 W/ft ²	0.1 W/ft ²

Massachusetts Public Library

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Entry Lobby

1st Floor | Floor plan



Massachusetts Public Library

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Acoustical Breadth Study

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Daylighting Depth Study
Mechanical Breadth Study

Entry Lobby

Design Concepts

Visual Hierarchy-

- Stairs and elevators
- Help Desks

Impression-

- Circulation and Movement
- Big impact- Cover of a Book

Key Features-

- Red Ceiling
- Flow of Open Space

Illuminance/Distribution-

- Horizontal Illuminance
- Corridor - 5 FC min; Desks - 30 FC

Controls/Energy-

- Simple Switching
- 1.3 W/Sq. Ft. + 1.0 W/ Sq. Ft



Massachusetts Public Library

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Lighting Depth Study

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Daylighting Depth Study
Mechanical Breadth Study

Entry Lobby

1st Floor | Lighting Plan



Massachusetts Public Library

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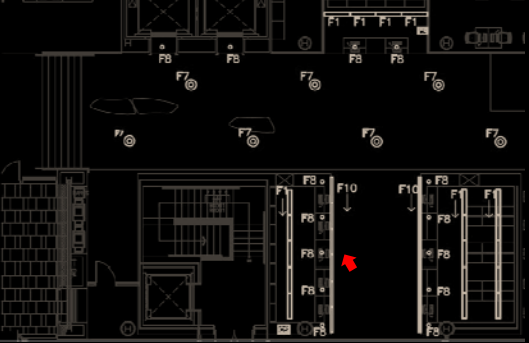
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Entry Lobby

1st Floor | Lighting Plan



F1



F7



F8



F10



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Exterior Space-
Lighting Depth Study

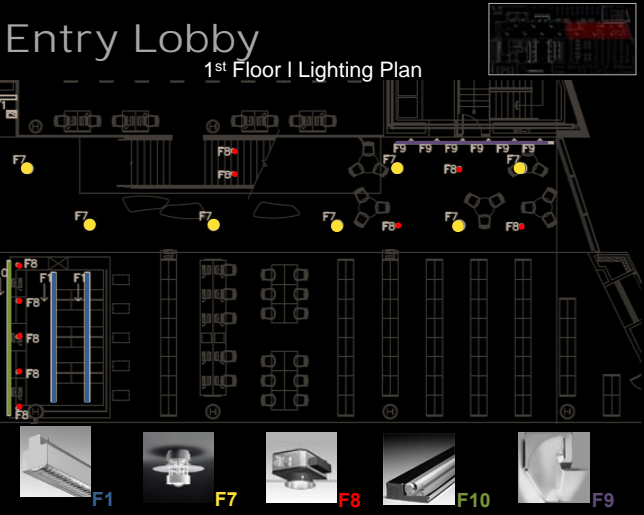
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Entry Lobby

1st Floor | Lighting Plan



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Massachusetts Public Library

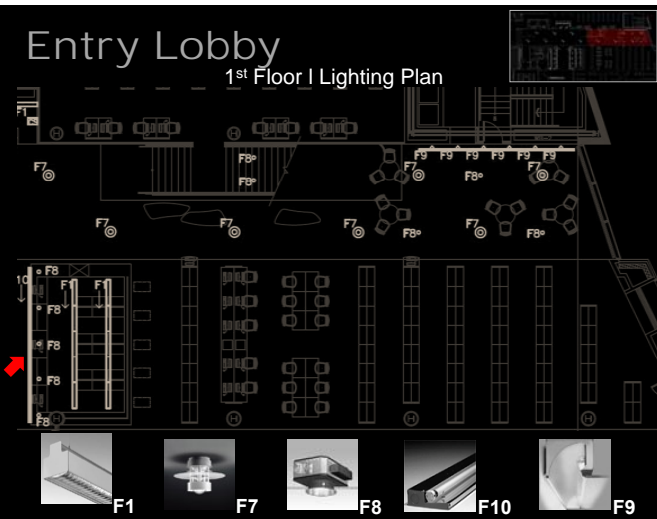
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Entry Lobby



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Entry Lobby-
Lighting Depth Study

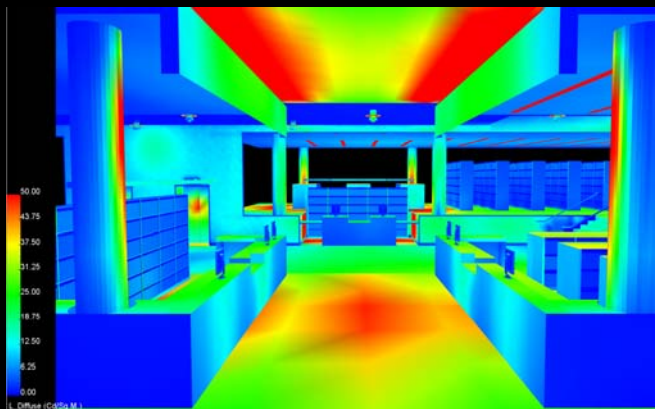
Meeting Room-
Lighting Depth Study
Acoustical Breadth Study

Stacks and Seating Area-
Lighting Depth Study
Daylighting Depth Study
Mechanical Breadth Study

Entry Lobby

Calculation Values

Description	Allowable/Target	Actual
Desk Horizontal Illuminance	30 fc	21.58 fc
Corridor Floor Horizontal Illuminance	5 fc min	10.99 fc
Main Entrance Floor Horizontal Illuminance	5 fc min	24.26 fc
Power Density	1.3 W/ft ² + 1.0 W/ft ²	0.67 W/ft ²



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Electrical Depth Study

Exterior Space-
Lighting Depth Study

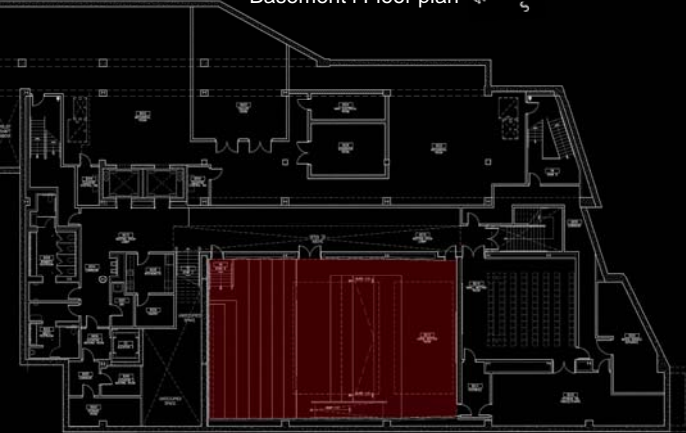
Entry Lobby-
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Stacks and Seating Area-
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Mechanical Breadth Study

Meeting Room

Basement I Floor plan



Massachusetts Public Library

Electrical Depth Study

Exterior Space-

Lighting Depth Study

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Meeting Room-

Lighting Depth Study

Acoustical Breadth Study

Stacks and Seating Area-

Lighting Depth Study

Daylighting Depth Study

Mechanical Breadth Study

Meeting Room

Design Concepts

Visual Hierarchy-

- Stage/Podiums
- Seating
- Architectural Features

Impression-

- Visual Clarity

Key Features-

- Sloped Wood Ceiling Panels
- Undulating Walls
- Rear Projection

Illuminance/Distribution-

- Uniform Horizontal Illuminance for Podiums/Seating Area- 30 FC
- Vertical Illuminance of Faces- 5 FC min

Controls/Energy-

- Dimming/Architectural Presets
- 1.3 W/Sq. Ft.



Massachusetts Public Library

Electrical Depth Study

Exterior Space-

Lighting Depth Study

Entry Lobby-

Lighting Depth Study

Meeting Room-

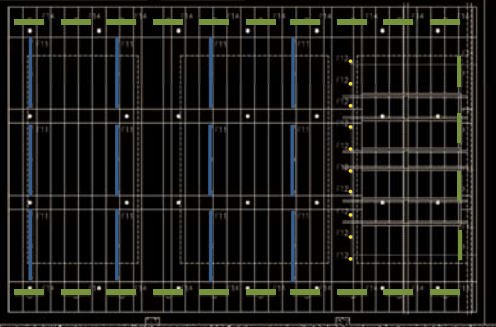
Lighting Depth Study
Acoustical Breadth Study

Stacks and Seating Area-

Lighting Depth Study
Daylighting Depth Study
Mechanical Breadth Study

Meeting Room

Basement I Lighting plan RCP



F11



F12



F14

Massachusetts Public Library

Electrical Depth Study

Exterior Space-
Lighting Depth Study

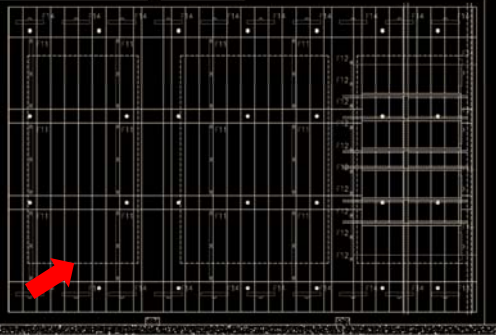
Entry Lobby-
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Meeting Room

Basement I Lighting plan RCP



Massachusetts Public Library

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Massachusetts Public Library

Electrical Depth Study

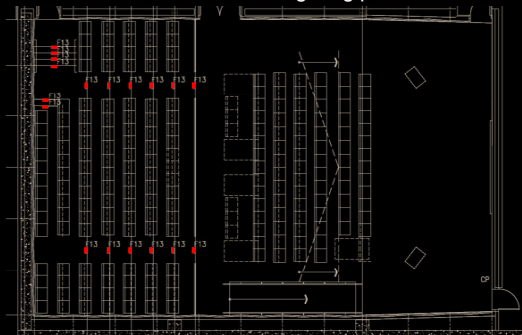
Exterior Space-
Lighting Depth Study

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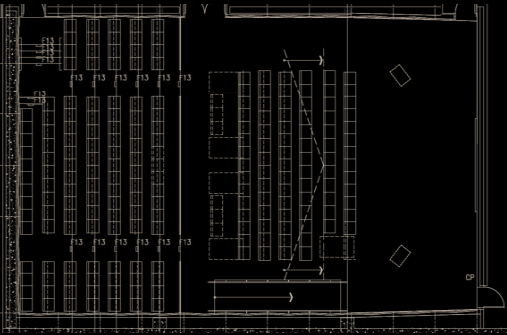
Meeting Room Basement I Lighting plan



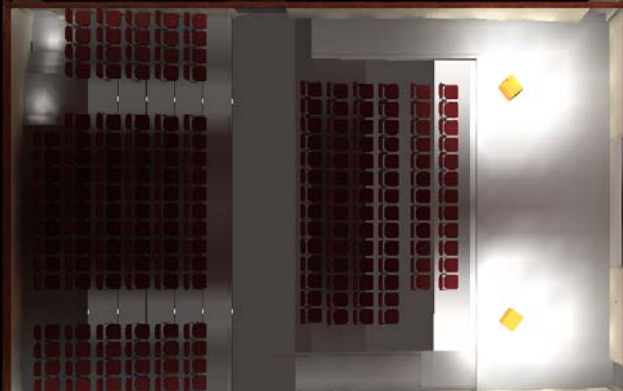
F13

Meeting Room

Basement I Lighting plan



F13



Massachusetts Public Library

Electrical Depth Study

Exterior Space-
Lighting Depth Study

Entry Lobby-
Lighting Depth Study

Meeting Room-
Lighting Depth Study
Acoustical Breadth Study

Stacks and Seating Area-
Lighting Depth Study
Daylighting Depth Study
Mechanical Breadth Study

Meeting Room

Classroom Scene

All Overhead Lights- 100%
Wallwashers- 100%
Stage Lights- 100%
Step Lights- Off



Massachusetts Public Library

Electrical Depth Study

Exterior Space-
Lighting Depth Study

Entry Lobby-
Lighting Depth Study

Meeting Room-
Lighting Depth Study
Acoustical Breadth Study

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Mechanical Breadth Study

Meeting Room

Podium Speakers/Projection Scene

- Overhead Lights- Off
- WallWashers- 25%
- Step lights- On
- Accent lights- On podiums only



Massachusetts Public Library

Electrical Depth Study

Exterior Space-
Lighting Depth Study

Entry Lobby-
Lighting Depth Study

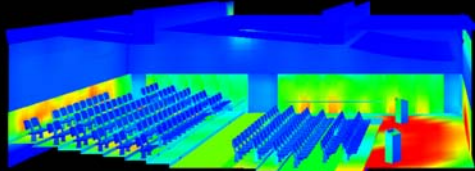
Meeting Room-
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Acoustical Breadth Study

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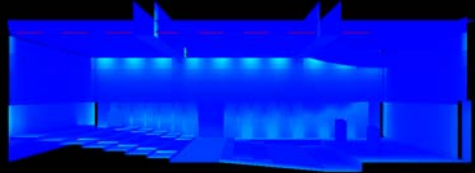
Meeting Room

Calculation values

Description	Allowable/Target	Actual
Auditorium Seating Horizontal Illuminance	30 fc	32.19 fc
Podium Vertical Luminance	3:1	8.6: 1
Project Screen	<5fc	0.97 fc
Power Density	1.3 W/ft ²	1.05 W/ft ²



Classroom Scene



Podium Speakers/Projection Scene

Massachusetts Public Library

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Exterior Space-
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Mechanical Breadth Study

Meeting Room

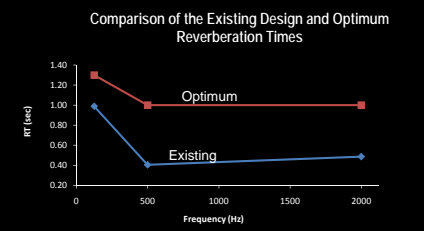
Acoustics Existing Design

Element	Units	Volume (m³)	Area (m²)	RT (sec)
1. Wood Wall Panels	m	0.00	0.00	0.00
Area RT	Sec Sabians	1000.00	1000.00	1.000.00
2. Wood Glass Floor	m	0.00	0.00	0.00
Area RT	Sec Sabians	100.00	100.00	0.100.00
3. Wood Ceiling Panels	m	0.00	0.00	0.00
Area RT	Sec Sabians	1000.00	1000.00	1.000.00
4. Glass Floor	m	0.00	0.00	0.00
Area RT	Sec Sabians	100.00	100.00	0.100.00
5. Glass Ceiling	m	0.00	0.00	0.00
Area RT	Sec Sabians	100.00	100.00	0.100.00
6. Acoustic Ceiling	m	0.00	0.00	0.00
Area RT	Sec Sabians	100.00	100.00	0.100.00
7. Acoustic Wall Panels	m	0.00	0.00	0.00
Area RT	Sec Sabians	100.00	100.00	0.100.00
8. Acoustic Ceiling Panels	m	0.00	0.00	0.00
Area RT	Sec Sabians	100.00	100.00	0.100.00
9. Acoustic Wall Panels	m	0.00	0.00	0.00
Area RT	Sec Sabians	100.00	100.00	0.100.00
10. Acoustic Ceiling Panels	m	0.00	0.00	0.00
Area RT	Sec Sabians	100.00	100.00	0.100.00
Total (existing, m³)		1000.0	1000.0	1.000.0
Total (existing, m²)		1000.0	1000.0	1.000.0
RT (sec) = 0.161V/A		0.161	0.161	0.161
Optimum RT_{0.5} = 1.0		1.0	1	1
RT_{0.5} = 1.0 (1.0) = 0.01				

Optimum reverberation time should be that of a **lecture room or cinema**, which is approximately **1.0 second**

Reverberation time is calculated by the equation:

$$RT(sec) = (0.05V) \sum A (Sabians)$$

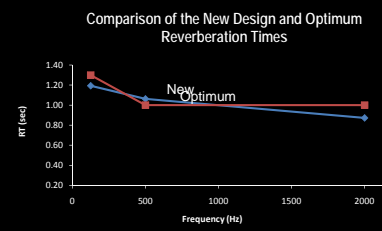


Massachusetts Public Library

- Electrical Depth Study
- Exterior Space-**
Lighting Depth Study
- Entry Lobby-**
Lighting Depth Study
- Meeting Room-**
Lighting Depth Study
Acoustical Breadth Study
- Stacks and Seating Area-**
Lighting Depth Study
Daylighting Depth Study
Mechanical Breadth Study

Meeting Room Acoustics New Design

Element	Units	RT	RT _{opt}	RT _{new}
Room		1.0	1.0	0.97
1. Wood Panel Ceiling	m ²	0.10	0.10	0.10
2. Wood Panel Walls	m ²	0.15	0.15	0.15
3. Wood Panel Floor	m ²	0.10	0.10	0.10
4. Carpeted Area	m ²	0.10	0.10	0.10
5. Acoustic Ceiling Panels	m ²	0.10	0.10	0.10
6. Acoustic Wall Panels	m ²	0.10	0.10	0.10
7. Acoustic Floor Panels	m ²	0.10	0.10	0.10
8. Acoustic Ceiling Panels	m ²	0.10	0.10	0.10
9. Acoustic Wall Panels	m ²	0.10	0.10	0.10
10. Acoustic Floor Panels	m ²	0.10	0.10	0.10
11. Acoustic Ceiling Panels	m ²	0.10	0.10	0.10
12. Acoustic Wall Panels	m ²	0.10	0.10	0.10
13. Acoustic Floor Panels	m ²	0.10	0.10	0.10
Total absorption, 125 Hz		0.10	0.10	0.10
Total absorption, 500 Hz		0.10	0.10	0.10
Total absorption, 2000 Hz		0.10	0.10	0.10
RT (new) = (0.166/0.17)		1.00	1.00	0.97
Optimum RT_{opt} = 1.0		1.0	1	1
RT_{new} = 1.0(1.0) = 1.0				

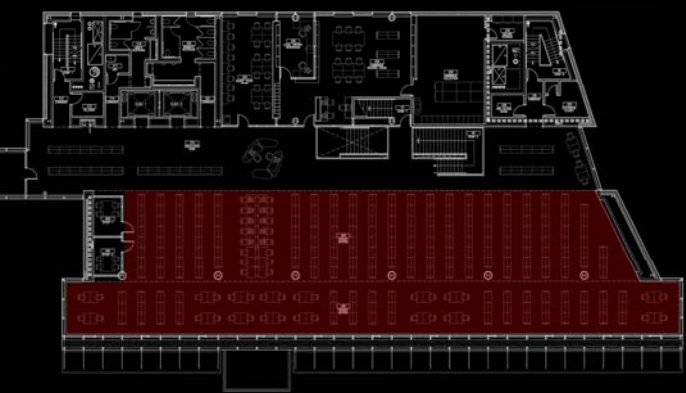


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Lighting Depth Study
Daylighting Depth Study
Mechanical Breadth Study

Stacks and Seating Area

2nd Floor | Floor plan



Massachusetts Public Library

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Acoustical Breadth Study

Stacks and Seating Area-
Lighting Depth Study
Daylighting Depth Study
Mechanical Breadth Study

Stacks and Seating Area

Design Concepts

Visual Hierarchy-

- Stacks
- Seating

Impression-

- Visual Clarity

Key Features-

- Flow of Open Space
- Even Spacing, Uniform Geometry

Illuminance/Distribution-

- Uniform Horizontal Illuminance for Desks
- 30 FC
- Uniform Vertical Illuminance of Stacks
- 30 FC

Controls/Energy-

- Daylight sensors- Dimming
- Stacks- 1.7 W/Sq. Ft.



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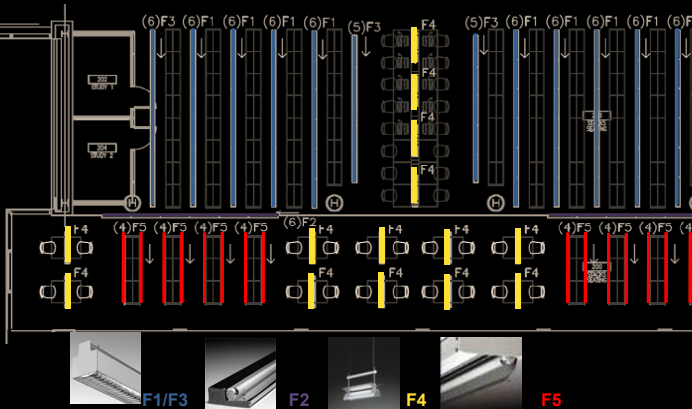
Lighting Depth Study
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Stacks and Seating Area

2nd Floor | Lighting plan



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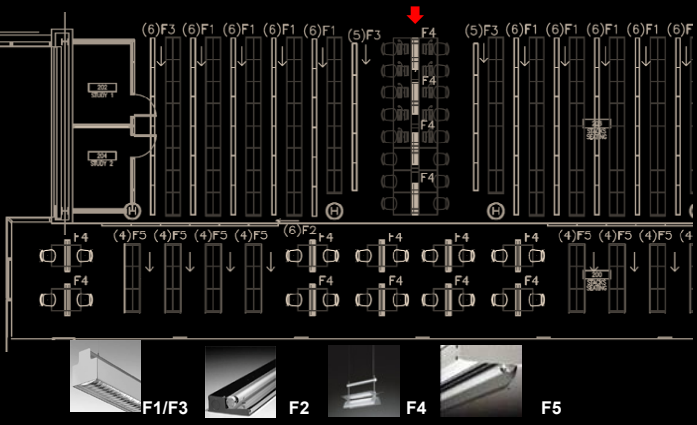
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Stacks and Seating Area

2nd Floor | Lighting plan



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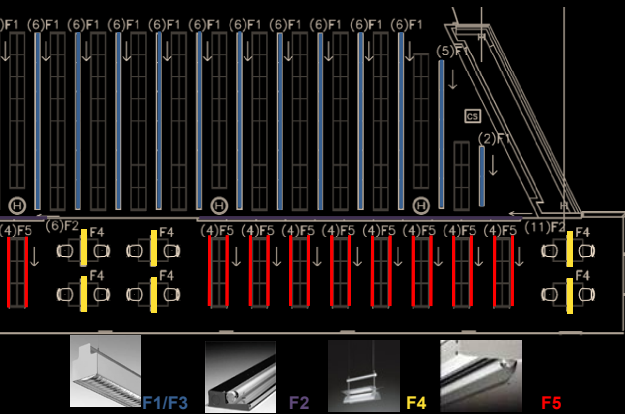
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Lighting Depth Study

Meeting Room-
Lighting Depth Study
Acoustical Breadth Study

Stacks and Seating Area-
Lighting Depth Study
Daylighting Depth Study
Mechanical Breadth Study

Stacks and Seating Area

2nd Floor | Lighting plan



Massachusetts Public Library

Electrical Depth Study

Exterior Space-
Lighting Depth Study

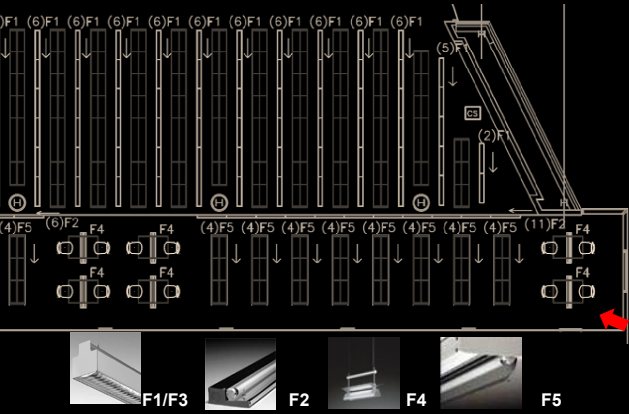
Entry Lobby-
Lighting Depth Study

Meeting Room-
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Lighting Depth Study

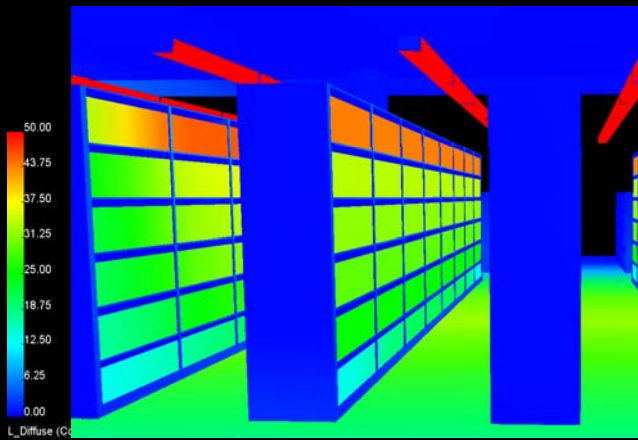
Daylighting Depth Study

Mechanical Breadth Study

Stacks and Seating Area

Calculation values

Description	Allowable/Target	Actual
Stacks Vertical Illuminance	30 fc	22.8 fc
Desks Horizontal Illuminance	30 fc	29.6 fc
Power Density	1.7 W/ft ²	1.4 W/ft ²



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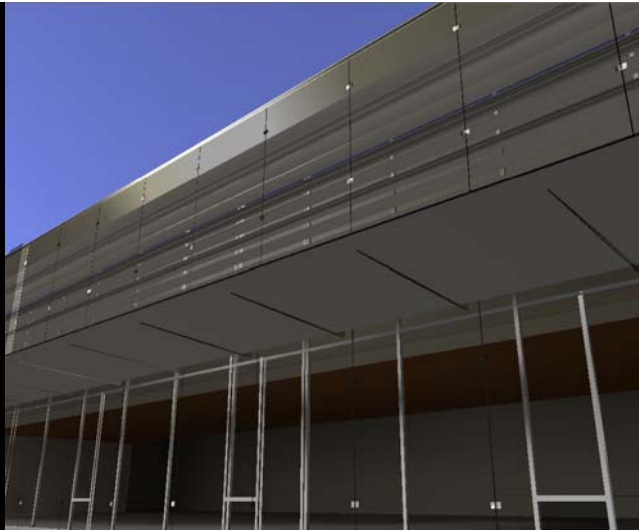
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Daylighting

Curtain Wall Facade

The extensive use of a state-of-the-art **curtain wall façade** in the new design maximizes views of the library's park setting, celebrates the library's openness and accessibility, and provides **abundance of daylight.**



Massachusetts Public Library

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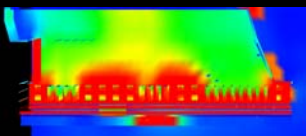
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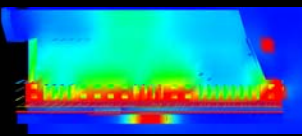
Stacks and Seating Area-
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Mechanical Breadth Study

Daylighting

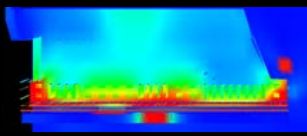
Pseudo Color Renderings



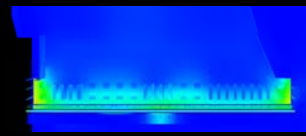
Clear sky- Dec. Noon



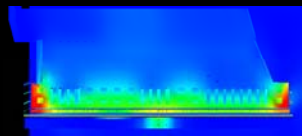
Clear sky- March Noon



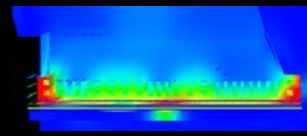
Clear sky- June Noon



Overcast- Dec Noon



Overcast-March Noon



Overcast-June Noon



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Daylighting Controls:

Stack Light
-On/Off
Photosensor

Pendants/Covelights
-Dimming Photosensor

Location	Controls	Energy Savings	Annual Savings
Shorter Stack Lights	On/Off Photosensor	3526.6 kWh	\$388
Pendants/Covelights	Dimming Photosensor	3192 kWh	\$351

Mechanical

Curtain Wall Facade

Low-E Tinted Insulating Glass U= 0.27, Glass SC= 0.35	Low-E Tinted Insulating Glass U= 0.35, Glass SC = 0.4	Low-E Tinted Insulating Glass U= 0.50, Glass SC= 0.45
508 W	440 W	493 W



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Conclusion

Overall Summary

Electrical Depth

A transformer comparison study was conducted to determine if the Powersmith energy efficient transformer was more beneficial than the industry standard.

Lighting Depth

The overall inspiration to the project was "words of light." People go to the library to be enlightened so light was used to guide occupants throughout the library. Lighting also supports the transparency and connection between spaces.

Daylighting Depth

There is an annual savings of \$739 a year due daylighting photosensors in the stacks and seating area. The curtain wall wraps around the entire addition, contributing to greater overall energy and cost savings in other similar spaces.

Acoustics Breadth

The new design of the space includes wood wall sound-absorbing panels on the upper portions of the walls, and sound reflective curved gypsum wallboard on the lower portions of the walls. The tilted ceiling panels are made of a hard sound-reflective wood unlike the wall panels to project sound further back in the space. Overall, the room is improved and matches the optimum reverberation time.

Mechanical Breadth

Changing the type of glass used throughout the curtain wall facade will have an impact on the cooling loads for the mechanical system. For approximately half the year, any reduction in electric lighting loads due to daylighting will directly impact the savings of the cooling load in the building.

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Acknowledgements

Thank You!

I would like to thank the following people:

My Advisors-

- Professor Mistrick
- Professor Dannerth
- Professor Holland
- Professor Parfitt

Project Architects-

- William Rawns Office
- Ken Amano

Project Lighting Designers-

- HLB Lighting

Friends, Family and Roomies

Special thanks to my lighting classmates! ❤️

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