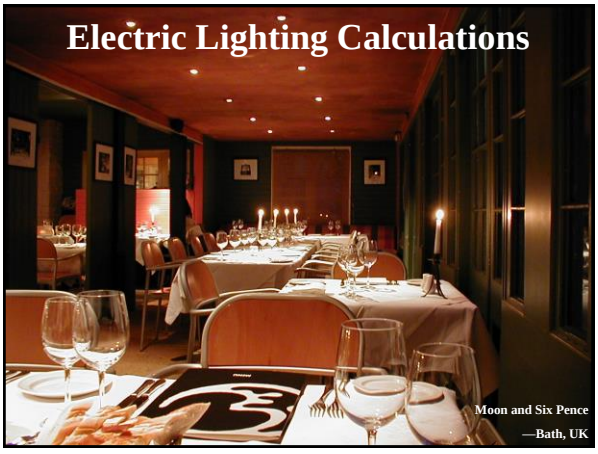
Electric Lighting Calculations



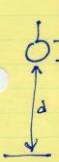
1

Two kinds of calculations

	**Task Lighting** (point source or line source method)
	**Ambient Lighting** (lumen or zonal cavity method)

2

Point Source Method



for the basic point source formula to be operative no dimension of the source can exceed 20% of d the distance between the source and the reference point

The basic formula is $fc. = \frac{c.p.}{D^2}$

3

Line Source Method

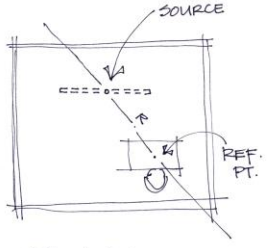
If the dimensions of the source exceed 20% of d in only one direction which is perpendicular to the line from the source to the reference point – then the basic line source formula is operative: $f.c. = \frac{c.p.}{D}$

(fluorescents end to end)

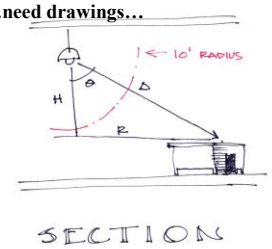
Or LED tubes

4

Find the illuminance from a point or line source…



…need drawings…



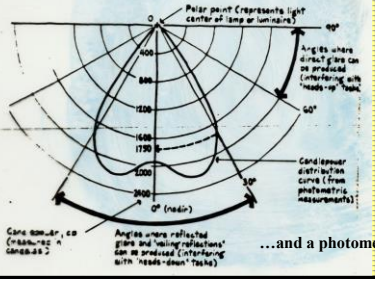
…measure D = 26 ft. and θ = 60°…

5

Photometric

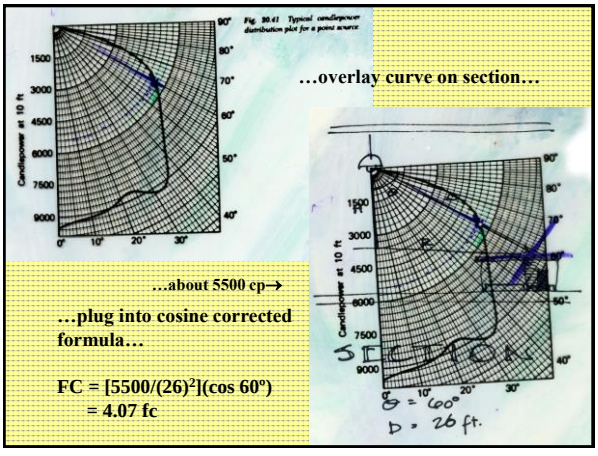
HOW TO READ CANDLEPOWER DISTRIBUTION CURVES

Candlepower distribution curves show light output produced by bare lamps or luminaires. Curves, plotted on polar coordinate graphs, can be used to represent the relative distribution of light. Candlepower values are found on the vertical scale of a graph which has degree lines radiating from the polar point. The nadir angle is 0° or the direction straight down. The horizontal plane containing the light source is 90°. For example, at 30° from the nadir, the luminaire represented by the graph below has a candlepower of 1750 cd (see dashed line on graph below).



…and a photometric curve…

6



…overlay curve on section…

…about 5500 cp→

…plug into cosine corrected formula…

FC = [5500/(26)^2](cos 60º)
= 4.07 fc

7

For multiple point and line sources:

If you have more than one point and/or line source in a room calculate the fc from each source by either method

then simply add them up:

$fc_T = fc_1 + fc_2 + \ldots + fc_n$

Warning: assumes IRC = 0

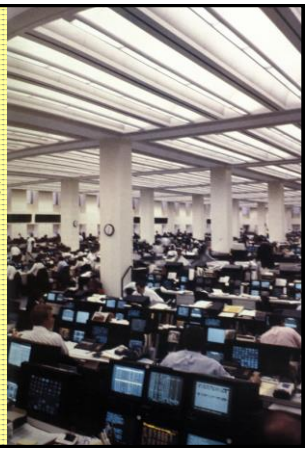
8

Lumen Method

Suitable for luminous ceilings or evenly spaced lighting grids

…rooms with ambient lighting or uniform lighting…

Zonal cavity method is same except it figures in floor reflectivity…



9

Lumen Method
based on f.c. definition

$$fc = \frac{\text{lumens}}{\text{area sq. ft. (work surface)}}$$

…but in real rooms light is reflected & absorbed by surfaces, this factor is labeled the coefficient of utilization (CU)…

so formula becomes

$$fc = \frac{\text{lumens} \times CU}{\text{area}}$$

10

…also the fixture and other installation details reduce the light… this is labeled light loss factor (LLF)…

$$fc = \left(\frac{\text{lumens} \times CU}{\text{area}}\right) LLF$$

so solving for lumens

$$\text{lumens} = \frac{fc \times \text{area}}{LLF \times CU}$$

11

...the number of lumens in the room is determined by the number of fixtures, lamps per fixture, and lumens per lamp

$$\text{lumens} = \#\text{fixtures} \times \text{lamps/luminaire} \times \text{lumens/lamp}$$

…since the two previous formulas are solved for lumens, they can be combined to give…

$$\#\text{fixtures} \times \text{lamps/luminaire} \times \text{lumens/lamp} = \frac{fc \times \text{work surface area}}{LLF \times CU}$$

12

…we can solve this for either the number of fixtures (black)
…or the amount of illumination on the work plane in FC (green)…

$$\#\,\text{fixtures} = \frac{fc \times \text{work surface area}}{LLF \times CU \times \text{lamps/luminaire} \times \text{lumens/lamp}}$$

$$fc = \frac{\#\,\text{fixtures} \times LLF \times CU \times \text{lamps/luminaire} \times \text{lumens/lamp}}{\text{work surface area}}$$

 # fixtures for a new design

FC for an existing design

Pre-renovation ceiling plenum. An acoustic tile ceiling was installed in earlier renovations to disguise HVAC systems. The ceiling reduced daylighting potential and hid the historic fabric of the building.

Federal Building, Grand Junction, CO —HPB Mag

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EXAMPLE

Try this for a simple room:
20' x 40' office space
12' ceiling
requires ~50 fc

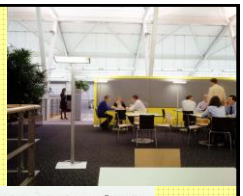

TABLE 18.8 **Comparison of Lighting Level Recommendations (Lux)**

Activity	Source of Recommendation: British IES	American IES Handbook (1981)	U.S. Gov't Agency
Classroom	500	200–500	400–600
Business office	500	300–750	500–750
Drafting room	750–1000	750–1500	800–1200

NOTES:
1. All levels are in lux. Divide by 10 for fc.
2. All levels refer to lighting on the task.

14

The room size (20' x 40' = 800 sqft)
and illuminance requirement (50 fc)
Give us the numerator for our formula…

$$\#\,\text{fixtures} = \frac{50fc \times 800\,sqft}{\text{whatever}}$$

…the denominator isn't so simple…

15

…pick a luminaire…

TABLE 20.2 Coefficients of Utilization for Typical Luminaires with Suggested Maximum Spacing Ratios (*continued*)

Typical Luminaire	Typical Distribution and Percent Lamp Lumens	Maintenance Category	Maximum S/MH Guide	RCR	ρ_{CC}: 80			70			50			0
					ρ_W: 50	30	10	50	30	10	50	30	10	0
					Coefficients of Utilization for 20% Effective Floor Cavity Reflectance (ρ_{FC} = 20)									
33		VI	N.A.	0	.77	.77	.77	.68	.68	.68	.50	.50	.50	.12
				1	.67	.64	.62	.59	.57	.54	.44	.42	.41	.10
				2	.59	.54	.50	.52	.48	.45	.38	.36	.34	.09
				3	.51	.46	.42	.45	.41	.37	.34	.31	.28	.07
				4	.45	.40	.35	.40	.35	.31	.30	.27	.24	.06
				5	.40	.34	.30	.35	.30	.27	.26	.23	.20	.05
				6	.36	.30	.26	.32	.27	.23	.24	.20	.18	.05
				7	.32	.26	.22	.28	.23	.20	.21	.18	.15	.04
				8	.29	.23	.19	.25	.21	.17	.19	.16	.13	.03
Luminous bottom suspended unit with extra-high-output lamp				9	.26	.20	.17	.23	.18	.15	.17	.14	.12	.03
				10	.24	.18	.15	.21	.16	.13	.16	.12	.10	.03
35		V	1.5/1.2	0	.81	.81	.81	.78	.78	.78	.72	.72	.72	.59
				1	.71	.69	.66	.69	.66	.64	.64	.62	.60	.50
				2	.64	.59	.56	.61	.58	.54	.57	.54	.51	.44
				3	.57	.52	.48	.55	.50	.47	.51	.48	.45	.38
				4	.51	.46	.41	.49	.44	.41	.46	.42	.39	.34
				5	.46	.40	.36	.44	.39	.35	.41	.37	.34	.29
				6	.41	.35	.31	.40	.35	.31	.38	.33	.30	.26
Two-lamp prismatic wraparound; multiply by 0.95 for four lamps				7	.37	.31	.27	.36	.31	.27	.34	.29	.26	.23
				8	.33	.28	.24	.32	.27	.23	.30	.26	.22	.19
				9	.30	.24	.20	.29	.24	.20	.27	.23	.19	.17
				10	.27	.22	.18	.26	.21	.18	.25	.20	.17	.15

↑ **Requires two fluorescent tubes…**

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…pick a lamp…

TABLE 19.11 Typical Fluorescent Lamp Data: Standard Lamps and Ballasts

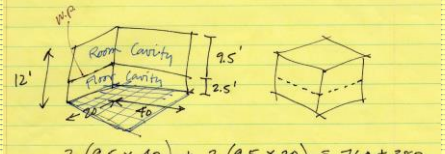
Lamp Abbreviation	Lamp Data: Lamp (W)	Diameter (in)	Length (in)	Lamp Current (mA)	Ballast (W)[a,c]	Total Watts[a]	Lamp Life (h)[a]	Initial Lumens Output (lm)[a]	Lumens at 40% Life	Initial Actual Efficacy (lm/W)[a]	Remarks
Preheat lamps[d]											
F15 T-8 CW	15	1"	18	430	8	23	7,500	870	785	38	Cool white
F20 T-12 WW	20	1½	24	430	10	30	9,000	1,300	1,155	43	Warm white
Rapid-start—product lamps[d]											
F40 T-12 CW	40	1½	48	430	7.5	46	20,000+	3,150	2,770	68	
F40 T-12 WW	40	1½	48	430	7.5	46	20,000+	3,200	2,815	70	Warm white
F40 T-12 CWX	40	1½	48	430	7.5	46	20,000+	2,250	1,955	49	Cool white deluxe
F40 T-12 D	40	1½	48	430	7.5	46	20,000+	2,600	2,290	57	Daylight
F40 T-12/C50	40	1½	48	430	7.5	46	20,000+	2,200	1,980	48	5000 K color
F40 T-12/C75	40	1½	48	430	7.5	46	20,000+	2,000	1,720	44	7500 K color
F40 T-12/U	40	1½	—	430	7.5	46	12,000	2,900	2,525	55	"U" shape
Rapid start—high output											
F48 T-12 CW/HO	60	1½	48	800	12.5	72.5	12,000	4,300	3,740	55	
F60 T-12 CW/HO	75	1½	60	800	15	90	12,000	5,400	4,700	60	
F72 T-12 CW/HO	85	1½	72	800	22.5	107.5	12,000	6,650	5,795	62	
F96 T-12 CW/HO	110	1½	96	800	18.5	128.5	12,000	9,200	8,005	72	
Rapid-start—very high output											
F48 PG-17 CW	110	1½	48	1500	5	125	12,000	6,900	5,100	55	G.E. Power Groove®
F72 PG-17 CW	165	1½	72	1500	10	175	12,000	11,500	8,510	66	G.E. Power Groove®
F96 PG-17 CW	215	1½	96	1500	10	225	12,000	16,000	12,160	71	G.E. Power Groove®
Instant-start (Slimline) lamps											
F42 T-6 CW	25	⅝	42	200	10.5	35.5	7,500	1,750	1,480	49	
F64 T-6 CW	40	⅝	64	200	9	49	7,500	2,800	2,350	57	
F24 T-12 CW	20	1½	24	430	14	34	7,500	1,150	1,035	34	
F36 T-12 CW	30	1½	36	430	13	43	7,500	2,000	1,800	47	Warm white
F48 T-12 CW	40	1½	48	430	12	52	9,000	3,000	2,760	58	
F72 T-12 CW	55	1½	72	430	11	66	12,000	4,550	4,275	69	
F96 T-12 CW	75	1½	96	430	13	85	12,000	6,300	5,800	74	

2770

17

…calculate the room cavity ratio…

$$RCR = 2.5 \frac{\text{area of cavity wall}}{\text{area of work plane}}$$



$2(9.5 \times 40) + 2(9.5 \times 20) = 760 + 380$

$= 1140$ sq ft

$RCR = 2.5 \frac{1140 \text{ sq ft}}{800 \text{ sq ft}} = 3.56$

…key to finding CU…

18

…need to know RCR (3.56), ceiling and wall reflectivity…

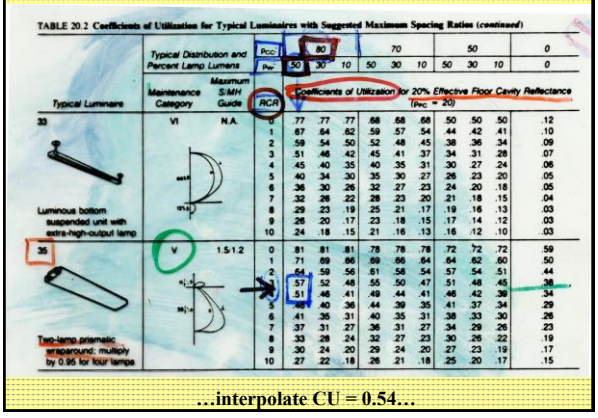


TABLE 20.2 Coefficients of Utilization for Typical Luminaires with Suggested Maximum Spacing Ratios (continued)

Typical Luminaire	Typical Distribution and Percent Lamp Lumens	Maintenance Category	Maximum S/MH Guide	RCR	Coefficients of Utilization for 20% Effective Floor Cavity Reflectance (Pfc = 20)									
	Pcc				80			70			50			0
	Pw				50	30	10	50	30	10	50	30	10	0
33 Luminous bottom suspended unit with extra-high-output lamp		VI	N.A.	0	.77	.77	.77	.68	.68	.68	.50	.50	.50	.12
				1	.67	.64	.62	.59	.57	.54	.44	.42	.41	.10
				2	.59	.54	.50	.52	.48	.45	.38	.36	.34	.09
				3	.51	.46	.42	.45	.41	.37	.34	.31	.28	.07
				4	.45	.40	.35	.40	.35	.31	.30	.27	.24	.06
				5	.40	.34	.30	.35	.30	.27	.26	.23	.20	.05
				6	.36	.30	.26	.32	.27	.23	.24	.20	.18	.05
				7	.32	.26	.22	.28	.23	.20	.21	.18	.15	.04
				8	.29	.23	.19	.25	.21	.17	.19	.16	.13	.03
				9	.26	.20	.17	.23	.18	.15	.17	.14	.12	.03
				10	.24	.18	.15	.21	.16	.13	.16	.12	.10	.03
35 Two-lamp prismatic wraparound: multiply by 0.95 for four lamps		V	1.5:1.2	0	.81	.81	.81	.78	.78	.78	.72	.72	.72	.59
				1	.71	.69	.66	.69	.66	.64	.64	.62	.60	.50
				2	.64	.59	.56	.61	.58	.54	.57	.54	.51	.44
				3	.57	.52	.48	.55	.50	.47	.51	.48	.45	.38
				4	.51	.46	.41	.49	.44	.41	.46	.42	.39	.34
				5	.46	.40	.36	.44	.39	.35	.41	.37	.34	.29
				6	.41	.35	.31	.40	.35	.31	.38	.33	.30	.26
				7	.37	.31	.27	.36	.31	.27	.34	.29	.26	.23
				8	.33	.28	.24	.32	.27	.23	.30	.26	.22	.19
				9	.30	.24	.20	.29	.24	.20	.27	.23	.19	.17
				10	.27	.22	.18	.26	.21	.18	.25	.20	.17	.15

…interpolate CU = 0.54…

19

…plug in lamp, fixture, and CU info…

$$\#\,fixture = \frac{50\,fc \times 800\,sq\,ft}{LLF \times .54 \times 2\,lamps/luminaire \times 2770\,\frac{lumens}{lamp}}$$

only LLF left

$$LLF = a \times b \times c \times d \times e \times f \times g \times LDD$$

luminaire dirt depreciation

…this alphabet soup of factors is described in MEEB 12 p 730…

Or you can approximate LLF = .65 for good, .55 for average, or .45 for poor conditions
MEEB 12 p. 738

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LUMEN METHOD - "SIMPLE" FORMULA

$$\#\,fixtures = \frac{fc\ req'd \times work\ plane\ area}{LLF \times CU \times lamps/luminaire \times lumens/lamp}$$

$$\#\,fixtures = \frac{50 \times 800\,sq\,ft}{.50 \times .54 \times 2 \times 2770}$$

$$= 26.7 \text{ or } 27$$

$$LLF = a \times b \times c \times d \times e \times f \times g \times LDD$$

$$LLF = 1.0 \times 1.0 \times .9 \times .9 \times .92 \times .85 \times .95 \times .83$$

$$= .50$$

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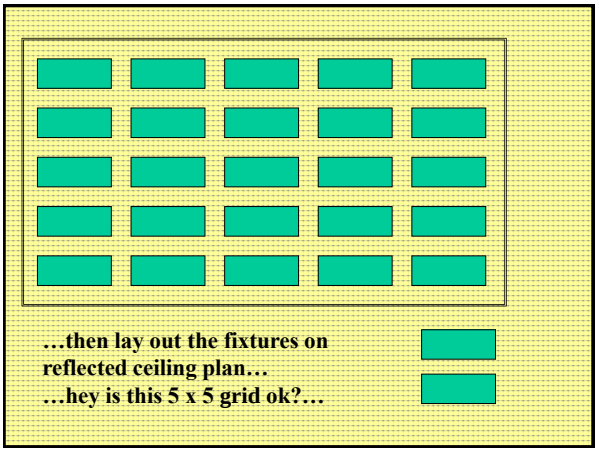

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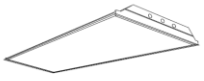
Columbia LIGHTING

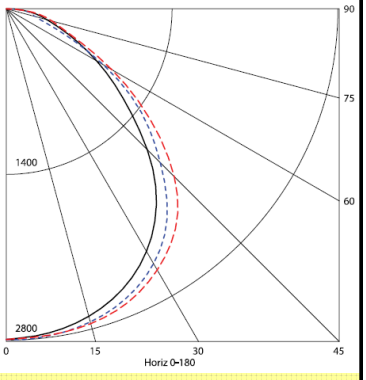


FEATURES

- T8 optimized fluorescent lensed troffer
- Shallow design frees up plenum space
- Hemmed fixture edges reduce risk of injury during fixture handling and installation
- Integral T-Bar clips quickly to secure fixture to the grid
- Metal to metal light leak protection on all four sides of shielding frame
- Snap-in ballast cover requires no tools for wireway access
- T-hinging for easy insertion and removal of shielding frame from either side of the housing
- Flush steel shielding frame is equipped with simple-to-use corner tabbing for diffuser replacement
- Housing embossments provide extra strength and rigidity

Fixture manufacturers provide the data needed for either type of calculation.

INDOOR CANDELA PLOT



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Columbia LIGHTING

JT824-2, JT824-3

2' × 4' Dedicated T8 Lensed Troffer / 2 or 3-Lamp T8

Test 13120 Test Date 11/07/2003

PHOTOMETRIC DATA

LUMINAIRE DATA

Luminaire	JT824-332G-FSA12 / Lensed Troffer 2' x 4' 3-Lamp with A-12 Pattern Acrylic Prismatic Lens
Ballast	B332I120RH-A
Ballast Factor	0.88
Lamp	F32T8
Lumens per Lamp	2900
Watts	84
Shielding Angle	N/A
Spacing Criterion	0° = 1.23 90° = 1.36

AVG. LUMINANCE (Candela/Sq. M.)

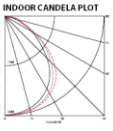
Average Luminance Angle	0.0	22.5	45.0	67.5	90.0
0	4289	4289	4289	4289	4289
30	4196	4277	4409	4495	4518
40	3635	4032	4230	4421	4515
45	3655	3764	3994	4218	4355
50	3299	3469	3781	3940	4047
55	2993	3133	3445	3569	3647
60	2706	2694	2903	3078	3161
65	2420	2238	2231	2547	2631
70	2178	1908	1645	2223	2326
75	2101	1792	1501	2130	2368
80	2255	1822	1830	2229	2583
85	2344	2009	2079	2559	2696

COEFFICIENTS OF UTILIZATION (%)

RC	80			70			50		
RW	70	50	30	70	50	30	50	30	10	0
1	90	89	85	86	85	82	90	87	84	81	83	81	79	72
2	85	78	73	68	83	77	72	67	74	70	66	61
3	78	69	63	58	76	68	62	57	65	60	56	52
4	71	62	55	49	70	61	54	49	59	53	48	45
5	66	55	48	43	64	54	48	42	53	47	42	39
6	61	50	43	38	59	49	42	37	48	42	37	35
7	57	45	38	33	55	45	38	33	44	37	33	31
8	53	42	35	30	51	41	34	30	40	34	29	28
9	49	38	31	27	48	38	31	27	37	31	27	25
10	46	35	29	24	45	35	29	24	34	28	24	23

RCR = Room Cavity Ratio
RC = Effective Ceiling Cavity Reflectance RW = Wall Reflectance

INDOOR CANDELA PLOT



ZONAL LUMEN SUMMARY

Zone	Lumens	Lamp	Fixt.
0-30	2232	25.7	30.3
0-40	3678	42.3	49.9
0-60	6216	71.4	84.4
0-90	7364	84.6	100.0
0-180	7364	84.6	100.0

ENERGY DATA

Total Luminaire Efficiency	84.6%
Luminaire Efficacy Rating (LER)	77
IECNA-RP-1-2004 Compliance	Non-Compliant
Comparative Yearly Lighting Energy Cost per 1000 Lumens	$3.12 based on 3000 hrs. and $0.08 per KWH

MASTER LEDtube InstantFit HF T8

The new generation of energy saving tube lighting

View the product

PHILIPS

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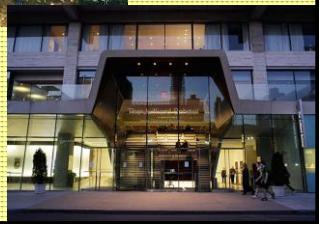
So, how did the professionals do?



Julliard School, NYC, remodel
Diller Scofidio + Renfro
with FOXFOWLE

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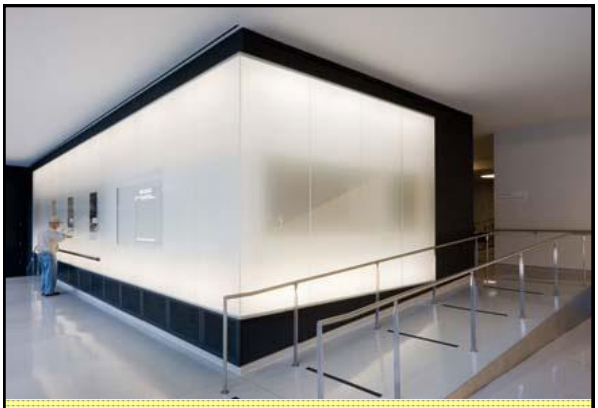
"Clerestory-like backlighted panels"

26

"Indirect ambient lighting and LED task lights"

27



“T-5s behind a base of frosted glass panels (box office).”

28

“Vibration and buzz-free lighting for orchestra rehearsal”

29

Grand Staircase

30

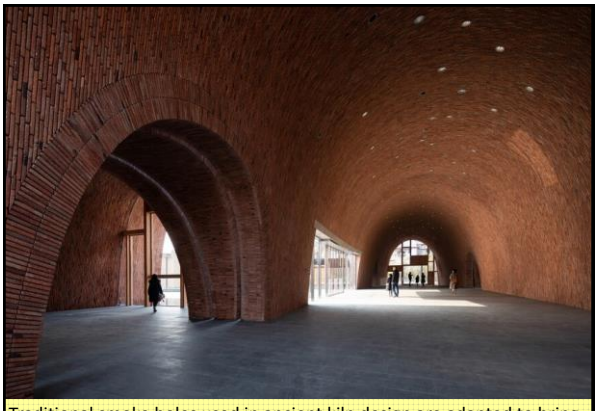
2022 AL DESIGN AWARDS

Jingdezhen Imperial Kiln Museum

Merit Award • Whole Building Lighting • Design Team: Dongning Wang

The Jingdezhen Imperial Kiln Museum is located in the center of the historical area of Jingdezhen, which is known as the "porcelain capital" of the world.

31

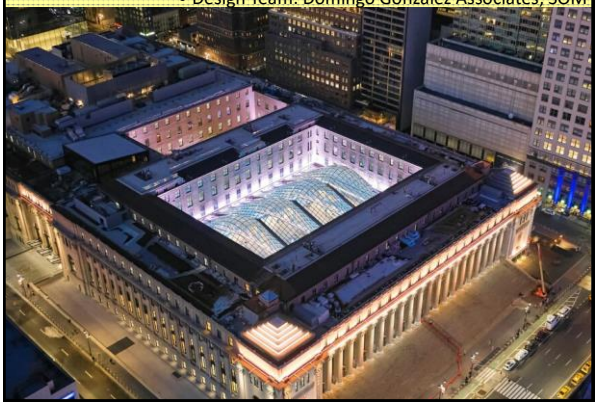


Traditional smoke holes used in ancient kiln design are adapted to bring in natural light or to hide artificial light sources.

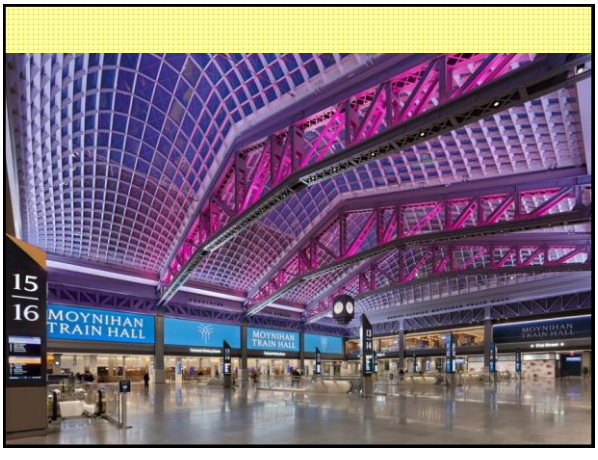
32

33

Daniel Patrick Moynihan Train Hall Honor Award • Interior Lighting • Design Team: Domingo Gonzalez Associates; SOM



34



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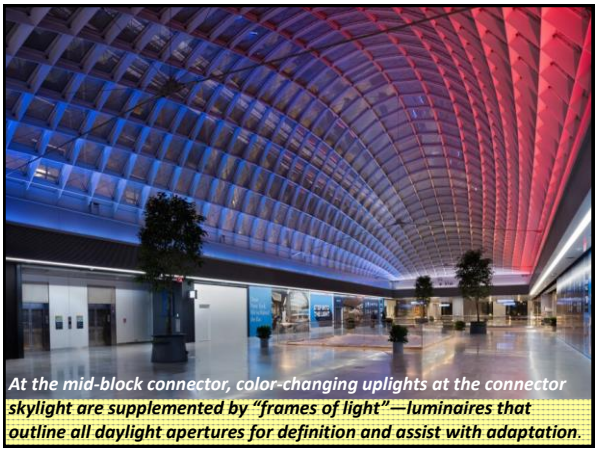


At the mid-block connector, color-changing uplights at the connector skylight are supplemented by "frames of light"—luminaires that outline all daylight apertures for definition and assist with adaptation.

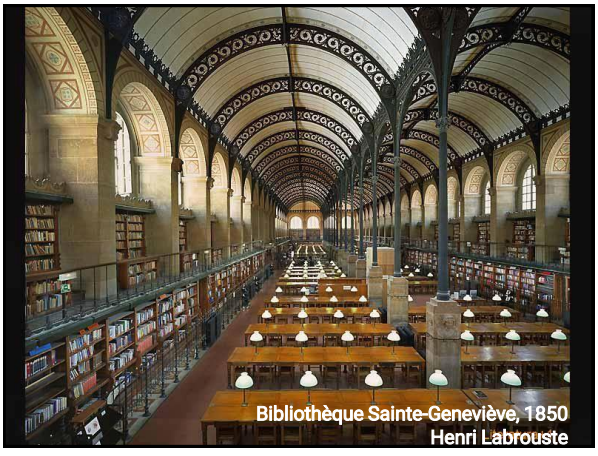
36

GES-2, Moscow

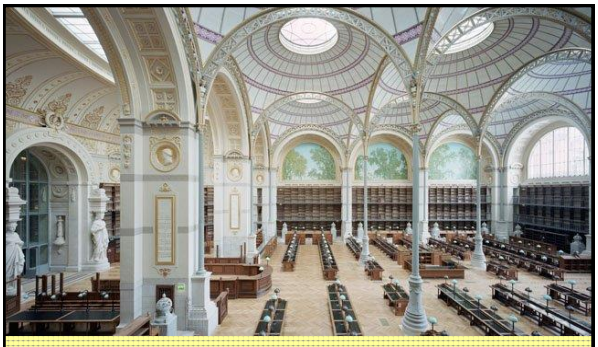
Thanks Daria!

37

38



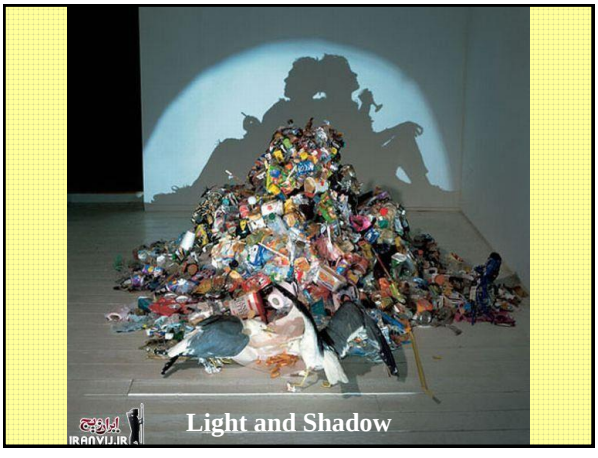
39



Bibliothèque Nationale, Paris, Henri Labrouste
1865

Photo: Yves Marchand & Romain Meffre

40



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