

**ILLUMINANCE LEVELS AND LUMINANCE DISTRIBUTIONS IN SUNLIT ATRIA
WITH DIFFERENT CANOPY SYSTEMS AND WELL CONFIGURATIONS**

A Dissertation

by

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Submitted to the Office of Graduate Studies of
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December 1993

Major Subject: Architecture

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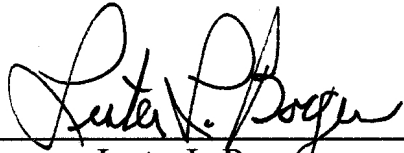
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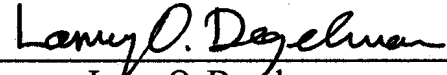
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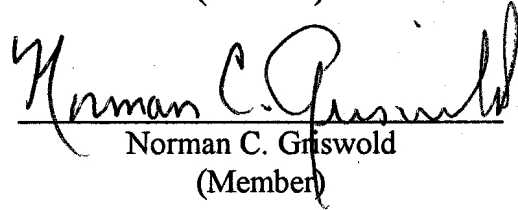
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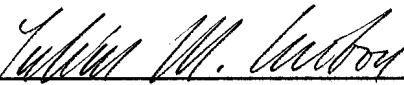
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ABSTRACT

Illuminance Levels and Luminance Distributions in Sunlit Atria with Different Canopy Systems and Well Configurations. (December 1993)

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The goal of this study is to provide building designers with daylighting and sunlighting performance data and design guidelines for sunlit atria with different well and canopy configurations which can be referenced during the early stages of an atrium design.

Several instrumentation systems were developed to overcome the limitations of conventional photometric instruments. The instrumentation systems include a video-based luminance mapping system to determine geometric and photometric daylighting parameters and an integrating box to measure hemispherical transmittance of canopy systems. Then, a total of seven different atrium well configurations and a total of thirty-six atrium canopy configurations were parametrically evaluated with physical scale models in terms of their impacts on the illuminance levels on the atrium floor and luminance distributions on the walls under different sky and sunlight conditions.

To obtain daylighting performance data, lighting measurements were conducted in a large-scale sky simulator which can create clear and overcast skies. To obtain net sunlighting performance data, lighting measurements were conducted with an artificial sun at an outdoor location at night.

Initial data analysis for diffuse skies was performed with Base Case Daylight Factors obtained without canopy. Then, Effective Transmittances of each canopy system at different atrium well configurations were determined as the ratio of canopy-covered Daylight Factors (DF) to the Base Case Daylight Factors. In addition, daylight luminance distributions and Luminance Ratios on the atrium walls were determined from luminance distribution maps captured by the video-based luminance mapping system.

Data analysis for sunlit atria was performed with Sunlight Illuminance Ratios (SIR) obtained with and without canopies. Furthermore, a new method was developed to quantitatively evaluate sunlight patches on atrium walls using the video-based luminance mapping system and physical scale models. With this method, it is possible to account for the locations and sizes of sunlight patches.

An example is presented to show how to determine the combined effect of diffuse daylight and sunlight contributions on the atrium floor using DF and SIR together with actual outdoor illuminance data.

Finally, an existing atrium building was selected to demonstrate the application of the findings of this study in the field.

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For my father and mother

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NOMENCLATURE

BCDF	Base Case Daylight Factor measured without canopy [%]
BCSIR	Base Case Sunlight Illuminance Ratio [%]
CDF	Corrected Daylight Factor considering light reduction factors [%]
CF	Configuration Factor
CSIR	Corrected Sunlight Illuminance Ratio [%]
CU	Coefficient of Utilization
DDF	Design Daylight Factor [%]
DF	Daylight Factor [%]
DSC	Direct Sun Component [lux]
DSIR	Design Sunlight Illuminance Ratio [%]
EP	Equidistant Projection
ERC	Externally Reflected Component [%]
ET	Effective Transmittance [%]
FF	Framing Factor [%]
HT	Hemispherical Transmittance [%]
IRC	Internally Reflected Component [%]
LI	Luminance Index
LLF	Light Loss Factor
LR	Luminance Ratio
OP	Orthographic Projection
PAR	Plan Aspect Ratio
SAR	Section Aspect Ratio
SC	Sky Component [%]
SIR	Sunlight Illuminance Ratio [%]
SPL	Sunlight Patch Location [elevation angle, ° or deg.]
SPS	Sunlight Patch Size [Configuration Factor, no unit]
WI	Well Index
WWI	Waffle Well Index
\bar{L}	average field luminance [cd/m^2]
θ	incident angle of light or elevation angle of a wall element [° or deg.]
ρ	reflectance [%]
ϖ	solid angle of a surface source [sr]
δ	thickness of each linear member for FF calculation [in.]

NOMENCLATURE (CONTINUED)

τ_{θ}	transmittance of sunlight at incident angle θ
τ_h	transmittance of flat horizontal skylight
A	bottom area of skylights for FF calculation [m ² , in ² , or ft ²]
d	distance [m, in., or ft]
D	distance from surface source to a receiving point [m]
$d\omega$	solid angle of infinitesimal area [sr]
dE	illuminance of infinitesimal area [lux]
d_{ep}	distance from the center in equidistant projection image
dL	luminance on infinitesimal point source [cd/m ²]
d_{op}	distance from the center in orthographic projection image
dS	area of infinitesimal element on surface source [m ²]
dS'	area of infinitesimal element on the surface of a unit hemisphere [m ²]
dS_o	orthographic projection area of an infinitesimal surface element [m ²]
E	illuminance [lux]
E_c	average of light intensity measured with canopy (for HT calculation) [lux]
E_{crit}	illuminance criterion [lux] (1000 lux in this study)
E_{di}	indoor horizontal illuminance measured under diffuse sky [lux]
E_{dic}	indoor horizontal illuminance calculated for clear sky [lux]
E_{do}	outdoor horizontal illuminance available from unobstructed diffuse sky [lux]
E_i	illuminance of a pixel [lux]
E_o	average of light intensity measured without canopy (for HT calculation) [lux]
E_p	indoor illuminance at point P [lux]
E_{si}	indoor horizontal illuminance measured under direct sunlight only [lux]
E_{so}	outdoor horizontal illuminance from direct sunlight only [lux]
h	height [m, in., or ft]
l	length [m, in, or ft]
L	luminance [cd/m ²]
L_i	pixel luminance in video image [cd/m ²]
L_s	average luminance of remainder of the field of vision (surrounding) [cd/m ²]
L_v	average luminance of visual task area [cd/m ²]
M	luminance emittance [rlx or lm/m ²]
n	number of pixels in orthographic projection image of surface source
N	total number of pixels in orthographically projected circle

NOMENCLATURE (CONTINUED)

r	radius of orthographic projection circle [m]
S	total area of surface source [m ²]
S'	area of surface source on the surface of a unit hemisphere [m ²]
S_o	orthographic projection area of a surface source on unit circle [m ²]
sr	steradian (unit of solid angle)
w	width [m, in., or ft]