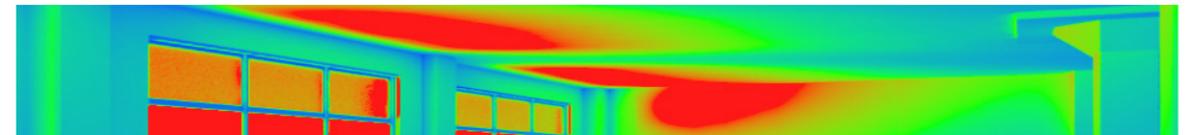


3M Daylight Redirecting Film :: Performance Analysis

1.14.2013



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3M Daylight Redirecting Film :: Introduction

This report was prepared at the request of the 3M Renewable Energy Division to analyze the effectiveness of their Daylight Redirecting Film product relative to illumination levels and visual comfort in comparison and conjunction with other established daylighting strategies for interior spaces.

This study is based on a 3D model of a typical office bay with 14'-2" floor to ceiling heights. Daylighting analysis was performed using RADIANCE, a suite of research-grade, ray-tracing programs run on native-UNIX OS. Sky conditions were determined using Typical Meteorological Year data - a compilation of 30 years of data which reports sky conditions for 8,760 hours in the year at a specific weather station in New York City. Other modeling inputs used in the simulations are as follows:

Building location: 40.74 N Lat, 74.00 W Long

Orientation: 30 degrees east of North

VLT of base case windows: 70%

Roller Blinds: 5% openness / 15% VLT

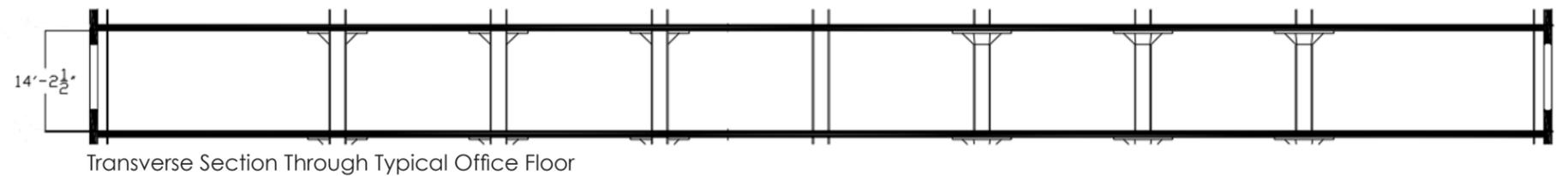
Floor Reflectance: 20%

Wall reflectance: 70%

Ceiling Reflectance: 80%

Exterior Reflectance: 30%

The 3M Daylighting Film was modeled using the BSDF (bidirectional scattering distribution function) file provided by 3M and is based on the Klems / LBNL Window 6 XML format.



3M Daylight Redirecting Film :: Overview of Analysis

In the following studies several daylighting strategies incorporating horizontal light shelves (interior, exterior or both) are analyzed relative to illumination levels and visual comfort and compared using both the 3M Film and clear glass respectively at the upper most lights of the sash windows. Each study is analyzed under key, exterior daylight conditions representative of annual variations and different building orientations:

Windows receive direct sun illumination @ noon, March 21

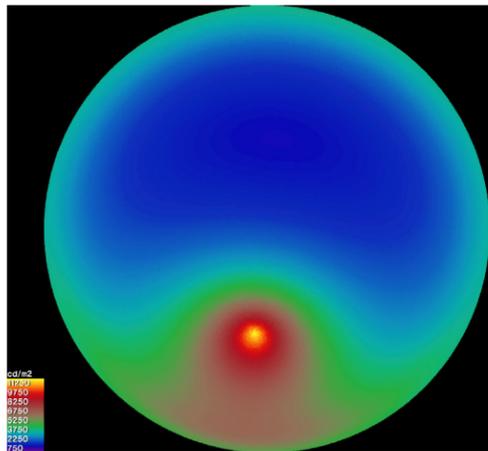
Windows receive direct sun illumination @ noon, June 21

Windows receive direct sun illumination @ noon, December 21

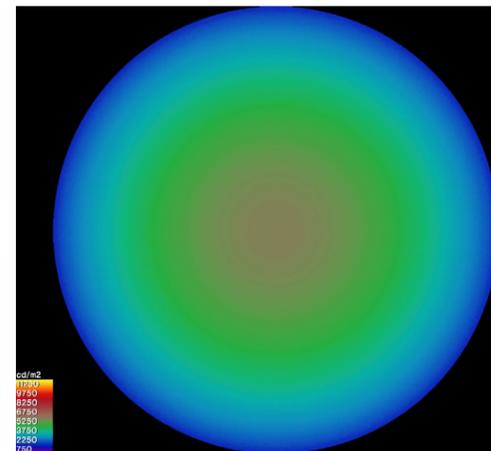
Windows receive overcast sky illumination @ noon December 21

Windows receive diffuse, clear sky illumination (no direct sun) March 21

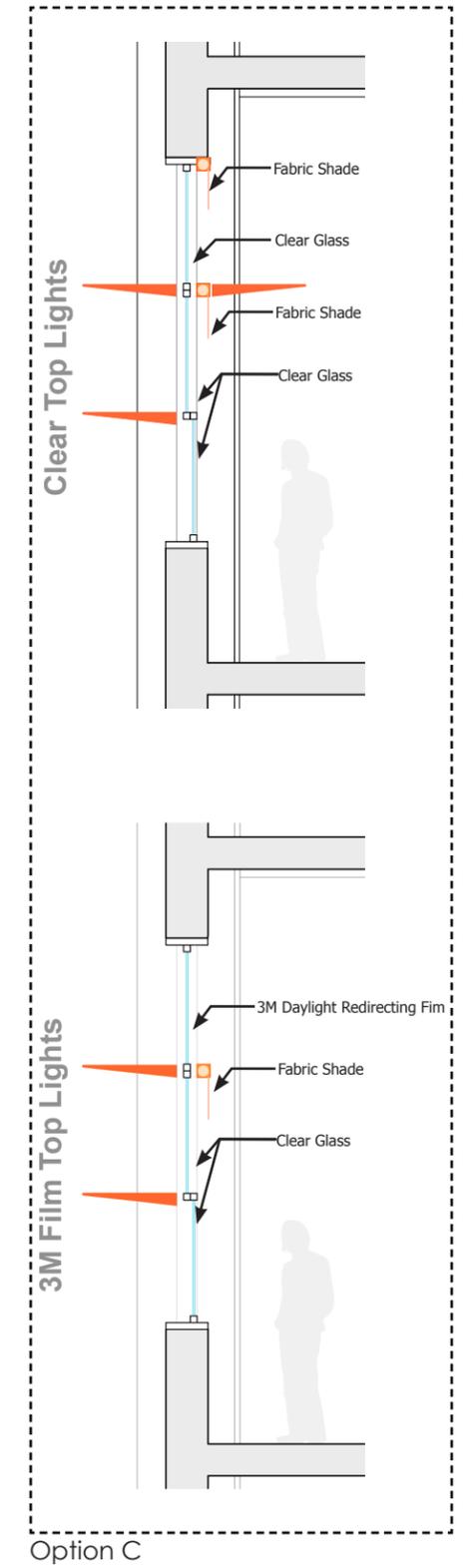
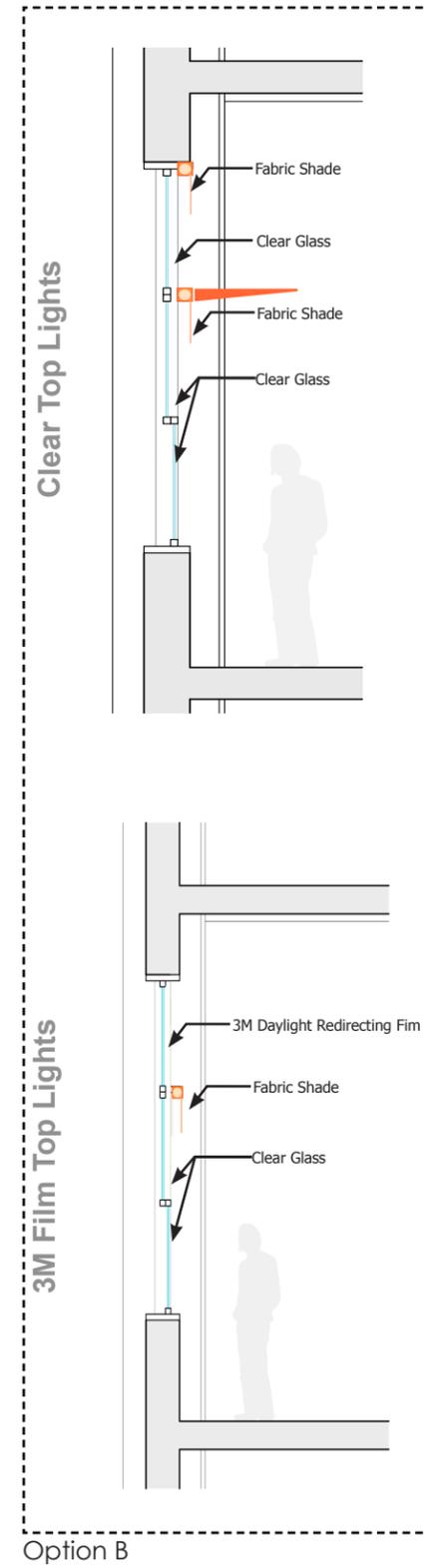
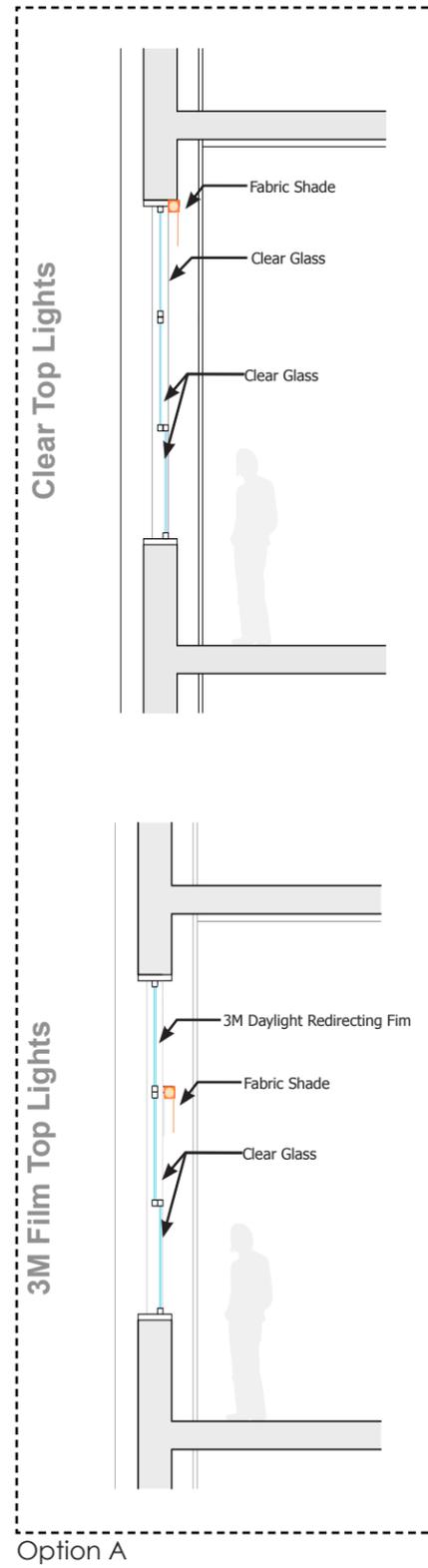
In all cases fabric roller-blinds are employed where necessary to reduce glare from bright skies and to control direct beam entering the space.



Fish-eye view of Typical Clear Sky



Fish-eye view of Typical Overcast Sky



3M Daylight Redirecting Film :: Illuminance Levels from Direct Sun on Window

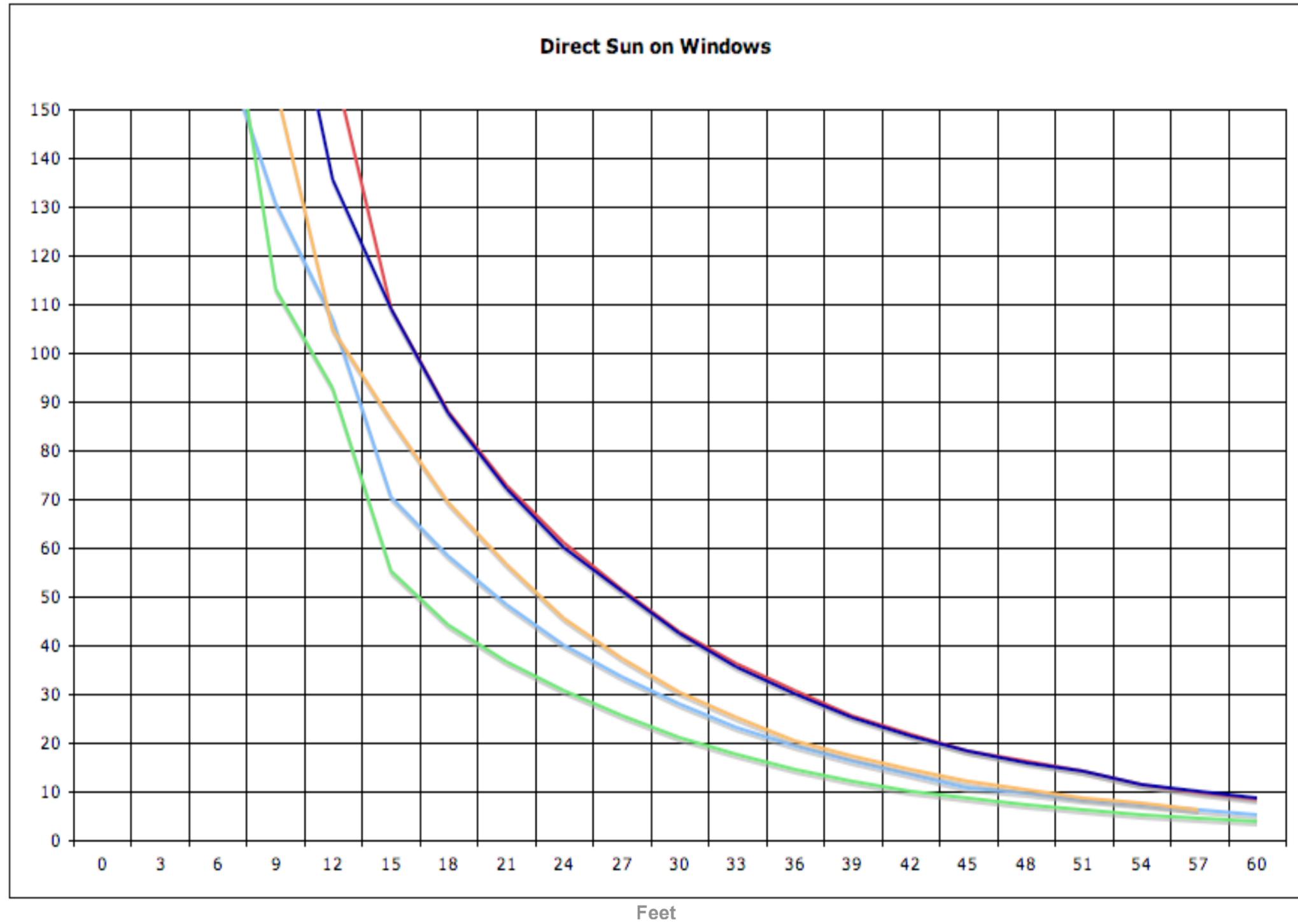
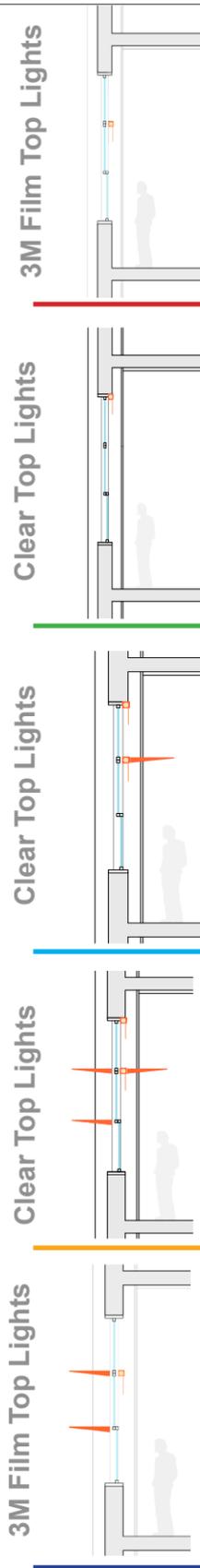
The proceeding analysis shows daylight penetration into a typical open-office space from diffuse sky-light and direct sun hitting the window for several fenestration options using both clear glass and the 3M Daylight Redirecting Film respectively. The illumination values are the average of three, key times of year representative of the full range of annual solar altitudes:

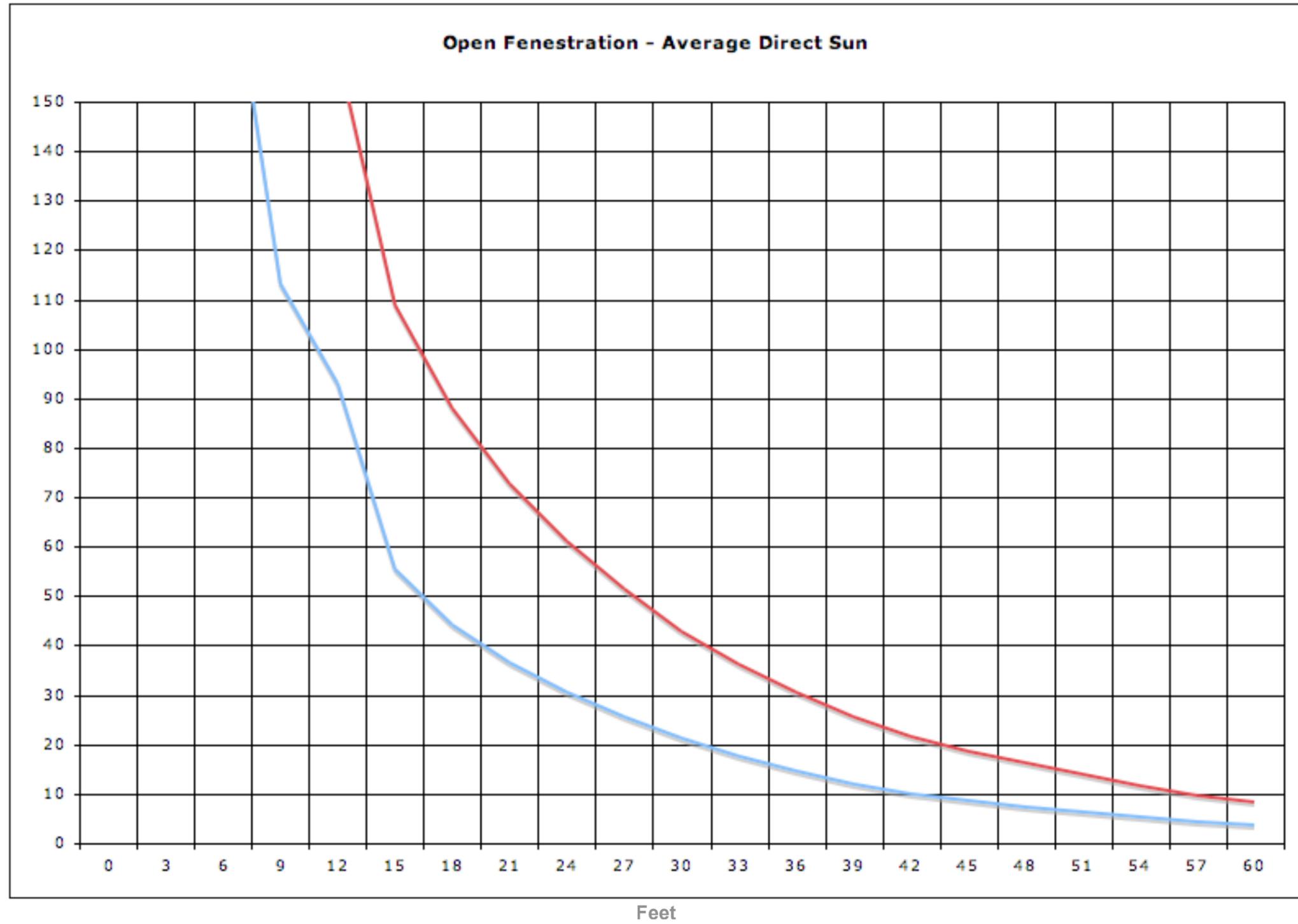
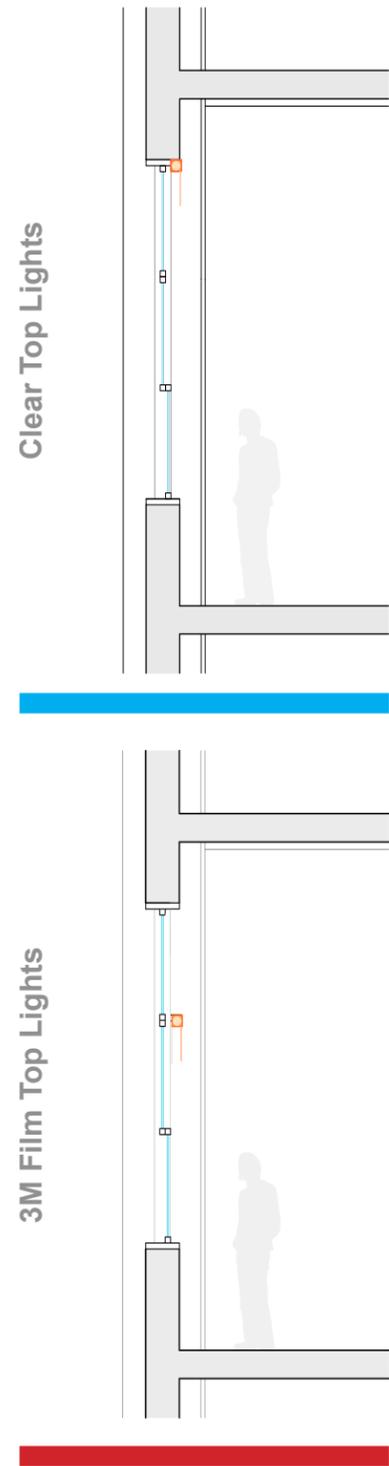
March 21 @ noon

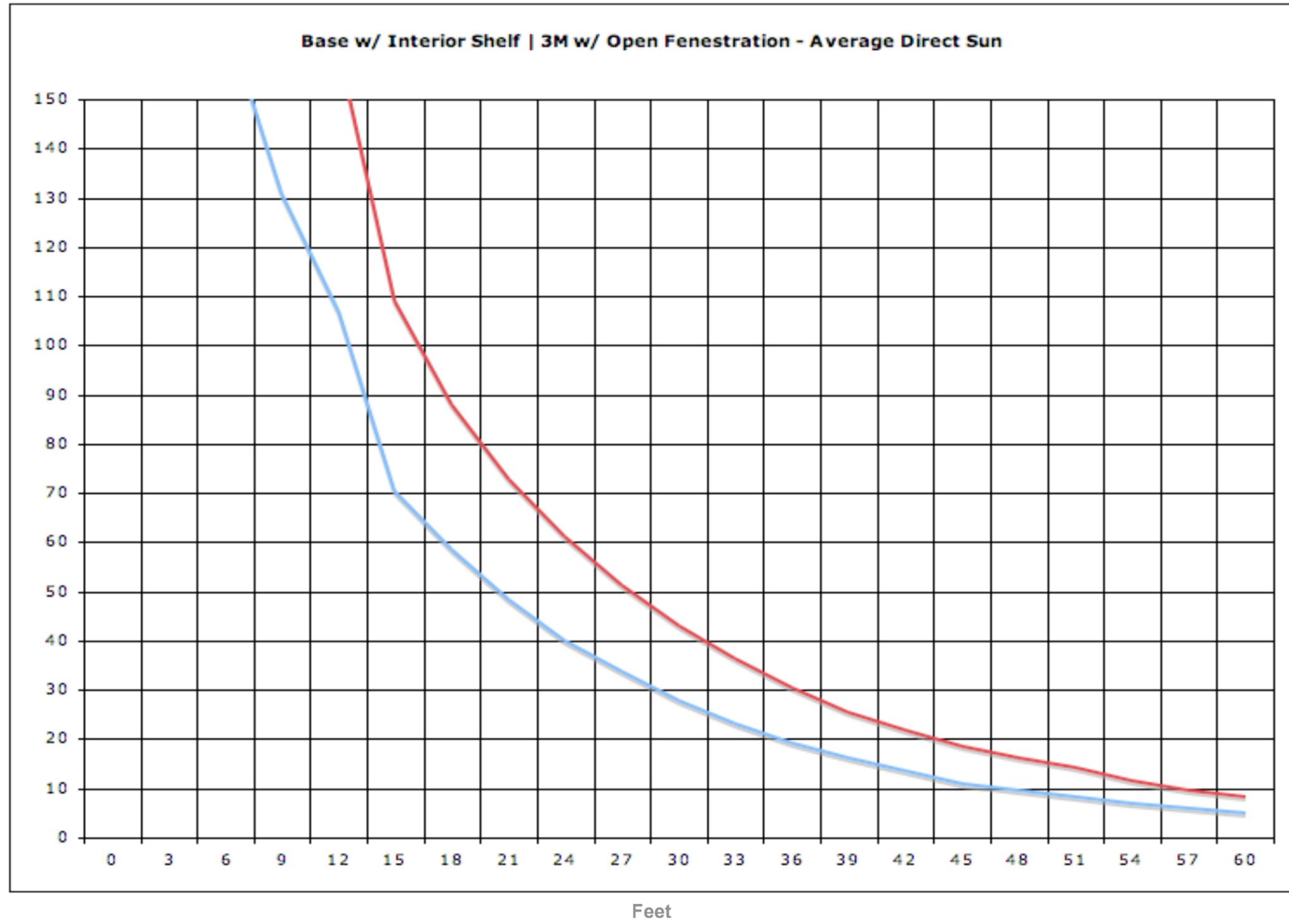
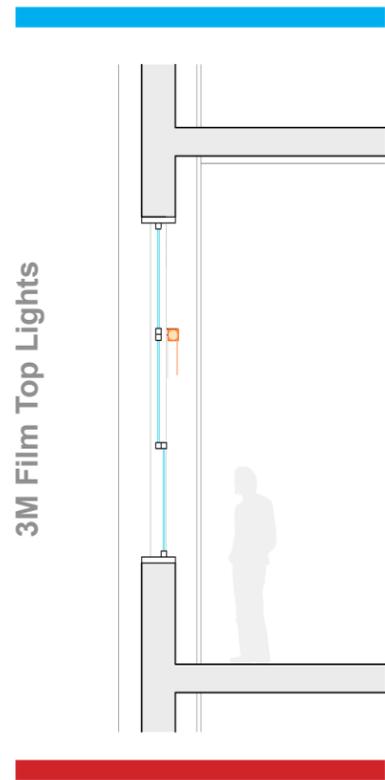
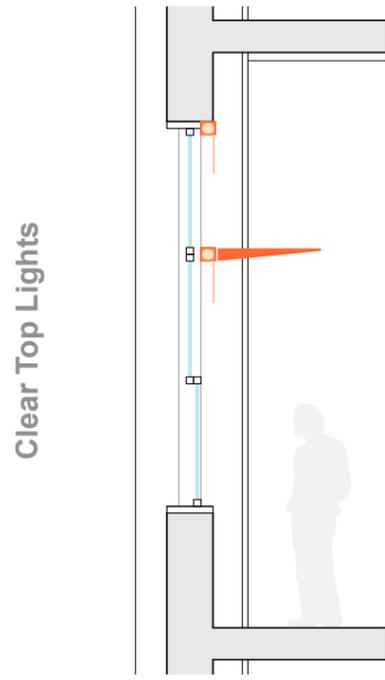
June 21 @ noon

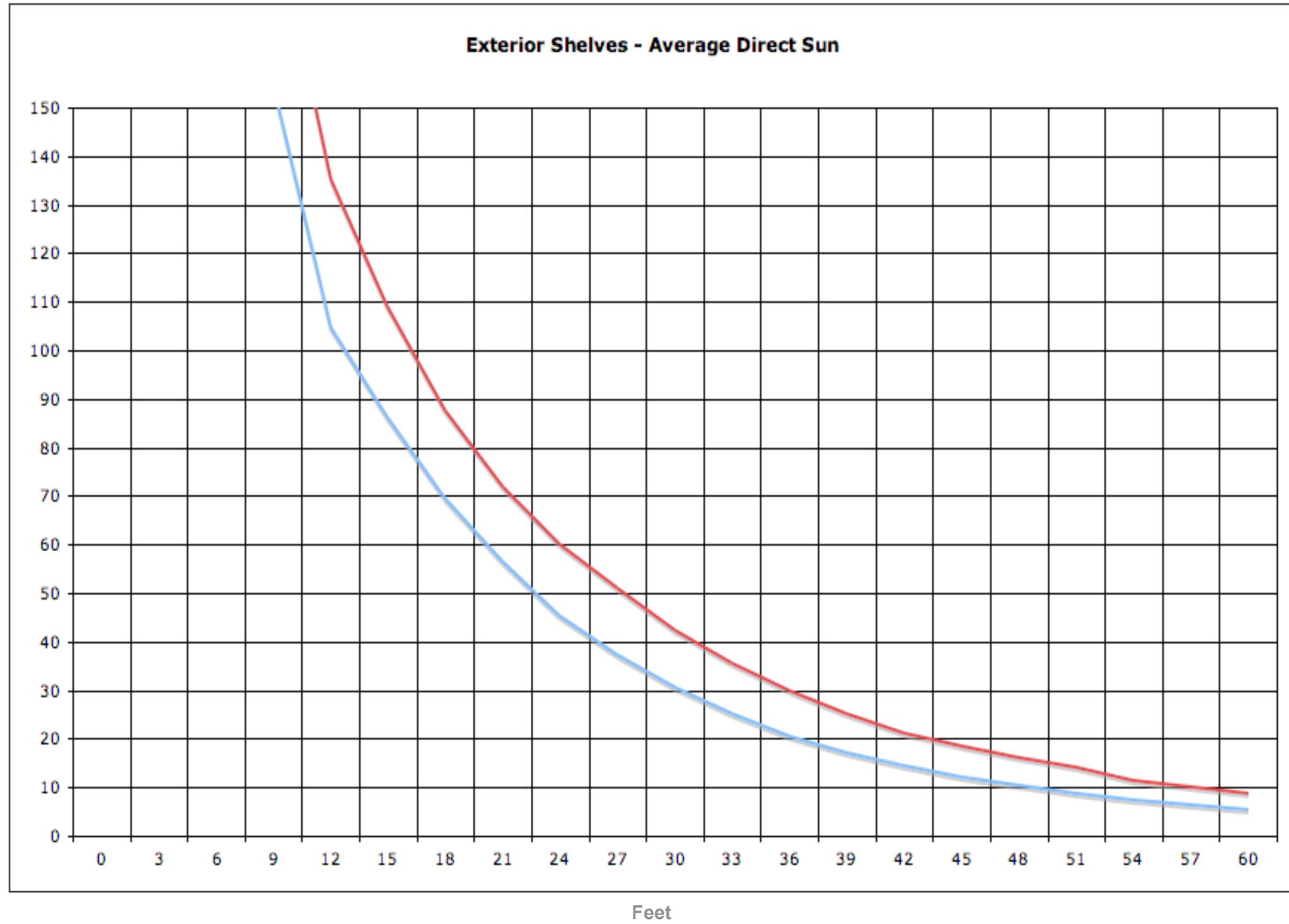
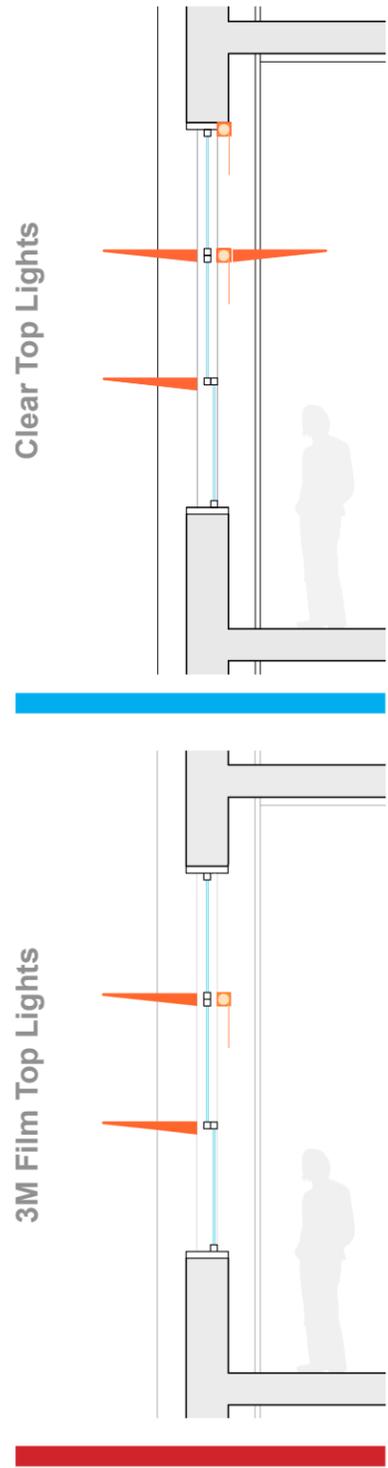
December 21 @ noon

3M Daylight Redirecting Film :: Illuminance Levels from Direct Sun on Window





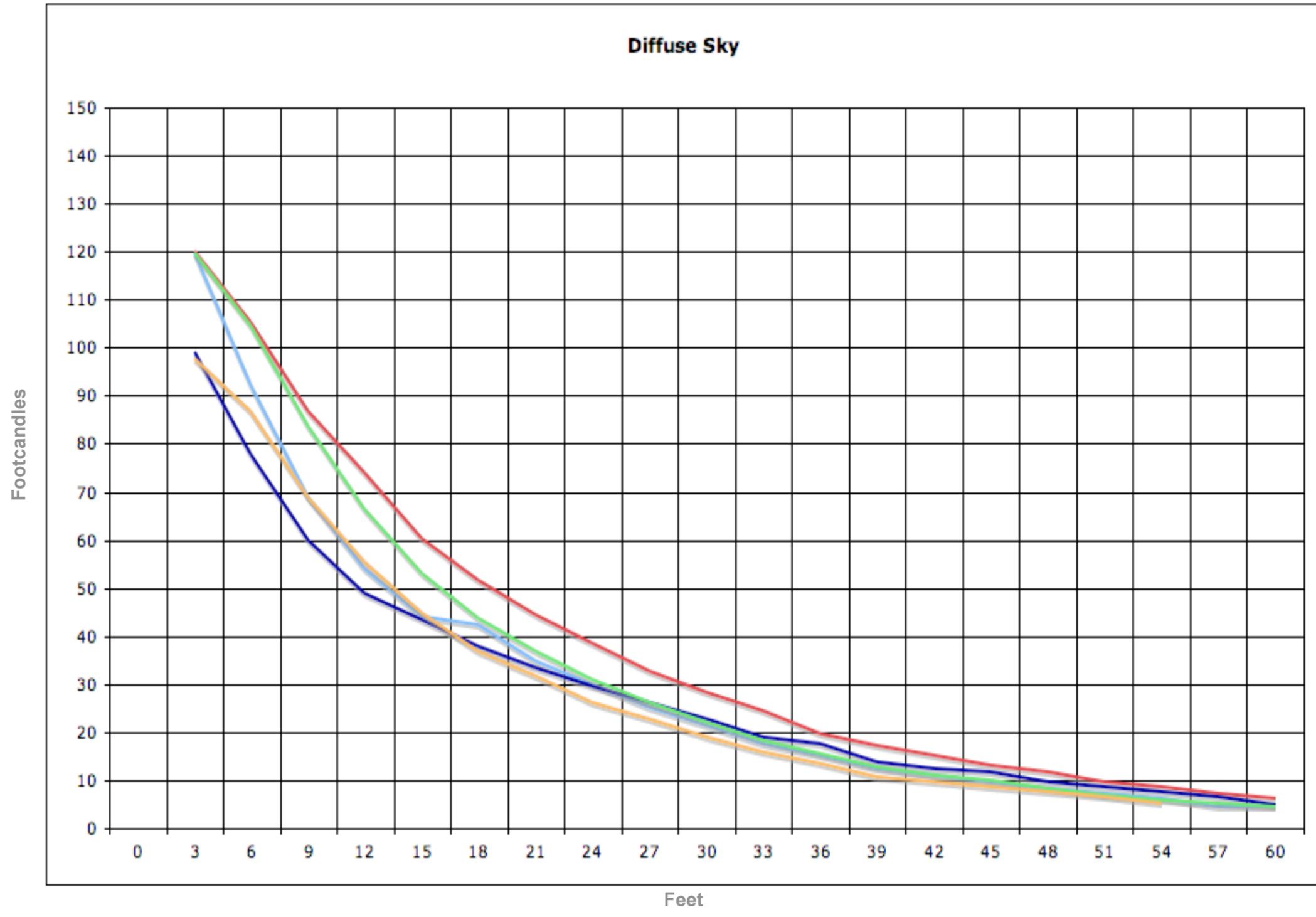
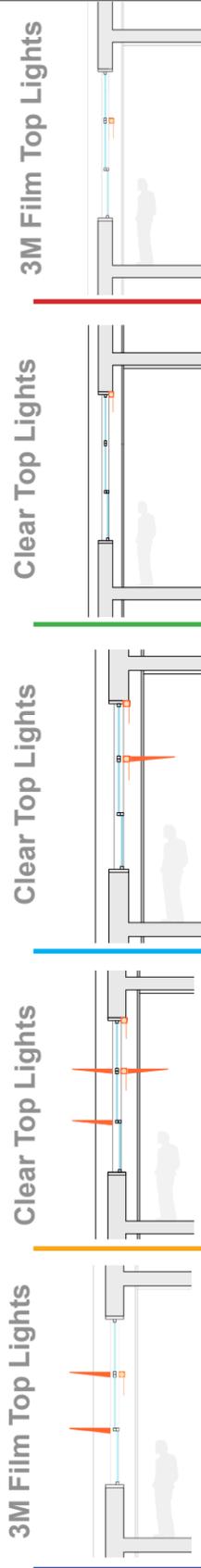


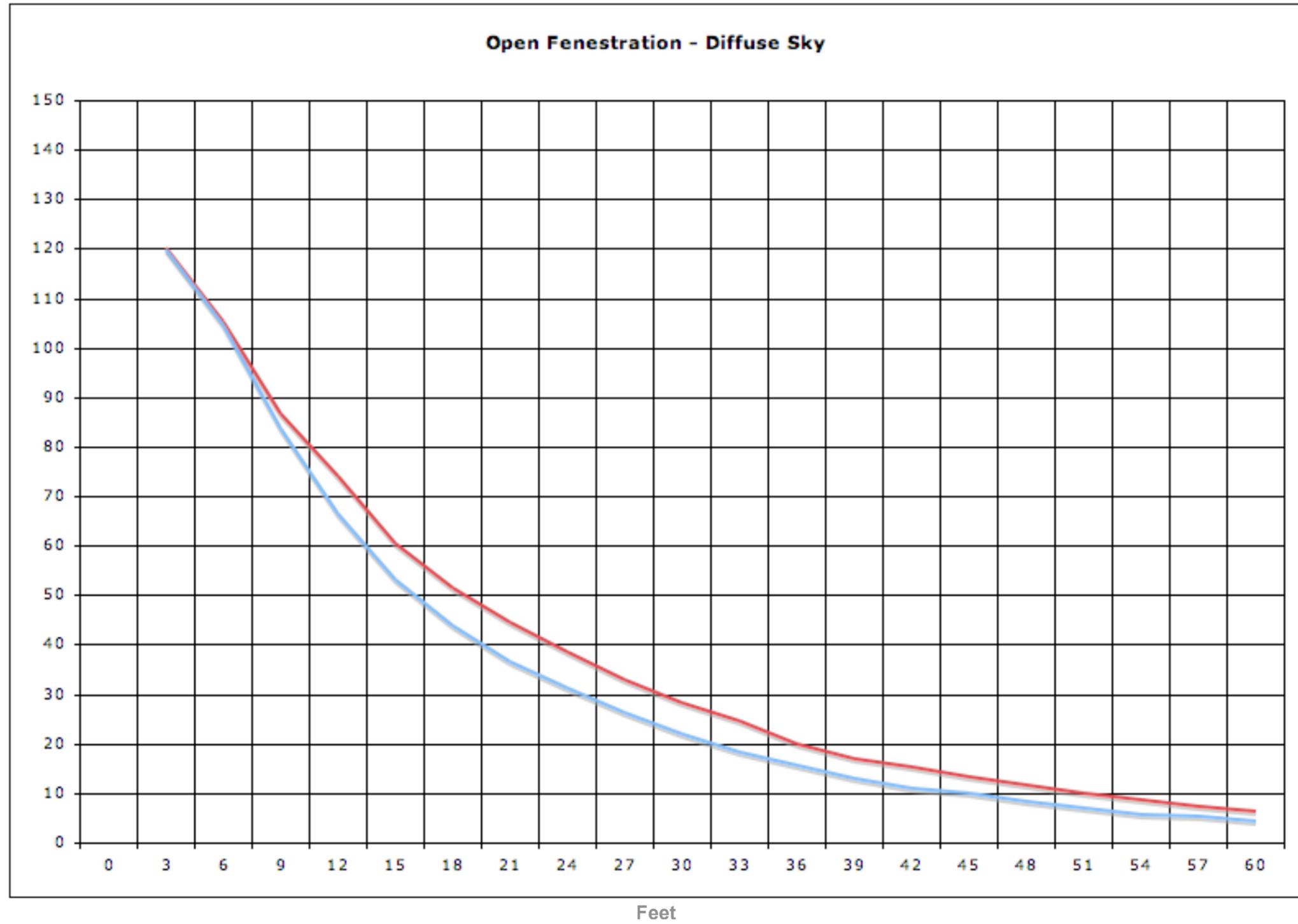
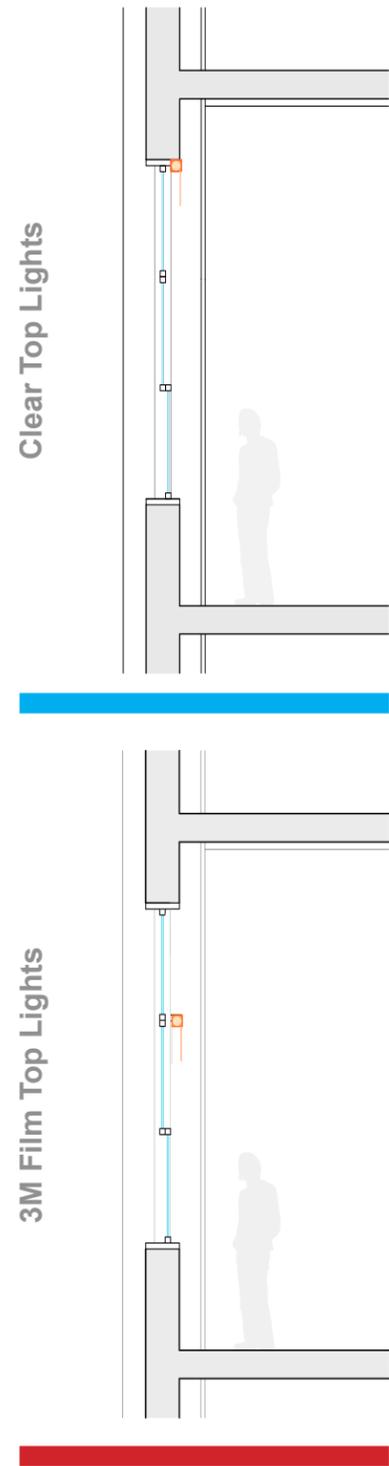


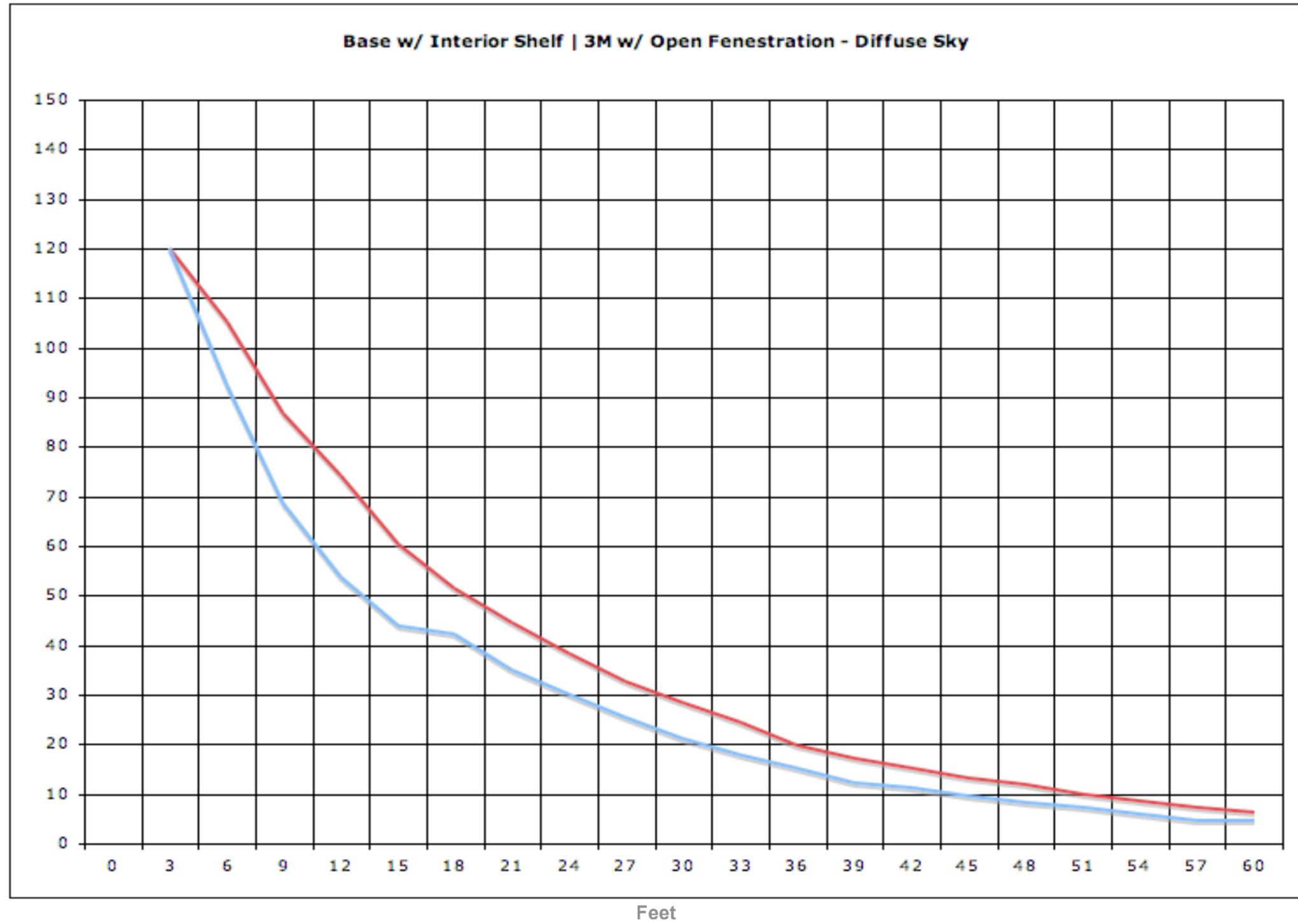
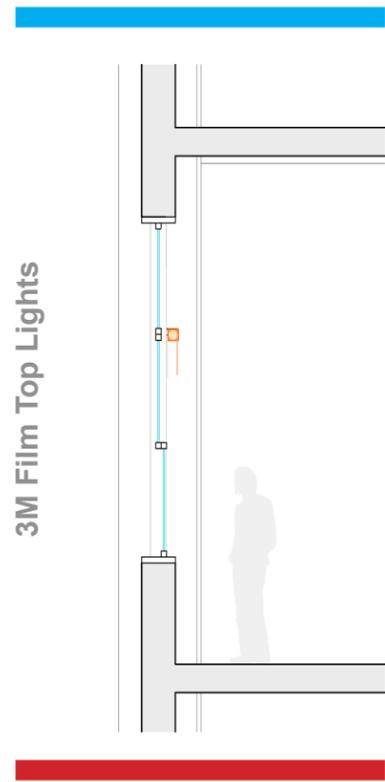
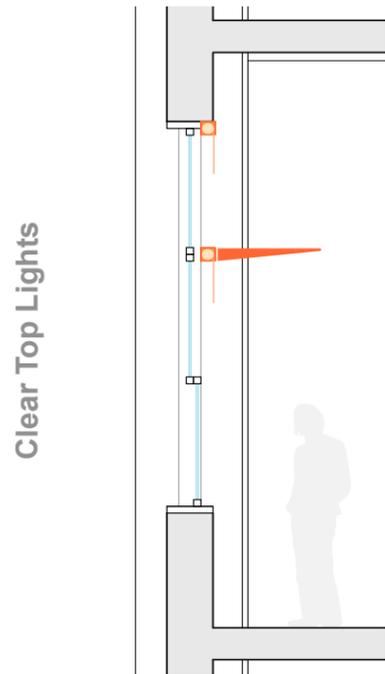
3M Daylight Redirecting Film :: Illuminance Levels from Diffuse Sky

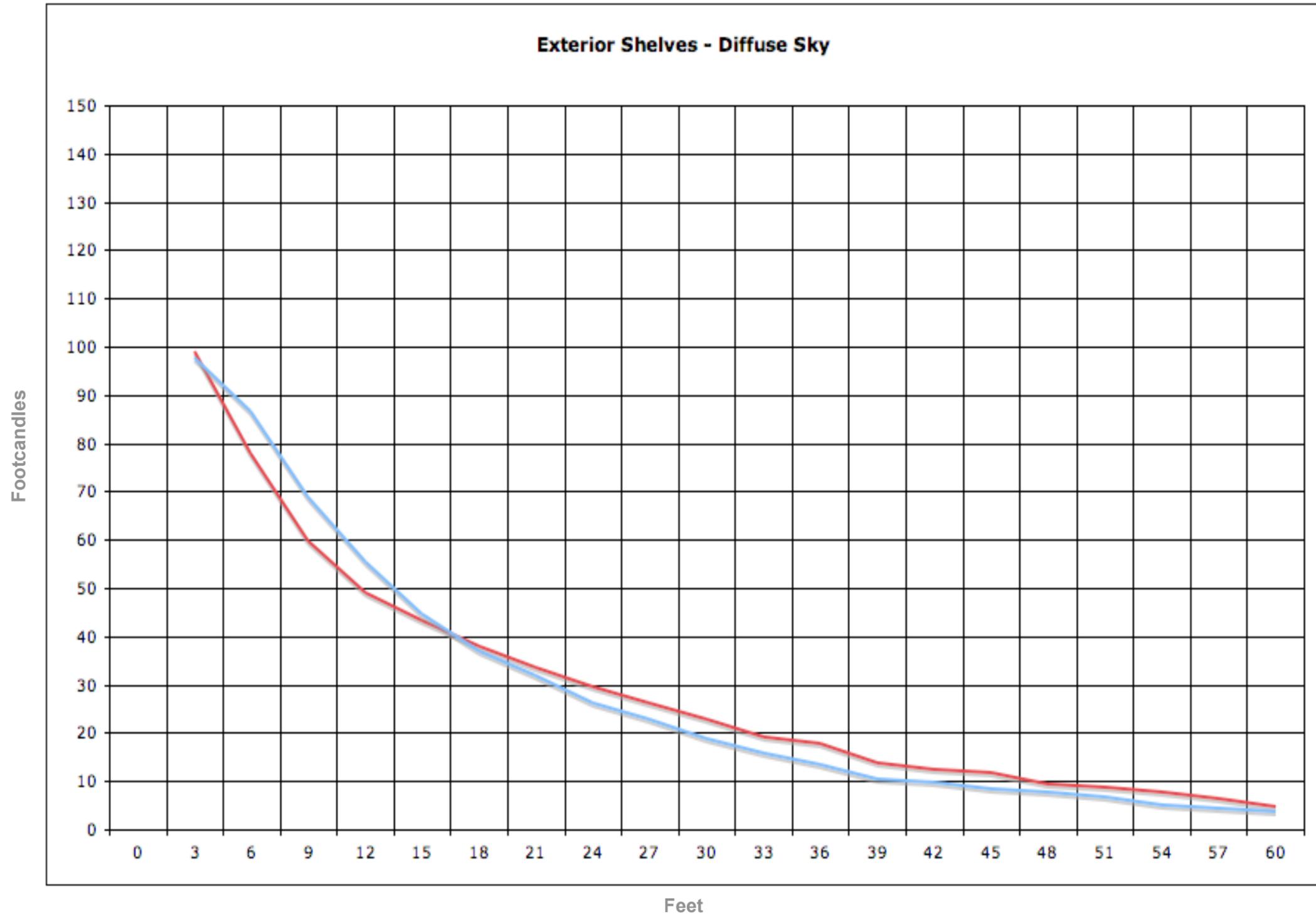
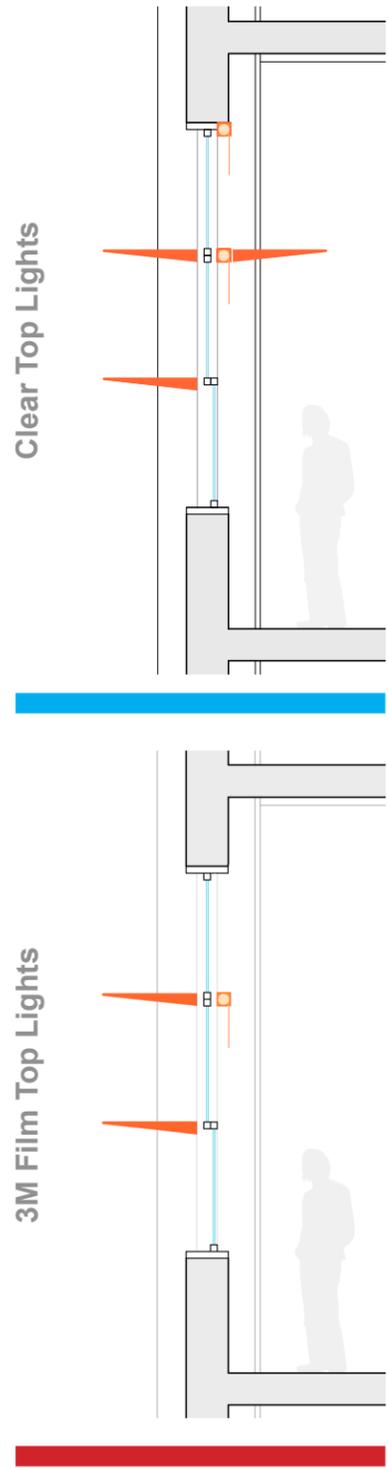
The proceeding analysis shows daylight penetration into a typical open-office space from diffuse sky-light (no direct sun) for several fenestration options using both clear glass and the 3M Daylight Redirecting Film respectively. The illumination values are for a typical March / September, clear sky day in the early morning or late afternoon when the sun is not incident on the window.

3M Daylight Redirecting Film :: Illuminance Levels from Diffuse Sky





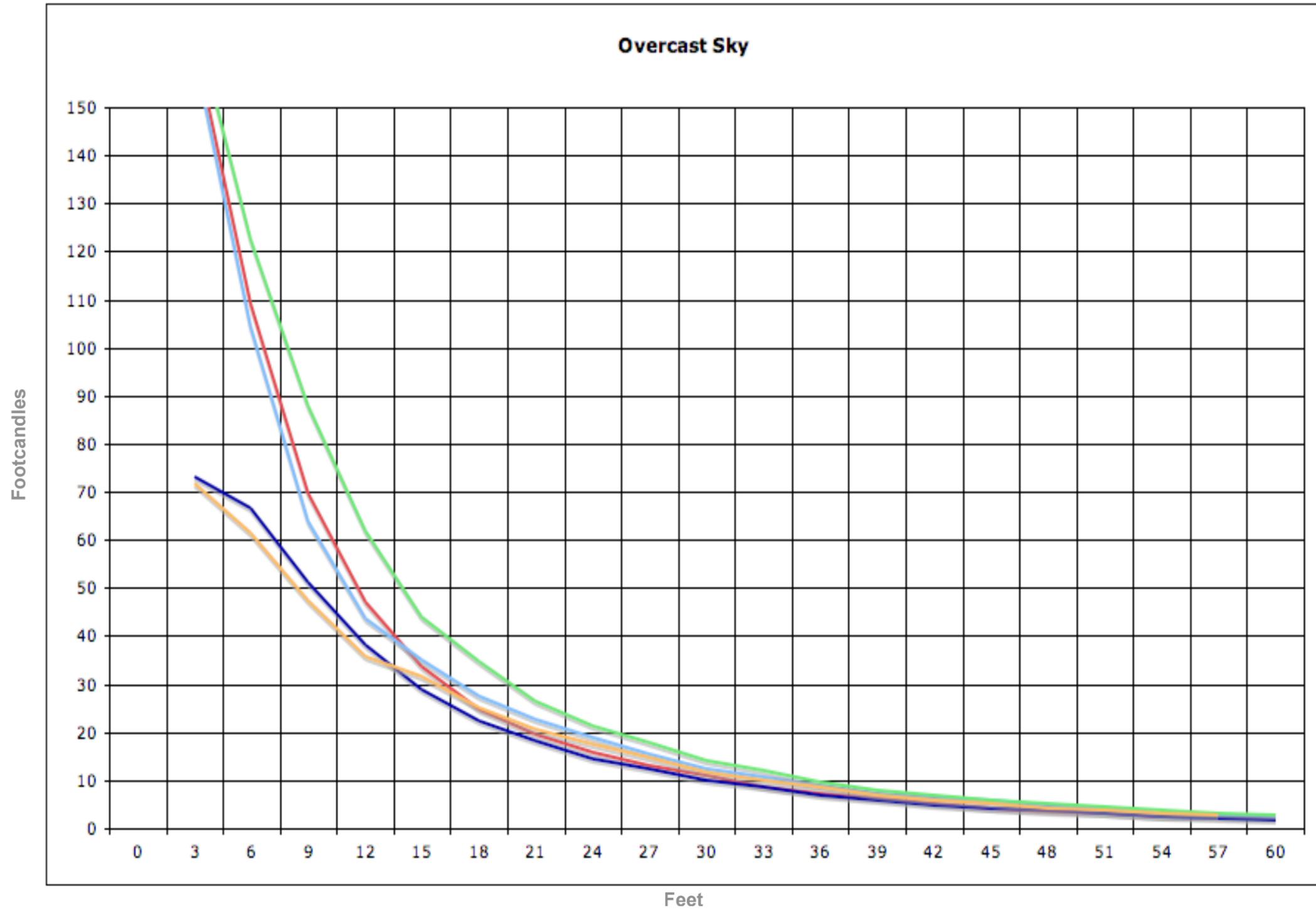
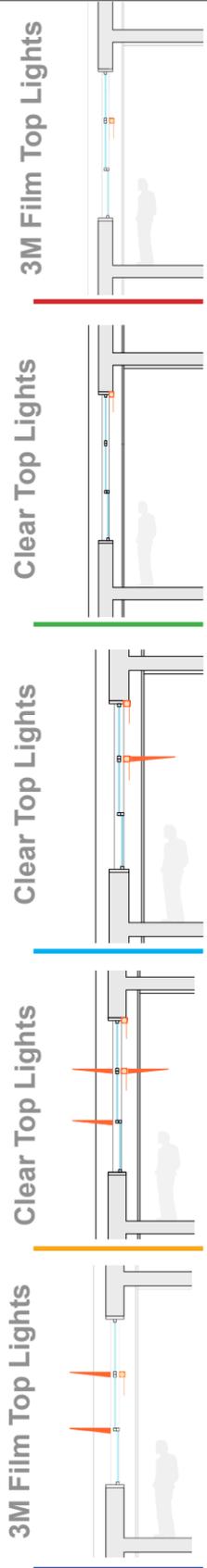


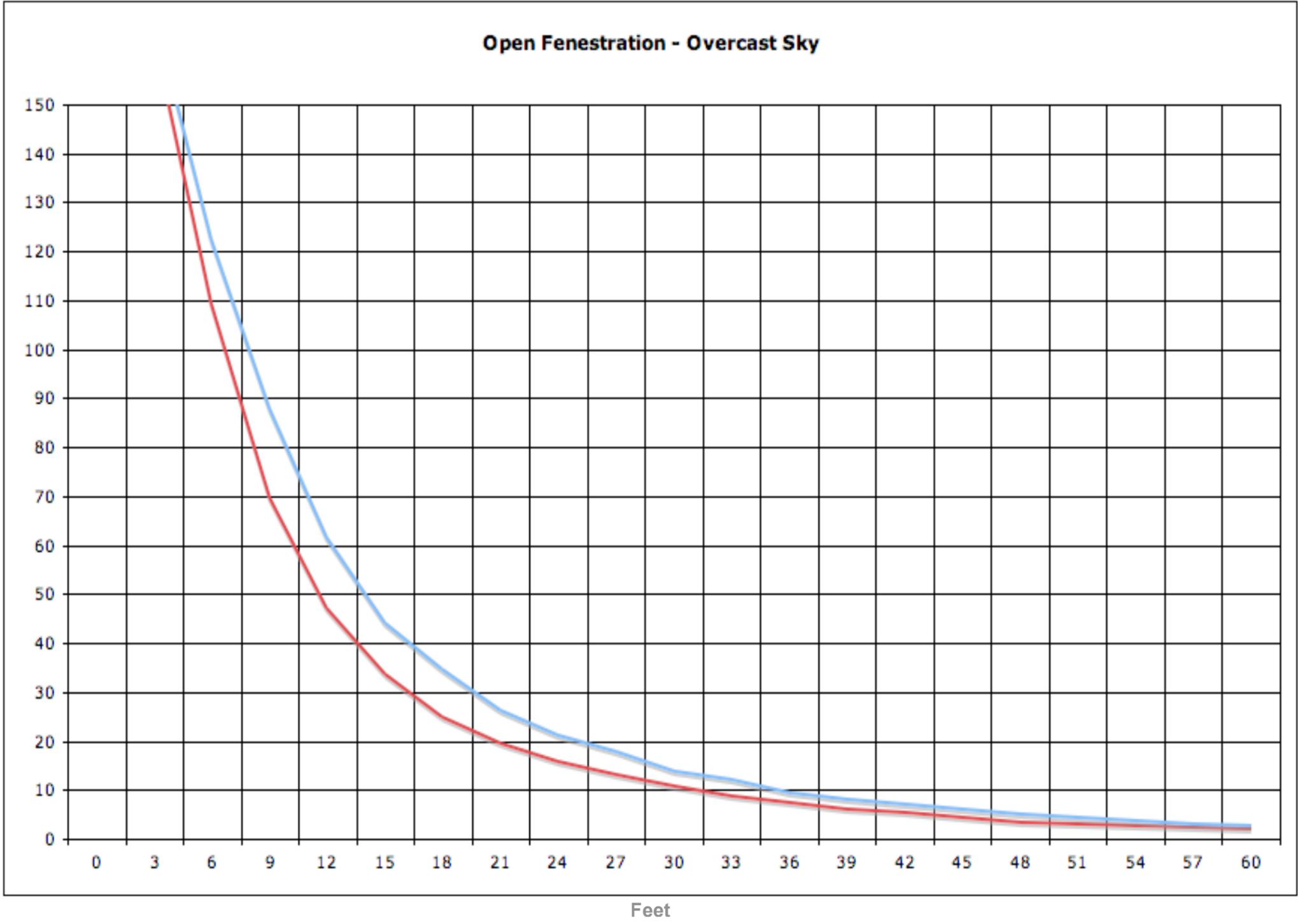
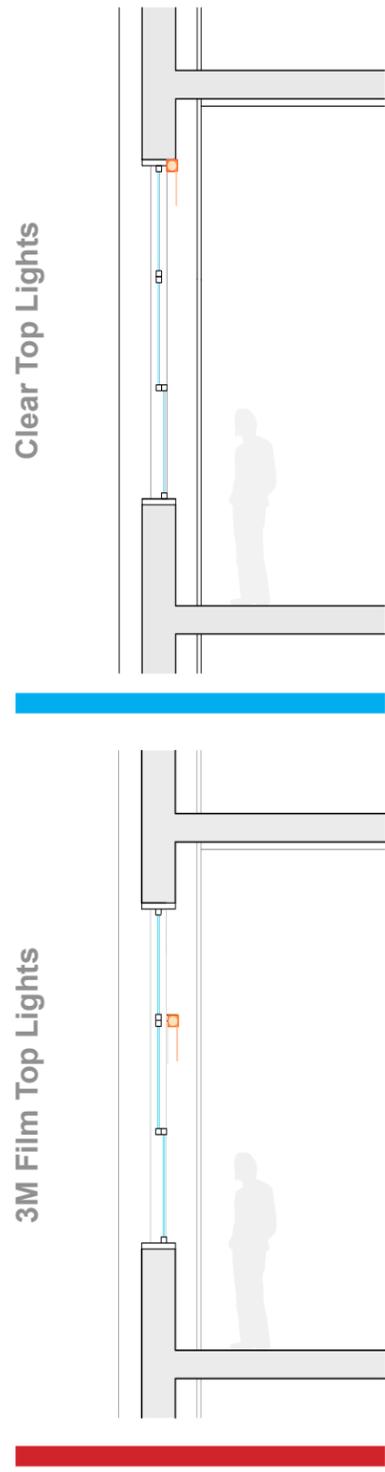


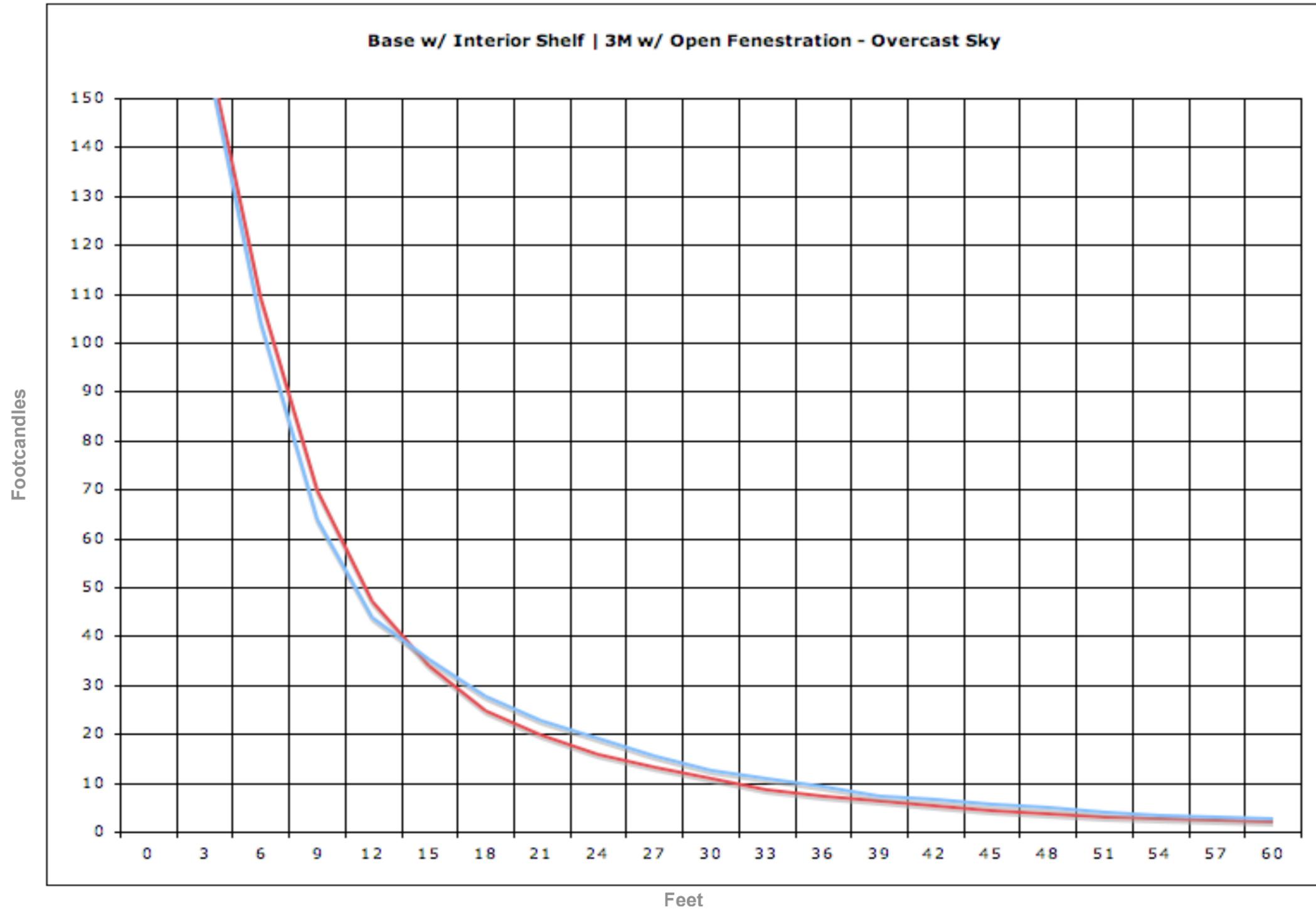
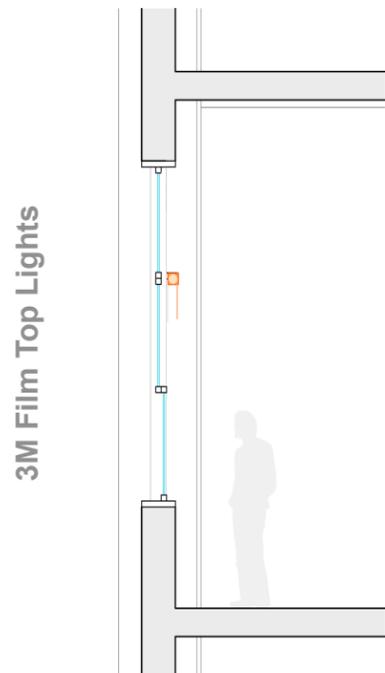
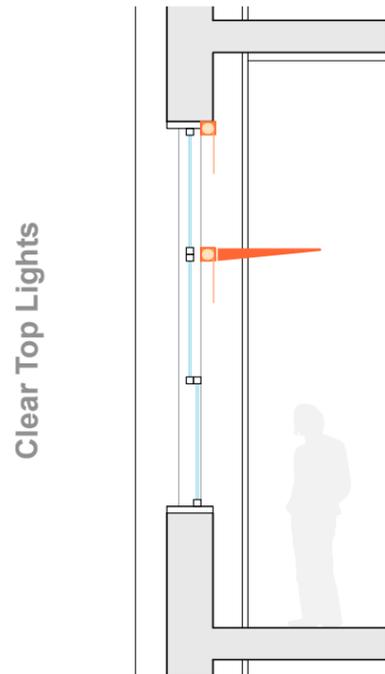
3M Daylight Redirecting Film :: Illuminance Levels from Overcast Sky

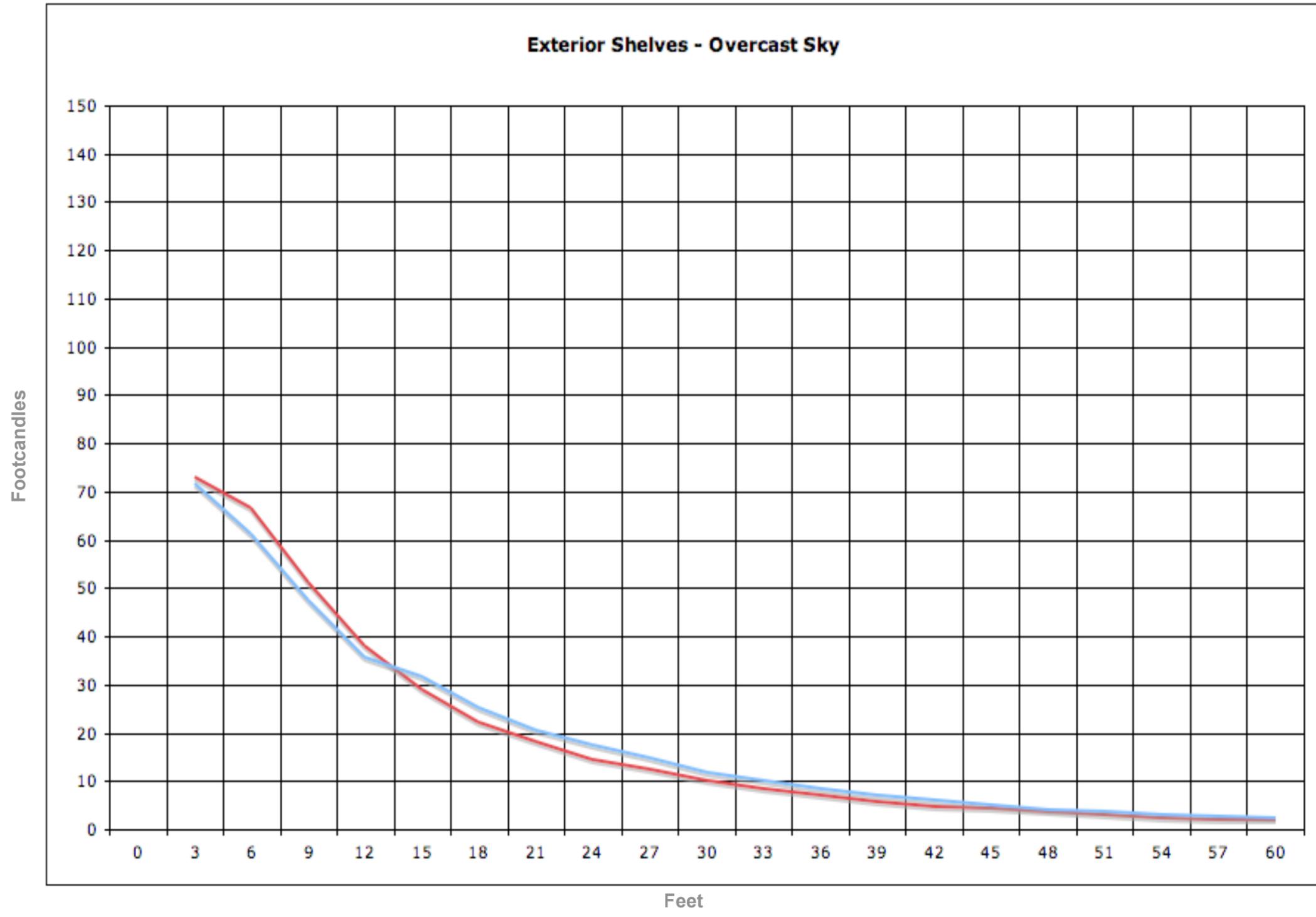
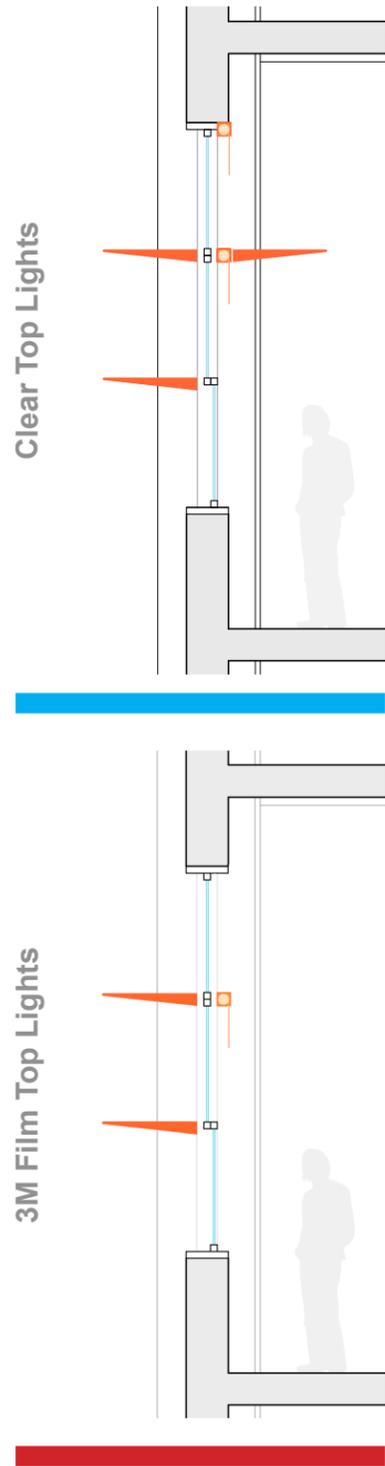
The proceeding analysis shows daylight penetration into a typical open-office space from completely overcast skies (no direct sun) for several fenestration options using both clear glass and the 3M Daylight Redirecting Film respectively. The illumination values are for a typical December overcast day at noon.

3M Daylight Redirecting Film :: Illuminance Levels from Overcast Sky









3M Daylight Redirecting Film :: HDR Images of Direct Sun on Window

The proceeding section show high dynamic range renderings of daylight distribution into a typical open-office space from diffuse sky-light and direct sun hitting the window for several fenestration options using both clear glass and the 3M Daylight Redirecting Film respectively.

Three, key times of year representative of the full range of annual solar altitudes were calculated:

March 21 @ noon

June 21 @ noon

December 21 @ noon

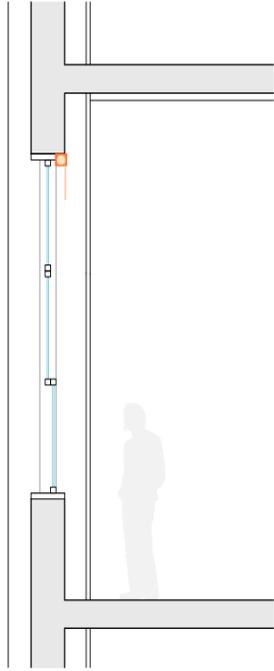
The calculations were post-processed with a tone mapping algorithm to approximate the human, visual response to the scene. The result is a close correlation to what a person's subjective impression to the space would be.

December @ 12:00 pm

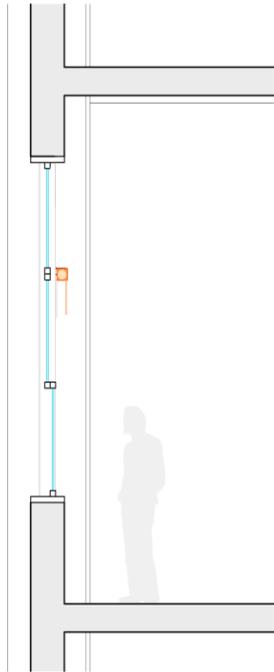
March @ 12:00 pm

June @ 12:00 pm

Clear Top Lights



3M Film Top Lights

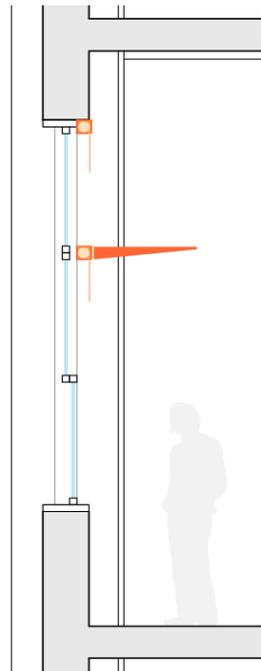


December @ 12:00 pm

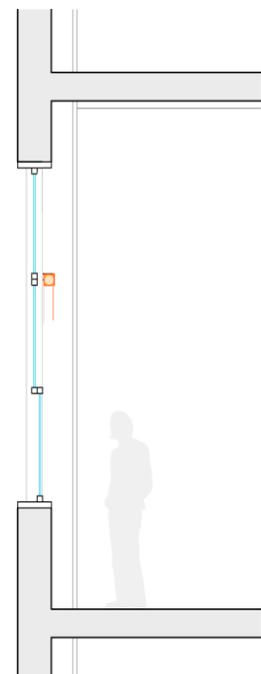
March @ 12:00 pm

June @ 12:00 pm

Clear Top Lights



3M Film Top Lights

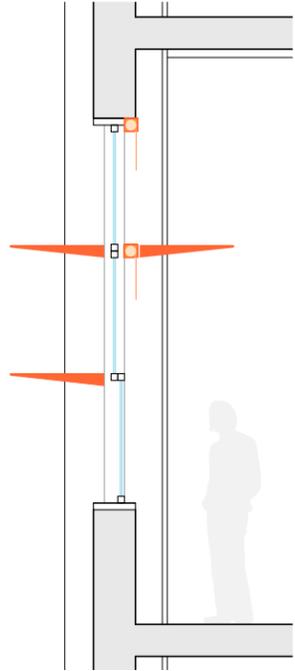


December @ 12:00 pm

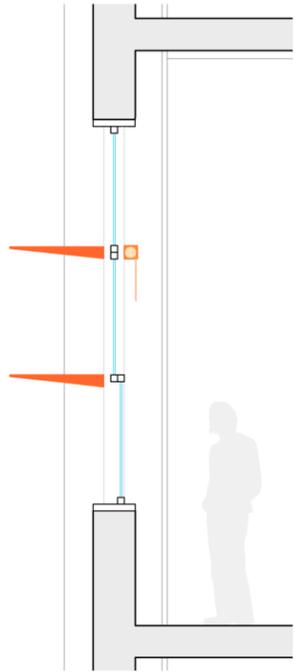
March @ 12:00 pm

June @ 12:00 pm

Clear Top Lights



3M Film Top Lights



3M Daylight Redirecting Film :: HDR Images of Overcast + Diffuse Skies

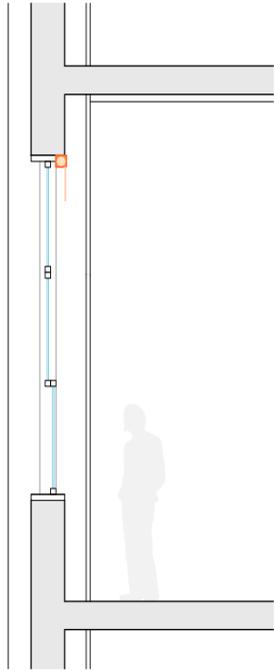
The proceeding section show high dynamic range renderings of day-light distribution into a typical open-office space from diffuse sky-light (no direct sun) and overcast skies for several fenestration options using both clear glass and the 3M Daylight Redirecting Film respectively. The calculations shown are for a typical March / September, clear sky day in the early morning or late afternoon and a typical overcast day in December.

The calculations were post-processed with a tone mapping algorithm to approximate the human, visual response to the scene. The result is a close correlation to what a person's subjective impression to the space would be.

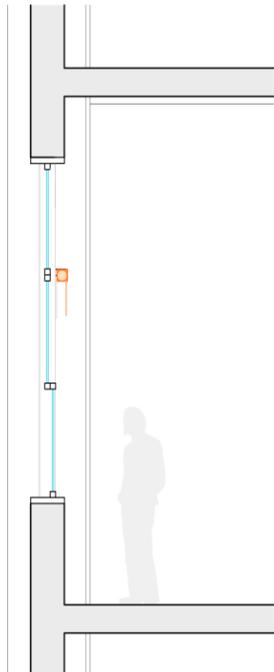
December @ 12:00 pm Overcast

March @ 3:00 pm Clear Skies

Clear Top Lights



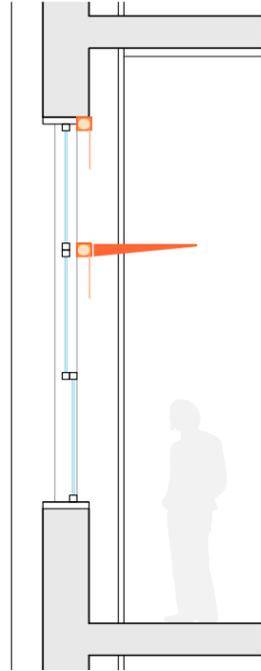
3M Film Top Lights



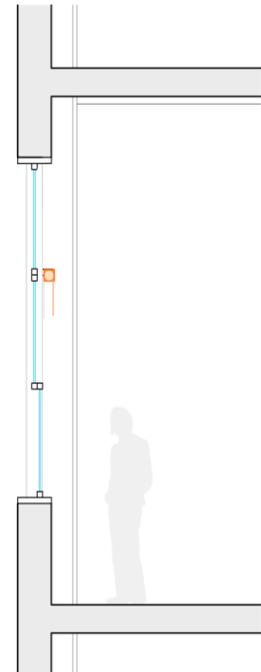
December @ 12:00 pm Overcast

March @ 3:00 pm Clear Skies

Clear Top Lights



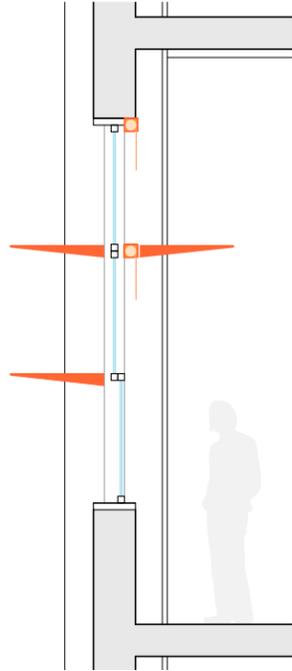
3M Film Top Lights



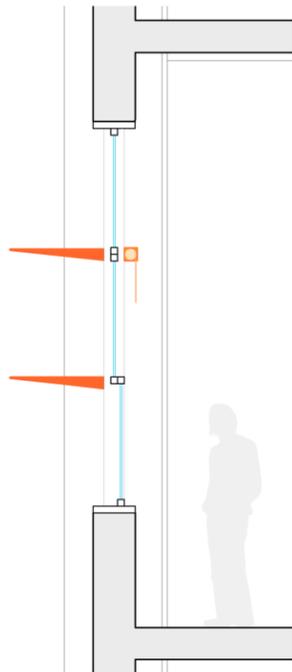
December @ 12:00 pm Overcast

March @ 3:00 pm Clear Skies

Clear Top Lights



3M Film Top Lights



3M Daylight Redirecting Film :: Glare Analysis of Direct Sun on Window

Visual comfort depends primarily on two conditions: quantity of light falling on a point (illuminance) and brightness of surfaces in the visual field (luminance). Most codes, guidelines, and lighting professionals concern themselves primarily with illuminance values, but the relative brightness of surfaces within the field of view contributes just as much to our visual comfort. Excessive contrast between adjacent surfaces causes glare, especially when those surfaces take up a large portion of our visual field. Because direct sun light is so much brighter than sky light, direct beam in a space can also cause discomfort glare when it falls within our visual field.

The proceeding sections shows false-color luminance (brightness) images of the preceding section's HDR images. For reference, glare conditions often result from contrast ratios exceeding 20:1 in a day-lighted space and 10:1 in a space primarily lighted with electric lighting.

In addition the metric of Daylight Glare Probability (DGP) is calculated for each image. DGP is a subjective measure based on several hundred test subjects in a controlled daylighted space. The value is derived from the vertical illumination measured at eye level within the scene and describes the percentage of people disturbed by daylight. DGP is broken down in to several categories according to perceptible levels of visual comfort:

<= 38% Imperceptible

<= 42% Perceptible

<= 53% Disturbing

> 53% Intolerable

A DGP value less than 38% is recommended. A DGP value over 38% suggests that those percentages of people perceive visual discomfort within the scene.

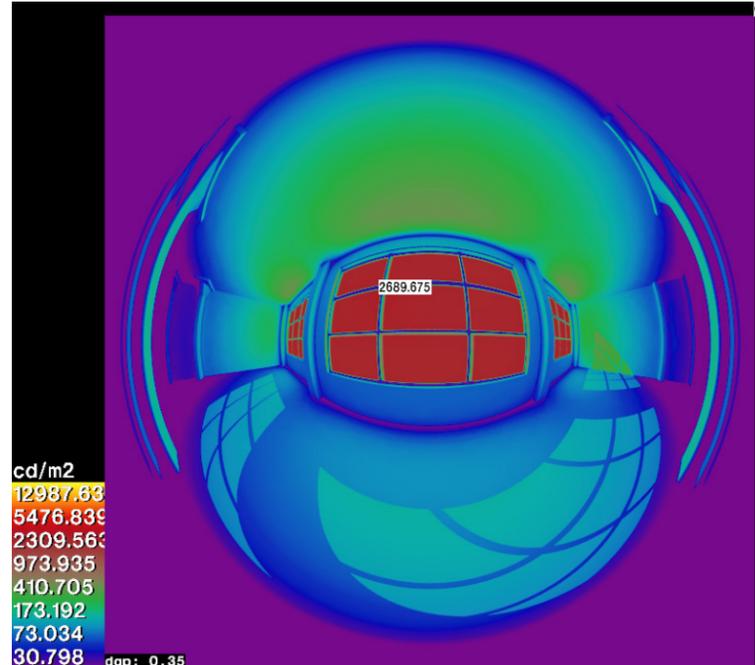
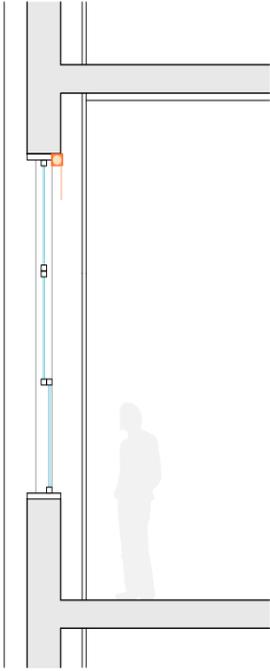
DGP
 <= 38% Imperceptible
 <= 42% Perceptible
 <= 53% Disturbing
 > 53% Intolerable

December @ 12:00 pm

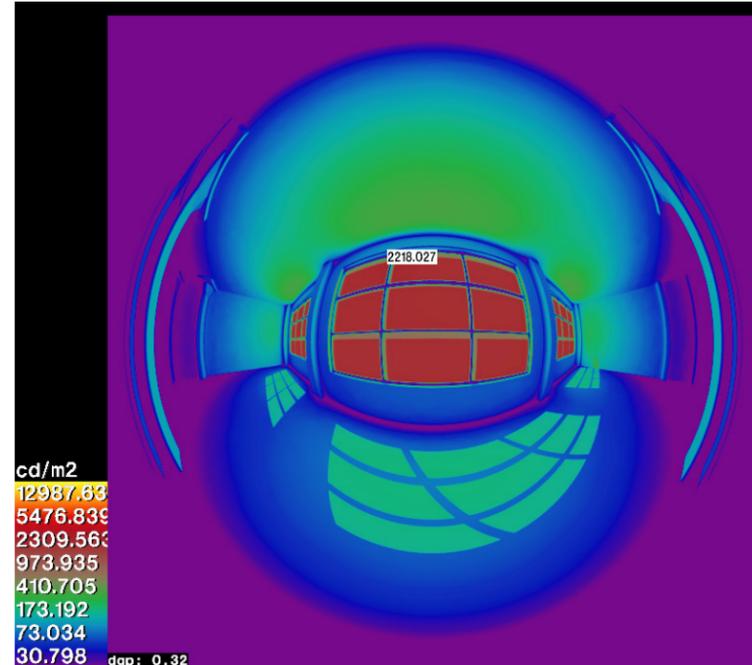
March @ 12:00 pm

June @ 12:00 pm

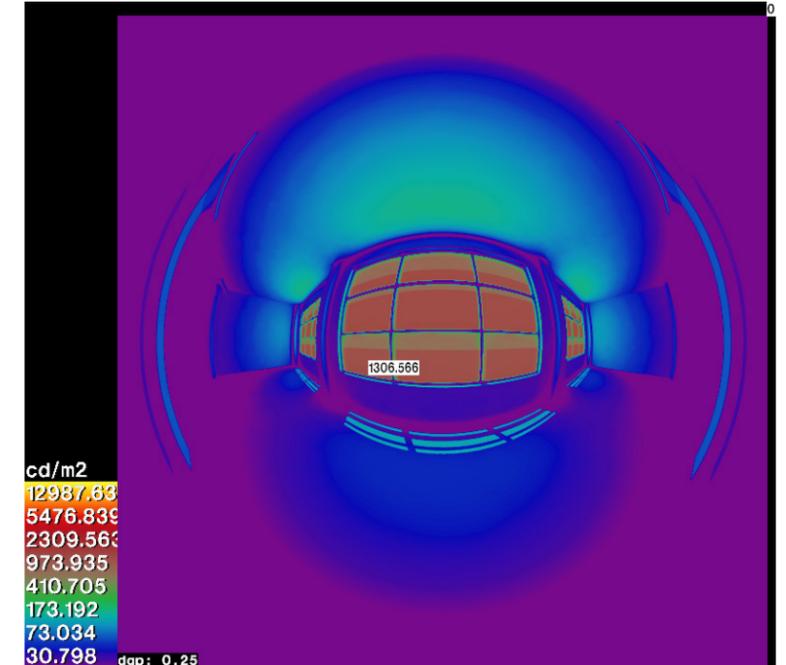
Clear Top Lights



DGP: 35%

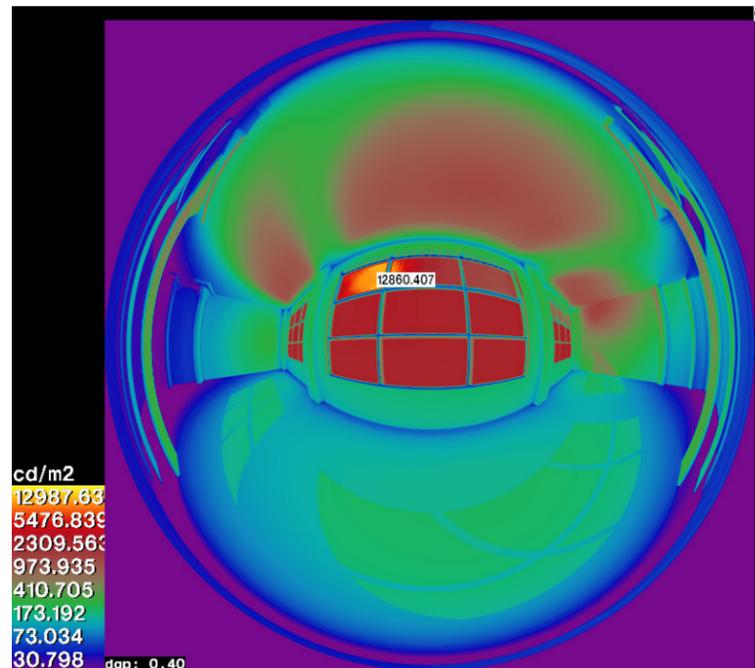
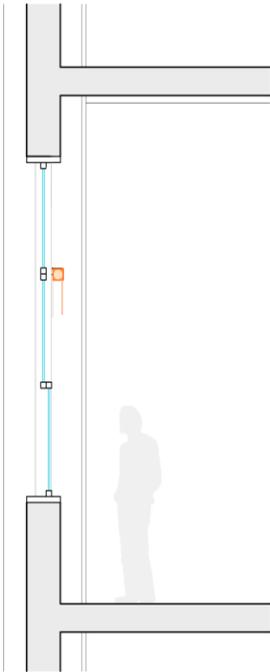


DGP: 32%

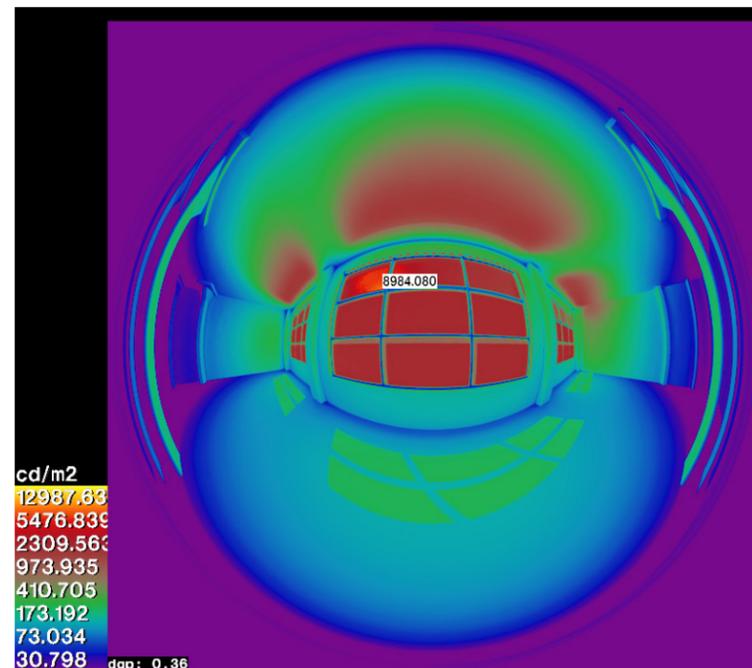


DGP: 25%

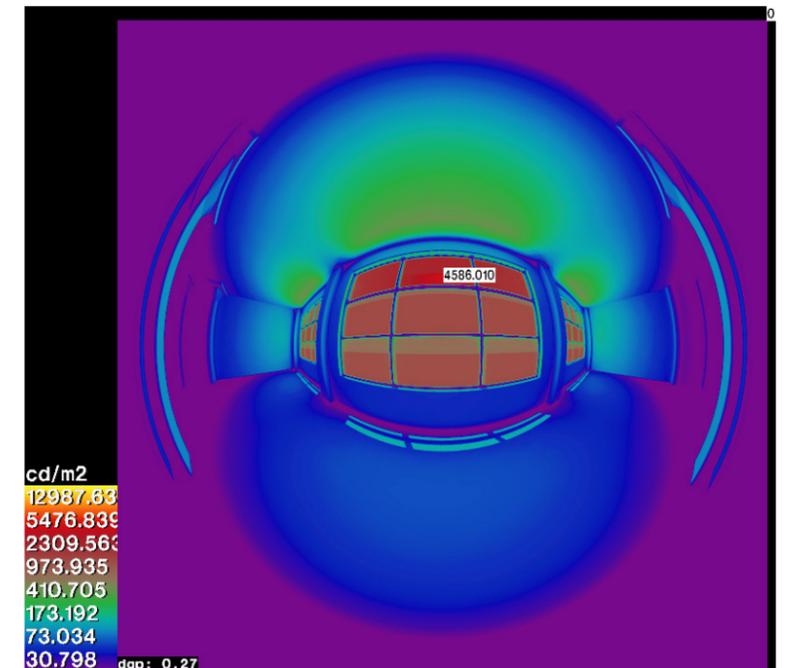
3M Film Top Lights



DGP: 40%



DGP: 36%



DGP: 27%

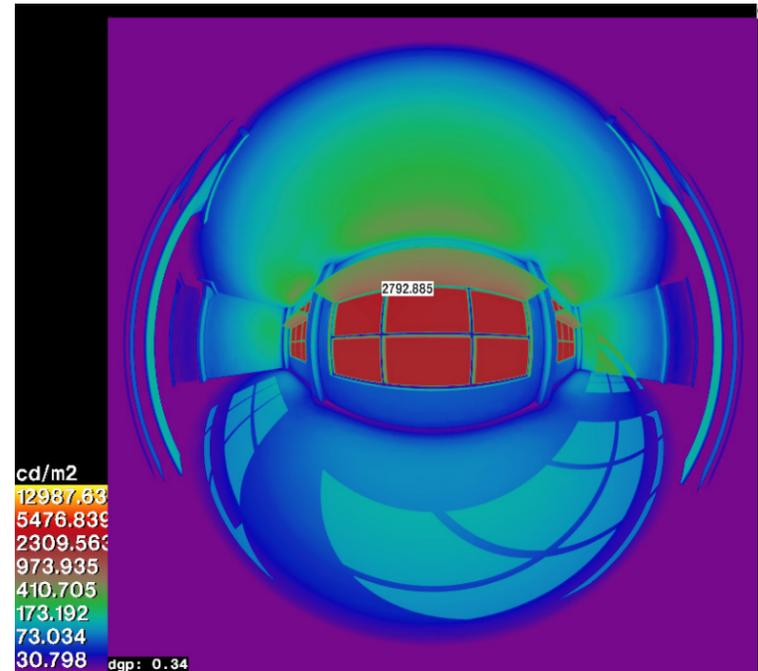
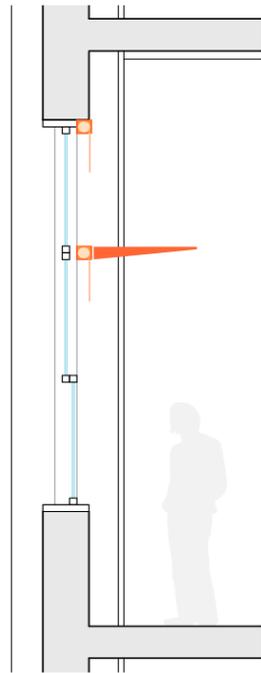
DGP
 <= 38% Imperceptible
 <= 42% Perceptible
 <= 53% Disturbing
 > 53% Intolerable

December @ 12:00 pm

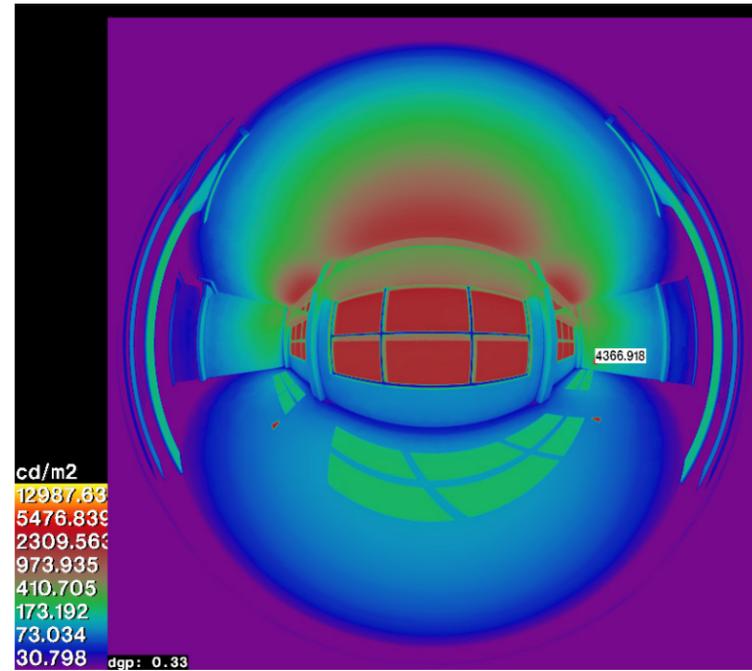
March @ 12:00 pm

June @ 12:00 pm

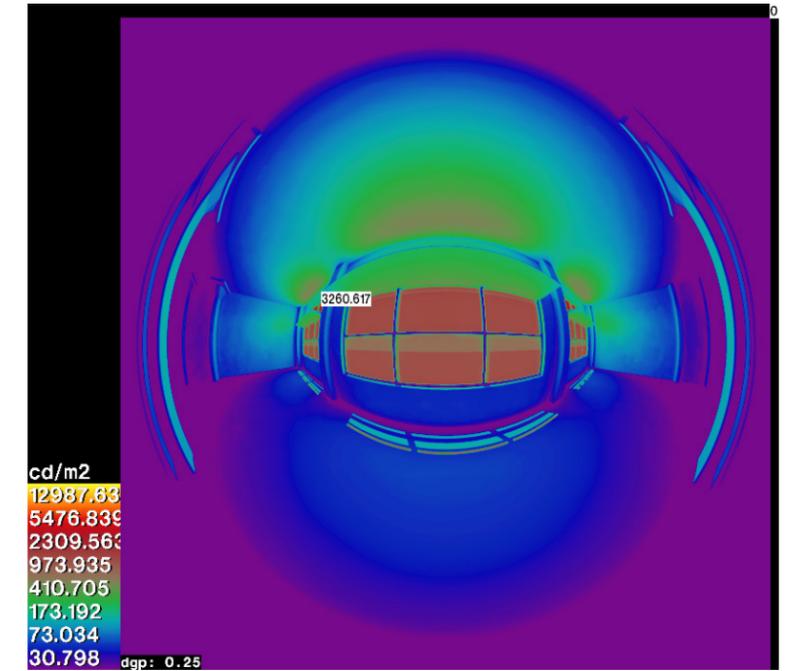
Clear Top Lights



DGP: 34%

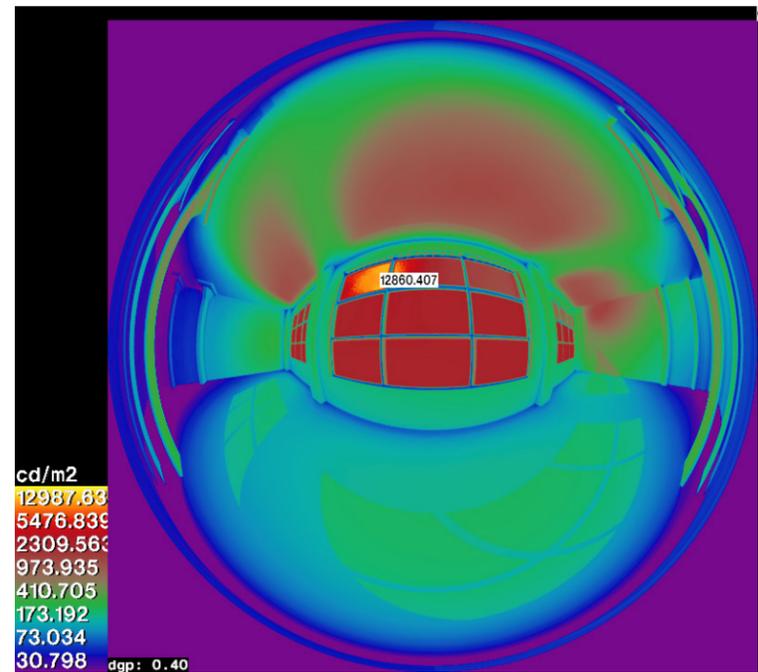
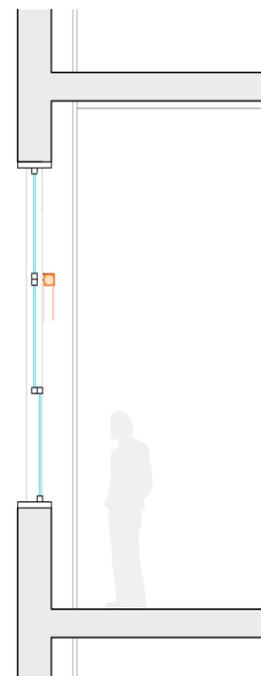


DGP: 33%

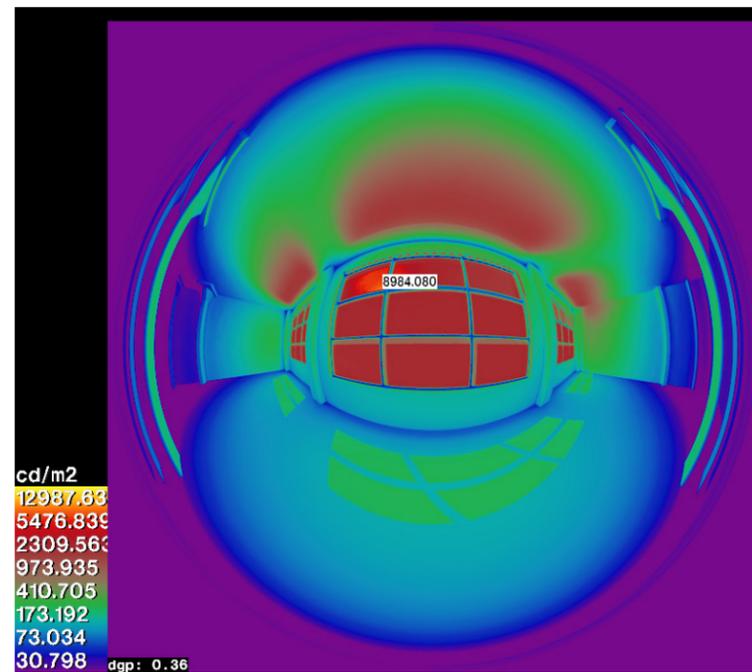


DGP: 25%

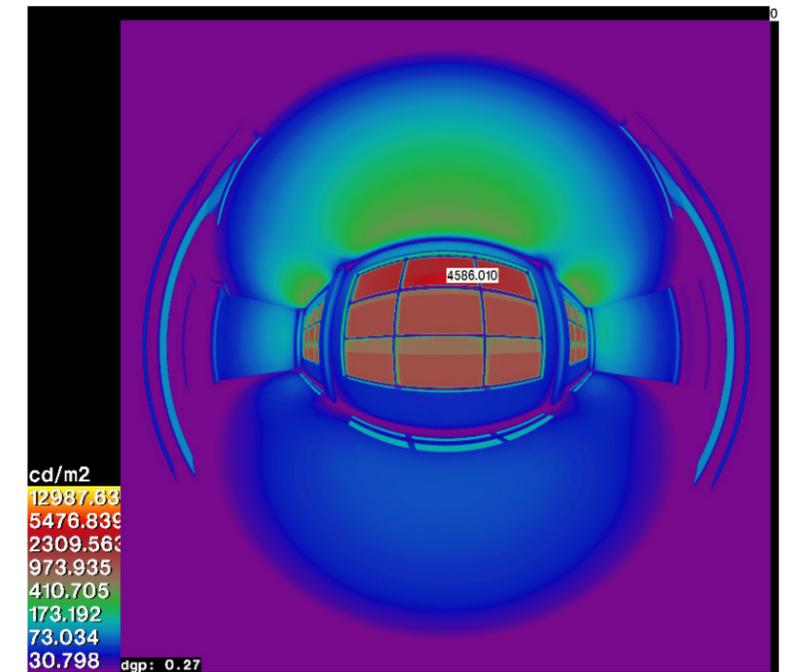
3M Film Top Lights



DGP: 40%



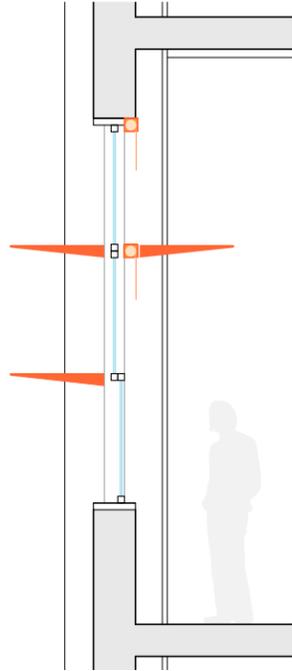
DGP: 35%



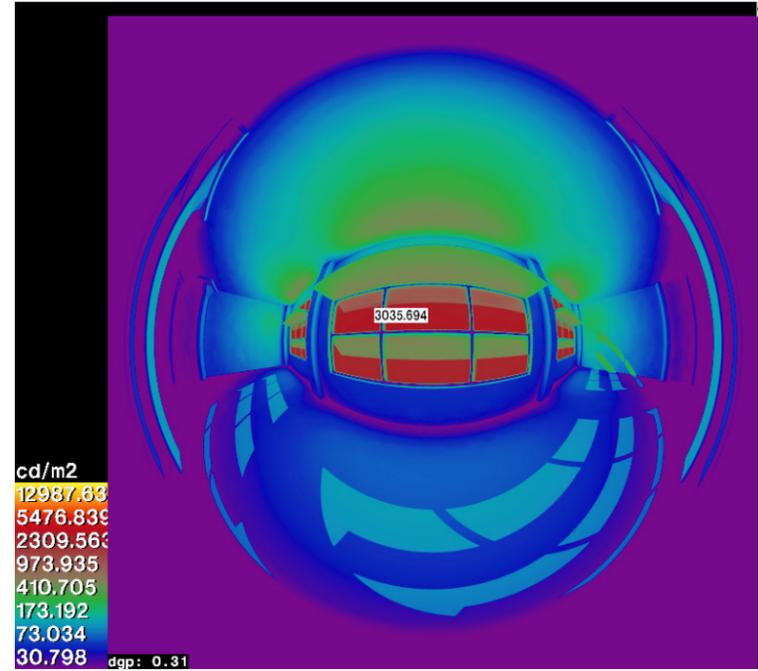
DGP: 27%

DGP
 <= 38% Imperceptible
 <= 42% Perceptible
 <= 53% Disturbing
 > 53% Intolerable

Clear Top Lights

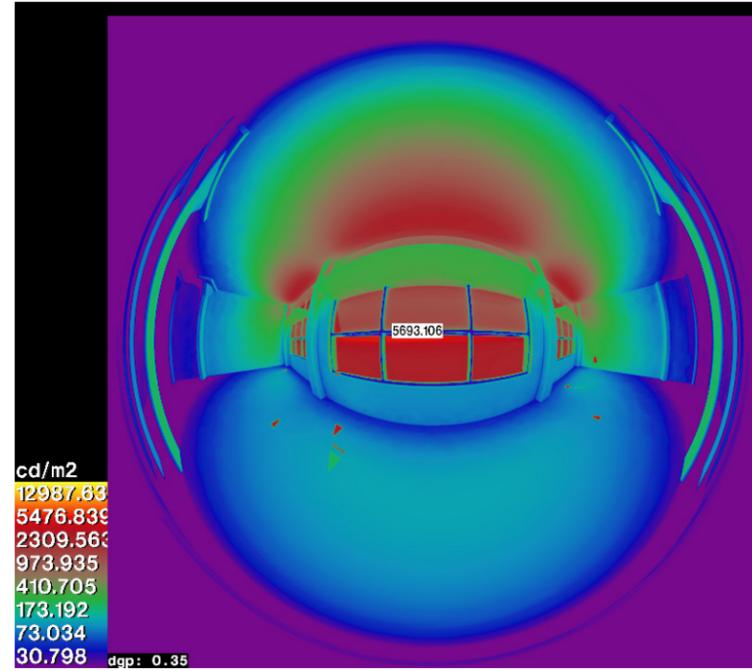


December @ 12:00 pm



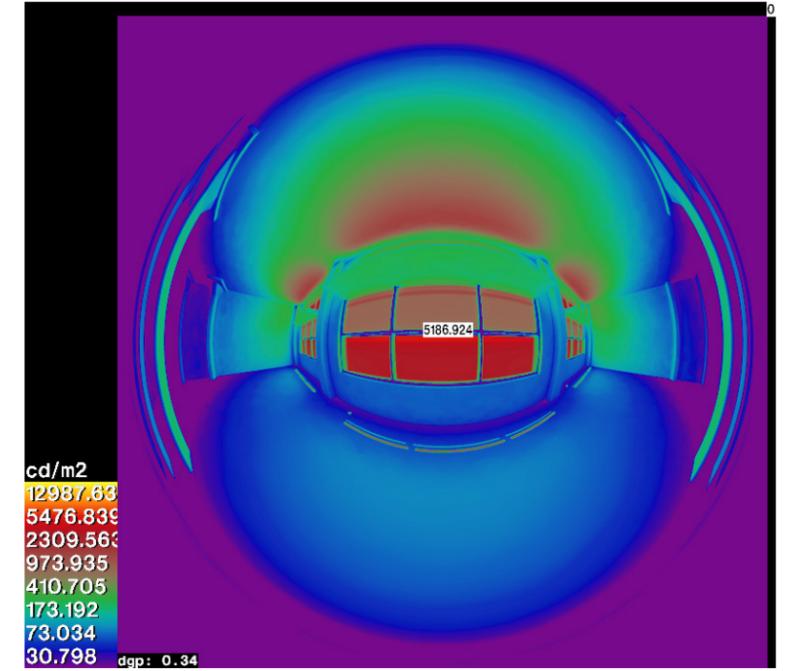
DGP: 31%

March @ 12:00 pm



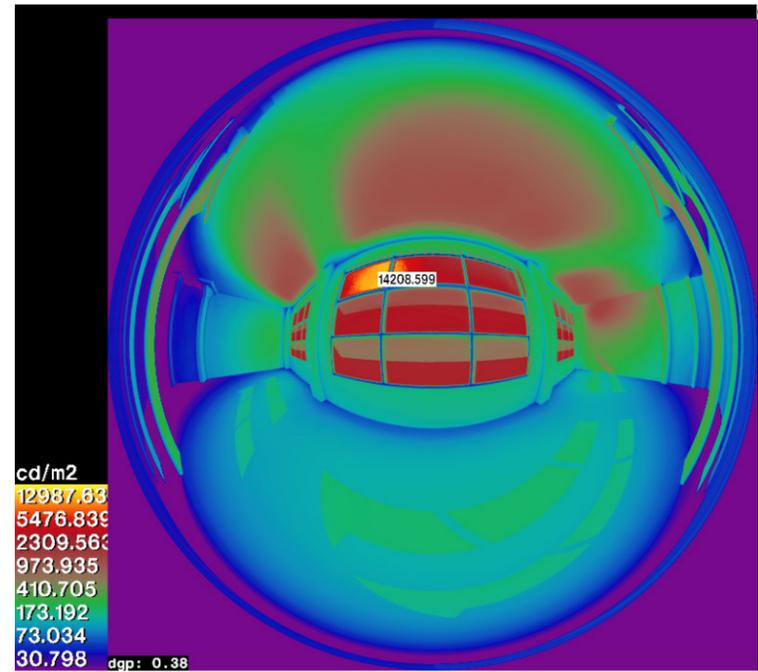
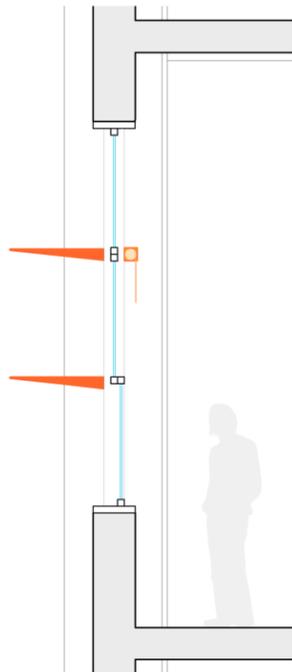
DGP: 35%

June @ 12:00 pm

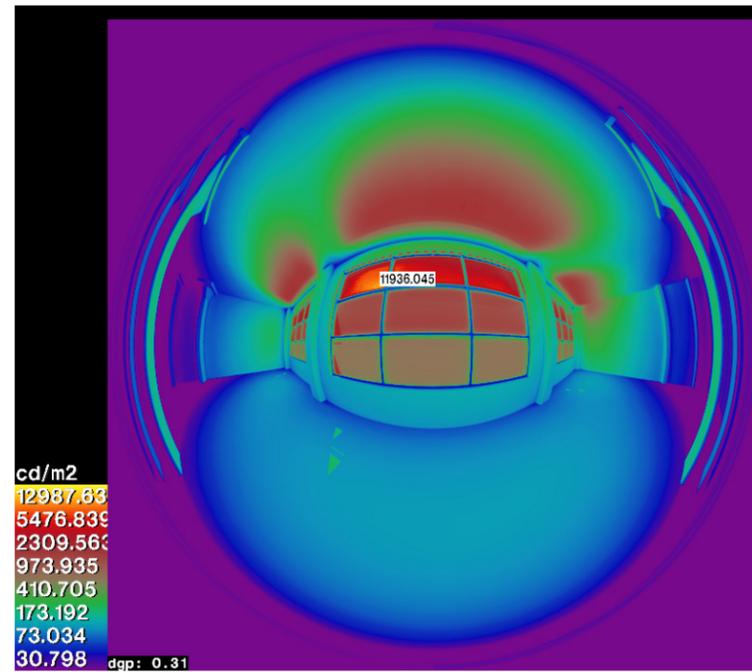


DGP: 34%

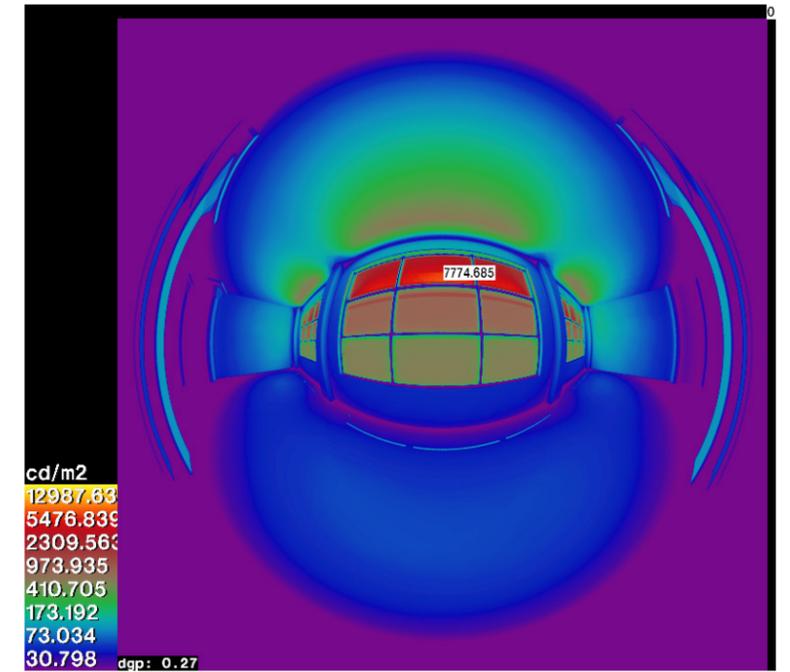
3M Film Top Lights



DGP: 38%



DGP: 31%



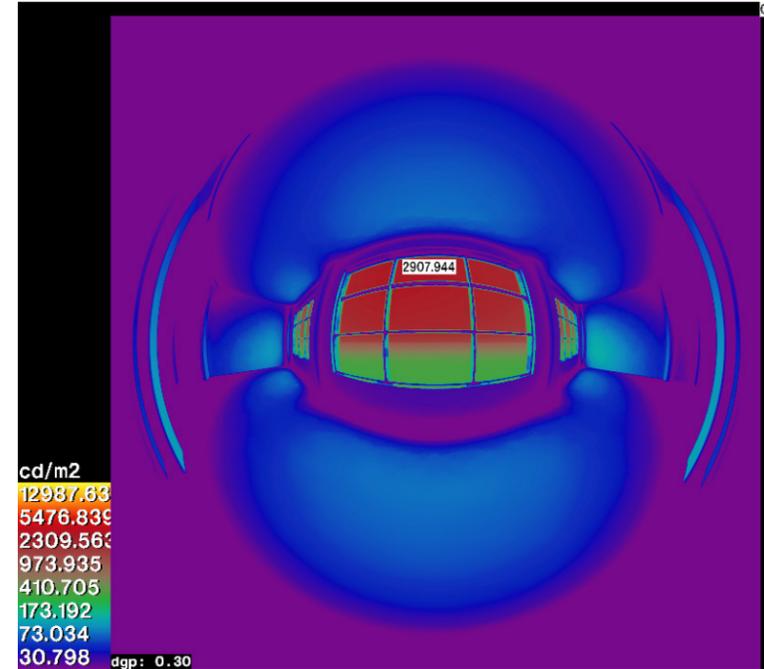
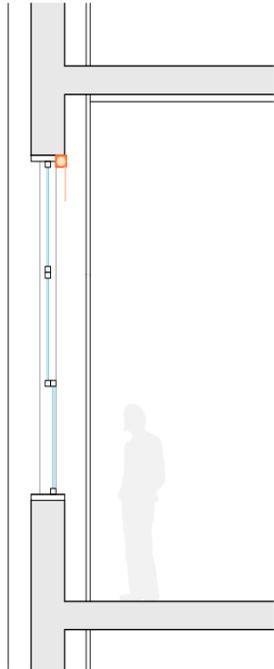
DGP: 27%

DGP
 <= 38% Imperceptible
 <= 42% Perceptible
 <= 53% Disturbing
 > 53% Intolerable

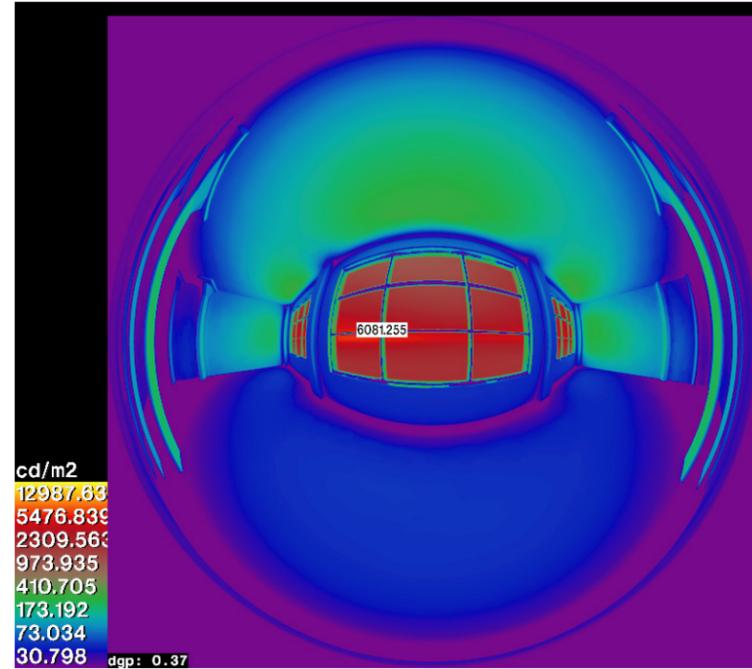
Clear Top Lights

December @ 12:00 pm Overcast

March @ 3:00 pm Clear Skies

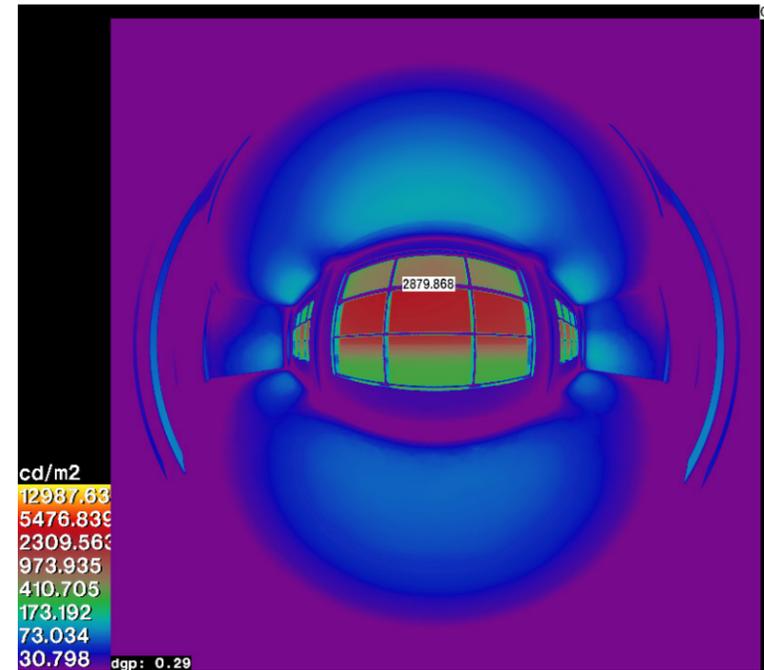
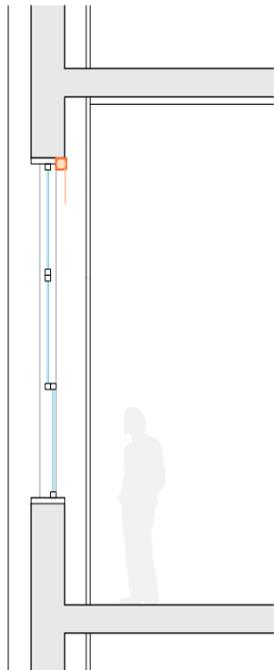


DGP: 30%

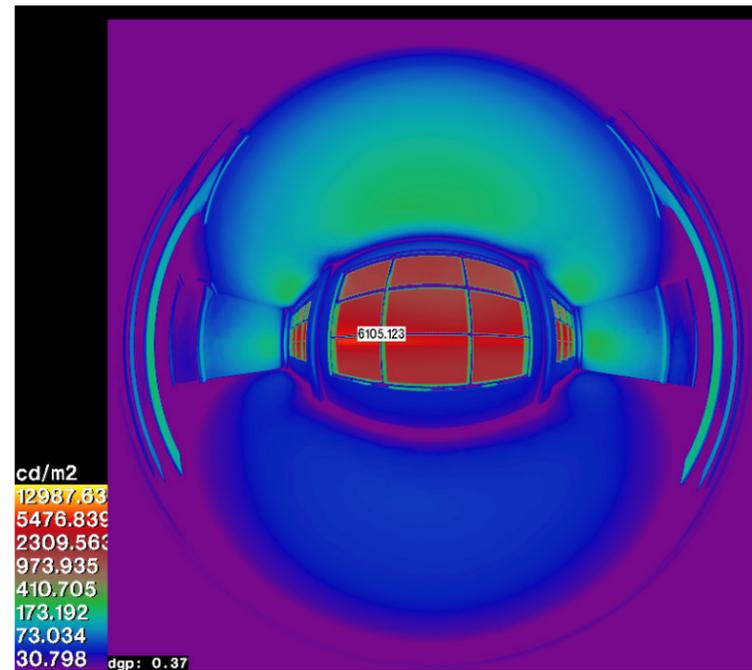


DGP: 37%

3M Film Top Lights



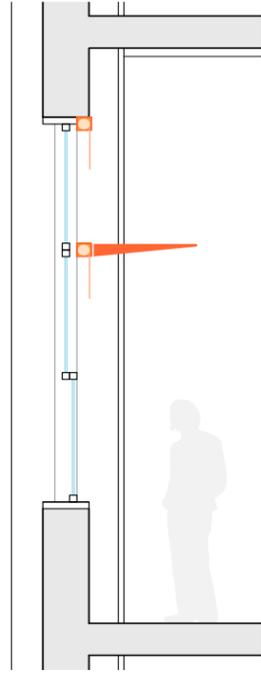
DGP: 29%



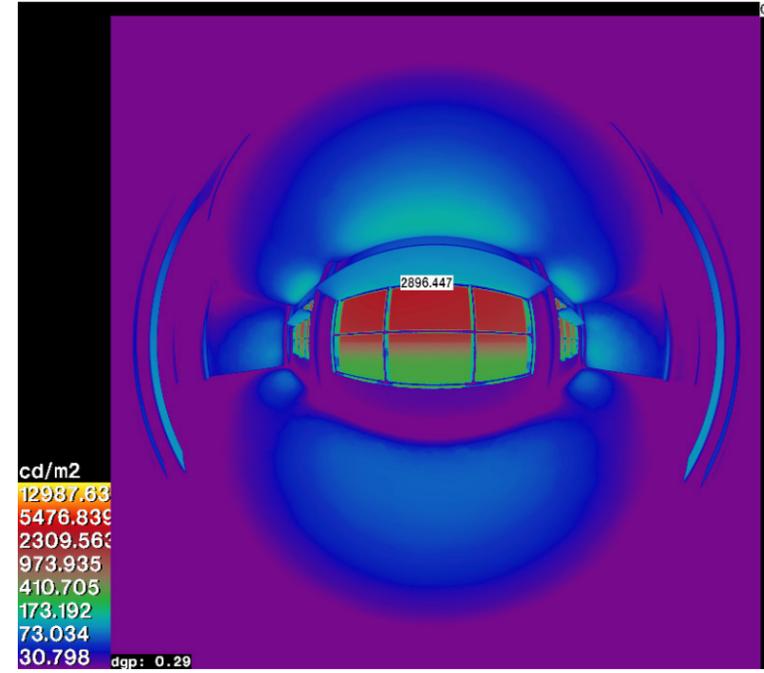
DGP: 37%

- DGP
- <= 38% Imperceptible
- <= 42% Perceptible
- <= 53% Disturbing
- > 53% Intolerable

Clear Top Lights

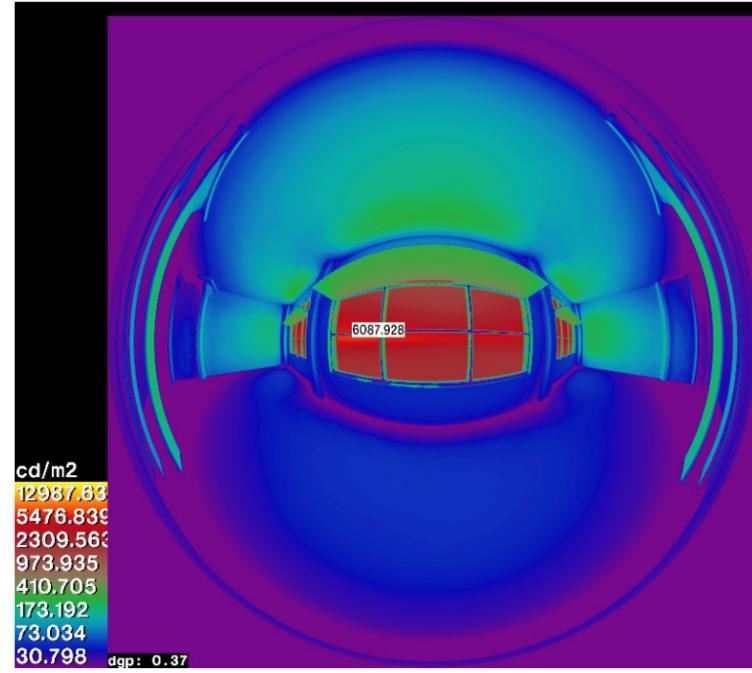


December @ 12:00 pm Overcast



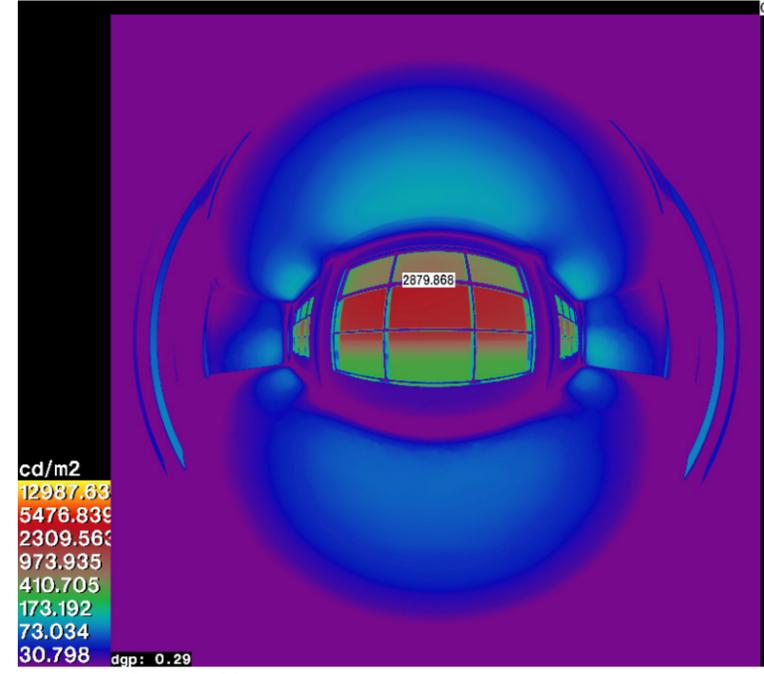
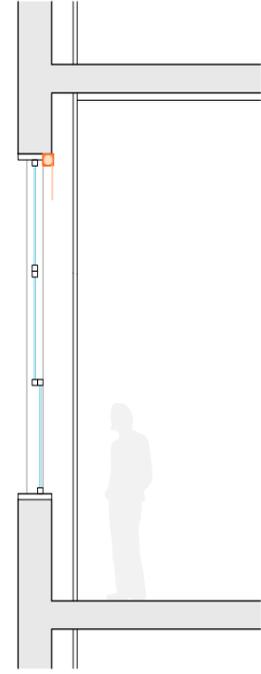
DGP: 29%

March @ 3:00 pm Clear Skies

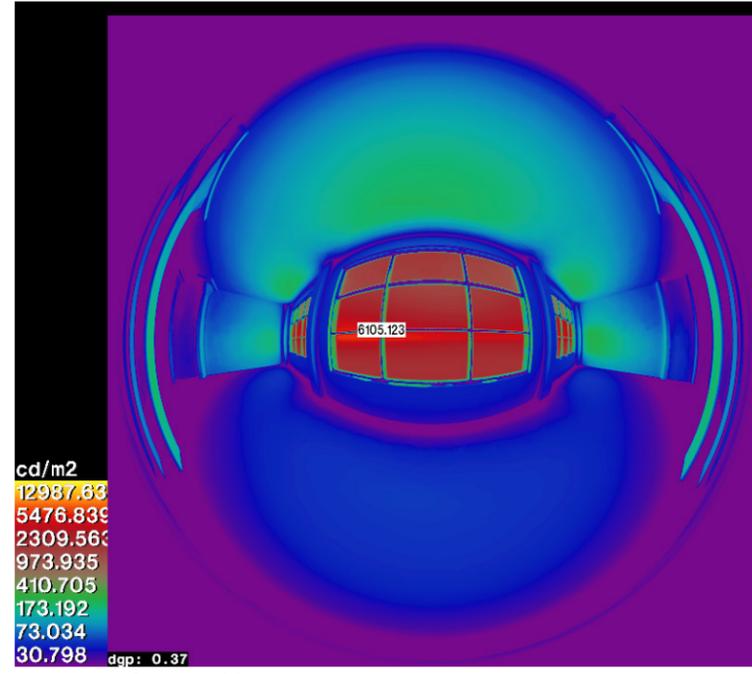


DGP: 37%

3M Film Top Lights



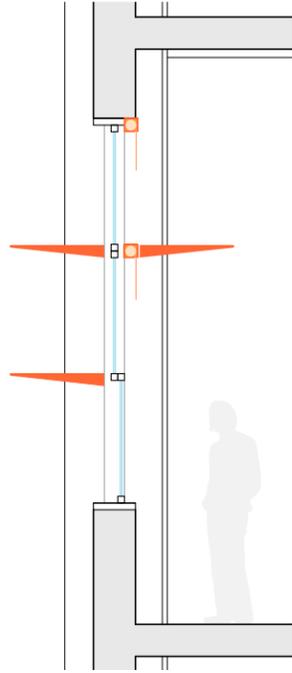
DGP: 29%



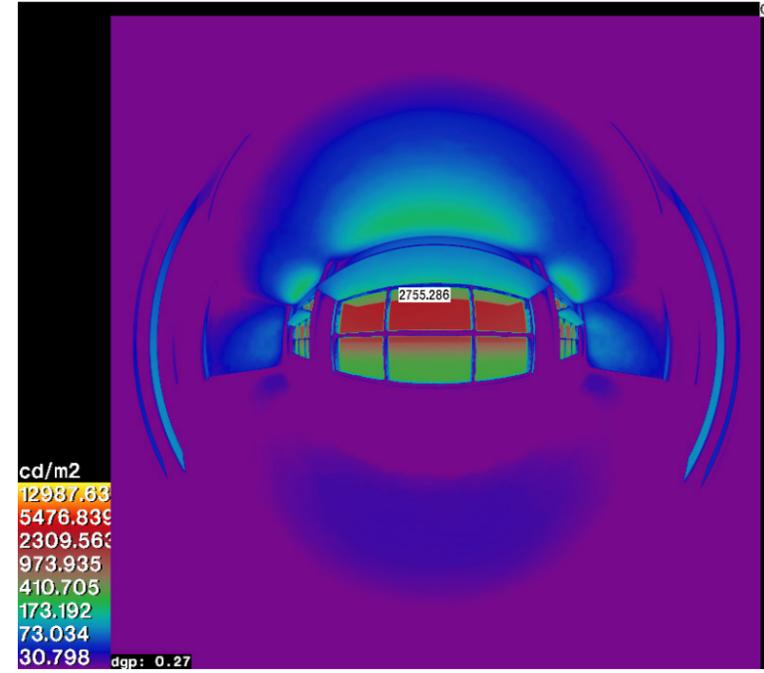
DGP: 37%

DGP
 <= 38% Imperceptible
 <= 42% Perceptible
 <= 53% Disturbing
 > 53% Intolerable

Clear Top Lights

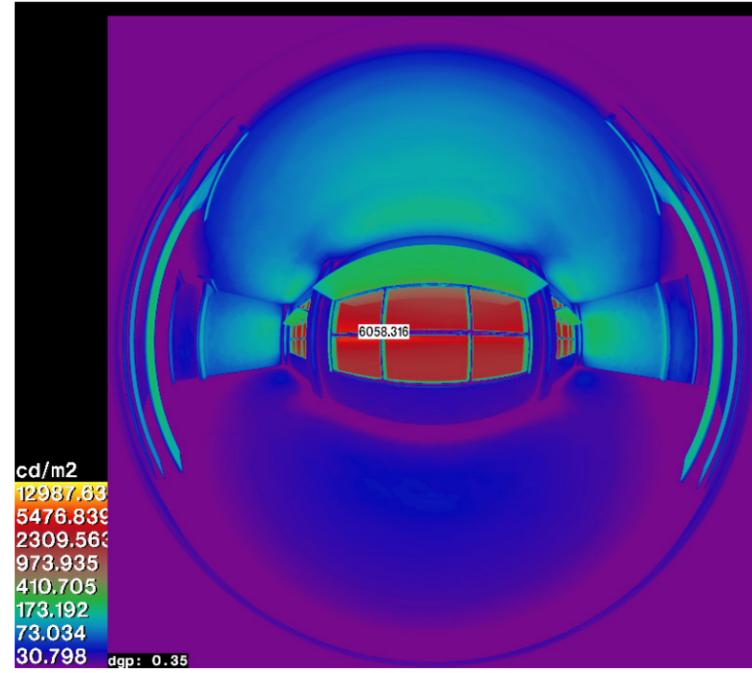


December @ 12:00 pm Overcast



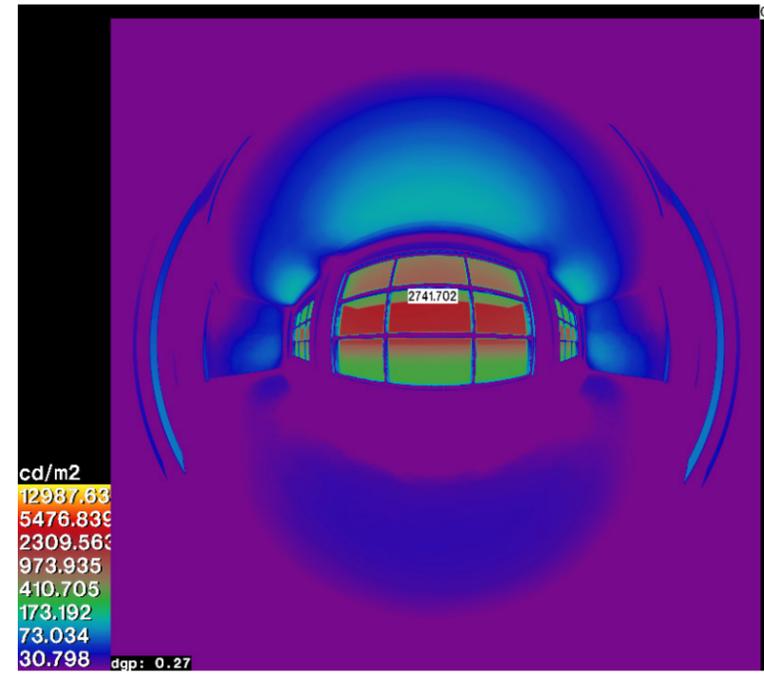
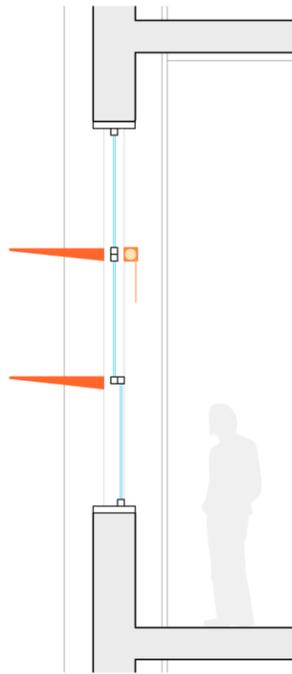
DGP: 27%

March @ 3:00 pm Clear Skies

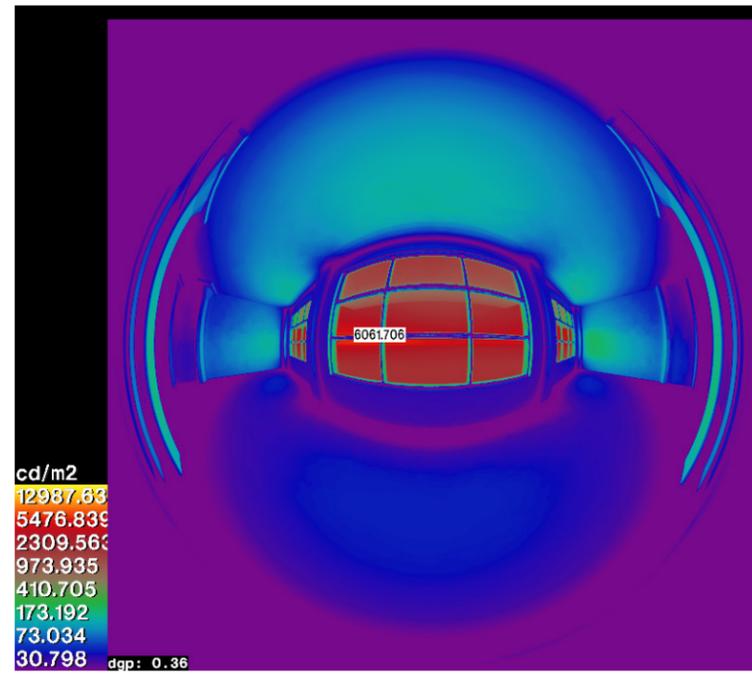


DGP: 35%

3M Film Top Lights



DGP: 27%



DGP: 36%

For more information on this report or other daylighting and energy analysis services please contact:

LOISOS + UBBELOHDE

ARCHITECTURE . ENERGY

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