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Visible Light Transmission and Visual Comfort

Why 1% or lower visible light transmission is essential for complete glare control

Abstract

This paper describes how View Smart Windows maintain visual comfort in even the most challenging daylight conditions. The reader will learn about the relationship between visible light transmission and visual comfort for different climates and the importance of achieving 0.5% to 1.0% visible light transmission to control direct sunlight. The results of the study demonstrate that a 1.0% or lower visible light transmission is required to reduce or eliminate intolerable glare.

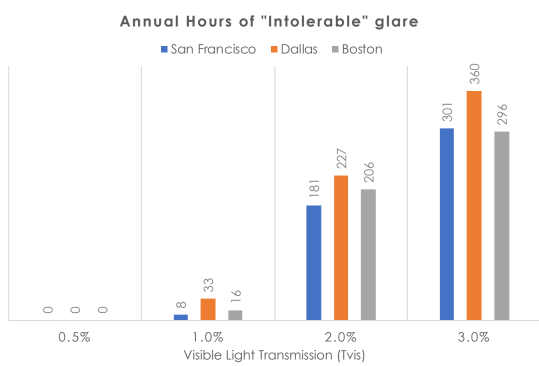

Figure 1: Annual hours of intolerable glare for a desk position located adjacent to a south façade in three different US cities.

Background on Visible Light Transmission

Visible light transmission (Tvis) is the percentage or fraction of visible light that passes through the glazing system, as opposed to being reflected or absorbed. It is the primary "filter" for reducing the highly dynamic and intense exterior daylight conditions to more tempered and comfortable interior conditions. Conventional glazing offers a fixed visible light transmission that cannot change, whereas View Smart Windows allow it to change in response to both the dynamic conditions outside and the variable needs of interior occupants.

Background on Daylighting

Daylight is the natural light provided by direct sunlight and the diffused light reflected by the clouds, atmosphere, and landscape, as shown in Figure 2. People prefer natural light, and good daylighting design maximizes operational, psychological, and health benefits for building occupants. The use of daylight also saves energy through the reduction of electric lighting.

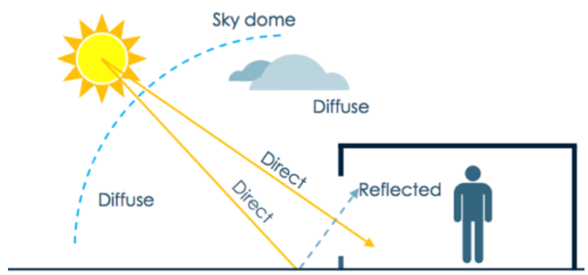

Figure 2: Constituents of daylight

It is important to note that the optimization of daylight levels is essential to occupant satisfaction. It is not a case of "more daylight is always better." Too much daylight in a space results in excessive glare and thermal discomfort, which leads to occupant dissatisfaction. Dynamic glazing aims to find the optimal balance of daylight and comfort without compromising views and aesthetics.

Background on Glare

The same components that contribute to a successful daylight design (Figure 1) can also be sources of glare if not properly controlled, as indicated below.

Direct – The solar disk represents only 0.2% of the sky at any given time, yet the brightness of the sun can be 200,000 times brighter. This means that any time the sun is in the field of view, visual discomfort is a significant risk unless its brightness is sufficiently reduced by the glazing. This is where View's lowest tint state 4 (0.5% to 1% Tvis) is critical for controlling glare.

Diffuse – The brightness of the sky, while much less than that of the sun, can still be a source of glare under some sky conditions and window configurations, particularly when in contrast with relatively dark surroundings. Fortunately, diffuse glare can be controlled with modest tint states.

Reflected – Reflected glare occurs when daylight or sunlight reflects off either exterior or interior surfaces in a manner that causes excessive brightness. Typically, this occurs when sunlight reflects off glass facades from adjacent buildings or glossy interior surfaces, such as polished floors or furniture. Interior reflected glare can be controlled with careful selection of interior surfaces, while exterior glare can be controlled using View Intelligence®, which anticipates problematic reflections before they arise.

Controlling Glare

View Smart Windows respond to all the above sources of glare using its dynamic tint states and predictive Intelligence® control system. The table below indicates the typical View tint states and the visual comfort issues addressed by each of them.

Table 1: Standard View tint states

Tint State	Tvis	Typical Function
Tint 1	50%	Typical sky condition without direct glare – no additional tinting required
Tint 2	30%	Reduce solar heat gains or diffuse glare from the sky
Tint 3	5%	Mitigate reflected glare
Tint 4	1% or 0.5%	Mitigate direct glare from the sun

As noted in the table above, Tint 4 is used to address glare from the sun itself and is available in either 1% or 0.5% Tvis. This means that Tint 4 blocks 99% to 99.5% of the light that shines on the outside of the glass.

The ultra-low light transmission of View's Tint 4 is relatively unique in the glazing industry and is of critical importance when addressing glare from direct sunlight. The results of this white paper study indicate that at least 99% of the sun's visible light must be eliminated to control glare in a workplace environment. Even then, it is never advised to look directly at the sun, just as when wearing sunglasses or viewing a solar eclipse without safety glasses.

Methodology

To demonstrate the sensitivity of visible light transmission to glare mitigation, a daylight analysis was performed for a typical south-facing office building in three US locations. The three locations were selected to represent a range of climates and latitudes, as shown in Figure 3.

Figure 3: Map showing locations studied for glare analysis. Typical Meteorological Year climate data was used for each location.

Four visible light transmissions were studied, including the 0.5% and 1.0% Tvis associated with View's Tint 4, and a 2% and 3% Tvis for comparison.

Annual glare analysis was performed for two desk locations behind the south facade. The desks were aligned perpendicular to the window with occupants facing east in the parallel direction of the façade, as shown in Figure 4. The occupant at Desk 1 was 3 feet from the window, and the occupant at Desk 2 was 9 feet from the window. The room was modeled with a 10-foot ceiling and floor-to-ceiling glazing.

Daylight Glare Probability (DGP) was calculated for each hour of the year for the two desk locations (sample daylight renderings shown in Figure 5). DGP is a metric proposed in 2005 by Jan Wienold and Jens Christoffersen, is the probability that an occupant will be dissatisfied with the visual environment due to glare. It uses a scale of 0 to 1, where values over 0.45 indicate "intolerable glare." For this study, only intolerable glare (DGP > 0.45) was considered.

Table 2: Subjective glare ratings for DGP

Subjective Rating	DGP Range
Imperceptible Glare	< 0.35
Perceptible Glare	0.35 – 0.40
Disturbing Glare	0.40 – 0.45
Intolerable Glare	>0.45

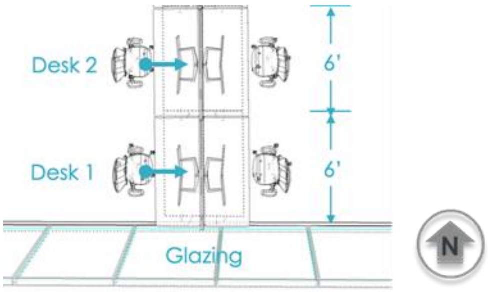

Figure 4: Seating Configuration used for analysis. The model assumes a 10' ceiling with floor to ceiling glazing.

Figure 5: 180-degree fisheye renderings from the two desk positions.

Results

The results of the annual glare analysis for Desk 1 are presented in Table 4 (next page) for each of the three location and four visible light transmission scenarios. A summary of the hours of "intolerable glare" is also summarized in Table 3, and in Figure 6, Figure 7, and Figure 8 for San Francisco, Dallas, and Boston, respectively. The hours in the table and figures represent the number of annual hours of "intolerable glare" (DGP > 0.45) for the given climate, desk position, and visible light transmission.

The results indicate a significant increase in the number of intolerable glare hours between 1% and 2% Tvis, while a 0.5% Tvis eliminated intolerable glare completely. A 1% Tvis exceeded this threshold only 6-30 hours per year, whereas a 2% Tvis exceeded intolerable glare 90-230 hours per year.

Table 3: Summary of results for hours of intolerable glare for all scenarios studied

		San Francisco	Dallas	Boston
0.5% VLT	Desk 1	0	0	0
	Desk 2	0	0	0
1.0% VLT	Desk 1	8	33	16
	Desk 2	6	12	13
2.0% VLT	Desk 1	181	227	206
	Desk 2	118	90	141
3.0% VLT	Desk 1	301	360	296
	Desk 2	183	118	195

Glare is reduced for desk positions farther away from the window (Desk 2 in this study), but hours of intolerable glare remain high (90-181 hours) for 2% and 3% Tvis. This implies more of the occupied floor area will be impacted by glare, and for longer time periods, when Tvis cannot drop to 1%.

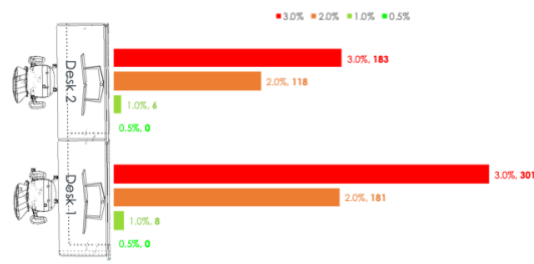

Figure 6: Hours of intolerable glare by desk position and Tvis for San Francisco

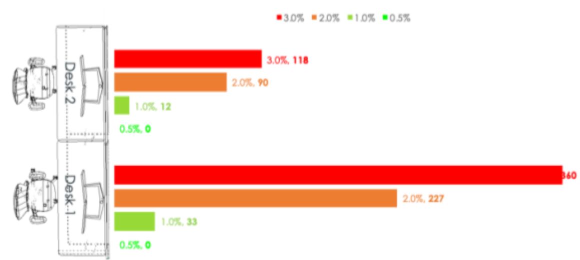

Figure 7: Hours of intolerable glare by desk position and Tvis for Dallas

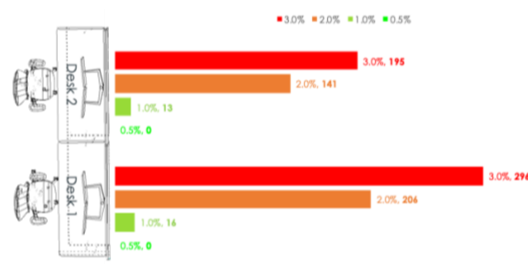

Figure 8: Hours of intolerable glare by desk position and Tvis for Boston

Table 4: Annual Daylight Glare Probability (DGP) plots for the three U.S. cities and four Tvis settings used in this study. The number in the center of each plot indicates the total predicted hours of intolerable glare (DGP > 0.45), also shown by the red tick marks.

Conclusion

Climate, desk position, and visible light transmission of the glazing all play influential roles in determining glare and visual comfort in a workplace environment. However, the differences seen in climate and desk position in this study are minor compared to the differences in comfort due to visible light transmission. A 0.5% to 1% Tvis is essential to reduce or eliminate intolerable glare for all scenarios studied. A 2% or higher Tvis produced significant hours (up to 360 hours or approximately 10% of annual daylight hours) of intolerable glare for desk locations within 10 feet from the facade. This frequency of glare would require an additional shading system, such as internal shades, which in turn eliminates views and connectivity to the outside.

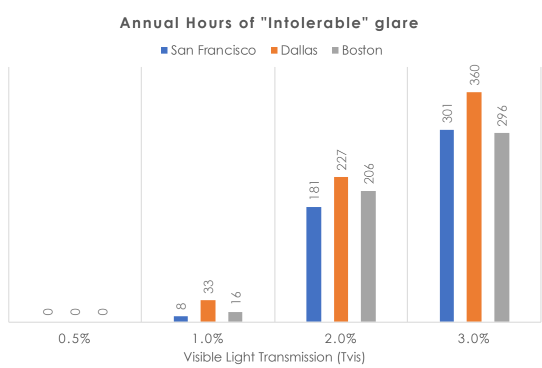

Figure 9: Annual hours of intolerable glare for a desk position located adjacent to a south façade in three different US cities.

About the Author

Galen Burrell is a lighting specialist at View, Inc with 16 years of experience in lighting and daylighting design. Throughout his career, his primary aim has been to develop design solutions that balance human comfort and energy performance, while providing for visual delight. Prior to joining View, Galen spent the 10 years of his career at a multinational engineering consulting firm where he served as one of the company's primary daylighting champions. Galen speaks regularly at lighting conferences such as IALD and Lightfair and in 2016 co-authored a paper on daylight glare published in IBPSA-USA SimBuild 2016. Galen also teaches daylighting at the University of Colorado at Boulder and was awarded *Lighting Magazine's* "40 Under 40" Award for International Lighting Designers in 2018.