
THEIA™

Performance

Specification

Rev 1.0

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Background on Performance Fabric Selection

The THEIA™ Performance Specification is a manufacturing specification for solar screen fabrics. By requiring tight manufacturing tolerances around fabric performance criteria, specifically Openness Factor and Visible Light Transmittance, and requiring a defined testing process and documentation, designers can be confident that the fabric delivered to the project will meet their design intent.

Shading systems are a key element to achieve high performance solar management. Improper design, specification, or manufacturing of these systems can lead to an unsatisfactory building environment. Specifically, occupant comfort and energy savings can suffer when performance is not considered in either the system design or manufacturing process.

A key performance feature of solar screens used for solar management is their ability to simultaneously provide glare control while allowing daylight into the space and preserving view to the outdoors. However, these key performance benefits are greatly affected by the solar screen fabric properties. Specifically, Openness Factor (OF) and Visible Light Transmittance (Tv) are critical to performance*.

It is important to note that the openness factor listed on fabric cards or marketing material is generally only the nominal value used for categorization, meaning that is only a relative approximation. The average, or mean, value is not usually provided, but is much more accurate for evaluating the true performance of the shade. In fact, the visible transmittance listed on fabric cards is typically not indicative of the average Tv for the fabric, but is based on a few or even a single measurement which can vary significantly from the true mean.

All mean fabric performance properties for THEIA™ compliant fabrics are based on the average value of at least 20 samples, not an approximation nor based on only a few measurements.

Nominal Openness Factor (OF_{nominal})*: An approximation for the percentage of light that transmits directly through a solar screen without being redirected or diffused.

Mean Openness Factor (OF_{mean})*: The percentage of light that transmits directly through a solar screen without being redirected or diffused, based on the average measured value of the fabric.

Visible Light Transmittance (Tv)*: The percentage of light that transmits through a solar screen, including both direct and diffuse. This value should be based on the average measured value of the fabric, but this is not the case for most fabric manufacturers.

*Note: Listed fabric properties are always based on normal (perpendicular) incident light unless noted.

Fabric Properties and Building Performance

Selecting a fabric to meet a single building performance requirement (such as glare, view, or daylight) is fairly straightforward, but optimizing fabric selection for multiple priorities is difficult. Generally, this requires project specific information evaluated for performance by a simulation tool (ex. www.performanceshadingadvisor.com). Below are some common example metrics for evaluating the performance of daylight spaces.







Daylight Glare Probability (DGP): The likelihood that an occupant will begin to experience daylight glare in a space. Generally, 35% or less is a good upper limit for glare critical spaces as this is generally considered the point at which glare starts to become “noticeable”.

Spatial Daylight Autonomy (sDA): The percentage of the work area where daylight contributes at least 30FC for 50% of work hours or more. This is an area of a building where even daylight switching of the light fixtures will give significant energy savings.

View Clarity: The quality of view when looking through a fabric to the outdoors. A value of 100% is perceived as clear as with no shade at all, and a value of 0 indicates that a typical occupant cannot see through the fabric. This metric does not account for the effect of the glass on view perception.

Regardless of metrics utilized for design, the selection of a solar screen fabric requires prioritization and optimization between multiple conflicting priorities. A low openness factor will provide good direct sun control, but will significantly reduce view preservation. A low visible transmittance will provide good diffuse daylight control (glare from light diffused by the shade) as well as better view preservation, but will significantly reduce daylight availability.

Table 1 Relationship between fabric properties and performance metrics

	GLARE		DAYLIGHT	VIEW
	Direct (sun orb)	Diffuse (DGP)	(sDA)	(VCI)
OPENNESS FACTOR (OF)	LOW OF 	--	HIGH OF 	HIGH OF 
VISIBLE TRANSMITTANCE (Tv)	--	LOW Tv 	HIGH Tv 	LOW Tv 

Note: Arrow size indicates importance, with larger arrows indicating greater importance. An arrow pointing down means that a lower value is desired to optimize that performance metric.

Industry Typical Fabric Tolerance

At this point, it is clear that the selection of optimal fabric properties is critical to building performance. However, what happens after the fabric is specified is just as important. In the past, solar screen selection has been primarily based on aesthetics and rules of thumb. Therefore, fabric manufacturers had little incentive to refine processes to maintain tight performance tolerances.

Fig. 1 illustrates this by comparing measured OF and Tv values to what was published by different manufacturers for over 200 samples that Lutron recently tested according to the THEIA™ testing protocol. These samples spanned multiple manufacturers including many that may or may not be affiliated with Lutron. The y-axis indicates the % error in Tv from the listed value with positive values indicating that the measured Tv is higher than the listed Tv. When this is not controlled, a diffuse glare problem can arise. Negative values indicate that the measured Tv is lower than what is published by the manufacturer, which can cause reduced daylight availability. The x-axis indicates the error in openness factor from the published value. Positive values here may cause direct glare problems, while negative values may reduce view preservation.

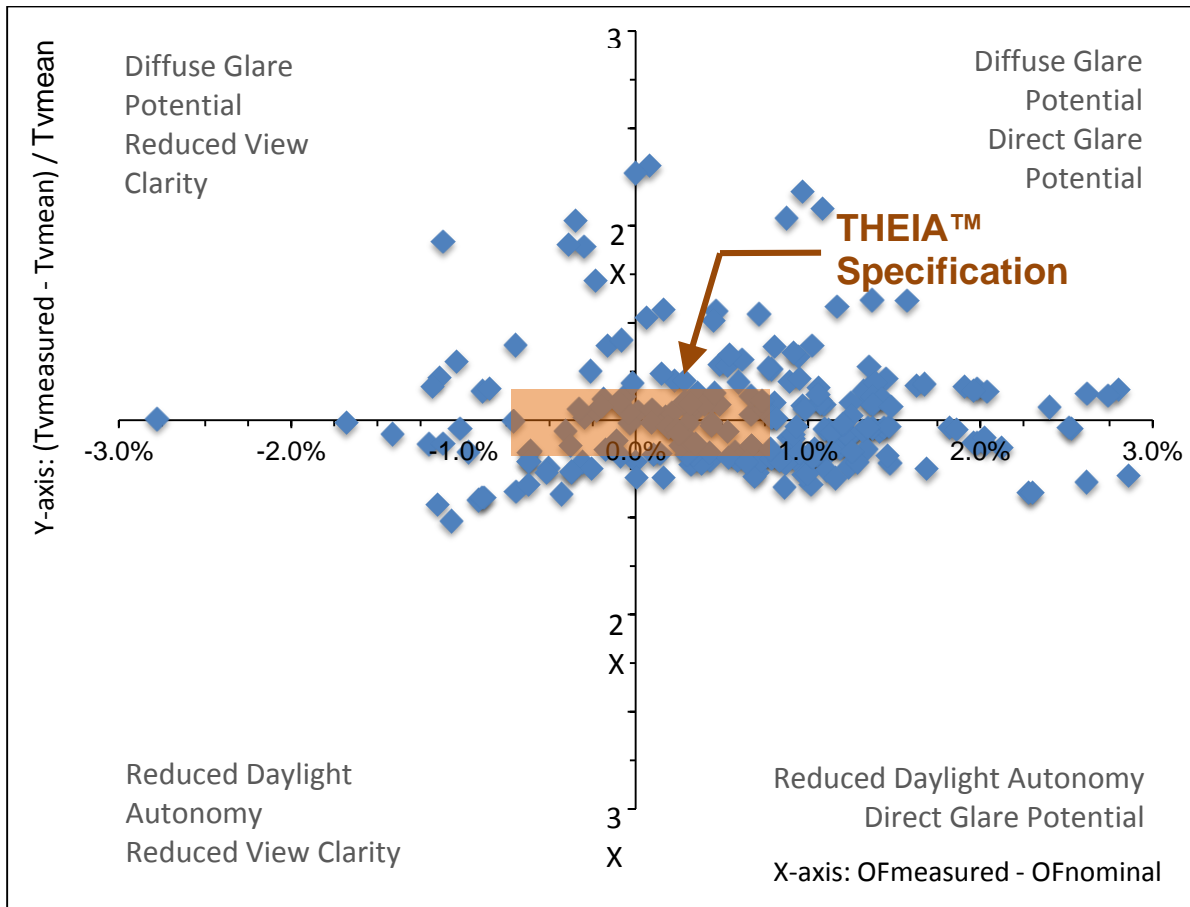


Figure 1. Errors between tested and claimed fabric properties.

Fabric Tolerance and Glare Performance

It is insufficient to indicate that fabric tolerance can greatly affect building performance without quantifying this effect. The most important daylighting performance metric is glare control, as this has the greatest impact on employee comfort and productivity. This is critical to a building’s operation as the cost of employee salaries and benefits outweighs energy savings by a factor of 100 or more.

The plot below shows the potential impact of fabric tolerance on Daylight Glare Probability. An optimized fabric Tv was chosen to meet the glare requirements of a project, then the Tv was increased to simulate what would happen if the installed fabric was near the tolerance limit for tight (+20% x Mean), fair (+ 60% x Mean), and high (+ 100% x Mean) tolerances. As shown, when the installed fabric has a tight tolerance, the expected glare perception still does not quite reach the “noticeable” point. A fair tolerance can create an environment where occupants perceive the space as “uncomfortable” for critical glare periods. A high tolerance, which is not uncommon as shown in the figure on page 3), can create an environment where “very uncomfortable” glare is present.

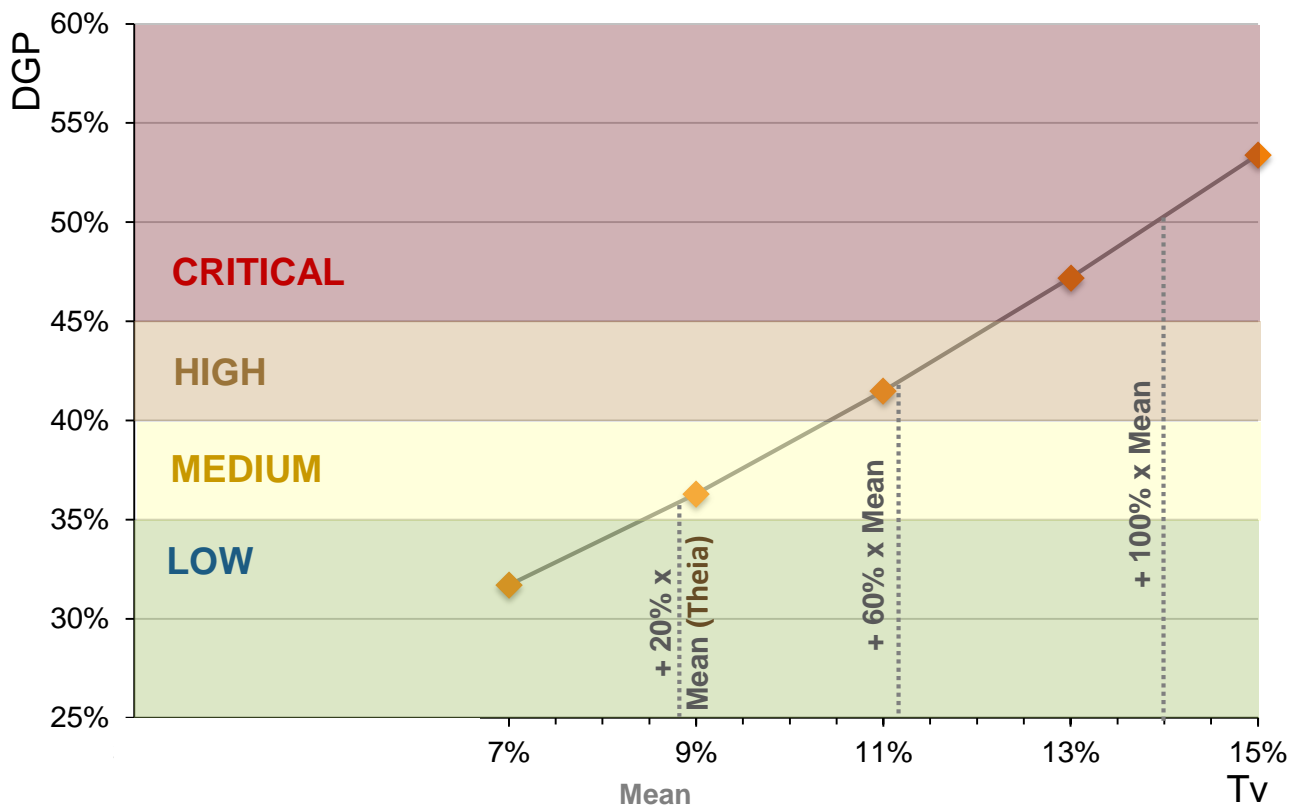


Figure 2. Potential impact of fabric tolerance on Daylight Glare Probability.

This simulation was performed for a South façade in Pheonix, AZ, with a 70% window to wall ratio, a typical clear double pane glass, and the occupant seated close to the glass. When the Tv approaches the typical tolerance limit, based on the data on the previous page, the glare become uncomfortable and sometimes very uncomfortable.

THEIA™ Performance Specification Measurement

From the research findings above, it is clear that a more stringent shading fabric performance specification should be introduced to address the tolerance issues of the current fabrics. The two parameters controlled by this specification are the mean openness factor and visible transmittance. Below are the tolerance limits set by this standard. These tolerances were selected to minimize the perceived impact of an installed fabric being at the high end of a tolerance range. It is important to note that the performance properties of fabrics may vary slightly over time due to stretch and color fade from UV energy. Therefore, the THEIA™ specification applies to the tolerance limits at the time of shade manufacture.

Openness Factor Tolerance:

$$OF_{\text{mean}} \pm 0.75\%$$

Visible Transmittance Tolerance:

$$\text{When } Tv \text{ is less than or equal to } 5\%: Tv \pm 1\%$$

$$\text{When } Tv \text{ is greater than } 5\%: Tv \pm (20\% \times Tv)$$

For example, a fabric with a mean OF of 3% must maintain an OF between 2.25% (3% - 0.75%) and 3.75% (3% + 0.75%). A fabric with a Tv of 4% must maintain a Tv between 3% (4% - 1%) and 5% (4% + 1%). A fabric with a Tv of 10% must maintain a Tv between 8% (10% - (10% x 20%)) and 12% (10% + (10% x 20%)).

The tolerance around Tv is higher for fabrics with a higher mean Tv. This is because fabrics with a higher Tv are generally selected for spaces that are less glare critical (i.e. limited direct sun), and therefore can have a higher tolerance without considerable impact on performance.

To evaluate the impact of these tight tolerances, it is important to compare this to typical fabrics. The orange box in the center of Fig. 1 indicates where these tolerance limits fit within most existing fabrics. As most of these fabrics cannot meet these strict tolerance requirements for a single sample, it is unlikely that any of them would meet these requirements across multiple samples to provide confidence in performance. Similarly, Fig. 2 shows that a THEIA™ compliant fabric maintains good glare control even at the tolerance limit.

The THEIA™ Specification provides confidence that even an outlying sample will not generate a significant increase in occupant glare perception.

The testing protocol for compliance to the THEIA™ Performance Specification is thorough to provide the utmost confidence in THEIA™ compliant fabrics. For a single roll to be certified, the entire cut that the roll came from must be tested and pass the statistical testing around the tolerance. A cut is a very long continuous piece of fabric with a single color and openness factor. Fabric rolls are smaller subsets of a cut, and these are delivered to the shade assembly plants. Every compliant roll must come with documentation that validates the statistical requirements of the fabric tolerance for the entire cut from which the roll was produced. Samples taken from each certified cut must be measured by a photo-spectrometer for openness factor and visible transmittance according to the measurement standards EN14500:2008 and ASTM891AM-1.5.

THEIA™ Statistical Requirements

To comply with this specification, every sample measured in the entire cut of fabric must be within tolerance for both the openness factor (OF) and visible transmittance (Tv). If a single sample within the cut is outside of either tolerance, none of the fabric rolls within the cut are acceptable. This requirement is necessary but not sufficient. By taking at least 20 samples across the entire cut of fabric, a statistical model can be created to evaluate the likelihood of any part of a supplied fabric being outside of tolerance.

The THEIA™ Performance Specification provides 95% confidence that at least 95% of the supplied fabric meets the tolerance limits.

The statistical methods utilized in this standard allow a high level of confidence that all of the supplied fabric will meet the already strict tolerance requirements. If the cut does not meet this statistical limit, even if a single sample is causing the failure, the entire cut cannot be supplied as THEIA™ compliant.

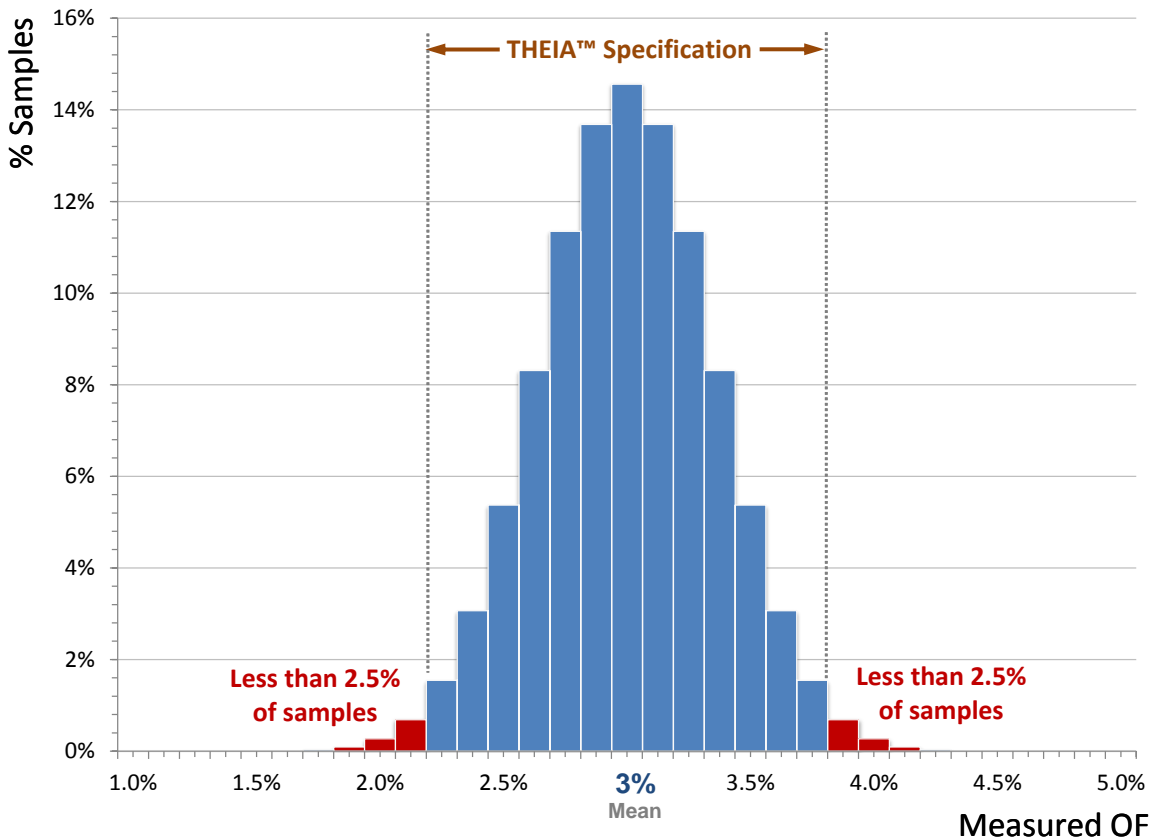


Figure 3. Statistical tolerance requirements of THEIA™ compliant fabrics.

Summary of THEIA™ Performance Specification

Key components to the THEIA™ Performance Specification:

- Tolerance limits for openness factor (OF) and visible transmittance (Tv) selected to minimize reduction in building performance
- Measurement process that utilizes approved EN and ASTM measurement standards
- Stringent statistical requirements for acceptance to provide “95% confidence that at least 95% of fabric from rolls in the cut are within the tolerance bounds”
- Provides mean (average) fabric performance properties, as opposed to approximate values, for use in tools that evaluate building performance
- Comprehensive documentation process for validating performance and traceability

The THEIA™ manufacturing specification is critical to ensure design intent for building performance is met. By selecting fabrics that adhere to this strict specification, designers can be confident that the delivered product will perform as well as the specified product.

