MERMET
Sun Control Textiles™

Understanding Fenestration
White Paper

There are a variety of design considerations made by architects when determining the concept for a new building project. Many of these considerations involve new and innovative ways to improve the energy efficiency of a building in order to save money, increase occupancy comfort, and reduce the impact to the environment. One important consideration is the fenestration of a building. Fenestration is any opening in a building's envelope including windows, doors and skylights. Anything placed into that opening (glass, frame, and attachments) is considered a part of that building's fenestration. Understanding the effect of each component of fenestration and how to use that data to contribute to innovative design is key for architects and designers.

All components of fenestration have a thermal impact and influence the overall performance and energy efficiency of a building. There are many factors concerning fenestration that an architect and/or designer should consider depending on the specific goals of the project. Is the design intent to reduce heat gain? Is the project goal to increase natural daylighting and reduce the dependency on artificial light? Is the main concern controlling visual comfort in an occupied environment? Understanding all the components of fenestration, how they work together and how this fenestration data is calculated can help answer many of these questions regarding design intent.

Important Terms

Total Solar Reflectance (Rs)
The percentage of solar energy at normal incidence (90° to surface) that is directly reflected by a material

Total Solar Absorptance (As)
The percentage of solar energy at normal incidence (90° to surface) that is absorbed by a material

Total Solar Transmittance (Ts)
The percentage of solar energy at normal incidence (90° to surface) that is directly transmitted through a material

Reflectance in the Visible Spectrum (Rv)
The amount of visible light reflected by a material

Transmittance in the Visible Spectrum (Tv)
The amount of visible light at normal incidence directly transmitted through a material

Reflectance in the Infrared Spectrum (Rs IR)
The amount of solar energy in the infrared range that is reflected by a material

Openness Factor (OF)
The percentage of holes in a material

Complex Glazing System
An integrated system comprised of glass, frame, and attachments such as window shades

Solar Heat Gain Coefficient (SHGC)
the percentage or fraction of solar energy reaching the interior of the building. This requires knowledge of the entire complex glazing system in order to calculate the coefficient.

Fenestration Properties

Fenestration properties can be divided into two categories; thermal and optical. Thermal properties relate to heat control. These properties include Rs, As, Ts, and Rs IR. Understanding how these properties function is beneficial to understanding how window shades regulate the heating and cooling of an indoor environment.

Optical properties relate to visual aesthetics and include Tv and Rv. Tv is the amount of transmitted solar energy that is visible. A dark color shade fabric has a lower Tv value, which allows the occupant to see more clearly out of the shade and provides more visual comfort. Shade fabrics with a lower Tv value are a good consideration for indoor environments where glare is a concern. Conversely, a light color shade fabric, which has a higher Tv value, allows more visible light into the interior space providing more natural daylighting. Depending on lighting needs, a shade fabric in a light color could reduce the dependency on artificial lighting.

Rv, the amount of visible light reflected off the surface of the shade, has an impact on exterior appearance and interior lighting. High Rv means more light is bouncing back towards the direction of the light source. For example, a dark color shade with a lower Rv value will require more overhead lighting to reach the required illuminance levels. Conversely, a light color shade with a higher Rv value will require less overhead lighting, because the light reflects off of the shade and back into the interior space allowing for more natural daylighting.

RAT Equation

The RAT equation is the combination of Rs, As, and Ts to equal 100% of total solar energy. Every material has a RAT distribution. All window shades reflect, absorb, and transmit solar energy. All three components will always equal 100%. The total solar energy of each property (Rs, As, Ts) is measured and reported as total solar energy, and it is also broken down into separate values by ultraviolet (UV), visible and infrared (IR) spectrums.

Rs IR

Rs IR is important in relation to heat control. This value is the reflectance of solar energy in the IR spectrum. The IR spectrum is where heat is generated. A window shade fabric that reflects a large amount of solar energy in this spectrum can aid in reducing the surface temperature of the material.

Complex Glazing System

So far, the properties discussed relate only to the fabric itself. However, rarely will you encounter a situation in which the fabric is used on its own. Almost all roller shade fabric is used in conjunction with a glass window. When combining everything that covers a building's fenestration (glass, frame, attachment), this is referred to as a complex glazing system. All portions of this system contribute to solar energy control, so it is important to understand how the fabric properties function within the entire glazing system. The calculation that explains the performance of the complex glazing system is SHGC. This calculation demonstrates the percentage of solar energy that is transferred into the interior space, both directly and indirectly, through the complex glazing system. Essentially, SHGC aids in understanding how the entire system performs in regard to heat control.

Mermet is involved with the Attachments Energy Rating Council (AERC) and Lawrence Berkeley National Laboratory (LBNL) to incorporate our shade fabric properties into their Complex Glazing Database (CGDB) to provide a SHGC. LBNL has created a software called WINDOW that is used by the National Fenestration Rating Council (NFRC) for labeling windows, doors, and skylights. The AERC is now working to incorporate a variety of window shade attachments into their complex glazing database in order to calculate SHGC in concert with any glass type found in the International Glazing Database (IGDB). This database includes optical data on over 4,700 glazing products. By combining shade fabric properties with this glazing database, Mermet is able to provide customized and project specific SHGC calculations for a complex glazing solution.

Aside from being able to provide custom SHGC values, Mermet reports some standard calculations on all product specification sheets in order to provide an initial "rule of thumb" SHGC value based on customer needs. SHGC is reported based on standard commercial and residential glazing units. Because there are so many options for glass at the commercial level, Mermet reports the percentage improvement by using a shade fabric rather than reporting the exact SHGC value. This gives an architect with an idea of how the fabric will perform in general based on using a standard commercial glazing (double glazing 6mm / 1/2” air / 6mm with low E on surface #2). Because residential glass is more standardized, and the consumer is less likely to know the specific glass makeup, Mermet reports the SHGC value based on a default residential glass (3mm clear glass / 1/2” air / 3mm clear glass). Since the majority of Mermet fabrics can be used in both interior and exterior applications, SHGC is calculated for both types of applications for those products that have an interior and exterior warranty.

Window shades provide more than just appealing design aesthetics. They provide architects the ability to control lighting, exterior appearance, occupancy comfort, heating and cooling to exact specifications. For the end user, window shades provide the ability to control their indoor environment to the most comfortable level for the occupant. As non-permanent attachments, window shades also allow for more flexibility in controlling the indoor environment. Understanding how fenestration data functions with the complex glazing system affords architects and designers more options for providing solutions to the overall project goals and design intent.

Methods of Measurement & Calculation

In order to fully understand how fenestration values are calculated it is important to understand the standards used to measure and calculate the data. The following procedures are the most commonly used procedures for the measurement and calculation of fenestration properties.

AERC 1.1: *Procedures for Determining the Optical and Thermal Properties of Window Attachment Materials*

AERC 1.1 sets the appropriate technical procedures for determining the optical and thermal properties of materials used in fenestration attachment products. This document supplements the standards listed below by providing a direct set of instructions with a clear step-by-step procedure that can produce consistently accurate results in the hands of a competent technician. Additionally, this document supports AERC 1 and AERC 2 which provide the technical rating procedures used to determine the energy performance properties of complete fenestration systems. A complete system includes the window attachment and a standardized glazing system.

Mermet uses ASTM E903 and E891 to measure and calculate fenestration properties while utilizing AERC 1.1 to ensure accurate and consistent results.

ASTM E903: *Standard Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres*

ASTM E903 covers the measurement of Rs, As, Ts, Rv, Tv, and Rs IR using a spectrophotometer like a Perkin Elmer Lambda 950. Measurements are taken incrementally every 5 nanometers (nm) in the spectral region of 250nm-2500nm.

Mermet uses this method to measure fenestration properties. This method of measurement was selected, because the procedure is repeatable and reproducible through the use of a spectrophotometer with an integrating sphere. Mermet also uses this method because it is specific to North America, which is the company’s predominant market. The use of AERC 1.1 with ASTM E903 provides details for making accurate and repeatable measurements of samples.

Perkin Elmer Lambda 950 UV/Vis/NIR: *Spectrophotometer with a 150mm Integrated Sphere*

When measuring all fenestration properties, Mermet uses a Perkin Elmer Lambda 950 UV/Vis/NIR spectrophotometer. This machine measures the total solar energy in wavelengths from 250nm to 2500nm. The range of wavelengths represents the entire solar spectrum (UV, visible, and infrared). This machine is highly accurate at reproducing results (≤ 0.02nm for UV/Vis, ≤ 0.08nm for NIR).

ASTM E891: *Tables for Terrestrial Direct Normal Solar Spectral Irradiance Tables for Air Mass 1.5*

ASTM E891 covers the calculations for the values Rs, As, Ts, Rv, Tv, and Rs IR. The standard uses established solar spectral irradiance distribution tables to calculate the overall fenestration values from the measurements taken using ASTM E903.

Mermet uses this method to calculate fenestration properties. Solar performance is heavily influenced by geographic locations and sun angles. Therefore, ASTM E891 is designed to reflect the general geographic area of North America. One major component is the value used for air mass. ASTM E891 uses an air mass of 1.5. Mermet feels that using this method, which is designed for the predominant geographic location of our market, would provide the most useful fenestration data. Although ASTM E891 has been superseded by ASTM G173, the reference tables have not changed between the two standards. Mermet uses Architectural Glass Software with UV WinLab, which is based on ASTM E891, to make the calculations.

LBNL WINDOW
WINDOW is a computer program, used for decades in the glazing industry, for calculating total window thermal performance indices consistent with the NFRC rating system. The software accesses the IGDB to analyze commercial glazing systems. The most recent versions of the software incorporate the CGDB allowing the inclusion of complex glazing elements such as blinds and shades.

Mermet uses LBNL WINDOW to calculate custom and “rule of thumb” SHGC values for solar screen fabrics. Initially the fenestration properties, measured and calculated by ASTM E903 and E891, are incorporated into the software program. The SHGC values are then obtained by modeling a complete fenestration system. This software is used in concert with AERC 1.1 to determine thermal performance.

NFRC 100: *Procedure for Determining Fenestration Product U-factors*
NFRC 200: *Procedure for Determining Fenestration Product Solar Heat Gain Coefficient and Visible Transmittance at Normal Incidence*

NFRC 100 & 200 specify methods for determining thermal performance of building fenestration through simulation and testing. The procedures and settings specified in these standards are used by the WINDOW software to make the calculations.

ISO 15099: *Thermal performance of windows, doors and shading devices – Detailed calculations*

ISO 15099 is a method used in computer programs for detailed calculation of the thermal and optical transmission properties of window and door systems. The WINDOW software is consistent with this standard.

Alternative Standards

Mermet recognizes that other markets, particularly Europe, use different methods of measurement and calculation of fenestration properties. These methods differ slightly from the ASTM methods utilized by Mermet, because of measurement or calculation parameters. One major difference between EN and ASTM is the regional temperatures and air mass coefficient which are based on the geographic area of that region.

ASHRAE Standard 74: *Method of Measuring Solar-Optical Properties of Materials*

A well-known method in the US of measurement and calculation of fenestration properties is ASHRAE Standard 74. Historically, this method was widely used by the industry for many years to evaluate the solar/optical properties of fenestration materials. The standard was withdrawn in 2015.

Mermet does not use this standard due to inconsistent measurement techniques in addition to its withdrawn status. The primary method of measurement is the use of an apparatus called a pyranometer that utilizes actual sunlight to obtain fenestration properties. This method of measurement requires that all environmental conditions be accounted for throughout the test, as cloud cover and weather cannot be held constant. This standard also indicates that the results are less accurate for materials for which the reflectance is non-uniform across the solar spectrum. For these reasons, Mermet has chosen to not use this method. The ASTM methods have proven to be more reliable and repeatable through the use of a spectrophotometer.

EN 410: *Glass in Building-Determination of Luminous and Solar Characteristics of Glazing*

In Europe, EN 410 is used to measure fenestration properties of glass. This procedure is most similar to ASTM E903.

Mermet does not use this standard because it is only applicable to glass and is more specific to the European geographic location. The thermal performance value determined by this method is the g-value, as opposed to the SHGC determined by NFRC 200. The g-value is calculated based on the Center of Glass, which only looks at the glass in fenestration and does not take the window frame into account.

EN 14500: *Blinds and Shutters-Thermal and Visual Comfort-Test and Calculation Methods*

In Europe, EN 14500 is used to measure and calculate the fenestration properties of window attachments. This method provides similar details on the experimental technique using a spectrophotometer as ASTM E903. The calculation aspect of EN 14500 is most similar to ASTM E891.

Mermet does not use this standard because it is a companion to EN 14501, which has elements that are more specific to Europe.

EN 14501: *Blinds and Shutters-Thermal and Visual Comfort-Performance Characteristics and Classification*

The most predominant method of calculating heat gain in Europe is EN 14501. This method is similar to the LBNL WINDOW software used by Mermet. Similar to EN 410, this method determines a g-value, instead of SHGC. Additionally, while ASTM E891 and LBNL WINDOW utilize an air mass coefficient of 1.5, EN 14501 uses a value of 1.0.

Mermet does not use this standard because of these differences in calculation. The thermal value of SHGC, determined with an air mass of 1.5, is a better representation of performance for the company's products.

ISO 10077: *Thermal performance of windows, doors and shutters. Calculation of thermal transmittance*

ISO 10077 specifies methods for calculation of thermal performance of building fenestration, including the windows, doors, and shutters. This method is most similar to NFRC 100 & 200 which are used by the LBNL WINDOW software to calculate SHGC. The settings used by the ISO 10077 and NFRC 100 & 200 have several significant differences: boundary temperature conditions, window frame design, glazing makeup, and calculation algorithms.

Mermet does not use ISO 10077 because it is designed to match the EN standards and is less compatible with the WINDOW software.

Mermet does not use this standard because it is a companion to EN 14501, which has elements that are more specific to Europe.