IMPROVING FENESTRATION PERFORMANCE

Understanding Solar Optical Properties and Solar Heat Gain

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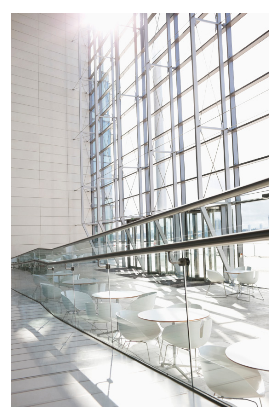
How Does It Work?

A friend and industry colleague who works for a leading supplier of textile and solar control products told me that he had been caught off guard during an architectural presentation earlier this year. After explaining how his company's materials would improve the energy performance of fenestration, and going over the solar heat gain coefficients [SHGC] and solar optical properties in great detail, one of the Architect's spoke up and asked "Yea, but how does it work?" My friend was surprised by the question because he was not sure what else he could tell the group about how the products "worked" in addition to the already very detailed description of fenestration data that he had just finished presenting. He went on to confide to me that although the facial expressions from some of the other members of the firm indicated that they too thought the question posed by their associate was surprising, my friend thought that it was a very good question. We both agreed that while the information is plentiful that confirms the performance of shading devices, there needs to be more discussion and information presented addressing the fundamental dynamics of how light and heat move through glass; and what effect various shading and other window treatments have on fenestration performance.

Fenestration - the weak link

Technically, when we talk about fenestration, we are talking about an opening in a building that may have various purposes, angles, orientations and materials involved. However, more often than not, we are talking about glass. And while glass is a remarkable building material that allows us to borrow light from outdoors and see the world around us from inside our buildings, it is not a very good insulator and is an energy trap for solar radiation. When we are considering heat-gain through glass, we are examining either solar heat-gain or conducted heat-gain and one form of heat-gain has nothing to do with the other. Conducted heat gain is when the warmer outdoor temperature is trying to invade the cooler indoor temperature [or escape if we are talking about heat-loss]. Faster moving atoms in the warm or hot ambient environment come in contact with slower moving atoms on the cooler air conditioned glass; and the warm faster moving atoms are trying to convince the cooler and slower moving atoms to speed up and move at the same pace so that all of the atoms are jiggling & moving at the same speed. Warm or hot is always trying to seek out cool or cold and energy will always flow in that direction - hot toward cold. Different materials conduct heat at different



rates and those rates are measured in u-values or the rate at which heat moves through the referenced material. Window products that control solar heat gain are rated using solar optical properties and shading coefficients; and because I am focusing on shading devices, I am going to write in greater detail about those properties and how shading devices control solar heat-gain through glass.

The Sun & Natures Own Facade

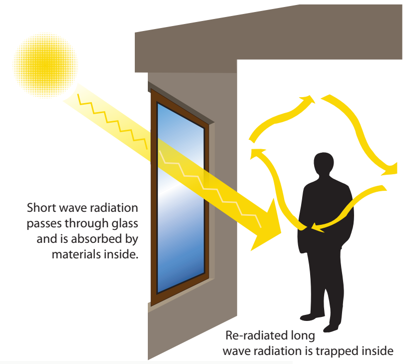
A good place to start when considering solar heat-gain is at the source. Roughly 100 times the size of our planet, and mostly hydrogen & helium that is heated to a state that is beyond gaseous [plasma], the Sun sends 89,000 terawatts [one terawatt = 1 million megawatts] of energy to the surface of our planet. It is fascinating to note that the photons that only take about eight minutes to make the 93 million mile trip to our planet have actually been trying to escape the Sun's immense mass for thousands of years before reaching the solar surface for the quick trip to planet Earth. As I am writing this paper, the Curiosity rover is exploring the surface of Mars and scientists are pondering the possibility of putting humans on a planet with no atmosphere; and while evaluating the value and effect of facades on buildings, one cannot ignore the comparison of natures own atmosphere that acts as a facade that wraps herself around our planet like a protective "thin blue line". The 89,000 terawatts that reach our planets surface represent about half of the energy that slams into our upper atmosphere every day through the cold clear vacuum of space. Natures own facade reflects, absorbs and diffuses sunlight in an elegant architectural design that not only protects us with an immaculate balance of light and energy, but also provides a beautiful blue canopy by scattering and proliferating the smaller blue light waves across the sky. When contemplating facade designs, we could probably do worse than looking to our own atmosphere for inspiration and ideas.

A Droplet or a Wave?

As we read more about energy from the Sun, we will also learn that light energy actually acts like a wave - which seems much different from an individual corpuscle or little "droplet" of energy like the photon that I referenced making the 93 million mile trip to Earth in eight minutes. In fact, some experiments will demonstrate that light is a little individual droplet or corpuscle while others clearly define light as a wave. So, which is it - a little individual corpuscle or a continuous wave? Well, it seems that it is both! Some of the worlds most brilliant scientific minds have pondered and debated the question of "What is light?" including Newton, Maxwell, Bohr, Einstein, Feynman and many others. The British born physicist Sir William Bragg quipped "On Mondays, Wednesdays, and Fridays we use the wave theory; on Tuesdays, Thursdays, and Saturdays we think in streams of flying energy quanta or corpuscles." [Bragg, Sir William , Electrons and Ether Waves, Scientific Monthly, 1922, 14, 158]. Even though Einstein was not completely comfortable with the idea that light was both a particle and a wave [Paul Arthur Schilpp, ed, Albert Einstein: Philosopher-Scientist, Open Court (1949) p 51], the scientific community has settled on the proposition that light has both particle and wave properties and this proposition or theory is called Wave-Particle Duality. Particle's only travel in straight lines while at the same time waves can bend; and while they are completely different they are both one and the same. While it makes for interesting reading for those wanting to learn more about this topic, the theory can be difficult for the non-scientist [like me] to completely understand. However, by believing that two things can be completely different and alike at the same time, it makes it easier to accept some of the unusual behavior you will read about when studying light.

In Layman's Terms

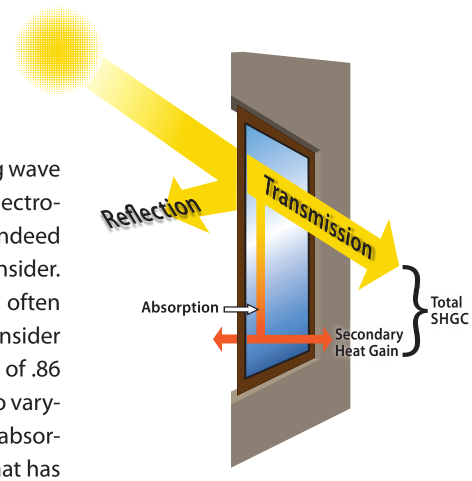
Should you ever find yourself placed in the position of being asked by a client "Yea, but how does it work?" during a shading or facade presentation, I suggest that you start the explanation by setting the fenestration and energy data aside and simply remind them [in most cases convince them] that there is no temperature in sunlight. That is to say, sunlight does not heat the air. Sunlight is, for the most part, visible, infrared and ultraviolet electromagnetic waves that is typically summed up neatly as "shortwave radiation." This type of energy does not heat the air any more than it does when coming from a campfire. A good question to ask in support of your statement is; if you are warming yourself in front of a campfire, does that campfire heat the air to keep you warm? And the answer is - no it doesn't! If it did heat the air, the air temperature would be just as warm behind you as it is in front of you and you would not have to turn round and round in order to keep both front and back warm while facing the fire. The shortwave energy is being absorbed by our cooler body causing the slower moving atoms in our body to jiggle and move faster creating heat. Our warm body temperature then radiates off our body temperature into the cooler night air and that warm energy is summed up neatly as long-wave energy. Glass, and I am referring mostly to untreated glass, is transparent to short-wave energy, yet it is opaque to long-wave energy - this is the phenomenon recognized in the construction of a greenhouse. Short-wave radiation enters the building envelope through glass, strikes various things inside the building, and is either absorbed and converted to heat by something inside the window or reflected back out through the glass by something at the window [or a combination of both]. Sunlight that comes through an untreated window bounces around the room until it is absorbed by objects inside the building and converted to heat. The trick is to reflect sunlight back out through the glass as short wave energy, or better yet, absorb it or reflect it back in the direction it came with a facade or exterior shade mounted outside the glass.



Designing Window Treatments Or Building Trombe Wall's?

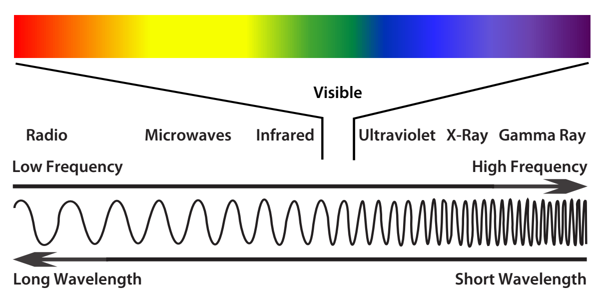
The bulk of fenestration projects that our company works on here in California are existing buildings; consequently the majority of the designs and products that we employ are installed inside the building. Although most of these products are referred to by our industry as shades, we look at them as "reflectors" when designing with solar control in mind. I recently attended an AIA class for continuing education taught by a leading window shading & automation company and when the topic of addressing direct solar heatgain on a sun-struck south west window wall came up, the instructor said that a "black roller shade made from 1% sunscreen installed inside the building would be the best application because it would block the most sun and would be easy to see through." In reality, the instructor had just described how to build a window treatment that would act like a "Trombe Wall" - a black absorber behind a sun-struck wall of glass that is a solar collector. The representation made by the instructor was not an intentional distortion of how energy moves through glass in order to sell his product. To the contrary, he actually had a material in his selection of products that would have done a better job of dealing with solar heat gain, he just didn't know it. Many manufacturers simply do not understand the dynamics of the products that they represent. It is also interesting to note that none of the people attending the class took issue with or questioned his proposal. It is not uncommon to see black or bronze interior window treatments installed on the west side of buildings in climate zones where cooling load is the primary concern because they are cosmetically consistent with the bronze or black window mullion. I was in Los Angeles this summer and stopped into a coffee shop that is a national chain with stores on every corner, the Seattle based company uses the ubiquitous dark charcoal colored solar screen on all of their windows - I know you have seen it. All of the seats were taken in the little shop except for those next to the wall of heat being generated by the combination of glass and the black absorbers installed just behind it.

Reflectance



If we agree that when dark colored window products are placed on the inside of glass that they absorb short wave energy and convert it to long wave energy where it is trapped; then you would also think that light colored materials would reflect short wave energy back through glass before it is converted to long wave energy. It is not that simple. Feynman's book "QED" [quantum electrodynamics] is sub-titled "The Strange Theory of Light and Matter." Indeed light is strange and also different than most things we typically consider. It is both an electrical and a magnetic field and how it behaves is often dependent on the material that it is striking. Even though we consider clear glass as transparent to solar energy, it still maintains a SHGC of .86 [single pane]. The rejected or lost energy into the building is due to varying reflectance from different solar incident angles, refraction and absorbance or solar density. When we attempt to reflect solar energy that has passed through glass into a building back out through that same glass, we have the same reflectance, refraction and absorbance going out as we did coming in working against us. The challenge of reflecting light energy back through glass becomes even more complex when we add additional panes because we are now trying to reflect light off of the front and back of each pane as well as the various layers of glass that make up each pane [Feynman, Richard P., Quantum Electrodynamics, (1985) p 104]. We also need to consider the surface of the light or reflective material; if it is not completely smooth, the photons may not reflect back out through the glass in straight lines relative to the incident angle. Instead, they will more than likely scatter and bounce off at different angles making accurate reflectance estimates difficult. However, if solar heat gain is a concern, it is always better to try and reflect short wave back through the glass then absorb it inside the building. In understanding how these products perform it is helpful to be able to interpret the Solar Optical Properties and Solar Heat Gain Coefficients - or at least have an understanding of how light behaves.

Solar Heat Gain Coefficient [SHGC]



SHGC is a measurement of an attachments [NFRC refers to window coverings as attachments] ability to manage direct solar heat gain ranging from zero to one [the lower the SHGC number the lower the solar gain] when installed outside or inside of glass. It is also used to measure solar gain through glass with no attachments. Some SHGC information may consider the entire fenestration including frame and mullions while some look at only the center of the glass. If the SHGC is a center of glass measurement, it is more similar to the "G-value" used in Europe. You might also see Solar Factor used and it is one and the same as SHGC center of glass or G-value. Many solar fabric manufacturers will provide the SHGC's of their materials when combined with different glazings [i.e. single clear, double clear, heat absorbing, Low e, etc.] for greater accuracy. You might also find an older measurement called a Shading Coefficient [SC], but when considering SC, SHGC or G-value, the lower number represents a percentage of less solar gain. If solar heat gain is a concern, the lower the number the better.

Solar Optical Properties

TS (Solar Transmittance) is the percent of solar radiation that passes through the product inside the building and will remain inside the building. About half the sunlight that comes through the glass is visible light and the other half is infrared & ultraviolet [we cannot see infrared & ultraviolet]; some of this energy is absorbed, some is reflected back out while the remainder is transmitted – which means it enters the building unchanged.

RS (Solar Reflectance) is the percent of solar radiation [not visible light] reflected by the product back out through the glass and out of the building.

TV (Visible Transmittance) is the percent of visible light (not solar radiation) that is transmitted inside the building. Although it may seem obvious, the term visible light refers to the spectrum of light that the eye recognizes [380 to 720 nanometers] and is a very important measurement when designing daylighting. The light that we can actually see represents a very small portion of the electromagnetic spectrum. We know that these other waves are really there flying all around us [and through us] because we can prove it by turning on a radio and listening to the sounds that come out as we move the dial listening for the different stations sending out different frequencies; and we can also see the picture of an X-ray taken of our body, but we could not see the waves as they passed through us recording the image. We know these waves are traveling all around us even though visible light is the only little slice of the spectrum that we can actually see with our eyes. Although window coverings, [facades, blinds, shades and drapery] sometimes increase the need for mechanical light, consideration must be given to the operation of each room where glare would cause a problem with computer monitors, video equipment and overall comfort and how treatments can scatter direct light and make it more usable.

AS (Solar Absorbance) is the percent of solar radiation that is absorbed by the product that will remain inside the building if the product is installed inside the glass. As we discussed earlier, dark colors absorb short wave radiation converting it to long wave radiation (heat) where it is trapped inside the building. If the goal is to reduce solar heat gain, you want to see low AS numbers because a high AS indicates a heat gain problem at that window if the product is installed inside the glass.

Openness Factor

Although Openness Factor is not a Solar Optical Property, it is the measure of a shading/solar fabrics level of privacy that is typically included in the Fenestration Data. If a material has a 10% Openness Factor, it is 90% closed or a 1% Openness Factor it is 99% closed. You might consider varying Openness Factors on the same building based on the solar orientations and need for light and privacy control in different areas. We have even combined two different Openness Factors on the same window treatment. Here is an example [see picture] of a shade designed with a 5% material on the upper portion of the shade welded to a 1% material on the lower portion. The client, DaVita Dialysis, wanted shades designed that would meet HIPPA privacy requirements for their patients in the treatment room, while at the same time allowing them the opportunity to enjoy an outside view while going through dialysis. The material has a metalized coating to the outside to reflect solar and reduce visible light transmittance [glare] for those patients facing the windows.

Exterior Shades vs Interior Reflectors

As mentioned above, the majority of projects that we are involved with in California involve interior mounted products. However, most of the work that I have done in Arizona and Nevada utilized exterior mounted shading devices that were applicable to the utility companies load management rebate programs. I was recently in Arizona and drove past some projects with fixed shade panels that we installed over 15 years ago and the shade panels were still in place and doing their job. As long as the building design, location and exposures will allow it, I prefer exterior mounted shades because they perform better when controlling solar heat gain through the glass if the primary intent and there can be additional benefits of shading mullion and walls adjacent to the windows. When looking at the SHGC of a dark material mounted outside the glass, you will note that it is different [lower] than if you mounted that same material inside the building. The short wave [light] to long wave [heat] conversion takes place outside the building where the material becomes hot and just convects the heat off into the outside air rather than inside the conditioned space. However, as pointed out in the 2011 report "High Performance Facades: Design Strategies and Applications in North America and Northern Europe" [Krystyna Zelenay, Mark Perepelitza, David Lehrer]* there are other considerations that must be taken into account when looking at exterior mounted shading devices, both fixed and automated; such as wind damage, intentional and unintentional damage caused by the public and maintenance. When installing exterior mounted operable shades, manual or automated, we either use cables that run through the bottom hem-bar or side channels to hold the shades in place. A "zipper system" that also holds the material into side channels is preferable when high winds or gusts are a concern. I highly recommend reading the Zelenay, Perepelitza and Lehrer report referenced above - it is very well researched and presents several excellent case studies. After considering all of the site and project requirements if it is determined that interior shading makes best sense, we specify metalized shading materials where the outside surface [facing the sun] has a reflective coating so that no matter what color the occupants see inside the building, the sun will always see a reflective non absorbing reflective surface. The challenge has always been with shade materials installed inside windows that when considering view, glare, and solar control, that there was no material that performed on all fronts. Light colored materials that reflected solar were difficult to look through because they would "glow" when sun-struck and dark materials that provided a better view were solar collectors because they absorbed and converted light to heat inside the glass. These new metalized solar materials also provide designs with low emissivity coatings, like Ferrari Soltis 99 - Low E, that emit low levels of radiant energy [heat].

In Closing

Many of the problem projects that we become involved with had no input from the Architect with respect to the window coverings. Consequently, many thoughtful designs were later blemished by decisions made by others who were not trained to recognized heat gain problems. Sadly, in many cases, making the right window treatment decision was no more expensive than making the wrong one - the wrong decision was made because someone didn't understand "how it worked." There are a number of exciting new products being introduced that control light and heat through glass and we would be happy to share any and all information as we become aware of new fenestration technology through our newsletter. I can be reached at: john@windowproducts-mangement.com. Thank you for your consideration.

[Bragg, Sir William , Electrons and Ether Waves, Scientific Monthly, 1922, 14, 158]

[Paul Arthur Schilpp, ed, Albert Einstein: Philosopher-Scientist, Open Court (1949) p 51],

[Feynman, Richard P., QED Quantum Electrodynamics, (1985) p 104]

***[Krystyna Zelenay, Mark Perepelitza, David Lehrer. (Center for the Built Environment, University of California, Berkeley). 2011. High-Performance Facades: Design Strategies and Applications in North America and Northern Europe. California Energy Commission. Publication number: CEC-500-99-013]**