



# Advance Solar Control Education Guide



## **Foreword**

The following material presented in this educational study guide is provided for the education of window film industry participants. Our hope is that IWFA members and non-members will use the information provided to promote window film professionally and competently. Additionally, accreditation tests are available through the IWFA education system. Passing grades on each test will give IWFA members additional accreditation references on the IWFA dealer locator.

The information presented has been reviewed for technical accuracy by the IWFA Technical Committee. Therefore, we believe this guide presents a wide range of materials in a balanced and unbiased format. We not only welcome but encourage readers and users to continually offer suggestions for future edits.

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We sincerely hope the use of this Guide in your business dealings will enhance your professional development and success.

IWFA Board of Directors

# Introduction

The biggest problem in controlling comfort, glare, and furnishing deterioration in homes and offices is dealing with radiant energy from the sun. While walls and roofs absorb this energy, it literally pours through window and is absorbed by all it touches. The Guide will focus on describing the sun’s energy journey through the atmosphere, interaction with clear glass, variations in glass types and coatings, window glazing types and framing, window film constructions, and finally the measurement and impact of solar radiation on the interior of homes and buildings.

## The Sun – A Source of Radiant Electromagnetic Energy

The sun is a tremendous source of energy. It is constantly sending its energy through space towards the earth in the form of electromagnetic radiation or energy waves. This transfer of heat from the sun to earth is called radiation. Throughout this Guide it will be important to remember that heat energy always flows from high temperature to lower temperatures. Freezers and coolers don’t “keep the cold in”; they prevent heat from entering and warming the interior contents. Earth’s atmosphere protects it from the sun’s energy reaching the surface. Changes in that atmosphere can change the rate at which that heat transfer occurs.

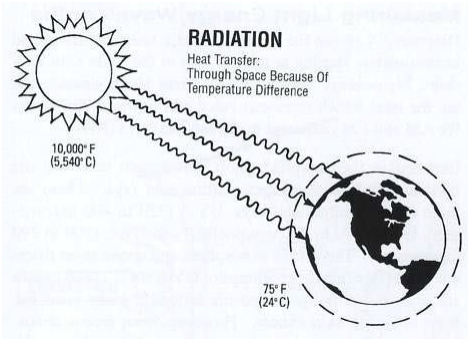


Figure 1.1

Electromagnetic energy is expressed in units called wavelengths. A wavelength is the length of a full cycle in a repeating curve. As electromagnetic waves are impossible to see with normal vision it is helpful to use an example of something visual like the waves formed in a bowl of water in contact with a vibrating needle. The wavelength is the distance from the beginning of a positive phase through positive and negative phases to the beginning of the next positive phase.

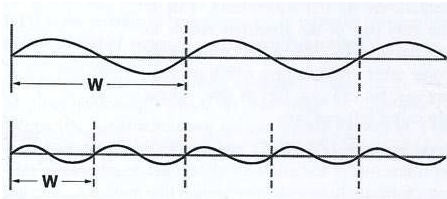


Figure 1.2

Individual waves are not visible within the electromagnetic spectrum although human senses and biology interact with these wavelengths in many ways. These waves are measured in nanometers. A nanometer (nm) equals one billionth of a meter or 0.0000000394 inches! Another common measure of electromagnetic energy is frequency, a measure of the number of wavelengths per second. Using the bowl and needle example, the frequency could be visualized by the number of waves hitting the side of the bowl per second. Figure 1.3 below, shows the electromagnetic spectrum from shorter, higher frequency wavelengths up to the longer, low frequency wavelengths.

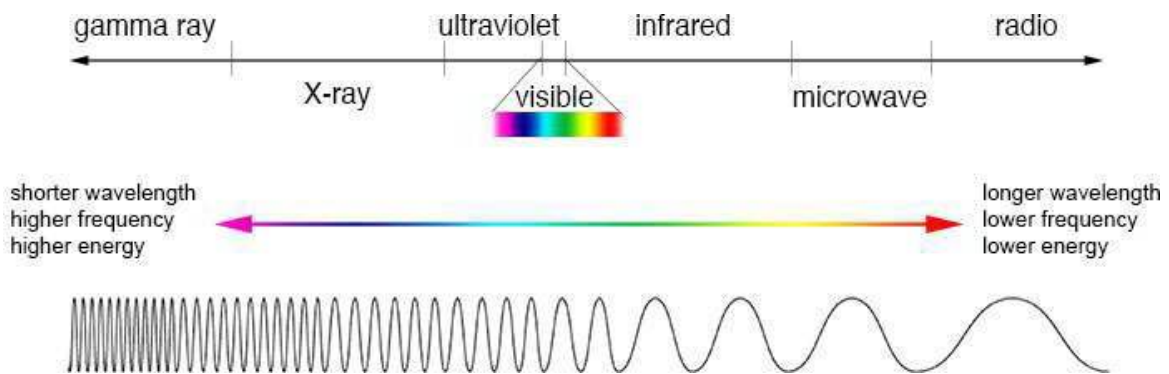


Figure 1.3

## Measuring Light Energy Wavelengths

Figure 1.4 shows the electromagnetic spectrum (EM), with nanometer measurements, starting at the low level of the scale with very short, high-energy wavelengths. Energy from the sun is only found in a portion of the EM spectrum and is referred to as the solar spectrum.

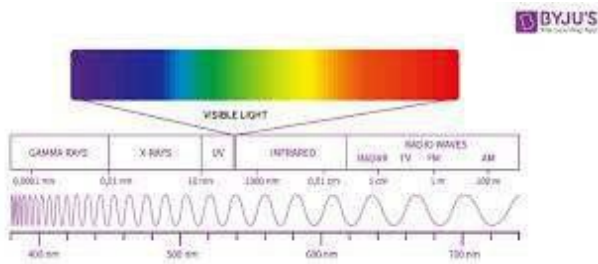


Figure 1.4

### Ultraviolet

Included in the powerful, short wavelength band are the invisible and more energetic (higher frequency) ultraviolet rays. There are three types of ultraviolet rays: UV-C (100 – 290 nanometers), UV-B (290 -320 nanometers), and UV-A (320- 400 nanometers). The earth's atmosphere and ozone layer filter out most UV-C and a percentage of the UV-B.

### Visible

What is considered the visible band of the solar spectrum runs from roughly 380 nanometers to 780 nanometers. "Visible" is a subjective term as there are no globally agreed limits to the visible spectrum. CIE (International Commission on Illumination) defines the visible radiation as "any optical radiation capable of causing a visual sensation". Age plays a significant role in a person's ability to see. UV absorption increases in the human lens over time thus blocking more and more of the UV region. This is nature's way of protecting the eye as excessive UV is a strong contributor to macular degeneration. Most spectral charts show the UV region overlapping with the visible region between 380-400 nm. Industry standard measurements will be reviewed later in this Guide. A similar situation occurs at the top range of the visible region. Most experts believe the range where humans start to lose the ability to perceive light is somewhere between 760 – 830 nm. Above this range are other invisible rays that we cannot see as light but can only feel as heat. These are called infrared rays.

### Infrared

Infrared is electromagnetic energy with wavelengths great than that of red visible light. Infrared is in the solar spectrum from 780 nanometers to greater than 1 millimeter. There are different ranges in the Infrared regions. Near- IR is from 780 – 2500 nm. Far-IR radiation is re-radiated from objects that have been heated by the sun or other heat sources. Far-IR is measured from 2500 nm to 40,000 nm. Beyond that point the amount of radiation from the sun is extremely low.

**Solar Heat: Visible and Invisible Light**

Electromagnetic energy from anywhere in the solar spectrum will heat a surface but the intensity and energy from the different wavelengths are not equal at all wavelengths. Roughly 44% of the sun’s radiant energy is received by the earth in the form of visible light. Invisible light in the form of infrared solar energy accounts for another 53%, with ultraviolet radiation making up the final 3%. Other references may show slight differences in these percentages due to different standard setting bodies setting different wavelength cut-off points for UV, Visible, and IR radiation. Figure 1.5 below illustrates the radiation intensity in each wavelength range throughout the solar spectrum.

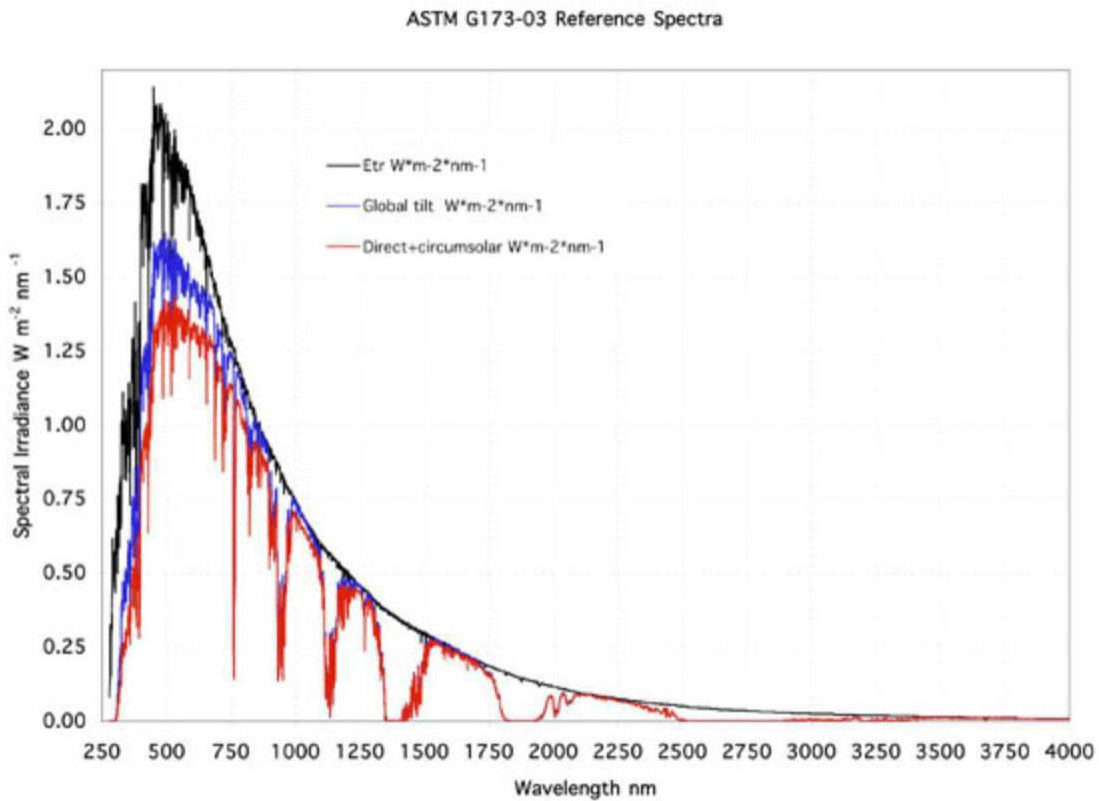


Figure 1.5

**Other Forms of Heat Transfer**

While it is important to understand the various forms of the sun's electromagnetic energy, it is also important to understand how heat transfer works. There are three forms of heat transfer: radiation (discussed in the previous sections), conduction, and convection.

### Conduction

Conduction transfers heat within an object or between two bodies that are in contact. It is a point-by-point process of heat transfer. Conduction can occur in solids, liquids, or gases that are at rest.

Consider a cup of coffee. Using a microwave oven heats the coffee with microwave radiation. Conduction is the transfer of heat from the cup to the tabletop when the cup sits in contact with the table. Conduction is also what warms the cup but also the air immediately adjacent to the cup. The warmth felt when hands are placed around the cup without touching it.

Conduction

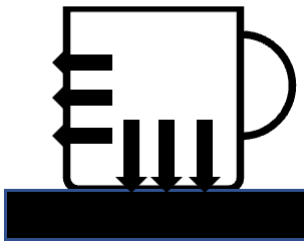


Figure 1.6

### Convection

Convection is the transfer of energy in a liquid or gas due to the motion of that fluid. The motion may be natural or forced.

Natural convection: Using the coffee cup example once again, natural convection occurs when the coffee cup is in a room with a cooler temperature than the coffee. As the surrounding air warms through conduction, it expands pulling new cooler air in and creating a cycle in which cooler air is warmed, expands, and continues to pull in cooler air. The transfer of heat through this natural air movement process is natural convection.

Forced convection: Providing an outside force which moves the gas or liquid faster than would occur naturally. In the coffee cup example, blowing over the surface of the cup is forced convection.

Natural Convection



Forced Convection

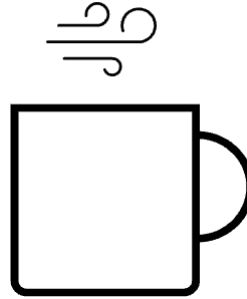


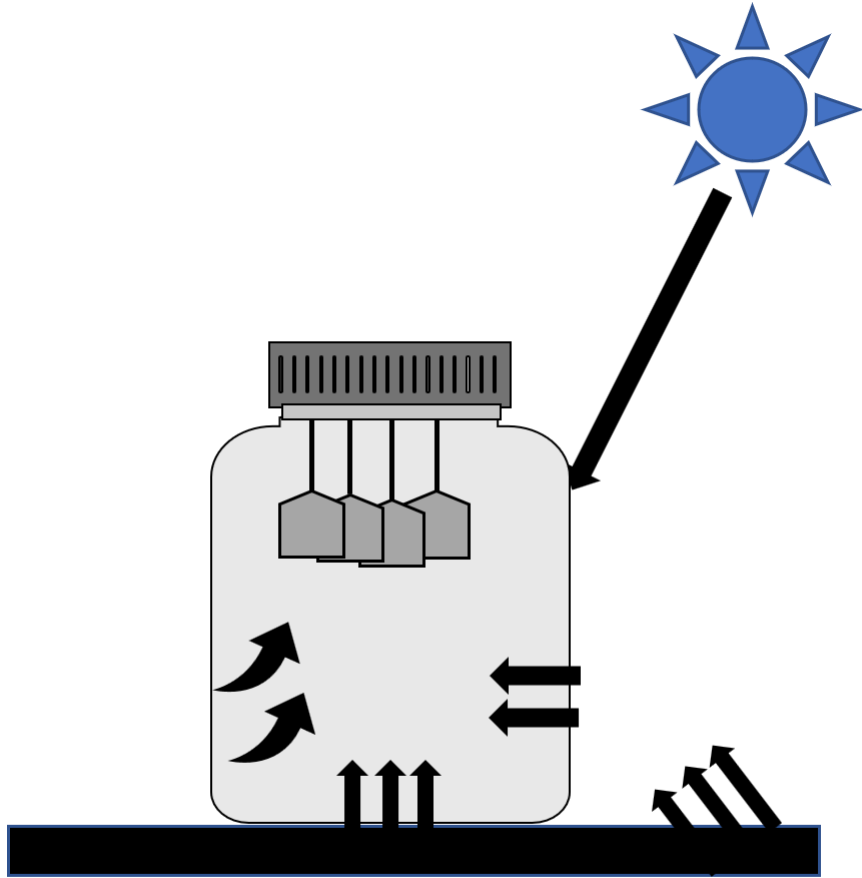
Figure 1.7

With both conduction and convection, the larger the temperature differences between the warmer body and the cooler body the faster the heat transfer occurs.

### Thermal Equilibrium

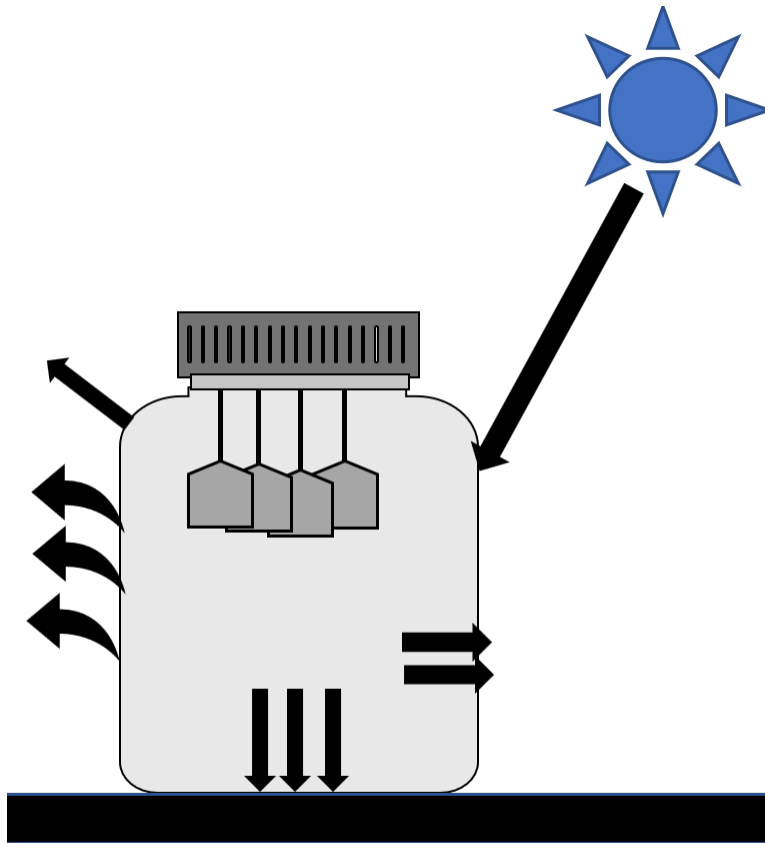
Heat energy flows from a high temperature to a lower temperature. When these temperatures balance heat stops flowing, and the system is said to be in thermal equilibrium. In the case of the coffee cup, once the temperature of the coffee reaches the temperature of the room, heat transfer stops. But in a closed system where the input energy continues, heat transfer can easily change directions. A closed jar of cool water placed in the sun will absorb radiant energy from the sun. If the contact surface and outdoor temperature are warmer than the jar and liquid, then energy from radiation, conduction, and convection are all flowing towards the jar and the air around the jar.





Water Temperature less than outside temperature and surface temperature

Once the temperature of the liquid inside the jar and the jar are warmer than the outside temperature and the contact surface the heat transfer from conduction and convection will change directions while the radiant heat transfer from the sun's rays will continue to heat the liquid to the point at which the radiant energy cannot heat the liquid further than the conduction and convection cool it due to temperature differences.



Water Temperature more than outside temperature and surface temperature

### **What Happens when Sunlight Strikes Glass**

When sunlight (incidental solar radiation) strikes glass, three things can happen:

1. The energy can be reflected away from the glass.

2. The energy can be absorbed by the glass.
3. The energy can pass through the glass.

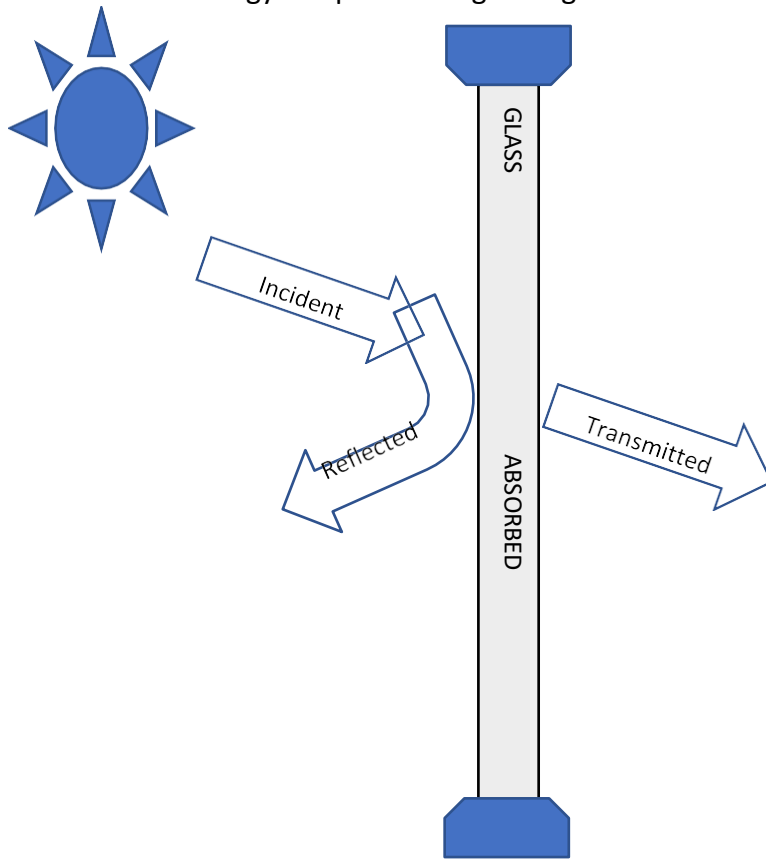


Figure 1.10

The performance definition for each of these events is expressed as a percentage, which will total 100%. Let's see what happens when sunlight strikes clear 1/8" glass.

Total Solar Reflectance	=	8%
Total Solar Absorptance	=	9%
Total Solar Transmittance	=	83%

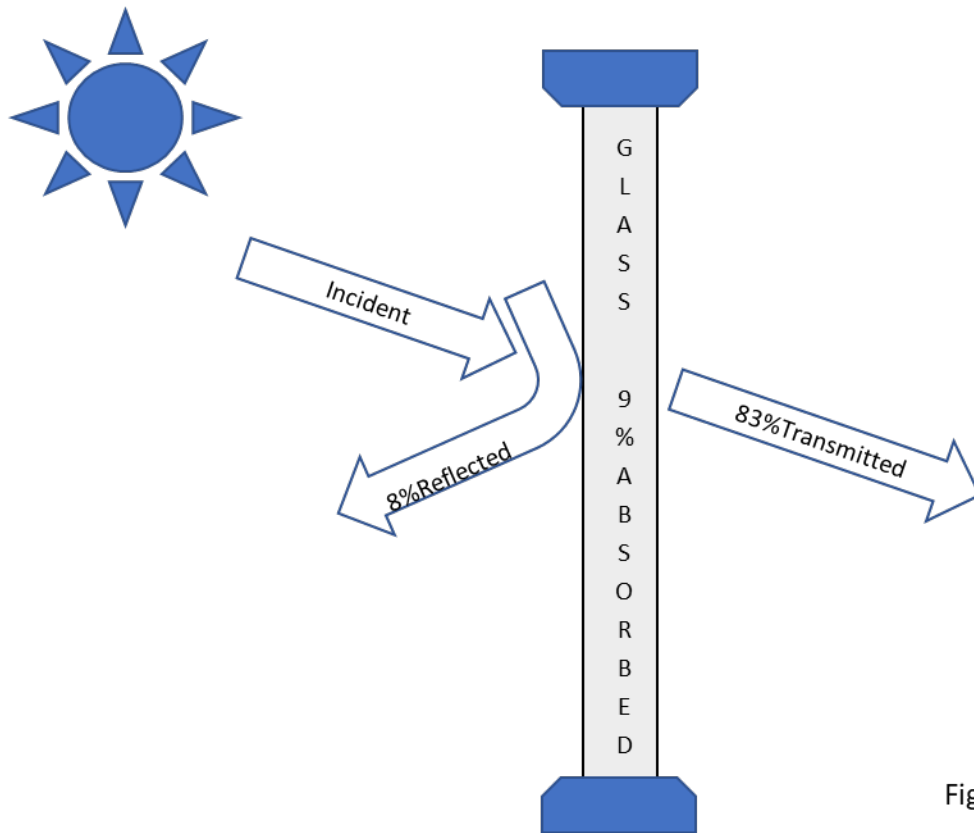


Figure 1.11

One of the easiest ways to remember this equation is using the acronym RAT. The sum of the reflectance (R), Absorption (A), and the Transmittance (T) must always equal 100%. If the values on a specification sheet do not equal 100% then the manufacturer should be contacted. One percentage point in either direction may just be a rounding issue. If the variation from 100% is more than 1%, then the data should be considered suspect.

Let's explore next what happens after the sunlight strikes the glass and heat transfer occurs.

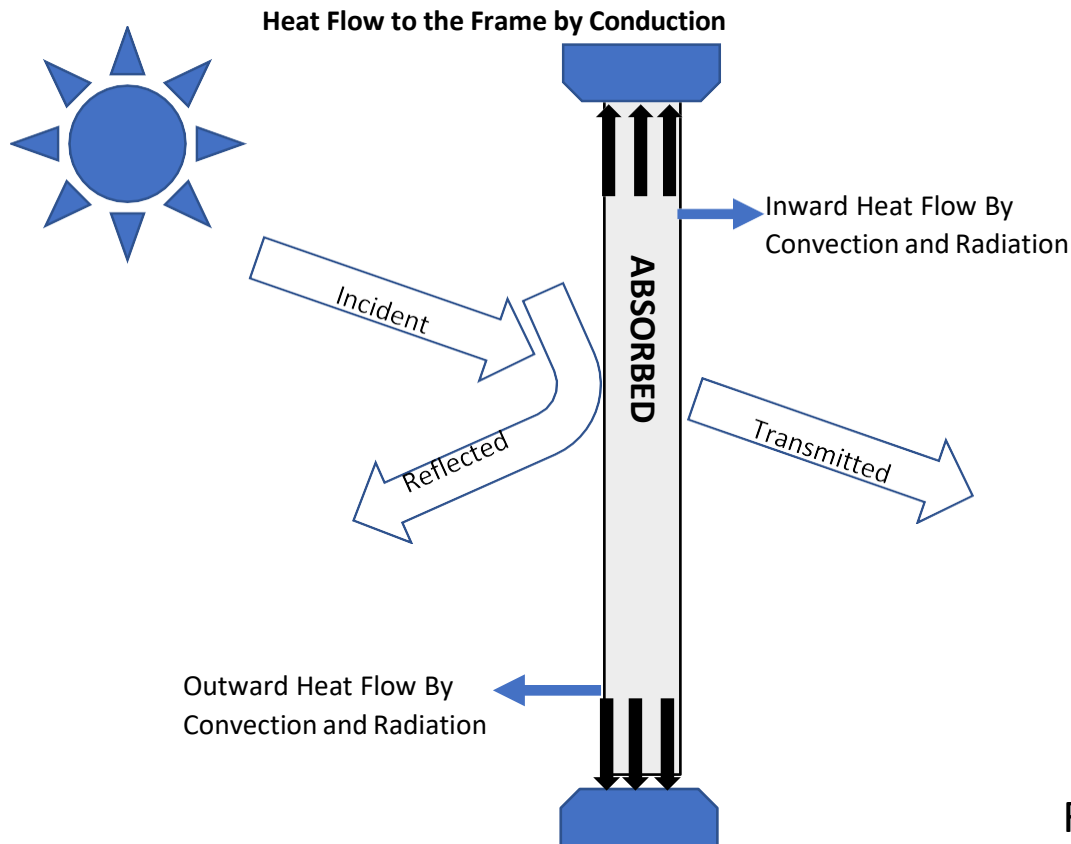


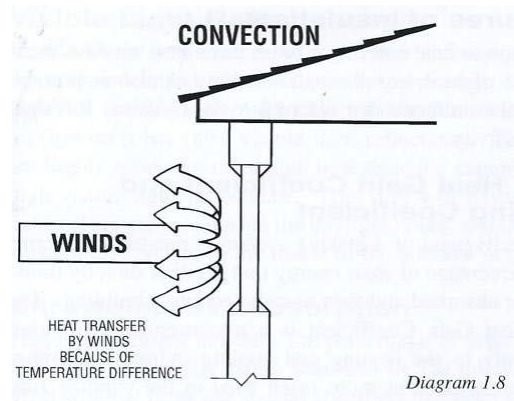
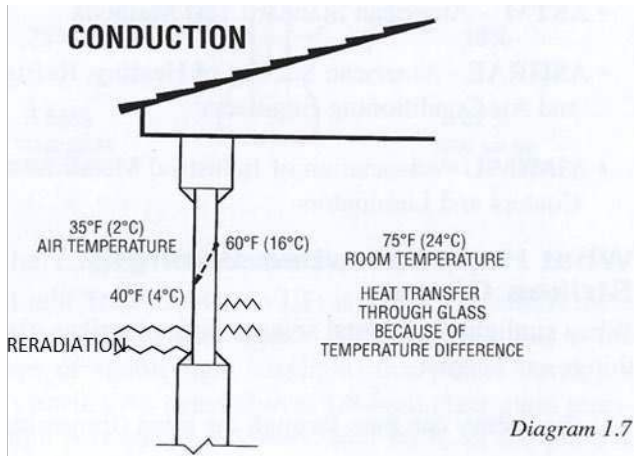
Figure 1.12

The solar energy is reflected, absorbed, or transmitted. The reflected energy does not enter the room and the transmitted energy goes through the glass without stopping. The absorbed energy flow is more complicated with absorbed energy flowing inward, outward, or both depending on the temperature difference from inside to outside. This heat transfer happens through convection and re-radiation. The absorbed energy can also flow to the frame through conduction.

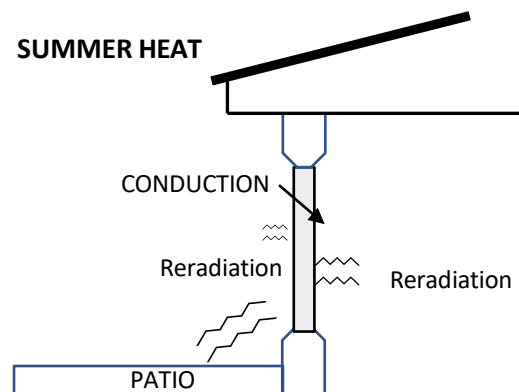
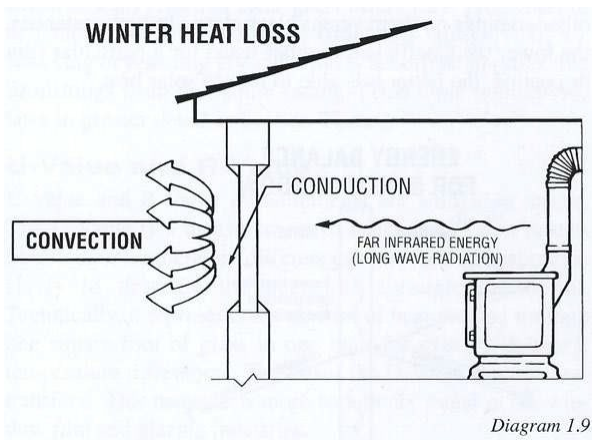
### Heat Transfer of Absorbed Energy in Glass

While transmittance and reflectance are fairly easy concepts to grasp, solar absorption is more complex. As seen in the previous Diagram, the absorbed energy is partially transferred through radiation. Absorbed solar energy is said to be “re-radiated” in this case. This refers to the fact that the transfer of energy occurs at different wavelengths than the source energy. While solar energy absorbed is from Ultraviolet, Visible, and Near IR, it radiates away from the glass as Far IR. In the glass jar example, the jar and its contents are heated by near IR from the sun but the increase in temperature underneath the jar is reradiated Far IR.

The following two figures illustrate the heat transfer of absorbed energy in an architectural setting where the outdoor temperature is cooler than the indoor temperature through conduction and convection. Re-radiation is a surface phenomenon. As all heat transfer is from heat to cold the radiation from the glass will occur at different speeds depending on the outside and inside temperatures. Figure 1.7 illustrates conduction and reradiation while Figure 1.8 only illustrates convection.



In addition to solar energy absorbed, heat transfer can occur with Far IR energy from other sources. Diagram 1.9 illustrates winter heat loss from an interior Far IR heat source. Diagram 1.95 illustrates summer heat gain from an exterior Far IR heat source. In both cases heat will also re-radiate at the glass in both directions depending on temperature differential.



## Emissivity

As noted above re-radiation happens at the surface of the glass. Different types of surfaces differ in their re-radiation and absorption capabilities. The emissivity of the surface of a material is its effectiveness in emitting energy as thermal radiation. Thermal radiation is electromagnetic radiation that may include both visible, near IR, and Far IR radiation. Emissivity measurements are reported as a comparison to a surface that would have an extremely high absorption rate and would re-radiate all the energy absorbed. Following this logic, the lower the emissivity value the better the surface would be at limiting re-radiation. Consider aluminum foil wrapped around a baked potato. Aluminum has a very low emissivity value. Holding your hand over a baked potato wrapped in foil will not feel very warm but grabbing it will burn your hand through conduction. In the chart below, polished aluminum has an emissivity of 0.05. Glass is not an inherently low emissivity surface with an emissivity of 0.84. A “perfect” emitter would have an emissivity of 1.00. It follows that glass will re-radiate a lot of heat and windows are one of the biggest sources of heat transfer in a building.

Material	Emissivity
Gold, polished	0.02 (Poor absorber, good reflector)
Silver, polished	0.02
Aluminum, polished	0.05
Glass, 1/8”	0.84
Paper	0.89
Wood	0.91
White Enamel	0.91
Flat Black Paint	0.96 (Good absorber, poor reflector)

## **Review of Solar Terms**

Below are short definitions of many of the terms introduced in this Section. Remember to keep in mind the differences between the individual wavelength ranges of the electromagnetic spectrum. Some definitions refer to specific ranges within the solar spectrum while others refer to the complete solar spectrum. In this section the glass used in the examples was clear, single pane, 1/8" glass. The next section will give a brief history of glass and then explain differences in glass types, thicknesses, and coatings. In addition, the section will explain window systems.

### **Total Solar Reflectance (TST)**

The percentage of incident solar radiation that is reflected by a glazing system.

### **Total Solar Absorptance (TSA)**

The percentage of incident solar radiation that is absorbed by a glazing system.

### **Total Solar Transmittance (TST)**

The percentage of incident solar radiation that is transmitted (passes directly through) a glazing system.

### **Visible Light Transmission (VLT)**

The percentage of visible light that is transmitted (passes through) a glazing system.

### **Visible Light Reflectance (VLR)**

The percentage of visible light that is reflected by a glazing system.

### **Ultraviolet Transmittance (UVT)**

The percentage of ultraviolet radiation that is transmitted through a glazing system. Many people prefer to report the percent of ultraviolet radiation that is prevented from passing through the glazing system for ease of customer understanding, but the actual measurement is UVT.

### **Infrared Transmittance (IRT)**

The percentage of infrared radiation that passes through a glazing system. As with UVT, many people prefer to report a value that is the percent of IR that is prevented from passing through a glazing system, but this is more problematic in the case of IR since there is a high degree of absorption and the wavelength range is large and highly variable by wavelength in solar intensity. Calculations for a more accurate performance value will be discussed later in this guide.



## Section II: Glass and Glazing Systems

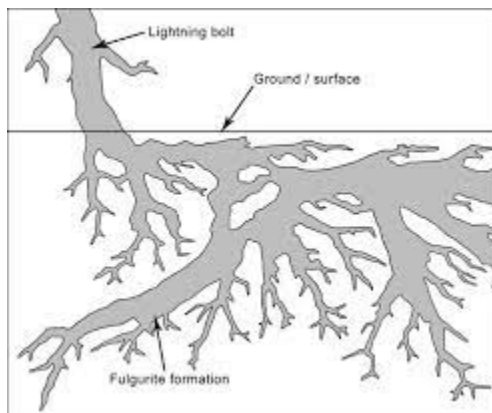
### History of Glass

Glass may be one of the oldest known man-made materials with examples of glass found at historic sites dating back to 7000 BC. By 3000 BC glass was being used on a regular basis in Egypt but primarily for decorative purposes. It was another 1500 years before the art of making glass into useable shapes was perfected. The New York Metropolitan Museum showcases a vase believed to have been made around 1490 BC.

In simple terms, glass is liquid sand reformed into a transparent “solid”. The process requires heating the quartz sand, also known as silica sand, to temperatures above 3090 degrees Fahrenheit until it melts into a clear liquid.

The idea for making glass from sand may have had its origins from the natural occurrence of fulgurites. Fulgurites are tubes or crusts of glass formed when lightning strikes sand high in silica content and fuses the silica into a shape that mimics the path the lightning bolt travels through the sand.

Insert diagram of fulgurite.



Unlike the movies suggest, fulgurite doesn't look like glass but more like a sand encrusted piece of driftwood. Interestingly, fulgurites tend to be hollow and these hollow tubes when exposed to bright light can be somewhat transparent.

Given the high temperatures needed to create glass it is not surprising that glass took centuries to perfect. Glass blowing, which was believed to have originated in Phoenicia around 50 BC, greatly improved the possible uses for glass. Hollow objects such as glasses and urns are produced by “catching” a blob of molten glass on the end of a long hollow tube and then blowing air into the molten glass to form a bubble in the middle. The glass is rolled and manipulated at the same time to keep the molten glass from slumping to one side. The Venetians became masters at glass making, finding additives to give more flexibility in the manufacturing process and introduce color to the glass. Still, glass making remained more of

an art form than a production process. The first “window” glass was made by catching a glob of glass, spinning it to increase the circumference, and then pressing it against a flat surface to make a circular sheet of glass. While the glass was roughly uniform in thickness, it was certainly flatter on one side than the other and the spinning produced concentric circles visible in the glass and a dimple in the center where the glass was removed from the blowing tube. The circular glass was then cut into a square or rectangular shape to be used as a windowpane. The air bubbles, uneven texture, and general poor clarity made it difficult to see clearly through the glass, but it did provide light transmission.

The French perfected this type of glass by grinding and polishing the glass to improve clarity and thickness. The best of these became known as “French Panes”, a term used to this day to describe small lites of glass even though they are no longer made with this process.

### **Modern Glass**

Glass making and specifically glass blowing remained an art and the industry was controlled by a small group of craftsmen motivated to keep the production of glass small and the skill required to produce it in high demand.

This all changed in 1916 when Michael J. Owens mechanized the production of glass containers and perfected the first machine for flat drawn window glass. In 1955, manufacturing took another leap forward when Pilkington introduced the float glass manufacturing method.

### **Types of Glass**

Glass can be categorized by the amount of heat used in the manufacturing process, namely hot, hotter, hottest. At the low end of the scale is annealed glass, followed by heat-treated glass, and finally tempered glass. All three types of glass start as annealed glass, but heat-treated and tempered glass are subjected to subsequent processes which change their breakage characteristics. Annealed glass can be cut at a glass shop, but heat-strengthened and tempered glass must be heat treated at the size they will be used as they cannot be cut to size after heat treatment.

### **Annealed Float Glass**

The most common window glass available on the market is commonly referred to as annealed float glass or simply annealed glass. Annealed float glass is manufactured in a process where molten glass is poured continuously onto a bed of molten tin. The molten glass tends to seek a level configuration as it floats on the surface of the molten tin. The thickness of the glass is relative to the rate at which the molten glass flows from the tank onto the tin. If the flow rate is slowed down, the glass is thicker. Because the melting point of the tin is much less than that for the glass, the glass solidifies as it cools on top of the tin. Once the glass solidifies, it is fed into an annealing oven where it is slowly cooled so that the residual stresses are minimized. This process results in the production of a glass product, which is very flat with nearly parallel surfaces.

Since annealed glass has a minimum amount of residual surface compression, it is subject to easy breakage. Annealed glass is the most fragile of all manufactured glass. It is subject to breakage from airborne flying objects, human impact, and thermal stress fracture as a result of temperature changes.

When annealed glass breaks, it does so in many sharp, irregular-shaped pieces referred to as shards. Depending on the cause of the glass breakage these jagged pieces of glass can be propelled at high speeds and can cause serious bodily injuries and even death.

### **Heat Treated Glass**

Heat treated glass is a type of glass that is the result of a heating and controlled cooling process to induce a change in structure within the glass leading to an increase in strength. The glass is heated to about 1150°F and then cooled with short blasts of cool air. The cooling process is also referred to as quenching. This type of glass has a strength factor about twice the strength of annealed glass and is a process often used with tinted glass to lower the risk of glass breakage due to thermal stress. Heat strengthened glass tends to break in a similar way to regular annealed glass.

Almost all original properties of the glass remain unchanged. The glass is more resistant to heat induced stress, wind-loads and impacts by wind-borne debris and hail. However, heat treated glass is not accepted as a safety-glazing product as it tends to break in a similar way to regular annealed glass.

Glass strength is defined by the degree of edge or surface compression. Surface compression is the end result of the heat strengthening process, where the outer state of the glass is locked in a state of high compression, and the middle is in a state of tension.

### **Tempered Glass**

Tempered glass is the result of heating and rapid cooling of float glass to induce a change in structure leading to an increase in strength. Single sheets of annealed glass are heated to temperatures around 1200°F. This is the temperature at which annealed glass begins to soften. The outer surfaces of the glass are then rapidly cooled. This creates high compression in the surfaces.

This type of glass is about four times stronger than regular annealed glass. The change in structure has two main benefits. First, the glass is much stronger, and second when the glass is broken it breaks into small fragments as opposed to the large, sharp, shards created by annealed glass. This is a major benefit in areas that are at high risk of accidental human impact such as sliding doors or shop front doors and windows.

There is another great benefit to tempered glass. It is very resistant to cracking from the thermal stress caused by solar absorption and temperature differentials from edge to center of

glass. This phenomenon is known as thermal shock fracture, and usually occurs when the edge and center of the glass pane have a relatively high difference in temperature.

In many cases, tempered glass or laminated glass is required in high-risk areas to satisfy local building codes as well as federal mandates. For example, in homes it is required that tempered glass be used where there is floor to ceiling glass windows, glass doors, or glass panels next to doorways. Similar requirements are mandated for commercial buildings and any glass areas exposed to heavy pedestrian traffic.

### **Chemically Strengthened Glass**

There is another type of glass produced, which is called chemically strengthened glass. This type of glass is produced when glass is submerged in a molten salt bath at temperatures below normal annealing. This results in an exchange of ions at the surface level of the glass. This is a complex process beyond the scope of this document.

Chemically strengthened glass has similar compressive strength to heat treated glass. The product is not generally used for window glass but more commonly seen in industries where very thin, strong glass is needed. This glass breaks in a similar fashion to annealed glass.

### **How to Identify Glass Types**

Most tempered glass products are identified through a clearly visible corner etching stating that the glass complies with safety glazing standards. The presence of this marking is intended to assure that the glass is fully tempered.

If there is no corner etching, the most direct way to tell the difference between annealed and heat strengthened glass in the field is using two sheets of “polarized film”. One sheet should be positioned on each side of the glass pane and the character of the light that shines through the glass is examined. Annealed glass will exhibit a neutral appearance, while heat-strengthened glass will exhibit a mottled display of residual stress patterns. Today the easiest way to identify heat treated glass is with a meter that is available for that use.

### **Glass Constructions**

For the purposes of this training guide, types of glass can be divided into two major categories: monolithic and laminated.

#### **Monolithic**

Monolithic glass is the simplest glass type. It consists of a single flat piece of glass of constant thickness. Virtually all monolithic glass produced throughout the world is produced using the float glass method. Monolithic glass can be annealed, heat-treated, or tempered. Additionally monolithic glass can be coated by various methods. Combining individual, spaced, monolithic layers to make dual pane or triple pane glass units that can then be used to make complex window systems which will be discussed in a later section. While most glass used today is 1/8”

or 3mm minimal thickness, new manufacturing methods have been developed to produce thinner commercially viable glass.



Figure 2.1

### Laminated Glass

Laminated glass is produced using two or more layers of glass permanently bonded together using an “interlayer”. The most common interlayer is polyvinyl butyral (PVB) although polyurethane (PU) interlayers are also used. The glass used can be annealed, heat-strengthened, or tempered.

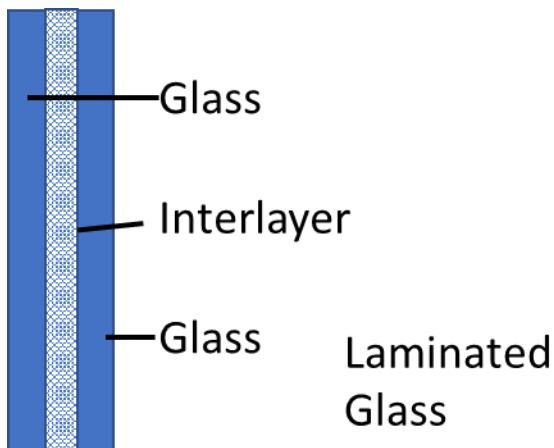


Figure 2.2

Laminated glass is designed to be used in areas where increased strength, impact resistance, and noise reduction are required, or an incident of flying glass may cause serious injury. Glass can also be laminated to multiple layers that are not glass. Glass laminated with plastic glazing such as polycarbonate or acrylic is used primarily for safety or security uses and is discussed in more detail in the Safety and Security Training Guide.

## **Other Miscellaneous Glass Types**

There are several different glass constructions that may be encountered in the marketplace such as: wired, textured, and patterned glass. The manufacturing processes associated with these types of glass typically introduce surface and edge flaws, which make them more susceptible to glass breakage. Discussions about the various uses for these glass types is outside the scope of this document.

## **Non-Clear Glass**

### **Tinted Glass**

Glass is now manufactured primarily by the float glass method, with a large percentage of the auto glass and a smaller percentage of the architectural glass manufactured utilizing a full-bodied coloration process. In this process the color is mixed in with the glass at the time of manufacture, resulting in a glass that is colored consistently throughout its thickness. Tinted architectural glass can also be produced by applying the color as a surface coating during the cooling phase of the manufacturing process when the glass is still in a semi-molten state, or in a separate operation after the glass is manufactured.

Tinted glass is used in many commercial buildings for solar heat control, privacy, and exterior aesthetics. When used alone, tinted glass has very little reflectivity and achieves solar heat control primarily through absorption thus making it lower performing than other coatings which work through solar reflection. It is often heat strengthened to limit the glass breakage risk. Tinted glass may be hard to detect if the tinting is light. If the architectural specifications for are not available, placing a white piece of paper behind the glass and viewing from the other side can be helpful.

### **Reflective Glass Coatings**

Glass that has metallic or metallic oxide coatings applied onto the surface is generally known as reflective coated glass. These coatings have a wide range of visible light transmissions and colors. Many different colors are available by combining the metallic layers with tinted glass layers to yield colors such as silver, gold, copper, grey, bronze, blue, and green.

Additionally metallic and metallic oxide coatings can be applied in combination yielding high performance glass coatings. Two specific coatings are known as “spectrally selective” and Low emissivity or “Low E” for short.

Spectrally selective coatings are produced using a combination of metal and metal oxide coatings and have the distinction of producing glazing products with a combination of high visible light transmission and low visible reflectivity but high solar reflectivity. These glazing products are especially desirable in homes where owners do not desire the low light transmission and high reflectivity often seen in commercial buildings with reflective glass.

Low emissivity coatings are produced using either a metal oxide or a combination of metal and metal oxides. It comes in an earlier version which is referred to as standard Low E and a newer version referred to as high performance Low E.

Standard Low E coatings have very high visible light transmission, but very low emittance and very low visible and solar reflectance. This glass is used most often in heating dominant climates (northern climates in the northern hemisphere). When used in the proper window construction they can be very beneficial in reducing winter heat loss from interior heat sources while also allowing winter heat gain from the sun (free daytime heating).

High Performance Low E coatings have high visible light transmission, low visible light reflectance, low emittance, but high solar reflectivity. This glass is used most often in cooling dominant climates (mid and southern climates in the northern hemisphere). When used in the proper window construction these glazing materials can be very beneficial in reducing summer heat gain.

### Dynamic Coatings

Dynamic coatings are those that change solar performance in some manner based on an input. They are of high interest among researchers as they offer the best performance as they can change based on the outdoor conditions. There are three general types of dynamic coatings and several variations within those types.

Thermochromic – Coatings that change solar performance properties with temperature.

Electrochromic – Coatings that change solar performance properties with electric stimulus.

Photochromic – Coatings that change solar performance properties with light stimulus.

Many different glass types are available today with many different combinations of properties. The number of variations takes on even greater complexing as the type of window constructions are included.

## **Glass Breakage**

No discussion of glass is complete without discussing how and why it breaks. Glass can break for any number of reasons associated with either pressures on the glass or direct impact to the surface from objects. They include:

Human Impact – An adult or child running into or falling into a piece of glass.

Forced entry – Breakage resulting from attempted illegal entry through glass.

Windstorm – Breakage from flying objects or pressures associated with windstorms

Earthquake – Breakage from the racking motion created during an earthquake

Blast – Breakage resulting from the pressure wave of an explosion.

Nickel-sulfide inclusions – Tempered glass breakage from a glass contaminant.

Thermal breakage- Cracking associated with edge stresses caused by heat.

The first five of these are covered in more detail in the Safety and Security Training Manual but nickel sulfide inclusions and thermal breakage can occur without a significant event and are issues that every student of this guide should understand.

### **Nickel Sulfide Inclusions**

Infrequently glass will contain very small particles of nickel sulfide produced from a nickel contaminant in the glass during the float process. A subsequent tempering process make the glass 4-5 times stronger than annealed glass. The combination of this glass tension and a rare nickel sulfide stone forming in the center tension zone of the tempered glass can lead to a spontaneous breakage later when the glass is exposed to varying temperatures after installation. Float glass manufacturers go to great lengths to eliminate nickel in their processes and so this has become a rare form of glass breakage. It is important to remember that this can only occur in tempered glass, and it is likely to be an edge defect or other impact that breaks tempered glass. Since tempered glass tends to fall out of the frame when broken, it is often very difficult to locate the epicenter of the breakage and thus difficult to determine the cause of the glass breakage. If the tempered glass has been filmed, it may be possible to determine whether the breakage occurred in the middle of the glass or at an edge.

### **Thermal Stress Fractures**

The most common cause of glass breakage not associated with an impact or pressure wave event is thermal stress fractures. Thermal stress fractures are the result of uneven temperature distribution across the glass surface. This leads to internally induced stress. Consider glass installed in the mountains or the desert. The glass temperature can drop significantly during the cold night-time hours but when the sun rises the center of the glass heats up rapidly while the glass under the frame remains cold. The resulting temperature variance may be sufficient to induce stress, which the glass cannot withstand, and it cracks. Factors that can exacerbate thermal stress can include type of glass, glass thickness, framing systems, surface or edge damage, heat absorption characteristics of the glass, edge bite, and unfavorable external shading on the glass or blockage of air flow due to close window coverings on the interior.



It is possible to get some understanding of the cause of the breakage by looking at the breakage pattern on the surface of the glass. Breakage patterns which emanate from the corner of the glass may indicate a window out of square. Thermal stress fractures normally emanate from the edge of the glass, perpendicular to the edge at a 90-degree angle for the first ½ -1", from there the crack may go in any direction. See Figure 2.3 below.

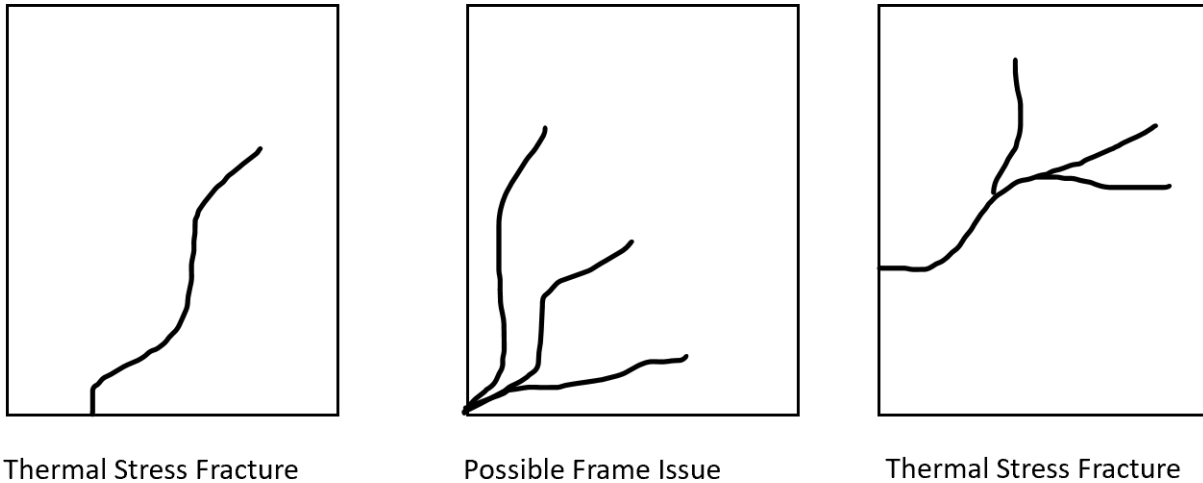


Figure 2.3

## Glazing Systems

A glazing system is comprised of the framing system, glazing materials, and the glass itself.

### Framing Systems

The framing system serves to hold and minimize the edge deflection of the glass, keep water and air out of the building, and provide a method of cushioning as well as thermal isolation for the glass. In residential applications, most frames are wood, vinyl, or aluminum. In the case of commercial buildings where the windows are often large and part of the overall structure of the building, or curtainwall where the glass is part of the building envelope but not part of the structural support, aluminum and steel are most often used. Some curtain wall buildings use a complex series of "spider" fittings to hold the glass. Aluminum is used extensively as it is a very diverse material that can be manufactured in a variety of shapes and is easily fabricated. The framing system should provide support to the glass and is obviously necessary to provide integrity to the facade of the building.

## Aluminum Frames

Aluminum was one of the most used materials in residential windows and is still found in many existing homes. It is light, strong, durable, and easily extruded into complex shapes. It can be fabricated to extremely close tolerances, to create special forms for the insertion of glazing, weather-stripping, and thermal breaks. Aluminum frames are available in anodized and factory-baked enamel finishes that are extremely durable and low-maintenance. Aluminum resists corrosion and is ideally suited for sliding doors because of its strength and low weight.

The biggest disadvantage of aluminum as a window frame material is its high thermal conductivity. It readily conducts heat greatly raising the heat transfer of a window unit. In cold climates, a simple aluminum frame can easily become cold enough to condense moisture or frost on the inside surface of the frame. This condensation problem alone (in addition to the issue of heat loss) have spurred the development of better insulating capabilities for aluminum frames. The most common solution to the heat conduction and condensation problem is to provide a “thermal break” by splitting the frame components into interior and exterior pieces and using a less conductive material to join them. Diagram XX illustrates the principle and design of a “thermal break”.

**INSERT DIAGRAM 5-2 from the original manual found on paid 5-2.**

There are several methods for creating a thermal break but all of them involve using a less conductive material to bridge the interior and exterior of framing. Collectively these are sometimes referred to as “warm edge” spacers.

## Wood Frames

The traditional window frame material is wood because of its availability and ease of milling into complex shapes and required to make windows. Today, wood units tend to be thought of as “high end” because other competing units are often less expensive. Wood is not the most durable of material and require high maintenance, but well-built and well-maintained wood windows can have a very long life.

Wood windows are favored in many residential applications because of appearance and traditional house design applications. Water-repellent and/or chemical treatments can be applied in the factory to reduce swelling and warping, improve paint retention, and wood’s resistance to decay and insect attack.

Cladding the exterior face of wood frame with either vinyl or aluminum creates a more permanent weather-resistant surface. Clad frames have lower maintenance costs, while still retaining the attractive wood finish on the interior. Dark-colored finishes absorb more of the sun’s energy and are more susceptible to aging from heat and ultraviolet radiation.

From a thermal standpoint, wood-framed windows perform well having low conductance values. The thicker the frame, the more insulation it provides. When metal cladding is used, it can lower the thermal performance. If the metal extends through the window from the cold side to the warm side, it creates a thermal short circuit, conducting heat more quickly through that section of the frame.

### Vinyl Frames

Vinyl Frames have been quickly taking over the US market and now represent a large percentage of the overall residential new construction and replacement market. Vinyl offers good insulating value, high impact resistance, and excellent resistance to corrosion, air pollutants, and termites. Because the color goes all the way through, there is no single finish coat that can be damaged or deteriorate over time.

To provide structural performance, vinyl sections often need to be larger than aluminum sections, and closer to the dimensions of wood frame sections. Larger vinyl units often need to incorporate metal or wood stiffeners. In terms of thermal performance, most vinyl frames are comparable to wood. Many improvements have been made in vinyl framing over the years with constant improvement in the thermal performance of quality vinyl frames. Such frames are often referred to as “insulated” vinyl frames.

### Hybrid Frames and other materials

The wood industry has long built vinyl and aluminum clad windows to reduce exterior maintenance, while vinyl manufacturers have developed frames featuring interior wood veneers to produce more attractive offering for homeowners. It is increasingly difficult to gauge the thermal properties of a frame by simple inspection. The best source of information for new windows is the labels provided on the windows.

### Wood Composites

Most people are familiar with composite wood products such as particleboard and laminated strand lumber, in which wood particles and resins are compressed to form a strong composite material. The window industry is following a similar lead and using such material for frames since it is highly stable and has better thermal properties than conventional wood, in addition to being better suited to resist moisture and wood decay. Since wood composites are produced in lineal fashion, they have all the manufacturing advantages of vinyl and aluminum in terms of fabricating custom sizes.

### Fiberglass

Other poly-based technologies like fiberglass are making significant strides in the market. Fiberglass frames are dimensionally stable and have good insulating values. Because fiberglass is stronger than vinyl, it can have smaller cross-sectional shapes and less area. However, windows incorporating fiberglass are typically more expensive than vinyl windows.

## Summary

In general, there are many trade-offs between frame types. Those characteristics include frame size (width profile), cost, durability, and energy performance. In heat dominated locations improving the frame energy performance reduces heat transfer and thus the heating load. In locations with significant cooling costs, changing the framing material has less impact. Both the framing and the glazing materials must be considered in tandem to evaluate the best value in any given climate. It is important for the dealer to remember that frame type matters depending on the climate zone and while filming windows may provide a significant improvement in the solar performance. Poorly framed windows may be a better candidate for replacement than the installation of film.

## **Glazing Materials**

Gaskets, sealants and tapes are used to provide an effective seal, cushion the glass and provide thermal insulation between the glass and frame. In general, there are three common glazing materials. These are gaskets, sealants, and tapes.

### Gaskets:

Gaskets can be made of solid or foam sections and are generally made of rubbery type materials which could include vinyl or silicone, as examples. They need to be resistant to the elements, but still be able to maintain elasticity and hardness properties. Depending on the system and design requirements, these gaskets can be keyed or wedge type. Gaskets are engineered in such a manner that they have an appropriate thickness, hardness in profile required to apply proper pressure on the glass and still take into consideration the likely glass tolerances, framing material and the overall gasket dimension.

### Sealants:

Sealants may be used individually or may be combined with gaskets or tapes. Common sealants are silicones, polysulfides, polyurethanes, and other materials that can be applied with a sealant gun. Most of these materials can also be manipulated with tools to provide a designed shape. There are many factors that are taken into consideration when a decision is to be made on the type of sealant to be used. Some of these factors include the materials to be joined or sealed, environmental conditions that may prevail, thermal considerations such as expansion and contraction, as well as joint size. As the sealants have varying levels of performance and a multitude of different properties, careful consideration must be made to ensure that the appropriate sealant is used for the appropriate application.

Tapes:

Tapes are frequently used in the design of window systems and will function in a similar manner to sealants and gaskets. These tapes normally have a rectangular cross section and can be provided in solid foam material. In some cases, they can have an adhesive on one or both faces. As the requirements of a framing system can be demanding, in many cases, tape is used as a backup to the sealant application. The tape can provide a temporary cushioning effect, while the sealant is curing or may provide a holding method prior to the application of a vinyl gasket.

## **Window Construction**

Windows are part of a larger set of products described by the building industry as fenestration products. A fenestration is any opening in a building and includes windows, doors, skylights, tubular daylighting openings, etc. Windows come in many different configurations from the standard double hung found in many homes, through casements, and non-operable commercial windows.

### Glazing Configurations

#### **Single Pane Windows**

The most basic window design is a single pane of glass in a basic frame. This was once the only type of window found in almost every building around the world. While single pane windows allowed a lot of light and views, they were very energy inefficient. Something better was needed.

#### **Dual Pane Windows**

These windows, as their name implies, are built using two sheets of glass separated by an airspace of constant thickness. They are commonly referred to as insulated glass units or IGUs. Early units consisted of clear, annealed sheets of glass. Modern IGUs often use coated glass in different configurations to achieve varying energy performance standards.

“Spacers” or edge seals are placed between the two sheets of glass to create the airspace.

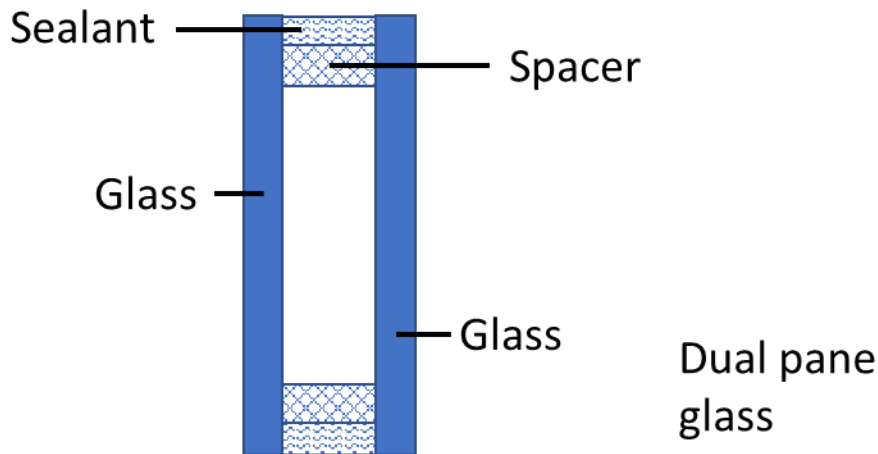


Figure 2.4

The seal between the glass sheets is accomplished through the use of a variety of different types of materials and sealants. High performance IGUs use special technologies to minimize heat transfer through warm edge spaces, thermally improved sashes and frames, thermally broken framing, and special weatherstripping. In addition, a desiccant is incorporated into the edge seal technology to absorb water vapor that migrates across the seal.

The intervening airspace reduces heat transfer by conduction and convection through the glass. To increase the insulating performance of the IGU, inert gases such as Argon and Krypton may be used to replace air between the panes of glass. Both Argon and Krypton are invisible, harmless, odorless, and heavier than air, which results in slower convective movement, few molecular collisions, and a reduction in heat transfer. Clear IGUs improve the performance of a window more in a cold climate than a warm climate, since the temperature difference between a building's interior and the outside air temperature is much greater in cold climates. Diagram 2.6 illustrates a dual seal IGU. One important note is how glass surfaces are numbered for users to identify and understand the placement of coatings. In the diagram below the faces of the glass are numbered 1-4 with the number one (1) face being the outside, number two (2) face being the inside surface of the outside pane, number three (3) being the air gap side of the inner pane, and finally the number four (4) face being the inside surface of the inner pane. Understanding the location of coatings in an IGU will be important in later sections of this guide as the location greatly impacts the solar performance and the heat transfer characteristics of a window.

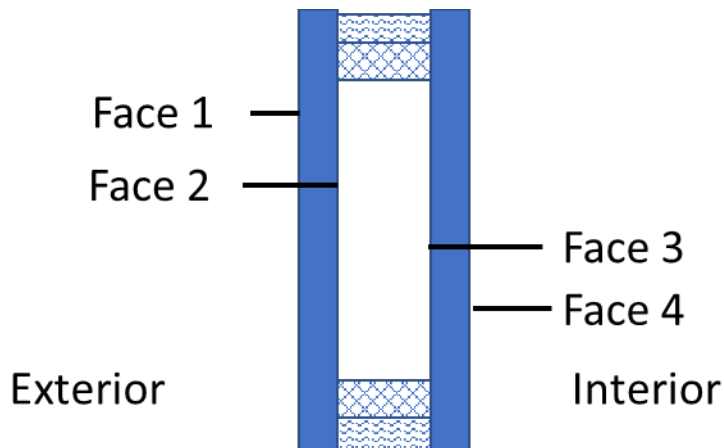


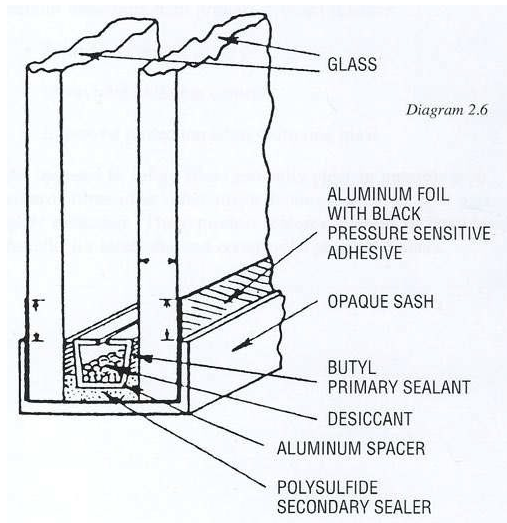
Figure 2.5

### Triple Pane Windows

These windows are built using three panes of glass. The third pane of glass further improves the performance of these windows by slowing the convection and conduction through the unit. Triple pane windows tend to be heavy and do not fit in a standard opening so are not very useful for retrofit applications. Newer versions use a very thin pane of glass in the middle and smaller air gaps to allow for retrofit in existing openings.

### IGU Seal Failure

One of the most common IGU consumer complaints is “fogging”. Almost everyone has seen a window that has turned very hazy, blocking the view, and creating a very “dirty” looking window. An IGU seal failure occurs when the desiccant used to keep the gas or airspace dry between the two glass plates can no longer absorb migrating moisture or other vapors that invade the seal. All IGU seals allow this migration to happen at some rate. This happens because of the natural aging process of an IGU, or it can be greatly accelerated by a poor window design, which allows moisture to be trapped near the edges of the unit. Early IGUs used a single seal but most modern IGUs use a dual seal with one acting as the structural seal and the other as the moisture barrier. The result of a seal failure is the condensation of excess moisture on the inside glass surfaces of the unit. This eventually causes the IGU to have a hazy or fogged appearance.



### **Vacuum insulated glazing**

These windows are like dual pane IGUs but instead of sealants and air or inert gases, the gap between the glass layers is a vacuum and the units are sealed to maintain that vacuum. VIGs have a higher performance level as there is almost no convection from one pane to the other. Newer versions have a very thin profile which allows for substitution into existing framing.

### **Fenestration Assembly**

While much focus is placed on the glazing material used and its design parameters, the overall performance of any glazing system is determined by the complete window assembly. The assembly includes the operating and fixed parts of the window sash and frame as well as associated hardware accessories. This section will examine the various types of window assemblies.

### **Window Sash Operations**

When selecting a window there are numerous operating types to consider. Traditional operable window types include the projected and hinged types such as casement, awning, hopper, and the sliding types, such as double and single-hung and horizontal sliding.

In addition to these traditional window types, the window market also includes other design types such as: fixed windows, storm windows, sliding and swinging patio doors, skylights, and roof windows, not to mention greenhouses and sunrooms.



There are subtle performance differences between a fixed and operable window that fills an identical rough opening. The fixed unit will typically have a smaller fraction of frame and proportionately more glass than the similar operable unit. Fixed windows with high-performance glass will have a better, lower U-value or SHGC than operable windows but then they also do not provide natural ventilation and may not satisfy building codes requirements for fire egress.

Air-leakage also differs by window type.

Air leakage, also referred to as “infiltration” is defined as ventilation that is not controlled and usually not wanted. It is the leakage of air through cracks in the building envelope. Tight sealing and weather-stripping of windows, sash, and frames are of paramount importance in controlling air leakage.

Weather-stripping is an essential component of an operable window. It must flex each time the window is opened and return to its original shape each time the window is closed. The quality of the weather-stripping on a window is one of the main factors that distinguish the quality of the window. Cheaper windows tend to save on cost by using poorer quality, less expensive weather-stripping.

There are two basic design formats for weather-stripping: brush or wiper types and compression types. Brush weather-stripping wipes sweep against the window sash as it moves. Compression weather-stripping squeezes and expands with the window operation.

### **Projected or Hinged Windows**

Hinged windows include casements, awnings, and hoppers hinged at the side, top, and bottom respectively. Some manufacturers also make pivoting combination windows that allow for easier cleaning of the exterior surface. Hinged windows, especially casements, generally project outward and provide better ventilation than sliders since they can capture passing breezes. Screens if used, must be attached to the interior side.

Hinged windows generally have lower air-leakage rates versus sliding type units. The hinged design allows the sash to be tightly clamped against the frame. In fact, when wind speeds are high, they tend to force pressure against the frame forming an even tighter seal.

### **Sliding Windows**

Sliders, the most common type of residential windows, include horizontal sliders, single-hung and double-hung windows. Ventilation can vary from a small crack to an opening of one-half the total glass area. Screens can be put on the interior or the exterior of the window unit. In double-hung or double-sliding units, both sashes can slide. The same amount of space can be opened for ventilation as in the single slider, but it can split between top and bottom for better airflow control.

Sliding windows generally have higher air-leakage rates than hinged windows. This occurs for two reasons. First, the weather-stripping effectiveness tends to be reduced over time due to the wear and tear from repeated movement of the sliding sash. Secondly, frames and sashes are often made of lighter, less rigid materials since they need only to support their own weight to facilitate sliding movement. As a result of this lightness, sliding frames may flex more in windy conditions and allow more air leakage.

### **Sliding Glass Doors**

Sliding glass doors (often referred to as patio doors) are extremely large expanses of glass and can exaggerate all issues related to comfort and energy performance. As previously noted, glass used in this type of unit is mandated by federal law to be tempered.

Sliding doors are essentially large sliding windows and are more complicated due to their weight and size. Because the sill is also a door threshold, which must keep water out while allowing easy passage for people and objects, the threshold is typically the more difficult part of the frame to weatherstrip effectively.

### **French Doors and Folding Patio Doors**

French doors and folding glazed doors are growing in popularity for new residential construction. A basic double French door consists of two hinged doors with no center mullion, resulting in a 5' to 6-foot-wide opening. Folding doors are typically made of pairs of hinged doors so that a double folding door with two pairs of doors can create an opening of 12 feet or more.

French doors have an advantage over sliding doors in that the weather-stripping is less subject to abuse, and the operating hardware is more effective against air leakage.

### **Skylight and Roof Windows**

Typical skylights include flat insulated glass units with coating and tints but domed profiles with single or double layers of clear, tinted, or diffused plastic still exist.

Roof windows have become increasingly popular to better utilize space in smaller homes, and in rooms featuring sloped ceilings. They are glazed with glass rather than plastic and are available with a wide array of different glazing types. Most roof windows can be equipped with operable interior shading systems to diffuse or reject intense sunlight. Because of the angle the sun hits during the peak intensity periods these windows are subject to often brutal conditions. Care should be taken when using any type of interior shading devices. Due to safety concerns, the interior glazing of skylights should be laminated glass per code. This adds to the complexity of determining what type of interior solar control can be used.

## **Greenhouse (Garden) Windows**

While less popular than in years past greenhouse windows, also known as garden windows, are still seen today. They are typically prefabricated frame and glass kits that can be inserted into a new or existing window opening. They include a bottom shelf to house a variety of plants and may have multiple shelves. A greenhouse window will generally have higher heat loss and heat gain than a regular window of the same size because it contains more glazing surface than a conventional window that fills the same wall space.

## **Sunrooms and Solariums**

Sunrooms and solariums are glazed spaces attached to a house that are used for sitting or eating areas as well as growing plants. They may be prefabricated kits or built with the same construction and window types found in the rest of the house. Sunrooms and solariums may be fully heated and air-conditioned living spaces, or they may be used only seasonally. Because they contain such a large amount of glazing area, it is essential to select efficient glazing solutions, especially if the space is fully air-conditioned.

## **Emergency Egress and Security**

Windows have long been used as alternative escape routes during emergencies, especially during fires. Recognizing this, most codes regulate the size of free openings in windows, which must allow a person to escape from a bedroom or permit a fire fighter to enter. Most windows do this as part of an operable window system. If a fixed window is used in an egress area, it must be easily broken to allow escape or entry.

With the high variety of glass types, coatings, glazing materials and window designs, there are endless options and configurations for architectural windows. The next section will describe the benefits, basic structures, manufacturing methods, solar performance properties, and the interaction with glass and window constructions for architectural Solar Control Window Films.

# **Solar Control Window Film**

## **Introduction**

As glass coatings became prominent and energy became more costly, building owners and managers looked for ways to improve their existing commercial properties without the expense and disruption of replacement windows. Solar control window film fit that need and dating back to the 1960's reflective films made with metallized aluminum polyester coatings were offered for sale. Such early films were excellent at reflecting solar radiation back to the outside of the building and were especially popular in cooling dominant climates.

As window film technology evolved additional benefits beyond solar control were discovered and promoted. Today the most widely marketed benefits for commercial buildings are solar heat control for occupant comfort, cost savings, fade protection, glare control, and exterior building aesthetic improvement. The cost of a window film installation is often justified and budgeted based on the payback in energy savings over a period. Not all building types are the same and the computer modeling software used for these calculations, called *Efilm*, considers many factors. Big buildings often also experience hot and cold spots which can make the heating and cooling systems in a building are conflict at times. Often the heat is trying to run on the east side of the building while the system is trying to cool the west side. Window film can modulate those effects making the whole system work more efficiently. Commercial buildings are often modernized by changing the look of the glass through the addition of window film, especially on clear single pane glass.

For residential consumers the benefits match common complaints including, rapid fade of furnishings, hot or cold spots and glare causing viewing issues with home electronics. While window film will often help mitigate the hot and cold spot issues in homes it is difficult to assign a cost savings benefit. Residential homes have a much small “window to wall” ratio meaning the surface area that window film could improve is a much smaller percentage than is found on large commercial buildings. Marketing of window film for homes often focuses on comfort from room to room or within a room rather than trying to predict an annual cost savings. While no product can prevent fading, window film does an excellent job of slowing down the fading process and helping to protect valuable furnishings and belongings. Glare protection is directly associated with the amount of light coming in the home and again, window film can do an excellent job of helping occupants see their favorite work or entertainment on their screen. Very few consumers want to change the appearance of their home from the outside and so most residential window films, unlike commercial products, are designed to be more neutral in color and less visibly reflective to not detract from the beauty and architecture of the home.

Both markets may benefit from improved protection from shattered glass, but this benefit is covered in the Safety and Security Manual.

The rest of this section will focus on the basic building blocks of window films, how those layers are manufactured, basic window film structures, the measurements and industry standards used to describe window film performance and end with how window film interacts with glass and window constructions.

## **Basic Window Film Manufacturing Principles**

Window film is produced in what is termed a “conversion process”. This term applies to the process by which several different layers and raw materials are combined or “converted” into one cohesive final product. There are several raw materials used in the final structure and they may include: raw polyester film, dyed polyester, metal or metal oxide/nitride coated polyester, various performance coatings, and liner material. How these raw materials are combined or

“converted” will determine the type of window film produced. No matter what the final combination, they all will require the addition of a scratch resistant coating and an installation adhesive.

The five basic processes used in the production of window film are:

Dyeing or coloring film

Vacuum Deposition (electron beam, metallizing, sputtering)

Laminating

Coating

Slitting

Manufacturers of window film will possess the ability to perform some, or all the processes shown above. To maintain the optical quality of the finished products, most of the processes will be performed in “cleanroom” environments. This simply means a sealed off area which has the incoming air filtered to remove impurities. These “rooms” are also kept at slight positive air pressure to prevent air contaminants from entering through openings. The personnel who work in clean room environments are required to wear special uniforms to prevent contamination. These processes are all very technical and must be tightly controlled to produce an acceptable product. While window film may look like a simple product that is far from the truth.

## **Raw Materials**

### **Polyester Film**

Developed in the late 1920s and early 1930s, polyester film is a popular laminating substrate. Manufactured by melting polyester chips and then extruding and stretching the film in both the length and then width at high speeds, polyester film is a highly useful substrate. It is durable, tough, and highly flexible, absorbs little moisture, and has both high and low temperature resistances. It offers crystal clarity and can be pre-treated to accept different types of coatings such as adhesives. Polyester film can be dyed, or vacuum coated to produce an array of colored and spectrally selective films. Polyester film thickness is measured in the United States in “mils” which is .001 inches. In other parts of the world this same film is measured in microns with that same 1 mil film measuring 25 microns. Unless the product is going to be a safety film, standard window film widely uses 1 mil (25 micron) or ½ mil (12 micron) film. Polyester film serves as the backbone for the window film industry.

## **Coatings and Coloration**

### **Coloration processes**

Color is imparted to the film in several ways. The color can be infused throughout the film either as part of coloring the PET chips before extrusion or deep dyed in a secondary immersion process after the film is at its finished width and thickness. Additionally, the color can be achieved by surface coating the film and then infusing the color into the polyester or surface coating the film with a colored coating that is left on the surface and laminated over in subsequent steps. There are many positives and negatives to each of these processes which are outside the scope of this document.

### **Ultraviolet UV Absorbers**

Special ultraviolet (UV) absorbers are utilized to prevent the sun's ultraviolet rays from breaking down the polyester film or adhesives that laminate the layers of polyester film together or bond the film to the glass. These UV absorbers can be present in either or both the adhesives, and/or be impregnated into the original polyester film. All UV absorbers decrease in effectiveness over time but vary significantly in their longevity depending upon chemical makeup.

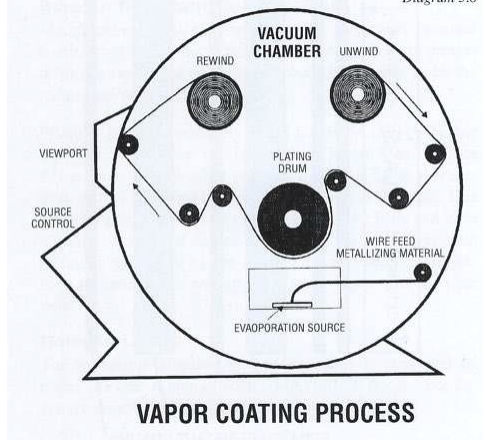
### **Vacuum Deposition**

Metals and other metal oxides or nitrides are coated onto polyester film through processes that run in a vacuum (negative air pressure). Collectively these are known as vacuum deposition processes. There are two basic deposition processes with some variations within those processes.

#### Metallizing

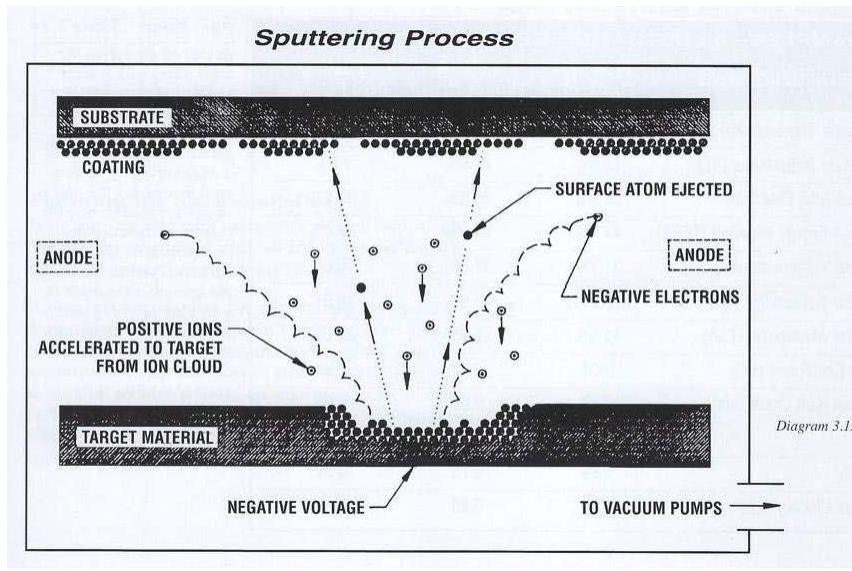
In simple terms, metallizing (or vapor deposition) is a process whereby a metal (almost exclusively aluminum) is applied as a coating onto clear film. Pure metal wire is continuously fed onto shallow electrically heated 'boats'. Because the chamber, containing the film and the boats, has been pumped down to a very low pressure, the metal wire turns from solid to liquid and then gas at a temperature much lower than would be required at standard atmospheric pressure. This gaseous aluminum rises out of the boat much like steam out of a teapot and converts back to a solid when it hits cooled polyester film moving at a high rate of speed over the boats. The thickness of the coating is controlled by a shutter mechanism, the power to the boats, and the speed of the process. The aluminum layer deposited on the surface of the film has a very "open" porous structure. Diagram 3.8 below shows the basic elements of a vapor deposition chamber. A newer version of metallizing uses similar principles but uses an electronic beam to convert the metal to gas and can be used on metals with higher boiling points than aluminum.

Diagram 3.8



### Sputtering

The basic sputtering process involves a large vacuum chamber and an inert (non-reactive) gas atmosphere as well as electrical energy. The electrical energy imparts a negative charge to the inert gas molecules. Because the atmospheric pressure is very low the negatively charged gas particles move freely and are attracted to the negative voltage underneath the material to be deposited. That material can be either in a solid flat plate or a cylindrical spinning roll both called targets. When the negatively charged particles strike the target, they dislodge metal atoms which fly at high speeds to strike the film moving over the target. The cloud of highly charged particles found between the target and the film is called the plasma. This process allows the composition of the coatings on the film to match the composition of the target material almost exactly. If a non-inert gas like oxygen is introduced to this process, it will react with the metal atoms and form oxides, which will have very different properties than the original metal. Because this process involves physical deposition of the target material it is often called a physical vapor deposition process (PVD). The sputtering process allows metals with high melting points and alloys with varying melting metals to be deposited, something which would be impossible with standard vapor deposition.



### Scratch Resistant Coating (SRC)

Manufacturers utilize numerous types of scratch resistant coatings applied to the exterior surface of the film to protect it from normal wear and tear and abuse by humans or by the natural environment. They will not protect the surface from gouges or abrasion from sharp objects or tools. Scratch resistant coatings are formulated to be either for exterior protection or interior protection. Exterior coatings must withstand much harsher conditions than those formulated for interior coatings. Polyester film by itself is not scratch resistant.

Window films are normally tested to ASTM D1044, the Test for Resistance of Transparent Plastics to Surface Abrasion. This is often referred to as the Taber Abrader Test, as this is the equipment used to perform this test. This device repeatedly abrades the surface of the film; and after a certain number of cycles, it measures the amount of haze (scratching) created by the abrader mechanism. The difference in haze before and after the test is known as the haze delta.

### Adhesives

Window film manufacturers have developed and utilized a variety of patented adhesive formulations to adhere their films to the glass (installation adhesives) and to laminate one or more layers of polyester film together (laminating adhesives).



## **Laminating Adhesives**

Laminating adhesives are typically used to bond two or more layers of film together. These layers may in turn be laminated to form a final product. Laminating adhesives can be pressure sensitive with a high degree of tack, or may be a cured adhesive which makes a very permanent bond which would destroy the layers of film if they were pulled apart. The cured adhesive types tend to have a much lower coating thickness.

## **Installation Adhesives**

Adhesives used to apply window film to the surface of glass fall into two main categories:

- Pressure Sensitive Adhesives (a.k.a. PS)
- Water Activated Adhesives (a.k.a. Dry Adhesives)

Films utilizing either type of adhesives are installed in similar fashion, i.e., a soapy water or a proprietary solution is sprayed on both the glass surface and the film adhesive surface after the protective liner over the adhesive has been removed. The film is then positioned on the glass, cut to size, and squeegeed to remove excess water, etc.

The main difference between pressure sensitive and dry types of adhesives is how they bond with the glass. PS Adhesives form a “flat” mechanical bond with the surface of the glass based on pressure between film and glass. Water Activated Adhesives, on the other hand, form a chemical or molecular bond with glass. This chemical reaction makes for a very strong bond, offers excellent clarity, and generally has a greater longevity versus PS adhesives. However, should the film become damaged and need to be replaced, its removal may be more difficult.

## **Performance Coatings**

### **IR nanoparticle coatings**

Many manufacturers have developed special performance coatings that impart solar properties. Some of the most common coatings combine infrared absorbing particles with an adhesive or UV cured coating. These coatings may be incorporated into the scratch coating, laminating adhesive, installation adhesive or may be coated as a separate layer. There are pros and cons to each option and discussions of those are outside the scope of this document. Please refer to the manufacturer for any questions concerning the placement of the coatings. There are also several different chemical structures for the IR nanoparticles with each having a

different color, and different degree of solar performance. All current nanoparticle solar coatings work predominantly through solar absorption and not solar reflectance.

### **Release Liners**

The mounting adhesive of window films is protected by either silicone or non-silicone coated release liners. The liners are removed in the installation process. Since release liners are eventually discarded, the films used will vary in haze. To view window film samples with the highest degree of optical clarity, the release liner should be removed prior to inspection. Even then, slight irregularities on the adhesive surface may appear as visual flaws but they may disappear after bonding to glass has occurred.

## **Basic Architectural Window Film Types and Structures**

There are four basic categories of architectural window films:

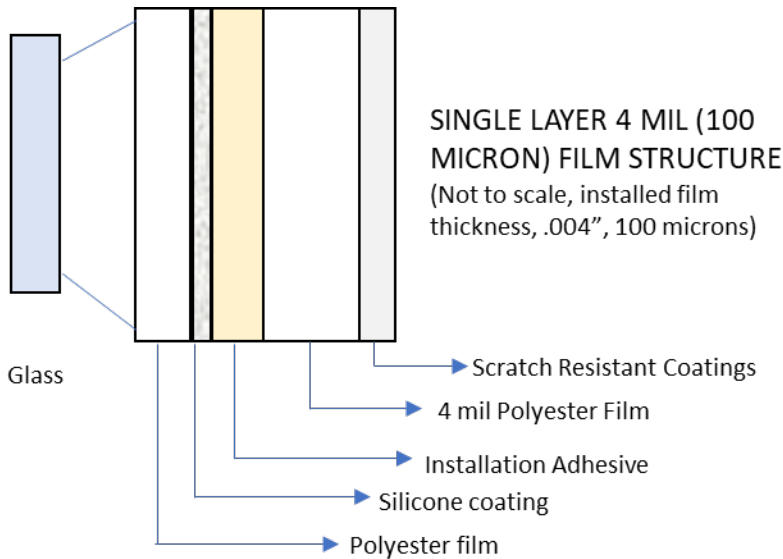
1. Clear
2. Nanoceramics - IR absorbing coated films
3. Reflective – Metallized films
4. Sputtered films
  - a. Neutral in color, low reflectivity metals
  - b. Metal Nitride Ceramics
  - c. Spectrally Selective

Most window films are installed on the interior of the window but there are films designed to go specifically on the exterior of the window.

### **Clear Film**

Most clear film products fall into the category of Safety Films. These films offer safety protection and some UV control to reduce fading. Safety films are generally considered to be 4-Mil and greater with thicker pressure sensitive adhesive layers to hold broken glass together after a glass breakage event. These films are considered non-reflective since they do not contain any metals to reflect solar radiation. (Note: Some safety films can exhibit color when one or more layers are dyed, or metallized, and are laminated together.) There are some thin clear UV films available that are used in specialized UV protection applications such as

museums and art galleries. The diagram below shows a standard clear 4 mil safety film structure.

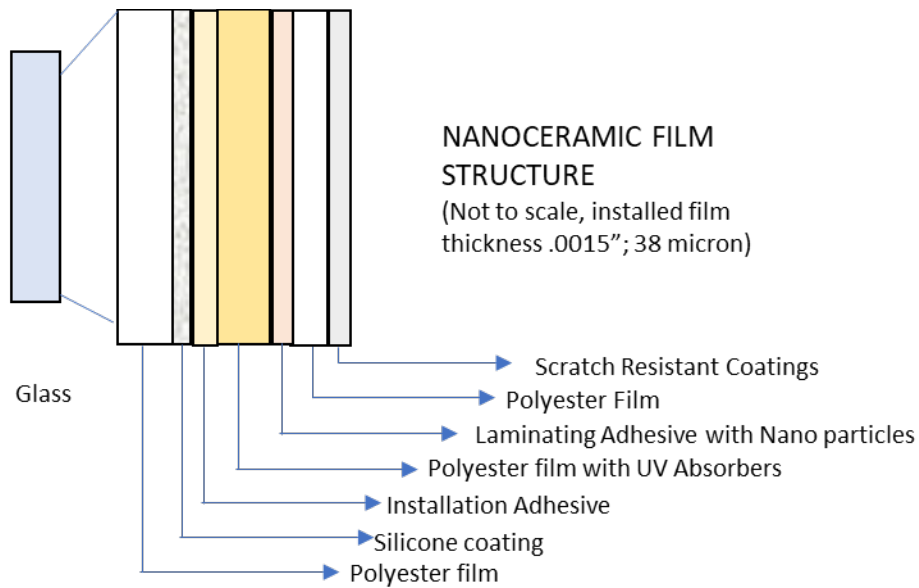


### Colored films

Films that contain a coloration layer only are rarely used with architectural windows since the only heat control would be through absorption and is limited by the visible light transmission of the film. Occasionally tinted film is used in places where the only desired benefit is glare control or privacy. Very dark films with high absorptance are not recommended for many glass types and sun exposures due to the possibility of glass breakage from thermal stress. These films are also considered non-reflective.

### Nanoceramic

These films contain no metals and are considered non-reflective. Based on their VLT they can provide glare and fade control and reduce heat gain by solar absorption. The films come in a variety of colors achieved by a combination of the IR absorbing nanoparticle and the other dyed or colored films used in the structure. As these films do not contain metal, they are often less effective in terms of solar control because all heat control occurs as the result of absorptance, which is less efficient than reflectance. High absorptance can also lead to glass breakage. The diagram below shows a 70% visible light transmission window film where the IR performance coatings is part of the laminating adhesive. Most nanoceramic solar performance particles are not capable of producing a dark film using just the particles. The high visible light transmission of these films with relatively high solar absorption makes them good candidates for windows that require high visibility such as store fronts and some residential applications.



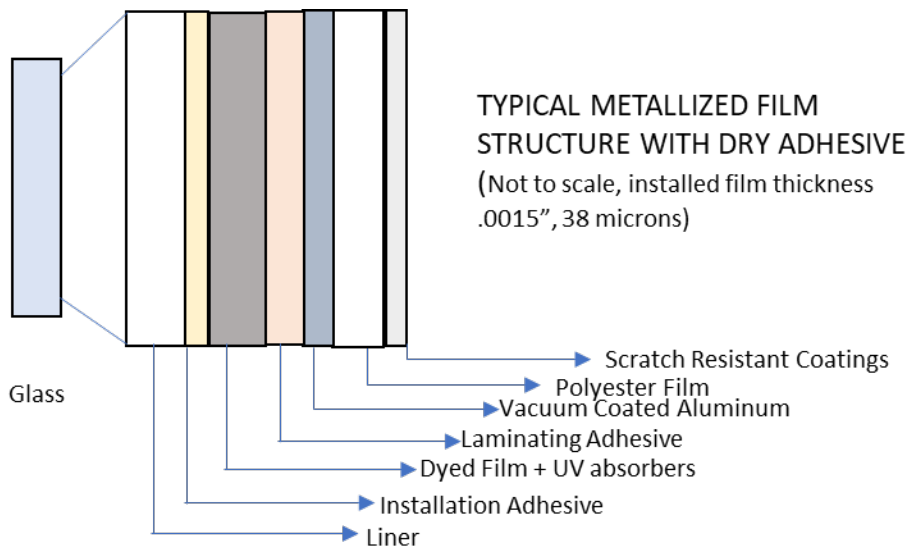
### Vacuum Coated Films

Many films are manufactured using the previously described methods for depositing metals, oxides, and nitrides. These films have tremendous solar control properties because they can reflect significant amounts of solar radiation. They are traditionally identified as reflective, neutral, or sputtered films. There are new films that contain metal, metal oxides, metal nitrides or combinations but do not appear visually "reflective."

### Reflective Films

These products are excellent solar control films with some dark VLT products capable of rejecting over 80% of all solar radiation. As the vacuum metallizing process can be tightly controlled, the thickness of the layer of aluminum layer can be manufactured to precise tolerances. The thicker the aluminum layer the lower the visible light transmission. In general, the lower the visible light transmittance, the higher the solar heat rejection and the higher the visible reflectance. The visible light transmissions usually range from a low of 15% to a high of 70%.

Combining the aluminum substrate layer with a dyed film or coloration layer, instead of a clear layer, can produce various colored versions of this film (bronze, gray, etc.). They in turn may have various levels of light transmission and solar control properties, leading to a wide variety of reflective films. The diagram below shows a metallized film laminated to a colored film with a dry adhesive and liner without silicone. In this case the colored film is facing the glass which will give the film a colored appearance to the outside of the building. Other products put the dyed film to the scratch resistant coated side which reduces the interior reflectivity and is useful for buildings that are occupied at night.



### Sputtered Films

A layer of sputtered metal is deposited on the film in a denser form than metallizing, and as such, most sputtered films will be slower drying unless the manufacturer goes through special steps to improve the porosity of the sputtered layer.

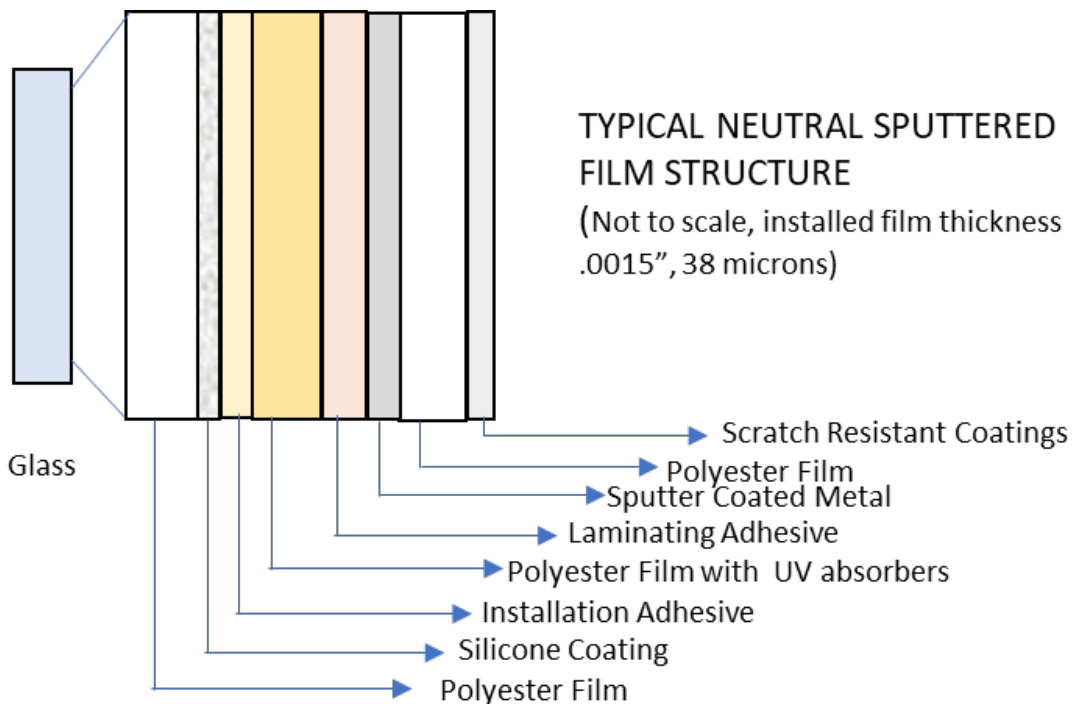
There are three types of sputtered films:

- Films which feature a metal or metal alloy, e.g., stainless steel, nickel-chromium, etc.
- Films which feature a metal nitride such as titanium nitride (ceramic).
- Films which feature a metal oxide in combination with a metal (spectrally selective).

Sputtered films have excellent solar heat control properties like those that are produced by the metallizing process. Sputtering is a versatile process as several layers of different metals can be applied to a single piece of film (metal on metal layering) resulting in unique colors and higher levels of selective transmission.

When comparing metallized vs sputtered products, metallized films will dry faster due to the more "open" crystalline structure produced by metallizing and will be less expensive due to the speed of the process. However, metallizing works best with a single metal since it relies solely on heating the metal until it reaches a gas state. It is difficult to metallize alloys since the

individual metals that make up the alloys melt and turn to gas at different temperatures. Sputtering is thus preferred for alloys or for depositing oxides or nitrides, but it has the disadvantage of slower drying due to a tighter crystalline structure and higher cost due to slower processing rates in manufacturing. Some manufacturers have special processes for improving the drying time of sputtered products. The effect of slower drying often results in a thin water layer collecting at the sputtered surface after installation which often shows up as “haze” to the consumer. This haze may take several days to clear and if a lot of water is left during installation it can pool into water pockets which can leave a permanent “water spot” even after drying. Sputtered products therefore take more care and the use of better squeegee techniques during installation. The diagram below illustrates a standard neutral sputtered film structure with a PS adhesive.

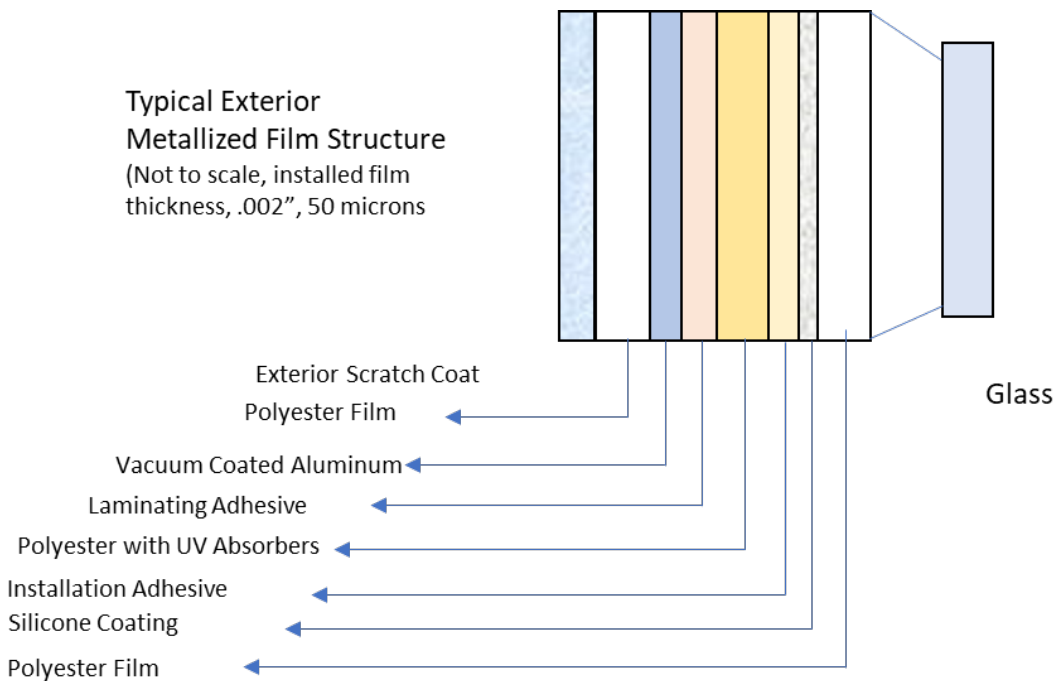


Some of the most interesting, sputtered films are those found in the “spectrally selective” category. These films have a sputtered “stack” of coatings as opposed to a single sputtered layer which gives the products interesting solar properties not possible with a standard sputtered layer. These films are a good example that there is not always a direct correlation between the visible light transmittance and the solar performance.

Many vacuum coated films are conductive since they use metals in their construction. This conductivity can lead to electronic signal blocking. Unless there is a very high window to wall ration (curtain-wall buildings, for example) this should not cause an issue. Some specialty films are designed to specifically block signal with a high degree of conductivity (low resistivity). These are used for anti-eavesdropping applications.

## Exterior Films

As mentioned earlier and shown in all the product structure diagrams, most window films are designed to be applied on the interior of the window. There are films that are designed for exterior installation. These films can be used to change the aesthetics of a building where an interior film would not significantly change the look of the existing glass or because the glass is not accessible from the interior. Exterior film will have better solar performance as there is no glass layer to interfere with film properties. Additionally, placing the film on the exterior of a dual pane unit will generally mean lower glass breakage risk due to increased convection on the surface. Exterior films will normally have special scratch resistant coatings designed specifically for harsher exterior environments including weather variables and higher UV-B exposure. Polyester film is not a natural exterior product. A reflective exterior film is shown in the diagram below. Note the position of the layers compared to an interior film.



## **Window Film Performance Values and Measurements**

There are many different combinations of technologies and materials that make up the window film architectural offering. It is important to understand the different performance values and how they are used to market and communicate the benefits of each product. In previous sections interaction of the sun with glass was explained using the reflectance, absorptance, and transmittance values for a single pane of glass. How the absorbed energy was transferred and how transmitted energy is converted to far infrared and re-radiated was also explained. The complexity of the interaction between the sun and the glass can be hard to easily describe. Calculated values based on these measurements have been developed which pull the individual energy transfer values together in a more easily communicated way.

This section will expand on previous discussions with specific emphasis on heat transfer through both simple and a complex window assemblies and describe the most widely-used values for communicating window performance.

### **HEAT TRANSFER MECHANISMS**

As previously discussed, heat flows through a window assembly in three ways: (1) conduction, (2) convection, and (3) radiation. When these basic mechanisms of heat transfer are applied to the performance of windows, they interact in complex ways. These three heat transfer means are not typically discussed and measured separately. Instead, three energy performance values are used to portray how energy is transferred: (1) heat gain from solar radiation, (2) insulating value, and (3) infiltration.

### **HEAT GAIN FROM SOLAR RADIATION**

A major energy performance characteristic of windows is the ability to control solar heat gain through glazing. Solar heat gain through windows tends to be the single most significant factor in determining the air-conditioning load of a commercial or residential building. The degree to which this factor contributes to the overall load is dependent on the overall window to wall ratio and the orientation to the sun. The intensity of the heat gain from solar radiation can greatly surpass heat gain from other sources, such as outdoor air temperatures (conduction and convection) and humidity. It is in this arena that coated glass and window film performance is highly desirable.

As we know, sunlight is composed of electromagnetic radiation of many wavelengths, ranging from short-wave invisible ultraviolet, to the visible spectrum, to the longer, invisible infrared waves. Using different types of glass, coatings, and window film, it is possible to selectively admit or reject different portions of the solar spectrum.

While reducing solar radiation through windows during the summer in particular climates is advantageous, glass coatings and window films may also reduce certain significant benefits



under winter conditions, such as the “free heat” from the sun. This often-conflicting situation can make the selection of the best window and/or window film a challenging task.

The most widely used value for reporting solar heat gain in the glass, window, and window film architectural market is the Solar Heat Gain Coefficient (SHGC).

### Solar Heat Gain Coefficient

SHGC measures how well a product blocks heat caused by sunlight. The SHGC is the fraction of incident solar radiation admitted through a window system, both directly transmitted and absorbed, then subsequently released inward. SHGC is expressed as a number between 0 and 1. The lower the SHGC, the less solar heat transmitted. The calculation uses the complete window assembly and considers the effects of shading from the frame and the ratio between glazing surface and frame surface. All values reported in the Applied Film Data Base on the NFRC web site are “whole window” values and use a default frame in the calculation. (Most window film specification sheets report a “center of glass” value for SHGC so further calculations can be done for job specific frame types. For this reason, the values on the NFRC web site and the manufacturer’s websites will not match.)

Here are some typical SHGC values for numerous types of window assembly units taken at random from various manufacturers specification charts.

- |  |           |
|--|-----------|
| 1. Clear Single Glazing                                | SHGC 0.63 |
| 2. Single Glazing with Gray Tint                       | SHGC 0.54 |
| 3. Clear Double Glazing (IGU)                          | SHGC 0.56 |
| 4. Double Glazing (IGU) with Gray Tint                 | SHGC 0.46 |
| 5. Double Glazing (IGU) with High Performance Coating  | SHGC 0.37 |
| 6. Double Glazing (IGU) with High Performance Low E    | SHGC 0.30 |
| 7. Double Glazing (IGU) with Face 2 and Face 4 Coating | SHGC 0.17 |

### Energy Effects of SHGC

Diagrams XX illustrate the effect of changing the Solar Heat Gain Coefficient on energy costs in a typical house in two different climates. In general, reducing the SHGC of the glazing reduces the cooling costs, but increases the heating cost since passive solar gain is diminished during the heating season. This occurs when the sun’s warming sunlight entering through the glazing system is reduced, which forces the internal heating system to work harder to increase or maintain a steady indoor temperature.

In a predominantly cooling climate, such as Phoenix reducing the SHGC will result in a noticeable decrease in the total annual energy costs, whereas in a heating dominated climate, such as Boston, reducing the SHGC may result in a modest increase in total annual energy costs. This is because the savings derived in summer by reducing the cooling costs could be offset by the higher costs to heat the interior during the winter months.

INSERT Diagram 3.3 on page 3-4 from original Advanced Solar control Guide

These statements are however generalities and situations exist in which it still makes sense to improve the SHGC even for buildings in heating climate zones. Factors such as peak demand energy penalties, differences in costs of electricity vs heating fuels, highly uneven solar loads from one side of a building to the other causing conflicting heating and cooling in the HVAC system and a myriad of other factors all make it desirable to run an energy analysis of each commercial building being considered for glazing upgrade or film installation.

### Shading Coefficient

Used less commonly today but still found in some documents the Shading Coefficient (SC) is the ratio of solar heat gain passing through a glazing system compared to the solar heat gain that occurs under the same conditions for a clear, unshaded, window glass. The lower the number, the better the solar shading qualities of the glazing system. Shading Coefficient is only defined for the glazing portion of a window and does not consider the frame effects unlike a window system as used in the SHGC. For that reason, SHGC has become a more widely used value in the fenestration market.

### Total Solar Energy Rejection

As with many product measurements, the most scientific measurement is often not the easiest to explain to a consumer. Many people have trouble with the concept that a lower number is a higher performing product. For that reason, the window film industry has used the Total Solar Energy Rejection (TSER) value to explain solar performance.  $TSER = 1 - SHGC$  expressed as a percentage. The total solar energy minus the amount of solar energy transmitted.

## **INSULATING VALUE**

When there is a temperature difference between the inside and outside, heat is lost or gained through the window frame and glazing by the combined effects of conduction, convection, and radiation. This is indicated in terms of the U-Value of a window assembly. The ability of the overall window assembly to resist this heat transfer is referred to as its insulating value. Heat flows from warmer to cooler bodies, thus from the inside to the outside in winter, and reverses direction in the summer, flowing from the outside to the inside.

### U-Value

The U-Value (also referred to as the U-Factor) is a measurement of heat transfer due to outdoor/indoor temperature differences. It is used almost exclusively to describe heat loss through a material. Technically the U-Value represents the amount of heat passing through one square foot of glass in one hour for every degree (F) temperature difference. The lower the U-Value the less heat transfers through the glazing. The previously described low emissivity value is a direct factor in achieving a low U-Value.

## R-Value

Commonly referenced in the insulation industry, the R-Value, conversely, is a measurement that denotes a material's ability to act as an insulator. The higher the R-Value the less heat transfer. It is the reciprocal of the U-Value, expressed as  $R = 1/U$ -Value.

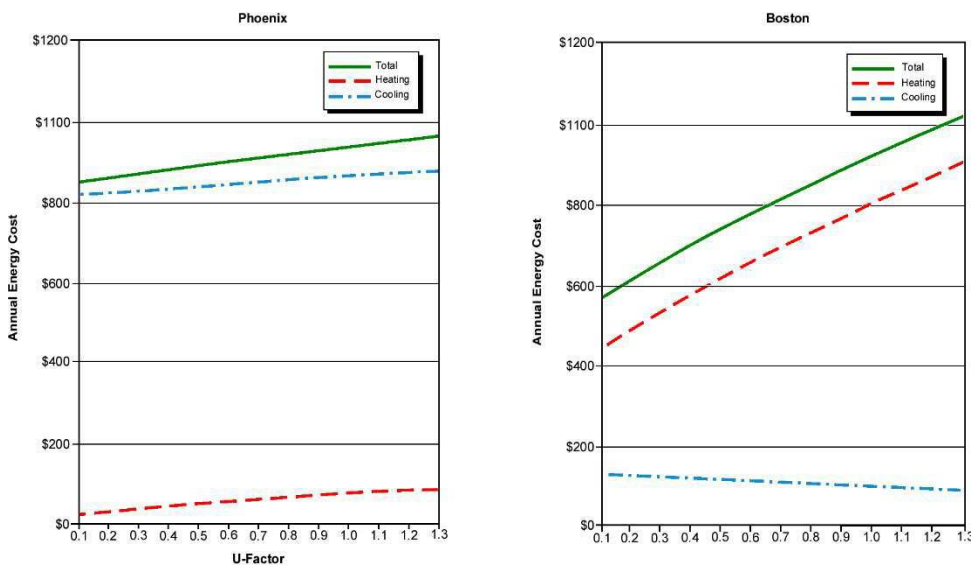
## British Thermal Units

Most discussions of heat loss and gain in buildings use the British Thermal Unit (BTU) as the unit of measure. One BTU is the amount of heat required to raise the temperature of one pound of water by one degree (F). One ton of air-conditioning removes 12,000 BTUs per hour.

Compared to a well-insulated wall, heat transfer through a typical older window is generally much higher. A single-glazed window has roughly the same insulating qualities as a sheet of metal. Such a window is considered a "thermal hole" and has a heat loss rate ten to twenty times that of an insulated wall.

Through radiant exchange, the objects in a room, and especially people (who are often the warmest objects), radiate heat to the colder window. People often feel the chill from this radiant loss, especially on the exposed skin of their hands and faces, but they attribute the chill to room air rather than to a cold window surface. Because of this misconception, few people realize that closing a curtain on a window, as a barrier to the radiant heat loss, could be more effective than turning up the thermostat.

Diagram 3.2. Effect of window U-factor on annual energy costs.



Determining the U-Value of a total window assembly is a combination of the insulating values of the glazing itself, the edge effects that occur in the insulated glazing units, and the window frame and sash. The total number of glazing layers, size of the space between the layers and the type of gas that fills the separation, and the characteristics of coatings on the

various surfaces (including film on glass) all play a part in determining the overall U-Value of the glazing unit.

Heat loss through a window frame can be quite significant. In a typical four-foot by three-foot double-hung wood frame window, the frame and sash can occupy approximately 30% of the window area and will therefore impact the U-Value of the total window assembly accordingly.

As a reminder, reducing the U-Value has a more significant impact on reducing heating costs versus cooling costs. Diagram XX shows the decrease in annual energy costs as the U Value improves, especially in the heating dominated climate. (Remember, the lower the U-Factor the better the energy performance)!

### **AIR LEAKAGE (INFILTRATION)**

Air leakage can have a significant impact on heating costs, especially when winter temperature differentials between inside and outside are quite high or the weather conditions are windy. Air leakage generally plays a much less role relative to cooling cost because the temperature differential tends to be lower, and weather conditions milder. Diagram XX illustrates the relative impact of air leakage in different climates.

### **Other Performance Values**

In addition to heat transfer performance measurements there are several other performance values used for reporting window film benefits.

### **Light-to-Solar Heat Gain Coefficient (LSG)**

LSG is the ratio of visible light transmission to solar heat transmission that passes through a window. It is calculated by dividing the VLT by the SHGC ( $VLT/SHGC$ ). The higher the number the better it indicates how much of the transmitted solar energy is visible light, versus heat. This value is a good indicator of the trade-off in energy usage between power used to provide light in a building and the power needed to heat or cool that same building. The more natural light a glazing allows, while at the same time optimizing the energy needed for heating or cooling, the more efficient the overall building. Much of this is dependent on the climate and orientation of the building. While reducing solar radiation through windows during the summer is desirable in many cooling-dominated locations, that same reduction in “free” winter heat from the sun (often called passive solar heating) is less desirable in heating-dominated locations. Any LSG value over 1.00 is considered “spectrally selective”, a term applied to coatings or films which preferentially screen the sun’s energy in a way that delivers higher visible light and less solar heat gain. A previously used term, Luminous Efficacy is calculated by dividing the VLT by the Shading Coefficient. It is important to review specification sheets and understand that there is a wide range of performance values between products with the same visible light transmission.

## **Glare Reduction**

Glare is a fascinating and complicated subject. Simply put, glare is the loss of visual performance when the intensity of the light in the field of vision is greater than the eyes' ability to adapt. The wavelength of the light and other factors contribute to a person's ability to deal with light. While not an all-inclusive measurement, comparing the VLT of a product to the visible light transmission of clear glass does give a relative number by which to compare products. It may be just as easy to simply compare the VLT of two products and surmise that the darker product will give better glare protection than the lighter product. With the rapidly advancing research into blue light and other factors of glare this may be too simplistic an approach for light sensitive customers.

Blue light is defined as light found between 415- 490 nm. From previous sections in this guide, it was shown that blue light is among the shortest of the visible light wavelengths meaning it has higher energy and higher frequency than other visible light. This high energy can cause visual flickering leading to glare or loss of contrast and clarity. Many sunglasses and prescription eyewear are now available with blue light-blocking lenses. More research is needed as there are still conflicting studies on the negative and positive human impacts of blue light exposure both in natural sunlight and from modern electronics.

## **Industry Standards**

Manufacturers generally provide dealers and distributors with individual sample sheets, or sample books of their various window film offerings. These film sample sheets provide performance specifications for the respective film type. Performance values can also be found on most manufacturers' web sites. IWFA guidelines recommend the use of the National Fenestration Rating Council (NFRC) procedures for measurement, calculation, and reporting of these performance values. The initial measured data is usually based on 1/8-inch clear monolithic, annealed glass of a particular type. The values for other glass types may also be shown on data sheets in addition to the 1/8-inch clear glass, but the glass type and thickness applicable for each measured value should always be included in the data sheets. NFRC works in cooperation with ASTM (American Standard Test Methods) and ANSI (American National Standards Institute) to make their standards the same wherever possible. Also mentioned on some data sheets will be standards from ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineers) which set constants for test methods around wind speed, etc. Calculations and data in areas outside the U.S. may be particular to the region or use the ISO (International Standards Organization) test methods. It is important to note that the "solar spectrum" used in the various standards are not equal. There are at least three different "standard" solar spectrums used globally.

## **Seasonal Differences in Sunlight**

In addition to differences in solar spectrums it is important to understand that sunlight will vary depending on time of year and of course climate zones. In the Northern Hemisphere, the sun rises higher above the horizon in the summer than in the winter. This creates seasonal differences in the directions from which sunlight is brightest on windows. In the summer the highest exposure is in the east and the West but in the winter the southern exposure is the highest as the sun rises in the southeast and sets in the southwest. The exact opposite is true in the Southern hemisphere and the differences are much smaller to non-existent at the equator. All performance values are measured with the sun at 90 degrees to the window. You can imagine the complexity of calculating year around performance and energy savings with differences in building orientation and geography. Energy analysis programs take these effects into account, but specification sheets will be reported with the sun perpendicular to the glass. One might question why not measure the performance at the height of the sun's intensity at noon, but the sun for the most part is on top of the building and there is less sunlight hitting the windows. The performance values look better but simply because there is less radiant energy hitting the windows. Peak load for utility companies in the northern hemisphere is almost always at mid to late afternoon.

## **Matching Measurements to Benefits**

### Commercial

Today the most widely marketed benefits for commercial buildings are solar heat control for occupant comfort, cost savings, fade protection, glare control, and exterior building aesthetic improvement.

1. Occupant comfort and cost savings are mostly driven by SHGC, especially in cooling dominated climates. Consult with your manufacturer for a possible energy analysis for large buildings.
2. Fade Protection is a function of UV protection, lower visible light, and to some extent by lowering the near IR directly transmitted through the glass as well. Read the additional information at the end of this section about Fade and UV.
3. Glare control is almost exclusively a function of visible light although the color of the light (wavelength dependent) can play a role with blue light being a bigger issue.
4. Exterior building aesthetics are a combination of color, reflectivity, and glass type. These decisions should be made with full-size glass samples to properly judge the look from outside the building. Make sure to view the samples at different times of the day and in different weather conditions.

### Residential

For residential consumers benefits match common complaints including, rapid fade of furnishings, hot or cold spots, privacy, and glare causing viewing issues with home electronics.

1. Rapid fading of furnishing is similar to the commercial space, but often residential furnishings utilize fabrics and finishes that are more delicate than used in commercial spaces. See discussion below.
2. Hot and cold spots in a room are often associated with furniture placement in conjunction with the windows. Lowering the overall need for constant air cooling will help alleviate some of these issues. You may consider low emissivity options if the problem is feeling cold next to a window in the winter.
3. Privacy in homes is often an issue of lighting. Make sure to understand the exact time of day the residents expect privacy and other issues. While highly reflective films can provide significant privacy during the day, that privacy virtually disappears once there is more light inside the home than outside. Explaining that phenomenon is important to avoiding complaints later.
4. Glare control is often challenging in a residential setting as many homeowners do not want to lower the incoming light. It is important to help them understand that the room is probably receiving more visible light than the occupants need to see clearly and may be causing eye fatigue and strain. Choose something with a medium light transmission in a neutral shade with low reflectivity to minimize the feeling of a big change in lighting.

## **Ultraviolet Radiation Control**

### Health considerations

As we learned from the earlier discussion about the sun and its electromagnetic radiation, invisible ultraviolet (UV) radiation represents only about 3% of the energy being transmitted in normal sunlight. However, these are very powerful and more energetic (higher frequency) rays. There are three types of ultraviolet rays: UV-C (100 to 290 nanometers), UV-B (290 to 320 nanometers) and UV-A (320 to 380 nanometers). The earth's atmosphere and ozone layer filter out most UV-C and a percentage of UV-B rays. UV-B causes sunburn, and prolonged exposure to it over many years has been linked to skin cancer, particularly basal and squamous cell. Glass absorbs heavily in the UVB range and screens most of those wavelengths. UV-A is now thought to cause 90% of skin aging and has been linked to melanoma since the longer wavelength of the UV-A rays penetrate deeper into the skin. "Broad-spectrum" sunscreens were developed to screen UV-B and UV-A. Early sunscreens only screened in the UV-B and allowed people to stay in the sun longer without experiencing a sunburn, thus allowing more UV-A skin damage. According to the Skin Cancer Foundation, there are about 106,000 new cases of non-invasive and 101,000 cases of invasive melanoma carcinoma and about 3.6 million basal cell and 1.8 million squamous cell skin cancers diagnosed annually in the US. There are roughly 7000 melanoma skin cancer deaths per year. (2021 SCF website) Window film is designed to absorb

UV-A radiation so while glass may protect from a sunburn, the addition of window film can be a significant improvement in the blocking of aging and cancer-causing UV radiation.

There are no less than 20-25 syndromes which are exacerbated by UV radiation. These can vary from easily treatable to extremely rare and life-threatening genetic diseases. There is an increasing number of physicians aware of the UV benefits of window film. A doctor should always be involved in the determination of the efficacy of window film to mitigate UV exposure through the use of film for these rare diseases. A listing and explanation of many of these diseases can be found at [www.skincancerfoundation.org](http://www.skincancerfoundation.org).

Additionally, several eye conditions are made worse by exposure to UV. Again, have your consumers consult their doctor for matching the wavelengths of concern to a possible window film installation.

### Fading considerations

Fading is a complex issue because each material has a different propensity to degrade from exposure to both normal visible sunlight and ultraviolet radiation, in addition to a host of other factors. For example, wood is extremely vulnerable to fading. Different types of hardwood floors have varying tolerance levels to fading from exposure to sunlight. Similarly, papers, inks, natural plant dyes, and natural fibers are more susceptible to fading than synthetics. While the exact percentages of impact vary from item to item it can be generalized that at least five factors contribute to fading.

1. Ultraviolet radiation
2. Visible light both from the sun and artificial sources
3. Humidity and heat
4. Dye fastness
5. Chemical vapors in the air

Ultraviolet radiation is considered the harshest of the factors although the percentages will differ based on the material. Going into a museum with priceless artifacts is a good lesson in understanding fading and deterioration. The light will be extremely dim, generally it is cool, with a highly controlled humidity. Not seen is that all the lighting has extra UV radiation protection. Some exhibits require the visitor to push a button which illuminates the objects for a short period of time.

To provide the best possible fading protection films that absorb a high percentage of the UV radiation, block significant visible light, and provide high heat rejection are the best choice. However, most consumers do not want to live in museum-type conditions, causing the need for a balance between the best protection and the desired aesthetics.

The International Standards Organization (ISO) has developed the tdw-ISO which considers two of the factors above, UV and visible light, giving more weight to the shorter wavelengths while accounting for the possible damage from visible light. While these attempts to provide a



standard for fading may allow someone to compare two different glazing systems offering protection efficiency for the same exact material to be protected, it gives very little insight into how quickly or how completely something will fade.

Dealers are encouraged to exercise caution in this area and not oversell the products' potential benefits in "preventing" fading. ***Again, no film or glazing product will totally prevent or stop fading.***

## Energy Analysis

As stated earlier, one of the primary benefits of window film in commercial buildings is energy savings. In many cases the dollars saved based on the energy savings over a number of years can pay for the installation of window film on a commercial building. These savings are calculated by simulating the energy use of a building before and after the installation of window film. IWFA funded and helped create an energy analysis tool called *Efilm* based on the U.S. Department of Energy EnergyPlus™ program.

According to the Department of Energy website, EnergyPlus™ is a whole building energy simulation program that engineers, architects, and researchers use to model both energy consumption—for heating, cooling, ventilation, lighting and plug and process loads—and water use in buildings. Some of the notable features and capabilities of EnergyPlus™ include:

- **Integrated, simultaneous solution** of thermal zone conditions and HVAC system response that does not assume that the HVAC system can meet zone loads and can simulate un-conditioned and under-conditioned spaces.
- **Heat balance-based solution** of radiant and convective effects that produce surface temperatures thermal comfort and condensation calculations.
- **Sub-hourly, user-definable time steps** for interaction between thermal zones and the environment; with automatically varied time steps for interactions between thermal zones and HVAC systems. These allow EnergyPlus™ to model systems with fast dynamics while also trading off simulation speed for precision.
- **Combined heat and mass transfer** model that accounts for air movement between zones.
- **Advanced fenestration models** including controllable window blinds, electrochromic glazings, and layer-by-layer heat balances that calculate solar energy absorbed by window panes.
- **Illuminance and glare calculations** for reporting visual comfort and driving lighting controls.

- **Component-based HVAC** that supports both standard and novel system configurations.
- **A large number of built-in HVAC and lighting control strategies** and an extensible runtime scripting system for user-defined control.
- **Functional Mockup Interface** import and export for co-simulation with other engines.
- **Standard summary and detailed output reports** as well as user definable reports with selectable time-resolution from annual to sub-hourly, all with energy source multipliers.

EnergyPlus™ replaced the original Department of Energy program called DOE-2 which is no longer supported. Programs still based on the original DOE-2 software do not have the level of sophistication of EnergyPlus and do not give as accurate a simulation. Since *Efilm* is based on EnergyPlus™, it is the most current and up to date program for the simulation of building energy use after the installation of window film. The IWFA funds on-going updates to *Efilm* and is proud to supply this valuable tool to its member manufacturers for use by their customers.

## **Window Film Application Considerations for Different Types of Glazing and Windows**

### **Wired Glass**

Solar control window films should not be applied to the interior surface of any exterior facing wired glass. The wire contained within the glass absorbs heat and if film is installed on the interior surface, the heat reflected out of the film greatly increases the heat absorption of the wire, leading to a high rate of expansion. This can lead to glass breakage. Wired glass is designed to keep the glass in place during a fire. It is not an impact resistant film and has come under scrutiny in recent years as a human impact hazard as the wires can cause serious damage if a head or limb penetrates the wired glass. Clear safety film can be installed on wired glass without concern of thermal shock fracture as it has very low absorption.

### **Patterned or Textured Glass**

Patterned or textured glass surfaces will not allow window film adhesive to form an adequate bond to the glass surface. In most cases, this type of glass is installed with the smooth side facing the exterior of the building, in which case the use of an exterior film is recommended.

### **Plastic Glazing**

Window film should not be applied to acrylic or polycarbonate windows unless it is specifically designed for that purpose. These products have the potential to “out-gas”. Out-gassing is the release of chemical components or moisture from the plastic glazing leading to bubbles between the plastic and the window film. Additionally, the thermal expansion of these glazing types is significantly higher than glass, but not the same as window film. This leads to

expansion and contraction differences over the course of the day/night cycle often causing the film to delaminate. Plastic is often soft, and attempts to remove failed film will scratch the plastic glazing and ruin the surface.

### **Glass Thickness and Size**

It should be noted again that the thickness of glass does increase its absorption, and subsequently adds stress. The amount of stress induced will depend on the glass type, thickness, and the type of film selected. Often thick glass is extremely expensive to purchase and to install. Any profit to be made by the installation of window film in these cases rarely balances the risk.

Extreme caution should be used when recommending or installing film on large panes of glass. The pressure required to squeegee the moisture out may result in breaking the glass as the area of the glass compared to the edge bite is very large.

### **Skylights**

The application of window film to skylights is much more restricted versus vertical glazing systems. Installing the film on the inside often requires lifts and other expensive equipment along with the installation issues of hanging film overhead. Exterior film can also be problematic as most skylights are parallel to the roof or at a slight angle meaning rain, snow, etc. tend to pool and sit on the film unlike in a vertical application. Additionally, skylights are often annealed laminated glass which has special glass breakage considerations. Always consult the film manufacturer for special instructions and rules around the installation of film on skylights.

### **Louvered Windows**

Because of the nature of the design of louvered windows, any film applied to them is likely to be exposed to the elements. Furthermore, louvered windows expose an edge of the glass and film to exterior weather which can lead to film issues along the edge. For this reason, it is recommended that exterior films be used on these windows.

### **Self-cleaning Glass**

Self-cleaning glass has special hydrophilic and photocatalytic coating on one face (usually the outer face of the outer pane) that is activated using UV rays found in natural daylight. The cleaning works as a two-stage process with the photocatalytic coating reacting with the UV light to break down organic dirt on the surface. The hydrophilic coating allows rainwater to wash the glass with a streak free, sheeting action. The coating is said to last anywhere from 3-10 years. Of concern to film installers, the hydrophilic coating will not create a good bond with the film adhesive and cleaning this type of glass with any type of scraper or blade will most likely ruin the coating. Since this coating is generally found on the outer pane it should not be an issue for a normal interior installation, but cases have been reported where the unit were

installed backwards. If a glass surface is sprayed with a normal installation solution and the solution does not wet the window in the standard way, be very cautious and determine what type of coating is on the glass before proceeding. Installing film on any type of exposed glass coating is not recommended.

### **Glass Breakage and Seal Failure considerations with Film**

All glass types except tempered glass are susceptible to thermal glass breakage if the wrong film is installed. IGU's require special consideration when considering film installation. These window types are more susceptible to thermal glass breakage due to a complex list of considerations but certainly can be filmed very effectively if certain film selection rules are followed. Each manufacturer will have information available on which films can be installed on different window types. The information required to compare film and glass compatibility will include, film type (especially absorption), glass type, glass tint, glass thickness, single, dual, or triple pane units, glass coating and orientation in the window, gas fill, climate, altitude, and uneven shading. In general, high absorption, automotive type films should be avoided for architectural applications.

Window manufacturers have often blamed the application of window films for IGU seal failure. There is little objective evidence to support this claim and more recently the practice of voiding warranties after film application has been reduced by more reputable manufacturers. Installation of film may cause the moisture already in the air gap to vaporize making existing seal failures more obvious. Dealers should consult their film manufacturers on warranties and policies around seal failure to understand their liabilities in these situations.

### **Filming complex glazing systems**

Determining an appropriate film installation on complex glazing systems requires a deep understanding of the various factors and their interactions with the glazing and frame system.

The biggest factor in selecting a film is often the solar absorptance. This value indicates the amount of heat held in the glass and then dissipated by re-radiation, conduction into the frame and convection off the surface. The ease with which the heat is released from the glass is determined by the glass coatings and their location in the overall window structure. The likelihood of glass breakage is determined by the amount of heat the glass can hold without thermally breaking. As a reminder, thermal breakage occurs when the temperature at the center of a glass pane is significantly different from the temperature of the glass under the frame. Anything that heats the center of the glass faster than the edge of the glass will contribute to the likelihood of glass breakage. Keeping these key elements in mind, the following paragraphs will explore glass breakage factors individually to explain how they either add to the heat of the glass or impact the difference between center and edge of glass temperature.

Almost all architectural window film manufacturers have their own film to glass installation guidelines often with a point system for added risk factors. Always follow your manufacturers' recommendations to ensure you are adequately covered under their warranty. It is best practice to have the product approved for installation before presenting it to the customer. The information given in this section is for the purposes of instruction and comparison only. The information in this guide should never supersede or be used in lieu of the manufacturers' rules and guidance.

### Glass types

As discussed previously glass types in buildings can include standard annealed glass, heat-strengthened glass, and tempered glass. The glazing system might also include a laminated glass system which would be two layers of annealed or tempered glass with a layer of PVB interlayer between. There is very little difference between the heat absorption of annealed, heat-strengthened, and tempered glass but how each glass type handles the absorbed heat is very different. Annealed glass breaks fairly easily with a significant temperature differential between the edge and center. Heat strengthened glass breaks less easily and is often the glass of choice in high thermal load locations such as spandrel panels. Tempered glass can withstand a large temperature differential between the center and edge but is most often used for safety due to its break pattern and not specifically for thermal risk

Laminated glass will absorb more heat and dissipate it in a different manner than any of the other glass types. Annealed laminated glass is even more susceptible to glass breakage than standard annealed glass because there is also a temperature differential between the two panes of glass in the laminate. Tempered laminated glass is not more susceptible to glass breakage than tempered glass. It is highly unlikely that any glazing system with tempered glass will experience thermal glass breakage.

### Glass thickness

The thicker the glass the higher the absorption although this is not as significant a difference as found with glass coatings. The main consideration with glass thickness is cost of a replacement pane. Very thick glass is often expensive and difficult to install leading to a risky installation. In the absence of manufacturer's recommendations, these general rules may be considered:

- 1) The use of solar control film is not recommended for clear annealed glass thicker than 3/8" (10 mm).
- 2) The use of solar control film is not recommended for tinted annealed glass thicker than 1/4" (6 mm).
- 3) The use of solar control film is not recommended for annealed laminated glass of any thickness.

### Glass size

Most film to glass charts only adds points when the individual glass panes exceed a certain size. The larger the pane of glass the more distance available to create a temperature differential between the center and edge. As with glass thickness, the larger the pane, the more expensive and very large panes are also expensive to install. In the absence of manufacturer's recommendations, these general rules may be considered:

- 1) The use of solar control film is not recommended for single-pane, annealed glass with an area greater than 100 square feet (9.3 square meters).
- 2) The use of solar control film is not recommended for annealed IGU's with an area greater than 40 square feet (3.7 square meters).
- 3) The use of solar control film is not recommended for laminated glass.

### Glass coatings

Tinted glass already has a higher absorption than clear glass and adding film will normally increase that absorption level. On dual pane units the tinted glass is generally the outer pane and adding highly reflective film to face 4 will increase the absorption on the outer glass pane. It is counter intuitive but, in this case, an absorbing film on face 4 may be a better choice. Tinted glass is often heat strengthen and if it is possible to determine the glass type in an older building this may widen the approved films for this type of installation.

Solar reflective coatings on single pane glass are often found in older buildings in cooling dominated climates. Care must be taken when installing film over these coatings as they can be easily scratched during cleaning and will react differently depending on the film installed. On dual pane window units, it is important to understand exactly what the coating is doing and where it is located. If it is unclear from the film to glass chart which films are safe, consult your manufacturer.

Low E coatings create specific challenges when determining safe installations. While becoming more rare, single pane, pyrolytic low E glass coatings still exist. Filming on top of a low e coating will eliminate the low e properties of the coating and installation is not recommended for that reason. Most low e coatings are in dual pane units. Those used in heating dominated climate zones are usually clear and located on face 3. Placing a low e film on these types of windows is very problematic as now both sides of the glass cannot emit any of the absorbed heat. This is not usually recommended. Another example of this is coatings on face 2 with an exterior film applied. Those low e coatings found in moderate or cooling dominated climates are usually found on face 2 and often include solar control properties. These coatings screen significant heat from reaching the second pane and so actually may widen the choices of film from those allowed on a standard clear dual pane unit. The location of the low e coating inside a dual pane unit does not significantly change the U Factor rating but can yield a significant difference in the SHGC depending on a face 2 or 3 location. Increasingly, dual pane units may be found with a coating on face 2 and face 3, with some having a coating on face 4 instead of face 3.

Glass coatings are the most complicated variable to consider in film installation. It is advised to get as much information as possible about the windows to be filmed and then consult the manufacturer if there are any questions.

### Shading

Since differential temperatures between the center and edge of the glass are the basis for glass breakage, any outside shading of the window which exacerbates this differential creates higher risk. While overall shading is not usually a problem (example 1 in the following chart), it is shading which only covers part of the window either all the time or as the sun advances through the day which creates the biggest issues (example 2 and 3 in the following chart). Some examples of uneven shading patterns are shown below. In the absence of manufacturer's recommendations, the guidelines shown may be helpful in determining whether a particular type of shading is risky.

### Sun Orientation

Windows which face east are the most likely to exhibit glass breakage, especially in the fall and winter. As the sun heats up the glass, the glass under the frame remains cool creating a temperature differential. It is highly possible that a new installation can have no thermal breakage issues but exhibit breakage with the first cold, sunny days.

### Altitude

Anyone who hikes in the mountains knows the sun is more intense at higher altitudes. For that reason, most film to glass charts indicate an increased risk for installations at higher altitudes. A combination of high altitude and an east-facing window can easily lead to glass breakage.

### Interior Shading

Close fitting blinds or curtains impede convection off the surface of the glass and so high heat absorption will be more problematic if close fitting window treatments are part of the décor. In the absence of manufacturer's recommendations, the following can be considered:

- 1) There should be a minimum of 2" clearance between the window treatment and the glass at all points
- 2) There should be a minimum of 1.5" clearance at the top and bottom of the window treatment, or a minimum of 1.5" clearance at the bottom and one side of the window treatment.
- 3) All heating and cooling outlets must be directed to the room side of the window treatment.

### History of Glass breakage

Often a building may have a history of unexplained glass breakage. The unexplained breakage could be caused by a wide variety of different factors. If the amount of unexplained glass

breakage exceeds 1% of the total amount of glass to be filmed, caution should be exercised. Window film should not be applied until the causes of the breakage can be logically identified and explained. Many of the causes of breakage can stem from conditions that are unique to the building and will continue or be enhanced with the addition of film. Such items as surface and edge damage, shade patterns, or interior shading devices may be contributors to unexplained glass breakage. Additionally, any change to a building that significantly changes the shading or lack of shading on the windows should not be completed immediately prior to window film installation. Glass which has never been exposed to direct sunlight due to some type of exterior shading needs at least several months of exposure before window film should be installed.

While this list might seem overwhelming, the intent is not to intimidate anyone about the risk of installing film but to provide education on the possible risk factors. If dealers understand the reasons behind these risks and follow the manufacturers film to glass recommendations the risk of glass breakage is significantly reduced.

#### Decorative Film

While decorative installations are beautiful it is extremely difficult to determine the solar control properties of these installations. Even the films with an even surface create problems with the standard measurement equipment and as such, no solar performance values should be offered and if a relative measure of “opacity” is used be sure to note that these are not industry standard measurements.

The use of decorative films continues to be a rapidly expanding part of the window film industry. In general, decorative installations fall into three categories

1. Diffuse or light blocking film. These films have a specularly even surface which is used to block the view just a little progressing all the way to total white out or black out films.
2. Patterned films. While these films are also used to block the view or create a decorative look most contain “open areas” that are totally clear. There are patterned films that are combined with an overall diffuse surface.
3. Custom installations of 1 and/or 2 above. This category of decorative films is the fastest growing category. Installations can be as straightforward as a company logo cut out of a diffuse film but often the installations are complex with multi-layers of custom cut film designs, custom patterns or designs printed onto films, photography printed onto films, etc. The only boundary is the imagination of the decorative film designer and installer.



## APPENDIX A:

### IWFA ADVERTISING POLICY

Adopted by the IWFA Board of Directors, December 13, 2016

False or misleading advertising disseminated by companies and businesses participating in the window film industry in the United States and around the world may undermine the public confidence in the industry and undermine the IWFA's objectives to promote and grow the window film industry by, for example, serving as a source to which the media, government entities, and consumers can turn for accurate and objective information about window film generally. The IWFA therefore adopts this Advertising Policy and the incorporated Advertising Guidelines. This Policy, including the Advertising Guidelines, sets forth general principles that will assist members in identifying the types of representations and product claims that may violate or raise concerns under the false advertising laws in jurisdictions throughout North America, Europe, and Asia. The Guidelines do not provide a comprehensive list of conduct or representations that may be considered false or misleading advertising. IWFA recommends, therefore, that members with questions about the validity of their advertised claims should consult their legal counsel or, to the extent they are distributor or dealer members, their manufacturer's representatives.

All IWFA members are expected to conduct themselves ethically in connection with both their IWFA activities and their business operations. False or misleading advertising, in particular, represents a type of unethical conduct that can harm not just consumers, but the reputation of the industry as a whole. Generally and for purposes of this Policy, false or misleading advertising will be considered to be any explicit or implicit representation that is: (a) false or misleading, (b) reasonable for a customer or potential customer to rely upon, and (c) material in the sense that it affects the customer's or potential customer's purchasing decision. In addition, any objective and verifiable claim about product performance (*e.g.*, visible light transmittance percentages or solar heat gain coefficient measurements) will be deemed false or misleading unless reasonable substantiation exists for the claim *before* the advertiser incorporates the claim into its marketing and promotional content. This definition and guidance are consistent with the laws in the United States, the Europe Union, and elsewhere and the guidance issued by the authorities in these jurisdictions. See for example Federal Trade Commission, *Policy Statement on Deception*, October 14, 1983 available at <https://www.ftc.gov/public-statements/1983/10/ftc-policy-statement-deception>; European Commission, *Directive on Misleading and Comparative Advertising*, Directive 2006/114/EC of the European Parliament and of the Council of 12 December 2006, Official Journal of the European Union available at [http://ec.europa.eu/consumers/consumer\\_rights/unfair-trade/false-advertising/index\\_en.htm](http://ec.europa.eu/consumers/consumer_rights/unfair-trade/false-advertising/index_en.htm).

The IWFA has held itself out to the media, the consuming public, and government agencies, including law enforcement and regulatory agencies, as an objective and accurate source for information about window film and the window film industry. It therefore would be particularly detrimental to the IWFA and its efforts to promote and grow the window film industry if its members, which have a limited license to display the IWFA to identify and

promote themselves as an IWFA member, engage in illegal conduct involving deceit, including false or misleading advertising about window film products.

Accordingly, any IWFA member that engages in any illegal conduct involving deceit, including but not limited to false or misleading advertising, counterfeiting, unauthorized or misleading use of the IWFA Service Marks, falsification of product specifications or government licenses, etc., may be subject to penalty under this Policy. The IWFA Board of Directors, in its sole discretion, may impose one or more of the following penalties upon a member found to have engaged in false or misleading advertising or any illegal conduct involving deceit: (1) suspension of the member's IWFA membership; (2) termination of the member's IWFA membership; (3) suspension of the member's limited license to the IWFA Service Marks; and (4) revocation of the member's license to the IWFA's Service Marks. The IWFA Board of Directors may also report any offending member to the relevant law enforcement or regulatory authorities. In the event of suspension or termination of a member's IWFA membership, all monies paid to the IWFA shall be deemed to be earned and nonrefundable. IWFA therefore will not reimburse any such monies already paid by the member to IWFA even if the dues, fees, or other payments were made in consideration for membership during a timeframe which has not yet ended.

### **IWFA Advertising Guidelines**

The Guidelines set out below provide insight into certain types of advertising and promotional activities that will likely be considered false or misleading as well as others that will likely be considered legitimate and consistent with IWFA's Advertising Policy. Compliance with the following guidelines will reduce the possibility that an advertisement will be found to be false or misleading and thus reduce the possibility that a member will violate this Advertising Policy:

- A.** Clearly and accurately communicate all claims regarding window film attributes. Ensure that each representation, whether express or implied, is substantiated.
- B.** Do not overstate the protective qualities of window film or the implications of satisfying building codes. For example:
  - 1) Avoid using the term "proof" in window film advertisements such as "hurricane proof" "earthquake proof", or "bullet proof." Such terms likely will be interpreted as claiming that window film will protect against all eventualities in any hurricane, earthquake, or when penetrated by a bullet. Rather, it is permissible, for example, to advertise that properly-installed window film can reduce damage caused by broken glass during windstorms, reduce the rate of glass fragments falling from windows during earthquakes, or offer more protection from broken glass fragments during other types of glass breakage events, such as impacts or explosive events compared to a window with no film applied.
  - 2) Also, do not advertise that window film is "earthquake safe" because it satisfies local building codes. It is proper, for example, to advertise that

the film satisfies local building codes, but satisfaction of those codes does not certify the film is "safe" in earthquakes of all magnitudes and against all flying debris during those earthquakes.

- C. Ensure that general claims regarding the protective quality of film are applicable to the typical consumer, not a particular limited class or type of consumer.
- D. Do not use pictures or other visual images that create a misleading impression in the minds of viewers.
- E. Advertisements should not contain claims that are inconsistent with product labeling, or use, or installation instructions.
- F. Do not use comparative terms such as "film is safer" without accurately providing a reference to what the film is safer than.
  - 1) Such unqualified language will be interpreted broadly and likely will be deemed false or misleading unless the claims are true under all circumstances, and there exists adequate substantiation to support the broad claims at the time they are made. For example, the unqualified language "window film makes windows safer in storms" likely will be interpreted as claiming that window film offers greater protection against storm damage than all other products on the market, including even windows made for storm protection.
  - 2) Comparative claims will not be deemed false or misleading, however, if they are qualified and the qualified claims are accurate and substantiated at the time they are published. For example, "film is safer" may be qualified by explaining that if windows shatter in a bad weather event, less damage to property or persons may occur when film is applied to a window as compared to a standard window with no film applied. Additionally, visual portrayals and pictures can be used to clarify the text of a claim if the text and images, when taken in the context of the entire advertisement, are accurate and substantiated.
- G. When relying on tests or studies in an advertisement, do not misrepresent the purpose, quality, content, or conclusion of such test or study, and do not make any statement that is inconsistent with the results or general conclusions of any such test or study.
  - 1) For example, do not explicitly or impliedly claim that satisfaction of a test to determine whether a window film complies with a particular building code also determines the window film is earthquake or windstorm safe. Such a claim likely is an overstatement of the purpose and conclusion of that test.

- 2) It is permissible to advertise that a particular film has achieved certain test scores or standards under particular test conditions. It is not permissible, however, to explicitly or impliedly suggest that these performance standards will be met under any condition other than those included in the test. It is also impermissible to modify products to attain a higher test score and to advertise that an unmodified product might have achieved the same score.
  
- 3) Unconventional product testing methodologies may produce misleading product performance results. Advertising claims based on unconventional testing methodologies must certainly be considered suspect and likely would be deemed false or misleading. Certainly, using such methodologies with the purpose and intent to support unfounded or exaggerated product performance claims would violate this Advertising Policy.
  - a) The IWFA has identified various product testing standards that have been promulgated by reputable standard setting organizations, are commonly used in the window film industry, and are endorsed by IWFA as credible and reliable testing methodologies. The endorsed testing standards, and effective dates for the endorsed standards, may be found in the International Window Film Association's Endorsed Testing Standards ("Endorsed Standards"), which the Board of Directors or its designee may update and revise from time to time and which are attached as Exhibit A to these Policies and Procedures.
  
  - b) A member will be deemed to have complied with the IWFA Advertising Policy if it bases advertising or promotional claims about a window film product's properties, attributes, or performance on testing conducted pursuant to one of the standards identified on the list of the Endorsed Standards in effect at the time the member makes the particular advertising or promotional claim, the tests were reasonably and properly conducted, and the results of such testing and the corresponding advertising claims can be replicated and substantiated by others. For testing and test results to be considered reasonable and proper, the testing must be conducted under general and normal, not unusual or particular, conditions in which the window film is typically used by the customer.
  
  - c) If a member uses other testing methodology other than those incorporated into the Endorsed Standards as support and substantiation for any advertising or promotional claims or representations about product properties, attributes, or performance, such claims or representations will be considered suspect. If questioned, a member will bear the burden to establish

that the alternative testing methodology is credible and reliable and that testing conducted under the alternative methodology adequately substantiated the relevant claims about the product. The IWFA Board of Directors, in its sole discretion, may determine whether the alternative testing methodology is credible and reliable and the tests conducted adequately substantiate the advertising at issue. If necessary or desirable, *e.g.*, to avoid confidentiality or competitive concerns, the Board may delegate the matter to an independent and objective third-party for consideration and a determination.

- H.** Do not advertise, without qualification, that certain window film is in compliance with state law. Such a claim fails to inform consumers that federal law and local building codes may be applicable to the application of window film and the failure to disclose such information may be deemed to be a material or intentional omission and, therefore, constitute a false or misleading representation.
- I.** As with any other claim, advertisements containing comparisons between the advertiser's product and a competitor's product must be based on prior substantiation for the comparative claims. Tests substantiating such comparisons should apply under general and normal, not unusual or particular, conditions under which the window film is used.
- J.** As to product superiority claims, emphasize only those features that are significantly superior, do not stress insignificant differences that will cause consumers to draw false or misleading conclusions about produce superiority.
  - 1) Superiority claims are not false or misleading if there is a material difference in an aspect of a product's performance that consumers find meaningful and there is substantiation for the claim.
  - 2) Superiority claims cannot be based on minute technical differences in test results. For example, a security film advertisement likely would be found to be false or misleading if the superiority claim were based on a slight difference in test results that did not translate into an effective increase in protection to the consumer or the consumer's property.
- K.** Ensure that there is substantiation establishing a reasonable basis prior to making any performance or other objective claim about a product.
  - 1) Maintain files and records of information substantiating any claim.
  - 2) Ensure that substantiation is current with the state of knowledge at the time the advertisement is published.

## **MEMBERSHIP ELIGIBILITY & GENERAL TERMS OF MEMBERSHIP**

Adopted by the IWFA Board of Directors, December 13, 2016

As an applicant for membership in the IWFA, you (“you” or “Applicant”) acknowledge and agree that you may be denied membership in the IWFA, or your membership in the IWFA may be properly suspended or terminated, if the IWFA Board of Directors, in its sole discretion, determines that Applicant conducts or has conducted its business or activities in a manner that are inconsistent or in conflict with any Policies & Procedures applicable to members in the IWFA. Similarly, you acknowledge and agree that you may be properly denied membership in the IWFA, or your membership in the IWFA may be properly suspended or terminated, if the IWFA Board of Directors, in its sole discretion, determines that Applicant engages or has engaged in conduct detrimental to or in conflict with the best interests of either the IWFA or the window film industry generally.

You further agree and acknowledge that, in the event that your membership in the IWFA is suspended or terminated, all monies paid to the IWFA shall be deemed to be earned and nonrefundable. IWFA therefore will not reimburse any such monies already paid by the member to IWFA even if the dues, fees, or other payments were made in consideration for membership during a timeframe which has not yet ended.

Whether or not you become an IWFA member, you further agree that any legal action, suit, or proceeding that you initiate either relating to your application to join the IWFA (including the IWFA Board of Director’s consideration, rejection, acceptance, deferral, suspension, or any other action upon your application) or in any way arising from the IWFA’s Policies & Procedures (including any obligation imposed by or enforcement of the Service Mark License, the IWFA Antitrust Policy & Guidelines, the IWFA Advertising Policy, or the Membership Eligibility & General Terms of Membership) must be brought solely and exclusively in the state or federal courts located in the State of Delaware, United States of America. You also agree that you irrevocably accept and submit to the sole and exclusive jurisdiction of each of the aforesaid courts in person, generally and unconditionally, with respect to any action, suit, or proceeding brought by you against the IWFA or against you by the IWFA. You further irrevocably consent to the service of process from any of the aforesaid courts, effected by mailing copies thereof by registered or certified mail, postage prepaid, to you at the address that you submit to the IWFA in your membership application, with such service of process to become effective thirty (30) days after such mailing.

