EWFA
EUROPEAN WINDOW FILM ASSOCIATION
A CHAPTER OF THE IWFA

ADVANCED SOLAR CONTROL EDUCATION GUIDE

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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 and EWFA 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 (more information available here). Passing grades on each test will give IWFA and EWFA members additional accreditation references on the IWFA/EWFA dealer/business locator.

The information presented has been reviewed for technical accuracy by the IWFA Technical Committee and the EWFA dedicated Working Group. 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.

The Guide does not purport to state that any particular product should be used in any specific application. The user has the responsibility to ensure that any product selected and/or installed complies with all applicable laws, rules, regulations, standards, and other requirements. The IWFA and its Chapters do not design, develop, or manufacture any products, processes, or equipment referenced in this Guide and, accordingly, make no guarantee, representation, or warranty expressed or implied, as to their fitness, merchantability, patent infringement, or any matter respecting their performance. The IWFA and its Chapters cannot guarantee and disclaims any responsibility for any specific result relating to the use of the Guide.

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

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Acronym	Definition
AM	Air Mass
ASTM	American Society for Testing and Materials
BC	Before Christ
BTU	British Thermal Unit
CIE	International Commission on Illumination
EM	Electromagnetic (Spectrum)
EN	European Norm
EU	European Union
HVAC	Heating, Ventilation, and Air Conditioning
IGU	Insulated Glass Unit
IR	Infrared
IRER	Infrared Energy Rejection
IRT	Infrared Transmittance
ISO	International Organization for Standardization
NFRC	National Fenestration Rating Council
PET	Polyethylene Terephthalate
PS	Pressure Sensitive (adhesive)
PU	Polyurethane
PVB	Polyvinyl Butyral
PVD	Physical Vapor Deposition
RAT	Reflectance, Absorptance, Transmittance
SSI	Solar Selectivity Index
SRC	Scratch Resistant Coating
UV	Ultraviolet
UVA	Ultraviolet A
UVB	Ultraviolet B
UVC	Ultraviolet C
UVT	Ultraviolet Transmittance
VIG	Vacuum Insulated Glazing
VL	Visible Light
VLR	Visible Light Reflectance
VLT	Visible Light Transmission
Tdw-ISO	Damage Weighted Transmittance
TSER	Total Solar Energy Rejection
TSA	Total Solar Absorptance
TSR	Total Solar Reflectance
TST	Total Solar Reflectance

1. SECTION I: THE SOLAR SPECTRUM

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 do not "keep the cold in"; they remove the heat from the interior contents, transferring it to the room air, acting like a heat pump. 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.

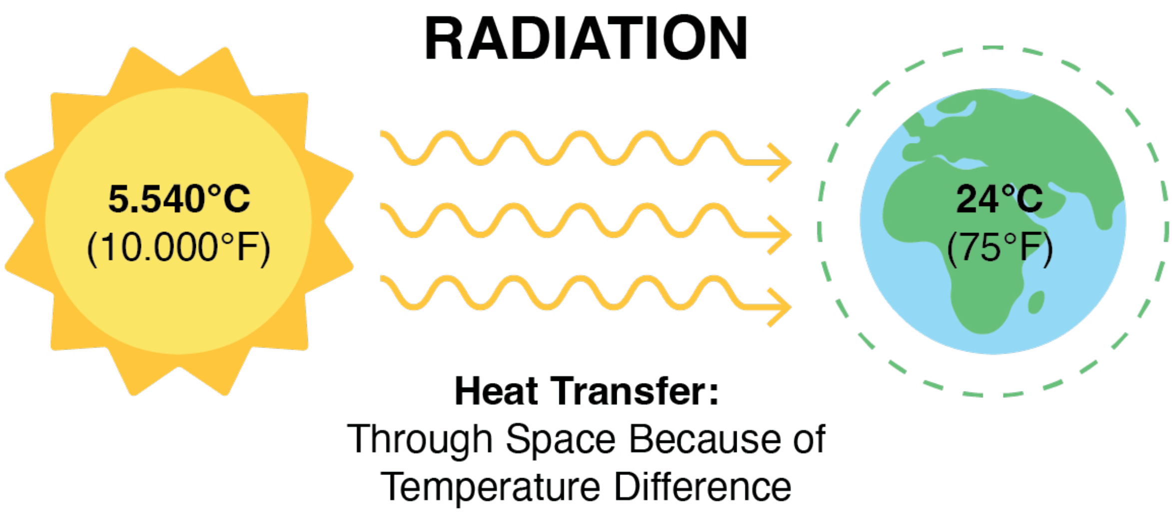

Figure 1.1 The Sun's Radiation

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 phasesto the beginning of the next positive phase.

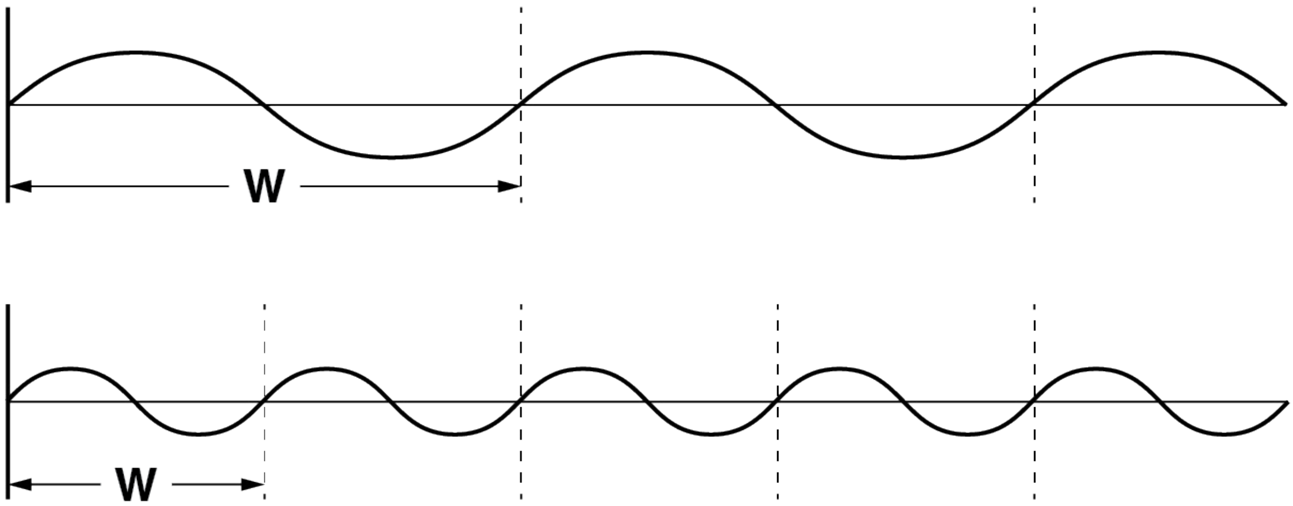

Figure 1.2 Electromagnetic Wavelengths

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 nanometres. A nanometre (nm) equals one billionth of a metre! 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.

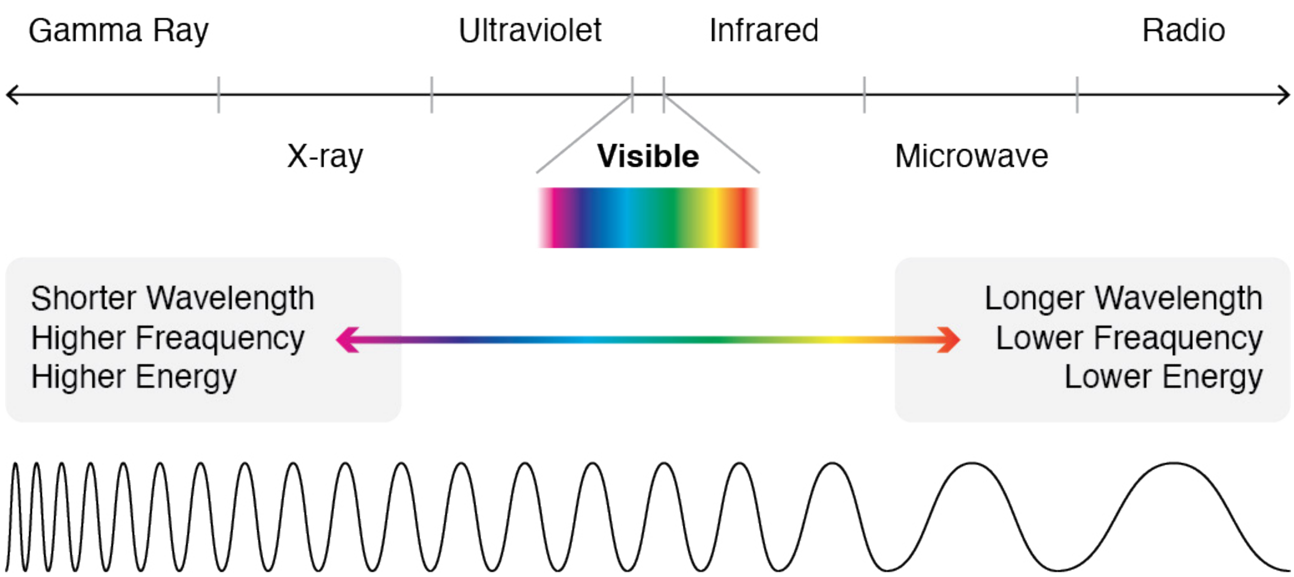

Figure 1.3 – Electromagnetic Spectrum

Measuring Light Energy Wavelengths

Figure 1.4 below shows the electromagnetic spectrum (EM), with nanometre 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.

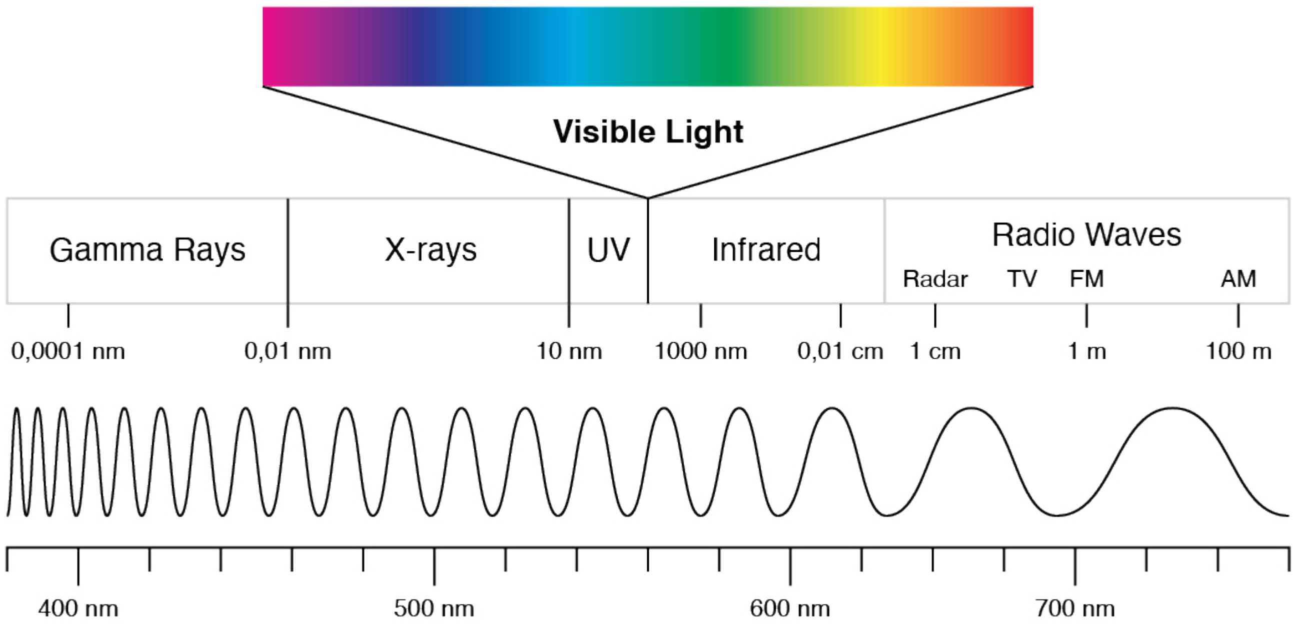

Figure 1.4 – Electromagnetic Spectrum with Nanometre Measurements

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: UVC (100 – 290 nanometres), UVB (290 -320 nanometres), and UVA (320- 400 nanometres)[1]. The earth's atmosphere and ozone layer filter out most UVC and a percentage of the UVB.

Visible

What is considered the visible band of the solar spectrum runs from roughly 380 nanometres to 780 nanometres. "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.

[1]Source: European Commission Scientific Committees.

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 nanometres to greater than 1 millimetre. There are different ranges in the Infrared regions. Near-IR is from 780-2,500 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 2,500 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% [2]. Other references may show 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.

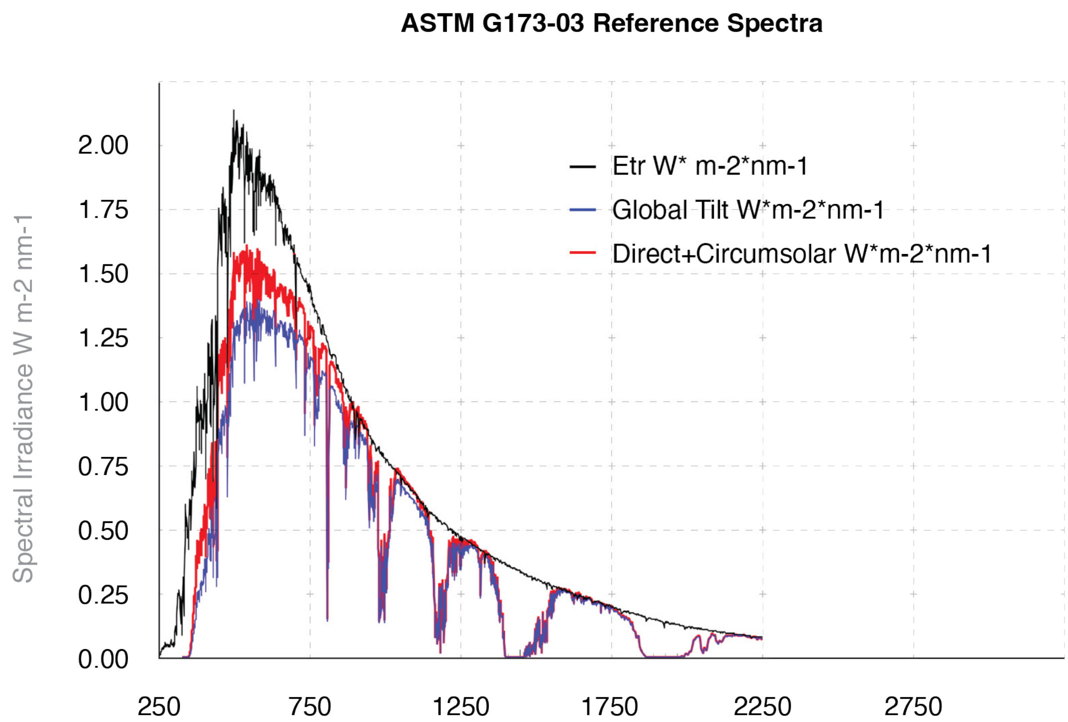

Figure 1.5 – Radiation Intensity Per Wavelength Range

[2]Data estimates for CIE 85 AM (Air Mass) 1.5 Global, the standard for solar panel testing and most real-world applications, which accounts for the sun at about 48° elevation.

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.

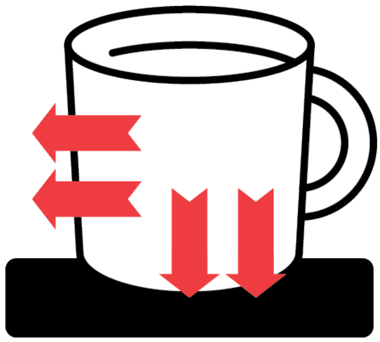

Figure 1.6 – Conduction

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.

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

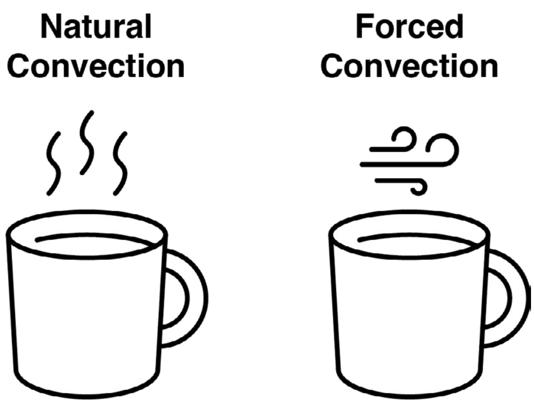

Figure 1.7 – Natural and Forced Convection

Thermal Equilibrium

Heat energy flows from a high temperature to a lower temperature. When these temperatures' balance heat stops flowing 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.

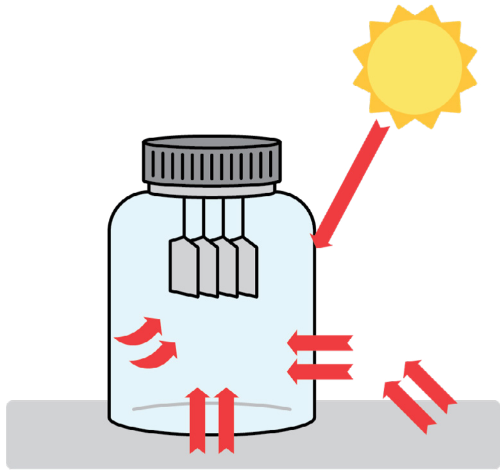

Figure 1.8 – Thermal Equilibrium, Closed Jar of Cool Water

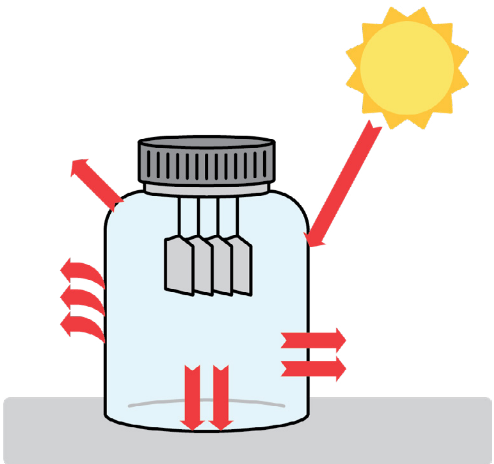

Figure 1.9 – Thermal Equilibrium, Closed Jar of Warm Water

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.

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

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 4 mm glass.

Total Solar Reflectance	=	8%
Total Solar Absorptance	=	5%
Total Solar Transmittance	=	87%

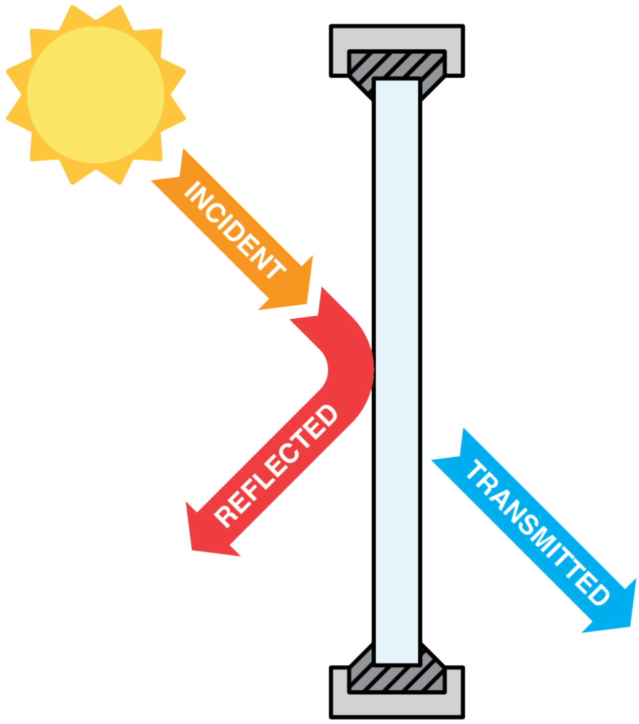

Figure 1.10 – Sunlight Striking Glass

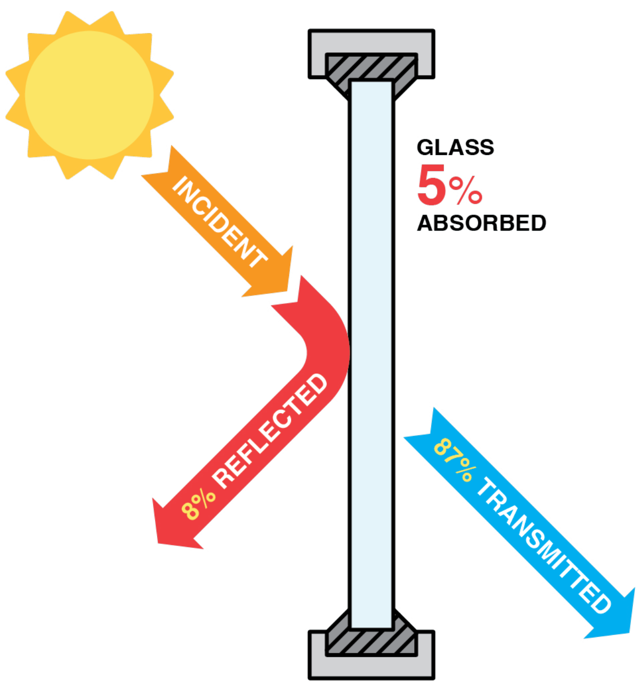

Figure 1.11 – Incidental Solar Radiation

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.

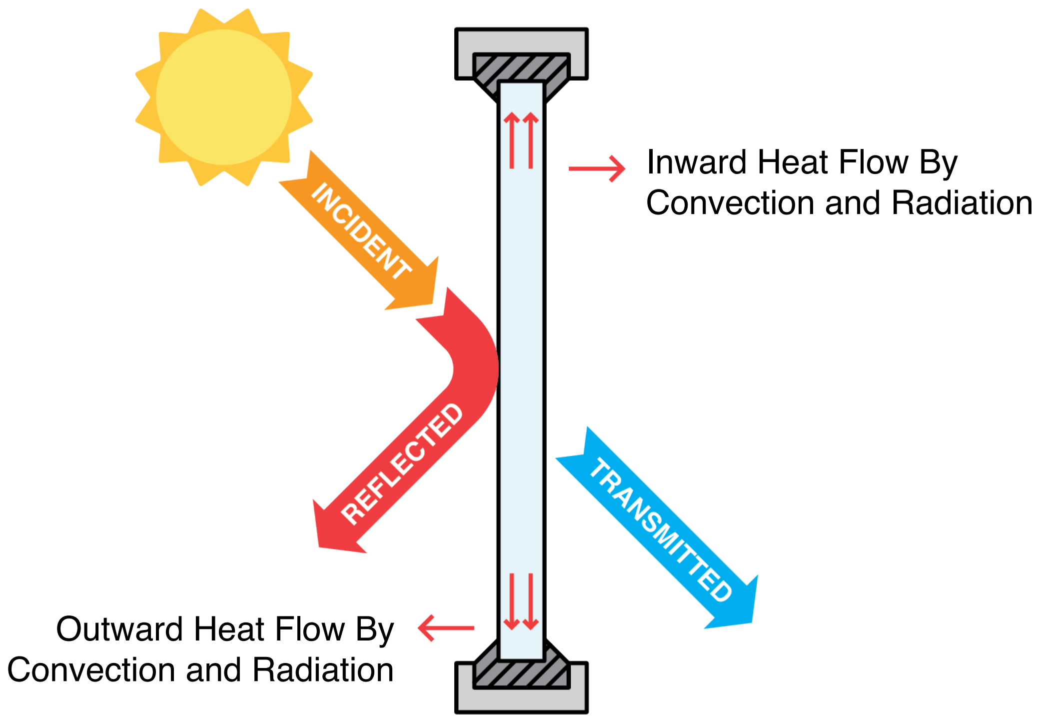

Figure 1.12 – Incidental Solar Radiation, RAT

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 easy concepts to grasp, solar absorption is more complex. As seen in the previous Figure, 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 re-radiated 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 1.13 below illustrates conduction and re-radiation, while Figure 1.14 only illustrates convection.

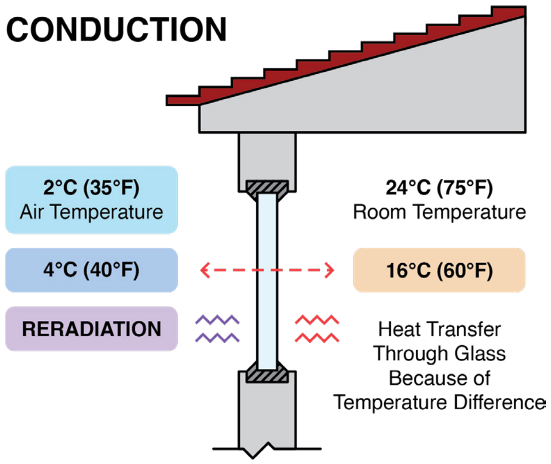

Figure 1.13 – Heat Transfer through Conduction

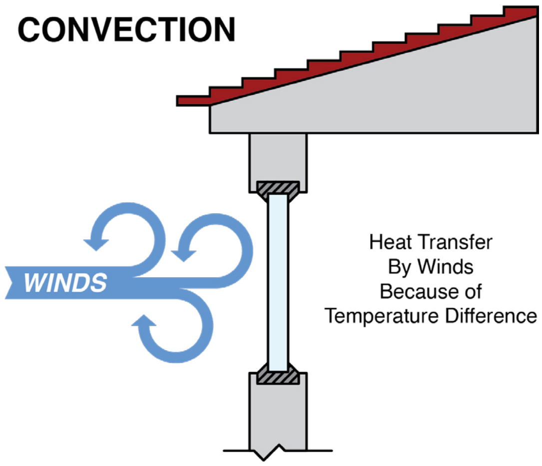

Figure 1.14 – Heat Transfer through Convection

In addition to solar energy absorbed, heat transfer can occur with Far-IR energy from other sources. Figure 1.15 illustrates winter heat loss from an interior Far-IR heat source. Figure 1.16 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.

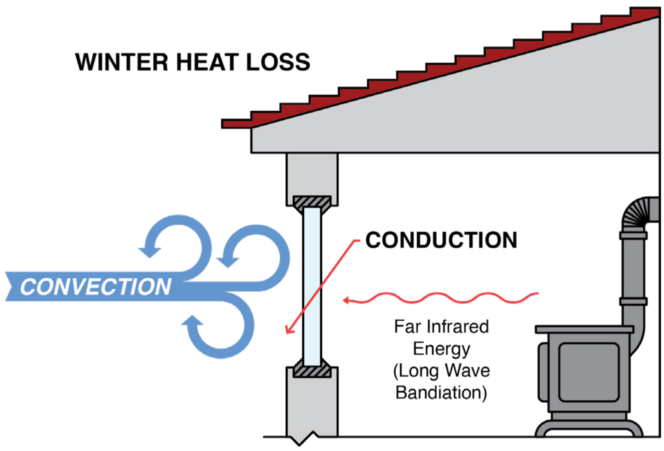

Figure 1.15 – Winter Heat Loss

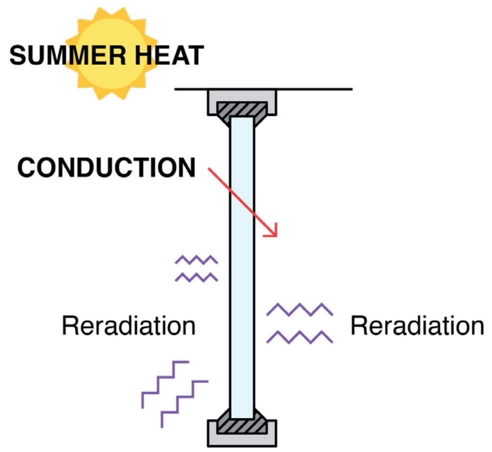

Figure 1.16 – Summer Heat Gain

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 aluminium foil wrapped around a baked potato. Aluminium 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 aluminium 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
Aliminium, Polished	0.05
Glass, 4 mm	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, 4 mm 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 (TSR)

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.

2. 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 1,700 Celsius degrees 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 lighting strikes sand high in silica content and fuses the silica into a shape that mimics the path the lightning bolt travels through the sand.

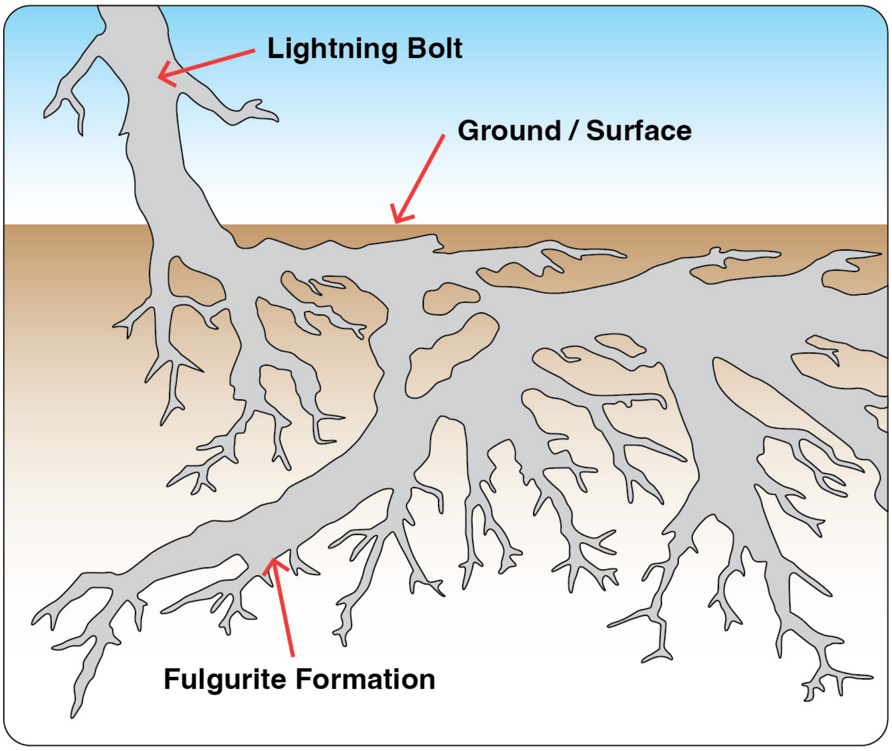

Figure 2.1 – Fulgurite

Unlike the movies suggest, fulgurite does not 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 introducing colour 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 centre 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 tothis 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 toughened glass. All three types of glass start as annealed glass, but heat-treated and toughened glass are subjected to subsequent processes which change their breakage characteristics. Annealed glass can be cut at a glass shop, but heat-strengthened and toughened 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. Glass strength is defined by the degree of edge or surface compression. Surface compression is the end results 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. 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 621°C 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.

Toughened Glass

Toughened 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 648°C. 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 toughened glass. It is very resistant to cracking from the thermal stress caused by solar absorption and temperature differentials from edge to centre of glass. This phenomenon is known as thermal shock fracture and usually occurs when the edge and centre of the glass pane have a relatively high difference in temperature. In many cases, toughened glass or laminated glass is required in high-risk areas to satisfy local building codes. For example, in homes it is required that toughened 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: Glass Construction

Most toughened 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 toughened.

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 metre that is available for that use. For the purposes of this training guide, types of glass can be divided into two major categories: monolithic and laminated.

Monolithic Glass

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 toughened. Additionally monolithic glass can be coated by various methods, or can combine 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 3- or 4-mm minimal thickness, new manufacturing methods have been developed to produce thinner commercially viable glass.

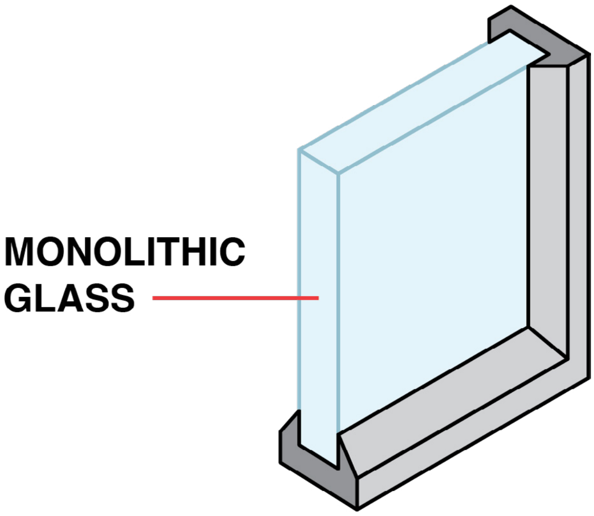

Figure 2.2 – Monolithic Glass

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 toughened.

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 IWFA-EWFA Safety and Security Training Guide.

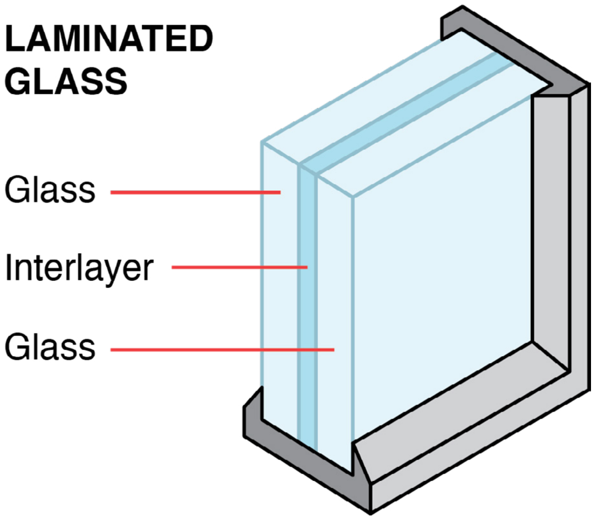

Figure 2.3 – Laminated Glass

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 automotive industry glass and a smaller percentage of the architectural industry glass manufactured utilising a full colouration process. In this process the colour is mixed in with the glass at the time of manufacture, resulting in a glass that is coloured consistently throughout its thickness. Tinted architectural glass can also be produced by applying the colour 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 tinted glass 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 colours. Many different colours are available by combining the metallic layers with tinted glass layers to yield colours 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").

Spectrally Selective Coatings

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

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 about 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	:	Toughened 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. Nickel sulfide inclusions and thermal breakage can occur without a significant vent 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 centre tension zone of the toughened 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, so this has become a rare form of glass breakage. It is important to remember that this can only occur in toughened glass, and it is likely to be an edge defect or other impact that breaks toughened glass. Since toughened glass tends to fall out of the frame when broken, it is often very difficult to locate the epicentre of the breakage and thus difficult to determine the cause of the glass breakage. If the toughened 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 centre 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 unfavourable 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 1 to 2.5 cm, from there the crack may go in any direction (see Figure below).

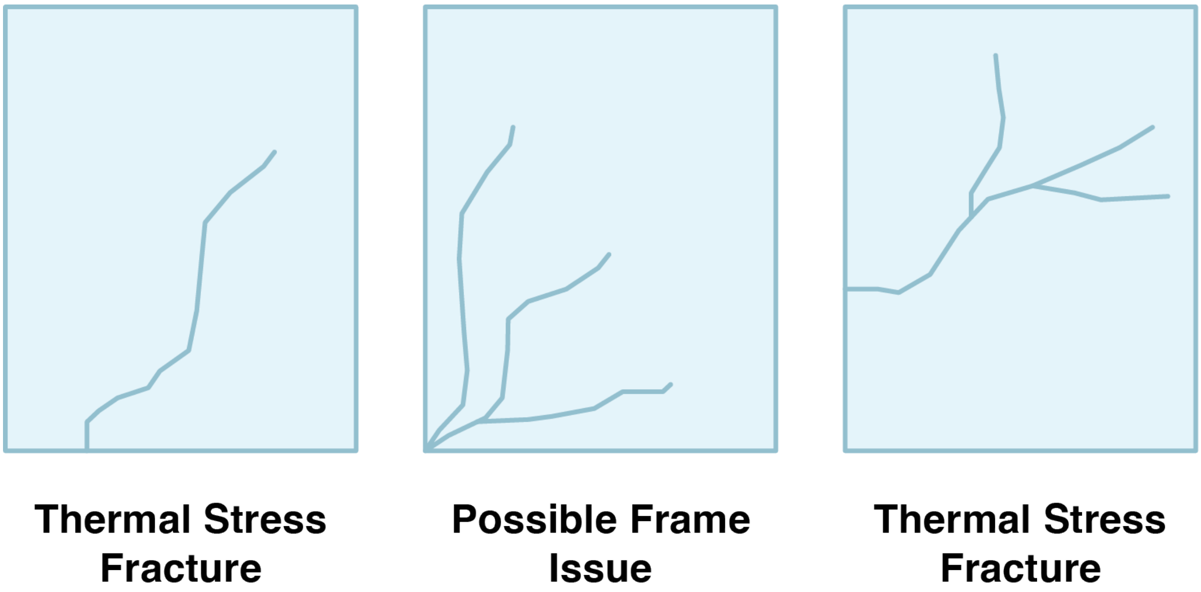

Figure 2.4 – Thermal Stress Fracture

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 made of wood, vinyl, or aluminium. In the case of commercial buildings, where the windows are often large and part of the overall structure of the building, or curtain wall where the glass is part of the building envelope but not part of the structural support, aluminium and steel are most often used. Some curtain wall buildings use a complex series of “spider” fittings to hold the glass. Aluminium 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.

Aluminium Frames

Aluminium 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, weatherstripping, and thermal breaks. Aluminium frames are available in anodised and factory-baked enamel finishes that are extremely durable and low-maintenance. Aluminium resists corrosion and is ideally suited for sliding doors because of its strength and low weight.

The biggest disadvantage of aluminium 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 aluminium 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 aluminium 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. Figure 2-5 illustrates the principle and design of a thermal break.

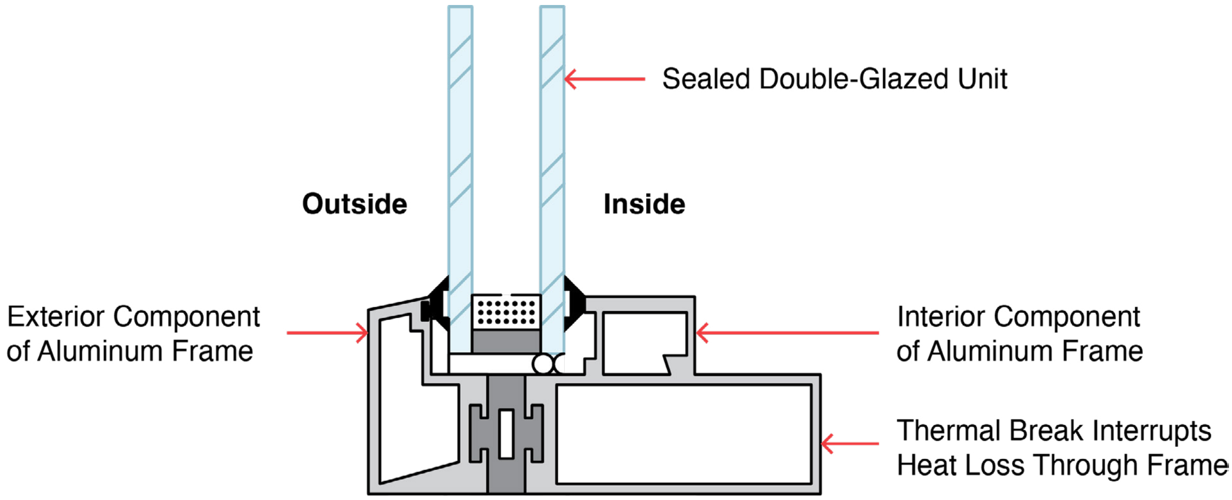

Figure 2.5 – Thermal Break in Window Frame

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 material and requires high maintenance, but well-built and well-maintained wood windows can have a very long life.

Wood windows are preferred 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 aluminium creates a more permanent weather-resistant surface. Clad frames have lower maintenance costs, while still retaining the attractive wood finish on the interior. Dark-coloured 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 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 colour 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 aluminium 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 aluminium 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 particle board 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 aluminium 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 colder 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 window or glazing professional to remember that frame type matters depending on the climate zone and that 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 window film.

Glazing Materials

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

Gaskets

Gaskets can be made of solid or foam sections and are generally made of rubbery type materials which could include vinyl or silicone. 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.

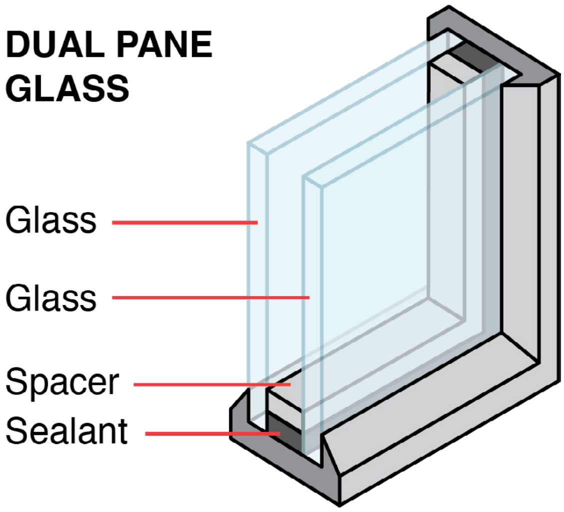

Figure 2.6 – Dual Pane Windows

The seal between the glass sheets is accomplished using 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, odourless, 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. Figure 2.5 below illustrates a dual seal IGU. One important note is how glass surfaces are numbered for uses to identify and understand the placement of coatings. In the Figure below, the faces of the glass are numbered from 1 to 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.

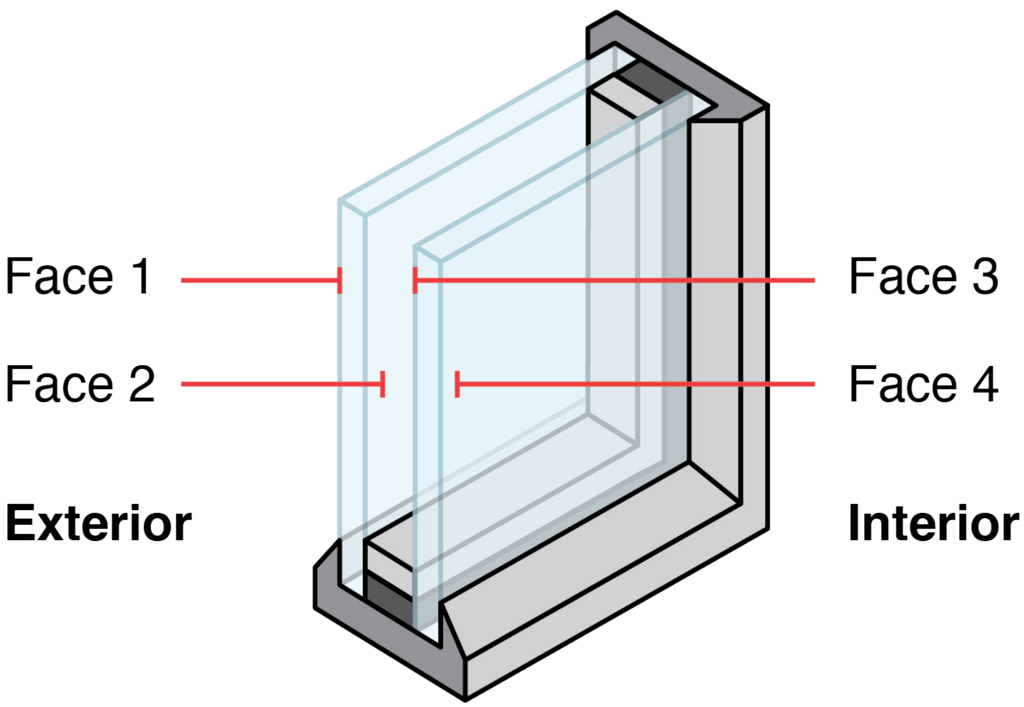

Figure 2.7 – Dual Seal IGU

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. Newer triple pane 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 a 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 vapours 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.

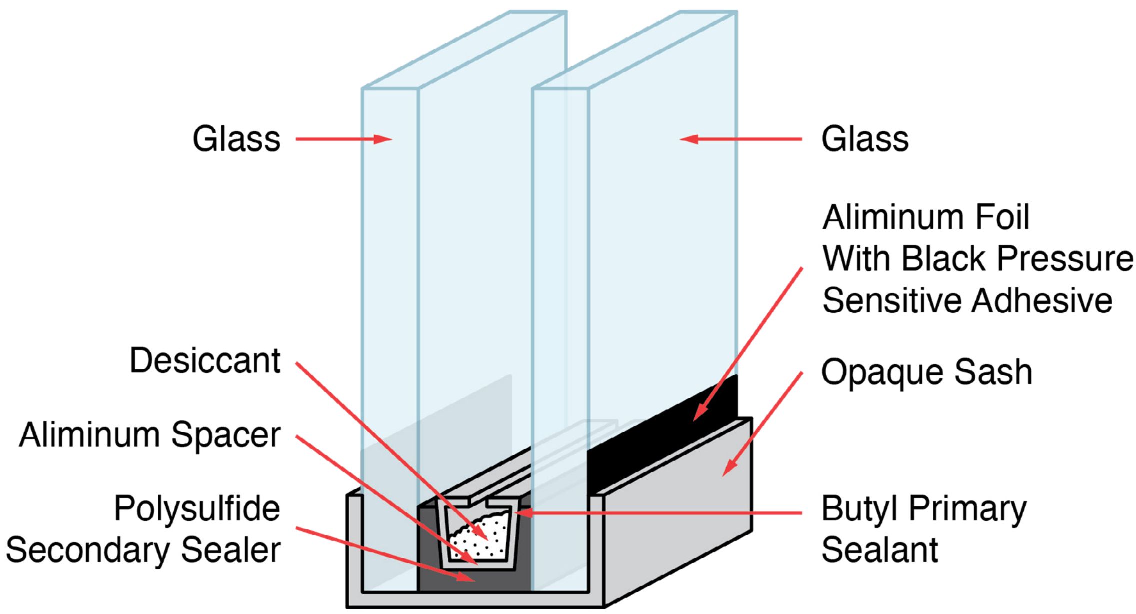

Figure 2.8 – IGU Seal Failure

Vacuum Insulated Glazing

These windows are similar to 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. Vacuum Insulated Glazings (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.

Figure 2.9 – Fenestration Assembly

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.

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 weatherstripping of windows, sash, and frames are of paramount importance in controlling air leakage.

Weatherstripping 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 weatherstripping 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 weatherstripping.

There are two basic design formats for weatherstripping: brush or wiper types and compression types. Brush weatherstripping wipes sweep against the window sash as it moves. Compression weatherstripping 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

Sliding windows, or 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 air flow control.

Sliding windows generally have higher air leakage rates than hinged windows. This occurs for two reasons. First, the weatherstripping's 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 legislation to be toughened.

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 centre mullion, resulting in a 150 to 180 cm-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 3.5 metres or more.

French doors have an advantage over sliding doors in that the weatherstripping 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, although 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, 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, and these windows are often subject to 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. This adds to the complexity of determining what type of interior solar control can be used.

Greenhouse (Garden) Windows

Greenhouse windows, also known as garden windows, 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 Exits and Security

Windows have long been used as alternative escape routes during emergencies, especially during fires. Recognising this, most building 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 a fire exit 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.

3. Section III: 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. Dating back to the 1960’s, reflective films made with metallised aluminium 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 modelling softwares used for these calculations consider 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 favourite 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 colour and less visibly reflective to not detract from the aesthetics and architecture of the home.

Both commercial and residential markets may benefit from improved protection from shattered glass. This benefit is covered in the IWFA-EWFA 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 colouring film
- Vacuum Deposition (electron beam, metallising, 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 “clean rooms”. 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 rooms 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 coloured 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 25 microns (1 mil) or 12 microns (½ mil) film. Polyester film serves as the backbone for the window film industry.

Coatings and Colouration

Colouration Processes

Colour is imparted to the film in several ways. The colour can be infused throughout the film either as part of colouring 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 colour can be achieved by surface coating the film and then infusing the colour into the polyester or surface coating the film with a coloured 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 Absorbers

Special ultraviolet (UV) absorbers are utilised 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.

Metallising

In simple terms, metallising (or vapour deposition) is a process whereby a metal (almost exclusively aluminium) is applied as a coating onto clear film. This process is made inside a vacuum chamber. Pure metal wire is continuously fed onto shallow electrically heated 'boats". Because the vacuum 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 aluminium 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 aluminium layer deposited on the surface of the film has a very "open" porous structure. Figure 2.7 below shows the basic elements of a vapour deposition chamber. A newer version of metallising 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 aluminium.

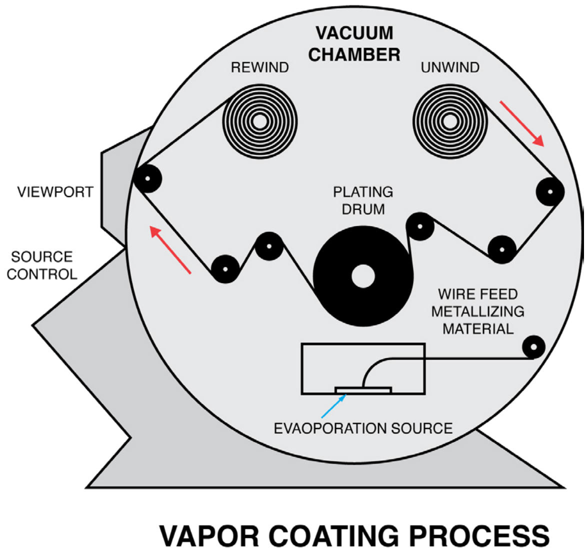

Figure 3.1 – Vapour Coating Process

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 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 vapour 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 vapour deposition.

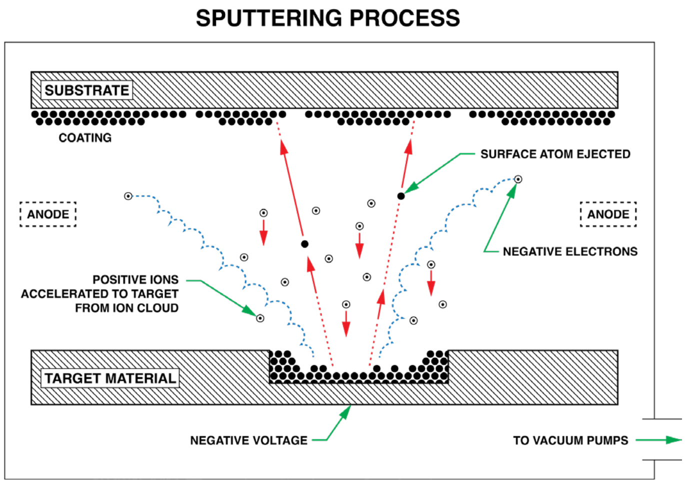

Figure 3.2 Sputtering Process

Scratch Resistant Coating

Manufacturers utilize numerous types of scratch resistant coatings (SRCs) 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. It is to be noted that polyester film by itself is not scratch resistant.

Window films can be tested to European standard EN 15752-1:2014 (Annex A) “Abrasion testing of adhesive backed polymeric film with measurement of haze” or ASTM[3] D1044, the Standard Test Method 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)

[3](ASTM International, formerly known as the American Society for Testing and Materials, is a standards development organisation).

Films utilising either type of adhesives are installed in similar fashion, i.e., a soapy wateror 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 squeeged to remove excess water.

The main difference between pressure sensitive and water activated adhesives is how they bond with the glass. Pressure sensitive 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: Infrared Nanoparticle Coatings

Many manufacturers have developed special performance coatings that impart solar properties. Some of the most common coatings, named infrared nanoparticle 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. Several different chemical structures exist for the infrared nanoparticle coatings, with each having a different colour, 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 Films
2. Nano Ceramic Films - Infrared Absorbing Coated Films
3. Reflective Films – Metallised films
4. Sputtered Films
    a. Neutral in colour, low reflectivity metals
    b. Metal Nitride Ceramics
    c. Spectrally Selective

Most window films are installed on the interior of the window, although some films are designed to go specifically on the exterior of the window.

Clear Window Films

Most clear films 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 100 microns (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.

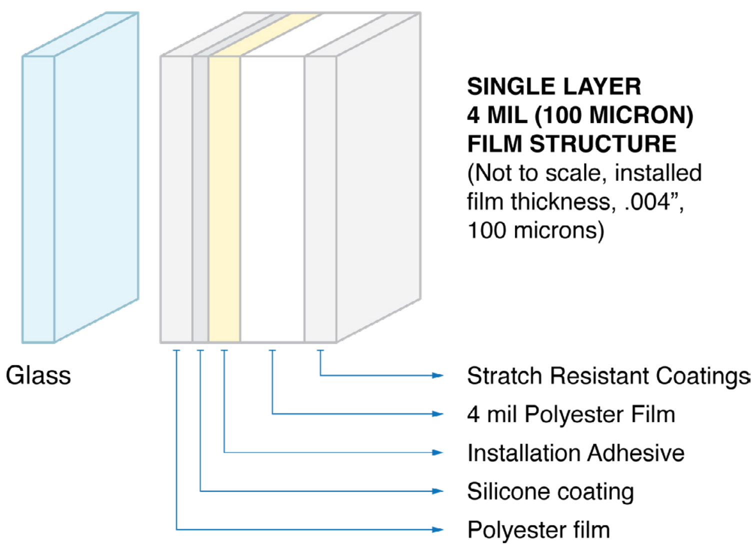

Figure 3.3 Safety Window Film Structure

(Note: Some safety films can exhibit colour when one or more layers are dyed, or metallised, 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. Figure 3.3 shows a standard clear 100 microns (4 mil) safety window film structure.

Coloured Window Films

Films that contain a colouration 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 Window Films/Infrared Absorbing Coated Window Films

These films contain no metals and are considered non-reflective. Based on their Visible Light Transmission (VLT), they can provide glare and fade control and reduce heat gain by solar absorption. The films come in a variety of colours achieved by a combination of the infrared absorbing nanoparticle and the other dyed or coloured 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 absorbance can also lead to glass breakage.

The diagram below shows a 70% VLT window film where the infrared 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 VLT 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.

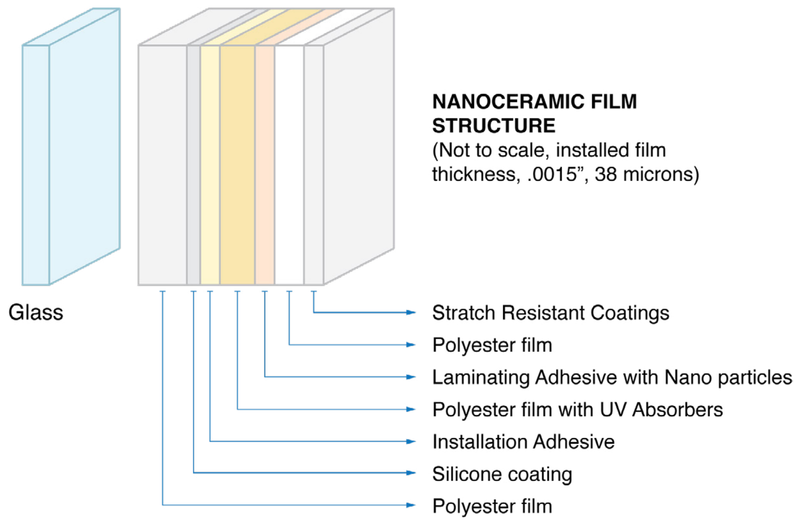

Figure 3.4 - Nanoceramic Window Film Structure

Vacuum Coated Window 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 Window 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 metallising process can be tightly controlled, the thickness of the aluminium layer can be manufactured to precise tolerances. The thicker the aluminium 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. For this type of films, the visible light transmissions usually ranges between 15% and 70%.

Combining the aluminium substrate layer with a dyed film or colouration layer, instead of a clear layer, can produce various coloured 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. Figure 3.5 shows a metallised film laminated to a coloured film with a dry adhesive and liner without silicone. In this case, the coloured film is facing the glass, which will give the film a coloured 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.

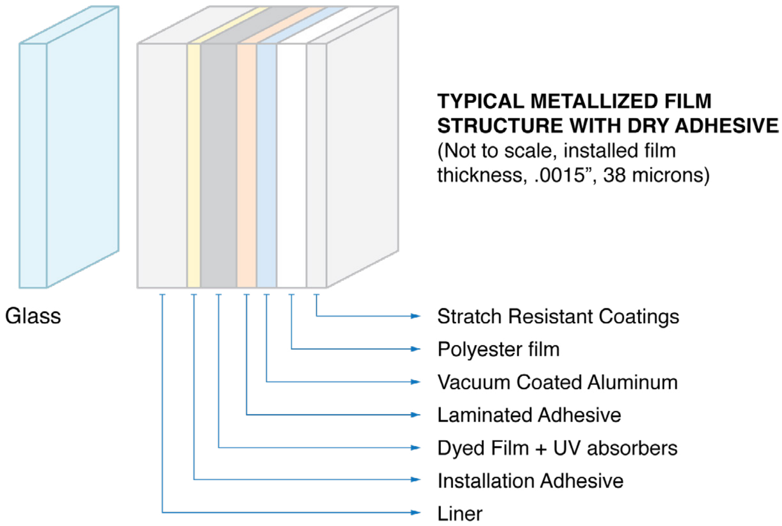

Figure 3.5 – Typical Metallised Window Film Structure with Dry Adhesive

Sputtered Window Films

A layer of sputtered metal is deposited on the film in a denser form than metallising, 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.

Three types of sputtered window films exist:

- 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 window films have excellent solar heat control properties, similar to those that are produced by the metallising 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 colours and higher levels of selective transmission.

When comparing metallised and sputtered products, metallised films will dry faster due to the more "open" crystalline structure produced by metallising and will be less expensive due to the speed of the process. However, metallising works best with a single metal, since it relies solely on heating the metal until it reaches a gas state. It is difficult to metallise 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 sputtured 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 need more care and the use of better squeegee techniques during installation. Figure 3.6 illustrates a standard neutral sputtered film structure with a pressure sensitive adhesive.

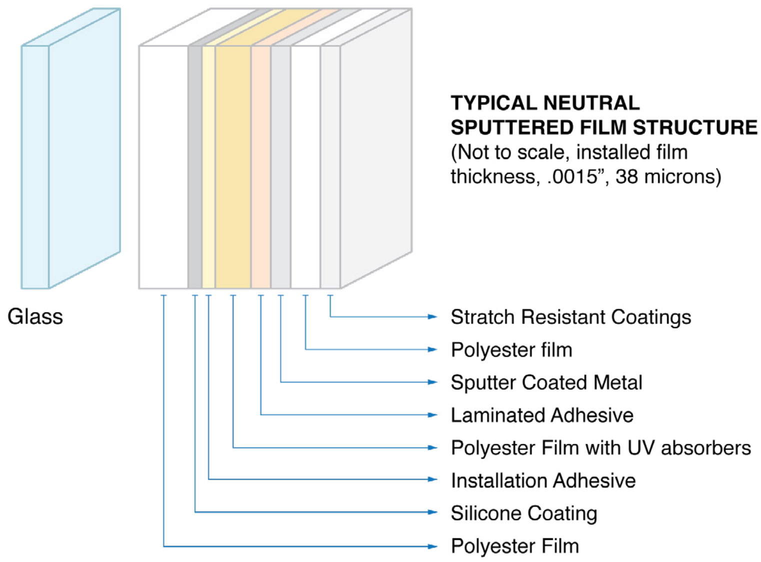

Figure 3.6 - Typical Neutral Sputtered Film Structure

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 Window Films

As mentioned earlier and shown in all the product structure Figures, most window films are designed to be applied on the interior of the window. However, films that are designed for exterior installation also exist. 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 or triple 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 UVB exposure.

Note: Polyester film is not a natural exterior product. A reflective exterior film is shown in Figure 3.7. Note the position of the layers compared to an interior film.

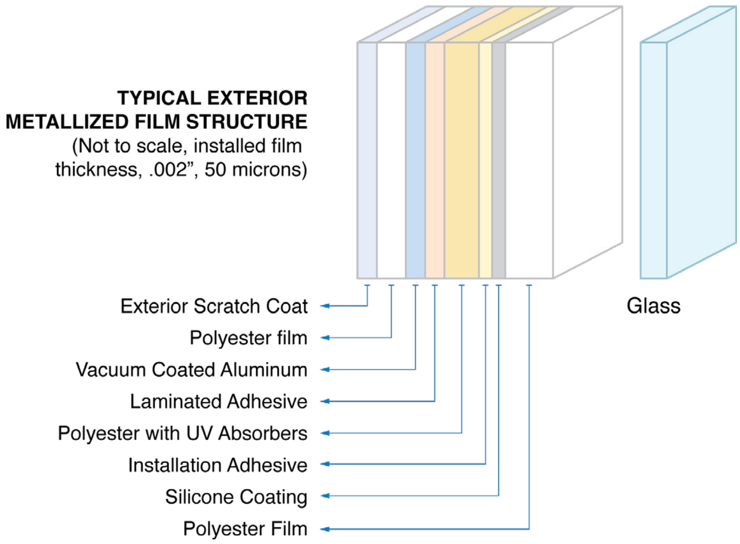

Figure 3.7 – Typical Exterior Metallised Film Structure

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 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 complex window assemblies and describe the most widely-used values for communicating window performance.

Heat Transfer Mechanisms

As discussed in previous sections, 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 explained in previous sections, 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 G-value (also known as Solar Heat Gain Coefficient, SHGC).

G-value

G-value measures how well a product blocks heat caused by sunlight. G-value is the fraction of incident solar radiation admitted through a window system, both directly transmitted and absorbed, then subsequently released inward. It is expressed as a number between 0 and 1. The lower the G-value, 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.

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

1	Clear Single Glazing	G-value: 0.86
2	Double Glazing (IGU) laminated	G-value: 0.70
3	Single Glazing with Gray Tint	G-value: 0.57
4	Clear Double Glazing (IGU)	G-value: 0.51
5	Double Glazing (IGU) with Gray Tint	G-value: 0.46
6	Double Glazing (IGU) with High Performance Coating	G-value: 0.39
7	Double Glazing (IGU) with High Performance Low E	G-value: 0.33
8	Double Glazing (IGU) with Face 2 and Face 4 Coating	G-value: 0.48
9	Triple Glazing	G-value: 0.39[4]

Energy Effects of G-value

Figures 2.14 and 2.15 below illustrate the effect of changing the G-value on energy costs in a typical house in two different climates. In general, reducing the G-value 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 warm climate, reducing the G-value will result in a noticeable decrease in the total annual energy costs, whereas in a cold climate, reducing the G-value 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.

These statements are however generalities and situations exist in which it still makes sense to improve the G-value even for buildings in cold climates. 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.

[4]Calculations made with the Calumen software, on a 6 mm glass panel.

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 G-value. For that reason, G-value 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. The TSER is the total amount of solar energy rejected by the glazing. It is calculated directly from the G-value/solar factor. The higher the number, the higher the amount of total solar energy that will be rejected.

Insulating Values

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 from inside to outside. The U-value, also referred to as the U-factor, is a measurement of heat transfer due to outdoor/indoor temperature differences. Technically, the U- value shows the heat transmittance through a structure in units of W/m^2K. The lower the U-value, the less heat transfers through the material, the better insulated the material. 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.

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 is 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.

Other Performance Values

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

Solar Selectivity Index

Solar Selectivity Index (SSI) is the ratio of visible light transmission to solar heat transmission that passes through a window. It is calculated by dividing the Visible Light Transmission (VLT) by the G-value (VLT/G-value). 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 warm locations, that same reduction in "free" winter heat from the sun (often called passive solar heating) is less desirable in colder locations. Any SSI 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.

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 contributes 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 Visible Light Transmission (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

Window film manufacturers generally provide distributors and installers 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. In North America, IWFA guidelines recommend the use of the National Fenestration Rating Council (NFRC) procedures for measurement, calculation, and reporting of these performance values.

In Europe, EWFA recommends determining the luminous and solar characteristics of window films according to the European standard EN 410 Glass in building - Determination of luminous and solar characteristics of glazing. The initial measured data is usually based on 4 mm clear float glass. The values for other glass types may also be shown on data sheets in addition to the 4 mm clear glass, but the glass type and thickness applicable for each measured value should always be included in the data sheets.

In order to converge towards common standards for the window film industry, IWFA and EWFA recommend the publishing of window film data sheets including G-value, TSER, IRER (Infrared Energy Rejection), UV and VL data, which will facilitate comparison of different products performances. U-value can be determined thanks to European standard EN 673 Glass in building - Determination of thermal transmittance (U value) - Calculation method.

More specifically, two European standards gather the needs for window films: EN15752-1: Glass in building - Adhesive backed polymeric film – Part 1: Definitions and requirements and EN 15755-1: Glass in building - Adhesive backed polymeric filmed glass - Part 1: Definitions and requirements.

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, while the differences are much smaller to non-existent at the equator. All performance values are measured with the sun at 60 or 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 it is simply because there is less radiant energy hitting the windows.

Matching Measurements to Benefits

Commercial Buildings

Today, the most widely marketed benefits of window films for commercial buildings are solar heat control for occupant comfort, cost savings, reduction of the building's carbon footprint, fade protection, glare control, and exterior building aesthetic improvement.

1. Occupant comfort and cost savings are mostly driven by G-value, especially in warm climates. Consult with your window film manufacturer for a possible energy analysis for large buildings.

2. Fade protection is a function of UV protection, lower visible light, and to some extend by lowering the Near-Infrared directly transmitted through the glass as well. Read the additional information at the end of this section ("Fading Considerations").

3. Glare control is almost exclusively a function of visible light, although the colour of the light (which depends on the wavelength) can play a role, with blue light being a bigger issue.

4. Exterior building aesthetics are a combination of colour, 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 Buildings

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

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. Low-emissivity options may be considered 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 avoid complaints.

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 a window film 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 per this Guide’s section 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: UVC (100 to 290 nanometres), UVB (290 to 320 nanometres) and UVA (320 to 380 nanometres). The earth’s atmosphere and ozone layer filter out most UVC and a percentage of UVB rays. UVB 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. UVA is now thought to cause 90 % of skin aging and has been linked to melanoma, since the longer wavelength of the UVA rays penetrates deeper into the skin. “Broad-spectrum” sunscreens were developed to screen UVB and UVA. Early sunscreens only screened in the UVB and allowed people to stay in the sun longer without experiencing a sunburn, thus allowing more UVA skin damage.

According to the European Cancer Information System, it is estimated that skin melanoma accounted for 4 % of all new cancer diagnoses in EU-27 countries in 2020 (all cancers, excluding non-melanoma skin cancers) and for 1.3 % of all deaths due to cancer. This made it the sixth most frequently occurring cancer and one of the 20 most frequent causes of cancer death. Window film is designed to absorb UVA 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 window film for these rare diseases.

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 fibres 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 vapours 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.

Window film professionals 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 money saved based on the energy savings over a number of years can pay for the installation of window film.

These savings are calculated by simulating the energy use of a building before and after the installation of window film. In the United States, IWFA funded and helped create an energy analysis tool called Efilm, based on the U.S. Department of Energy EnergyPlusTM 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. 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 mock-up 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.

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 a window 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 window 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. Also, plastic is often soft, so attempts to remove failed window 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 window 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 window 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.

It is important to note that modern skylights predominantly feature a construction comprising an outer toughened glass and an inner laminated glass, moving away from the traditional annealed laminated glass design. Always consult the window 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 window 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 potentially last between 3 and 10 years. Of concern to window 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 Window Film

All glass types (except toughened glass and heat-strengthened glass) are susceptible to thermal glass breakage if the wrong window film is installed. IGUs require special consideration when considering window 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 window film selection rules are followed. Each window film 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 window 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 vaporise, making existing seal failures more obvious. Window film professionals should consult their window film manufacturers on warranties and policies around seal failure to understand their liabilities in these situations.

Filming Complex Glazing Systems

Determining an appropriate window 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 window 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 centre of a glass pane is significantly different from the temperature of the glass under the frame. Anything that heats the centre 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 centre and edge of glass temperature.

Window Film Installation Guidelines

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 toughened glass. The glazing system might also include a laminated glass system which would be two layers of annealed or toughened glass with a layer of PVB interlayer between. There is very little difference between the heat absorption of annealed, heat-strengthened, and toughened glass. However, 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 centre. Heat-strengthened glass breaks less easily and is often the glass of choice in high thermal load locations such as spandrel panels. Toughened glass can withstand a large temperature differential between the centre 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 difference in temperature between the two panes of glass in the laminate. Toughened laminated glass is not more susceptible to glass breakage than toughened glass. It is highly unlikely that any glazing system with toughened 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 the 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:
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 10 mm.

2. The use of solar control film is not recommended for tinted annealed glass thicker than 6 mm.

3. The use of solar control film is not recommended for annealed laminated glass of any thickness.

Glass Size

Most window 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 centre 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 9.3 square meters.

2. The use of solar control film is not recommended for annealed IGU's with an area greater than 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 window film will normally increase that absorption level. On dual pane window 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-strengthened, and if it is possible to determine the glass type in an older building, this may widen the approved window films for this type of installation.

Solar reflective coatings on single pane glass are often found in older buildings in warm climates. Care must be taken when installing window 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 window 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, which is why window film installation is not recommended. Most Low E coatings are in dual pane units. Those used in colder climates 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 window film applied. The Low E coatings found in mild or warm 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 window 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-value but can yield a significant difference in the G-value, 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 window 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 centre 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, it is shading which only covers part of the window either all the time or as the sun advances through the day. In the absence of a window film manufacturer's recommendations, these guidelines 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, 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 5 cm clearance between the window treatment and the glass at all points.

2. There should be a minimum of 3-4 cm clearance at the top and bottom of the window treatment, or a minimum of 3-4 cm 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 window 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 window film, but to provide education on the possible risk factors. If window film professionals understand the reasons behind these risks and follow the manufacturers' window film to glass recommendations, the risk of glass breakage is significantly reduced.

Decorative Window Film

While decorative installations are beautiful, it is extremely difficult to determine the solar control properties of these installations. Even the window films with an even surface create problems with the standard measurement equipment. For this reason, 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 window 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 an even surface which is used to block the view just a little, progressing all the way to total white out or black out window 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. Some patterned films 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.

4. 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.

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 labelling, 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.

EWFA
EUROPEAN WINDOW FILM ASSOCIATION
A CHAPTER OF THE IWFA

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