Laminated Glass – Thermal and Optical Properties

In today's architectural construction, laminated glass applications are widely used in commercial and residential building projects. Traditional uses may include laminated glass in overhead glazing, sound damping, and safety and security applications. Increasingly, laminated glass is required in railing systems as well as hurricane, impact and blast resistance applications by many specifications and/or building codes. Additionally, laminated glass can be certified as a safety glazing product to the Consumer Product Safety Commission, Title 16, *Code of Federal Regulations*.

A laminate is two or more sheets of glass with an inner layer of transparent plastic (interlayer material) to which the glass is adhered. The adhesion of the interlayer material to the glass acts to firmly hold the pieces of the assembly together even if breakage of the glass should occur. For this reason laminated glass is commonly used for overhead glazing, applications requiring safety glazing and anywhere the consequences of glass breakage would desire the majority of the glass to be retained in place.

Surface Orientation

The surface orientation nomenclature that is common within the fenestration industry is illustrated in figures 1 and 2. A thorough understanding of this nomenclature is important as today's laminated glass constructions can be complex. An example and as discussed in more detail later in this document, the surface location of low-emissivity (low-E) coatings incorporated in a laminate will have a great impact on the optical, aesthetic and thermal properties of the laminate and IGU.

A monolithic laminate is considered to be two or more lites of glass laminated together as one unit and glazed in the building as such.

Figure 1. - Monolithic Surface Orientations

An IGU with laminated glass will have a minimum of six glass surfaces, possibly more. Examples of inboard and outboard laminate configurations are shown below.

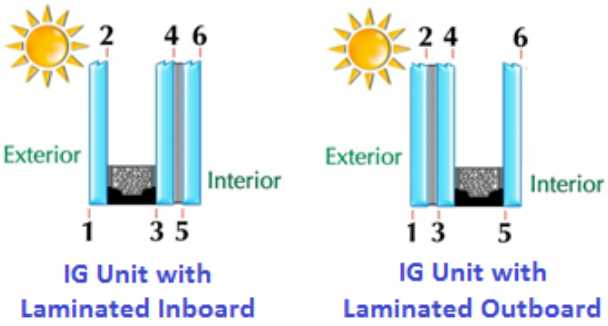

Figure 2. - Laminate IG Surface Orientation

Laminates Incorporating a Low-E Coating

In laminated IGU glass construction, the low-E coated surface location will have a significant impact on both performance and aesthetics,

Laminated Glass – Thermal and Optical Properties

and should be appropriately considered. In some applications, number two surface is the best location for the coating, in other applications number three, four or five surface would be the best location.

Performance Considerations:

If the laminate is constructed with the low-E coating in direct contact with the interlayer material, the low emissivity effect and the associated U-Value performance improvement of the low-E coating will be lost. In cases where it is desirable to laminate the coating in direct contact with the interlayer material, the U-Value of the glass will be about the same as that of uncoated clear or tinted glass. However, the solar control properties of the coating will still be intact as shown by the Solar Heat Gain Coefficient (SHGC) value. In fact, depending on how the plastic interlayer material properties compare to the low-E coating properties, there may even be a slight improvement of the SHGC value caused by absorption of some solar near-IR radiation by the interlayer material.

Aesthetic Considerations:

When the air interface is eliminated by laminating a low-E coating against an interlayer material, the reflected color of the low-E coating will change and may also exhibit lite to lite variability. The color of low-E coating results from the interference of light reflected from the top surface of the coating (i.e. the "air interface") and from the interfaces between the coating layers. The amount and direction of the color difference and associated increases in variability may be different from one low-E coating to another. The potential for color shift may be minimized when a tinted substrate is located in front of the coating and highlighted when a tinted substrate is behind it, with darker tints resulting in greater highlighting of the color shift. This phenomenon needs to be considered during the design work and enforces the need to evaluate full size mock-ups.

Vitro Certified Fabricators & Laminators

Vitro (formerly PPG Industries) recommends that the location of the low-E coated surface within the glass construction be based on the glazing application and the design intentions and requirements of the project architect(s) and owner(s). Vitro does not require that the low-E coating be used on any specific surface. Vitro does require that in all glass constructions, Vitro Solarban® and Sungate® low-E coatings cannot be used on a surface exposed to the atmosphere. These low-E coatings must be located adjacent to a dry, desiccated, hermetically sealed airspace or adjacent to an approved interlayer material as fabricated by a Vitro Certified Laminator Program (CLP) member. Only members of the CLP in good standing will be extended a low-E Glass Warranty for low-E coated glass products incorporated adjacent to the interlayer material. When the low-E coating is oriented adjacent to the interlayer material, the laminates can be used in a monolithic installation or incorporated into an IG unit. In addition, Vitro requires that all low-E coatings located in contact with the interlayer material be properly edge deleted. Vitro Technical Document, TD-141 *Edge Deletion of Vitro Coated Glass* is available for further information.

Color and Performance Consistency

Vitro recommends that laminated glass constructions utilize the same interlayer material manufacturer and type of interlayer material throughout any given project. Different interlayer materials may impart reflected color differences, transmitted color differences and/or visible light transmittance differences to the laminate construction particularly with low-E

Laminated Glass – Thermal and Optical Properties

coatings (reference ASTM C1376 for additional details on color uniformity).

Fabricators should be consistent with interlayer materials throughout any given project, just as they would be consistent with glass substrate. Furthermore, for the best color consistency Vitro recommends that the same coating type be utilized throughout projects. Intermixing of laminated annealed and laminated heat-treatable coatings could increase the perceivable color variation.

In addition to using consistent materials, the orientation of the coated surface should always be maintained throughout any given project. The color of low-E coatings changes or shifts when oriented adjacent to an interlayer material. The performance and aesthetics also change when the coating is moved from one side of an interlayer material to the other. One possible IGU assembly error is shown in Figure 3 below with the coated lite shown in red.

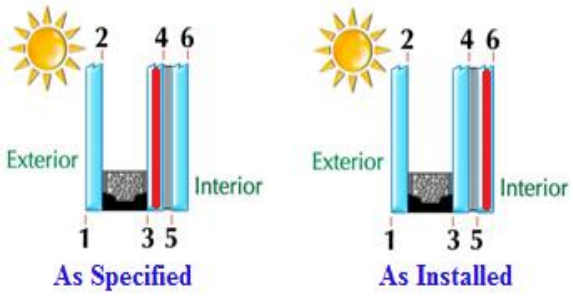

Figure 3. - Improper Installation

Although the laminate was constructed correctly, it was placed into the IGU backwards changing both performance and color of the IGU.

Additional Design Considerations

It is important to consider other design requirements, such as total weight of the final glazing construction, thermal stress, wind/snow loading and safety before making the final glass product decisions. Various glass thicknesses and tinted glass substrates can be used to meet thermal stress and wind load requirements.

For laminates, if one lite requires heat strengthening to resist thermal loading, then Vitro recommends that both lites be heat strengthened due to the fact that the laminate will act as a single piece of glass in regards to thermal stress. In other words, both lites in the laminate will reach the same temperature and must both be able to resist the same thermal stresses.

In architectural applications utilizing heat-treated glass, including sloped glazing applications, Vitro reaffirms its longstanding recommendation that heat strengthened glass be specified and used, except where tempered glass is mandated for safety or other purposes by code. Vitro Technical Document, TD-138 *Heat Treated Glass for Architectural Glazing* is available for further information.

Laminates are also utilized to limit the fading associated with UV and short wavelength visible light. The interlayer material typically reduces UV transmission to less than 1%. Vitro Technical Document, TD-148 *Reducing Fading and Material Degradation of Interior Furnishings Caused by Solar Radiation Exposure* is available for further information on fading reduction.

Laminated Glass – Thermal and Optical Properties

In certain coastal regions, laminated glass can be utilized for hurricane impact resistance as well as meet the requirements for environmentally friendly "Turtle Glass". Vitro Technical Document, TD-123 *Turtle Glass* is available for further information on glass that meets the Turtle code.

Conclusions

1. Laminates are increasingly utilized in a variety of applications for their unique traits.
2. Low-E Coating location plays an important role in determining the aesthetic and performance attributes of a given laminate.
3. When the Low-E coating is oriented away from the interlayer material on an outer glass surface of the laminate, the low-E coating must be adjacent to a dry, desiccated, hermetically sealed, airspace.
4. Vitro recommends that the same interlayer material manufacturer and type of interlayer material be used throughout any given project.
5. The color of low-E coatings may change/shift when oriented adjacent to an interlayer material and creates a potential for lite to lite variation which may be highlighted if a tinted glass or darker background is located behind the coating.
6. Laminates with the low-E coating adjacent to the interlayer material must be properly edge deleted and assembled using an approved interlayer material by a Vitro Certified Laminator Program (CLP) member.
7. In applications where the low-E coating is in direct contact with the interlayer material Vitro recommends that the same coating type, (annealed or heat-treatable) be utilized throughout a given project
8. Vitro recommends that a full size mock-up be reviewed under the specific job-site conditions and retain the mock-up as a basis of acceptable product.

Tabulated Data

As a point of departure, this document contains attached tables showing the thermal and optical properties of selected laminates using Vitro glass products. The tables are not all inclusive, even for Vitro glass products. Rather they represent a selection of the more common combinations.

The following tables are included:

- Table 1A – *Uncoated Commercial Monolithic Laminates*
- Table 1B – *Uncoated Residential Monolithic Laminates*
- Table 2 – *Monolithic Solarcool® & Vistacool® Coated Laminates*
- Table 3 – *Uncoated and Tinted IG Units with Laminates*
- Table 4 – *Solarcool® & Vistacool® Coated on Tints in IG Units with Laminates*
- Table 5A - *Solarban® Coatings in a Commercial IG Unit with Laminates*
- Table 5B - *Solarban® Coatings in a Residential IG Unit with Laminates*

Laminated Glass – Thermal and Optical Properties

TABLE 1A - Uncoated Commercial Monolithic Laminates THERMAL AND OPTICAL PROPERTIES OF SELECTED COMMERCIAL LAMINATED GLASS COMBINATIONS CALCULATED USING LBNL OPTICS AND WINDOW											
	Transmittance (%)		Reflectance (Exterior %)		U-Value (Btu/hr ft² °F)		U-Value (W/m² K)		Fading Factor	Solar Heat Gain Coefficient (SHGC)	Light to Solar Gain (LSG)
Product Type and Description	Visible	Total Solar Energy	Visible	Total Solar Energy	Winter Night	Summer Day	Winter Night	Summer Day	Tdw-ISO		
9/16" Monolithic Uncoated Laminate with 0.060" Clear PVB Interlayer — Indicates a Turtle Friendly Configuration											
¼" Clear + Interlayer + ¼" Clear	86%	61%	8%	6%	0.95	0.87	5.41	4.91	0.58	0.71	1.21
¼" Starphire® + Interlayer + ¼" Starphire®	90%	79%	8%	7%	0.95	0.87	5.41	4.91	0.61	0.83	1.08
¼" Solexia® + Interlayer + ¼" Clear	75%	39%	7%	5%	0.95	0.87	5.41	4.91	0.50	0.57	1.32
¼" Atlantica® + Interlayer +¼" Clear	65%	29%	7%	5%	0.95	0.87	5.41	4.91	0.41	0.51	1.27
¼" Azuria® + Interlayer + ¼" Clear	66%	28%	7%	5%	0.95	0.87	5.41	4.91	0.49	0.50	1.32
¼" Pacifica® + Interlayer + ¼" Clear	41%	23%	5%	5%	0.95	0.87	5.41	4.91	0.34	0.46	0.89
¼" Solarblue® + Interlayer + ¼" Clear	54%	37%	6%	5%	0.95	0.87	5.41	4.91	0.42	0.56	0.96
¼" Solarbronze® + Interlayer + ¼" Clear	52%	39%	6%	5%	0.95	0.87	5.41	4.91	0.33	0.57	0.91
¼" Optigray® + Interlayer + ¼" Clear	61%	41%	6%	5%	0.95	0.87	5.41	4.91	0.42	0.58	1.05
¼" Solargray® + Interlayer + ¼" Clear	43%	33%	6%	5%	0.95	0.87	5.41	4.91	0.31	0.53	0.81
¼" Graylite® II + Interlayer + ¼" Clear	9%	6%	4%	4%	0.95	0.87	5.41	4.91	0.06	0.36	0.25

Laminated Glass – Thermal and Optical Properties

TABLE 1B - Uncoated Residential Monolithic Laminates THERMAL AND OPTICAL PROPERTIES OF SELECTED RESIDENTIAL LAMINATED GLASS COMBINATIONS CALCULATED USING LBNL OPTICS AND WINDOW											
	Transmittance (%)		Reflectance (Exterior %)		U-Value (Btu/hr ft² °F)		U-Value ($W/m^2 K$)		Fading Factor	Solar Heat Gain Coefficient (SHGC)	Light to Solar Gain (LSG)
Product Type and Description	Visible	Total Solar Energy	Visible	Total Solar Energy	Winter Night	Summer Day	Winter Night	Summer Day	Tdw-ISO		
5/16" Monolithic Uncoated Laminate with 0.090" Clear SGP Interlayer — Indicates a Turtle Friendly Configuration											
⅛" Clear + Interlayer + ⅛" Clear	87%	67%	8%	7%	0.96	0.87	5.44	4.94	0.60	0.75	1.16
⅛" Starphire® + Interlayer + ⅛" Starphire®	90%	79%	8%	7%	0.96	0.87	5.44	4.94	0.62	0.83	1.08
⅛" Solexia® + Interlayer + ⅛" Clear	80%	50%	8%	6%	0.96	0.87	5.44	4.94	0.55	0.64	1.25
⅛" Solarbronze® + Interlayer + ⅛" Clear	65%	52%	7%	6%	0.96	0.87	5.44	4.94	0.43	0.65	1.00
⅛" Solargray® + Interlayer + ⅛" Clear	58%	47%	6%	5%	0.96	0.87	5.44	4.94	0.41	0.62	0.94
⅛" Graylite® II + Interlayer + ⅛" Clear	23%	17%	5%	4%	0.96	0.87	5.44	4.94	0.16	0.43	0.53

Laminated Glass – Thermal and Optical Properties

TABLE 2 - Monolithic Solarcool® & Vistacool® Coated Laminates THERMAL AND OPTICAL PROPERTIES OF SELECTED COMMERCIAL LAMINATED GLASS COMBINATIONS CALCULATED USING LBNL OPTICS AND WINDOW											
	Transmittance (%)		Reflectance (Exterior %)		U-Value (Btu/hr ft² °F)		U-Value (W/m² K)		Fading Factor	Solar Heat Gain Coefficient (SHGC)	Light to Solar Gain (LSG)
Product Type and Description	Visible	Total Solar Energy	Visible	Total Solar Energy	Winter Night	Summer Day	Winter Night	Summer Day	Tdw-ISO		
9/16" Monolithic Solarcool® & Vistacool® Coated Laminates with 0.060" Clear PVB Interlayer — Indicates a Turtle Friendly Configuration *NOTE: (1) & (2) Indicate Location of Coating per PPG Standard Nomenclature.*											
¼" Solarcool® Azuria® (1) + Interlayer + ¼" Clear	25%	11%	36%	30%	0.95	0.86	5.40	4.91	0.16	0.30	0.83
¼" Solarcool® Azuria® (2) + Interlayer + ¼" Clear	30%	13%	16%	8%	0.95	0.86	5.40	4.91	0.19	0.39	0.77
¼" Solarcool® Pacifica® (1) + Interlayer + ¼" Clear	19%	12%	21%	16%	0.95	0.86	5.40	4.91	0.14	0.36	0.53
¼" Solarcool® Pacifica® (2) + Interlayer + ¼" Clear	19%	12%	9%	6%	0.95	0.86	5.40	4.91	0.13	0.39	0.49
¼" Solarcool® Solarbronze® (1) + Interlayer + ¼" Clear	20%	20%	36%	30%	0.95	0.86	5.40	4.91	0.11	0.36	0.56
¼" Solarcool® Solarbronze® (2) + Interlayer + ¼" Clear	24%	23%	11%	9%	0.95	0.86	5.40	4.91	0.13	0.45	0.53
¼" Solarcool® Solarblue® (1) + Interlayer + ¼" Clear	26%	22%	21%	16%	0.95	0.86	5.40	4.91	0.17	0.42	0.62
¼" Solarcool® Solarblue® (2) + Interlayer + ¼" Clear	25%	21%	12%	9%	0.95	0.86	5.40	4.91	0.16	0.44	0.57
¼" Solarcool® Solargray® (1) + Interlayer + ¼" Clear	17%	17%	36%	30%	0.95	0.86	5.40	4.91	0.10	0.34	0.50
¼" Solarcool® Solargray® (2) + Interlayer + ¼" Clear	20%	19%	9%	8%	0.95	0.86	5.40	4.91	0.12	0.43	0.47
¼" Solarcool® Solexia® (1) + Interlayer + ¼" Clear	29%	18%	37%	30%	0.95	0.86	5.40	4.91	0.17	0.35	0.83
¼" Solarcool® Solexia® (2) + Interlayer + ¼" Clear	35%	21%	19%	10%	0.95	0.86	5.40	4.91	0.20	0.43	0.81
¼" Vistacool® Azuria® (2) + Interlayer + ¼" Clear	56%	24%	14%	8%	0.95	0.86	5.40	4.91	0.41	0.46	1.22
¼"Vistacool® Pacifica® (2) + Interlayer + ¼" Clear	35%	20%	8%	6%	0.95	0.86	5.40	4.91	0.29	0.44	0.80

Laminated Glass – Thermal and Optical Properties

TABLE 3 - Uncoated & Tinted Commercial IG Units with an Inner Laminate THERMAL AND OPTICAL PROPERTIES OF SELECTED COMMERCIAL LAMINATED GLASS COMBINATIONS CALCULATED USING LBNL OPTICS AND WINDOW											
	Transmittance (%)		Reflectance (Exterior %)		U-Value (Btu/hr ft² °F)		U-Value (W/m² K)		Fading Factor	Solar Heat Gain Coefficient (SHGC)	Light to Solar Gain (LSG)
Product Type and Description	Visible	Total Solar Energy	Visible	Total Solar Energy	Winter Night	Summer Day	Winter Night	Summer Day	Tdw-ISO		
1 5/16" Uncoated Insulating Glass Units with 9/16" Clear Glass Laminate - (¼" Clear + 0.060"Clear PVB Interlayer + ¼" Clear)											
Indicates a Turtle Friendly Configuration											
¼" Clear + ½" Airspace + Laminate	77%	49%	15%	11%	0.46	0.48	2.59	2.73	0.52	0.66	1.17
¼" Starphire® + ½" Airspace + Laminate	79%	55%	15%	13%	0.46	0.48	2.59	2.73	0.53	0.73	1.08
¼" Solexia® + ½" Airspace + Laminate	67%	32%	13%	8%	0.46	0.48	2.59	2.73	0.44	0.47	1.43
¼" Atlantica® + ½" Airspace + Laminate	58%	25%	11%	6%	0.46	0.48	2.59	2.73	0.37	0.39	1.49
¼" Azuria® + ½" Airspace + Laminate	59%	24%	11%	7%	0.46	0.48	2.59	2.73	0.44	0.38	1.55
¼" Pacifica® + ½" Airspace + Laminate	37%	19%	7%	5%	0.46	0.48	2.59	2.73	0.31	0.34	1.09
¼" Solarblue® + ½" Airspace + Laminate	49%	30%	9%	7%	0.46	0.48	2.59	2.73	0.37	0.46	1.07
¼" Solarbronze® + ½" Airspace + Laminate	46%	31%	8%	7%	0.46	0.48	2.59	2.73	0.29	0.48	0.96
¼" Optigray® + ½" Airspace + Laminate	54%	33%	9%	7%	0.46	0.48	2.59	2.73	0.37	0.49	1.10
¼" Solargray® + ½" Airspace + Laminate	38%	26%	7%	6%	0.46	0.48	2.59	2.73	0.27	0.43	0.88
¼" Graylite® II + ½" Airspace + Laminate	8%	5%	4%	4%	0.46	0.48	2.59	2.73	0.05	0.21	0.38

Laminated Glass – Thermal and Optical Properties

TABLE 4 - Solarcool® & Vistacool® Coating on Tints in IG Units with an Inner Laminate THERMAL AND OPTICAL PROPERTIES OF SELECTED COMMERCIAL LAMINATED GLASS COMBINATIONS CALCULATED USING LBNL OPTICS AND WINDOW											
	Transmittance (%)		Reflectance (Exterior %)		U-Value (Btu/hr ft² °F)		U-Value (W/m² K)		Fading Factor	Solar Heat Gain Coefficient (SHGC)	Light to Solar Gain (LSG)
Product Type and Description	Visible	Total Solar Energy	Visible	Total Solar Energy	Winter Night	Summer Day	Winter Night	Summer Day	Tdw-ISO		
1 5/16" Solarcool® and Vistacool® Coated Insulating Glass Units with Clear Glass Laminate – (¼" Clear +0.060" Clear PVB Interlayer + ¼" Clear)											
NOTE: (1) & (2) Indicate Location of Coating per PPG Standard Nomenclature. Turtle Indicates a Turtle Friendly Configuration											
¼" Solarcool® Azuria® (1) + ½" Airspace + Laminate Turtle	23%	9%	37%	30%	0.46	0.48	2.59	2.73	0.14	0.20	1.15
¼" Solarcool® Azuria® (2) + ½" Airspace + Laminate Turtle	23%	10%	20%	10%	0.46	0.48	2.59	2.73	0.15	0.24	0.96
¼" Solarcool® Pacifica® (1) + ½" Airspace + Laminate Turtle	14%	8%	36%	30%	0.46	0.48	2.59	2.73	0.10	0.20	0.70
¼" Solarcool® Pacifica® (2) + ½" Airspace + Laminate Turtle	14%	8%	10%	7%	0.46	0.48	2.59	2.73	0.10	0.24	0.58
¼" Solarcool® Solarbronze® (1) + ½" Airspace + Laminate Turtle	18%	15%	37%	31%	0.46	0.48	2.59	2.73	0.10	0.29	0.62
¼" Solarcool® Solarbronze® (2) + ½" Airspace + Laminate Turtle	18%	16%	14%	12%	0.46	0.48	2.59	2.73	0.10	0.32	0.56
¼" Solarcool® Solarblue® (1) + ½" Airspace + Laminate Turtle	19%	14%	37%	30%	0.46	0.48	2.59	2.73	0.12	0.27	0.70
¼" Solarcool® Solarblue® (2) + ½" Airspace + Laminate Turtle	19%	14%	15%	11%	0.46	0.48	2.59	2.73	0.13	0.30	0.63
¼" Solarcool® Solargray® (1) + ½" Airspace + Laminate Turtle	15%	13%	36%	30%	0.46	0.48	2.59	2.73	0.09	0.26	0.58
¼" Solarcool® Solargray® (2) + ½" Airspace + Laminate Turtle	15%	13%	11%	9%	0.46	0.48	2.59	2.73	0.09	0.29	0.52
¼" Solarcool® Solexia® (1) + ½" Airspace + Laminate Turtle	26%	14%	37%	30%	0.46	0.48	2.59	2.73	0.15	0.26	1.00
¼" Solarcool® Solexia® (2) + ½" Airspace + Laminate Turtle	26%	15%	24%	12%	0.46	0.48	2.59	2.73	0.15	0.30	0.87
¼" Vistacool® Azuria® (2) + ½" Airspace + Laminate	46%	19%	21%	11%	0.46	0.48	2.59	2.73	0.34	0.32	1.44
¼" Vistacool® Pacifica® (2) + ½" Airspace + Laminate Turtle	29%	15%	11%	7%	0.46	0.48	2.59	2.73	0.23	0.30	0.97

Laminated Glass – Thermal and Optical Properties

TABLE 5A - Solarban® Coatings in a Commercial IG Unit with an Inner Laminate THERMAL AND OPTICAL PROPERTIES OF SELECTED COMMERCIAL LAMINATED GLASS COMBINATIONS CALCULATED USING LBNL OPTICS AND WINDOW											
	Transmittance (%)		Reflectance (Exterior %)		U-Value (Btu/hr ft² °F)		U-Value (W/m² K)		Fading Factor	Solar Heat Gain Coefficient (SHGC)	Light to Solar Gain (LSG)
Product Type and Description	Visible	Total Solar Energy	Visible	Total Solar Energy	Winter Night	Summer Day	Winter Night	Summer Day	Tdw-ISO		
1 5/16" Solarban® Coated Insulating Glass Units with Clear Glass Laminate – (¼" Clear + 0.060" Clear PVB Interlayer + ¼" Clear)											
NOTE: (2) Indicates the Location of Coating per PPG Standard Nomenclature.				***Indicates a Turtle Friendly Configuration***							
¼" Solarban® 60(2) Clear + ½" Airspace + Laminate	68%	30%	11%	28%	0.28	0.27	1.61	1.52	0.44	0.38	1.79
¼" Solarban® 60(2) Solexia® + ½" Airspace + Laminate	60%	23%	9%	10%	0.28	0.27	1.61	1.52	0.38	0.32	1.88
¼" Solarban® 60(2) Atlantica® + ½" Airspace + Laminate	52%	19%	8%	7%	0.28	0.27	1.61	1.52	0.32	0.27	1.93
¼" Solarban® 60(2) Solarblue® + ½" Airspace + Laminate	43%	19%	7%	12%	0.28	0.27	1.61	1.52	0.32	0.28	1.54
¼" Solarban® 60(2) Optigray® + ½" Airspace + Laminate	49%	21%	8%	14%	0.28	0.27	1.61	1.52	0.32	0.30	1.63
¼" Solarban® 67(2) Clear + ½" Airspace + Laminate	52%	22%	19%	34%	0.28	0.27	1.61	1.52	0.34	0.29	1.79
¼" Solarban® 67(2) Solexia® + ½" Airspace + Laminate	46%	17%	16%	13%	0.28	0.27	1.61	1.52	0.29	0.25	1.84
¼" Solarban® 67(2) Atlantica® + ½" Airspace + Laminate	40%	14%	13%	9%	0.28	0.27	1.61	1.52	0.24	0.22	1.82
¼" Solarban® 67(2) Solarblue® + ½" Airspace + Laminate	33%	14%	10%	15%	0.28	0.27	1.61	1.52	0.24	0.22	1.50
¼" Solarban® 67(2) Optigray® + ½" Airspace + Laminate	37%	16%	12%	17%	0.28	0.27	1.61	1.52	0.24	0.23	1.61
¼" Solarban® 70XL(2) Starphire® + ½" Airspace + Laminate	62%	23%	12%	52%	0.28	0.26	1.58	1.47	0.39	0.27	2.30
¼" Solarban® 70XL(2) Solexia® + ½" Airspace + Laminate	57%	20%	10%	12%	0.28	0.26	1.58	1.47	0.35	0.27	2.11
¼" Solarban® 70XL(2) Atlantica® + ½" Airspace + Laminate	49%	16%	9%	8%	0.28	0.26	1.58	1.47	0.29	0.24	2.04
¼" Solarban® 70XL(2) Solarblue® + ½" Airspace + Laminate	41%	15%	8%	15%	0.28	0.26	1.58	1.47	0.29	0.23	1.78
¼" Solarban® 70XL(2) Optigray® + ½" Airspace + Laminate	46%	17%	8%	18%	0.28	0.26	1.58	1.47	0.29	0.24	1.92
¼" Solarban® z50(2) Optiblue® + ½" Airspace + Laminate	49%	23%	8%	22%	0.28	0.27	1.61	1.52	0.35	0.32	1.53
¼" Solarban® z75(2) Optiblue® + ½" Airspace + Laminate	47%	18%	8%	29%	0.28	0.26	1.58	1.47	0.32	0.24	1.96

Laminated Glass – Thermal and Optical Properties

TABLE 5B - Solarban® Coatings in a Residential IG Unit with an Inner Laminate THERMAL AND OPTICAL PROPERTIES OF SELECTED COMMERCIAL LAMINATED GLASS COMBINATIONS CALCULATED USING LBNL OPTICS AND WINDOW											
	Transmittance (%)		Reflectance (Exterior %)		U-Value (Btu/hr ft² °F)		U-Value (W/m^2 K)		Fading Factor	Solar Heat Gain Coefficient (SHGC)	Light to Solar Gain (LSG)
Product Type and Description	Visible	Total Solar Energy	Visible	Total Solar Energy	Winter Night	Summer Day	Winter Night	Summer Day	Tdw-ISO		
13/16" Solarban® Coated Insulating Glass Units with Clear Glass Laminate – (¼" Clear + 0.090" Clear SGP Interlayer + ¼" Clear) ***NOTE: (2) Indicates the Location of Coating per PPG Standard Nomenclature.***											
⅛" Solarban® 60(2) Clear + ½" Airspace + Laminate	70%	33%	11%	34%	0.29	0.27	1.62	1.53	0.46	0.39	1.79
⅛" Solarban® 60(2) Solexia® + ½" Airspace + Laminate	65%	27%	10%	17%	0.29	0.27	1.62	1.53	0.42	0.34	1.91
⅛" Solarban® 60(2) Solargray® + ½" Airspace + Laminate	47%	23%	7%	19%	0.29	0.27	1.62	1.53	0.32	0.30	1.57
⅛" Solarban® 70XL(2) Starphire® + ½" Airspace + Laminate	63%	24%	12%	55%	0.28	0.26	1.59	1.48	0.39	0.27	2.33
⅛" Solarban® 70XL(2) Solexia® + ½" Airspace + Laminate	57%	21%	11%	20%	0.28	0.26	1.59	1.48	0.35	0.27	2.11
⅛" Solarban® 70XL(2) Solargray® + ½"Airspace + Laminate	42%	16%	8%	24%	0.28	0.26	1.59	1.48	0.26	0.22	1.91

Laminated Glass – Thermal and Optical Properties

HISTORY TABLE		
ITEM	DATE	DESCRIPTION
Original Publication	5/6/2003	TD-510
Revision 1	8/28/2015	Updated, Revised and Moved to TD-128 Original TD-128 (SG100) Discontinued
Revision 2	2016-10-04	Updated to Vitro Logo and format