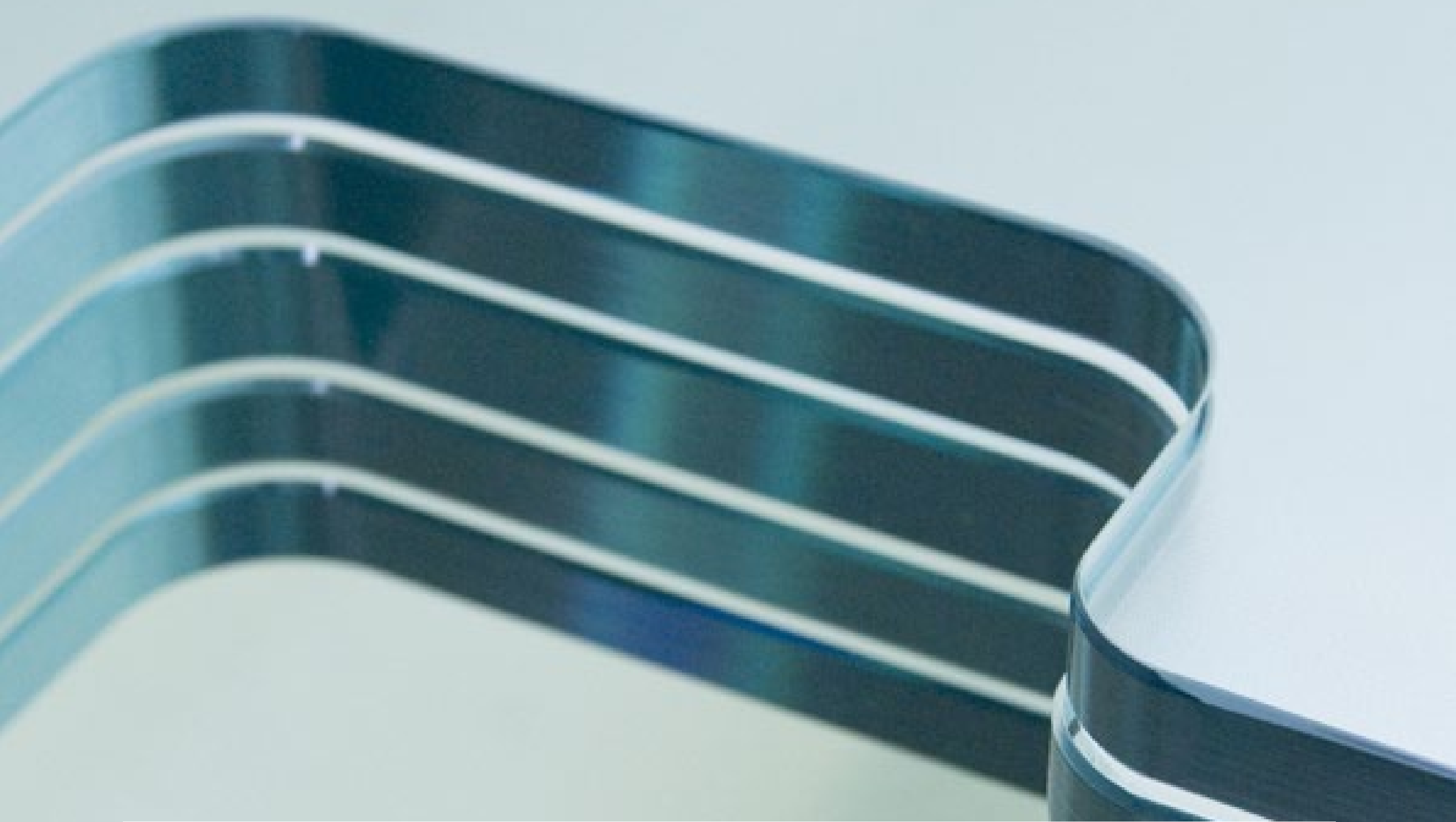

OPTICAL, VISUAL AND SOUND CONTROL PROPERTIES

Laminated architectural glass is being used increasingly to meet modern safety codes and to save energy through added daylighting and solar design.

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OPTICAL, VISUAL AND SOUND CONTROL PROPERTIES

INTRODUCTION

Laminated safety glass made with Kuraray interlayers can help reduce sound transmission through glass or let more natural light into the building.

Laminated architectural glass is being used increasingly to meet modern safety codes and to save energy through added daylighting and solar design. It also adds anti-intrusion security, sound reduction and protection from UV rays. Some applications require laminated glass with high UV-transmittance properties, allowing more natural light into the building.

Two common types of interlayer for laminated glass are films made from PVB and SentryGlas® ionoplast interlayers. The optical, visual clarity and acoustic performance of these interlayers are often critical design considerations for architects and structural designers.

VISUAL CLARITY

In terms of architectural glazing applications, choosing the right laminated safety glass can improve the visual clarity (visibility) and visual comfort of people occupying the building, primarily by protecting the human eye from glare due to sunlight.

HOW IS VISUAL CLARITY MEASURED?

The visual clarity (transparency) of laminated glass is normally measured by using the Yellowness Index (YID), which is a measure of the tendency of plastics to turn yellow upon long-term exposure to light. YID is a number calculated from spectrophotometric data that describes the change in color of a test sample from clear or white toward yellow. This yellowing / coloration process is described by the DeltaE value (see ASTM D1925 'Test Method for Yellowness Index of Plastics'). These tests are most commonly used to evaluate color changes in a material caused by real (or simulated) outdoor exposure.

DESIGNING WITH LOW-IRON GLASS

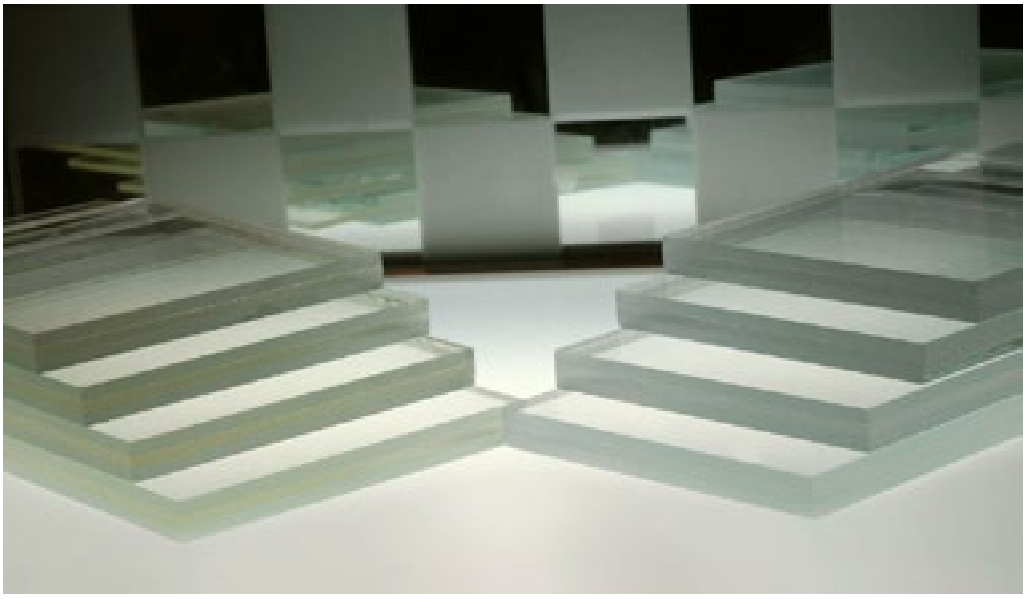
Visual clarity and optical quality are therefore important design considerations. Low-iron glass (i.e. glass with reduced iron content) provides improved visual clarity by increasing light transmission and reducing the greenish tint in clear glass that is most apparent when viewed from the edge. This green tint becomes more visible as the thickness of the glass increases.

Due to its high clarity, SentryGlas® ionoplast interlayers enable architects and structural designers to achieve their ultimate visions in low-iron safety glass. SentryGlas® interlayer eliminates the undesirable 'yellow' or 'greenish' tint that affects safety glass produced with conventional interlayers such as most PVB products, even at the outermost edge of weather-exposed laminates. This means that for the first time, designers can specify low-iron and safety glass, but still achieve the full clarity they require for the application, without sacrificing visibility, clarity or the overall beauty of their designs. This is particularly important in critical clarity applications such as skylights, doors, entranceways, display cases and retail storefronts.

SENTRYGLAS® IONOPLAST INTERLAYER VS PVB

Not only does SentryGlas® interlayer start clearer than other safety glass interlayers, it also remains clearer throughout its life. With a Yellowness Index (YID) that starts at 1.5 or less (compared to 6-12 YID for PVB alternatives), SentryGlas® interlayer keeps its initial clarity after years of service. This means extra transparency and a more predictable color in laminated glass, which is more consistent with the glass color selected for the project.

With a higher YID than SentryGlas® interlayer, PVB interlayers often cause a 'greenish' tint effect in the glass after years of service, whereas SentryGlas® ionoplast interlayer takes on a more favorable 'blue' tint over time. The clarity of SentryGlas® interlayer is permanent and the laminate will under normal conditions such as proper lamination not turn yellow. SentryGlas® is therefore ideally suited to a wide range of architectural safety glass applications, including overhead glazing, façades, balustrades, staircases, flooring, storefronts (retail outlets), and other typical low-iron glass applications.



SOLAR ENERGY CONTROL

Architectural design is enhanced with an abundance of natural light. Energy savings can often be achieved by considering the solar control properties of glass design. Sunlight can cause heat gain within a structure, which is sometimes undesirable in terms of the costs of energy and air conditioning. However, at other times, for example in colder climates, it may be appropriate to maximize the heat retention in order to reduce heating costs. For laminated safety glass, there are no obvious technical advantages in terms of solar energy control by specifying either PVB, monolithic or SentryGlas® ionoplast interlayers.

SOLAR CONTROL CHARACTERISTICS OF CLEAR GLASS LAMINATED WITH SENTRYGLAS® INTERLAYER

Nominal Laminate Thickness mm (in)	SentryGlas® mm (mil)	Glass Type	U-Value (W/m2K)	SHGC	SC	Tvis %
6 (1/4)	**1.52** (60) **2.28** (90)	clear clear	5.57 5.39	0.76 0.74	0.88 0.86	88 85
11 (7/16)	**1.52** (60) **2.28** (90)	clear clear	5.49 5.31	0.73 0.71	0.84 0.82	86 84
15 (9/16)	**1.52** (60) **2.28** (90)	clear clear	5.82 5.82	0.81 0.81	0.94 0.94	85 85
6 (1/4)	**1.52** (60) **2.28** (90)	low-iron low-iron	5.90 5.90	0.91 0.91	1.04 1.04	91 91
11 (7/16)	**1.52** (60) **2.28** (90)	low-iron low-iron	5.85 5.31	0.90 0.81	1.04 0.94	91 87
15 (9/16)	**1.52** (60) **2.28** (90)	low-iron low-iron	5.43 5.25	0.84 0.81	0.96 0.93	90 87

SOLAR CONTROL CHARACTERISTICS OF TINTED GLASS LAMINATED WITH SENTRYGLAS® INTERLAYER

Nominal Laminate Thickness mm (in)	SentryGlas® mm (mil)	Glass Type	U-Value (W/m2K)	SHGC	SC	Tvis %
6 (1/4)	**1.52** (60) **2.28** (90)	bronze bronze	5.57 5.39	0.58 0.57	0.67 0.66	49 47
6 (1/4)	**1.52** (60) **2.28** (90)	grey grey	5.57 5.39	0.53 0.52	0.62 0.61	40 38
11 (7/16)	**1.52** (60) **2.28** (90)	bronze bronze	5.49 5.31	0.51 0.50	0.59 0.59	37 36
11 (7/16)	**1.52** (60) **2.28** (90)	grey grey	5.49 5.31	0.46 0.46	0.54 0.53	28 27
15 (9/16)	**1.52** (60) **2.28** (90)	bronze bronze	5.43 5.25	0.47 0.47	0.55 0.55	31 30
15 (9/16)	**1.52** (60) **2.28** (90)	grey grey	5.43 5.25	0.43 0.43	0.50 0.50	22 21

The tables above show the solar control values for a limited number of laminated glass configurations. These values were calculated using the LBNL (Lawrence Berkeley National Laboratory) OPTICS and WINDOW software calculation programs. The table only provides a subset of the possible configurations that can be calculated using this software. Specific configurations can be calculated by downloading the WINDOW software or by requesting help from Kuraray.

WINDOW is a publicly available software program for calculating total window thermal performance indices (i.e. U-values, solar heat gain coefficients, shading coefficients, etc.). The software allows users to model complex glazing systems using different glass types and to analyze products made from any combination of glazing layers, frames, spacers and dividers under any environmental conditions and at any tilt angle. The program is also able to calculate performance indices for glazing systems, including color properties, U-values, visible transmittance; reflectance of the glazing system; and the center-of-glass temperature distribution. The tables above show laminated clear glass configurations with SentryGlas® interlayer and solar energy control characteristics for laminated glass configurations for different types of tinted glass (i.e. grey, blue, etc.).

DEFINITIONS

The U-Value is a measure of the rate at which heat is lost through a material.

The Solar Heat Gain Coefficient (SHGC) measures how well a product blocks heat caused by sunlight. The lower a window's SHGC, the less solar heat it transmits.

The Shading Coefficient (SC) is the ratio of total solar transmittance to the transmittance through 3 mm (1⁄8 in) clear glass.

The visible light transmittance (VLT or Tvis %) is the percentage of visible light that is transmitted through a material. The VLT is measured in the 380-780 nm wavelength range perpendicular to the surface. The higher the percentage, the more daylight. Also known as Tv, LT and VT.

Ultraviolet Elimination is the percentage of ultraviolet radiation eliminated by the glass, measured over the 290-380 nm wavelength range. The higher the percentage, the less UV is transmitted. This value is calculated from the percentage transmission of ultraviolet (TUV). Therefore UV Elimination = 100 - TUV.

HEAT AND LIGHT CONTROL CHARACTERISTICS – BUTACITE® PVB WITH CLEAR GLASS

Nominal Laminate Thickness (2 lites) mm (in)	Butacite® Interlayer	Designation	Visible Light Transmittance %	Solar Transmittance %	Shading Coefficient	Relative Laminate Instantaneous Heat Gain BTU/hr/ft²	Relative Laminate Instantaneous Heat Gain W/m²
6 (1/4)	Clear	Clear	89	73	0.92	198	625
	Blue Green	0377300	73	65	0.85	185	584
	Azure Blue	0637600	76	67	0.86	187	590
	Bronze Light	0645200	52	49	0.72	160	505
	Translucent White*	0216500	65	58	0.77	168	530
	Soft White*	0218000	80	68	0.87	188	594
	Gray*	0654400	44	50	0.73	160	505

*All specimens consisted of two plies of 3 mm (1⁄8 in) clear glass laminated with 0.38 mm (15 mil) Butacite® solid colored interlayer. Glass source may affect light transmission.

The data values in this table are based on samples tested and may differ for other glass sources.

HEAT AND LIGHT CONTROL CHARACTERISTICS – BUTACITE® PVB WITH TINTED GLASS

Nominal Laminate Thickness (2 lites) mm (in)	Clear Butacite® Interlayer Thickness mm (mil)	Glass Color	Visible Light Transmittance %	Solar Transmittance %	Shading Coefficient	Relative Laminate Instantaneous Heat Gain BTU/hr/ft²	W/m²
6 (1/4)	**0.38** (15)	Grey	60	54	0.75	165	521
	0.76 (30)	Grey	61	53	0.75	165	521
	1.52 (60)	Grey	60	52	0.74	163	514
6 (1/4)	**0.38** (15)	Bronze	64	54	0.76	151	505
	0.76 (30)	Bronze	64	53	0.75	149	527
	1.52 (60)	Bronze	64	53	0.74	147	521
10 (3/8)	**0.38** (15)	Grey	50	45	0.68	151	476
	0.76 (30)	Grey	50	44	0.67	149	470
	1.52 (60)	Grey	50	43	0.66	147	464
10 (3/8)	**0.38** (15)	Bronze	56	47	0.70	155	489
	0.76 (30)	Bronze	56	46	0.69	153	483
	1.52 (60)	Bronze	56	45	0.68	151	476

All specimens consisted of two glass plies laminated with clear Butacite®, one clear and one colored glass ply with interlayer thickness tabulated. Glass source, type, color and thickness affect light transmission. Laminates prepared with commercial grey and bronze tint float glass. For close color matching, examine sample of desired construction.

- Minimum and maximum thickness tolerances are defined by ASTM C 1172.
  Actual laminates measured were within 8 % of total nominal thickness.

- Nominal total visible light transmittance measured as CIE standard illuminate C. Actual values may vary.

- Shading Coefficients (SC) and summer U-values based on ASHRAE standard summer conditions where outdoor temperature is 32 °C (89 °F), indoor temperature is 24 °C (75 °F,) incident solar radiation is 248 BTU/hr/ft2, and outdoor wind velocity is 7.5 mph; calculated per guidelines in 1985 ASHRAE Fundamentals Handbook, Chapter 27.

- Relative total instantaneous heat gain is: SC*SHGF + U-value* (To-Ti) Based on a Solar Heat Gain Factor (SHGF) of 200 BTU/hr/ft2 and an outdoor temperature -10 °C (14 °F) higher than indoor (To-Ti).

UV-TRANSMITTANCE

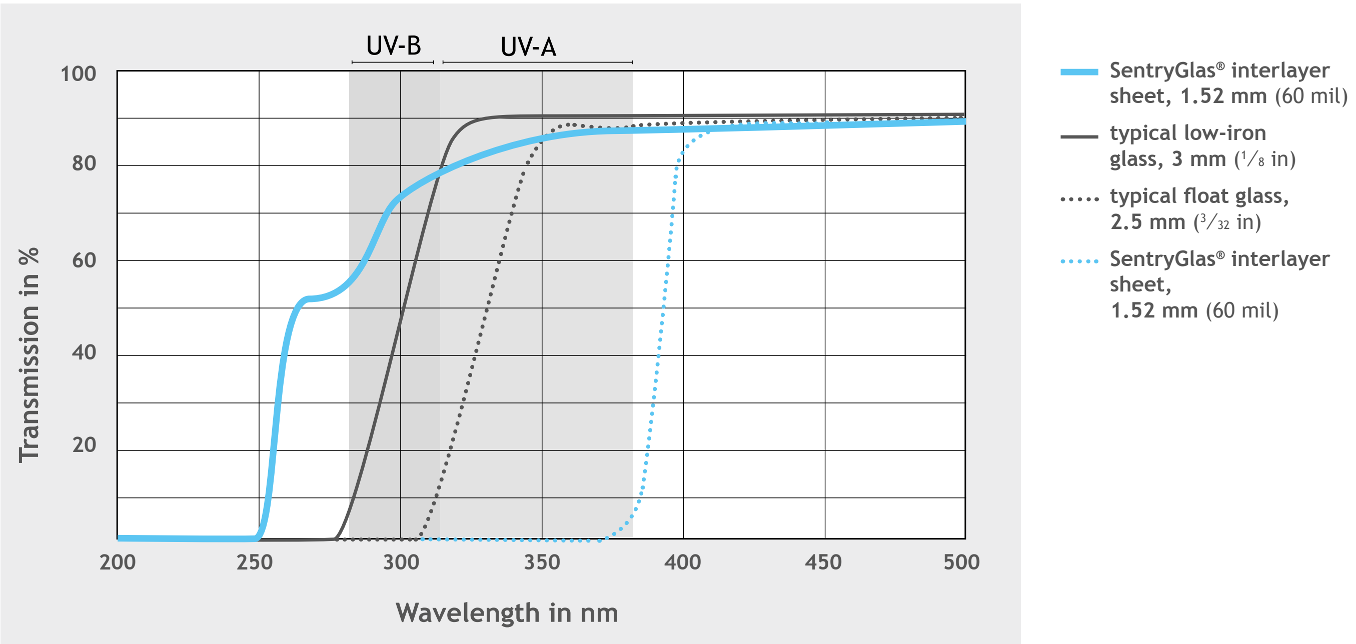
Some buildings require glass with high UV-transmittance properties, others with low transmittance. For example, when designing controlled environments for animals or plants, extra caution must be taken to supply unfiltered, broad-spectrum light, as close as possible to the species' normal habitat and environmental conditions. Full spectrum light includes ultraviolet (UV) rays in wavelengths that are too short for the human eye to detect. Wavelengths of light in the UV-A and UV-B ranges, for example, are of particular interest to the health and survival of many natural species.

Other laminated glass applications may require lower transmittance properties. For example, a UV blocker may be used in the glass to minimize the amount of natural UV light through a retail storefront, in order to protect the textiles on display from being damaged.

SentryGlas® N-UV is a structural interlayer for safety glass that combines the strength, safety and edge stability of SentryGlas® interlayer with increased transmittance of natural ultraviolet (UV) light. Unlike most safety glass interlayer technologies, SentryGlas® ionoplast requires no UV protection for lasting strength and clarity. SentryGlas® interlayer can be manufactured in a special, high UV-transmittance sheet, which is suitable for use in botanical gardens or other special environments where exotic plants, fish, reptiles and insects demand unique UV light requirements.

Using SentryGlas® interlayer N-UV with float glass or low-iron float glass can dramatically increase the UV-transmittance through the resulting laminated glass panels. The UV-transmittance level of a glass laminate is highly dependent on the transmittance level of the chosen glass at the required thickness for a given structure. Generally, by specifying SentryGlas® N-UV over other types of laminated glass, the level of UV light transmittance is inherently higher due to the reduced glass thickness required.

UV LIGHT TRANSMITTANCE CURVES



High levels of UV-A and UV-B light pass through a SentryGlas® N-UV interlayer. However, other glazing materials, including monolithic glass, block out much of the UV-A and UV-B energy.

ACOUSTIC / SOUND PERFORMANCE

In architectural applications, improving the acoustic / sound insulation properties of the building and any glass structures is increasingly important. People in a building may need to be insulated from noisy traffic, aircraft from a nearby airport or simply from the noise generated by pedestrians walking by.

HOW IS IT MEASURED?

One test standard used for acoustical performance measurement is ASTM E90 'Laboratory Measurement of Airborne Sound Transmission of Building Partitions'. There are several ratings derived by testing according to this standard. Acoustical test results are presented below for both monolithic and insulating glass (IG) units made from Kuraray interlayers.

COMPARISON OF INTERLAYERS

In terms of architectural glass, there are many different methods of improving the acoustic properties of a building, including the use of double skin façades or double / triple insulated glazing units (IGU). Sometimes, a specific acoustic PVB may be specified, although in reality, when it comes to sound attenuation in closed glazing applications, there is very little difference between the various types of interlayers.

Butacite® PVB and SentryGlas® interlayers are used in many monolithic and insulated glass (IG) architectural applications where sound attenuation is desirable. One test standard used for acoustical performance measurement is ASTM E90 'Laboratory Measurement of Airborne Sound Transmission of Building Partitions'. There are several ratings derived by testing according to this standard. Acoustical test results are presented in the table below for monolithic and insulating glass (IG) units made with Kuraray interlayer.

SOUND TRANSMISSION LOSS (TL) MEASUREMENTS: SENTRYGLAS® AND BUTACITE® PVB LAMINATED GLASS INTERLAYERS

Nominal Thickness mm (in)	Glass Make up mm (in)	Kuraray Interlayer mm (mil)	STC[a]	OITC[b]	Frequency (Hertz) 80	100	125	160
14.29 (9/16) **lam**	2 lites **6.35** (1/4)	**1.52** (60) **Butacite® PVB**	37	34	25	25	30	29
14.29 (9/16) **lam**	2 lites **6.35** (1/4)	**1.52** (60) **SentryGlas®**	35	32	25	24	30	30
14.29 (9/16) **lam**	2 lites **6.35** (1/4)	**0.89** (35) **SentryGlas®**	35	33	25	25	31	29
30.23 (3/16) **IG**	**6.35** (1/4) | **12.7** (1/2) air | **11.11** (7/16) **lam**	**1.52** (60) **Butacite® PVB**	40	33	25	24	24	30
30.23 (3/16) **IG**	**6.35** (1/4) | **12.7** (1/2) air | **11.11** (7/16) **lam**	**1.52** (60) **SentryGlas®**	38	32	25	24	23	28
30.23 (3/16) **IG**	**6.35** (1/4) | **12.7** (1/2) air | **9.52** (3/8) **lam**	**0.89** **(35) SentryGlas®**	38	32	24	24	26	28
33.27 (5/16) **IG**	**6.35** (1/4) | **12.7** (1/2) air | **14.29** (9/16) **lam**	**1.52** (60) **Butacite® PVB**	41	33	25	25	26	30
33.27 (5/16) **IG**	**6.35** (1/4) | **12.7** (1/2) air | **14.29** (9/16) **lam**	**1.52** (60) **SentryGlas®**	39	33	25	25	25	29
33.27 (5/16) **IG**	**6.35** (1/4) | **12.7** (1/2) air | **12.7** (1/2) **lam**	**0.89** (35) **SentryGlas®**	39	33	25	27	24	30

ATI Test Report 86743.01 completed 2008 at Architectural Testing, Inc. (ATI).

[a] **Sound Transmission Class (STC)** assesses privacy for interior walls. It is achieved by applying the Transmission Loss (TL) values from 125 Hz to 4000 Hz to the STC reference contour found in ASTM E413. STC is the shifted reference contour at 500 Hz.

[b] **Outside Inside Transmission Class (OITC)** assesses exterior partitions exposed to outside noise. It covers the 80 Hz to 4000 Hz range. The source noise spectrum is weighted more to low frequency sounds, such as aircraft, train, and truck traffic. The OITC rating is calculated in accordance with ASTM E1332.

Frequency (Hertz)														
200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
30	30	31	33	35	36	37	37	35	36	39	43	46	49	52
29	30	31	34	33	35	34	33	31	34	37	41	44	46	48
30	29	32	33	34	36	35	33	31	35	38	42	45	46	49
25	27	32	35	38	40	42	44	45	44	43	43	49	52	58
26	26	32	35	37	38	39	39	40	40	40	40	44	48	53
25	26	31	34	37	39	40	40	40	40	40	40	45	47	53
27	28	33	35	38	39	41	43	44	44	44	44	49	52	57
27	28	33	34	35	37	39	41	41	42	43	42	46	48	54
27	28	33	35	36	38	39	41	41	43	43	43	48	50	56

STC and OITC values can be affected by glass thickness, interlayer thickness, air space and framing. An in-depth acoustical analysis may be required to understand project-specific factors.

Kuraray Interlayer Solutions:

OPTICAL, VISUAL AND SOUND CONTROL PROPERTIES

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