laminated glass

Sell Sheet

Safety and
Burglary-Resistant Glass

Sloped and Overhead
Glazing, Skylights
and Point-Supported
Canopies

Sound Control

Light and Solar Control

ArmorProtect®

ArmorResist®

Hurricane
Impact-Resistant Glass

Blast-Resistant Glass

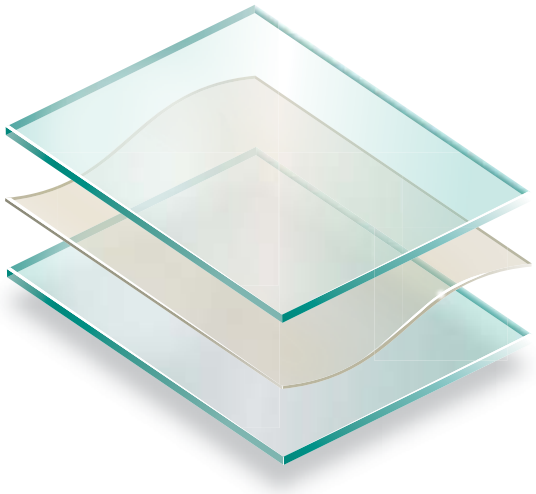
Decorative
Laminated Glass

Installation Guidelines

Rhythm City Skybridge
Davenport, Iowa
Architects: Holabird & Root and
Neumann Monson, P.C.

laminated glass

Oldcastle BuildingEnvelope™ *Engineering your creativity*™



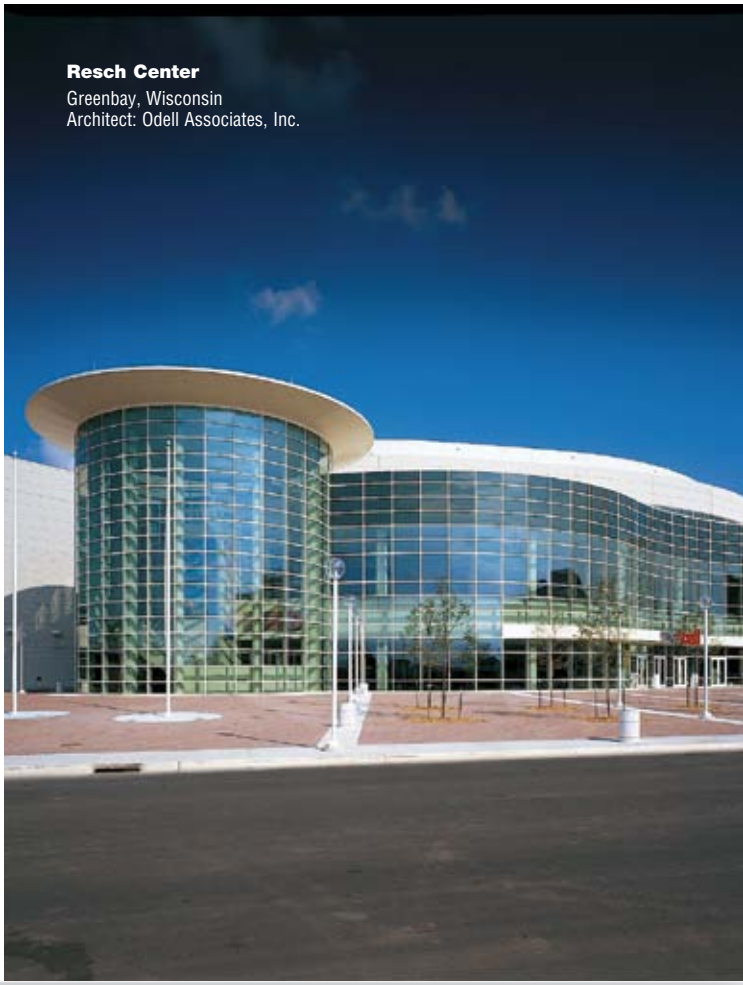
Laminated Glass is a multifunctional glazing material that can be used in a variety of applications.

It is manufactured by permanently bonding two or more lites of glass with layers of polyvinyl butyral (PVB) interlayer, under heat and pressure, to create a single construction.

Laminated Glass Applications

Laminated Glass is used in a wide range of applications including:

- Sloped/Overhead Glazing
- Museums
- Prisons
- Government Buildings
- Jewelry Stores
- Banks
- Airports
- Schools
- Hospitals
- Hotels
- Interior Partitions
- Office Buildings
- Residential Buildings



Resch Center
Greenbay, Wisconsin
Architect: Odell Associates, Inc.

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Safety and Burglary-Resistant Glass

Introduction

Laminated safety glass is a multifunctional glazing material that can be used in applications ranging from residential to commercial installations. All model building codes require that the glass used in certain locations, such as doors, sidelites, overhead glazing, patio doors, tub and shower enclosures and certain other glazed openings, must be safety glass that meets the requirements of the Consumer Products Safety Commission (CPSC) 16 CFR 1201 *Safety Standard for Architectural Glazing Materials*. Oldcastle BuildingEnvelope™ laminated glass meets these requirements.

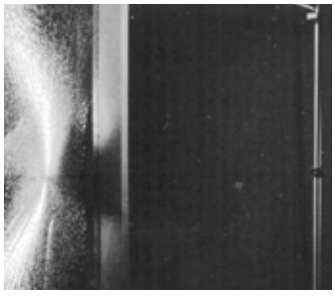
When impacted, laminated glass breaks safely and remains an integral part of the opening. The plastic interlayer minimizes splinters and glass fragments, reducing the risk of injury or property damage. In addition, the external envelope of the building is maintained, and therefore boarding up may not be necessary. This is particularly important during natural disasters such as hurricanes, tornadoes and earthquakes, and it is subsequently widely specified for these types of applications. Impulse burglaries can also be resisted by laminated glass because it is difficult to gain access or remove property, even if a puncture is made in the interlayer.

Description

Laminated safety glass is manufactured by permanently bonding two or more lites of clear, tinted, Low-E, patterned, or reflective glass with one more or more layers of polyvinyl butyral (PVB) or ionomer sheets. Assembly takes place in the carefully controlled environment of a clean room, ensuring no contaminants are trapped in the product. Final bonding is achieved in an autoclave under heat and pressure, which creates a single solid construction. The glass can be annealed, heat-strengthened or fully tempered, and the lites can be of equal or unequal thickness. Laminated safety glass can be used as the inboard, outboard or both lites in an insulating glass unit.

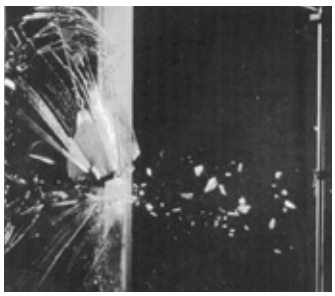
By combining tinted glass, reflective coatings, printed ceramic silk-screened patterns and pigmented interlayers, a wide array of laminated glass configurations can be used to meet specific visual, aesthetic, security, performance and code requirements.

Breakage Behavior of Glazing Materials:



Laminated Glass

Meets safety glazing standards because on impact, when the glass breaks, the broken pieces typically remain adhered to the PVB or ionomer interlayer.



Annealed Glass

Easily fractures; breakage typically produces long razor-sharp shards; is not a safety glazing material.

Safety and Burglary-Resistant Glass

Description (continued)

Glass Designation		Construction (Glass-PVB-Glass)		Weight		Test Standards	
Traditional inches	Metric mm	Traditional inches	Metric mm	Traditional LBS/FT²	Metric kg/m²	Safety Category(1)	UL972 Burglary
1/4	5.8	Laminated - 0.015 - Laminated	2.7 - 0.38 - 2.7	2.93	14.30	I	-
1/4	6.1	Laminated - 0.030 - Laminated	2.7 - 0.76 - 2.7	3.01	14.69	II	-
1/4	6.4	1/8 - 0.015 - 1/8	3 - 0.38 - 3	3.33	16.26	I	-
1/4	6.8	1/8 - 0.030 - 1/8	3 - 0.76 - 3	3.42	16.70	II	-
5/16	7.5	1/8 - 0.060 - 1/8	3 - 1.52 - 3	3.58	17.48	II	yes
5/16	8.2	1/8 - 0.090 - 1/8	3 - 2.28 - 3	3.75	18.31	II	yes
3/8	10.8	3/16 - 0.030 - 3/16	5 - 0.76 - 5	5.05	24.65	II	-
7/16	11.5	3/16 - 0.060 - 3/16	5 - 1.52 - 5	5.21	25.44	II	yes
7/16	12.2	3/16 - 0.090 - 3/16	5 - 2.28 - 5	5.38	26.27	II	yes
1/2	12.8	1/4 - 0.030 - 1/4	6 - 0.76 - 6	6.67	32.56	II	-
9/16	13.5	1/4 - 0.060 - 1/4	6 - 1.52 - 6	6.83	33.34	II	yes
9/16	14.2	1/4 - 0.090 - 1/4	6 - 2.28 - 6	7.00	34.17	II	yes
13/16	21.5	3/8 - 0.060 - 3/8	10 - 1.52 - 10	10.09	49.26	II	yes
13/16	22.2	3/8 - 0.090 - 3/8	10 - 2.28 - 10	10.26	50.09	II	yes

This table shows data for symmetrical lay-ups. Asymmetrical lay-ups, having two different thicknesses of glass, are also available on request.
(1) Applies to CPSC 16 CFR 1201 and CAN/CGSB-12.1. All laminated safety glass also meets ANSI Z97.1.

Performance

Safety

Laminated safety glass is tested using a taped, leather bag filled with lead shot weighing 100 LBS. A standard size piece of glass is clamped vertically in a frame. The impactor is supported from a wire cable so that it will impact the glass in the center. The ball is lifted to the required height and allowed to swing freely into the glass. Numerous cracks and fissures may occur but no shearing or opening through which a 3-inch diameter sphere may pass freely. All laminated glass with a minimum of 0.015" (0.38 mm) PVB meets the requirements of safety glass as defined by ANSI Z97.1, CPSC 16 CFR 1201, Category I (9 square feet or less) and CAN/CGSB-12.1, Category I. Laminated glass with a PVB or ionomer thickness of 0.030" (0.76 mm) and greater also meets the requirements of CPSC 16 CFR 1201, Category II (over 9 square feet) and CAN/CGSB-12.1, Category II.

Burglary

Thicker PVB and ionomer laminates will also meet the requirements of Underwriters Laboratories, UL 972 *Burglary Resisting Glazing Material*. This standard uses a 5 LB. steel ball dropped on the glass from various heights to simulate a typical “smash and grab” attack.

Structural Strength

Laminated glass strength and deflection are discussed in detail in ASTM E1300 *Standard Practice for Determining the Load Resistance of Glass in Buildings.* The model building codes contain requirements for wind, snow and dead loads on glass. The applicable state laws and local building codes must be checked to determine minimum glass strength requirements governing each project.

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Safety and Burglary-Resistant Glass

Performance (continued)

Safety Standard	Category/ Class	Weight of Impactor LBS	Height of drop inches	Energy FT-LBS	Required thickness of PVB, inches
CPSC 16 CFR 1201	I	100	18	150	0.015
CPSC 16 CFR 1201	II	100	48	400	0.030
ANSI Z97.1	A	100	48	400	0.030
ANSI Z97.1	B	100	18	150	0.015
ANSI Z97.1	C	100	12	100	0.015
CAN/CGSB-12.1	I	100	18	150	0.015
CAN/CGSB-12.1	II	100	48	400	0.030

Butt Joint Glazing Systems

Laminated glass supplied by Oldcastle BuildingEnvelope™ can be used for butt joint glazing systems—i.e., systems where the glass is captured in a frame on two edges, and the other two edges butt up against each other with a small space, without use of a frame. Any silicone sealant used at this butt joint can, under certain circumstances, cause a discoloration of the edge of the PVB laminate over time. The extent of this depends on the actual sealant, but it generally does not exceed 1/4". Where possible, especially in internal applications, it is advisable not to use any sealant on the gaps between the glass. If a sealant is used, please check for compatibility with the manufacturer of the sealant. The use of a black sealant often produces a better visual effect. Lonomer laminates will typically perform better in these applications as they are generally stiffer and have improved edge stability (resistance to moisture and chemical attack).

Inspection and Quality

The tolerance and quality standards for these products are detailed in ASTM C1172 *Standard Specification for Laminated Architectural Flat Glass*—reference to which should be made in any specification.

ASTM C1172 Length and Width Tolerance for Rectangular Shapes of Symmetrically Laminated Glass

Laminate Thickness Designation, t inches (mm)	Transparent Glass inches (mm)	Patterned and wired glass inches (mm)	Heat-Strengthened and Tempered Glass inches (mm)
t ≤ **1/4** (6.4)	+**5/32** (4.0) -**1/16** (1.6)	+**5/16** (7.9) -**1/8** (3.2)	+**7/32** (5.6) -**3/32** (2.4)
1/4 (6.4) < t ≤ **1/2** (12.7)	+**1/4** (6.4) -**1/16** (1.6)	+**5/16** (7.9) -**1/8** (3.2)	+**1/4** (6.4) -**1/8** (3.2)
1/2 (12.7) < t ≤ **1** (25.4)	+**1/4** (6.4) -**1/8** (3.2)	+**5/16** (7.9) -**1/8** (3.2)	+**5/16** (7.9) -**1/8** (3.2)

Note: The length and width is measured from edge to edge and includes any flares, mismatch or offset.

Safety and Burglary-Resistant Glass

Performance (continued)

ASTM C1172–Maximum Allowable Laminating Process Blemishes: inches (mm)

	Up to 25 FT² (2.5 m²)		25-75 FT² (2.5-7.0 m²)		Over 75 FT² (7.0 m²)	
Blemish	**Central[A]**	**Outer[A]**	**Central[A]**	**Outer[A]**	**Central[A]**	**Outer[A]**
Boil (bubbles)	**1/16** (1.6)	**3/32** (2.4)	**1/8** (3.2)	**3/16** (4.8)	**1/4** (6.4)	**1/4** (6.4)
Blow-in; edge boil	B	CE **1/4** (6.4) EE **1/32** (0.8)	B	CE **1/4** (6.4) EE **1/16** (1.6)	B	CE **5/16** (8.0) EE **3/32** (2.4)
Fuse	**1/32** (0.8)	**1/16** (1.6)	**1/16** (1.6)	**3/32** (2.4)	**3/32** (2.4)	**5/32** (4.0)
Hair, lint (single strand)	light intensity	medium intensity	light intensity	medium intensity	medium intensity	medium intensity
Inside dirt (dirt spot)	**1/16** (1.6)	**3/32** (2.4)	**3/32** (2.4)	**5/32** (4.0)	**1/8** (3.2)	**3/16** (4.8)
Lint-areas of concentrated lint	light intensity	light intensity	light intensity	light intensity	light intensity	light intensity
Separation, discoloration	none	none	none	none	none	none
Short Interlayer; unlaminated area chip	B	CE **1/4** (6.4) EE **1/16** (1.6)	B	CE **1/4** (6.4) EE **3/32** (2.4)	B	CE **1/4** (6.4) EE **1/4** (6.4)
Interlayer scuff; streak	light intensity	light intensity	light intensity	light intensity	light intensity	light intensity

A–The central area is an area, formed by an oval or circle, whose axis, when centered, does not exceed 80% of the overall dimension. The outer area is the area outside the central area. **B**–not applicable; **CE**–covered edge of glass edge bite; **EE**–exposed edge (if CE or EE is unknown, use CE tolerance.
Light Intensity–barely noticeable at 36 inches (914.4 mm); **medium intensity**–noticeable at 36 inches (914.4 mm) but not at 11 feet (3352.8 mm).

All imperfections noted should be separated by a minimum of 12 inches (305 mm).

Special Applications

Oldcastle BuildingEnvelope™ regularly supplies laminated glass for special applications such as swimming pools and aquariums, zoo enclosures, glass floors and stairs, balustrades and handrails. These applications all have structural loading conditions very different from those for conventional architectural glass and therefore require careful consideration. To date, there are no national consensus standards for these applications.

Typically, the loading is of a longer-term duration than for wind load. The key issue related to the selection of the appropriate glass types and thicknesses for these applications is limiting the maximum stress in the glass in order to keep the probability of breakage to a very low level. Often, failure of this type of glass constitutes a life safety issue. Where total failure of the glazing is unacceptable, multiple lite laminated glass should be used and designed so that a breakage of one lite will not result in total failure. The remaining lites must be designed to provide reasonable assurance that they will withstand the load for a limited period of time until the unit can be replaced.

Determining the risk of failure and deciding on the appropriate design of the glazing are the responsibility of the design professional, so reference should always be made to an engineer with experience in these types of glass design.

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Safety and Burglary-Resistant Glass

Additional Important Information

Specifications

A sample Section 08 81 00 Specification for North America can be found in Section 11M of this binder titled: Sample Architectural Glass Specifications.

For specifications on other laminated glass make-ups, call 1-866-OLDCASTLE (653-2278) or log on to www.oldcastlebe.com and click on "Project Assistance" and enter your request.

Contact Us

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Sloped and Overhead Glazing, Skylights and Point-Supported Canopies

Introduction

Glass which slopes more than 15° from the vertical is considered sloped glazing by the major model building codes. Laminated glass is the preferred product for sloped and overhead glazing, because the glass is retained in the opening, even when broken, reducing the possibility of injury from falling glass. Costly and unsightly screens are therefore not required. Laminated products are widely used in malls and in atriums in hotels and offices.

Description

Laminated glass for use in sloped and overhead glazing can be used monolithically or fabricated into insulating glass units. Insulating glass units typically consist of an outboard lite of heat-strengthened glass that resists accidental damage caused by falling objects and an inboard laminated glass that captures any fragments. Tempered glass is not normally recommended for the outboard lite as small broken particles can easily slide down the outside of the roof and onto the ground in the event of accidental damage. Tempered glass is also not desirable for the laminated lite because of the “wet blanket” effect. Pointed supported applications are the exception and must be fully tempered.

This type of laminated glass often incorporates heat-strengthened or tempered glass to meet the structural performance requirement, so that heavy snow loads and high wind loads can be accommodated. In addition, when tinted, Low-E, or reflective glass is used to control the solar heat gain, it is usually necessary to use heat-strengthened glass to avoid the possibility of thermal breakage. When heat-strengthened or tempered glass is used in a laminated glass, the recommended minimum interlayer thickness is generally 0.060" (1.52 mm).

Capabilities

Oldcastle BuildingEnvelope™ can calculate the most suitable glass for use in any given application. However, it is the responsibility of the design professional to calculate and provide the equivalent design load. This calculation must take into account the correct combination of snow load (if applicable), wind load, anticipated human live load, and dead load. Without the equivalent design load Oldcastle BuildingEnvelope™ must rely on the conservative limits recommended by the American Architectural Manufacturers Association (AAMA) for four-side uniform support.

Sloped and Overhead Glazing, Skylights and Point-Supported Canopies

Capabilities (continued)

AAMA Guidelines for Overhead Glazing

Designation in inches	Glass Type	Outboard Lite in inches	Air Space in inches	Inboard Construction Glass-PVB-Glass in inches	Maximum Size SQ FT	Weight LBS/FT²
1/4	Annealed	–	–	1/8 - 0.030 - 1/8	12	3.42
3/8	Annealed	–	–	3/16 - 0.030 - 3/16	18	5.05
1/2	Annealed	–	–	1/4 - 0.030 - 1/4	24	6.67
5/16	Heat-strengthened	–	–	1/8 - 0.060 - 1/8	25	3.58
7/16	Heat-strengthened	–	–	3/16 - 0.060 - 3/16	40	5.21
9/16(1)	Heat-strengthened	–	–	1/4 - 0.060 - 1/4	40	6.83
13/16(1)	Heat-strengthened	–	–	3/8 – 0.060 – 3/8	40	10.09
1 1/16(1)	Heat-strengthened	–	–	1/2 – 0.060 – 1/2	40	13.33
7/8	Annealed	1/8	1/2	1/8 - 0.030 - 1/8	12	5.05
1 1/16	Annealed	3/16	1/2	3/16 - 0.030 - 3/16	18	6.67
1 1/4	Annealed	1/4	1/2	1/4 - 0.030 - 1/4	24	8.29
7/8	Heat-strengthened	1/8	1/2	1/8 - 0.060 - 1/8	25	5.21
1 1/8	Heat-strengthened	3/16	1/2	3/16 - 0.060 - 3/16	40	6.83
1 5/16	Heat-strengthened	1/4	1/2	1/4 - 0.060 - 1/4	40	8.45

These are conservative designs assuming the glass is horizontal with maximum snow load.
Detailed engineering design particularly on sloped glazing can often increase the maximum allowable size.
(1) These products are recommended for point-supported canopies.

Point-Supported Canopies

Point-supported canopies are commonly used as features at entrances to offices, stores and residential properties. They are defined as overhead glazing where the glass is supported by fasteners that pass through holes in the glass and that cannot be offered in annealed glass due to high stresses. The support structure can be either above or below the glass. This type of design is specifically excluded from ASTM E1300 *Standard Practice for Determining the Load Resistance of Glass in Buildings* and needs careful, specific engineering design.

Oldcastle BuildingEnvelope™ regularly supplies this type of glass but insists that a thorough engineering design should be completed. Oldcastle BuildingEnvelope™ offers the following design guidelines for point-supported glass:

1. The glass in these applications is typically designed as a non-enclosed structure as the wind load acts both as an uplift on the upper surface and a pressure on the lower surface. Adding this wind load to the snow load and dead load can result in very large loads.

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Sloped and Overhead Glazing, Skylights and Point-Supported Canopies

Capabilities (continued)

2. The maximum stress on point-supported canopies may not be at the point of maximum bending moment. The holes and fasteners often create large local stresses that must be accounted for. Fasteners must therefore have a flexible capability so that local loads do not develop as a result of deflections.

3. Deflection is often the limiting design criterion on these types of applications. If one is designing for strength, a safety factor of 5 should be used.

4. It is extremely important that the holes are sized to give adequate clearance from fasteners. It is common in laminated glass to experience a small amount of slippage between the two lites, and therefore extra clearance is often used to avoid any problems.

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Sound Control

Introduction

Shielding a building's environment from increasing noise levels, especially near airports and busy highways, is a critical factor in the specification of glazing materials for both new and renovated structures. Laminated glass is a proven, effective solution for acoustical protection.

Description

Sound Pressure is measured in decibels (dB) and has a logarithmic scale. A difference of 10dB indicates a difference of 10 times the sound pressure level. A difference of 20dB indicates a 100 times difference in sound pressure level. As a rule of thumb, the sound pressure level drops by about 6dB every time the distance is doubled. The sound transmission class (STC) is the common measure by which acoustical performance is rated. It is a weighted average over the frequency range 100 to 5,000 Hz of the STL (Sound Transmission Loss). The higher the STC rating, the more able the material is to resist the transmission of sound. The ASTM E90 *Standard Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements* describes a standard test method for measuring the Sound Transmission Loss for building components. The ASTM E413 *Standard Classification for Rating Sound Insulation* describes the method by which the STC is calculated.

In addition to STC, there are several other methods of determining a weighted average. The ASTM E1332 *Standard Classification for Determination of Outdoor-Indoor Transmission Class* (OITC) is used for external building components. In Europe the ISO 140-3 *Acoustics Measurement of Sound Insulation in Buildings and of Building Elements* defines a weighted average, Rw. Each of these classifications gives slightly different classification numbers. It is important that an acoustic consultant be retained to determine the exact requirements.

Sound sources vary in the range of wavelengths. Airports, for example, generate noise in both the low and high-frequency range, whereas other sources of unwanted noise may generate noise only in one frequency range. In these cases, using the single-number STC, OITC or RW rating may not be adequate. The acoustics engineer in these cases will need to know the attenuation at each 1/3 octave band frequency, as shown in the following tables.

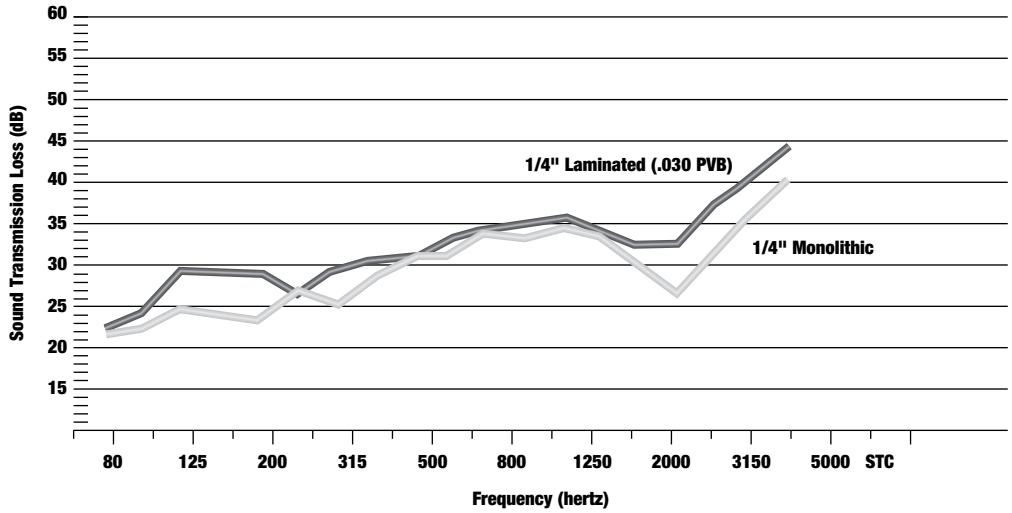
The greatest sound transmittance occurs at different wavelengths for each different thickness of glass, because each has a different mass. Combining different thicknesses of glass, either in an IG unit or a laminated glass makeup, can significantly improve performance. The shear damping characteristics of PVB that are used in laminated glass further reduce the sound transmission. Laminated glass can reduce the perceived noise level by nearly 50% at certain frequencies.

It is very important that suitable windows or frames be used. They must be well made and have a mass capable of dampening sound transmission. Operable windows must have good seals; otherwise, the window will "leak" sound. All joints must be sealed, and the space between the opening and the window must also be filled with a suitable sealant during installation.

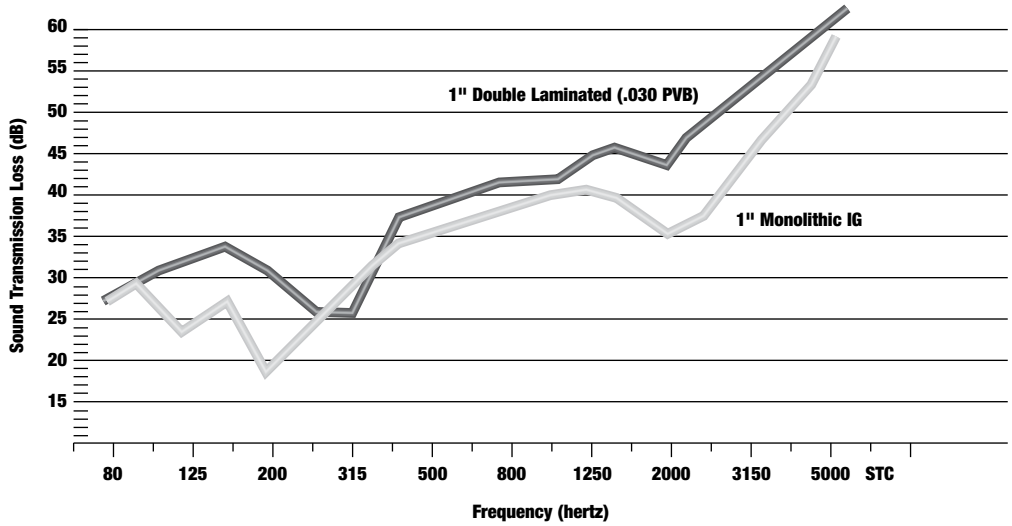
Sound Control

Description (continued)

Typical Improvement in Sound Attenuation when using Laminated Glass[1]



SINGLE LITE DESIGN



INSULATING GLASS UNITS

(1) Sound Transmission Loss Measurement performed at Riverbank Acoustical Laboratories.

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Sound Control

Capabilities

Laminated Glass: Sound Transmission Loss Data[1]

1/3 Octaveband (HZ)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	STC	OITC	Rw
1/4" RAL-TL85-169	23	25	25	24	28	26	29	31	33	34	34	35	34	30	27	32	37	41	31	29	32
1/2" RAL-TL85-198	26	30	26	30	33	33	34	36	37	35	32	32	36	40	43	46	50	51	36	33	37
Lam-0.030"-Lam RAL-TL85-218	24	26	27	27	28	29	30	32	34	35	36	36	36	35	35	39	43	46	35	31	35
1/8"-0.030"-1/8" RAL-TL85-170	25	26	28	27	29	29	30	32	34	35	35	36	36	35	35	38	43	46	35	31	35
1/8"-0.060"-1/8" RAL-TL85-224	25	26	27	28	28	29	30	33	34	35	36	37	37	37	36	38	42	46	35	32	35
1/8"-0.045"-1/8" RAL-TL85-234	24	27	27	28	28	29	30	32	34	35	36	36	37	36	35	38	43	46	35	31	35
3/16"-0.030"-3/16" RAL-TL85-200	27	27	27	30	31	31	33	34	35	36	36	35	34	37	41	45	49	52	36	33	36
1/4"-0.030"-1/8" RAL-TL85-229	27	27	28	31	30	31	32	34	35	36	36	36	35	36	40	44	48	52	36	33	36
1/4"-0.060"-1/8" RAL-TL85-223	27	28	27	30	31	31	33	35	36	37	37	37	36	37	41	44	48	51	37	33	37
1/4"-0.030"-1/4" RAL-TL85-225	25	29	28	30	33	33	34	36	37	37	37	36	37	41	45	48	51	53	38	34	38
1/4"-0.045"-1/4" RAL-TL85-232	26	30	27	30	33	33	34	36	37	38	37	36	37	41	45	48	51	54	38	34	38
1/4"-0.060"-1/4" RAL-TL85-228	26	29	28	30	33	33	35	36	37	38	38	37	38	41	44	47	51	54	39	34	39
3/8"-0.030"-1/4" RAL-TL85-222	29	30	28	32	34	35	36	38	38	38	36	38	42	46	49	52	55	57	40	36	40
1/2"-0.060"-1/4" RAL-TL85-230	29	30	29	32	35	35	37	38	38	38	37	41	44	48	50	53	56	56	41	36	41

Insulating Glass: Sound Transmission Loss Data[1]

1/3 Octave band (HZ)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	STC	OITC	Rw
1/8"-1/4"AS[2]-1/8" (SEALED) RAL-TL85-212	26	21	23	23	26	21	19	24	27	30	33	36	40	44	46	39	34	45	28	26	30
1/8"-3/8"AS-1/8" (SEALED) RAL-TL85-213	26	23	23	20	23	19	23	27	29	32	35	39	44	47	48	41	36	43	31	26	32
1/4"-1/2"AS-1/4" (SEALED) RAL-TL85-294	29	22	26	18	25	25	31	32	34	36	39	40	39	35	36	46	52	58	35	28	35
3/16"-1"AS-3/16" (SEALED) RAL-TL85-215	20	25	18	17	26	28	33	36	38	39	41	44	46	43	38	40	48	51	35	27	37
1/4"-1"AS-1/4" (UNSEALED) RAL-TL85-293	22	19	27	23	31	30	35	35	36	39	41	42	41	36	37	46	51	56	37	30	37
3/16"-4"AS-3/16" (UNSEALED) RAL-TL85-216	24	28	30	33	30	38	38	44	46	50	50	50	51	49	41	42	50	52	44	35	44

(1) The data here is based on samples tested at Riverbank Acoustical Laboratories in accordance with ASTM E90-97, ASTM E413-87 and ASTM E1332-90 and are not guaranteed for all samples or applications.

(2) Airspace

See important note on page 14.

Sound Control

Capabilities (continued)

Laminated Insulating Glass: Sound Transmission Loss Data[1]

1/3 Octaveband (HZ)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	STC	OITC	Rw
1/4" Lam-1/4" AS[2]-1/8" (SEALED) RAL-TL95-296	32	31	30	28	27	24	26	28	31	34	37	39	41	43	49	52	51	57	35	31	35
1/4" Lam-3/8" AS-3/16" (SEALED) RAL-TL85-189	27	27	26	24	22	28	32	35	38	38	39	40	42	43	41	45	52	57	37	31	37
1/4" Lam-1/2" AS-3/16" (SEALED) RAL-TL85-238	26	23	25	23	27	31	34	36	38	39	41	43	45	46	43	49	55	55	39	31	39
1/4" Lam-1/2" AS-1/4" (SEALED) RAL-TL85-235	28	20	29	24	26	30	34	36	39	42	43	44	44	41	40	47	52	56	39	31	39
3/8" Lam-1/2" AS-1/4" (SEALED) RAL-TL85-192	28	17	28	29	33	34	38	40	40	41	41	41	41	40	43	49	54	58	40	31	40
1/4" Lam-1" AS-3/16" (UNSEALED) RAL-TL85-239	22	27	27	28	31	35	38	41	42	43	44	45	47	47	45	50	58	61	42	33	42
1/4" Lam-2" AS-3/16" (UNSEALED) RAL-TL85-173	24	25	34	33	34	40	41	44	44	46	47	47	48	48	46	50	55	56	45	35	45
1/2" Lam-2" AS-3/16" (UNSEALED) RAL-TL85-194	27	36	33	33	35	39	41	45	45	46	46	46	49	51	52	56	60	62	46	38	46
1/2" Lam-2" AS-3/8" (UNSEALED) RAL-TL85-196	34	37	33	38	40	42	44	48	47	46	45	42	46	51	55	59	61	62	46	42	47
1/2" Lam-1" AS-3/16" (UNSEALED) RAL-TL95-298	24	30	32	32	36	39	42	45	47	50	51	50	53	57	57	60	62	63	47	36	47
1/4" Lam-4" AS-3/16" (UNSEALED) RAL-TL85-174	26	36	34	37	37	43	44	48	49	51	51	50	51	50	47	51	58	60	48	39	48
1/2" Lam-4" AS-3/16" (UNSEALED) RAL-TL85-195	30	37	33	38	37	42	45	49	50	51	50	48	50	53	53	57	61	64	49	41	49
1/2" Lam-4" AS-3/8" (UNSEALED) RAL-TL85-197	38	38	33	40	40	43	46	51	52	52	50	45	48	53	56	59	62	64	49	44	50
3/4" Lam-4" AS-1/8" (UNSEALED) RAL-TL85-240	29	33	31	36	38	43	44	46	47	49	50	52	52	55	59	59	58	60	49	40	49

(1) The data here is based on samples tested at Riverbank Acoustical Laboratories in accordance with ASTM E90-97, ASTM E413-87 and ASTM E1332-90 and are not guaranteed for all samples or applications.
(2) Airspace

Note: The numbers contained in the above tables should be used as a guide and treated as glass only numbers. They may not be indicative of performance in the intended fenestration system. Variables such as air infiltration, size, temperature and glazing methods may have adverse affects on the performance of the entire system. Whenever possible, actual installation practices should be utilized on a mock-up panel to ensure accurate rating of the desired acoustical fenestration products.

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Sound Control

Capabilities (continued)

Double-Laminated Insulating Glass: Sound Transmission Loss Data[1]

1/3 Octaveband (HZ)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	STC	OITC	Rw
1/4" Lam 1/2" AS[2]-1/4"Lam (SEALED) RAL-TL85-172	26	21	29	28	30	34	36	40	42	44	44	44	45	46	47	52	57	58	42	33	42
1/4" Lam 1" AS-1/4" Lam (UNSEALED) RAL-TL95-299	28	28	36	32	34	37	40	44	47	50	50	49	49	48	55	62	63	62	46	37	46
1/2" Lam 1" AS-1/4" Lam (UNSEALED) RAL-TL85-236	21	28	33	37	38	42	43	45	44	44	44	45	49	53	57	59	62	63	46	34	46
1/2"-0.060"-1/4" 4" AS-1/4"-0.030"-1/4" (UNSEALED) RAL-TL85-220	31	42	33	40	42	43	46	50	50	50	49	50	52	55	60	62	64	64	50	42	50
1/4"-0.060"-1/4" 4" AS-1/2" Lam (UNSEALED) RAL-TL85-221	31	39	35	39	41	43	46	51	52	52	49	48	50	54	59	61	63	64	50	42	50
1/2"Lam 4" AS-1/8"-0.060"-1/8" (UNSEALED) RAL-TL85-237	34	38	34	40	41	45	47	51	52	53	53	51	52	55	58	60	62	64	51	44	51
1/4" Lam 4" AS-1/4" Lam (UNSEALED) RAL-TL95-301A	24	37	39	38	41	44	47	49	51	53	54	54	54	53	57	60	63	62	52	38	51
1/4" Lam 4" AS-1/2" Lam (UNSEALED) RAL-TL95-302	34	42	40	41	42	45	48	50	52	54	54	54	56	58	60	63	64	65	53	45	53

Triple Insulating Glass: Sound Transmission Loss Data[1]

1/3 Octaveband (HZ)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	STC	OITC	Rw
1/4"-1/2" AS-1/4"1/2" AS-1/4" (SEALED) RAL-TL95-294	25	22	29	24	25	29	34	37	40	43	46	48	47	41	41	47	52	58	39	31	39
1/4" Lam-1/2" AS[2] 1/4"Lam-1/2" AS-1/4"Lam (UNSEALED) RAL-TL95-295	22	24	34	33	30	37	38	41	44	48	48	49	48	47	52	57	59	55	44	33	44
1/4"-1" AS-1/4"-1/2" AS-1/4" (UNSEALED) RAL-TL95-297	28	34	33	28	31	37	42	45	48	51	53	54	54	48	51	60	62	63	46	37	47
1/4" Lam-1" AS-1/4" Lam 1/2" AS-1/4" Lam (UNSEALED) RAL-TL95-300	31	28	38	36	35	41	43	47	50	53	54	54	55	55	60	63	64	63	49	39	49

(1) The data here is based on samples tested at Riverbank Acoustical Laboratories in accordance with ASTM E90-97, ASTM E413-87 and ASTM E1332-90 and are not guaranteed for all samples or applications.

(2) Airspace

Note: The numbers contained in the above tables should be used as a guide and treated as glass only numbers. They may not be indicative of performance in the intended fenestration system. Variables such as air infiltration, size, temperature and glazing methods may have adverse effects on the performance of the entire system. Whenever possible, actual installation practices should be utilized on a mock-up panel to ensure accurate rating of the desired acoustical fenestration products.

Sound Control

Additional Important Information

Specifications

A sample Section 08 81 00 Specification for North America can be found in Section 11M of this binder titled: Sample Architectural Glass Specifications.

For specifications on other laminated glass make-ups, call 1-866-OLDCASTLE (653-2278) or log on to www.oldcastlebe.com and click on "Project Assistance" and enter your request.

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Light and Solar Control

Introduction

Laminated architectural glass may be designed to reduce solar energy transmittance, control glare and screen out ultraviolet (UV) radiation. Transmitted solar energy is reduced by the use of tinted or coated glass, colored interlayers, or combinations of each that absorb part of the solar radiation in the ultraviolet, visible and near-infrared ranges. The absorbed energy is converted to heat, and a large portion is dissipated to the exterior.

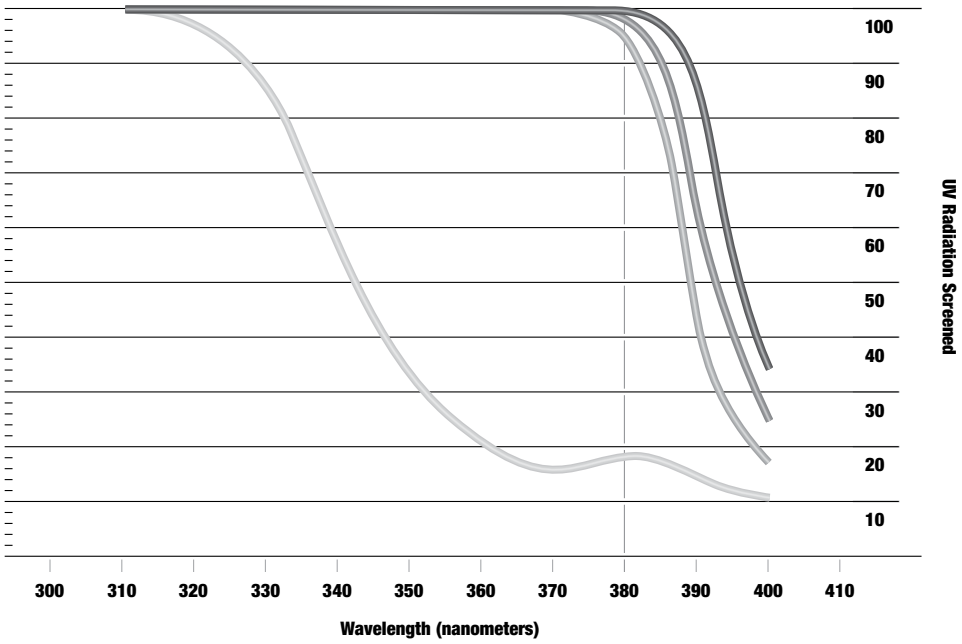
Laminated glass can be manufactured using almost all the full range of tinted, reflective and Low-E glasses currently available. In addition, a range of tinted PVB is available. Laminated architectural glass can be combined into insulating glass units for greater thermal performance.

UV Control

Approximately 2% of the total solar radiation comprises ultraviolet light (wavelengths of 290–380 nm). This UV radiation can cause degradation of dyes, pigments and polymers, resulting in decomposition of unprotected plastics and fading of carpets, drapes, art and other interior fixtures. Laminated glass is essentially opaque to UV radiation and is stable over time. Greater than 99% of UV radiation with a wavelength of less than 380 nm is absorbed, even with an 0.030" interlayer.

Thickness of Clear Saflex® in 1/4" (6 mm) Clear Glass	No Saflex® 1/4" clear Float Glass	0.015" (0.38 mm)	0.030" (0.76 mm)	0.060" (1.52 mm)
% UV energy blocked of total incident energy 290 nm–380 nm wavelengths	29	99	over 99	over 99

Calculation of UV screening performance is based upon integration of transmission curves from 290nm–380nm.



Upper lines show 1/4" laminated glass with 0.060", 0.030" and 0.015" PVB (1.52 mm, 0.76 mm and 0.38 mm).
The lower line shows the transmission of 1/4"clear glass.

Light and Solar Control

Introduction (continued)

Damage to interior fabrics and furnishings is caused by a number of factors. These include UV radiation, visible light radiation, oxygen, moisture, elevated temperatures and air pollutants. Not all of these factors can be eliminated; however, minimizing one of the major sources of deterioration helps to significantly slow the process.

The screening of UV radiation has no adverse effect on plant life. This is because the photoreceptors in plants typically absorb radiation in the visible light wavelengths of 450, 660 and 730 nm. Laminated glass does not significantly block transmitted light in these wavelengths.

Thermal Stress

When considering using tinted annealed laminated glass for solar control, it is important to consider thermal stress.

Capabilities

Oldcastle BuildingEnvelope™ offers a full range of laminated products to control light and solar energy. The following table indicates a selection of the performances that can be achieved using clear glass. A complete range of laminated solar control glasses complete with tinted and reflective glass can be found at www.oldcastlebe.com using the GlasSelect® program. For the solar performance for the Vanceva® range of laminated glass products please *see page 39.*

Color Stability

Extensive testing has been carried out on the hue stability of pigmented PVB interlayers. This testing, which includes natural and accelerated exposure, shows that there is no adverse color shift (yellowing or otherwise). Three-year exposure in Arizona sun showed color shifts below the threshold of normal vision detection.

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Light and Solar Control

Capabilities (continued)

Saflex® Laminated Glass Light and Solar Control Characteristics

Description(2)	Visible Light Trans. % (1)	Visible Refl. % (1)	Solar Trans. % (1)	Winter U-Factor BTU/hr-FT²-°F	SC(1)	SHGC(1)	RHG(1) BTU/hr-FT²
0.015" Clear Saflex®	89	8	74	1.01	0.92	0.79	196
0.030" Clear Saflex®	88	8	72	1.00	0.90	0.78	194
0.045" Clear Saflex®	88	8	70	0.99	0.89	0.77	190
0.060" Clear Saflex®	88	8	71	0.98	0.89	0.77	191
0.090" Clear Saflex®	88	8	68	0.96	0.87	0.76	187
0.100" Clear Saflex® HP	87	9	67	0.95	0.87	0.75	185
0.075" StormGlass™	87	10	71	0.97	0.89	0.77	190
0828 Blue-gray	30	5	38	1.01	0.64	0.55	140
0855 Light Blue-gray	52	6	51	1.01	0.74	0.64	160
3609 Dark Neutral Brown	8	5	15	1.01	0.47	0.40	106
3628 Neutral Medium Brown	28	5	32	1.01	0.60	0.51	132
3655 Neutral Light Brown	55	6	52	1.01	0.75	0.65	162
3773 Blue-green	72	7	64	1.01	0.84	0.72	180
6376 Cool Blue	74	7	67	1.01	0.86	0.74	184
6428 Medium Bronze	28	5	34	1.01	0.61	0.53	135
6452 Light Bronze	52	6	51	1.01	0.74	0.64	161
6544 Gray	42	5	47	1.01	0.71	0.61	155

Information provided by Solutia Inc. The data and information set forth above are based on calculations and are not guaranteed for all samples or applications. All data calculated using Lawrence Berkeley National Laboratory Window 5.2 Product; NFRC/ASHRAE Conditions; center of Glass Values; USD Standard units. Laminates constructed as: 3mm (0.125 inch) Clear glass - [Saflex® Interlayer] - 3mm (0.125 inch) Clear glass. Colored laminate configurations consist of 0.38 mm Saflex® interlayer. All other interlayer thicknesses as designated.

(1) **Trans.**-Transmittance, **Refl.**-Reflectance, **SC**-Shading Coefficient, **SHGC**-Solar Heat Gain Coefficient, **RHG**-Relative Heat Gain.
Saflex is a registered trademark of Solutia Inc.

Light and Solar Control

Additional Important Information

Specifications

A sample Section 08 81 00 Specification for North America can be found in Section 11M of this binder titled: Sample Architectural Glass Specifications.

For specifications on other laminated glass make-ups, call 1-866-OLDCASTLE (653-2278) or log on to www.oldcastlebe.com and click on "Project Assistance" and enter your request.

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ArmorProtect® Forced-Entry-Resistant Glass

Introduction

ArmorProtect® is used where glazing is required to resist penetration for some considerable time, typically measured in minutes rather than seconds. These types of attacks are usually planned, sustained attacks executed by more than one intruder having experience of security glazing and using more than one type of weapon.

When considering these types of attacks, two methods of failure are generally considered. The lesser test is to see when an opening large enough to pass contraband, such as drugs or weapons, is created. The more exacting test is to establish when an opening is created that is large enough for the passage of a whole body.

Description

Glass in this product category can be divided into three broad categories.

ArmorProtect® burglary and attack-resistant institutional laminates offer improved detention security and provide unobstructed vision while eliminating the confined look of bars and metal screens. Typical applications include penal institutions, detention centers, psychiatric hospitals and police stations. In addition, institutional laminated architectural glass provides increased protection in other high-security locations such as embassies, computer centers and sensitive research centers. These products are multi-ply laminates with three or more layers of glass bonded together with thicker layers of PVB or ionomer. Increasing interlayer thickness yields greater resistance to penetration

ArmorProtect® Plus prolonged attack resistant security glazing laminates contain the toughest plastics available, often containing multiple layers for maximum forced-entry resistance. Typically, these products are used in detention facilities and other secure establishments.

ArmorProtect® Plus includes a family of multi-ply laminates containing one or more core layers of polycarbonate, often called glass-clad polycarbonates. Polycarbonates offer the strongest available clear plastic and have 250 times the impact strength of glass. Both the inner and outer lites of the laminate are glass, to provide the durability that the polycarbonate alone could not offer. The polycarbonate is laminated to the outer glass lites using an aliphatic urethane interlayer. Both the polycarbonate and urethane are very clear, haze-free plastics that maintain high light transmission, even with thick laminates having multiple layers of polycarbonate and urethane. High visible light transmittance is essential for observing detainees. Composite materials having several thin layers bonded together give a greater attack resistance than one thick layer. The outer glass surfaces add to the durability of heat and light stable glass-clad polycarbonates. The outer glass lites are usually heat-strengthened to provide increased impact resistance against accidental damage during installation and service. Tempered glass should not be used where it is necessary to retain reasonable vision after the glass has been cracked.

ArmorProtect® Max features lightweight laminates with multiple layers of polycarbonate containing no glass and offering prolonged resistance to sustained physical attack. These products also offer ballistic protection.

Sheets of aliphatic urethane are used to bond the layers of polycarbonate permanently together. The external faces of polycarbonate are protected with a mar-resistant hard coating to provide durability; however, they are not recommended for external use.

ArmorProtect® Forced-Entry-Resistant Glass

Capabilities

Test Procedures

Several test procedures evaluate glazing performance in the medium and maximum security institutional setting. Each one specifies the specimen size and condition, the opening size that constitutes failure, the weapons used and the number of impacts and sequence of attacks using those specified weapons. This section provides only a summary of the various test methods. It is essential that the design professional has a full understanding of the complete test document.

ASTM F1233 Standard Test Method for Security Glazing Materials and Systems (see Table 1).
The H.P. White Laboratories HPW-TP-0500 procedure (replacing the outdated HPW-TP-0100) *Transparent Materials for Use in Forced-Entry or Containment Barriers (see Table 2).*

The Walker-McGough-Foltz & Lyerla (WMFL) thirty- and sixty-minute "Ballistics and Forced-Entry Test Procedure" *(see Table 3).*

ASTM F1915 Standard Test Method for Glazing for Detention Facilites (see Tables 4 and 5).

Oldcastle BuildingEnvelope™ manufactures a comprehensive range of laminated products for Forced-Entry Resistance *(see Table 6).*

Table 1: ASTM F1233 Main-Force/Forced-Entry Test Sequences

	Test Sequences for Each Class of Security Glazing				
Test Implement (Assault)	**Class I**	**Class II**	**Class III**	**Class IV**	**Class V**
Blunt Impact (Impacts)					
Sledgehammer (25)	NR(1)	5	10,16	19,22,27	30,33,36,39
4" pipe/sledge (25)	NR	NR	9	18	29
Ram (10)	NR	NR	8	17	28
Ball peen hammer (10)	1	2	NR	NR	NR
Sharp Tools (Impacts)					
Ripping bar (10)	NR	7	12	23	NR
Chisel/hammer (25)	NR	NR	13	25	35,40
Angle iron/sledge (25)	NR	NR	15	NR	NR
1.5" pipe sledge (25)	NR	3	NR	NR	NR
Fire axe (25)	NR	NR	NR	24	32,38
Wood-splitting maul (25)	NR	NR	NR	21	34,41
Thermal Stress (Minutes)					
CO_2 extinguisher (1)	NR	4	NR	NR	NR
Propane torch (5)	NR	61	112	202	312
Chemical Deterioration (Amount)					
Gasoline (0.5 pints)	NR	NR	14	NR	NR
Acetone (0.5 pints)	NR	NR	NR	26	37
Total Test Sequences	1	7	16	27	41

(1) **NR**–Not Required.

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ArmorProtect® Forced-Entry-Resistant Glass

Capabilities (continued)

Table 2: H.P. White TP-0500 Ballistics and Forced-Entry Test Procedure

	Test Sequences for Each Class of Security Glazing				
Phase I–Ballistics–optional	**Level A**	**Level B**	**Level C**	**Level D**	**Level E**
Caliber	.38 Special	9 mm	.44 Mag.	7.62 mm, M80	.30-06 AP
Shots	3	3	3	3	3
After the sample has successfully resisted one of the optional ballistic threats of the Phase I test, follow numerical sequence (1-54) below.					
Phase II–Forced-Entry	**Level I**	**Level II**	**Level III**	**Level IV**	**Level V**
Blunt Impacting (Impacts)					
Sledgehammer/wedge(25)	1,4	8,10	18,24,26	29,32,39	42,45,48,51,54
4" dia. pipe/sledge (25)	2	7	17	28	41
Ram (10)	NA(3)	6	16	27	40
Pinch bar(1)					
Sharp Tool (Impacts)					
Chisel/hammer(25)	NA	12	21,23	33,36,38	47,52
Angle iron/sledge(25)	NA	13	22	NA	NA
1-1/2" dia. pipe/sledge(25)	5	NA	NA	NA	NA
Fire axe(25)	NA	NA	NA	35	44,50
Wood maul(25)	NA	15	20	31	46,53
Keyhole saw(2)					
Hacksaw(2)					
Thermal Stress (Minutes)					
Extinguisher, CO_2(1)	3	9	NA	NA	NA
Propane burner(5)	NA	11	19	30	NA
Acetylene(5)	NA	NA	NA	NA	43
Chemical Deterioration (Amount)					
Gasoline (1/2 pint)	NA	14	NA	NA	NA
Windshield washer (1/2 pint)	NA	NA	25	34	NA
Acetone (1/2 pint)	NA	NA	NA	NA	49
Total Forced-Entry Sequences	5	15	26	39	54

(1) Pinch or ripping bars may be substituted for any portion of the blunt impacting sequence at the rate of 1 minute for each 5 impacts (test director's option).
(2) Additional sequences of one-minute intervals in conjunction with all sharp tool sequences except sequences 5 and 15 (see paragraphs 3.5.7 and 3.5.8 of the H.P. White TP-0500 ballistics and forced-entry test procedure).
(3) **NA**– Not Applicable.

The numbers in this chart indicate the sequence number. For example, to successfully pass Level 1, a glazing must resist 25 impacts from a sledgehammer, followed by 25 impacts from a 4"-diameter pipe, followed by 1 minute of a CO_2 extinguisher, followed by a further 25 impacts from a sledgehammer, followed by 25 impacts from a 1-1/2" pipe–a total of 5 sequences. To successfully pass Level II, the glazing must resist all those sequences of Level 1, followed by all the sequences of Level II detailed in the table–a total of 15 sequences.

ArmorProtect® Forced-Entry-Resistant Glass

Capabilities (continued)

Table 3: WMFL Ballistics and Forced-Entry Test Procedure

Attack Tools and Sequence of Use	60-Minute Physical Attack	Ballistics and 60-Minute Physical Attack	30-Minute Physical Attack
.44 magnum 240 grain soft point	25 rounds	NA(1)	NA
Nominal 2 LB. claw hammer, claw end	5 minutes	5 minutes	5 minutes
Cold steel chisel or screwdriver hitting end with nominal 2 LB. hammer	5 minutes	5 minutes	5 minutes
Nominal 10 LB. sledgehammer	5 minutes	5 minutes	5 minutes
1-1/2"-diameter steel pipe, 3 FT. long, or 2" x 2" x 1/4" steel angle, 3 FT. long	5 minutes	5 minutes	NA
Grade 60, No. 8 rebar, 3 FT. long	5 minutes	5 minutes	NA
4" x 4" oak post, 3 FT. long	5 minutes	5 minutes	NA
Dry chemical fire extinguisher	5 minutes	5 minutes	5 minutes
Nominal 10 LB. sledgehammer	5 minutes	5 minutes	NA
Clothes hanger or knife with 10" long x 1/4" thick cold steel blade, heated during use	5 minutes	5 minutes	NA
Propane burner with nozzle sized to create approximately a 1"-diameter heat source (applied within 4" or less of glass surface)	5 minutes	5 minutes	5 minutes
Nominal 4 LB. hammer	5 minutes	5 minutes	5 minutes
3"-diameter steel pipe, 3 FT. long or 1" x 1" x 1/4" steel angle, 3 FT. long	5 minutes	5 minutes	NA

(1) **NA**–Not Applicable.
Where more than one weapon is specified in a given 5-minute time period, each weapon was used for approximately equal portions of the time.
Spall is not measured in the ballistic test of WMFL.

TABLE 4: ASTM F1915 Impact Test Criteria: Large Blunt and Sharp Impactors

Security Grade	Total Time	Sequence and Impacts[1]			
		1 Blunt Impactor	2 Sharp Impactor	3 Blunt Impactor	Total Number of Impacts
1	60 min	150	300	150	600
2	40 min	100	200	100	400
3	20 min	50	100	50	200
4	10 min	25	50	25	100

[1] To be performed on both hot and cold conditioned samples..

TABLE 5: ASTM F1915 Impact Test Criteria: Torch and Small Blunt Impactor

Security Grade	Blunt Impacts[1]	Security Grade	Blunt Impacts[1]
1	150	3	75
2	100	4	50

[1] To be performed on a room temperature sample only.

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ArmorProtect® Forced-Entry-Resistant Glass

Capabilities (continued)

Inspection and Installation Guidelines

Tolerances and quality references are detailed in ASTM C1349 *Standard Specification for Architectural Flat Glass-Clad Polycarbonate.* Most laminated glazing designed for security applications has been engineered to provide extreme performance and therefore contains several layers of glass and plastic lites. Moderate distortion due to the extrusion of the polycarbonate and the heat-treating of the glass lites is unavoidable, especially with thick laminates that provide protection to high test levels. Optical distortion is usually not obtrusive in service and is not a cause for rejection. Holes, notches, pass-throughs, etc., often show greater distortion around these fabricated areas. The correct edge engagement and clearance is very important.
(See Installation Guidelines, pages 42-43 for additional information.)

Specifications

For specifications on security laminates, please call 1-866-OLDCASTLE (653-2278) or log on to www.oldcastlebe.com and click on “Project Assistance” and enter your request.

Table 6: Oldcastle BuildingEnvelope™ Security Laminates for use in Forced-Entry Applications

Trade name	Product #	HPW-TP-0500 FE	HPW-TP-0500 BR	WMFL	ASTM F1233	ASTM F1915	UL 752	Nominal Thickness inches	Weight LBS/FT²	Max Size inches	Assembly(1)
ArmorProtect®	111000	–	–	–	1-body passage	–	–	1/2	5.4	60 x 96	AGL
ArmorProtect®	112000	–	–	–	1	–	–	3/4	7.2	60 x 96	AGL
ArmorProtect®	113000	–	–	–	1	–	–	1	9.1	60 x 96	AGL
ArmorProtect® Plus	121000	1	A(2)	–	–	–	–	7/16	4.6	60 x 96	GCP
ArmorProtect® Plus	121100	1	A(2)	–	–	–	–	9/16	5.4	60 x 96	GCP
ArmorProtect® Plus	121200	1	B(2)	–	–	–	–	11/16	6.2	60 x 96	GCP
ArmorProtect® Plus	122000	2	B(2)	3	–	–	–	13/16	6.4	60 x 96	GCP
ArmorProtect® Plus	123000	3	B(2)	3	–	3	–	3/4	6.3	60 x 96	GCP
ArmorProtect® Plus	123200	2	B(2)	2	–	2	–	15/16	7.2	60 x 96	GCP
ArmorProtect® Plus	123100	3	B(2)	2	–	–	–	7/8	7.1	60 x 96	GCP
ArmorProtect® Plus	124100	–	–	1(2)	–	1	–	1-1/4	10.8	60 x 96	GCP
ArmorProtect® Plus	124200	–	–	1	–	–	3	1-3/8	11.8	60 x 96	GP
ArmorProtect® Max	132000	2-step 14	A	–	–	–	–	3/8	2.5	60 x 96	LPC
ArmorProtect® Max	133000	3-step 16	A	–	–	–	–	1/2	3.4	60 x 96	LPC
ArmorProtect® Max	134000	4-step 38	B	–	–	–	–	3/4	5.0	60 x 96	LPC
ArmorProtect® Max	135000	5	B	–	–	–	2	1	6.6	60 x 96	LPC
ArmorProtect® Max	135100	5	C	2	–	–	3	1-1/4	8.2	60 x 96	LPC

ArmorProtect® Forced-Entry-Resistant Glass

Capabilities (continued)

HP White Test Summary

HPW-TP-0500

Forced-Entry		Ballistics	
Level 1:	Steps 1-5	**Level A:**	38 Special
Level 2:	Steps 1-15	**Level B:**	9 mm
Level 3:	Steps 1-26	**Level C:**	.44 Magnum
Level 4:	Steps 1-39	**Level D:**	7.62 mm
Level 5:	Steps 1-54	**Level E:**	.30-06 AP

ASTM F1915 Test Summary

Grade 1:	60 Minutes	600 Impacts
Grade 2:	40 Minutes	400 Impacts
Grade 3:	20 Minutes	200 Impacts
Grade 4:	10 Minutes	100 Impacts

ASTM F1233 Test Summary

Forced-Entry	
Class 1:	Steps 1
Class 2:	Steps 1-7
Class 3:	Steps 1-16
Class 4:	Steps 1-27
Level 5:	Steps 1-41

WMFL Test Summary

Level 3:	30 Minutes
Level 2:	60 Minutes
Level 1:	60 Minutes and 25 rounds .44 Magnum(3)

(1) **GP**–glass-clad polycarbonate with exposed polycarbonate; **GCP**–glass-clad polycarbonate; **LPC**–laminated polycarbonate; **AGL**–all-glass laminate.
(2) These products resisted bullet penetration. They are not designed to resist spalling.
(3) This is not a no-spall ballistics test.

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ArmorResist®: Bullet-Resistant Glass

Introduction

Laminated glass can be designed to resist attacks by a wide range of weapons. There are many standards and test methods available throughout the world. Almost all of these have two main requirements: (1) the glazing must resist penetration by specified ballistics and (2) the spall or flying shards of glass leaving the rear face, as a result of the impact, cannot exceed the limits of the specified test criteria.

Bullet-resistant laminated glass can typically meet both of these requirements. It is important to note that most ArmorResist® bullet-resistant glazing materials are not classified as forced-entry resistant.

ArmorResist® laminated glazing products consist of assemblies of several different materials. Figures 1 and 2 show typical compositions.

Figure 1.
AmorResist® All-Glass Bullet-Resistant Laminate

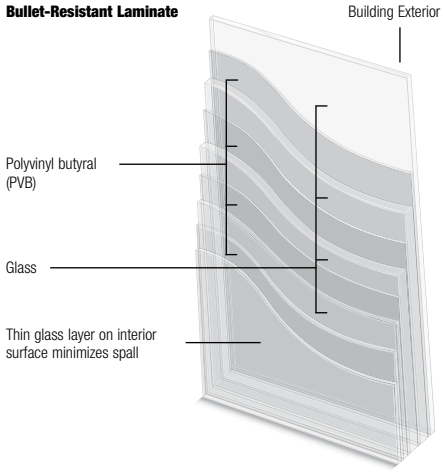
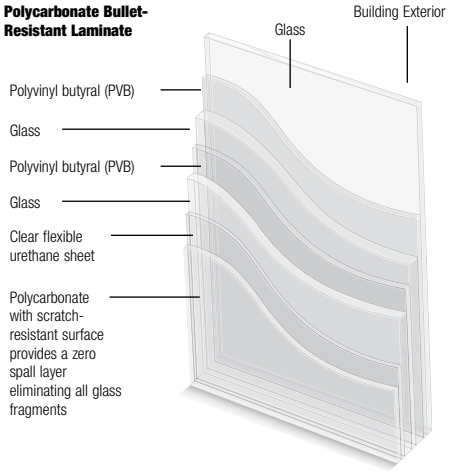


Figure 2.
AmorResist® Plus Glass Polycarbonate Bullet-Resistant Laminate



Description

Oldcastle BuildingEnvelope™ manufactures two types of bullet-resistant glass to meet the above requirements.

ArmorResist® is a multi-ply laminated glass having multiple layers of glass and PVB bonded together into a monolithic unit. The rear most lite of glass is usually a thin glass that allows the glass to meet all the requirements of UL 752. This range of products is the most economical and durable range of bullet-resistant glasses manufactured by Oldcastle BuildingEnvelope™.

ArmorResist® Plus is a combination of glass and polycarbonate. PVB and/or a Thermo Plastic Urethane (TPU) is used as the interlayer in this product range. Polycarbonate is one of the toughest clear plastics, having 250 times the impact strength of glass and is used toward the rear of the laminate to flex and absorb the energy of the bullet. The rear face is always exposed polycarbonate with a scratch-resistant coating. ArmorResist® Plus is generally thinner and lighter than the corresponding ArmorResist® product when it is designed to resist the same threat.

ArmorResist®: Bullet-Resistant Glass

Description (continued)

Underwriters Laboratories UL 752 *Bullet Resisting Equipment* is the most well-known standard in the USA. It defines ten levels of attacks ranging from a 9 mm handgun to a 7.62 mm military rifle. This standard defines the type of round, the muzzle velocity and the number of impacts each sample must receive. This standard also details environmental conditioning at high and low temperatures so that this type of glass can be used externally over a wide range of conditions. *(See Table 1 below.)*

Table 1: UL 752 Ratings of Bullet-Resistant Materials

		Projectile Weight		Minimum Velocity(1)		
Rating	**Ammunition**	**Grain**	**grams**	**ft/sec**	**m/sec**	**No. of Shots**
Level 1	9 mm Full Metal, Copper Jacket with Lead Core	124	8.0	1,175	358	3
Level 2	357 Magnum Jacketed Lead, Soft Point	158	10.2	1,250	381	3
Level 3	.44 Magnum Lead Semi-Wadcutter, Gas Checked	240	15.6	1,350	411	3
Level 4	.30 Caliber Rifle, Lead Core, Soft Point	180	11.7	2,540	774	1
Level 5	7.62 mm Rifle, Lead Core, Full Metal, Copper Jacket, Military Ball	150	9.7	2,750	838	1
Level 6	9 mm Full Metal, Copper Jacket with Lead Core	124	8.0	1,400	427	5
Level 7	5.56 mm Rifle, Full Metal, Copper Jacket with Lead Core	55	3.56	3,080	939	5
Level 8	7.62 mm Rifle, Lead Core, Full Metal, Copper Jacket, Military Ball	150	9.7	2,750	838	5
Level 9	.30 Caliber Rifle, Armor Piercing, Steel Core, Lead Point Filler, Full Metal Jacket	166	10.8	2,715	828	1
Level 10	.50 Caliber Rifle, Lead Core, Full Metal, Copper Jacket, Military Ball	710	45.9	2,810	856	1
Supplementary Shotgun	12-Gauge Rifled, Lead Slug, and 12-Gauge 00 Lead Buckshot (12 pellets)	437 650	28.3 42	1,585 1,200	483 366	3 3

(1) Maximum velocity is 110% of the minimum velocity.

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ArmorResist®: Bullet-Resistant Glass

Description (continued)

In addition to UL 752, some specifying authorities use the National Institute of Justice standard NIJ 0108.01: *Ballistic-Resistant Protective Materials.* The test variables are detailed in Table 2 below.

Table 2: NIJ Standard 0108.01: Ballistic Resistance Test Variables and Requirements

	Test Variables			Performance Requirements		
Armor Type	**Test Ammunition(1)**	**Nominal Bullet Mass**	**Suggested Barrel Length**	**Required Bullet Velocity**	**Required Hits Per Armor Specimen**	**Permitted Penetrations**
I	22 LRHV Lead	2.6g 40gr	15 to 16.5cm 6 to 6.5in	320±12m/s 1050±40ft/s	5	0
	.38 Special RN Lead	10.2g 158gr	15 to 16.5cm 6 to 6.5 in	259±15m/s 850±50ft/s	5	0
II-A	.357 Magnum JSP	10.2g 158gr	10 to 12 cm 4 to 4.75 in	381±15m/s 1250±50ft/s	5	0
	9 mm FMJ	8.0g 124gr	10 to 12cm 4 to 4.75in	332±12m/s 1090±40ft/s	5	0
II	.357 Magnum JSP	10.2g 158gr	15 to 16.5cm 6 to 6.5in	425±15m/s 1395±50ft/s	5	0
	9mm FMJ	8.0g 124gr	10 to 12cm 4 to 4.75in	358±12m/s 1175±40ft/s	5	0
III-A	.44 Magnum LeadSWC GasChecked	15.55g 240gr	14 to 16cm 5.5 to 6.25in	426±15m/s 1400±50ft/s	5	0
	9 mm FMJ	8.0g 124gr	24 to 26cm 9.5 to 10.25in	426±15m/s 1400±50ft/s	5	0
III	7.62 mm (308 Winchester) FMJ	9.7g 150gr	56cm 22in	838±15m/s 2750±50ft/s	5	0
IV	.30-06 AP	10.8g 166gr	56cm 22in	868±15m/s 2850±50ft/s	1	0
Special requirement (See Sec. 2.2.7 of this standard)	(2)	(2)	(2)	(2)	(2)	0

(1) **AP**–Armor Piercing; **FMJ**–Full Metal Jacketed; **JSP**–Jacketed Soft Point; **LRHV**–Long Rifle High Velocity; **RN**–Round Nose; **SWC**–Semi-Wadcutter.
(2) These items must be specified by the user.

ArmorResist®: Bullet-Resistant Glass

Description (continued)

Table 3: Oldcastle BuildingEnvelope™ Security Laminates for Use in Bullet-Resistant Applications

Trade name	Product #	UL 752	NIJ	Nominal Thickness inches	Weight LBS/FT²	Max Size	Assembly[3]
ArmorResist®	211000	1[1]	–	1-3/16	14.7	500 LBS[2]	AGL
ArmorResist®	211100	1[1]	–	1-5/16	15.5	500 LBS[2]	AGL
ArmorResist®	212000	2[1]	–	1-1/2	19.3	500 LBS[2]	AGL
ArmorResist®	213000	3[4]	–	2	25.8	500 LBS[2]	AGL
ArmorResist®	214000	4[1]	–	2	25.8	500 LBS[2]	AGL
ArmorResist®	215000	5[1]	–	2	25.8	500 LBS[2]	AGL
ArmorResist®	216000	6[1]	–	1-13/16	22.6	500 LBS[2]	AGL
ArmorResist®	212100	–	2A	1-3/16	14.7	500 LBS[2]	AGL
ArmorResist®	212200	–	2	1-1/2	19.1	500 LBS[2]	AGL
ArmorResist®	213100	–	3A	1-3/4	22.7	500 LBS[2]	AGL
ArmorResist® Plus	221000	1[1]	–	0.81	8.4	60 x 96	GP
ArmorResist® Plus	222000	2[1]	–	1.03	11.2	60 x 96	GP
ArmorResist® Plus	223000	3[1]	–	1.22	13.5	60 x 96	GP
ArmorResist® Plus	223100	3	–	0.93	11.2	60 x 96	GP
ArmorResist® Plus	224200	4[1]	–	1.22	13.5	60 x 96	GP
ArmorResist® Plus	225000	5[1]	–	1.28	13.6	60 x 96	GP
ArmorResist® Plus	226000	6[1]	–	1.04	10.0	60 x 96	GP
ArmorResist® Plus	227100	7[1]	–	1.64	18.5	60 x 96	GP
ArmorResist® Plus	228000	8[1]	–	2.17	25.1	60 x 96	GP
ArmorResist® Plus	223010	–	3	1.68	18.5	60 x 96	GP
ArmorResist® Plus	224100	–	4	2.27	26.6	60 x 96	GP

UL 752 Test Summary

Level 1: 9 mm
Level 2: .357 Magnum
Level 3: .44 Magnum
Level 4: .30-06
Level 5: 7.62 mm
Level 6: 9 mm
Level 7: 5.56 mm
Level 8: 7.62 mm
Level 9: 0.30" AP
Level 10: 0.50" FMJ

National Institute of Justice: NIJ Standard 0108.01

Level 1: .38 Special
Level 2A: .357 Magnum/9 mm-LV
Level 2: .357 Magnum/9 mm-HV
Level 3A: .44 Magnum/9 mm
Level 3: 7.62 mm
Level 4: .30-06

(1) indicates UL certification and permanent UL logo.
(2) maximum size is limited by the listed weight.
(3) **AGL**–all-glass laminate; **GP**–glass-clad polycarbonate with exposed polycarbonate.
(4) indicates UL certification and permanent UL logo - indoor only

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ArmorResist®: Bullet-Resistant Glass

Capabilities

Oldcastle BuildingEnvelope™ manufactures a wide range of bullet-resistant products. *(See Table 3 on previous page.)*

Bullet-resistant glazing is not necessarily resistant to a sustained physical attack or forced-entry; however, some glazing is designed to be resistant to both forms of attack. Products which have been designed to resist both forced-entry and ballistic attacks are to be found in the Laminated Glass section under Forced-Entry. *(See pages 21-26).*

Other Considerations

ArmorResist® bullet-resistant glass and ArmorProtect® Plus forced entry products can form part of an insulating glass unit. In the case of ArmorResist®, it is recommended that the bullet-resistant glass be used as the inboard lite of the unit.

Installation

It is most important that bullet-resistant glass be installed in a framework that is also bullet-resistant. It is up to the installer to verify that the total installation resists the specified threat. ArmorResist® is usually nonsymmetrical and has a strike face or impact face that faces the threat. The opposite face is known as the protected or safe side. Oldcastle BuildingEnvelope™ applies a removable impact face label, which identifies the threat side. This should be left on until final inspection to ensure that the glass has been installed correctly, as it can be difficult to determine this at a later stage. Oldcastle BuildingEnvelope™ does not recommend butt-glazing ArmorResist®, as the bullet can penetrate the small space between the lites. Any speak-hole covers should also be bullet-resistant.

Inspection and Installation Guidelines

Black specks are an inherent, allowable characteristic of the polycarbonate material used in certain Oldcastle BuildingEnvelope™ laminated glass products. Specifications regarding the allowable limits for size are set by industry standards. *(See ASTM C1349 for full details.)* The extrusion process of manufacturing polycarbonate material may produce a minor distortion that is noticeable under certain conditions. Holes, notches, pass-throughs, etc., produce greater distortion around these specially fabricated areas. The correct edge engagement and clearance is very important. *(See Installation Guidelines, pages 42-43.)*

Additional Important Information

Specifications

A sample Section 08 81 00 Specification for North America can be found in Section 11M of this binder titled: Sample Architectural Glass Specifications.

For specifications on other laminated glass make-ups, call 1-866-OLDCASTLE (653-2278) or log on to www.oldcastlebe.com and click on “Project Assistance” and enter your request.

Contact Us

For any additional information, including details, technical data, specifications, technical assistance and samples, call 1-866-OLDCASTLE (653-2278).

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Log on to www.oldcastlebe.com for project photos, product colors, general inquiries and project assistance.

To view performance data on a wide range of glass make-ups, or to build your own product specification, log on to www.oldcastlebe.com and choose GlasSelect®.

Hurricane Impact-Resistant Glass (Windborne Debris)

Introduction

The stringent code requirements of Florida and other coastal regions require that the building envelope be maintained during a hurricane. All elements of the building shell must resist the effects of windborne debris as well as sustained turbulent winds lasting several hours. Extensive research, following Hurricane Andrew in 1992, showed that breech of the envelope led to internal pressurization of the building. This effectively doubled the forces on major structural elements such as walls and roofs, leading to catastrophic failure.

The South Florida Building Code introduced hurricane-impact protection requirements in 1994. To meet these codes in South Florida, the glazing must resist the penetration of either a large missile (a 9 LB wood 2" x 4" traveling at 50 feet per second/33mph) or small missiles (2 gram steel ball bearings traveling at 130 feet per second). These impacts are then followed by 9,000 inward and outward acting pressure cycles.

Other areas of the world are gradually introducing similar codes. The Texas Department of Insurance (TDI) has specified similar testing for property close to the Gulf Coast. The model code of SBCCI, which was used as the basis of the Florida Building Code that was made into law in 2002, includes windborne-debris protection requirements, as does the International Building Code.

Description

The latest national standard is the ASTM E1996 *Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors and Storm Shutters Impacted by Windborne Debris in Hurricanes.* It defines several other missiles applicable to different wind zones, building types and building heights, while incorporating the requirements of southern Florida. Tables 1 and 2 show the requirements of ASTM E1996, with the southern Florida counties of Broward and Miami-Dade being in Wind Zone 4. Essential facilities are hospitals, evacuation centers and command and control positions, which are required during emergencies. All other building types come under the category of Basic Protection, apart from a few specifically excluded uninhabited buildings such as greenhouses.

Table 1: ASTM E1996 Wind Zones and Missile Types (See Missile Types in Table 2, page 33)

		Enhanced Protection (Essential Facilities)		Basic Protection	
System Height		≤ 30 FT	> 30 FT	≤ 30 FT	> 30 FT
Wind Zone 1	110 - 120 mph + Hawaii	D	D	C	A
Wind Zone 2	120 - 130 mph more than 1 mile from coast	D	D	C	A
Wind Zone 3	130 - 140 mph or 120 - 140 within 1 mile of coast	E	D	D	A
Wind Zone 4	> 140mph (South Florida)	E	D	D	A

For systems intended to be used 30 feet and higher from ground level, a small missile is used. Following either the small or large missile impact, the specimens are subjected to pressure cycling, as described in Table 3 on the following page.

Each cycle takes between one and three seconds, so the complete test can last up to 7-1/2 hours for each specimen. P_{pos} and P_{neg} are defined as the design pressures of the system being tested.

Hurricane Impact-Resistant Glass (Windborne Debris)

Description (continued)

Table 2: ASTM E1996–Applicable Missiles

Level	Missile	Speed (f/s)	Comment
A	2 g ± 5% steel ball	130	Small missile
B	2 LB ± .25 LB 2 x 4 lumber	50	Some residential skylights
C	4.5 LB ± .25 LB 2 x 4 lumber	40	Lower wind zones only
D	9 LB ± .25 LB 2 x 4 lumber	50	Large missile
E	9 LB ± .25 LB 2 x 4 lumber	80	Essential facilities only

Table 3: ASTM E1996–Cyclic Static Air Pressure Loading

Loading Sequence	Loading Direction	Air Pressure Cycles	Number of Cycles
1	Positive	0.2 to 0.5 P_{pos}	3,500
2	Positive	0.0 to 0.6 P_{pos}	300
3	Positive	0.5 to 0.8 P_{pos}	600
4	Positive	0.3 to 1.0 P_{pos}	100
5	Negative	0.3 to 1.0 P_{neg}	50
6	Negative	0.5 to 0.8 P_{neg}	1,050
7	Negative	0.0 to 0.6 P_{neg}	50
8	Negative	0.2 to 0.5 P_{neg}	3,350

Testing is carried out on the glazing system. Glass is therefore a component in this system, which includes aluminum, gaskets, sealants, weather-stripping, hardware and fasteners. Most codes require that three identical specimens be tested without penetration. All components used on the tested specimens must be carefully detailed on the test report so that exactly the same system is used in practice. Glass supplied by Oldcastle BuildingEnvelope™ has been successfully tested in many glazing systems for both residential and commercial applications.

All the products supplied by Oldcastle BuildingEnvelope™ for these types of applications have Component Product Approvals from Miami-Dade County. Full details are available on request. This component product approval must be specified on the System Product Approval, which is owned by the manufacturer of the glazing system. System Product Approval is now required in all of Florida.

Each of the test standards mentioned above has slight variations in such items as impact locations and pass/fail criteria. Careful examination of the standards is necessary to ensure that any testing is correctly performed.

Capabilities

Hurricane Impact-Resistant Glass Selection

Oldcastle BuildingEnvelope™ supplies all the main types of laminated glass used for hurricane-resistant applications. *(See Table 4 on the following page.)* Usually, the laminate is made up of two pieces of glass of the same thickness; however, the two pieces of glass may be annealed, heat-strengthened or tempered, depending on the system in which it was tested.

For small missile performance, glass with an 0.060" PVB interlayer is normally adequate. For best performance, the outer lite of glass should be tempered and the inner lite heat-strengthened.

For large missile performance up to about 25 SQ FT and 65 PSF design pressure, laminated glass with an 0.090" PVB interlayer is usually used. This is combined with various glass configurations, depending on the opening size, design pressure and window or glazing system design.

For the higher-level performance that is required for curtain wall, storefront and large residential

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Hurricane Impact-Resistant Glass (Windborne Debris)

Capabilities (continued)

applications, it is often necessary to use StormGlass™, a unique, high-performance interlayer by Oldcastle BuildingEnvelope™. Alternatively laminated glass containing a Saflex® HP interlayer by Solutia, or SentryGlas™ Plus ionomer by DuPont can be used. These products contain interlayers that are much stiffer than regular PVB, and that can sustain much greater design pressures during the pressure cycling phase of the test. In addition, they can be used in very large sizes, even exceeding 50 SQ FT in some cases. These types of products are usually laminated between two lites of 3/16" or 1/4" heat-strengthened glass.

For the ultimate performance, it is necessary to use a glass-clad polycarbonate construction. The core of this 5-layer laminate is a thin polycarbonate sheet that is the strongest clear plastic available today. It is virtually unbreakable and therefore can resist the greatest forces.

Often, a window or glazing system will only have been tested with a small selection of the products detailed below, so it is essential to check with the system manufacturer in order to specify the correct one. None of the building codes permit the substitution of one product for another, without testing.

Table 4: Oldcastle BuildingEnvelope™ Hurricane Impact-Resistant Products

			2 x 1/8" glass		2 x 3/16" glass		2 x 1/4" glass	
Product #	**Description**	**Test**	**Thickness inches**	**Weight LBS/FT²**	**Thickness inches**	**Weight LBS/FT²**	**Thickness inches**	**Weight LBS/FT²**
411000	Laminated glass with .060 PVB	Small Missile	0.31	3.58	0.44	5.21	0.56	6.53
412000	Laminated glass with .090 PVB	Large Missile	0.34	3.75	0.47	5.38	0.59	7.00
452000	Laminated glass with .100 HP PVB	Large Missile	0.35	3.77	0.48	5.40	0.60	7.02
462000	Laminated glass with .090 SGP	Large Missile	0.34	3.75	0.47	5.38	0.59	7.00
462500	Laminated glass with .100 SGP	Large Missile	0.35	3.77	0.48	5.40	0.60	7.02
472000	StormGlass™ by Oldcastle BuildingEnvelope™	Large Missile	0.33	3.67	0.46	5.30	0.56	6.76
422000	Glass-clad polycarbonate	Large Missile	0.43	4.29	0.55	5.88	0.68	7.50

Additional Important Information

All the laminates detailed in the table above can be supplied with tinted, reflective or Low-E glass to allow the designer and the engineer to control solar heat gain and glare in the building. As the impact codes are adopted by other municipalities outside Florida, more hurricane impact-resistant glass will be supplied as insulating glass units. In this case, the laminated glass lite is usually the inboard lite of the insulating glass unit. For detailed recommendations and glass selection, it is necessary to carefully examine all the requirements of the glazing system and the desired design pressure rating. Oldcastle BuildingEnvelope™ has extensive experience with the testing of hurricane impact-resistant systems and welcomes the opportunity to discuss the selection of a suitable laminated glass for your application.

Hurricane Impact-Resistant Glass (Windborne Debris)

Additional Important Information (continued)

Tornadoes

The speeds of windborne debris and the peak wind pressures in tornadoes can be, in many cases, much higher than those specified in ASTM E1996.

The Federal Emergency Management Agency (FEMA) has produced a document titled *Design and Construction Guidance for Community Shelters.* This document presents test methods and construction guidance, and specifies a 15 LB. wood 2x4 fired at 100 mph. This has approximately 14 times the energy of the large missile used in wind zone 4 of ASTM E1996.

Oldcastle BuildingEnvelope™ can manufacture glass to meet these requirements; however, FEMA states in section 6.5, Windows: “Testing indicates that glass windows in any configuration are undesirable for use in tornado shelters. The thickness and weight of glass systems required to resist penetration and control glass spall, coupled with the associated expense of these systems, make them impractical for inclusion in shelter designs”.

Glass and glazing that are designed and tested to resist hurricane impact and cyclic pressure loads can, however, give considerable resistance and protection against lower categories of tornadoes.

Specifications

A sample Section 08 81 00 Specification for North America can be found in Section 11M of this binder titled: Sample Architectural Glass Specifications.

For specifications on other laminated glass make-ups, call 1-866-OLDCASTLE (653-2278) or log on to www.oldcastlebe.com and click on “Project Assistance” and enter your request.

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Blast-Resistant Glass

Introduction

In recent years, the bomb has become the weapon of choice for many terrorist attacks. The high-explosive detonation, with its associated property damage, injury, flames and noise, draws immediate attention and instills fear beyond that of armed attacks.

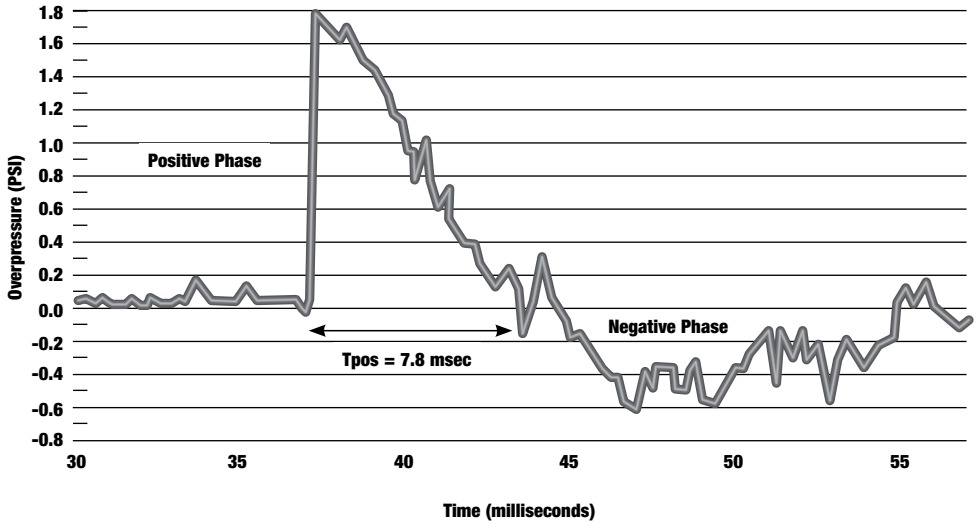
Extensive research has been carried out following terrorist bombing events in New York, Oklahoma, London, Israel and many other locations. It has been documented that the blast energy causes collateral damage to many surrounding structures, not just the intended target. Glass fragmentation hazards have been identified as a main cause of injury in the targeted site, as well as the peripheral sites. Because collateral damage often extends several blocks from the site of the bomb, it can affect hundreds, possibly thousands, of people, especially in urban areas.

Description

Laminated glass is an excellent glazing choice in all types of buildings that may be subjected to bomb blasts. The tough plastic interlayer holds the glass together after an impact, and with the proper framing systems, the glazing will be retained in the opening. Thus, the amount of flying glass, as well as the consequential injuries, can be dramatically reduced.

The pressure from a bomb typically consists of a wave that rises almost instantaneously to a very high peak pressure that falls back to zero in a very short duration, as measured in milliseconds. For example, a 27 LB. bomb detonated from a stand-off distance of 48 FT. produces a peak pressure of 10 PSI (1,440 PSF) for 3.3 milliseconds. The area under the pressure time graph is called the impulse and is measured in PSI-ms. Blast wave energy decreases very rapidly with distance so that the most effective protection is to increase this “stand-off” distance. However, this is not always a viable or economic option.

Typical Blast Wave–Incident (Side-on) Overpressure



8 LBS of C-4 explosive (TNT equivalent of 10 LBS) detonated 57 feet from target; atmospheric pressure of 12.9 PSI.

Blast-Resistant Glass

Description (continued)

The General Services Administration (GSA), which is responsible for all US nonmilitary federal buildings, developed an approach for blast resistance. This approach has been included by the Interagency Security Committee (ISC) in their *ISC Security Design Criteria* document that is now being used to evaluate vulnerability and provide design guidelines for government-owned and leased buildings.

The building type is defined in Table 1, and the protection level is defined in Table 2, taking into account the sensitivity of the area behind the glazing.

Table 1

ISC Building Classification	Examples	Max Overpressure	Max Impulse
A	No protection	0	0
B	No protection	0	0
C	Fed courts, fed buildings, etc.	4 PSI	28 PSI ms
D	High-level military, e.g., Pentagon	10 PSI	89 PSI ms
E	White House	Classified	Classified

Table 2

Hazard 1	Hazard 2	Hazard 3	Hazard 3B	Hazard 4	Hazard 5
No glass breakage	Minimal spall	Spall up to **3FT** (1m)	Spall up to **10FT** (3m)	Hits back wall up to **2FT** high	Hits back wall ≥ **2FT** high

Hazard 1 allows no breakage at all. This is required in locations where complete vision must be maintained after the event and where personnel would be situated immediately behind the glazing. Control points and lookout positions would fall into this category. Hazards 2-3 and 3B allow increasing amounts of limited spalling, very small chips of glass, so the immediate injuries would be minor. The glazing in these locations would remain in the frame, providing protection from additional outside debris or the weather. Hazards 4 and 5 occur when larger amounts of glass, or other debris, fly off with considerable energy and can cause serious injury to the occupants of the building. The glazing would not always be retained in the frame. Hazards 4 and 5 would only be specified for very low occupancy buildings and/or storage areas.

ASTM F1642 *Standard Test Method for Glazing and Glazing Systems Subject to Airblast Loadings* details a test method for this type of glazing. The newest version of this standard has six hazard criteria similar to the GSA recommendations. However, the detailed definitions vary slightly. The frame is an integral part of the blast mitigation glazing system. The blast pressure applies a load to the glass and will be transmitted to the frame through the fasteners, and on to the structure of the building. If the glazing is made very stiff, this entire load will be transmitted to the building, which can damage the structural integrity of the building. In the case where the glazing is very thick and stiff the structure of the building has to be significantly modified and strengthened to accept this additional load.

The Department of Defense (DoD) has produced UFC 4-010-01 *DoD Minimum Antiterrorism Standards for buildings.* Section B-3.1 deals with Windows, Skylights and glazed doors and two critical sub-sections are included here.

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Blast-Resistant Glass

Description (continued)

B.3.1.2 Glazing. *Use a minimum of 6-mm (1/4-in) nominal laminated glass for all exterior windows, skylights and glazed doors. The 6-mm (1/4-in) laminated glass consists of two nominal 3-mm (1/8-in) glass panes bonded together with a minimum of a 0.75mm (0.030-in) polyvinyl-butyral (PVB) interlayer. For insulating glass units, use 6-mm (1/4-in) laminated glass inner pane as a minimum.*

B-3.1.2.2 Glazing Frame Bite. *The glazing shall have a minimum frame bite of 9.5-mm (3/8-in) for structurally glazed systems and 25-mm (1-in) for window systems that are not structurally glazed.*

Other subsections in Section B-3.1 give further guidance on installation and anchoring.

Capabilities

The following constructions of laminated glass are most commonly specified for bomb-blast resistance. As with all laminated glazing, the glass can be supplied as tinted or reflective for light and solar control purposes. The lites of glass can be either annealed or heat-strengthened. Oldcastle BuildingEnvelope™ does not recommend tempered laminated glass in this type of application. When insulating glass units are required for thermal performance, Oldcastle BuildingEnvelope™ recommends that both lites of the IG unit be laminated in order to provide maximum protection for those both inside and outside the building. If only one lite in the IG unit is to be laminated, it must be the interior lite so as to protect the occupants of the building.

Product #	Construction	Thickness		Weight	
	Glass-PVB-Glass: inches	inches	mm	LBS/FT²	kg/m²
110100	1/8–0.060–1/8	5/16	8	3.58	17.5
110110	3/16–0.060–3/16	7/16	11	5.21	25.4
110120	1/4–0.060–1/4	9/16	14	6.83	33.3

Additional Important Information

Specifications

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Decorative Laminated Glass

Introduction

Laminated glass allows great flexibility for decorative glass. Many different effects can be created by deliberately adding other substances to the laminate. Most of the decorative effects offered by Oldcastle BuildingEnvelope™ are light- and heat-stable and therefore can be used both internally and externally.

Silk-screened and Printed Glass

Silk-screened and printed glass *(see the Silk-Screened Tab)* is used to apply decorative designs to all types of architectural glass. This printed glass can be laminated to increase functional and performance values.

Vanceva® Color

Vanceva® Color offers a unique custom color system that can produce a seemingly endless spectrum of transparent or translucent color options in laminated glass. Applications are almost endless but include curtain walls, atriums, partitions and conference rooms.

The pigmented interlayers are heat- and light-stable, so they will not fade. When subjected to vigorous test conditions, Vanceva® interlayers retained their colorfast properties as well as structural integrity. Vanceva® Color is currently available in a foundational palette of 12 basic colors.

Each of these interlayers is 0.015" thick and can be combined, in up to 6 layers, to form a 0.090" total thickness. Over 1,000 combinations are possible and can help the designer create the perfect blend of tone and intensity. If safety glass is required and only one color is needed, a clear layer of .015" should be added to bring the total up to the minimum requirement of 0.030" for safety glass. The Arctic Snow, Cool White, Polar White and Absolute Black options are added to give translucent or opaque appearance to the product.

A specification for a purple translucent glass could, for example, be the code 1259. This number designates both the layer types and the layer order. It is important to note that this glass is not symmetrical and therefore will have a different look when viewed from opposite sides. For a truly symmetrical glass, the numbering must be symmetric, e.g., 1221.

Example:
Code 1221 = 1/8" clear glass / .015 78% red, .015 78% blue, .015 78% blue, .015 78% red / 1/8" clear glass.

Decorative Laminated Glass

Vanceva® Data Charts

Vanceva® Color Data Chart

Vanceva™ Design	Color/ Design Code	Visible Light Trans(1) %	Solar Trans(1) %	inter U-Factor BTU/hr-FT²-°F	SC(1)	SHGC(1)	RHG(1) BTU/hr-FT²
Colors							
Coral Rose	1	76	70	1.01	0.89	0.77	190
Aquamarine	2	77	69	1.01	0.87	0.76	188
Smoke Gray	3	78	67	1.01	0.86	0.75	185
Sahara Sun	4	78	63	1.01	0.83	0.72	179
Ruby Red	5	48	62	1.01	0.83	0.72	178
Sapphire	6	52	55	1.01	0.77	0.67	167
Evening Shadow	7	49	48	1.01	0.72	0.62	156
Golden Light	8	85	69	1.01	0.88	0.76	188
Arctic Snow	9	68	60	1.01	0.78	0.68	170
Cool White	A	81	67	1.01	0.85	0.74	182
Deep Red	C	15	38	1.01	0.63	0.54	139
True Blue	D	12	42	1.01	0.66	0.57	145
Tangerine	E	21	54	1.01	0.75	0.65	163
Polar White	F	6	7	1.00	0.27	0.23	0.67

Information provided by Solutia Inc. The data and information set forth above are based on calculations and are not guaranteed for all samples or applications. All data calculated using Lawrence Berkeley National Laboratory Window 5.2 Product; NFRC/ASHRAE Conditions; center of Glass Values; USD Standard units. Laminates constructed as: 3 mm (0.125 inch) clear glass - (Saflex® Interlayer) - 3 mm (0.125 inch) Clear glass. Colored laminate configurations consist of 0.38 mm Saflex® interlayer. All other interlayer thicknesses as designated.

(1) **Trans.**–transmittance; **Refl.**–reflectance; **SC**–shading Coefficient; **SHGC**–solar heat gain coefficient; **RHG**–relative heat gain. For definition of terms, see Section 19 pages 7-11

Vanceva® is a trademark of Solutia Inc.

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Decorative Laminated Glass

Additional Important Information

Specifications

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Installation Guidelines

Guidelines

These guidelines are to be used in addition to, and in conjunction with, the guidelines in the latest edition of the *Glazing Manual* published by the Glass Association of North America and Oldcastle BuildingEnvelope™ *Glazing Instructions,* section 16, pages 1-6. These should be included as part of the glazing specifications. Failure to follow these guidelines may result in voiding of the warranty.

Setting Blocks

All laminated glass should be installed on setting blocks positioned on the lower edge at the quarter points. The setting block should have a Shore A durometer of 85 ± 5, support the entire thickness of the glass and be 0.1" long, per square foot of glazing, but not less than 4" in length. Ensure that the setting blocks are manufactured from Santoprene, Silicone, EPDM or any other material compatible with silicone and the rest of the glazing components. Pay particular attention to compatibility when the laminated glass contains a polycarbonate.

Clearances

Adequate clearances must be maintained to prevent glass damage or breakage as a result of glass-to-metal contact. A minimum of a 1/8" face clearance should be maintained using a cushioning material. Edge clearance should be a minimum of 1/4"; however, due to the expansion of polycarbonate, any laminate containing this material should have a 1/16" edge clearance per foot of glass length. To reduce in-service breakage, avoid excessive clamping pressures, especially on thin annealed glass, such as the low-spall glass on bullet-resistant materials.

Edge Engagement

All forced-entry and bullet resistant glass must have a minimum of a 1" edge engagement. Clearances and setting block allowances are in addition to this engagement. Any reduction in this edge engagement can cause the performance of the product to be reduced and the test certificate may no longer be applicable.

Weep System

The edges of laminated glass must not be exposed to standing water. All framing systems must be designed to accommodate a reliable weep system, as no cap seal is 100% reliable. In addition, it is extremely important that any cleaning solutions used on either face of the glass be allowed to drain out of the frame. It is the responsibility of the designer and the installer to ensure that the weep system works correctly. Do not glaze any laminated glass in a system without adequate drainage.

Sealants and Caulking

An appropriate sealant should be used to seal the glazing to the frame. Sealant and caulking manufacturers regularly change their products' raw materials. Therefore, it is essential that the installer checks with the appropriate manufacturer for compatibility of any product, before use. This is particularly important for security glazing containing polycarbonate, as some solvents used in sealants can cause crazing and ultimate failure of the product. This warning also applies to any varnishes, primers or paints used on the framing system. These finishes should be allowed to fully dry before glazing commences.

Threat Surface

Most bullet-resistant glazing products and some forced-entry products are not symmetrical and have a threat side, attack face or impact face. All glass of this type supplied by Oldcastle BuildingEnvelope™ is shipped with a removable label specifying the impact face. This side MUST be installed toward the threat side. Failure to do this can seriously affect the ability of the product to resist the specified threat. This label should be left on until final inspection and/or sign-off occurs.

Installation Guidelines

Guidelines (continued)

Storage

Shipments should be scheduled so that glass is stored on the site for a maximum of 30 days. If the glass is to be stored for longer than this, it should be removed from the construction site to a controlled environment. When on the site, store crates indoors, and keep them dry. Ensure that the stored glass remains above the dew point at all times; otherwise, condensation and staining can occur. Protect the crates from exposure and possible damage from the practices of other construction trades.

Handling

Only remove the glass from the crates when it is ready to be installed. Remove glass from the front of the crate—never by sliding to the side. On security glass with exposed polycarbonate, pay particular attention to this face. Never allow glass to rest on uncushioned surfaces. When exposed polycarbonate is supplied with a protective removable sheet, this must be removed immediately after the installation. Never allow the sun to bake this protective film on to the glazing. Never allow anything to rest against the glass. DO NOT install any glass that has been damaged, however slightly. Even small cracks at the edges can ultimately "run" due to thermal expansion while in service. Oldcastle BuildingEnvelope™ does not warrant glass breakage.

Cleaning

Do not expose the edges of any laminated glass to organic solvents, acids or any cleaner containing ammonia, which can react with the plastic components. Once the glazing is installed, the glazing contractor should ensure that the glazing is protected from possible damage caused by the construction practices of other trades.

Take particular care during the initial cleaning, especially if the surfaces are severely soiled. Never attempt to remove dry deposits. NEVER use a sharp blade or scraper to remove deposits or clean the glass.

First flush with water to soften and remove as many contaminants as possible. Then use a clean squeegee to remove excess water, ensuring that abrasive deposits do not get trapped between the squeegee and the glass surface. Then use a mild nonabrasive, nonalkaline cleaner and a soft, grit-free cloth to clean the glass. Rinse immediately with water, removing excess water with a squeegee.

For routine cleaning, a mild soap or detergent, with lukewarm water, can be used with a clean, grit-free cloth. Dry the surface immediately and never allow metallic or hard objects, such as razor blades or scrapers, to come into contact with the glass.

Cleaning Exposed Polycarbonate

All exposed polycarbonate has a mar-resistant coating; however, extra care must be taken to avoid scratching or other damage. Do not use any abrasive cleaners or solvents. Wash with a mild detergent and lukewarm water, using a clean, grit-free cloth. Rinse immediately with clean water and dry with a chamois or moist cellulose sponge to avoid water spots.

Fresh paint, grease and smeared glazing compounds can be removed using isopropyl alcohol. Afterward, wash with warm water and a mild detergent, as noted above.

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