English

Security Glazing



Photo: © juancajuarez - stock.adobe.com

kuraray Trosifol® SentryGlas®

Introduction

Interlayer strength, depth and capabilities

Delivering your window into the world of advanced interlayers for laminated safety glass, Kuraray's Advanced Interlayer Solutions Division (AIS) is underpinned by decades of innovation, application knowledge, domain experience and market success.

OUR ADVANCED INTERLAYER PORTFOLIO – comprising Trosifol® PVB and SentryGlas® ionoplast interlayers – has continually revolutionized aesthetic, structural and functional design, fabrication, installation and sustainability in the architectural and automotive/transportation segments.

Designed to benefit consumers, society and industry, our products are advancing the functionality of glass, while our engineers and consultants are setting new application benchmarks by collaborating on solutions that both sustain and inspire.

We are committed to helping you transform your mindset and take your applications to the next level – aesthetically, functionally and structurally. Enjoy greater design freedom and give your glazing strength, clarity, character and purpose with solutions that cover sustainability, safety, security, sound insulation, UV/solar/energy management, color and print.

OUR DIVERSE PRODUCT RANGE, the broadest on the global market and our domain expertise create strength; and we channel this strength into helping you succeed. We strive to be your strongest ally and supporter and will help you navigate and conquer the ever-changing demands of the global glass industry. Worldwide production, R&D and support, means we are always by your side … no matter where you are.





San Francisco Police Department, USA

Photo: © Tim Griffith / HOK + Mark Cavagnero Associates

More protection in aesthetic glass design

Architects are incorporating more glass in buildings for better aesthetics, improved daylighting, and occupancy comfort. Despite these benefits, glass is also the most vulnerable component of the building envelope when it comes to attacks by intruders. The use of laminated glass not only offers improved safety, but also can help to prevent intrusion. Laminated glass can be designed for enhanced performance beyond basic safety to provide burglary and forced entry resistance, as well as bullet resistance.

Kuraray offers a range of products to meet various security glazing requirements. Laminates made using Trosifol® PVB, Trosifol® Spallshield® CPET or SentryGlas® ionoplast interlayer provide superior durability when compared to glass clad polycarbonate solutions.

THE ORIGINAL
SentryGlas®

SentryGlas®

SENTRYGLAS® (SG®)

- SentryGlas® is 100 times stiffer and 5 times more tear resistant than PVB
- Excellent tear resistance-improved resistance from physical attack
- Lowest yellowness index of all interlayers. Ideal for use with low iron glass and /or thick laminates
- Provides highest level of security glazing performance

SENTRYGLAS XTRA® (SGX®)

- Next generation SentryGlas®
- Improvements over SentryGlas®
  - Improved optics over SentryGlas® in thick constructions making it an ideal choice in higher security protection constructions
  - Ideal for multi-ply laminates as no adhesion promoter required



Photo: © Joaquin Corbalan P/shutterstock.com



Photo: © Mr. Music/shutterstock.com

Trosifol®

TROSIFOL® CLEAR

- Meets global safety standards for safety glass
- Works very well to delay entry into building by attacker vs standard monolithic glass

TROSIFOL® ULTRACLEAR

- Ideal for use with low iron glass and / or thick laminates
- Lowest Yellowness Index of any PVB
- YID 0.76 mm < 0.4
- YID 7.6 mm < 4 vs traditional clear < 10.0

TROSIFOL® SPALLSHIELD® CPET

- Composite of polyester and durable hard coat that provides spall protection to occupants
- Spall is a term used to describe the action of glass splintering and flying inward after the glazing is struck by object or bullet
- Increases penetration resistance
- Commonly used in bullet resistant and high level bomb blast glazing

TROSIFOL® EXTRA STIFF PRO

- Higher stiffness relates to higher performance in load-bearing applications
- Trosifol® Extra Stiff Pro is more neutrally colored and perfectly complements low-iron glass
- Ideal for open edge application



Photo: © valeriy eydlin/shutterstock.com

Types of security glazing

Laminated glass can be designed to meet the requirements from basic safety to various types of intrusion. Security glazing is designed to deter intruders by making it difficult to gain entry through the glazing and delaying the time required to penetrate the glass. This delay gives law enforcement more time to respond, and may discourage the attacker from continuing the assault on the glass.

Types of laminated glass

	Safety	Enhanced	Forced entry
Entry delay time	<1 min	< 3 min	> 3 min
Threat to glazing	Accidental human impact Minimum requirement for lobby, entry, first floor windows and doors	Burglary / smash and grab	Very high risk areas, schools
Test method	ANSI Z97.1 EN12600 ASTM F3006 LPS 1270 Level B1 (with a 4.56 mm [180 mil] SG® construction)	UL 972 ASTM E2395 ASTM F3561 Level 1-3 EN 356 level 1-5	ASTM F1233 ASTM F3561 Level 4-6 HPW-TP-0500.03 EN356 level 6-8
Typical construction*	Glass 0.89 mm (35 mil) SG® Glass	Glass 2.28 mm (90 mil) SG® Glass	Glass 4.56 mm (180 mil) SG® Glass

TAB 1 * Adding double laminate IGU will further increase delay time to greater than 2 times the current amount of time. Depending on security level, may need to increase thickness of interlayer or add multiple plies of glass. For very high threat levels should consider a double laminate IGU. Results could vary due to differences in testing procedures and laboratories. The lamination process can impact final results.
The actual performance achieved may be affected by the quality controls employed by the laminator. It is therefore recommended to ensure the glazing unit supplied is covered by valid third party certification.

For specific glass makeups see additional info on each test method in the brochure.

Reference: NGA PG 07-0114 Glass Technical Paper, Security Glazing



Photo: © Brian A. Jackson/shutterstock.com



Enhanced forced entry	Vandal resistance	Ballistics protection
> 6 min	3-10 min attack	> 11 min
Very high risk areas, schools	Public buildings, transport	Ballistics protection
ASTM F1233 ASTM F3561 Level 7-8 HPW-TP-0500.03 5-aa1	ift Rosenheim E1-06/1 FE1 0 FE5 TP1 – TP5 LS1 – LS5	UL 752 (tested to the UL 752) EN 1063 NIJ 0108.01
Glass 6.84 mm (270 mil) SG® Glass	Glass** FE5 / TP5 / LS2 8 mm Float 3.8 mm SGX® 8 mm Float 3.8 mm SGX® 8 mm Heat Strengthened	Glass 1.52 mm (60 mil) SG® Glass 1.52 mm (60 mil) SG® Glass 1.52 mm (60 mil) SG® Glass 0.76 mm (30 mil) Trosifol® Clear / 0.18 mm (7 mil) Trosifol® Spallshield® CPET Multi-ply – Number of plies increases with threat level. Includes a layer of Trosifol® Spallshield® CPET on the occupant side to prevent spall of glass.

** Further classifications on page 13

Basic safety glazing

The table shows the constructions that meet global safety glazing codes.

Safety standards
(Americas with 3 mm annealed glass thickness)

Safety standards	CPSC 16 CFR 1201		ANSI Z97.1		CAN/CGSB 12.1 M90	
	Category I	Category II	Class B	Class A	Class B	Class A
3 mm (⅛“) AN – 0.38 mm (15 mil) Trosifol® Clear – ⅛“ (3 mm) AN	✓		✓		✓	
3 mm (⅛“) AN – 0.76 mm (30 mil) Trosifol® Clear – ⅛“ (3 mm) AN	✓	✓	✓	✓	✓	✓
3 mm (⅛“) AN – 0.76 mm (30 mil) SentryGlas® – ⅛“ (3 mm) AN	✓		✓		✓	
3 mm (⅛“) AN – 0.89 mm (35 mil) SentryGlas® – ⅛“ (3 mm) AN	✓	✓	✓	✓	✓	✓
3 mm (⅛”) AN – 0.89 mm (35 mil) SentryGlas Xtra® – ⅛” (3 mm) AN	✓	✓	✓	✓	✓	✓
3 mm (⅛”) AN – 0.76 mm (30 mil) SentryGlas Xtra® – ⅛” (3 mm) AN	✓		✓		✓	

Safety standards
(European standard with 4 mm annealed glass thickness)

Safety standards	EN12600		EN356	
	1B1	2B2	P2A	P1A
4 mm (⅛“) AN – 0.38 mm (15 mil) Trosifol® Clear – ⅛“ (4 mm) AN		✓		
4 mm (⅛“) AN – 0.76 mm (30 mil) Trosifol® Clear – ⅛“ (4 mm) AN	✓	✓		✓
4 mm (⅛“) AN – 0.76 mm (30 mil) SentryGlas® – ⅛“ (4 mm) AN		✓		✓
4 mm (⅛“) AN – 0.89 mm (35 mil) SentryGlas® – ⅛“ (4 mm) AN	✓	✓		✓
4 mm (⅛”) AN – 0.89 mm (35 mil) SentryGlas Xtra® – ⅛” (4 mm) AN	✓	✓		✓
4 mm (⅛”) AN – 0.76 mm (30 mil) SentryGlas Xtra® – ⅛” (4 mm) AN		✓		✓

TAB 2



Photo: © nyker/shutterstock.com

Forced entry

There are two categories of forced entry:

FORCED ENTRY

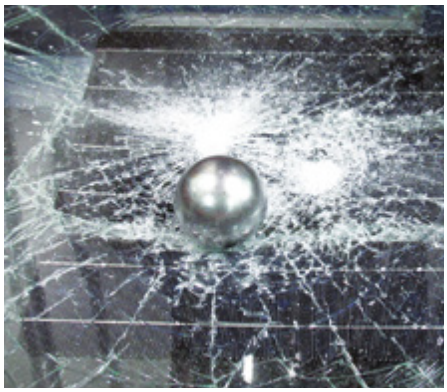
- ASTM F1233 Standard Test Method for Security Glazing Materials And Systems
- EN356 Glass in building - Security glazing - Testing and classification of resistance against manual attack
- UL972 UL Standard for Safety Burglary resisting glazing material

ENHANCED FORCED ENTRY

- Forced entry testing performed after weakening glass with ballistic assault. Bullets are allowed to penetrate the glazing.
- ASTM F1233 Standard Test Method for Security Glazing Materials and Systems – Multiple Ammunition Choices
- ASTM F3561 Standard Test Method for Forced-Entry-Resistance of Fenestration Systems After Simulated Active Shooter Attack
- 5-aa1 Certification Standards for Retrofitting and Reinforcing of Standard Commercial Entry Systems, Windows and Glazing (not a recognized standard)
- LPS 1270

UL 972 STANDARD FOR BURGLARY RESISTING MATERIAL

Underwriters Laboratories (UL) testing was conducted for multiple impacts and high impact energy at 21 – 27 °C. (70 - 80 °F.). Glazing that meet these requirements are typically used to deter smash and grab type threats seen in store fronts and display cases.



➔ Ball drop test

UNDERWRITERS LABORATORIES (UL) TESTING

- Multiple impacts required
- Five impacts of a 8.3 cm (3-1/4 inches) 2.27 kg (5 lb.) steel ball from a vertical height of 3 meters (10 feet)
- The High Energy Impact Test required one impact from a vertical height of 12 meters (40 feet).
- Pass criteria – no penetration of the glass

Minimum constructions to pass

Construction	Multiple impact penetrations	High energy impacts penetration
3 mm (⅛") annealed/1.52 mm (60 mil) SentryGlas®/3 mm (⅛") annealed	0	0
3 mm (⅛") annealed/1.52 mm (60 mil) Trosifol® Clear/3 mm (⅛") annealed	0	0

Forced entry and enhanced forced entry results

ASTM F1233

Test videos:

Sequence	Test implements	Impacts	Minutes	Class achieved
1	Ball pen hammer	10		1.0
2	Ball pen hammer	10		1.1
3	1-1/2" diameter pipe	25		1.2
4	Extinguisher, CO_2		1	1.3
5	Sledge hammer	25		1.4
6	Propane torch flame		5	1.5
7	Ripping bar	10		2.0
8	Ram	10		2.1
9	4" diameter pipe/sledge	25		2.2
10	Sledge hammer	25		2.3
11	Propane torch flame		5	2.4

TAB 4 First 11 of 41 sequences

Pass criteria
- Contraband - No opening that allows the passage of an 3 mm (1/8") diameter rod
- Body - No opening that allows the passage of an 20 cm x 20 cm x 12 cm (8" x 8" x 5") block



ASTM F1233 Torch test

ASTM F1233 INCLUDES THE FOLLOWING TYPES OF ATTACKS

- Blunt impacts
- Sharp tools
- Thermal stress
- Chemical deterioration

ASTM F1233 results (ballistics – 3 shots from 9 mm)

Interlayer product	Ballistics	Thickness [mm]	Thickness [mil]	Class achieved 1.0	1.1	1.2	1.3	1.4	1.5	2.0	2.1	2.2	2.3	2.4
Trosifol® Clear	w/o	1.52	60	●										
	w/o	2.28	90	●	●									
	w & w/o	4.56	180	●	●	●	●	●						
	w & w/o	6.84	270	●	●	●	●	●						
SentryGlas® ionoplast	w/o	1.52	60	●										
	w/o	2.28	90	●	●									
	w & w/o	4.56	180	●	●	●	●	●						
	w/o	6.84	270	●	●	●	●	●	●	●	●	●	●	
	w/	6.84	270	●	●	●	●	●						

TAB 5 w/o = without ballistic assault / w = with ballistic assault - bullet allowed to penetrate
Laminated glass only testing with 2 x 3 mm (2 x 1/8") annealed glass

All of the testing was conducted on a laminate only. A system that uses SentryGlas® stiffness has the potential to improve the system in this test.

5-aa1 Test method

- Ballistics with 7.62 mm NATO projectile followed by a series of attacks
- Pass criteria
  - No opening that allows passage of a 4" (10 cm) diameter ball without touching glazing



➔ 5-aa1 Sledge hammer test – Sentry Glas®

5-aa1 Test

Sequence	Test implements	Impacts	Minutes	Time to pass [min]
1	Shot 7.62 mm round	5		
2	Bricks	20		
3	Kicks with steel toe	10		
4	Tools set #1*		2	2
5	Tools set #2**		3-1/2	5.5
6	Sledge hammer		6	11.5

TAB 6 ➔ * Tools set #1: wrench, small 2 x 4 wood, claw hammer
** Tools set #2: 3 lb hammer, aluminum baseball bat

Ballistics allowed to penetrate the glazing.

5-aa1 Test results

Interlayer product	Thickness [mm]	Thickness [mil]	Ballistic impact 5 shots 7.62 mm	Concentrated assault 20 Bricks	Concentrated assault 10 Kicks	Forced entry Tools 2 min*	Forced entry Tools 3-1/2 min**	Forced entry Sledge hammer 6 min	Forced entry protocol time***	Notes
Trosifol® Clear	1.52	60	●	●					N/A	
	2.28	90	●	●	●				N/A	
	4.56	180	●	●	●	●	●		5 min 30 sec	
	6.84	270	●	●	●	●	●	●	11 min 30 sec	Small openings
SentryGlas® ionoplast	1.52	60	●	●	●				N/A	
	2.28	90	●	●	●	●			2 min	
	4.56	180	●	●	●	●	●	●	11 min 30 sec	Small openings
	6.84	270	●	●	●	●	●	●	11 min 30 sec	No openings

TAB 7 ➔ * 2 min tools - a small 5 x 10 cm (2 x 4"), claw hammer and wrench
** 3-1/2 min tools - 1.36 kg (3 lb.) hammer and aluminum baseball bat
*** Total test time is 11 min 30 seconds

Laminated glass only testing with 2 x 3 mm (2 x 1/8") annealed glass.

Ballistics allowed to penetrate the glazing.



Photo shue/stone:
© Petr Malyshev/Anton Starikov/shutterstock.com

ENHANCED FORCED ENTRY – ASTM F3561

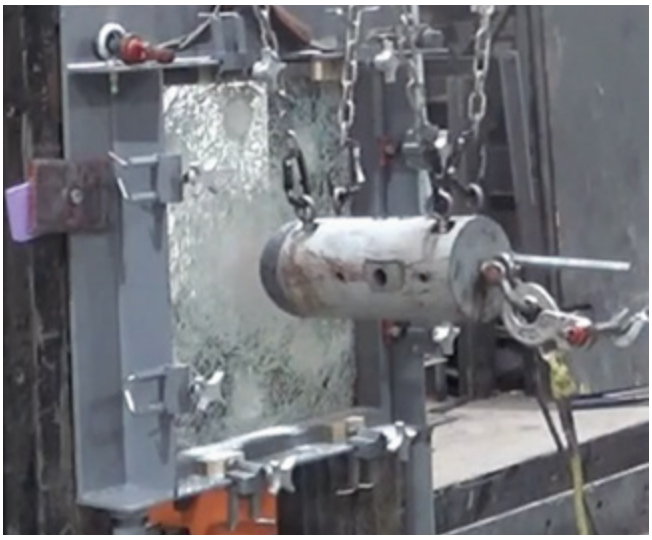
Simulates an active shooter forced entry situation where the glass is pre-weakened with shots from a 5.56 mm round followed by progressive impacts from a cylindrical impactor.

- Shot 10 x with AR-15 5.56 NATO FMJ
- The bullets are allowed to penetrate the laminate.
- Steel 152 mm (6") diameter impactor weighing 45 kg (100 lb) with a polymer nose cone
- 8 levels based on drop height
- 2 impacts per level
- Progressive impacts



Photo: © Campbell Boulanger

Elementary School in Tulsa, Oklahoma, USA



Enhanced Forced Entry – ASTM F3561

Level	Potential energy, J		Drop Heigth, H	
	[J]	[ft*lbf]	[mm]	[ft]
1	68	50	152	0.50
2	136	100	305	1.00
3	203	150	457	1.50
4	271	200	610	2.00
5	339	250	762	2.50
6	407	300	914	3.00
7	475	350	1067	3.50
8	542	400	1219	4.00

TAB 8

Enhanced Forced Entry – ASTM F3561 – Test results

Interlayer	Thickness		5.56 M193	Class achieved							
	[mm]	[in]	(10 shots)	1	2	3	4	5	6	7	8
Trosifol® PVB	1.52	0.060	Penetrated	●	●						
	2.28	0.090	Penetrated	●	●			●*			
	4.56	0.180	Penetrated	●	●	●	●	●			
	6.84	0.270	Penetrated	●	●	●	●	●	●	●	●
SentryGlas®	1.52	0.060	Penetrated	●	●						
	2.28	0.090	Penetrated	●	●	●				●*	
	4.56	0.180	Penetrated	●	●	●	●	●	●	●	●*
	6.84	0.270	Penetrated	●	●	●	●	●	●	●	●

TAB 9 Laminated Glass only testing with 2 x 3mm (2 x 1/8") Annealed Glass
Results per ASTM F3561-23 version

●* when tested in a system

Vandal resistance

HIGH-FORCE ATTACK AND PUBLIC-ORDER PROTECTION

Vandal-resistant glazing is designed to withstand deliberate, high-force attacks where glazing may be subjected to thrown objects, repeated heavy impacts and coordinated manual attack.

The ift Rosenheim Guideline EI-06/1 evaluates the complete glazing system, including glass, framing, hardware, anchorage and installation. Laminated glass constructions incorporating SentryGlas® and SentryGlas Xtra® interlayers provide outstanding post-breakage retention and resistance, making them particularly suitable for public buildings, transport hubs, retail environments and other vulnerable sites.



Three performance dimensions

FE – FORCED ENTRY

Manual attack using defined tools and physical force

FE1-FE5

TP – THROWING PROJECTILES

Impact from stones or similar thrown projectiles

TP1-TP5

LS – LIQUID SAFE

Resistance to an opening that permits incendiary liquids or devices

LS1-LS5

Test sequence

01 – PROJECTILE IMPACT

50 kg pendulum
3.2 kg impact adapter

02 – HEAVY CORNER IMPACT

50 kg cylindrical impactor

03 – MANUAL ATTACK

Specified hand tools
Class-dependent attack time

Forced entry performance

Class	Heavy-corner impacts	Manual attack [min]	Test team
FE1	5	3	2
FE2	7	4	2
FE3	9	5	2
FE4	11	7	4
FE5	13	10	4

TAB 10 ➔

BEYOND CONVENTIONAL EN356 TESTING

EN 356 resistance alone does not demonstrate performance under the combined high-force impact and manual-attack conditions evaluated by EI-06/1. Vandal-resistance performance depends on the complete installed glazing system and not solely on the glass construction.

Examples of tested SGX® glazing configurations



FE5 / TP5 / LS2

8 mm Float
3.8 mm SGX®
8 mm Float
3.8 mm SGX®
8 mm Heat Strengthened



FE5 / TP5 / LS4

8 mm Float
4.56 mm SGX®
8 mm Float
4.56 mm SGX®
8 mm Float
4.56 mm SGX®
8 mm Heat Strengthened



FE5 / TP5 / LS5

8 mm Float
5.32 mm SGX®
8 mm Float
5.32 mm SGX®
8 mm Float
5.32 mm SGX®
8 mm Heat Strengthened

Examples only. Classification applies to the tested complete glazing system, including framing, fixings, anchorage and installation.

Burglary resistance EN356

(Axe Test – Resistance against manual attack)

EN356 P1A THROUGH P5A

Impact-resistant safety glass provides protection from burglary and vandalism in buildings and resists unpremeditated assault on the glazing. The P-A categories defined in EN 356 cover five groups with ascending protective effect. The test method simulates heavy projectiles with the following test set-up:

EN356 TEST SET-UP

- **Steel ball: 4.11 kg (9 lb.) mass, 10 cm (4") diameter**
- **Laminated safety glass test size: 900 x 1100 mm (35.4 x 43.3")**
- **Test procedure: three steel balls are dropped from the same height onto an impact triangle. The test is passed if no ball smashes through the glass.**

EN 356 P6B THROUGH P8B

Penetration-resistant testing is conducted using a machine axe that simulates an attack using a handheld axe weighing 2 kg. The test established the number of strikes required to produce a 400 x 400 mm hole in a 900 x 1100 mm test specimen. The glazing is initially impacted with hammer strikes to break the glass before the axe strikes begin. The total number of hammer and axe strikes count toward the overall number of strikes. The rating is based on the number of strikes.

Significantly, thinner constructions are possible with SentryGlas® & SentryGlas Xtra®.

Thin constructions with SentryGlas®

Level	Total number of strikes	Total Trosifol® laminate thickness [mm]	Total SentryGlas® laminate thickness [mm]
P6B	30-50	21.8	11
P7B	51-70	22.5	11
P8B	Over 70	28	16.5

TAB 12



EN356 performance levels by construction

EN 356	Level	SentryGlas® ionoplast	SentryGlas Xtra® ionoplast	Trosifol® PVB
Ball drop test	P1A	3 mm (⅛") 0.76 mm (30 mil) 3 mm (⅛")	3 mm (⅛") 0.76 mm (30 mil) 3 mm (⅛")	3 mm (⅛") 0.76 mm (0.30 mil)* 3 mm (⅛")
	P2A	4 mm (5⁄32") 1.52 mm (60 mil) 4 mm (5⁄32")	4 mm (5⁄32") 1.52 mm (60 mil) 4 mm (5⁄32")	4 mm (5⁄32") 0.76 mm (0.30 mil)* 4 mm (5⁄32")
	P3A	4 mm (5⁄32") 1.52 mm (60 mil) 4 mm (5⁄32")	4 mm (5⁄32") 1.52 mm (60 mil) 4 mm (5⁄32")	4 mm (5⁄32") 1.14 mm (45 mil) 4 mm (5⁄32")
	P4A	4 mm (5⁄32") 2.28 mm (90 mil) 4 mm (5⁄32")		4 mm (5⁄32") 1.52 mm (60 mil) 4 mm (5⁄32")
	P5A	4 mm (5⁄32") 3.04 mm (120 mil) 4 mm (5⁄32")		4 mm (5⁄32") 2.28 mm (90 mil) 4 mm (5⁄32")
Axe test	P6B	4 mm (5⁄32") 3.04 mm (120 mil) 4 mm (5⁄32")	4 mm (5⁄32") 3.04 mm (120 mil) 4 mm (5⁄32")	3 mm (⅛") 1.52 mm (60 mil) 10 mm (⅜") 2.28 mm (90 mil) 5 mm (3⁄16")
	P7B	4 mm (5⁄32") 3.04 mm (120 mil) 4 mm (5⁄32")		4 mm (5⁄32") 0.76 mm (30 mil) 8 mm (5⁄16") 0.76 mm (30 mil) 5 mm (3⁄16") 0.76 mm (30 mil) 3 mm (⅛")
	P8B	4 mm (5⁄32") 2.28 mm (90 mil) 4 mm (5⁄32") 2.28 mm (90 mil) 4 mm (5⁄32") or 4 mm (5⁄32") 4.56 mm (180 mil) 4 mm (5⁄32")	4 mm (5⁄32") 2.28 mm (90 mil) 4 mm (5⁄32") 2.28 mm (90 mil) 4 mm (5⁄32") or 4 mm (5⁄32") 4.56 mm (180 mil) 4 mm (5⁄32")	4 mm (5⁄32") 0.76 mm (30 mil) 6 mm (¼") 0.76 mm (30 mil) 5 mm (3⁄16") 0.76 mm (30 mil) 6 mm (¼") 0.76 mm (30 mil) 4 mm (5⁄32")

TAB 13 ➔ * not valid for Trosifol® UltraClear

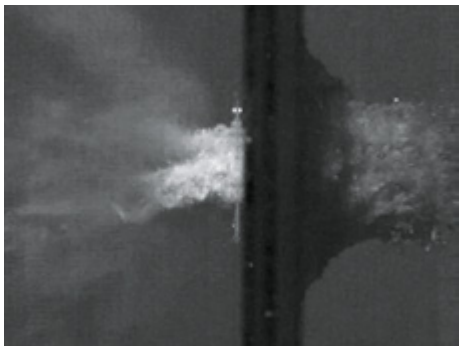
Bullet resistant

Depending on the desired level of protection, bullet resistant glass – also known as transparent armored glass in the automotive industry – is made up of multiple layers of laminated materials, including glass panes, transparent ceramic, acrylic, interlayers, and plastic glazing sheet material. Additionally, there are a variety of choices within each material category.

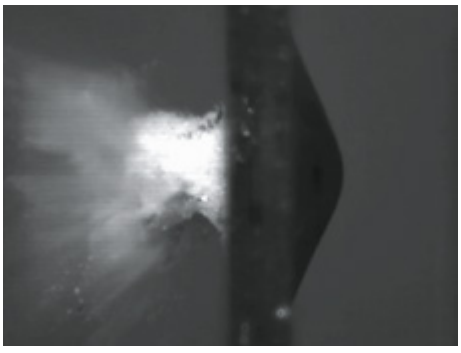
Different types of glass have different densities and hardnesses due to their different chemical compositions. A bulletproof laminate can have plastic glazing material integrated within it or utilized as an exposed anti-spall layer. Polyurethane (PU), ionomers, or polyvinylbutyral (PVB) are typical materials used as interlayers. Those interlayers can offer varying degrees of ballistic resistance, in addition to chemistry, stiffness, viscoelastic characteristics, and adherence to glass and other materials. There can be no incompatibility in the materials used.

BALLLISTIC TESTS WITH INTERLAYER MATERIALS

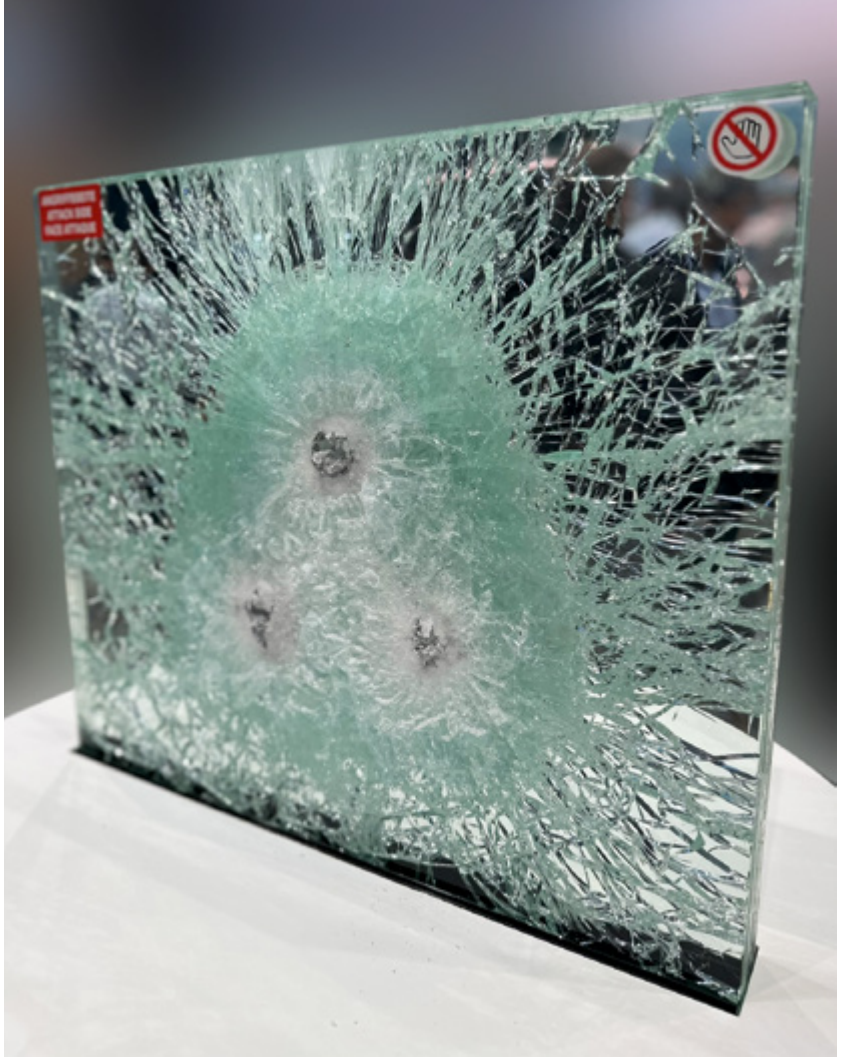
The tests investigates the ballistic resistance of interlayers in multi-layered laminates. Researchers prepared interlayer blocks with regular PVB film and ionoplast interlayer, stacked together to form a block. They used a conventional test set-up and a high-speed camera to determine the depth of penetration (DoP) for projectiles. The results showed significant differences in DoP for regular PVB and ionoplast interlayers, highlighting the importance of interlayers in multi-layered laminates.



without Trosifol® Spallshield® CPET



with Trosifol® Spallshield® CPET

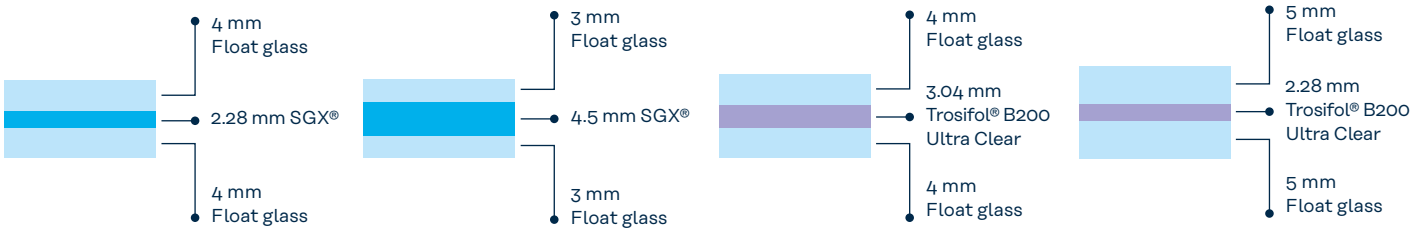


New BRG test results (2022-2024)

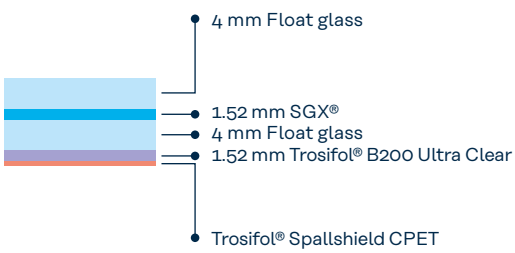
Test standard EN 1063:

BR 1 (all with official test reports)

A possibility to visualize the difference in thickness between SGX® and PVB laminate



BR1 NS (with official test report)



Bullet resistant configurations that comply with two of the EN 1063 standard threat levels are shown below:

European standard EN 1063

Threat level	Ammu-nition	Required velocity [mps]	[fps]	Composition	Thickness [mm]	[in]	Weight [kg/m²]	[lbs/ft²]	Number of shots
BR 1 S	0.22 LR	350-370	1148-1214	3 mm (⅛“) Float/ 4.56 mm (180 mil) SentryGlas Xtra®/ 3 mm (⅛“) Float	10.0	0.39	18.30	3.75	3
BR 1 S	0.22 LR	350-370	1148-1214	4 mm (5⁄32“) Float/ 2.28 mm (90 mil) SentryGlas Xtra®/ 4 mm (5⁄32“) Float	9.8	0.38	21.02	4.31	3
BR 1 S	0.22 LR	350-370	1148-1214	4 mm (5⁄32“) Float/ 3.04 mm (120 mil) Trosifol® UltraClear/ 4 mm (5⁄32“) Float	10.5	0.41	22.02	4.51	3
BR 1 NS	0.22 LR	350-370	1148-1214	4 mm (5⁄32“) Float/ 1.52 mm (60 mil) SentryGlas Xtra®/ 4 mm (5⁄32“) Float/ 1.52 mm (60 mil) Trosifol® UltraClear/ 0.18 mm (7 mil) Trosifol® Spallshield® CPET	10.8	0.43	22.56	4.62	3
BR 3 S	0.357 Magnum	420-440	1378-1444	3 mm (⅛“) Float/ 0.76 mm (30 mil) SentryGlas Xtra®/ 5 mm (3⁄16“) Float/ 0.76 mm (30 mil) SentryGlas Xtra®/ 5 mm (3⁄16“) Float/ 2.28 mm (90 mil) SentryGlas Xtra®/ 3 mm (⅛“) Float	19.0	0.75	41.88	8.58	3
BR 3 NS	0.357 Magnum	420-440	1378-1444	3 mm (⅛“) Float/ 0.76 mm (30 mil) SentryGlas Xtra®/ 5 mm (3⁄16“) Float/ 0.76 mm (30 mil) SentryGlas Xtra®/ 5 mm (3⁄16“) Float/ 2.28 mm (90 mil) SentryGlas Xtra®/ 3 mm (⅛“) Float/ 1.52 mm (60 mil) Trosifol® UltraClear/ 0.18 mm (7 mil) Trosifol® Spallshield® CPET	20.6	0.81	43.59	8.93	3
BR 4 NS	0.44 Magnum	430-450	1411-1476	6 mm (¼“) Annealed glass/ 0.89 mm (35 mil) SentryGlas®/ 6 mm (¼“) Annealed glass/ 5 mm (3⁄16“) SentryGlas®/ 2.5 mm (3⁄32“) Annealed glass/ 1.52 mm (60 mil) Trosifol® UltraClear/ 0.18 mm (7 mil) Trosifol® Spallshield® CPET	21.3	0.84	41.72	8.5	3
BR 6 NS	7.62 x 51 mm (M80)	820-840	2690-2755	8 mm (5⁄16“) Annealed glass/ 0.76 mm (30 mil) Trosifol® Clear/ 8 mm (5⁄16“) Annealed glass/ 0.76 mm (30 mil) Trosifol® Clear/ 8 mm (5⁄16“) Annealed glass/ 0.76 mm (30 mil) Trosifol® Clear/ 6 mm (¼“) Annealed glass/ 5 mm (3⁄16“) SentryGlas®/ 2.5 mm (3⁄32“) Annealed glass/ 1.52 mm (60 mil) Trosifol® UltraClear/ 0.18 mm (7 mil) Trosifol® Spallshield® CPET	39.5	1.55	85.92	17.6	3

TAB 14

SentryGlas Xtra® (SGX®) constructions

Threat level	Ammu-nition	Required velocity [mps]	[fps]	Composition	Thickness [mm]	[in]	Weight [kg/m²]	[lbs/ft²]	Number of shots
BR 1 NS	0.22 LR	360	1181	4 mm (5⁄32“) Annealed glass/ 1.52 mm (60 mil) SentryGlas Xtra®/ 4 mm (5⁄32“) Annealed glass/ 0.76 mm (30 mil) Trosifol® UltraClear/ 0.18 mm (7 mil) Trosifol® Spallshield® CPET	10.8	0.43	22.6	4.63	3
BR 3 NS	0.357 Magnum	430	1411	3 mm (⅛“) Annealed glass/ 0.76 mm (30 mil) SentryGlas Xtra®/ 5 mm (3⁄16“) Annealed glass/ 0.76 mm (30 mil) SentryGlas Xtra®/ 5 mm (3⁄16“) Annealed glass/ 2.28 mm (90 mil) SentryGlas Xtra®/ 3 mm (⅛“) Annealed glass/ 1.52 mm (60 mil) Trosifol® UltraClear/ 0.18 mm (7 mil) Trosifol® Spallshield® CPET	20.7	0.81	43.6	8.93	3
BR 4 NS	0.44 Magnum	430-450	1411-1476	6 mm (¼“) Annealed glass/ 0.89 mm (35 mil) SentryGlas Xtra®/ 6 mm (¼“) Annealed glass/ 5 mm (3⁄16“) SentryGlas Xtra®/ 2.5 mm (3⁄32“) Annealed glass/ 1.52 mm (60 mil) Trosifol® UltraClear/ 0.18 mm (7 mil) Trosifol® Spallshield® CPET	21.3	0.84	41.72	8.5	3
BR 6 NS	7.62 mm x 51 mm (M80)	820-840	2690-2755	8 mm (5⁄16“) Annealed glass/ 0.76 mm (30 mil) SentryGlas Xtra®/ 8 mm (5⁄16“) Annealed glass/ 0.76 mm (30 mil) SentryGlas Xtra®/ 8 mm (5⁄16“) Annealed glass/ 0.76 mm (30 mil) SentryGlas Xtra®/ 6 mm (¼“) Annealed glass/ 3.04 mm (120 mil) SentryGlas Xtra®/ 3 mm (18“) Annealed glass/ 1.52 mm (60 mil) Trosifol® UltraClear/ 0.18 mm (7 mil) Trosifol® Spallshield® CPET	41.4	1.63	87.39	17.9	3
BR 6 NS	7.62 mm x 51 mm (M80)	820-840	2690-2755	8 mm (5⁄16“) Annealed glass/ 0.76 mm (30 mil) Trosifol® Clear/ 8 mm (5⁄16“) Annealed glass/ 0.76 mm (30 mil) Trosifol® Clear/ 8 mm (5⁄16“) Annealed glass/ 0.76 mm (30 mil) Trosifol® Clear/ 6 mm (¼“) Annealed glass/ 5 mm (3⁄16“) SentryGlas Xtra®/ 2.5 mm (3⁄32“) Annealed glass/ 1.52 mm (60 mil) Trosifol® UltraClear/ 0.18 mm (7 mil) Trosifol® Spallshield® CPET	39.5	1.55	85.92	17.6	3

TAB 15 →





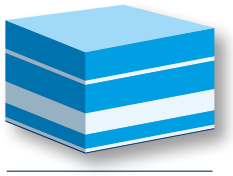
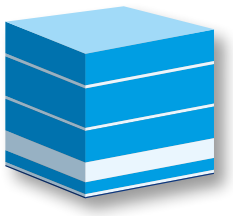
→ Trosifol® Spallshield® CPET impact test

Bullet resistant configurations that have been tested and found to comply with commonly specified Indoor UL Standard threat levels are shown below:

Indoor UL 752 Standard for Bullet Resisting Equipment

Threat level	Ammunition	Nominal bullet mass [g]	[grains]	Required velocity [mps]	[fps]	Composition
1	9 mm full metal copper jacket with lead core	8.0	124	358-394	1175-1293	6 mm (¼“) Annealed glass/ 0.89 mm (35 mil) SentryGlas®/ 6 mm (¼“) Annealed glass/ 4.5 mm (177 mil) SentryGlas®/ 3 mm (⅛“) Annealed glass/ 0.76 mm (30 mil) Trosifol® UltraClear/ 0.18 mm (7 mil) Trosifol® Spallshield® CPET
2	0.357 Magnum jacketed lead soft point	10.2	158	381-419	1250-1375	3 mm (⅛“) Annealed glass/ 0.89 mm (35 mil) SentryGlas®/ 5 mm (3⁄16“) Annealed glass/ 0.89 mm (35 mil) SentryGlas®/ 5 mm (3⁄16“) Annealed glass/ 4.5 mm (177 mil) SentryGlas®/ 3 mm (⅛“) Annealed glass/ 0.76 mm (30 mil) Trosifol® UltraClear/ 0.18 mm (7 mil) Trosifol® Spallshield® CPET
3	0.44 Magnum, lead semi-wadcutter gas checked	15.6	240	411-441	1350-1447	4 mm (5⁄32“) Annealed glass/ 0.89 mm (35 mil) SentryGlas®/ 6 mm (¼“) Annealed glass/ 0.89 mm (35 mil) SentryGlas®/ 6 mm (¼“) Annealed glass/ 4.5 mm (177 mil) SentryGlas®/ 3 mm (⅛“) Annealed glass/ 0.76 mm (30 mil) Trosifol® UltraClear/ 0.18 mm (7 mil) Trosifol® Spallshield® CPET
4	0.30-60 caliber rifle lead core soft point	11.7	180	774-852	2540-2794	8 mm (5⁄16“) Annealed glass/ 0.76 mm (30 mil) Trosifol® Clear/ 10 mm (⅜“) Annealed glass/ 0.76 mm (30 mil) Trosifol® Clear/ 8 mm (5⁄16“) Annealed glass/ 5 mm (3⁄16“) SentryGlas®/ 3 mm (⅛“) Annealed glass/ 0.76 mm (30 mil) Trosifol® UltraClear/ 0.18 mm (7 mil) Trosifol® Spallshield® CPET
5	7.62 mm rifle lead core full metal copper jacket, military ball	9.7	150	838-922	2750-3025	8 mm (5⁄16“) Annealed glass/ 0.76 mm (30 mil) Trosifol® Clear/ 10 mm (⅜“) Annealed glass/ 0.76 mm (30 mil) Trosifol® Clear/ 8 mm (5⁄16“) Annealed glass/ 5 mm (3⁄16“) SentryGlas®/ 3 mm (⅛“) Annealed glass/ 0.76 mm (30 mil) Trosifol® UltraClear/ 0.18 mm (7 mil) Trosifol® Spallshield® CPET
6	9 mm full metal copper jacket with lead core	8.0	124	427-469	1400-1540	8 mm (5⁄16“) Annealed glass/ 0.76 mm (30 mil) Trosifol® Clear/ 10 mm (⅜“) Annealed glass/ 0.76 mm (30 mil) Trosifol® Clear/ 8 mm (5⁄16“) Annealed glass/ 5 mm (3⁄16“) SentryGlas®/ 3 mm (⅛“) Annealed glass/ 0.76 mm (30 mil) Trosifol® UltraClear/ 0.18 mm (7 mil) Trosifol® Spallshield® CPET

TAB 16 ➔ Tested to the 11th edition of the UL 752 standard

Thickness [mm]	[in]	Weight [kg/m²]	[lbs/ft²]	Number of shots
21.6	0.85	44.24	9.1	3
				
22.4	0.88	44.78	9.17	3
25.4	1.00	52.20	10.7	3
36.4	1.43	79.63	16.3	1
36.2	1.43	78.67	16.1	1
				
36.5	1.44	79.42	16.3	5





Bullet resistant configurations that comply with several of the NIJ Standard threat levels are shown below:

NIJ 0108.01 Ballistic Protective Glazing Materials

Threat level	Ammunition	Nominal bullet mass [g]	[grains]	Required velocity [mps]	[fps]	Composition
I	0.22 long rifle high velocity lead	2.6	40	320±12	1050±40	3 mm (⅛") Annealed glass/ 5 mm (³⁄₁₆") SentryGlas®/ 2.5 mm (³⁄₃₂") Annealed glass/ 0.76 mm (30 mil) Trosifol® UltraClear/ 0.18 mm (7 mil) Trosifol® Spallshield® CPET
	.38 special round nose lead	10.2	158	259±15	850±50	
II-A	0.357 Magnum jacketed soft point	10.2	158	381±15	1250±50	4 mm (⁵⁄₃₂") Annealed glass/ 0.89 mm (35 mil) SentryGlas®/ 4 mm (⁵⁄₃₂") Annealed glass/ 5 mm (³⁄₁₆") SentryGlas®/ 2.5 mm (³⁄₃₂") Annealed glass/ 1.52 mm (60 mil) Trosifol® UltraClear/ 0.18 mm (7 mil) Trosifol® Spallshield® CPET
	9 mm full metal jacket	8.0	124	332±12	1090±40	
II	0.357 Magnum jacketed soft point	10.2	158	425±15	1395±50	4 mm (⁵⁄₃₂") Annealed glass/ 0.89 mm (35 mil) SentryGlas®/ 4 mm (⁵⁄₃₂") Annealed glass/ 5 mm (³⁄₁₆") SentryGlas®/ 2.5 mm (³⁄₃₂") Annealed glass/ 1.52 mm (60 mil) Trosifol® UltraClear/ 0.18 mm (7 mil) Trosifol® Spallshield® CPET
	9 mm full metal jacket	8.0	124	358±12	1175±40	
III-A	0.44 Magnum lead semi-wadcutter gas checked	15.5	240	426±15	1400±50	6 mm (¼") Annealed glass/ 0.89 mm (35 mil) SentryGlas®/ 6 mm (¼") Annealed glass/ 5 mm (³⁄₁₆") SentryGlas®/ 2.5 mm (³⁄₃₂") Annealed glass/ 1.52 mm (60 mil) Trosifol® UltraClear/ 0.18 mm (7 mil) Trosifol® Spallshield® CPET
	9 mm full metal jacket	8.0	124	426±15	1400±50	
III	7.62 mm (.308 Winchester) full metal jacket	9.7	150	838±50	2750±50	2.5 mm (³⁄₃₂") Annealed glass/ 0.76 mm (30 mil) Trosifol® Clear/ 8 mm (⁵⁄₁₆") Annealed glass/ 0.76 (30 mil) mm Trosifol® Clear/ 10 mm (⅜") Annealed glass/ 0.76 (30 mil) mm Trosifol® Clear/ 8 mm (⁵⁄₁₆") Annealed glass/ 5 mm (³⁄₁₆") SentryGlas®/ 2.5 mm (³⁄₃₂") Annealed glass/ 1.52 mm (60 mil) Trosifol® UltraClear/ 0.18 mm (7 mil) Trosifol® Spallshield® CPET

TAB 17

Typical applications for bullet-resistant glazing are military installations, banks, prisons, detention centers, prisons and embassies.

Thickness [mm]	[in]	Weight [kg/m²]	[lbs/ft²]	Number of shots
11.6	0.46	19.92	4.1	5
18	0.71	33.5	6.9	5
18	0.71	33.5	6.9	5
21.4	0.84	42.2	8.6	5
37.9	1.49	81.2	16.63	5





Photo: © YKK AP

Behavioral health – psychiatric hospitals

Behavioral health care facilities must minimize risk to patient safety while maintaining a caring and nurturing atmosphere. To ensure safety, behavioral health facilities must meet accreditation standards. Risk is determined by several factors such as population served, patient supervision, and ability of staff to intervene.

Risk can vary throughout parts of the building and patient access to objects. High risk areas are seclusion rooms, bedrooms and comfort spaces.

American Architectural Manufacturers Association (AAMA) 501.8, standard test method for determination of resistance to human impact of window systems intended for use in psychiatric applications.



Photo: © Mike_shots/shutterstock.com

TEST METHOD

- **This test assumes a patient is running into a window or strikes or throws an object against it. The energy must be transferred to the hardware, frames and substrates.**
- **Human impact can impart as much as 2.7 kJ (2,000 ft - lbs.) of energy based on shoulder impact of 90.7 kg (200 lbs.) person moving at 7.62 m (25 ft. /sec)**
- **Test requires a 90.7 kg (200 lbs.) dropped from 3 meters (10 feet)**
- **Pass criteria: the impact test load has not breeched or penetrated the inner most glazing layer. The inner most glazing remains held in place within the window frame**

Construction that meets this requirement

Interior glass of IGU
4 mm (5⁄32″) heat strengthen glass
2.28 mm (90 mil) SentryGlas®
4 mm (5⁄32″) heat strengthen glass
0.15 mm (6 mil) spall protective layer (occupant side)

TAB 18 ➔

UNITED STATES DEPARTMENT OF STATE (DOS) APPROVALS

- **Certified SentryGlas® interlayers for SD-STD-01.01 for forced entry (FE) and ballistics resistance (BR) for US Embassies in 2010**
- **In 2020, SentryGlas Xtra® (SGX®) was certified for use in forced entry (FE) and ballistics resistance (BR) applications for US embassies. SentryGlas Xtra® provides improved optical performance in thicker constructions.**
- **In 2026, two glazing constructions incorporating SentryGlas Xtra® (SGX®) successfully met the requirements of the Department of State's SD-STD-01.01 Rev H standard for forced entry (FE) and ballistics resistance (BR). These constructions also provide an option for a field-replaceable spall liner.**
- **Physical delamination of GCP products is a phenomenon that has been well-documented, resulting in significant maintenance and replacement costs. Testing to SD-STD-01.01 Rev H demonstrates that SGX® laminated glazing systems are a viable alternative to GCP systems and can help reduce life cycle costs because they do not experience delamination.**

The following pass SD-STD-01.01 Rev H certification for 15 minute Forced Entry and Rifle Ballistic Resistance.



UNCLASSIFIED

UNITED STATES DEPARTMENT OF STATE
Bureau of Diplomatic Security
Physical Security Programs/Physical Security Division

05/20/2026

Revision H Compliant, DS/PSD/RD Designed Glazing Release,

Dear Forced Entry/Ballistic Resistant System Manufacturers:

(U) The Bureau of Diplomatic Security, Physical Security Division, is pleased to release SD-STD-01.01, Revision H-compliant SentryGlas Xtra® glazing options. FE/BR Manufacturers may request DS FE/BR Certification, in accordance with Department requirements, to adopt and integrate these glazing(s) into previously certified Revision H window systems.

(U) This stems from a multi-year initiative by DS to create cost-effective, Revision H compliant glazing option(s) with a longer life cycle and replaceable spall-liners that address known performance issues associated with traditional glass-clad polycarbonate glazing and fragile PET film spall liners.

(U) Thank you for your ongoing dedication and efforts to protect U.S. diplomatic facilities worldwide.

UNCLASSIFIED

➔ Please ask your Kuraray contact if you like to have this letter.

Exterior/Threat Face

Construction
Heat Strengthened Glass
1.52 mm (0.06 inch) SGX®
Heat Strengthened Glass
2.53 mm (0.1 inch) SGX®
Heat Strengthened Glass
- air gap -
Heat Strengthened Glass
2.53 mm (0.1 inch) SGX®
Heat Strengthened Glass
2.53 mm (0.1 inch) SGX®
Heat Strengthened Glass
- air gap -
Annealed Glass
1.52 mm (0.06 inch) SGX®
Annealed Glass
0.76 mm (0.03 inch) PVB
0.18 mm (0.007 inch) PET Film*
Interior/Protected Face

TAB 19 ➔ * Either SRWF or PVB/CPET are approved and can be used

Exterior/Threat Face

Construction
Heat Strengthened Glass
2.53 mm (0.1 inch) SGX®
Heat Strengthened Glass
2.53 mm (0.1 inch) SGX®
Heat Strengthened Glass
- air gap -
Annealed Glass
2.53 mm (0.1 inch) SGX®
Annealed Glass
2.53 mm (0.1 inch) SGX®
Annealed Glass
- air gap -
Annealed Glass
1.52 mm (0.06 inch) SGX®
Annealed Glass
0.76 mm (0.03 inch) PVB
0.18 mm (0.007 inch) PET Film*
Interior/Protected Face

TAB 20 ➔ * Either SRWF or PVB/CPET are approved and can be used

Contact



FOR FURTHER INFORMATION
on products from Kuraray, please visit www.kuraray.com.
You can find further information on our Trosifol® and SentryGlas® products at www.trosifol.com.

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11/2026

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WORLD OF INTERLAYERS

New world of possibilities in Security Glazing.

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