DuPont™ SentryGlas®:

Safety, design possibilities & efficiencies. Latest innovations and developments

Kamal Niazy

DuPont Glass Laminating Solutions

Advances in Design with Laminated Glass

SentryGlas® interlayer

- Interlayer requirements: What do you need?
- Strength under loading
- Calculation methods
  - Approvals – France
- Post glass breakage - Overhead Glazing
- Fire performance – London underground testing
- Special applications - Cost saving with SentryGlas® interlayer
- Compatibility study with Dow Corning sealants

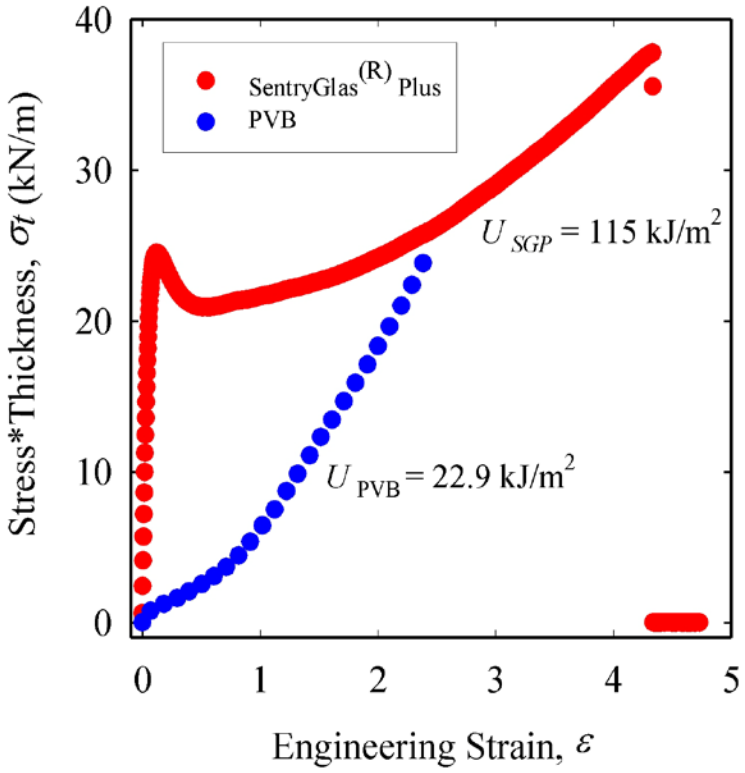
Interlayer Requirements for Architectural Glazing

What do architects & specifiers need?

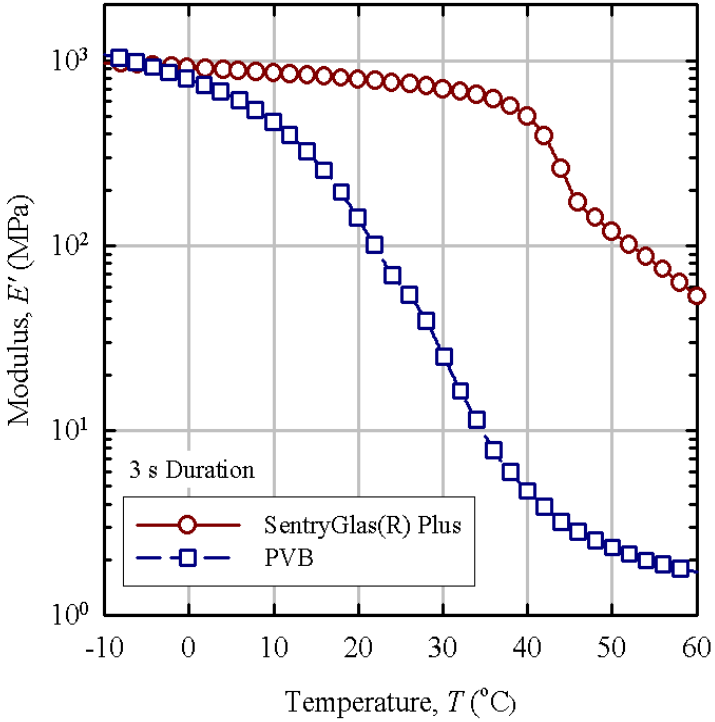
- Safety: Safe breakage and fragment retention
- Enhanced impact performance; greater security from range of threats; e.g. severe weather and man-made threats
- More demanding strength/deflection performance both pre & post glass breakage
- Greater durability/lifetime demands
- High temperature performance
- Cost efficiency

Greater scope for using stiffer, tough structural polymers

Structural interlayers: What is different?
Viscoelastic Properties

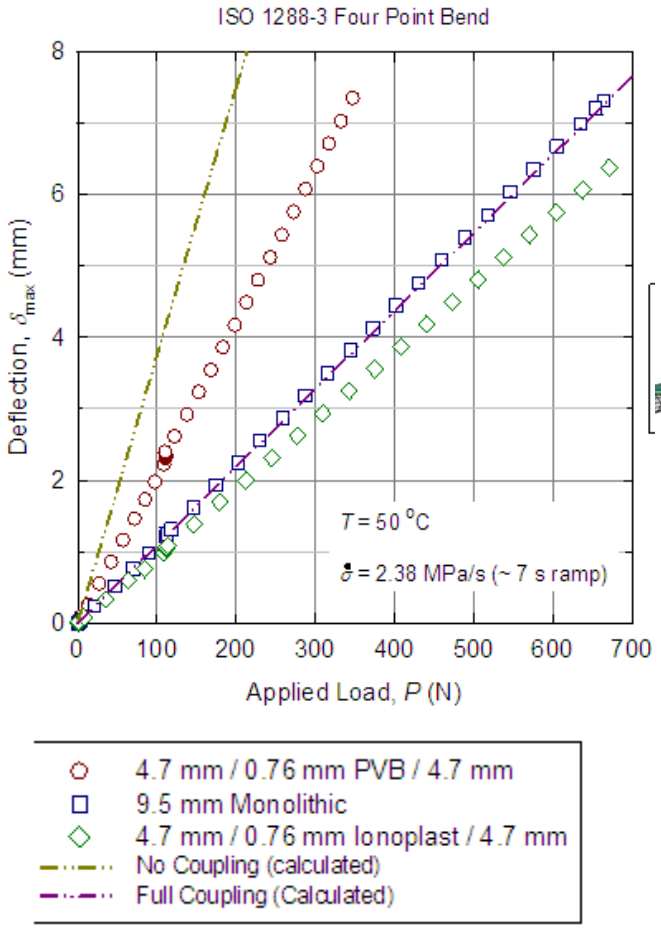


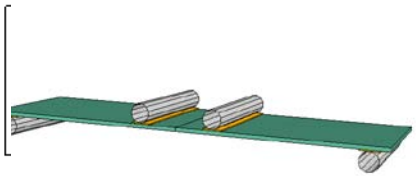
Standard test method for polymers (e.g. ASTM D 4065)

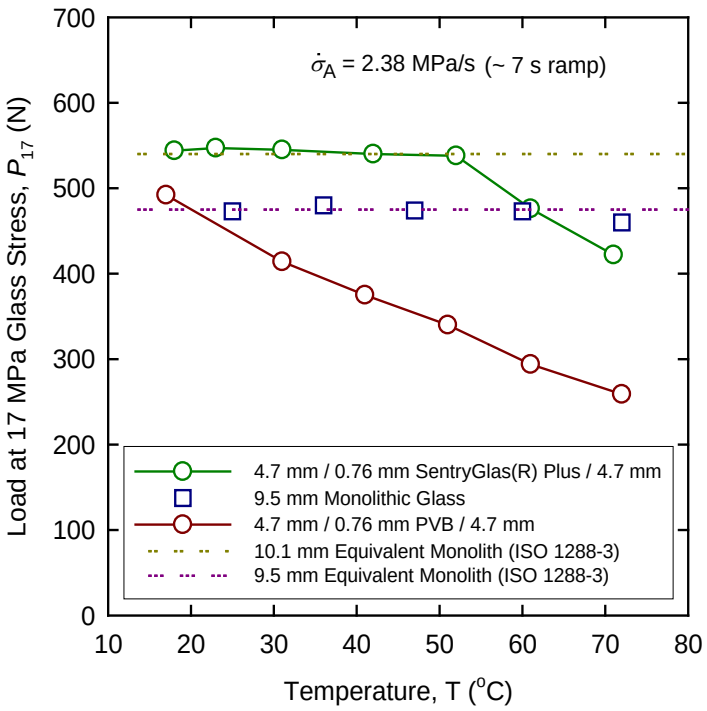


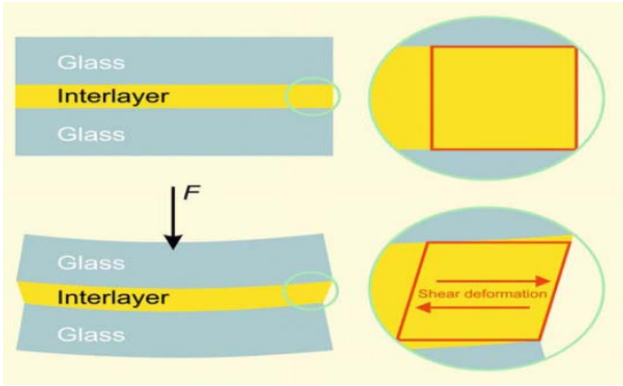
SentryGlas® is stiffer than PVB over a wide range of temperatures

Deflection Data for Laminated Glass









Laminates with SentryGlas® develop least deflection at a specified applied load – Note thickness differences

Strong Coupling Effect by the stiff SentryGlas®

SentryGlas® interlayer for laminated glass

What does it mean - Higher strength

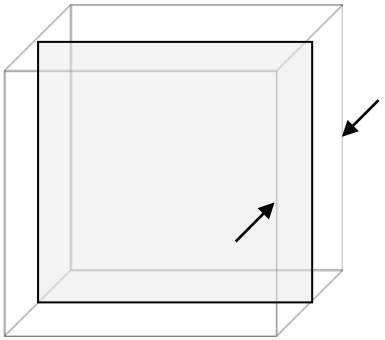
SentryGlas® provides a strong coupling effect of the glass panes.

- Larger spans
- Use of thinner glass

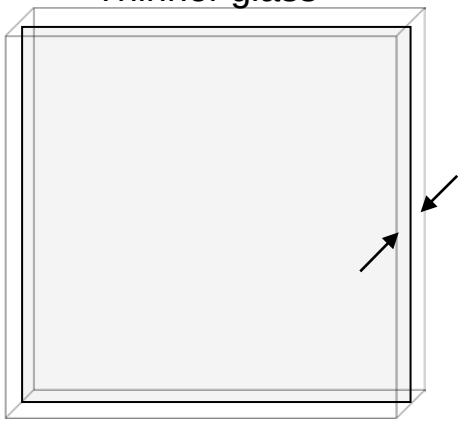
Thinner glass can translate to overall **lower cost:**

- ✓ Lower cost of glass
- ✓ Reduced framing costs
- ✓ Decreased installation costs

Traditional Interlayer:
Smaller spans
Thick glass



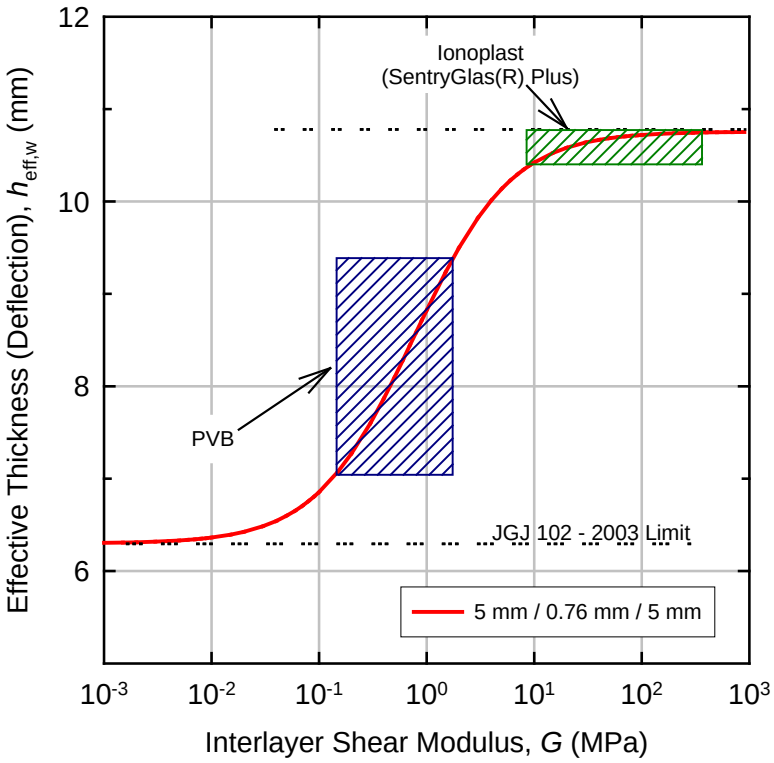
SentryGlas® interlayer:
Larger spans
Thinner glass

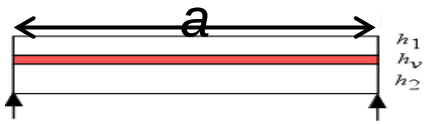


*DuPont™ Strength of Glass Calculator available free on the web (www.sentryglas.com)

SentryGlas® Strength Approvals

- Laminate effective thickness method – Adopted by ASTM E1300-2009
- German Dibt Approval: product approval and coupling effect (2011)
- Nearly similar approach in the European Code DRAFT EN 13474 / WG8 with ω interlayer stiffness families + numerical approach with G modulus.





$$h_{ef;w} = \sqrt[3]{h_1^3 + h_2^3 + 12\Gamma I_s}$$

$$\Gamma = \frac{1}{1+9.6\frac{EI_s h_v}{Gh_s^2 a^2}}$$

G – measure of shear transfer (0 –> 1)

Use effective thickness in engineering formulae / analytical approach.

SentryGlas® DTA french approval Approval

Document Technique d'Application

Référence Avis Technique **6/12-2086**

Vitrage feuilleté
Limited glass
Texte en allemand

Vitrage feuilleté

SentryGlas®

Relevant de la norme	**NF EN 14449**

Titulaire : Société DuPont de Nemours (France) S.A.S
23/25 rue Delarivière Lefoullon-Défense 9
FR-92800 Puteaux

SentryGlas® French DTA approval

Stabilité – Sécurité sous poids propre et sous charges climatiques

Il est prévu 2 possibilités de vérifications.

a) Calcul dans le cas de VEA et VEC

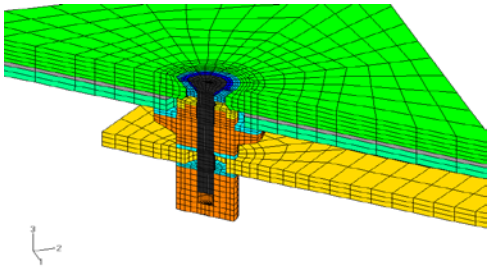
La définition du coefficient ε avec les valeurs précisées dans le tableau suivant (ε_f et ε_c) correspond à celle donnée dans le cahier du CSTB 3488_V2 relatif aux Vitrages Extérieurs Collés (paragraphe 2.3.1.3) ou bien celle découlant de l'annexe A du cahier du CSTB 3574_V2 relatif aux VEA.

Dans le cas de vitrages SentryGlas®, les valeurs de (ε_f et ε_c) prises en compte que cela soit des VEC ou VEA seront :

Type de chargement	ε_f (calcul flèche)	ε_c (calcul contraintes)
Vent	0,70	0,40
Neige	0,40	0,25
Poids propre	0,00	0,00

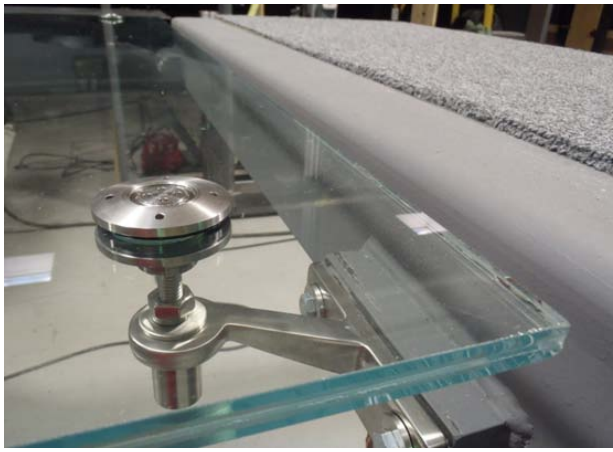
Approach

- Approval for wind, live and snow loads.
- Equivalent thickness method
- Maximum temp of SentryGlas® laminates is 80 °C (PVB 63 °C)
- Nearly "fully monolithic" behavior for wind loads
- Significant glass thickness reduction!



Overhead Impact Testing Program

- Comparing laminates Structure with different interlayers
  - Monolithic — **12mm FT (50KG @ room temp)**
  - SentryGlas® — **6mmFT/0.89mm SGP/6mmFT**
  - PVB — **6mmFT/1.52mm PVB/6mmFT**
  - “Stiff” PVB — **6mmFT/1.52mm Stiff PVB/6mmFT**
  - EVA — **6mmFT/1.52mm EVA/6mmFT**



- Tested Conditions:

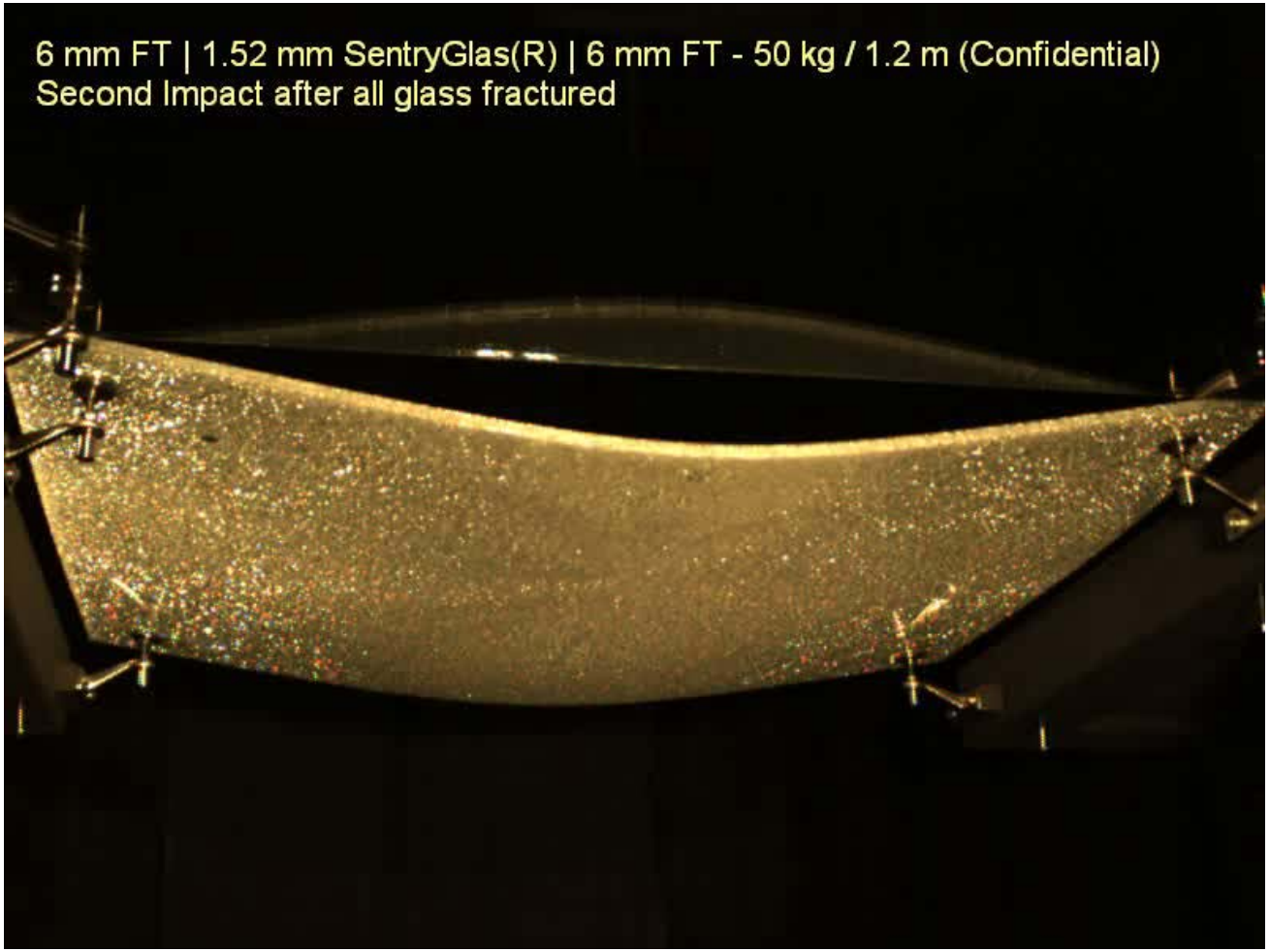
  50Kg for Monolithic

  100KG for laminates dropped from **1.2 m** height at **50°C**

  Panel size: 1500mm x 1200mm

  Laminates resist impact and supports 100Kg for **15 mins**

Overhead Impact Testing Program



Conclusions – Overhead Glazing

- Impact test method simulates potential loading from installation and/or maintenance workers in distress
- Tempered glass provides no barrier to fall-through after breakage
- Standard PVB laminates constructions tested resisted impact at room temperature but only show limited retention capability under load and higher temperature
- Standard PVB, Stiff PVB and EVA laminates provide no barrier to fall-through after breakage at 50 °C
- SentryGlas® Ionoplast laminates provide impact resistance and stay in place after glass breakage under load up to 50 °C
- Proof testing of glazing designs should take into account the impact load, load duration and in service temperature

Planar™ | SentryGlas® System

- **Significant post-fracture strength**
- **Temperature range**
  -20⁰C to +55⁰C
  [-5⁰F to 130⁰F]
  50-60 Cycles
- **4, 6 & 8 fixings**
- **Size range tested**
  1.8m x 3.6m
  [6ft x 12ft]

Structure: 88.4 SGP

Overhead: Bowling Green Subway Station Canopy

New-York, USA

Benefits:

- Post-glass breakage integrity
- Strength
- Proven durability / Open edges

Contractor W&W

System: Planar®

Laminator: Pilkington

SentryGlas®: Fire performance testing – London Underground(LU)

- Actual LU guidance: No laminated glass
- Behavior of laminated glass in fire situation
- Monolithic tempered glass issues:
  - Post breakage performance
  - Behavior under terrorist threat (blast)
- PVB toughened laminated glass improves performance
- SentryGlas® laminated glass required for optimum post breakage and high load performance

SentryGlas®: Fire performance testing – London Underground(LU)

- **Research program by LU: Test laminated tempered glass reaction to fire**
  - **PVB: Meets standards**
  - **SentryGlas®: 8mm toughened/1.52mm SentryGlas®/8mm toughened**
  - **BRE Garston august 2013 – Completed and successful**

Test Number	Test Standard	Result	
Test 1	BS 6853: Annex B.1- AMD 1	R 0.51	Toxicity (Y/N)
Test 2	BS 6853: Annex D 8.4 AMD 1	Ao (on) 0.17 Ao (off) 0.22	Fume Density
Test 3	BS EN 13823 (SBI) BS EN 11925-2 Single flame source test BS EN13501-1	Euroclass B-s1, d0.	Fire Resistance

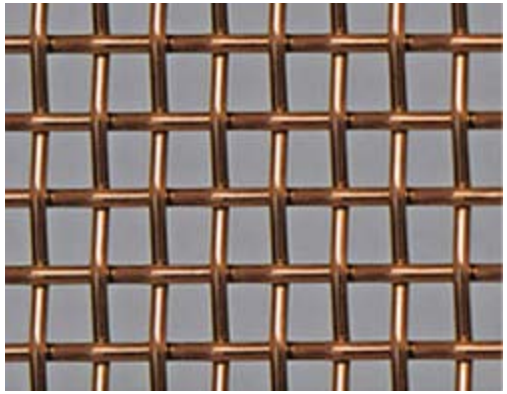
- **Approval: SentryGlas® was issued in October 2013 and added to the LU guideline**

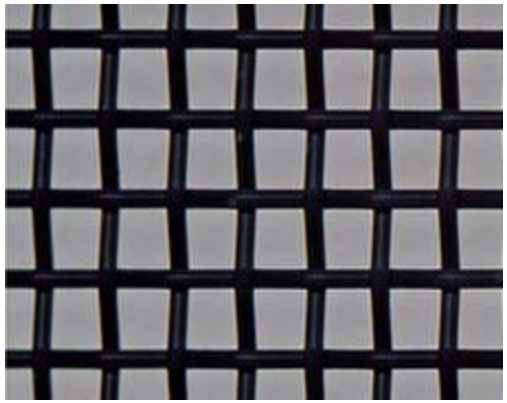
Special Applications with SentryGlas®

- SEFAR Architecture VISION Fabric Projects
- High temperature
- High UV Transmission SentryGlas®

SEFAR Architecture VISION Fabric

- High precision fabrics produced from synthetic fibers
- Different fabrics with a mesh opening of between 25% and 70%
- Metal coatings used: Aluminum, Chromium, Titanium and Gold, Aluminum/Copper alloy
- 1 or 2 sides visual aspect
- Proved compatibility with SentryGlas® interlayer.





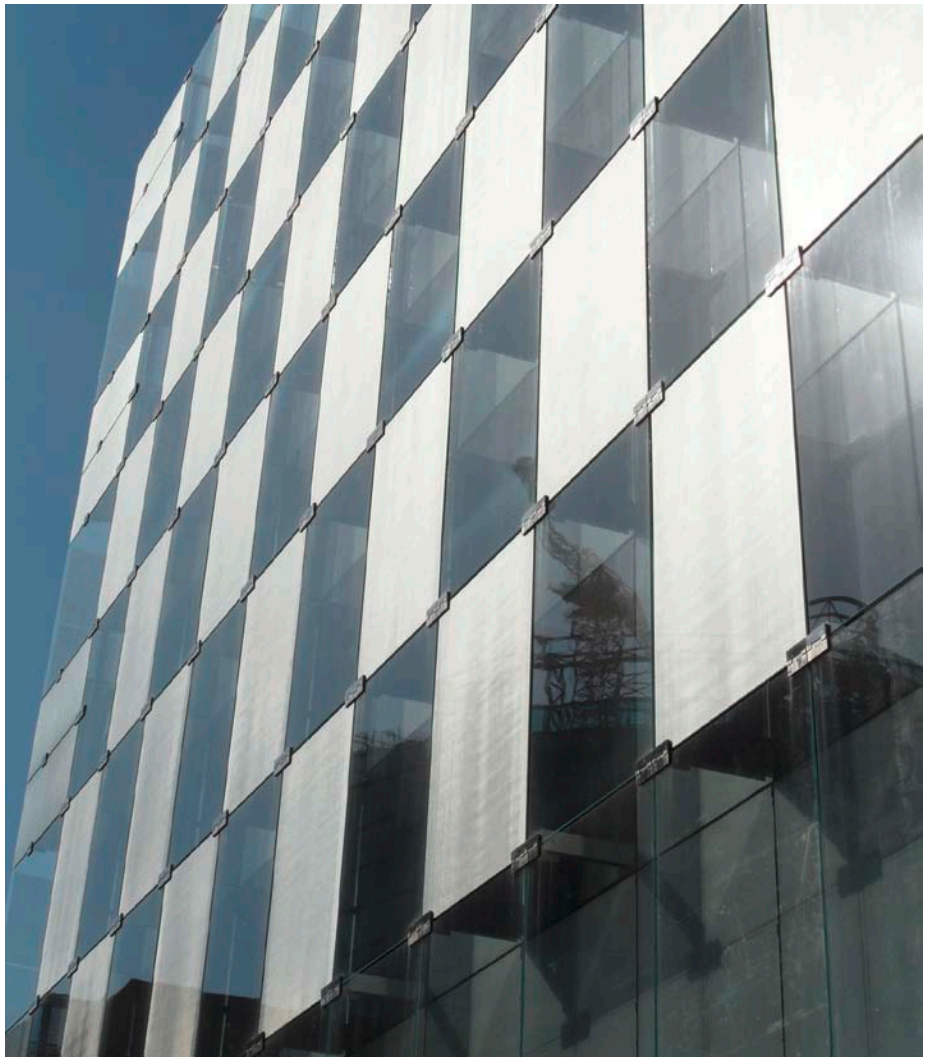
Project: Headquarters Belarusian Potash Company

Minsk, Belarussia

Benefits:

- Structural
- Edge durability
- Transparency
- Post-glass breakage integrity

Project: Castellano 79 Business Center



Madrid, Spain

Benefits:

- Structural
- Edge durability
- Transparency
- Post-glass breakage integrity

Checkerboard effect created by alternating panels of clear laminated and aluminum metal coated panels on exterior façade of this project in Madrid

High Temperature performance

Project: Cleveland Clinic Abu-Dhabi

Laminator: White Aluminum

Benefits:

- Structural performance – High temperature
- Edge durability
- Transparency
- Post-glass breakage integrity

High Temperature performance

Project: Maroc Telecom

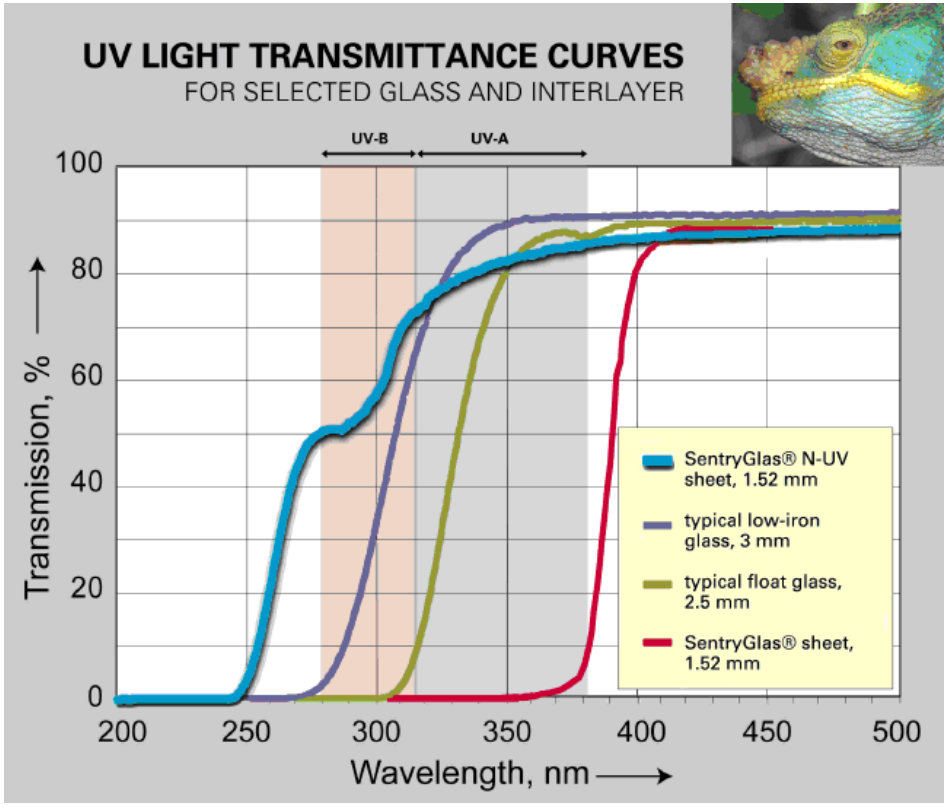
Rabat - Morocco

Benefits:

- Structural performance
- High temperature
- Edge durability
- Transparency
- Post-glass breakage integrity

High UV Transmission SentryGlas®

- Increases UV-Radiation transmittance
- For greenhouses, botanic gardens, or other special applications
- Similar mechanical properties versus standard SentryGlas®



High UV Transmission SentryGlas® Application

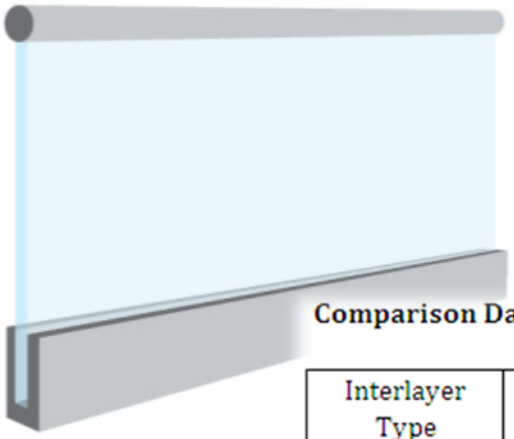
Bombay Sapphire Distillery – UK

Heatherwick Studio

Arup

Laminated glass with SentryGlas®: A cost competitive solution

Cantilevered Balustrade with Handrail- 3kN Line load



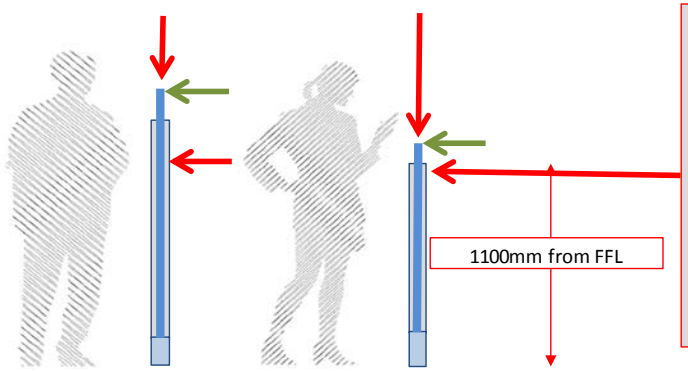
Type A: Cantilevered Balustrade- With a handrail
Size: 1500mm (W) x 1100mm (H)

Support Conditions:
Glass uniformly bonded into rigid channel in accordance with BS6180-2011.

Comparison Data

Interlayer Type	Glass Specification- mm	Comparison of Glass thickness as a %	Peak Deflection - mm	Peak Stress N/mm^2	Weight of Glass	Cost Comparison %
PVB	15 FT/1.52mm PVB/15 FT	125	13.73	33.44	130 KG	125%
SentryGlas®	12 HST/ 0.89 mm SGP/ 12 HST	100	13.38	32.87	105 Kg	100%
Monolithic	25mm	105	12.4	31.25	103 Kg	137%

Load Case



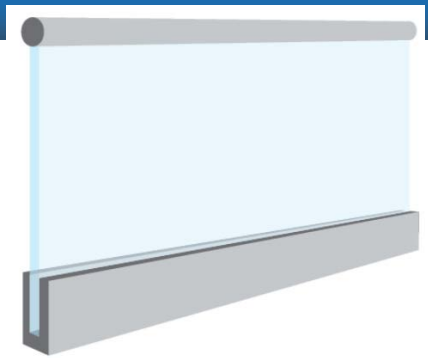
3000N/m run uniform line load applied 100mm from FFL, with associated loads applied to the infill.

1500N/m^2uniform load applied to the infill only.

1500N point load applied to the most onerous point anywhere on the barrier structure. The recommended size of the impactor is 25mm x 25mm.

Maximum allowable deflection: 20mm

Note these loads are not concurrent.



Cantilevered Balustrade with Handrail - 1.5KN Line load; 1500N/m^2 uniform load, 1500N point load

Comparison Data

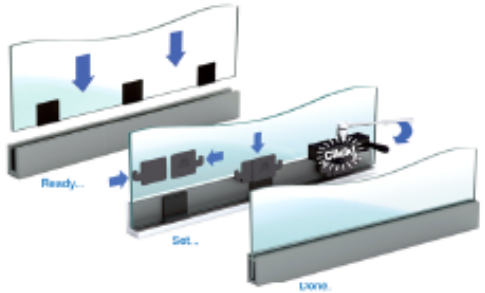
Interlayer Type	Glass Specification- mm	Comparison of Glass thickness as a %	Peak Deflection - mm	Peak Stress N/mm^2	Weight of Glass	Cost Comparison %
PVB	12 FT/1.52mm PVB/12 FT	120	13.07	25.68	105 KG	113%
SentryGlas®	10 HST/ 0.89 mm SGP/ 10 HST	100	11.74	23.91	87 KG	100%
Monolithic	19mm	95	14.7	27.78	78 Kg	107%

Cantilevered Balustrade with Handrail - 0.74KN Line load; 1000N/m^2 uniform load, 500N point load

Comparison Data

Interlayer Type	Glass Specification- mm	Comparison of Glass thickness as a %	Peak Deflection - mm	Peak Stress N/mm^2	Weight of Glass	Cost Comparison %
PVB	10 FT/1.52mm PVB/10 FT	125	11.31	18.43	87 KG	97%
SentryGlas®	8 HST/ 0.89 mm SGP/ 8 HST	100	11.58	18.72	72 KG	100%
Monolithic	15mm	93	13.87	21.12	62 Kg	75%

crlaurence.co.uk



Test date: 20th May 2013

Freestanding glass barrier Tested To BS6180:2011

Ref: CRLTL0001

Components

Clamping rail:	C.R.L TAPERLOC® L68S10D (surface mounted aluminium base shoe profile).
Glass:	17.5 mm laminated toughened glass comprising of 2 plies of 8 mm toughened glass laminated with a 1.52 mm Dupont SGP interlayer.
TAPERLOC® wedges	Spaced at 230 mm centres
Handrail:	Continuous (as described in BS 6180:2011) Top rail continuously seated, or through glass fixed rail with minimum two connector brackets per pane not more than 1000 mm apart.

Intended load resistance: 0.74 kN/m line load, 0.5 kN/m concentrated load, 1.0 kN/m2 uniform load.

Test sample

Pane size	1100 mm wide x 1195 mm high.
Clamping rail position	Bottom edge of profile installed at finished floor level.
Load application	1100 mm above finished floor level.

Test results

Load	Results
0.74 kN/m line load applied across whole width of pane	Deflection 14.1 mm
0.5 kN concentrated load applied at centre of width of pane	Deflection 9.1 mm
1.11 kN/m line load applied across whole width of pane	No failure, no permanent distortion
0.75 kN concentrated load applied at centre of width of pane	No failure, no permanent distortion

Range of applicability

Suitable for any pane width greater than 450 mm, provided there is a continuous handrail.
Suitable for pane heights up to 1500 mm above finished floor level, subject to a wind load resistance check if used externally.

Usage constraints

Not appropriate if mounted with the top edge of the clamping rail more than 60 mm below finished floor level.
LTL96X TAPERLOC® wedges installed at 230 mm are required to meet the BS6180:2011 loadings.

Signed

John Bernard Colvin M.A. (Cantab.)
Glass Consultant

NewGlassTechnology

TAPER-LOC X

NewGlassTechnology

Dow Corning® Sealants SentryGlas® Interlayer

Compatibility tests

Completed september 2013

Overview

1. Dow Corning Lab's Standard Compatibility Test
    - 1.1 Description
    - 1.2 Process
    - 1.3 Results with SentryGlas® – Dupont
    - 1.4 Comment
2. Compatibility Test Following IFT Guideline
    - 2.1 Process Reference
    - 2.2 Process 4.1 – Time line and Progress
    - 2.3 Process 4.2 – Time line and Progress
    - 2.4 Testing Method
3. Results
4. Conclusion

1. Dow Corning® Lab's Standard Compatibility Test

1.1 Description : qualitative test of chemical compatibility

- Special coating and all other material : Setting Blocks, Tape, Gasket, Backer Rod, Comp. Sealant

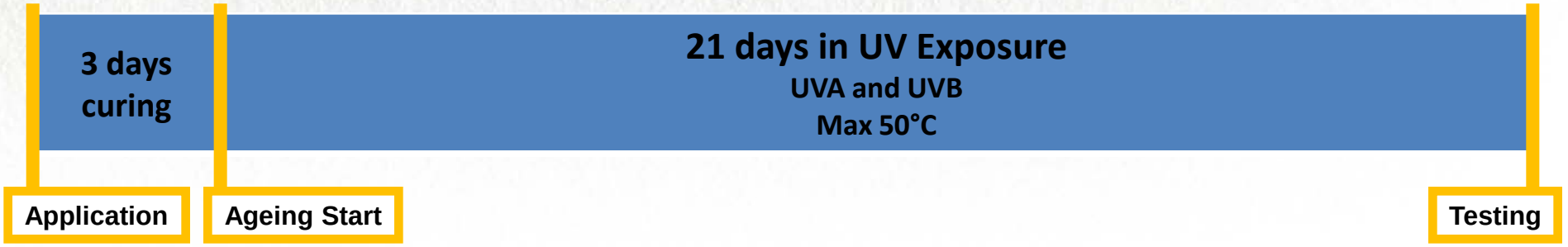
- Ageing : 21 days under UV exposure (direct and indirect) following ETAG

- Check of the adherence on glass, with extra material, change of color, apparition of bleeding

> Approval to use the interlayerl in contact with our Sealant

1. Dow Corning Lab's Standard Compatibility Test(1)

1.2 Process : Modified ASTM C1087 or ETAG 002 Paragraph 5.1.4.2.5.



(1) According to Modified ASTM C1087 or ETAG 002 Paragraph 5.1.4.2.5. – Dow Corning COOL project number 12-6710 sample number 28346 - 2013

1. Down Corning Lab's Standard Compatibility Test

1.3 Results with SentryGlas® - Dupont:

Sealant	Yello wing (Y/N)	Bubbles (Y/N)	Adhesion on interlayer (Y/N)	Adhesion on edge of glass (% CF/% AF)	Conclusion
Dow Corning® 993	No	No	Yes	70% Cohesive / 30% Adhesive Failure	Good Compatibility
Dow Corning® 994	No	No	Yes	70% Cohesive / 30% Adhesive Failure	Good Compatibility
Dow Corning® 895	No	No	Yes	70% Cohesive / 30% Adhesive Failure	Good Compatibility
Dow Corning® 995	No	No	Yes	70% Cohesive / 30% Adhesive Failure	Good Compatibility
Dow Corning® 3362	No	No	Yes	70% Cohesive / 30% Adhesive Failure	Good Compatibility
Dow Corning® 3362-HD	No	No	Yes	70% Cohesive / 30% Adhesive Failure	Good Compatibility
Dow Corning® 791	No	No	Yes	50% Cohesive / 50% Adhesive Failure	Good Compatibility
Dow Corning® 791-T	No	No	Yes	100% Cohesive Failure	Good Compatibility
Dow Corning® 757	No	No	Yes	100% Adhesive Failure	Good Compatibility
Dow Corning® 756-SMS	No	No	Yes	100% Cohesive Failure	Good Compatibility

1.4 Comment:

Loss of adhesion on the edge of the glass is due to the nature of the glass and not due to the chemistry of interlayer.

Edge of the glass is sandblasted. No good adhesion on that surface.

2. Compatibility Test Following IFT Guideline (2)

2.1 Process Reference : ift-GUIDELINE DI-02engl/1 (May 2009) § 4.1 and 4.2

4.1: Test Methods applying contact material to glazing rebate without UV radiation

3 samples by sealant + 1 without application, 21 weeks ageing in oven at 60° C, testing every 7 weeks

4.2: Test method for contact material applied to weather sealing fully exposed to weathering

3 samples by sealant + 1 without application, 7 weeks ageing in climatic chamber 58° C – 95% Humidity and 14 weeks ageing in UV exposure, testing every 7 weeks

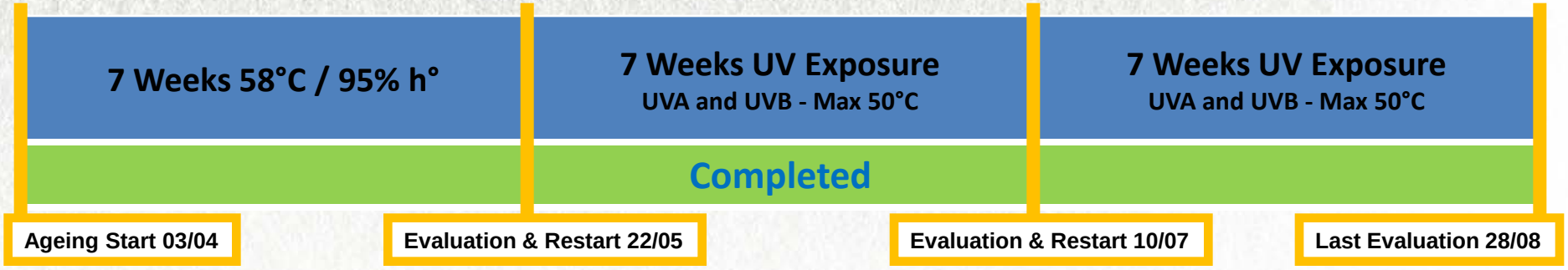
Blank test common to both method : 1 sample by sealant + 1 without application, no ageing

2.2 Process 4.1 - Timeline and Progress

(2) IFT guideline DI-02engl/1 (May 2009) § 4.1 and 4.2

2. Compatibility Test Following IFT Guideline

2.3 Process 4.2 - Timeline and Progress



2.4 Testing Method

Visual assessment subsequent to all test methods described
The percentage of the damaged edge (GK) is expressed by the following equation in % of the total length of the respective edge.

For autoclaved edge (long) : $GK = (x_1 + x_2 + \dots x_n) / L \cdot 100\%$
For cut edge (short) : $GK = (x_1 + x_2 + \dots x_n) / K \cdot 100\%$

X is the diameter of the bubbles.

L is the length of autoclaved edge (long)

K is the length of cut edge (short)

2. Compatibility Test Following IFT Guideline

2.4 Testing Method

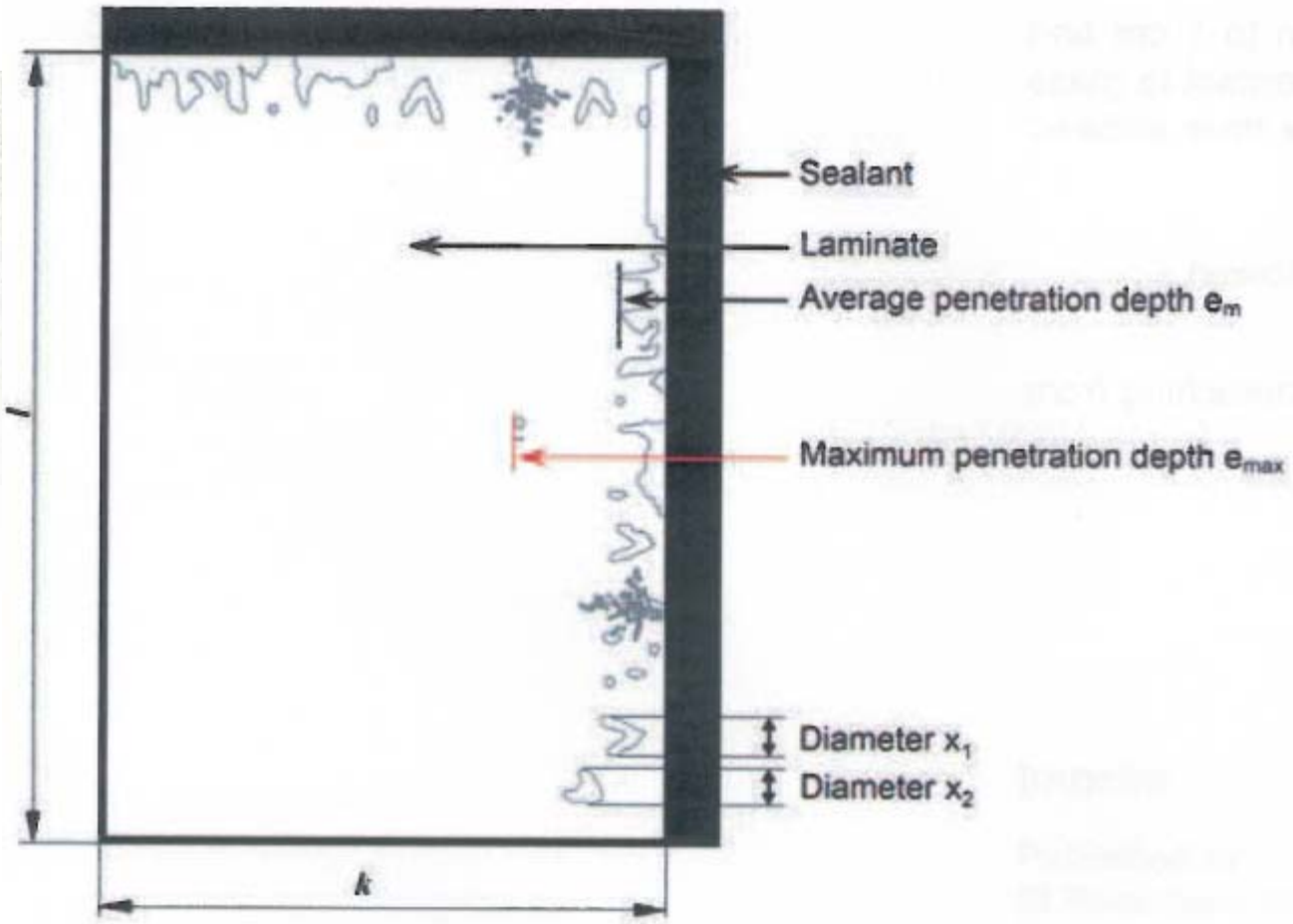


Fig. 4 Sketch to assess laminate changes

2. Compatibility Test Following IFT Guideline

2.4 Testing Method

Time in h	Edge K				Edge L				Comment
	e_{max} in mm	e_m in mm	x_{max} in mm	GK in %	e_{max} in mm	e_m in mm	x_{max} in mm	GK in %	

Following all exposures, a maximum penetration depth between aproximatively 1cm is permitted, if test and inspection show a stagnation of changes/migrations between the 1st, 2nd and 3rd assessment.

This include all changes such as bubble formation, clouding, discoloration.
Complete delaminations over the entire surface are excluded.

3. Results

Sealant	Sample	Oven 60°C		
		After 7 weeks	After 14 Weeks	After 21 Weeks
Blank		Nothing to report	Nothing to report	Nothing to report
Dow Corning® 993	1	Nothing to report	Nothing to report	Nothing to report
	2			
	3			
Dow Corning® 994	1	Nothing to report	Nothing to report	Nothing to report
	2			
	3			
Dow Corning® 895	1	Nothing to report	Nothing to report	Nothing to report
	2			
	3			
Dow Corning® 995	1	Nothing to report	Nothing to report	Nothing to report
	2			
	3			
Dow Corning® 3362	1	Nothing to report	Nothing to report	Nothing to report
	2			
	3			
Dow Corning® 3362-HD	1	Nothing to report	Nothing to report	Nothing to report
	2			
	3			
Dow Corning® 791	1	Nothing to report	Nothing to report	Nothing to report
	2			
	3			
Dow Corning® 791-T	1	Nothing to report	Nothing to report	Nothing to report
	2			
	3			
Dow Corning® 757	1	Nothing to report	Nothing to report	Nothing to report
	2			
	3			
Dow Corning® 756-SMS	1	Nothing to report	Nothing to report	Nothing to report
	2			
	3			

Sealant	Sample	58°C / 95% h°	UV Exposure	
		After 7 weeks	After 14 Weeks	After 21 Weeks
Blank		Nothing to report	Nothing to report	Nothing to report
Dow Corning® 993	8	Nothing to report	Nothing to report	Nothing to report
	9			
	10			
Dow Corning® 994	8	Nothing to report	Nothing to report	Nothing to report
	9			
	10			
Dow Corning® 895	8	Nothing to report	Nothing to report	Nothing to report
	9			
	10			
Dow Corning® 995	8	Nothing to report	Nothing to report	Nothing to report
	9			
	10			
Dow Corning® 3362	8	Nothing to report	Nothing to report	Nothing to report
	9			
	10			
Dow Corning® 3362-HD	8	Nothing to report	Nothing to report	Nothing to report
	9			
	10			
Dow Corning® 791	8	Nothing to report	Nothing to report	Nothing to report
	9			
	10			
Dow Corning® 791-T	8	Nothing to report	Nothing to report	Nothing to report
	9			
	10			
Dow Corning® 757	8	Nothing to report	Nothing to report	Nothing to report
	9			
	10			
Dow Corning® 756-SMS	8	Nothing to report	Nothing to report	Nothing to report
	9			
	10			

4. Conclusion

After following IFT guideline test for lamination foil and Dow Corning compatibility test, no negative effect of the SentryGlas® interlayer and on the silicone sealant has been observed. Additionally, no delamination of the SentryGlas interlayer has been observed.

Thank you !

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