

The Kuraray logo is displayed in a white rectangular box in the top left corner. The word "kuraray" is written in a lowercase, blue, sans-serif font.

**kuraray**

The background of the entire page is a close-up photograph of the edge of a laminated glass unit. It shows multiple layers of glass held together by a clear interlayer, with the edges of the glass layers appearing as curved, overlapping bands of varying shades of blue and teal. The lighting creates highlights and shadows that emphasize the three-dimensional structure of the glass edge.

## **EDGE STABILITY, DURABILITY AND WEATHERING**

Despite the long history of the use of laminated glass in buildings, there is still a concern for some architects and designers about the potential for serious delamination problems, durability and edge stability of laminated glass, as well as how well the laminated glass will perform under different climatic conditions, including high humidity, tropical climates, storm zones, low and high temperatures, and high saltwater conditions.

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# EDGE STABILITY, DURABILITY AND WEATHERING

## INTRODUCTION

Despite the long history of the use of laminated glass in buildings, there is still a concern for some architects and designers about the potential for serious delamination problems, durability and edge stability of laminated glass, as well as how well the laminated glass will perform under different climatic conditions, including high humidity, tropical climates, storm zones, low and high temperatures, and high saltwater conditions.

This chapter provides some examples of test data on the edge stability and weathering performance of SentryGlas® interlayer, as well as salt spray fog tests, sealant compatibility, ceramic frit compatibility, high temperature bake tests and adhesion to low-E and other solar glass coatings.



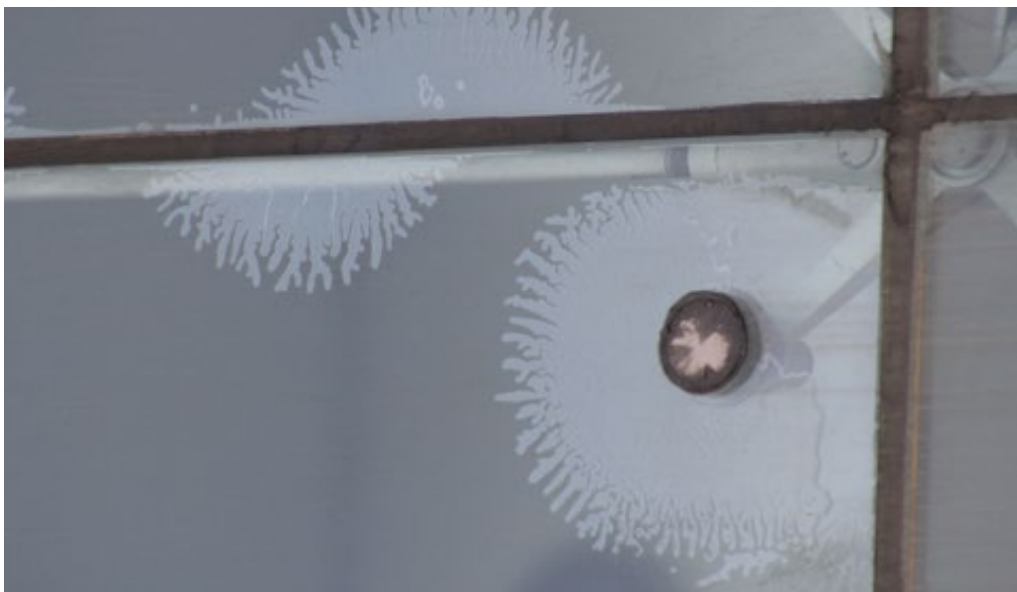
## WHAT IS EDGE STABILITY?

Edge stability is defined as a laminate's resistance over time to form defects along its edge. These defects can arise in the form of small 'bubbles' in the laminate or as discoloration of the laminate itself. For designers

and architects, edge stability is therefore critical. Ideally, laminated glass should show no signs of delamination over the complete life of the building.



Typical defects caused by delamination.



## TESTS AND COMPARISON OF INTERLAYERS

Compared to standard conventional laminated glass interlayers, SentryGlas® ionoplast is more resistant to moisture and the effects of weather, particularly at temperatures between -50 °C (-58 °F) and +82 °C (180 °F). These are the consistent findings of laboratory tests and research in real-life projects.

Due to the exceptional edge stability of SentryGlas® interlayer, no undesired changes such as delamination have been found to date on any of its applications, even on panels with open edges that have been exposed to hot and humid climates such as Florida. This proven edge stability opens up many

new design possibilities for SentryGlas®, enabling designers to create stronger, larger expanses of safety glazing including open-edged, structural and butt-glazed installations.

When used in combination with standard silicon sealing material, butt-joined glass elements with SentryGlas® interlayers show no discoloration or other forms of damage to their edges, even after years of weathering. Years later these interlayers still provide the same level of safety and feature the same intact edging, as they did when they were first installed.

### FLORIDA 15-YEAR TEST

In 1997 a test programme for laminated glass with SentryGlas® interlayer was started in Florida. The open-edge test samples are installed in open air conditions, fully exposed to the Florida climate. Since their installation, the samples with SentryGlas® interlayer have been tested annually for signs of weathering and delamination.

After 15 years of exposure to the weather, the edges of the laminates with SentryGlas® showed no visible sign of weathering, including no visible moisture ingress or delamination effects in open edge applications. In addition, with silicone butt-joined applications, the edges of the laminated glass also showed no visible moisture intrusion or delamination effects.



The table below shows test results after 149 months of exposure. After this time, SentryGlas® was assigned an Edge Stability Number (ESN). This weighted system assigns higher importance to progressively deeper defects. A laminate with no defects would have an ESN of 0 (zero), while the maximum would be 2500 (equivalent to continuous defects measuring > 6.4 mm [¼ in] around the entire perimeter).



## SENTRYGLAS® INTERLAYER EDGE STABILITY NUMBER (ESN) TEST DATA AFTER 15-YEAR EXPOSURE

| Sample ID | Laminate<br>Perimeter mm (in) | Defect Length (mm) |           |           |           |       | ESN |
|-----------|-------------------------------|--------------------|-----------|-----------|-----------|-------|-----|
|           |                               | < 1.6              | 1.6 - 3.1 | 3.2 - 4.6 | 4.7 - 6.3 | > 6.4 |     |
| 824-63-1  | 3912 (154)                    | 0                  | 0         | 0         | 0         | 0     | 0   |
| 824-64-2  | 3912 (154)                    | 0                  | 0         | 0         | 0         | 0     | 0   |
| 824-48-3  | 3912 (154)                    | 0                  | 0         | 0         | 0         | 0     | 0   |
| 824-46-4  | 3912 (154)                    | 0                  | 0         | 0         | 0         | 0     | 0   |
| 824-47-5  | 3912 (154)                    | 0                  | 0         | 0         | 0         | 0     | 0   |
| 824-44-6  | 3912 (154)                    | 0                  | 0         | 0         | 0         | 0     | 0   |
| 824-34-7  | 3912 (154)                    | 0                  | 0         | 0         | 0         | 0     | 0   |
| 824-27-8  | 3912 (154)                    | 0                  | 0         | 0         | 0         | 0     | 0   |
| 824-16-9  | 3912 (154)                    | 0                  | 0         | 0         | 0         | 0     | 0   |
| 824-71-10 | 3912 (154)                    | 0                  | 0         | 0         | 0         | 0     | 0   |
| 824-56-11 | 3912 (154)                    | 0                  | 0         | 0         | 0         | 0     | 0   |
| 824-75-12 | 3912 (154)                    | 0                  | 0         | 0         | 0         | 0     | 0   |
| 824-74-13 | 3912 (154)                    | 0                  | 0         | 0         | 0         | 0     | 0   |

ESN data in the table above includes test samples with open-edge exposure, as well as samples that are butt-joined using silicone sealant.

## WEATHERING TEST REPORT FOR LAMINATED GLASS WITH SENTRYGLAS®

Samples of laminated glass with SentryGlas® interlayer were weathered according to a test method outlined in ANSI Z97.1-2004:

‘Safety Glazing Materials Used in Buildings - Safety Performance Specifications and Methods of Test’. The test results are shown below.

| Xenon-Arc Type Operating Light Exposure |                                                               |
|-----------------------------------------|---------------------------------------------------------------|
| Apparatus                               | Atlas Ci5000 Xenon Weather-Ometer®                            |
| Exposure Time                           | Specimens were exposed for 3000 hours                         |
| Filter Type                             | Borosilicate inner and outer                                  |
| Cycle                                   | 102 mins of irradiation, 18 mins of irradiation & water spray |
| Black Panel Temp                        | 70 °C ± 3 °C (158 °F ± 5 °F)                                  |
| Relative Humidity                       | 50 % ± 5 %                                                    |
| Spray Water                             | De-ionized                                                    |
| Level of Irradiance                     | 0.35 W/m <sup>2</sup> @ 340 nm                                |
| Exposure                                | Xenon-Arc Exposure: 3780 kJ/m <sup>2</sup> @ 340 nm           |

**Note:** on average, a 3000-hour Xenon arc exposure approximates to a one-year direct South Florida exposure at 26° North Latitude, facing South.

## RESULTS

After the samples of laminated glass with SentryGlas® interlayer were irradiated and conditioned, the exposed samples were examined and compared visually with unexposed controls, as detailed in ANSI Z97.1-

2004. These samples were found to be visibly acceptable. No bubbles or delamination effects were visible and no crazing, cracking or discoloration was observed.

## APPLICATION EXAMPLES OF THE SUPERIOR EDGE STABILITY OF SENTRYGLAS® INTERLAYER

As well as test reports supporting the superior edge stability performance of SentryGlas®, there are numerous real life examples to support the test data.

For example, the BellSouth building in Fort Lauderdale, USA, silicone sealed, butt joined safety glass made with SentryGlas® helped the architects deliver panoramic corner office views, while meeting tough wind and storm protection codes.

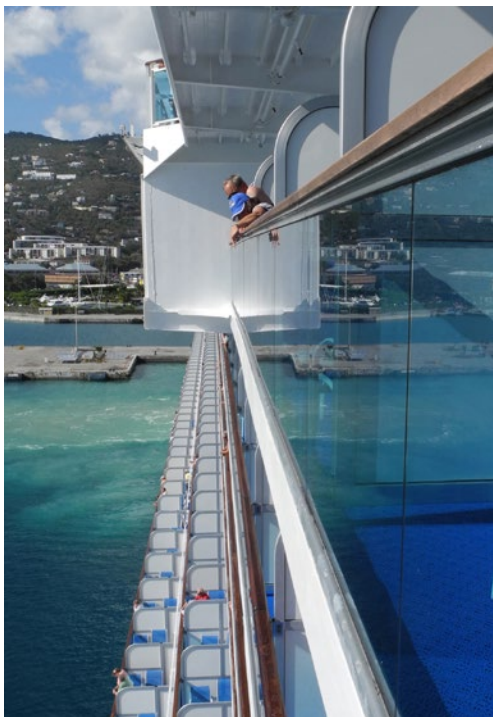
Elsewhere in the USA, cold winters, shadeless summer heat and occasional Mississippi River floodwaters were among the design challenges for a bandshell built on an island in St Paul, Minnesota. Open edged, butt-sealed glazing panels made with SentryGlas® interlayer remain free of any visual defects after years of exposure. The extra strength of the interlayer also helped to create a uniquely shaped overhead structure.



## EDGE STABILITY OF LAMINATES WITH SENTRYGLAS® IN COASTAL CLIMATIC CONDITIONS

For all marine and some architectural applications, prolonged exposure to salt water can cause defects in the laminated glass. However, laminates with SentryGlas® demonstrate excellent durability performance in coastal regions or landscapes with high concentration of salt water (e.g. due to high use of road salts due to snow). Extensive product testing, including salt spray fog testing (carried out by TÜV Süd Singapore, according to ASTM B 117-11) during which the glass panels laminates with SentryGlas® with open edges were exposed to salt spray solution continuously for 3000 hours. Three 15 by 10 cm (5.93 by 3.93 in) glass panels were placed in a climatic chamber for 3000 hours under the following experimental conditions:

- NaCl-concentration: 5%
- Volume of condensate: 1.0-2.0 ml/HR/80cm<sup>2</sup>
- pH of the solution: between 6.5 and 6.9
- Test chamber temperature: 35 +/- 2°C



After the test, the glass panels were visually inspected and evaluated. The results showed that the panels remained unchanged in terms of their transparency. The PVB laminates showed edge clouds after 500 hours of testing. Due to the excellent edge stability of SentryGlas® interlayer, no undesired changes such as edge cloudiness, delamination caused by the humidity occur. Copies of the test report are available on request.

Other salt spray tests have been conducted on laminated glass with SentryGlas® interlayer. In Germany for example, similar tests were carried out on SentryGlas® ionoplast interlayer by the Fachhochschule München as part of a DIBT approval for SentryGlas® ionoplast interlayer (Germany's regulatory body for products used in the construction industry).

# SEALANT COMPATIBILITY OF SENTRYGLAS® INTERLAYER

A wide variety of sealants are used by the glazing industry and it is therefore critical to understand the chemical and mechanical compatibility of these sealants with the interlayer produced in a glass laminate. Laminates prepared with SentryGlas® demonstrate excellent compatibility with different types of sealants used in glazing applica-

tions. This is supported by tests conducted by Kuraray but also by studies carried out by sealant manufacturers. These tests include accelerated QUV weathering and modified ASTM C1087 compatibility test methods as well as DI guideline, IFT Rosenheim, UV-radiation tests, high-temperature and high humidity test scenarios.

## OUTDOOR TESTING

Laminates with SentryGlas® show no edge defect formation, even after 15 years of natural outdoor weathering in Florida when tested with different types of sealants. In these tests, laminates with SentryGlas® have shown no signs of degradation from interactions with any of the sealants tested.

Details of all sealant compatibility tests carried out by Kuraray and by sealant manufacturers are available on request from Kuraray. For a complete list of compatible sealants for SentryGlas® interlayer, please refer to the following table.

## SEALANTS FOR GLASS RAILING INSTALLATIONS

Portland cement-based products are not recommended for use with SentryGlas® laminates. Gypsum-based products are acceptable for interior applications only. The

following Sika sealants have been tested and found to be acceptable for both interior and exterior railing installations:

| Company / Grade                       | Description                                | Test Method                                         |
|---------------------------------------|--------------------------------------------|-----------------------------------------------------|
| <b>Arbosil</b>                        |                                            |                                                     |
| Arbosil 1096                          | 1-component silicone sealant, neutral-cure |                                                     |
| <b>C.R. Laurence</b>                  |                                            |                                                     |
| C.R. Laurence 33SC                    | 1-component silicone sealant, acetic-cure  |                                                     |
| C.R. Laurence RTV408AL<br>999-A, 1199 | 1-component silicone sealant, neutral-cure |                                                     |
| <b>Dow Corning</b>                    |                                            |                                                     |
| Dow Corning® 756                      | 1-component silicone sealant, neutral-cure |                                                     |
| Dow Corning® 756-SMS                  | 1-component silicone sealant, neutral-cure | ASTM C1087, ETAG 002,<br>IFT-Guideline DI-02engll/1 |
| Dow Corning® 757                      | 1-component silicone sealant, neutral-cure | ASTM C1087, ETAG 002,<br>IFT-Guideline DI-02engll/1 |
| Dow Corning® 790                      | 1-component silicone sealant, neutral-cure |                                                     |



| Company / Grade      | Description                                            | Test Method                                      |
|----------------------|--------------------------------------------------------|--------------------------------------------------|
| Dow Corning® 791     | 1-component silicone sealant, neutral-cure             |                                                  |
| Dow Dorning® 791-T   | 1-component silicone sealant                           | ASTM C1087, ETAG 002, IFT-Guideline DI-02engll/1 |
| Dow Corning® 795     | 1-component silicone sealant, neutral-cure             |                                                  |
| Dow Corning® 895     | 1-component silicone sealant, neutral-cure             | ASTM C1087, ETAG 002, IFT-Guideline DI-02engll/1 |
| Dow Corning® 983     | 2-component silicone sealant, neutral-cure             |                                                  |
| Dow Corning® 993     | 2-component silicone sealant, neutral-cure             |                                                  |
| Dow Dorning® 994     | Ultra Fast, 2-component silicone sealant, neutral-cure |                                                  |
| Dow Corning® 995     | 1-component silicone sealant, neutral-cure             |                                                  |
| Dow Dorning® 999-A   | 1-component silicone sealant                           |                                                  |
| Dow Dorning® 1199    | 1-component silicone sealant                           |                                                  |
| Dow Dorning® 3362    | 2-component silicone sealant                           | ASTM C1087, ETAG 002, IFT-Guideline DI-02engll/1 |
| Dow Dorning® 3356 HD | 2-component, silicone sealant                          | ASTM C1087, ETAG 002, IFT-Guideline DI-02engll/1 |

#### GE Advanced Materials

|                         |                                            |  |
|-------------------------|--------------------------------------------|--|
| GE Silglaze® II SCS2802 | 1-component silicone sealant, neutral-cure |  |
| GE SilPruf® NB SCS9000  | 1-component silicone sealant, neutral-cure |  |
| GE UltraGlaze® SSG4000  | 1-component silicone sealant, neutral-cure |  |
| GE UltraGlaze® SSG4400  | 2-component silicone sealant, neutral-cure |  |

#### Kömmerring

|             |                                                      |                       |
|-------------|------------------------------------------------------|-----------------------|
| GD 116      | 2-component polysulfide sealant, solvent-free        | IFT Guideline DI-02/1 |
| GD 677      | 2-component polyurethane sealant, solvent-free       | IFT Guideline DI-02/1 |
| GD 920      | 2-component silicone sealant, neutral-cure           | IFT Guideline DI-02/1 |
| GD 823 N    | 1-component silicone sealant, neutral-cure           | IFT Guideline DI-02/1 |
| GD 826 N    | 1-component silicone sealant, neutral-cure           | IFT Guideline DI-02/1 |
| Ködiglaze S | 2-component silicone sealant, neutral-cure           | IFT Guideline DI-02/1 |
| Ködiglaze P | 1- or 2-component polyurethane, sealant solvent free | IFT Guideline DI-02/1 |

#### Pecora

|                |                                            |  |
|----------------|--------------------------------------------|--|
| Pecora 895 NST | 1-component silicone sealant, neutral-cure |  |
|----------------|--------------------------------------------|--|

#### Sika

|                        |                                                          |           |
|------------------------|----------------------------------------------------------|-----------|
| Icosit® KC-340/7       | 2-component polyurethane sealant, solvent-free           | CQP 593-7 |
| SikaGLaze® GG-735      | 2-component polyurethane sealant, solvent-free           | CQP 593-7 |
| Sikasil® GS-621        | 1-component silicone sealant, acetic-cure                | CQP 593-7 |
| Sikasil® IG-16         | 1-component silicone sealant, neutral-cure               | CQP 593-7 |
| Sikasil® IG-25         | 2-component silicone sealant, neutral-cure               | CQP 593-7 |
| Sikasil® IG-25 HM Plus | 2-component silicone sealant, neutral-cure, high modulus | CQP 593-7 |
| Sikasil® SG-18         | 1-component silicone sealant, neutral-cure               | CQP 593-7 |

| Company / Grade    | Description                                              | Test Method |
|--------------------|----------------------------------------------------------|-------------|
| Sikasil® SG-20     | 1-component silicone sealant, neutral-cure               | CQP 593-7   |
| Sikasil® SG-500    | 2-component silicone sealant, neutral curing             | CQP 593-7   |
| Sikasil® SG-500 CN | 2-component silicone sealant, neutral-cure, high modulus | CQP 593-7   |
| Sikasil® SG-550    | 2-component silicone sealant, neutral-cure               | CQP 593-7   |
| Sikasil® WS-305 CN | 1-component silicone sealant, neutral-cure               | CQP 593-7   |
| Sikasil® WS-355    | 1-component silicone sealant, neutral-cure               | CQP 593-7   |
| Sikasil® WS-605 S  | 1-component silicone sealant, neutral-cure               | CQP 593-7   |
| Sikasil® WS-680 SC | 1-component silicone sealant, neutral-cure               | CQP 593-7   |
| Sikasil® WT-480    | 2-component silicone sealant, neutral-cure, high modulus | CQP 593-7   |
| Sikasil® WT-485    | 2-component silicone sealant, neutral-cure               | CQP 593-7   |
| <b>Tremco</b>      |                                                          |             |
| Spectrem 1         | 1-component silicone sealant, neutral-cure               |             |
| Spectrem 2         | 1-component silicone sealant, neutral-cure               |             |
| Tremglaze S100     | 1-component silicone sealant, neutral-cure               |             |
| Vulkem 116         | 1-component polyurethane sealant                         |             |

## HIGH TEMPERATURE PERFORMANCE OF SENTRYGLAS® INTERLAYER

Properly laminated glass made with SentryGlas® interlayer has demonstrated capability of withstanding an environment of 100 °C (212 °F) for at least 16 hours, without bubble formation in the major viewing area. For more prolonged periods of time, of greater than 16 hours, a temperature limit of 82 °C (180 °F) or lower is recommended.

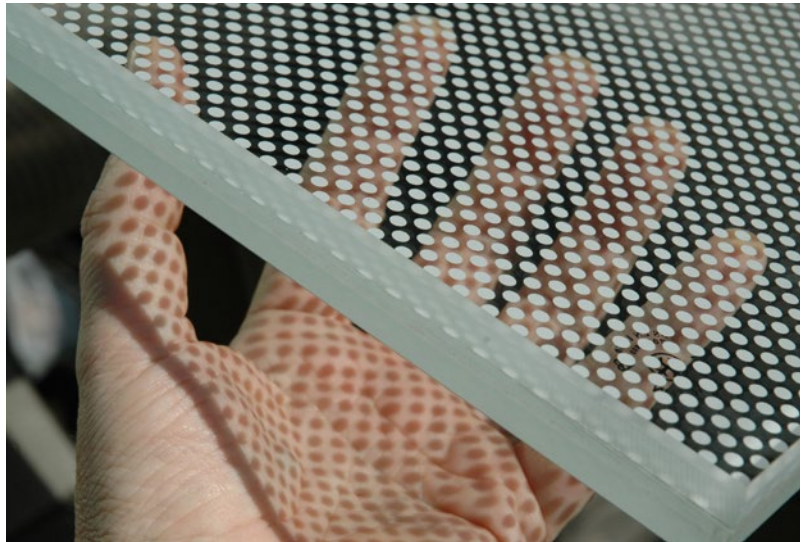
This information is based on the visual inspection of a glass laminate after a high temperature bake test. In this test, a test specimen of laminated glass is heated to

a temperature of 100 °C (212 °F). Bubble formation within the major viewing area of the laminate (typically excluding 12 mm or  $\sim 1/2$  in from the laminate edge) constitutes a failure of this test. Based on this limited data, properly laminated specimens with SentryGlas® appear capable of meeting these test conditions.

As with any application, specific glass constructions and designs may vary and prototype testing of systems is advisable.

## COMPATIBILITY WITH CERAMIC FRIT COATINGS

Used for both internal and external decorative glass, ceramic frit coatings can be specified in a wide variety of colors and patterns for improved aesthetics or solar control in laminated glass. These vitreous compounds are applied to the glass by screen-printing, roll coating, spraying or curtain coating, closely following the frit supplier's processing instructions. These are then heat-treated in order to create a permanent coating. When such a fritted surface comes into contact with the glass laminate interlayer, it is important to verify the lasting compatibility between the frit and the interlayer. Moisture and salts, for example, can be detrimental to frit coatings over time. Testing therefore requires extended contact between materials under controlled conditions. The table next page lists the various tests that Kuraray uses



to assess the compatibility of interlayers and ceramic frit.

| Method             | Standard                            | Intervals       |
|--------------------|-------------------------------------|-----------------|
| 76 Bake Test       | Kuraray Internal Method             | 500 & 1000 hour |
| Coffin             | ANSI Z26.1 (5.3 -3)                 | 2, 5 & 10 weeks |
| UV (UVA-340)       | ASTM G151, 154-06, ISO4892-1 & 4582 | 30 days         |
| Natural Weathering | ASTM G 7-05 and G 147-02            | 1 year          |

Kuraray has conducted these tests on laminates made with SentryGlas® ionoplast and fritted glass, in order to observe changes in

color, appearance or defects such as corrosion of the coating, bubbles, delaminations and other defects.

| Manufacturer                | Product Code | Product Name                                 |
|-----------------------------|--------------|----------------------------------------------|
| FERRO                       | 20-8496-1597 | 20-8496 ETCHIN 1597<br>24-8029 BLACK IN 1544 |
| FERRO                       | 24-8029-1544 | Medium<br>24-8075 WARM GREY IN               |
| FERRO                       | 24-8075-1544 | 1544 Medium                                  |
| Glass Coating Concept (GCC) | SX8876E808   | SPANDREL WHITE                               |
| Glass Coating Concept (GCC) | SX3524E808   | WARM GRAY                                    |

In the tests above, SentryGlas® interlayer showed no visual defects. In addition, adhesion was assessed before and after testing and no measurable differences were found. For other types of frit coatings not listed

above, users should conduct their own tests or seek guidance from Kuraray. To ensure that glass meets safety codes, additional testing, including adhesion strength tests, may be required.

## COMPATIBILITY WITH SOLAR SHADING OR GLASS COATINGS

The growing importance of the environment, energy efficiency and renewable building technologies are creating added value for glass manufactured with low-E (low emissivity) coatings. Often, in architectural

applications, this coated glass also requires high impact strength, which can be achieved by laminating with SentryGlas® ionoplast interlayers.



When placing any interlayer into contact with a glass coating, it is critical to test the chemical and mechanical compatibility between the materials. Moisture and salts can be detrimental to coatings over time. SentryGlas® interlayer shows excellent compatibility with many different low-E coat-

ings, and this compatibility is enhanced by the interlayer's low moisture absorption and low ionic content.

Listed below are low-E coatings that have been independently tested by their manufacturers and shown to be compatible with SentryGlas® interlayer.

| Low-E Coatings |                                                         |
|----------------|---------------------------------------------------------|
| AGC            | Comfort Ti-AC 23™, Comfort Ti-AC 36™, Comfort Ti-AC 40™ |
| Cardinal       | Cardinal LoE3-366® Glass                                |
| Guardian       | Guardian SunGuard® SN-68, SunGuard® SN-68 HT            |
| PPG            | PPG Solarban® 60, 70, 70XL and R100, Sungate® 400       |

The long-term performance of a coated glass laminate depends greatly on the laminator's care taken to preserve the integrity of the topcoat that protects the delicate metalized

layers of the low-E coating stack. Any compromise of the coating - such as scratches, scuffs, pinholes and fingerprints - will cause the coating to corrode over time.



# Kuraray Interlayer Solutions:

EDGE STABILITY, DURABILITY AND WEATHERING

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