

# PV framing and bonding

Technical manual

◀DUPONT▶

**Fortasun**<sup>™</sup>

Solar Silicones

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## Introduction

This manual is intended to provide guidance on sealant choice and proper application procedures for DuPont™ Fortasun™, formerly Dow Corning® brand, sealants for photovoltaic (PV) framing and bonding applications. This manual will aid in developing a basic quality assurance program around the use of sealants in solar PV applications that require durability and reliability. Since PV frames and modules vary in design and requirements, this manual cannot be considered a comprehensive guide for every situation. The recommendations made in this manual are based on our experience supporting window sealing and structural glazing projects in the construction industry for more than 40 years.

Frame sealing is a method utilizing sealant to ensure water tightness. Materials recommended for sealing PV frames are not developed for supporting mechanical loads.

Frame or rail bonding is a method utilizing a sealant to structurally attach glass, metal or other PV module material to the supporting structure (i.e., frame, rail or pad). Frame or rail bonding is a high-performance application, and not all silicone sealants are suitable for this application. Only silicone sealants that have been developed and tested specifically for structural bonding applications should be used. The Fortasun™ structural sealants recommended for frame or rail bonding are identified in the next section of this manual.

## Unlimited solar potential

Enough energy comes from the sun in one hour to power the global population for a year! The potential of solar energy is almost limitless as a completely renewable energy source that is not dependent on any fuel for its production. As the PV industry assumes an increasingly important role in meeting the world's energy needs, DuPont is committed to help PV producers grow and succeed.

We are investing to continue to make a difference in the solar industry by expanding our portfolio of silicon-based solutions for feedstock, cell manufacturing, module assembly and installation. Solution packages include high-performance encapsulants, adhesives, coatings, potting agents and sealants, as well as next-generation solar grade silicon. As one of the largest material suppliers to the PV industry, we service the entire PV value chain by bringing cost-effective Si-based solutions to our customers.

# DuPont™ Fortasun™ PV framing and bonding solutions

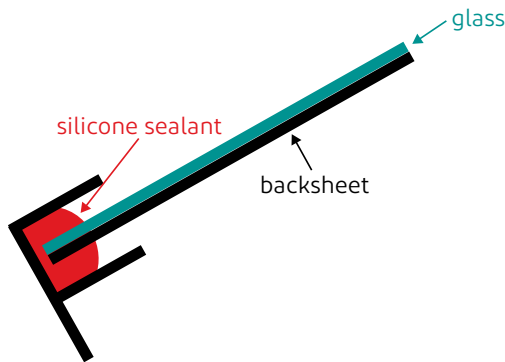
There are many different types of PV module designs and mounting systems available. Historically, PV modules have been mounted in aluminum frames to be mechanically attached to the supporting structure. To decrease cost, facilitate installation and improve aesthetic of PV modules, new frame designs are continually being introduced, as are frameless designs. A common feature of many of these innovative systems is the need for structural bonding to attach glass or another material to the supporting structure (frame, rail or pad). Some of the most common types of systems are discussed in this section.

## Frame designs

There are several framing systems to securely attach the PV modules to a supporting structure. The illustrations are provided as examples, but other designs and configurations are possible. All frame designs require validation by the module manufacturers via appropriate technical qualification tests (as detailed in the section about quality control).

### U-Frame design

PV modules are commonly mounted in aluminum frames to be mechanically attached to the supporting structure. The edges of the PV laminate (glass/backsheet or glass/glass) are inserted into the cavity of a U-profile. A silicone sealant is used for fixing the laminate inside the frame and ensuring water tightness. In this case, the silicone sealant does not have a structural bonding function.



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### Product recommendations

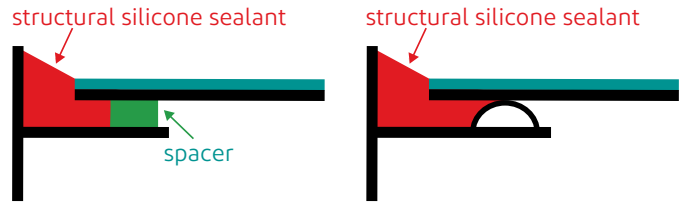
Fortasun™ PV-804 Neutral Sealant, Fortasun™ PV-8101 Sealant, Fortasun™ Solar PV InstantSeal, Fortasun™ PV-8301 Fast Cure Sealant, Fortasun™ PV-8303 Ultra Fast Cure Sealant

See product descriptions in the Fortasun™ product offerings section.

### L-Frame design

The L-frame design allows assembling the frame prior to insertion of the laminate (even one-piece frame designs), making the solution easier to automate. This design prevents entrapment of water and dirt at the bottom of the laminate. It also enables snow to slide off the module, avoiding excessive snow load. L-frame structural bonding typically uses structural silicone sealant for structurally attaching the laminate on the

frame. It reinforces the rigidity of the assembly by combining the mechanical strength of the laminate and the frame via the structural sealant.



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### Product recommendations

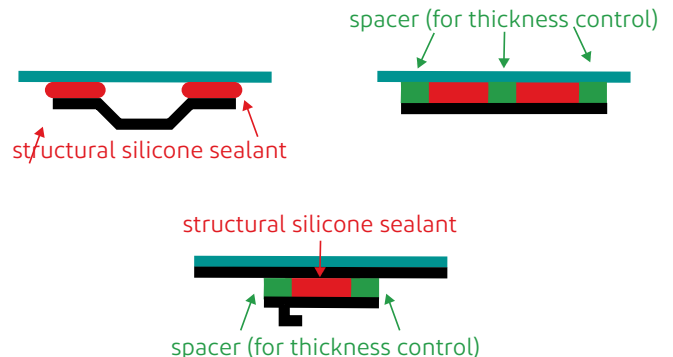
Fortasun™ PV-8030 Adhesive, Fortasun™ PV-8301 Fast Cure Sealant, Fortasun™ PV-8303 Ultra Fast Cure Sealant

See product descriptions in the Fortasun™ product offerings section.

## Frameless designs

Frameless designs have become more and more popular, especially for glass/glass laminates. The glass thickness can be minimized by optimizing the location of the support components in the laminate area. To ensure reliability and durability under load and thermal stress, mechanical clamping is not recommended because it introduces local stresses and does not allow for differential thermal dilatation of the PV module and the metallic supporting structure. Structural bonding of the PV laminate on supporting rails or pads with structural silicone sealant is recommended based on the proven performance of silicone sealant in the construction industry for structural glazing applications.

Application testing has shown that certain metal substrates will corrode over time and under certain environmental conditions, even though the sealants perform as intended. Therefore, DuPont recommends a thorough test program and a diligent solar panel maintenance program to routinely monitor the corrosion of the rail substrate.



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### Product recommendations

Fortasun™ PV-8030 Adhesive, Fortasun™ PV-8301 Fast Cure Sealant, Fortasun™ PV-8303 Ultra Fast Cure Sealant

See product descriptions in the Fortasun™ product offerings section.

## Fortasun™ product offerings

	PV-804	PV-8030	PV-8101	PV Instant-Seal	PV-8301	PV-8303
U-Frame	X	X	X	X	X	X
L-Frame		X			X	X
Frameless* (pads or rails)		X			X	X

\* For structural applications

For framing and bonding PV modules, DuPont offers several solutions. Fortasun™ silicone sealants are designed to provide durable weather sealing and/or structural bonding and stable mechanical and dielectric properties over an extended temperature range. Refer to the Frame design section for more information.

### One-part sealants

One-part silicone sealants have been used successfully for over 60 years. They cure by reaction with water vapor from the ambient atmosphere. The cure reaction progresses deeper into the joint by diffusion of water vapor. Typical cure times range from 24 hours to seven days depending on the joint depth. One-part silicone sealants are easy to apply manually or automatically, and dispensing equipment costs are lower compared to equipment costs for two-part sealants. The sealant cannot support load until cure is completed.

DuPont offers multiple silicone sealants that can meet your specific requirements.

#### Fortasun™ PV-804 Neutral Sealant

Fortasun™ PV-804 Neutral Sealant is an alkoxy-cure silicone sealant with proven performance in the industry. It is designed to provide long-term sealing and protection against moisture, environmental attack, mechanical and thermal shock, and vibration. It offers excellent adhesion to typical PV substrates, including anodized aluminum, polycarbonate, glass and fluoropolymer laminates such as DuPont™ Tedlar® based backsheets.

#### Fortasun™ PV-8030 Adhesive

Fortasun™ PV-8030 Adhesive is a high-performance alkoxy-cure silicone adhesive designed to provide long-term bonding and to protect against moisture, environmental degradation, and mechanical and thermal shock. It is specifically recommended for structural bonding to attach typical PV substrates.

#### Fortasun™ PV-8101 Sealant

Fortasun™ PV-8101 Sealant is a fast-curing, tack-free silicone oxime sealant designed for sealing PV frames and junction boxes. It offers excellent adhesion to PV substrates, including anodized aluminum, PPO, glass and fluoropolymer laminates such as Tedlar® based backsheets. It forms a flexible elastomer that protects against mechanical shocks and thermal cycling stress at components. It does not slump, sag or run off the surface.

#### Fortasun™ Solar PV InstantSeal

Fortasun™ Solar PV InstantSeal is a reactive hot-melt silicone for high-speed PV frame and junction box sealing. Its instant green strength allows immediate handling and shipment. It develops adhesion with the typical PV substrates.

### Two-part sealants

Two-part silicone solutions for framing and bonding are sealants that are supplied as two separate parts – base and catalyst. Appropriate pump equipment is required to meter and mix the components before dispensing. Two-part components typically cure within a few hours of dispensing, and finished units may be handled within a half hour or less and installed within 48 hours depending on your individual process and design. The ability to rapidly complete production will reduce the need for large space requirements for work-in-process inventory.

DuPont offers a fast cure and an ultra fast cure sealant to meet your specific application needs. Product information is listed below.

#### Fortasun™ PV-8301 Fast Cure Sealant

Fortasun™ PV-8301 Fast Cure Sealant is designed to provide long-term bonding and protection against moisture, environmental degradation and mechanical and thermal shock where cure speed is critical. It is recommended specifically for structural bonding to attach typical PV substrates. This two-part material consists of Fortasun™ PV-8300 Base and Fortasun™ PV-8301 Catalyst.

#### Fortasun™ PV-8303 Ultra Fast Cure Sealant

Fortasun™ PV-8303 Ultra Fast Cure Sealant is designed to provide long-term bonding and protection against moisture, environmental degradation, and mechanical and thermal shock where ultra fast cure is needed for automated processing. It is recommended specifically for structural bonding to attach typical PV substrates. This two-part material consists of Fortasun™ PV-8300 Base and Fortasun™ PV-8303 Ultra Fast Cure Catalyst.

## Cleaners and primers

Fortasun™ sealants can typically be used on clean parts without cleaner or primer. In some instances, a cleaner or primer may be required for the silicone sealant to achieve optimal adhesion to a particular substrate. See the section on Material Component Considerations for specific recommendations for each substrate.

## Joint dimensioning

When considering L-frame or frameless designs, a structural joint must be properly designed for the sealant to offer the intended reliability and durability. If a joint is improperly designed, the sealant stresses may be excessive, potentially causing failure. Considering the diversity of designs and requirements, the following recommendations do not constitute warranties and may not apply directly to your specific application. These guidelines are based on long experience with silicone structural sealants for structural glazing in construction. Please contact DuPont for specific support on your project.

### Structural joint dimensioning guidelines

Following are guidelines that apply for all structural bonding applications. These guidelines are minimum requirements and exclude any application tolerances.

- The minimum structural joint bite shall be as determined by the structural bite calculation for wind load and for dead load
- The minimum structural joint thickness shall be as determined by the joint thickness calculation for thermal dilatation
- The structural bite must be equal to or greater than the joint thickness
- The structural joint thickness must be greater than 2 mm
- The joint design must allow the sealant exposure to air so that it can cure and achieve full physical properties (especially critical for one-part sealants)

## Structural bonding technology

### Structural bite

Structural bite is the minimum width or contact surface of the silicone sealant on both the PV laminate and the supporting structure. The design wind load, dead load and thermal dilatation stresses must be considered in the determination of the structural bite dimension.

### Thickness

Thickness is the distance from the PV laminate to the supporting structure (i.e., frame, rail or pad). Proper thickness facilitates the installation of the sealant and allows reduced sealant stress from differential thermal movement between the PV laminate and the supporting structure.



## Minimal bite for wind load

The structural bite requirement is directly proportional to the wind load on the PV module and the dimensions of the module. The higher the wind load and the larger the dimensions of the module, the greater the amount of structural bite required. For reference, IEC 61215 and IEC 61646 request test with 2400 Pa.

## Structural bite calculation for wind load and laminate dimension

### For L-Frame design:

Minimum structural bite (m) =

$$\frac{\text{Laminate Short Span Dim. (m)} \cdot \text{Wind Load (Pa)} \cdot 0.5}{\text{Maximum Allowable Design Stress (Pa)}}$$

### For rail bonding:

Minimum structural bite (m) =

$$\frac{\text{Laminate Area (m}^2\text{)} \cdot \text{Wind Load (Pa)}}{\text{Bond Length (m)} \cdot \text{Maximum Allowable Design Stress (Pa)}}$$

### For pad bonding:

Please contact DuPont or a structural engineer for detailed calculations based on your specific design.

- Laminate Short Span Dimension is the shorter of the two dimensions of the rectangular laminate. For example, on a 0.9 m by 1.8 m laminate, the Laminate Short Span Dimension is 0.9 m
- Wind Load is the maximum wind pressure in Pascal. For reference, IEC 61215 and IEC 61646 request test with 2400 Pa
- 140,000 Pa (0.14 MPa) is the Maximum Allowable Design Stress for Fortasun™ PV-8030 Adhesive, Fortasun™ PV-8301 Fast Cure Sealant and Fortasun™ PV-8303 Ultra Fast Cure Sealant
- Maximum Allowable Design Stress is based on the Ru,5 value with a safety factor of 6. The Ru,5 value is the probability at 75% that 95% of the population will have a breaking strength above this value.

Note: The deflection of the glass is not taken into account in these formulas.

## Minimal bite for dead load

In frameless designs, the dead load weight of the PV laminate is supported by the structural silicone joint. Fortasun™ silicone sealants can support the weight of the laminate provided stresses. Do not exceed the Allowable Design Stress for Dead Load. DuPont will consider both the vertical and horizontal or long edges of the frame in the dead load calculation, provided the horizontal frame edges are as rigid as the vertical edges and the load is evenly distributed on the supporting structure (i.e., frame, rail or pad).

If the module is to be qualified to withstand heavy accumulations of snow and ice, the load applied to the front of the module for the mechanical load test of IEC 61215 and IEC 61646 is increased from 2400 Pa to 5400 Pa. The Allowable Design Stress for Snow Load is 40,000 Pa (0.04 MPa) for Fortasun™ PV-8030 Adhesive and Fortasun™ PV-8303 Ultra Fast Cure Sealant and 50,000 (0.05 MPa) for Fortasun™ PV-8301 Fast Cure Sealant.

### Structural bite calculation for dead load

#### Structural bite calculation for dead load

Minimum structural bite (m) =

$$\frac{\text{Laminate Weight (kg)} \cdot 9.81 \text{ m/s}^2}{\text{Bond Length (m)} \cdot \text{Allowable Design Stress for DL (Pa)}}$$

- 9.81 m/s<sup>2</sup> is the factor for gravity
- The Allowable Design Stress for Dead Load (DL) for Fortasun™ PV-8030 Adhesive is 7,000 Pa. The Allowable Design Stress for Dead Load for Fortasun™ PV-8301 Fast Cure Sealant and Fortasun™ PV-8303 Ultra Fast Cure Sealant are respectively 11,000 Pa and 9,500 Pa.

### Minimal joint thickness for thermal dilatation

The differential thermal movement between the PV laminate and the supporting structure will impose upon the structural sealant joint a shear stress that must be considered during the design of the joint. The amount of differential movement will depend on the laminate and supporting structure materials, maximum temperature change of the whole module, the temperature difference between the components of the module and the design of the system.

### Joint thickness calculation for thermal dilatation

#### Joint thickness calculation for thermal dilatation

Minimum joint thickness (m) =

$$\frac{\text{Thermal Dilatation (m)} \cdot \text{Young Modulus (Pa)}}{3 \cdot \text{Maximum Allowable Stress in Shear (Pa)}}$$

- The Thermal Dilatation is the amplitude of differential thermal movement between the glass and frame or rail
- Fortasun™ PV-8030 Adhesive has a Young Modulus of 0.9 MPa and Fortasun™ PV-8301 Fast Cure Sealant and Fortasun™ PV-8303 Ultra Fast Cure Sealant have a Young Modulus of 1.4 MPa
- The Maximum Allowable Stress in Shear is determined by Ru,5 value as determined in shear. For Fortasun™ PV-8030 Adhesive, this value is 140,000 Pa. For Fortasun™ PV-8301 Fast Cure Sealant and Fortasun™ PV-8303 Ultra Fast Cure Sealant, the value is 105,000 Pa.

## Material component considerations

It is important in the design of a system that the proper materials be used. See the information below to ensure that each substrate is compatible with Fortasun™ sealants. For more information, please contact DuPont. Adhesion tests must be performed as described in the section Quality control test procedures to ensure proper adhesion on your specific substrates.

### Glass

Fortasun™ PV sealants have been tested to develop good adhesion on standard glass after cure and after the accelerated aging conditions typical of IEC standards (e.g., damp heat test, thermal cycling test).

### Backsheets

Fortasun™ PV sealants have been tested to develop good adhesion on many PV backsheets (including Tedlar® based) after the accelerated aging conditions typical of IEC standards (e.g., damp heat test, thermal cycling test).

For information on a specific backsheet material, please contact DuPont. Adhesion tests must be performed as described in the section Quality Control Test Procedures to ensure proper adhesion on your specific substrates.

### Metals

Fortasun™ PV sealants have been tested to develop good adhesion on anodized aluminum after cure and after the accelerated aging conditions typical of IEC standards (e.g., damp heat test, thermal cycling test).

For structural applications, it is recommended that you treat the anodized aluminum with a proven, commercially available primer for optimal adhesion unless a customer-specific adhesion test ensures a reliable and durable adhesion without primer (initially and after aging).

For information on other metals, please contact DuPont. It is required to perform adhesion tests as described in the section Quality control test procedures to ensure proper adhesion on your specific substrates.

## Processing

DuPont has demonstrated success working with production-scale framing and bonding solutions. We have longstanding relationships with many equipment suppliers. We will happily make recommendations based on your specific needs and work with your preferred supplier. Please contact DuPont for more information.



## Product quality

DuPont performs extensive quality assurance testing in its manufacturing facilities in accordance with ISO 9001 standards. This section of the manual is intended to provide the sealant user with procedures and recommendations for the proper storage, handling, use and quality control of Fortasun™ PV sealants for framing and bonding applications. As a product user, it is your responsibility to understand and closely follow the procedures and recommendations set forth in this section of the manual as well as any additional tests required by your specific application and process. If you have questions regarding any of the following procedures or recommendations, please contact DuPont prior to using only Fortasun™ products.

### General considerations

#### Material storage and handling

Fortasun™ PV sealants must be stored at the recommended temperature and environment. Excessive temperatures or moisture may damage the sealant. Cure, adhesion and physical properties could be compromised if the sealant is not handled and stored properly. The user must understand and follow recommendations on the proper use of dispensing equipment for silicone sealants.

#### Shelf life

Fortasun™ PV sealants must be used within their stated shelf life. Sealant that is beyond its stated shelf life may not cure properly to its full physical properties and/or it may not develop the proper adhesion. Expired sealants must not be used.

#### Factory vs. site

Structural bonding should be performed in the controlled environment of a production facility. Weather sealing with silicone sealants may be performed in a production facility environment or at the job site. Specific local requirements may not permit site sealing in some instances. Cure requirements and considerations for site sealing are discussed later in this section.

#### Joint preparation and sealant application

Specific procedures and recommendations on joint preparation and sealant application are made later in this section. These procedures and recommendations will help to ensure proper sealant adhesion, cure and joint fill. Ignoring or skipping a step in the process could have an adverse effect on performance. These procedures should be understood and completely followed by the user.

#### Qualification and quality control

Comprehensive qualification and quality control programs are the most critical elements of a successful framing or bonding solution. DuPont provides procedures and recommendations that must be completely understood and followed by the sealant user. These procedures are proven to be effective and reliable.

## One-part sealants

### Storage temperature and conditions

One-part PV sealants from DuPont must be stored at temperatures below +30°C. They should be stored indoors in a dry environment. An expiry date is clearly marked on the sealant packaging; the sealant should be used only if it is within this expiration date. The sealant should be kept in its original, unopened package until the sealant is to be used.

### Skin-over time/elastomeric test

A skin-over time and elastomeric test should be performed once per day and on each new lot of sealant to be used. The purpose of this test is to ensure that the sealant cures fully and has typical elastomeric properties. Any variation, such as excessively long skin-over time, may indicate that the sealant is beyond shelf life or has been stored at excessively high temperature. Skin-over time will vary with temperature and humidity. Higher temperature and humidity will cause the sealant to skin over and cure faster.

The following procedure must be performed before any material is used in production. Production quality control procedures, such as adhesion tests on production materials, are described later in this section.

1. Spread a 2 mm thick layer of sealant on a polyethylene sheet.
2. Every few minutes, touch the sealant film lightly with your finger.
3. When the sealant no longer adheres to your finger, the skin-over time has been reached. If the skin-over time is greater than two hours, do not use this material and contact DuPont.
4. Allow the sealant to cure for 48 hours. After 48 hours, remove the sealant from the polyethylene sheet. Stretch the sealant slowly to determine whether it has cured to normal elastomeric properties. A control sample of "good sealant" can be used for comparison. If the sealant has not cured properly, do not use the material and contact DuPont.
5. Record results in your Quality Control log.

### **Cure requirements**

One-part silicone sealants cure by reaction with water vapor in the air. The cure reaction progresses deeper into the joint by diffusion of water vapor. Typical cure times range from 24 hours to seven days depending on the cure depth.

All one-part silicone sealants, whether one-part or two-part, require exposure to atmospheric moisture to cure. In a closed container or concealed joint that is not exposed to atmospheric moisture, sealant cure will be slow to nonexistent. Sealant adhesion will only occur if the sealant is allowed to cure to its full physical properties. Please ensure that the tooled sealant joint is fully exposed to the environment.

### **Maintain proper production facility temperature**

Ambient temperature in the production facility must be between +10°C and +40°C. For best performance, maintain a temperature of between +18°C and +30°C. At colder temperatures, between +10°C and +18°C, cure rate and adhesion development will be slower. In higher temperatures, between +30°C and +40°C, and working time will be shorter.

### **Avoid excessively high humidity**

The sealant will cure faster and have a shorter working time in higher relative humidity environments. Excessively high humidity (>80%) could cause moisture on the substrate surface and adversely affect sealant adhesion. To minimize moisture damage to the individual sealant components, pails and drums must be kept airtight during storage and after being placed on the dispensing equipment. When using a pressure pot, the air inside the drum or pail must be filtered and dried (silica gel filters are recommended).

### **Two-part sealants**

#### **Storage temperature and conditions**

Two-part framing and bonding sealants from DuPont must be stored at temperatures below +30°C. They should be stored indoors in a dry environment. An expiry date is clearly marked on the sealant packaging for the catalyst and base. The sealant should only be used if it is within this date. The sealant should be kept in its original unopened packages until it is to be used. Containers of catalyst and base are not lot-matched. It is best to use the oldest container of material first.

### **Two-part dispensing equipment guidelines**

When Fortasun™ PV sealants are properly applied, they will provide excellent long-term adhesion and durability, which is necessary for structural applications.

Two-part PV sealants from DuPont require correct pumping and mixing by the sealant user to achieve intended performance. State-of-the-art technology for the application of two-part sealants uses an appropriate pumping, metering and mixing machine with either a dynamic or static mixer.

There are several different suppliers for such equipment. The dispensing machines available in the market are all different in design; therefore, DuPont strongly recommends that the user follow the equipment supplier's guidelines regarding the proper use and maintenance of the dispensing equipment.

In addition to the guidelines from the equipment supplier, DuPont recommends that the sealant user understand and comply with the following best practices:

#### **Catalyst must be homogeneous**

Prior to placing material on the dispensing equipment, the catalyst should be visually inspected and agitated in the pail to ensure homogeneity. Do not incorporate excessive air during mixing of the catalyst. It is recommended to mix the catalyst one to three days before the pail needs to be changed to allow the catalyst to de-air.

### **Cure requirements**

#### **Maintain proper production facility temperature**

Ambient temperature in the production facility must be between +10°C and +40°C. For best performance, maintain a temperature of between +18°C and +30°C. At colder temperatures, between +10°C and +18°C, cure rate and adhesion development will be slower. In higher temperatures, between +30°C and +40°C, working time will be shorter.

#### **Avoid excessively high humidity**

The sealant will cure faster and have a shorter working time in higher relative humidity environments. Excessively high humidity (>80%) could cause moisture on the substrate surface and adversely affect sealant adhesion. To minimize moisture damage to the individual sealant components, pails and drums must be kept airtight during storage and after being placed on the dispensing equipment. When using a pressure pot, the air inside the drum or pail must be filtered and dried (silica gel filters are recommended).

## Surface preparation and sealant application

Every structural bonding application requires a diligent and thorough procedure to ensure that substrates are properly cleaned prior to sealant application. The following procedures should be followed for every structural bonding application. Further description of the cleaning, priming and placing procedures are included in the subsequent section.

1. **Inspect** substrates and materials prior to use. The materials used in production must be representative of the materials that were tested for technical qualification. The substrates (e.g., aluminum profiles) should be in good condition and not damaged by outdoor weathering.
2. **Clean** substrates. Joint surfaces must always be clean, dry, dust-free and frost-free. Moisture or contaminants on the surface may have an adverse effect on sealant adhesion to a substrate.
3. **Prime** the surface to receive sealant if required.
4. **Place** the PV laminate to be framed or bonded in the correct position. Care must be taken to not contaminate cleaned surfaces during any phase of production. If contamination occurs, surfaces must be cleaned again.
5. **Apply** sealant into the joint cavity. The joint must be completely filled with sealant. By “pushing the bead” of sealant into the joint in a continuous manner, air entrapment can be avoided.
6. **Tool** or strike the sealant joint surface with a tooling device such as a spatula. The sealant must be pushed into the joint with a tool. Scooping excess sealant from the joint is not acceptable tooling. Tooling helps to ensure that the sealant wets out the joint surfaces and completely fills the joint without air entrapment.
7. **Inspect** the finished modules. Determine whether the entire joints have been properly filled and tooled. Determine whether the modules are stored in the proper conditions and inspect whether the sealant is curing properly. Ensure that all of the recommended quality control tests are being performed.

## Substrate cleaning procedure

The key to acceptable sealant adhesion is a clean surface. Following is a proven procedure to clean non-porous substrates. Substrates such as glass and aluminum must be cleaned prior to application of sealant. DuPont recommends the two-cloth cleaning method to clean materials. A commercially available solvent such as R 40 Universal Cleaner is recommended for solvent cleaning of substrates. Alternate solvents (such as isopropanol and acetone) may be acceptable; however, pure water, soaps and detergent are not acceptable cleaning agents.

## Solvent consideration

The solvents named in this section are recommended based upon our experience with these sealants. You should always check with the supplier of the substrate to ensure that the cleaning procedures and solvents are compatible with each substrate.

## Two-cloth cleaning method

The two-cloth cleaning method is a proven technique to clean surfaces. The use of one cloth to clean a substrate is not as effective as two cloths and is not a recommended procedure. Clean, soft, absorbent, lint-free cloths must be used. This method consists of cleaning the substrate with a solvent-saturated cloth followed by a drying wipe with a separate clean cloth. Following is the procedure described in greater detail:

1. Thoroughly clean all surfaces of loose debris.
2. Pour a small quantity of cleaning solvent into a working container. A clear plastic, solvent-resistant squeeze bottle works best for this purpose. Do not apply solvent directly from the original container. Saturate a clean cloth with solvent.
3. Wipe the joint surfaces with sufficient force to remove dirt and contaminants.
4. Immediately wipe dry the solvent-wet surface of the substrate with a separate clean, dry cloth. The second cloth must wipe the substrate before the solvent has evaporated.
5. Visually inspect the second cloth to determine if contaminants were effectively removed. If the second cloth remains dirty, repeat the two-cloth cleaning method until the second cloth remains clean. For each subsequent cleaning, use a clean portion of the cloth. Do not clean with the dirty portion of the cloth. For best results, replace used and dirty cloths frequently.

### **Substrate priming procedure**

Commercially available 1200 OS Primer is the primer commonly recommended for structural bonding applications. The following procedure describes how to properly prime surfaces with commercially available 1200 OS Primer:

1. Before using, verify that the commercially available 1200 OS Primer is within its stated shelf life. The primer should be stored below +25°C in its original unopened container. The primer should be clear and water-like in appearance. If the primer is milky white in appearance, do not use it. Red-colored primer is also available.
2. Joint surface must first be clean and dry. Priming should begin within four hours after the cleaning step. If there is a greater time delay, joint surfaces must be recleaned prior to priming.
3. Pour a small amount of primer into a clean, dry container. Do not pour more than a 10-minute supply of primer into the working container. Replace and tighten the cap on the container immediately after dispensing the primer. Excessive exposure of the primer to atmospheric moisture will cause it to deteriorate and turn milky white in the container.
4. Pour a small amount of primer from the working container onto a clean, dry, lint-free cloth and gently wipe a thin film on all joint surfaces requiring primer. Apply only enough primer to wet the surface. Over-priming can cause adhesion loss between the sealant and the substrate. If too much primer is applied, a powdery white film will form on the substrate. Over-priming is not an acceptable practice and should be stopped immediately.
5. Allow the primer to dry until all of the solvent evaporates. This typically takes from five to 30 minutes depending on temperature and humidity.
6. Inspect the surface for dryness and for the appearance of over-priming. A primed non-porous surface will have a slight haze. If red-colored primer is used, the primed surfaces will appear red in color. Primed surfaces must be sealed within the next four hours. Any surfaces primed but not sealed within four hours must be cleaned again and primed again before applying sealant.

### **Properly maintain sealant dispensing equipment**

It is essential that the sealant user establish a quality program that will ensure the proper functioning of the sealant dispensing equipment. Because there are many different dispensing equipment manufacturers, maintenance requirements will differ. Requirements common to all equipment manufacturers include:

- Sealant must be dispensed free from exposure to air. Fortasun™ PV sealants must be processed in a closed system free from exposure to air. Air incorporated into the sealant may have a severe detrimental effect on adhesion and performance. Air trapped during the change of sealant containers must be completely bled out or flushed out of the system prior to use.
- Regularly inspect and maintain components of the dispensing equipment. Air can be incorporated into the sealant if the pump is defective or gaskets have hardened or are damaged; allowing air into the system. When using high pressure pumping equipment with a follower plate system, regularly check the follower plate to ensure that it is moving smoothly and will not be blocked by a damaged drum or pail or by a damaged or brittle gasket. Proper maintenance and cleaning of the mixer helps to ensure properly mixed sealant. Filters and gaskets should be regularly inspected and replaced as necessary.
- Ensure that there is no contamination of sealant components. Sealant must not come in contact with machinery oils from the equipment. Pumps must be checked for tightness and oil should not be used on the follower plates.
- When using a solvent such as commercially available 3522 Cleaning Solvent Concentrate for cleaning of the mixing line, the sealant lines must be completely closed against the solvent lines to avoid contamination of the sealant with solvent. All gaskets must be compatible with the cleaning solvent.
- Regularly maintain gaskets. Some gaskets, especially those in direct contact with the sealant components, could become brittle or will show a volume increase after prolonged exposure. Deteriorated gaskets must be immediately replaced. Please request from your equipment supplier gaskets and other components that are compatible and recommended for use with Fortasun™ PV sealants. The equipment supplier should also provide a schedule for regular replacement of gaskets. Please contact DuPont if you need specific recommendations.

## Sealant application and quality control procedures

### Sealant application procedure

Sealant must be applied to clean, dry, dirt-free and frost-free surfaces, and the joint surfaces must be primed if recommended by DuPont for the specific substrates. Sealant adhesion may be harmed by an improperly cleaned or primed joint. Sealant must also completely fill the joint. The performance of the system depends on appropriate structural bite. An underfilled joint may jeopardize the performance of the system.

The following procedures describe the proper sealant application methods:

1. Apply sealant in a continuous operation using an application gun or dispensing equipment. A positive pressure, adequate to fill the entire joint, should be used. By “pushing the bead” of sealant into the joint in a continuous manner, air entrapment can be avoided.
2. Tool the sealant with light pressure before a skin forms on it. This is typically within five to 10 minutes.
3. Avoid the use of wet tooling aids such as soaps or solvents during tooling. Dry tooling is recommended. Do not scoop sealant since this does not effectively push it into the joint; this causes the sealant to fully wet out the sides of the joint.
4. If the surface adjacent to the joint has been masked, remove the masking at this time.

### Quality control test procedures

Quality control is one of the most important elements of a successful structural bonding application. This section of the manual should be fully understood and continually reviewed by the sealant user. The procedures and recommendations made in this section are the foundation of a comprehensive quality control program.

### Sealant production quality control

During production, periodic quality control should be performed on Fortasun™ two-part sealants produced through two-part dispensing equipment. These test procedures help to ensure the sealant is being properly mixed at the correct ratio. These tests and their recommended frequency are shown in the following table:

Sealant production QC test	Frequency of Test		
	After each pump start-up	After each container change	Diagnostic investigation
Glass test	Required <sup>1</sup>	Required <sup>1</sup>	Required
Butterfly test	Required <sup>1</sup>	Required <sup>1</sup>	Required
Snap time test	Required	Required	Required
Mixing ratio test	Not required	Not required	Required

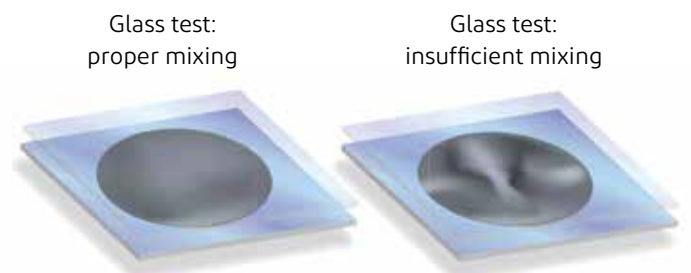
<sup>1</sup> Either the glass test or butterfly test must be performed at the scheduled frequency. It is not required that both tests be performed.

### Glass test

The glass test is a procedure used to evaluate the mix of two-part silicone sealants. This test is performed each time a pump starts up and after either the catalyst or base container is changed. The purpose of this test is to determine whether the two-part dispensing equipment is adequately mixing the sealant base and catalyst.

For Fortasun™ PV-8301 Fast Cure Sealant and Fortasun™ PV-8303 Ultra Fast Cure Sealant, the sealant base is white and the catalyst is either black or clear. When properly mixed, the finished sealant is either black or white, with no streaks. Improper mix can be the result of a damaged check valve, a clogged hose, a clogged mixer, etc. Regular equipment maintenance will help to ensure proper sealant mixing. Please consult with your dispensing equipment manufacturer for maintenance guidelines.

To perform the glass test, apply a bead of sealant to a clean, clear glass sample which is approximately 10 cm x 10 cm. Place another clean, clear glass sample on top of the silicone, pressing the two pieces of glass together. Please refer to the images below. In the case of the black catalyst, the resulting sandwiched sealant should then be visually inspected for white streaks. The sealant should appear completely uniform and black. If results are negative, perform the test again after additional material is processed through the machine. If the results are negative again, equipment maintenance may be necessary. If additional assistance is required, please contact DuPont.



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### Butterfly test

The butterfly test is a procedure that is similar to the glass test. This test is performed at each pump start-up and after either the catalyst or base container is changed. The purpose of this test is to determine whether the two-part dispensing equipment is adequately mixing the sealant base and catalyst.

For Fortasun™ PV-8301 Fast Cure Sealant and Fortasun™ PV-8303 Ultra Fast Cure Sealant, the sealant base is white and the catalyst is either black or clear. In the case of the black catalyst, when properly mixed, the finished sealant is uniform black with no white streaks. Improper mix can be the result of a damaged check valve, a clogged hose, a clogged mixer, etc. Regular equipment maintenance will help to ensure proper sealant mixing. Please consult with your dispensing equipment manufacturer for maintenance guidelines.

Following is the procedure for performing a butterfly test:

1. Fold a sheet of stiff, white A4 (or 8.5" x 11") paper in half.
2. Apply a bead of sealant to the fold in the paper.
3. Press the sheet of paper together compressing the sealant into a thin film.
4. Pull the paper apart and visually inspect the sealant for indications of poor mix.



Apply sealant to folded paper



Press together



Insufficient mixing



Proper mixing

AV13879

### Snap time test

Once proper mixing of the sealant is established by the glass test and/or butterfly test, a snap time test must be performed for two-part sealants. This test is performed each time a pump starts up and after either the catalyst or base container is changed. The snap time test helps to determine if the mix ratio is correct and whether the sealant is curing properly. Mixed sealant will handle like a one-part sealant until the chemical reaction between the base materials and catalyst begins to take place. The sealant will in a matter of minutes begin to "snap" and begin to show elastomeric or rubber properties.

Following is the procedure for the snap time test:

1. After proper mixing of the base and the catalyst, fill a small container with sealant.
2. Place a small stick or spatula into the sealant. Record the time (starting at the beginning of the mix). Every few minutes, pull the stick or spatula out of the sealant. Do not stir or agitate the sealant. As the sealant becomes more cured, it will become stringy. Once the sealant tears cohesively and snaps back when it is pulled, record the time.

This is the "snap time." The snap time will vary depending on temperature and humidity. Higher temperatures and higher humidity will cause the sealant to snap faster. Colder temperatures and lower humidity conditions will slow the snap time. Snap time will also vary from tester to tester depending on how the results are interpreted. Also, there will be variation from lot to lot of material and as the sealant ages. Highly unusual snap time values could be an indication of a problem with the pump. The most important determination from snap time is that the sealant does cure. If the sealant does not cure, then further investigation is required.



Stick inserted in cup

Before snap time

Snap time

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### Mixing ratio test

The mixing ratio test is not a test required by DuPont as a daily test. This test is useful to determine whether the sealant is mixing at the recommended ratio. Most two-part silicone dispensing machines provide a set of valves that allow the mixing ratio to be checked. Following is a procedure to perform the mixing ratio test:

1. Pressure valves must be adjusted in such a way that the pressure is equalized for both parts.
2. Hold a disposable cup underneath each valve outlet on the pump. Open the valve for 10 seconds or at least three strokes of both the base and catalyst pumps.
3. Weigh the two cups, minus the weight of the cup itself.

In the experience of DuPont, this test is not as reliable as a daily quality control test. It is a useful test if there are concerns about the mix of the sealant or the snap time. This test method is a very good diagnostic test and, along with the glass test or butterfly test and the snap time test, should be useful in the investigation of equipment problems.

### Adhesion and cure quality control tests

The following adhesion and cure quality control tests individually and together are the best means to determine whether you will have a successful structural bonding. Each test is valuable in its own way and must be considered as part of your comprehensive quality control program.

Dry peel adhesion testing is recommended as the daily test to verify sealant adhesion. H-piece testing is recommended to verify that the sealant has cured properly. Debonding is a procedure to verify proper sealant adhesion, cure and quality in actual production units.

DuPont requires the adhesion and cure quality control tests be performed by the sealant user at the frequency recommended in the following chart:

Sealant adhesion and cure QC test	Frequency of Test		
	After each pump start-up	After each container change	Diagnostic investigation
Peel adhesion test dry	Required	Required	Required
Peel adhesion test wet	Required (only for anodized aluminum)	Required (only for anodized aluminum)	Required (only for anodized aluminum)
H-Piece test	Alternate to peel adhesion test	Required <sup>1</sup>	Alternate to peel adhesion test
H-Piece test wet	Alternate to peel adhesion test wet (only for anodized aluminum)	Required <sup>1</sup> (only for anodized aluminum)	Alternate to peel adhesion test wet (only for anodized aluminum)
Deglaze test	Not generally required <sup>2</sup>	Not generally required <sup>2</sup>	Not generally required <sup>2</sup>

<sup>1</sup> H-piece testing after each container change may not be required by DuPont in some cases.

<sup>2</sup> Deglaze testing is a valuable test that should be included in every comprehensive quality control program.

Deglaze testing may be required for scientific projects or if special warranties are requested.

### Peel adhesion test

The peel adhesion test is the most effective daily test to verify sealant adhesion to a substrate. This simple screening test should be used as the daily test to verify adhesion of sealant to a substrate. This test should be performed on all substrates to which the sealant is expected to have adhesion at the following intervals:

- After each pump start-up or after extended breaks
- After a change of the catalyst or base container
- For each new lot of substrate

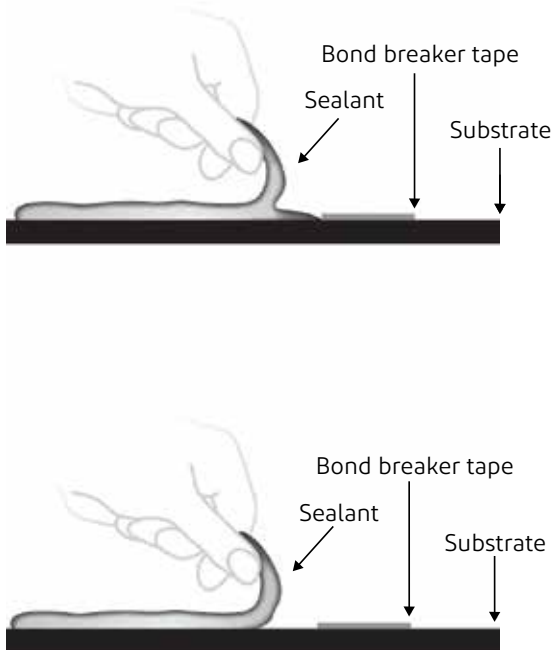
Following is a description of the peel adhesion test:

1. Clean and prime the substrate as recommended by DuPont and exactly the same way the production units will be prepared.
2. Place a piece of polyethylene sheet or bond breaker tape across the flat surface.
3. Apply a bead of sealant and tool it to form a strip approximately 20 cm long, 1.5 cm wide and 6 mm thick. At least 4 cm of the sealant should be applied over the polyethylene sheet or bond breaker tape.

4. It is best to embed a wire mesh halfway within the body of the sealant. For best results, solvent clean and prime the screen to ensure good adhesion to the wire mesh. If wire mesh is not available, reliable results can still be achieved.
5. After sealant cure, grasp the 4 cm tab of sealant which overlays the polyethylene sheet. Pull the sealant at a 180° angle. Peel back only 1 to 2 cm of sealant leaving the remainder in place for additional testing.
6. If the sealant tears within itself and remains fully bonded to the substrate, this is called “cohesive failure.” 100% cohesive failure is desirable since this indicates that the strength of adhesion is greater than the strength of cohesion.
7. If the sealant releases from the substrate, the sample indicates 100% adhesive failure (or 0% cohesive failure). Since sealant adhesion develops over time, repeat the test after an additional 24 hours of cure. Continue until 100% cohesive failure is achieved. If adhesion does not develop as expected, contact DuPont.

For anodized aluminum and when 100% cohesive failure is recorded in dry conditions, place the initial peel test under water for 15 minutes at room temperature. Remove the sealant from the water and again start the peel testing procedure. 100% cohesive failure in wet conditions is required. If adhesion does not develop as expected, contact DuPont.

An improved approach is to use a mechanical peel tester to give quantitative peel strength, and if the peel strength is above the required minimum, the failure made is of less importance.



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Following are some additional recommendations for peel adhesion testing:

- Peel adhesion tests must be run on production samples from the exact same lot of substrate or profile
- The substrate should be cleaned exactly the way the production units are cleaned
- The peel adhesion samples must be cured in the same temperature and humidity that the production units are stored
- Samples should be tested periodically, for example one, two and three days after cure for two-part sealants. Testing can conclude once the peel adhesion test shows full adhesion or 100 percent cohesive failure. For one-part sealants, peel adhesion tests should be performed at seven-day intervals.
- For additional details, please refer to ASTM C794-01

### H-Piece Test

The H-piece test is the primary test used to evaluate sealant cure properties. This test should be performed once for every combination of base and catalyst. If a container is changed, an H-piece test should be used to confirm that the sealant cure properties are acceptable. In some instances, DuPont may not require H-piece testing as a part of a comprehensive quality control program if other procedures, such as peel adhesion and deglaze testing, are performed at an appropriate frequency and if local standards and regulations do not require H-piece testing. The H-piece test can be used as a daily adhesion quality control test; but because the peel test is less complicated to perform, the peel test is the recommended daily adhesion quality control test.

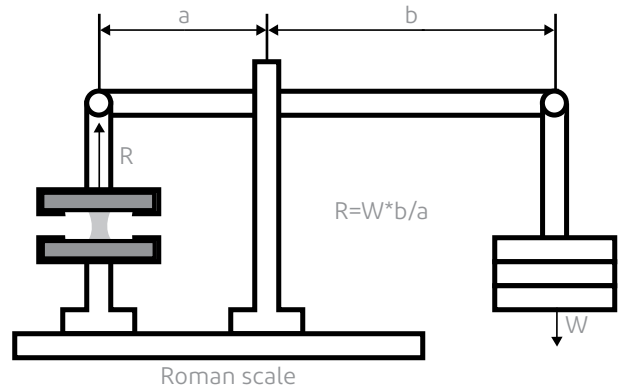
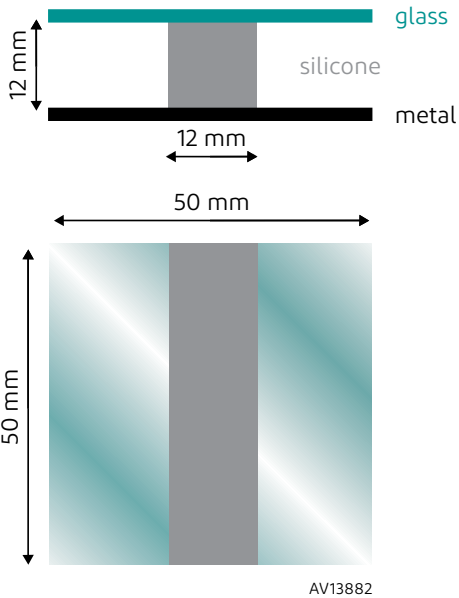
Every time a container is changed, four H-piece test samples should be produced. Samples should be made using actual production substrates. The substrates should be cleaned and primed in the same manner as production units are prepared. The test samples should be stored in the same temperature and humidity environment as the actual production units.

The first H-piece sample should be tested when production units are to be shipped. The peel adhesion tests should be used to verify full adhesion (100% cohesive failure). Full adhesion typically occurs after one to three days of cure for Fortasun™ PV-8301 Fast Cure Sealant and Fortasun™ PV-8303 Ultra Fast Cure Sealant and one to four weeks for Fortasun™ one-part Sealants. Adhesion times depend on joint geometry, temperature and humidity. Fortasun™ PV sealants must have full adhesion and cure in the actual production units before the modules are shipped. If properly cured, the sealant should have a minimum strength (check the technical data sheets or contact DuPont for each product). If results are not acceptable, a second H-piece is available for additional testing.



When dry results are acceptable or when the H-piece test is used as an alternate to the peel test for anodized aluminum, wet testing must also be operated after 15 minutes' water immersion at room temperature. Full adhesion (100% cohesive failure) and minimum strength (check the technical data sheets or contact DuPont for each product) must be achieved in dry and wet conditions.

The illustration below provides typical dimensions of an H-piece sample:



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H-piece samples can be tested with either a tensiometer or through the use of a Roman scale. A Roman scale as represented above will allow the silicone user to test sealant cure and adhesion with a low-cost piece of equipment. The weight applied to the silicone joint is equal to the weight ( $W$ ) on the Roman scale plate times the ratio of  $b/a$ . The H-piece sample should be tested to rupture.

The load should be applied for a maximum of 10 seconds with no adhesive or cohesive failure of the H-piece. If no rupture occurs, incrementally add 0.5 kg to the scale until the H-piece ruptures. Record the load at rupture and percent cohesive failure observed on the test sample. Results of H-piece testing should be recorded in a quality control log.

Test samples can be prepared using a wooden block that has been cut to allow a cavity to be filled with sealant in the dimension shown. The wooden block should be pretreated with a soap solution or paraffin wax to provide a bond-broken surface for the sealant. Alternatively, a polyethylene bond breaker tape can be applied to the wooden surfaces to contact the sealant. A polyethylene U-channel specifically designed for this test method can also be used. Two H-piece samples should be produced for every combination of catalyst and base used in production. Test samples should be stored in the same conditions as the actual production modules. One sample should be tested at the same time that production modules are to be shipped. Separately, peel adhesion testing should verify full adhesion (100% cohesive failure) at the same time.

## Deglaze test

Deglazing is a method of quality inspection used to confirm sealant adhesion, joint fill and quality on actual PV modules produced. Deglazing includes complete detachment of a structurally bonded laminate from a frame. Once the laminate is removed, the silicone sealant is inspected for cure, mix, uniformity of fill, lack of bubbles or air entrapment and, most importantly, to verify sealant adhesion. Deglazing is very useful to production personnel as a form of feedback on their performance. Production personnel should be present during the inspection. During inspection, the following elements should be evaluated:

- Measured dimension of the structural bite. The minimum structural bite as determined by the joint dimensioning must be satisfied. An under-filled joint may affect the performance of the bonding.
- Measured dimension of the joint thickness
- Adhesion of the structural sealant to the substrate and laminate. Sealant must achieve full adhesion (100% cohesive failure) to all substrates.
- Sealant uniformity of cure and sealant mix
- Lack of air entrapment and bubbles in the sealant

DuPont does not require this test method as a standard quality control procedure. Nevertheless, it is a good practice that should be incorporated in a comprehensive quality control program. For special warranties and certain projects, DuPont may require this procedure in the quality control program.

Deglazing should be performed as a regular quality control procedure in a production operation. This test can be performed randomly on any production sample. Additionally, this test should always be performed on modules where the laminate is damaged or needs to be replaced for some other reason. When replacing the laminate, a deglaze inspection can easily be performed. Laminate can be effectively removed using a knife or piano wire. It is best to cut the sealant mid-way in the joint so that enough sealant is left on the frame and panel to allow an adhesion test to be performed. A peel adhesion test, as described, can be performed on the remaining sealant.

Following is a recommended frequency for deglaze testing to be performed on a project:

1. First deglaze – one unit out of first 10 units manufactured (1/10).
2. Second deglaze – one unit out of next 40 units manufactured (2/50).
3. Third deglaze – one unit out of next 50 units manufactured (3/100).
4. Through remainder of the production, one unit of every 100 units manufactured.

For further assistance, please contact DuPont.

## Important information

The information contained herein offered in good faith based on DuPont research and is believed to be accurate. However, because conditions and methods of use of our sealants are beyond our control, this information shall not be used in substitution for customer's tests to ensure that Fortasun™ sealants are fully satisfactory for your specific applications. The Fortasun™ sole warranty is that sealant will meet its current sales specifications. Your exclusive remedy for breach of such warranty is limited to refund of purchase price or replacement of any sealant shown to be other than as warranted.

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