APPLICATION BULLETIN

SWM
engineered for tomorrow

ArgoBond®

ST-6050 TPU Interlayer Film

For Laminated Glass Applications

INTRODUCTION

Optical interlayers have been used to laminate layers of glass into clear composites since the 1930's. Typically made from polyvinyl butyral (PVB), these interlayers have performed well in a wide variety of glass-to-glass applications, particularly curved automotive windshields. With the evolution of security glass – like glass-to-polycarbonate used in today's bullet-resistant constructions – a new interlayer material was needed that could adapt to the varying rates of thermal expansion and contraction between such dissimilar substrates.

In the 1970's, interlayers made from thermoplastic polyurethane (TPU) were introduced to bond these dissimilar materials. SWM International (formerly Argotec) has been producing ArgoBond® TPU optical interlayers since the early 1980's.

The purpose of this application bulletin is to provide the prospective user with guidelines on selection, handling and design considerations for ArgoBond ST-6050 TPU optical interlayer film.

END USES

There are a wide variety of end uses for optical interlayers, PVB or TPU, wherever high strength and impact resistance are required:

- Architectural exterior & interior wall safety glass
- Security glass in banks, embassies, correctional facilities & retail store fronts
- Bullet-resistant glass
- Armored vehicles, both commercial and military
- Aerospace and aeronautic canopies and windows
- Hurricane resistant glazing

TPU interlayers possess the most desirable characteristics of both thermoset rubber and a thermoplastic. These characteristics make it ideal for laminating composites that combine dissimilar substrates like glass, polycarbonate, acrylic and other engineered plastics, whether flat or bent.

LAMINATE DESIGNS/ CONSTRUCTIONS

Laminated glass composites bonded together using optical interlayers can be constructed in a variety of flat and bent configurations:

Flat: Glass/TPU Interlayer/Glass (see fig. 1) Flat symmetrical compositions are the easiest to laminate.

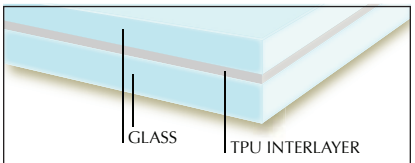


Fig. 1, Flat: Glass/Interlayer/Glass

Recommendations: Use a minimum of 0.050" (1.25 mm) TPU interlayer between the glass layers. There are no substrate min/max thickness requirements.

Flat: Glass/TPU Interlayer/ Polycarbonate (see fig. 2) Asymmetrical compositions are difficult to laminate. Ballistic compositions use polycarbonate as the anti-spall mechanism. A great deal of stress is induced into the polycarbonate during lamination that can cause breakage of the glass unless the glass is thick enough to withstand the stress. Typically, multiple layers of glass are used to overcome the stress in the polycarbonate.

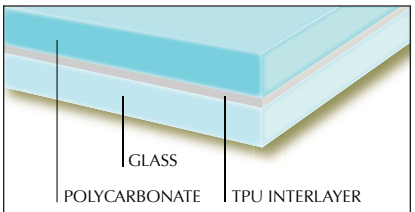


Fig 2, Flat: Glass/Interlayer/Polycarbon-

Recommendations: Use a minimum of 0.075" (1.9 mm) TPU interlayer between the polycarbonate and facing glass surface. Preforming the polycarbonate is recommended to reduce stress.

Flat: Glass/TPU Interlayer/ Polycarbonate/TPU Interlayer/Glass (see fig. 3) Symmetrical compositions are easier to laminate than asymmetrical substrates.

Recommendations: Use a minimum of 0.050" (1.25 mm) TPU interlayer between the glass and polycarbonate. There are no substrate min/max thickness requirements.

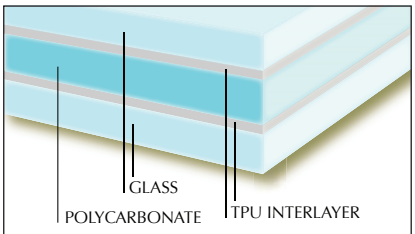


Fig. 3, Flat: Glass/Interlayer/ Polycarbonate/Interlayer/Glass

TYPICAL AUTOCLAVE LAMINATION CYCLES FOR TPU INTERLAYERS

Note: All of the parameters below are composition and process dependent.

	Time (minutes)	Temp (°F/°C)	Pressure (psi)
Pull vacuum	30 min. prior to application of heat	72°F (21°C)	Atmospheric = 14.72 psi (1 bar)
Ramp up	TBD core temperature	72°F (21°C) to 239°F (115°C)	30–180 psi (2-12 bars) composition dependent
Melting time	15 min. for every 1/4" (6 mm) of composition thickness	Maximum desired temperature 239°F (115°C)	30–180 psi (2-12 bars) composition dependent
Cool down	1°F (-17°C) per min at the core if using polycarbonate	Core temperature must be reduced below 125°F (52°C) before pressure is released	30-180 psi (2-12 bars) composition dependent

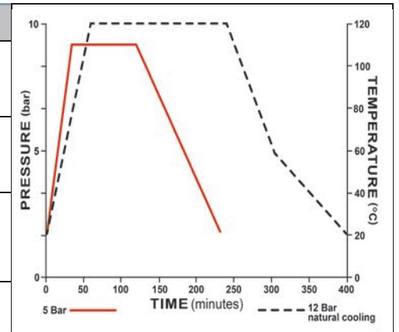


Fig. 5, graph of typical autoclave lamination cycle for TPU interlayer

Bent: Glass/TPU/Polycarbonate (see fig. 4) A flat ballistic composition uses polycarbonate as the anti-spall mechanism. As with asymmetric flat glass, stress is induced into the polycarbonate during lamination that can cause breakage of the glass.

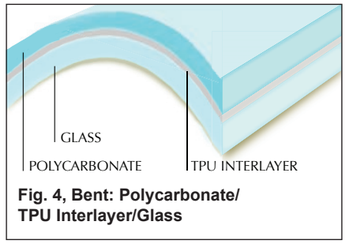


Fig. 4, Bent: Polycarbonate/ TPU Interlayer/Glass

Recommendations: Use a minimum of 0.075" (1.9 mm) TPU interlayer between the inboard surface and glass. Preforming the polycarbonate is recommended to reduce stress, including sheet that is coated one side with a scratch/abrasion-resistant coating; however, the coating must be designed to be formed.

Note that a laminated glass/TPU interlayer/polycarbonate composition cannot be formed following lamination.

Thin polycarbonate sheet, such as 1/8-inch (3 mm or less) can be formed during lamination. The polycarbonate is not really "formed;" it is pulled into shape by the vacuum bag and held in place by the adhesion of the TPU interlayer.

OTHER DESIGN CONSIDERATIONS

Additional factors can impact an optical interlayer's ability to bond to a substrate. For instance, there are different types of glass (chemically strengthened, tempered, float, etc.). These may also have additives or coatings that can affect adhesion and performance of the interlayer. Engineered plastic sheet, like polycarbonate, can have varying coatings (i.e., UV-absorbers, coated one or both sides) that can impact interlayer performance.

INTERLAYER SELECTION

Interlayer materials should be matched to the specific application:

- Adhesion
- Coefficient of thermal expansion and contraction
- Light transmission
- Ultraviolet resistance
- Color (clear, non-yellowing)
- Haze
- Impact resistance
- Strength
- Operating temperature range

INTERLAYER MATERIAL COMPARISON

PVB: Polyvinyl butyral works well in glass-to-glass and curved interlayer applications. However, it contains plasticizers that can migrate, embrittle and cause fogging around the edges of the composite. Plasticizers can cause variability in optical properties and adhesion. Because they are sensitive to water and other chemicals, PVB interlayers may require an edge seal to preserve the integrity of the laminate. PVB also requires refrigerated storage to prevent blocking. It does not bond well to plastic substrates. Finally, PVB interlayers can de-gas and cause bubbles between the substrates.

TPU: The base TPU polymer is 100% solids and contains no plasticizers. TPU interlayers exhibit excellent adhesion to glass, polycarbonate and polyester (up to 150 pli/26.3 kN/m), as well as the thermal expansion/contraction properties needed for bonding dissimilar materials to glass. TPU has good light transmission, low haze, and possesses high tensile strength (up to 6000 psi/41.4 MPa) for high-impact applications. No distortion (birefringence) is observed on bent-glass laminations. TPU interlayers are interleafed, so no refrigeration is needed during storage or processing.

LAMINATION PROCESSES

A number of processes are employed to create laminated glass composites:

- Autoclave
- Vacuum lamination
- Nip rolls
- Bladder presses

In each of these processes, the substrate preparation is critical to the successful bonding of the layers into a single composite, as is careful control of the process conditions:

- Layup (stacking of the layers)
- Preheat temperature ramp-up
- Pressure
- Press-time, temperature and pressure
- Ramp-down time down (reduction of temperature and pressure), see fig. 5

  Note: **The key temperature reading is at the core** of the interlayer and needs to be tracked throughout each cycle. A core coupon (see fig. 6) is a laminate of the same configuration that is placed centrally in the laminating chamber. It has a thermocouple placed in the center of the thickest configuration in the core of the laminate, with the thermocouple passed through the wall of the laminating chamber to a device that will allow constant monitoring of the core temperature.

GENERAL TEMPERATURE/ PRESSURE/TIME GUIDELINES

- Temperature/pressure/time are composition dependent.
- As glass thickness increases, the lamination cycle time is increased.
- As the number of layers increases, the lamination cycle time is increased.
- As polycarbonate thickness increases, the lamination cycle time is increased.

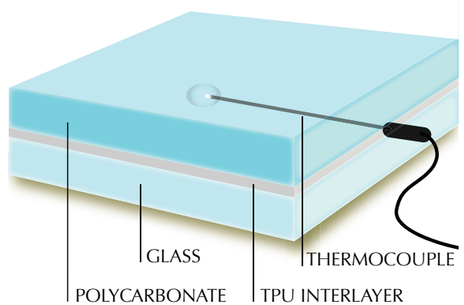


Fig. 6, Core Coupon. The thermocouple is inserted from the exterior of the composite into the center (core) of the laminate. When connected to a recorder it will display the temperature of the TPU interlayer throughout the entire lamination cycle.

Fig. 7, SWM produces the glass industry's cleanest TPU optical interlayer films. Its aliphatic extrusion operation is installed in an 8,000-square-foot hard-walled white room, with each individual extrusion lines housed its own ISO Class-7 soft-wall cleanroom.

- TPU interlayers should not be laminated to a coated polycarbonate surface because delamination may occur. The laminator should perform tests to ensure there is adequate adhesion/cohesion for their application.

SWM'S ARGOBOND® ST-6050

ArgoBond **ST-6050** optical interlayer has been in service for over 25 years. It is a great choice for security glazing applications that combine glass and polycarbonate or other engineered plastic substrates into an impact-resistant composite.

Optically clear **ST-6050** is extruded in a clean environment: an 8000-square-foot atmospherically controlled, hard-walled white room with each extrusion line housed in its own ISO Class-7 soft-walled clean room (see fig. 7 above).

Camera systems provide 100% in-line inspection of **ST-6050** that can detect contamination or inclusions, pin holes, voids, gels, wrinkles and streaks as small as 0.3 mm (0.012 in.). The result is the cleanest, most optically clear TPU interlayer film in the industry.

INTERLAYER SIZES

- Roll lengths (by gauge & width):

  0.025" x 40-60" x 240' roll
  0.050" x 40-60" x 120' roll
  0.075" x 40-60" x 80' roll

  Note: 80" width available upon request.
- Available thicknesses:

  0.150" (0.38 mm)
  0.025" (0.62 mm)
  0.030" (0.76 mm)
  0.050" (1.25 mm)
  0.075" (1.90 mm)

INTERLAYER HANDLING CONSIDERATIONS

Rolls are typically suspended on end plates and individually boxed, then palletized, nine rolls per pallet.

- Widths up to 80-inches depending on gauge.
- It is best to unwind by pulling the polyethylene interleaving.
- Contact the local waste management company for disposal of the interleaf.
- Store unused material in the original packaging.
- Keep in a cool and dry warehouse.

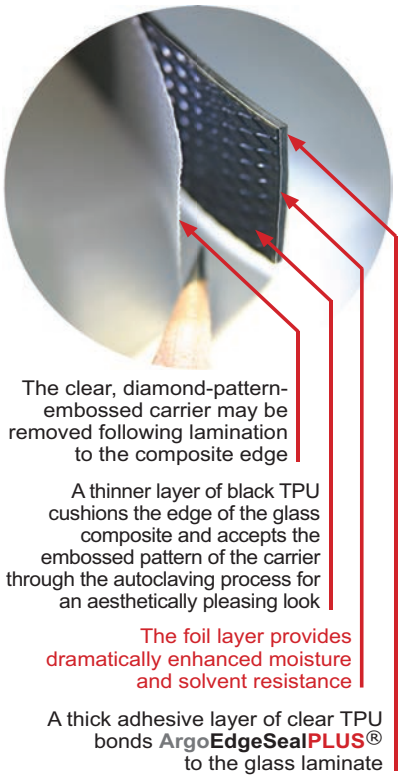
For more information on **ST-6050**, please visit our web site, www.swmintl.com.

EDGE-SEAL PRODUCTS

To provide glass laminators with more durable, longer lasting glass composites, SWM co-developed and manufactured its original multilayer **BOC-9450™ Edge Seal** in 1995 to provide a mechanical bumper and chemical barrier for the laminate. It is still available today and over the years has been used by the vast majority of laminators using interlayers.

In 2009 the company developed **ArgoEdgeSealPLUS®** (see fig. 8) to stand up to the ever-harsher environments in which security glazing is used. It contains a foil layer to better resist chemicals in caulks used to install glass and keep out moisture in the end use.

NOTE: **BOC-9450** and **ArgoEdgeSealPLUS** are compatible with both PVB and TPU optical interlayers.



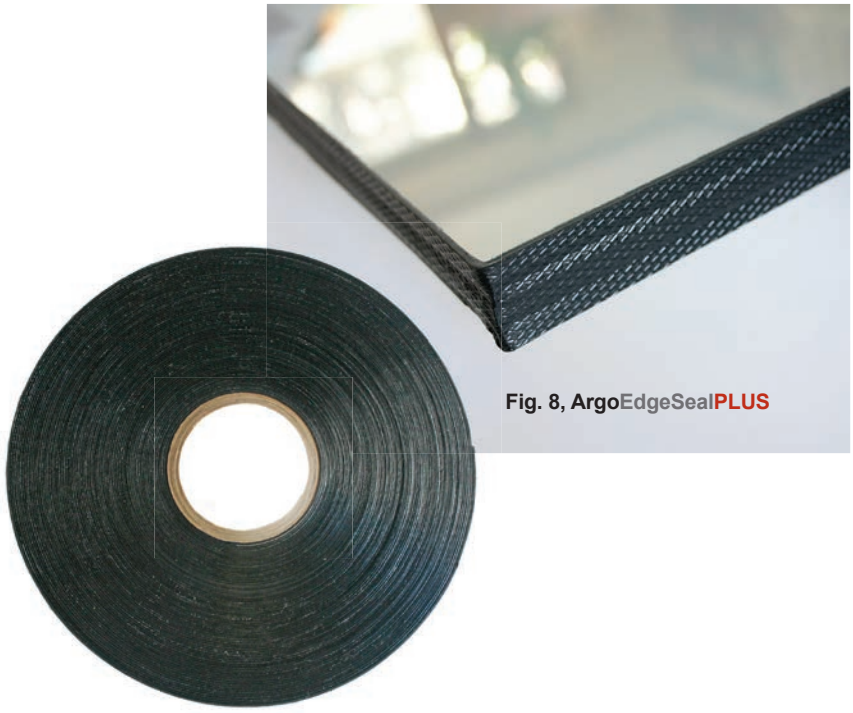


Fig. 8, ArgoEdgeSealPLUS

TYPICAL ST-6050 END USES

Revised: March 29, 2017

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