PRO-SET®

REPORT

2002 / 2

NEWS ABOUT

EPOXY CHEMISTRY,

COMPOSITE PROCESSES &

FABRICATORS

Product Update

Custom Untinted Adhesive

Gougeon Brothers, Inc.

In response to requests from several customers for an untinted version of PRO-SET® Adhesive, we are offering a new group of custom products. These can be used for any bonding or gluing operation where the green color of the standard PRO-SET Adhesive is not cosmetically suitable, such as strip planking boat hulls with bright finished interiors, or filleting and bonding Kevlar® structural members into a Kevlar hull shell. The new custom adhesive is a nearly clear material with a very slight white color. In thin film, there is no apparent color, but in a larger mass such as a fillet, it has a neutral translucence, like Vaseline®.

The new M1001 Adhesive Resin is the substitute for 175 Resin. M2001 is the untinted substitute for 273 Hardener, M2002 for 275, and M2003 for 277 Hardeners.

Tint is used in adhesives to provide a quality control check, visual confirmation that the product is fully mixed and at the proper ratio. Untinted products do not offer this feature.

The cartridge dispensing system is nearly foolproof. However, if the materials are very cold or if the adhesive has begun to cure in the static mixer, it is possible that flow will be reduced, creating greater back-pressure. The excess pressure may force some of the material to blow past the rear seal of the cartridge. This will cause the adhesive to be dispensed off-ratio, jeopardizing proper cure. Users should be diligent about keeping track of working time, temperature, and cure condition in the mixing wand to prevent this from occurring.

The mechanical properties, handling characteristics, and adhesion properties are the same for both kinds of products. Refer to the PRO-SET Adhesive product literature for complete information. The information is also available on the PRO-SET web site at www.prosetepoxy.com . Call Gougeon Brothers, Inc. at 989-684-7286 to order the custom adhesive. Please allow 2 weeks for shipment on custom products. ■

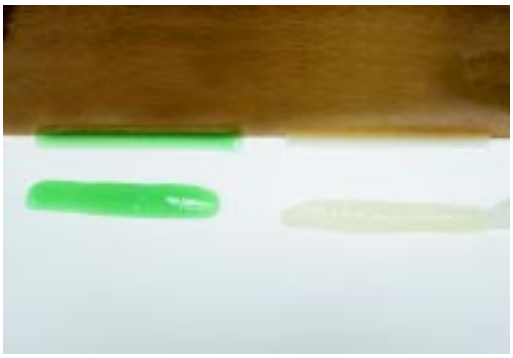

Photo shows our Standard Adhesive (left) and Custom Untinted Adhesive (right) in both fillet and bead form against a backdrop of mahogany and white laminate.

Speed	Standard	Custom
Fast	175/273	M1001/M2001
Medium	175/275	M1001/M2002
Slow	175/277	M1001/M2003

Custom Products

The standard PRO-SET product line includes a wide range of products for composites fabrication. We also offer a group of custom products, which have been developed for very specific applications. If you have a product requirement which is not being met by one of the standard products, please call us to dicsuss the specifics. We can formulate a solution for you. 989-684-7286.

Editor
Kay Harley

Design
Jennifer L. Jones

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3Weave™ Carbon Fiber Laminate

Brian Knight, Technical Services
Gougeon Brothers, Inc.

Recently, 3TEX, Inc. and Gougeon Brothers, Inc. teamed up to test a three dimensional carbon fiber pre-form. 3TEX manufactured the pre-form and TPI Composites, Inc. infused the pre-form with resin using VARTM (Vacuum Assisted Resin Transfer Molding).

For comparison purposes, two resin systems were used to infuse the pre-forms— an epoxy resin and a vinylester resin. The epoxy chosen was PRO-SET® 117LV Resin and 237 Hardener. The vinylester resin was Derakane® 470-300 manufactured by Dow Chemical.

To lower costs, vinylester resin is often used in Resin Transfer Molding (RTM) processes. These resins work well with e-glass laminates, but vinylester resins, historically, have not performed as well as epoxy in carbon fiber laminates. The following tests were used to evaluate the differences in the performance of the 3TEX carbon fiber pre-form when used with vinylester and epoxy. Typically, carbon fiber laminates made with epoxy resins will outperform vinylester resin panels, especially when the samples are tested in compression or shear, and this series of tests was no exception.

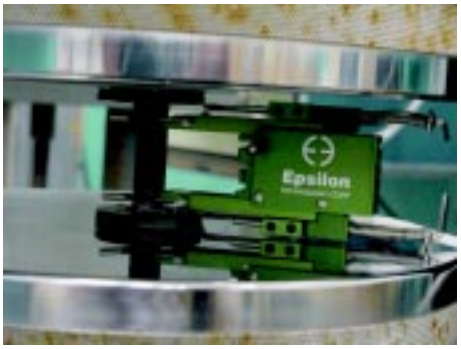
The laminates were tested for compressive strength, flexural strength and short beam shear. We also tested two thermal characteristics; Glass Transition Temperature (Tg) and Coefficient of Thermal Expansion (CTE).

The 3TEX pre-form used for the testing was a proprietary product made of carbon fiber woven in three dimensions. Its brand name is 3WEAVE™. Because there is continuous fiber woven vertically in the pre-form, 3WEAVE materials will not delaminate without destroying the composite. 3WEAVE pre-form can be made in any thickness up to 1 inch which allows a composite to be made in one piece, not the stacks of thin layers commonly used. The amount of fiber in any direction can be varied to suit the engineering requirements.

The pre-form used for these tests was .25″ thick and weighed 178 oz./yd^2 before infusion. The fiber distribution was 43% in the x (0°) direction, 52% in the y (90°) direction and 5% in the z (thickness) direction.

A total of 4 panels were infused by TPI. Two panels were made using the vinylester resin and two panels were made with PRO-SET® 117LV/237. Vinylester resin manufacturers typically state that their resin system will come to a full cure at room temperature. However, to be certain of a full cure, TPI post cured both sets of test panels. The samples made with vinylester were post cured for 2 hours at 150°F. The samples infused with

Compresssion (ASTM D695)

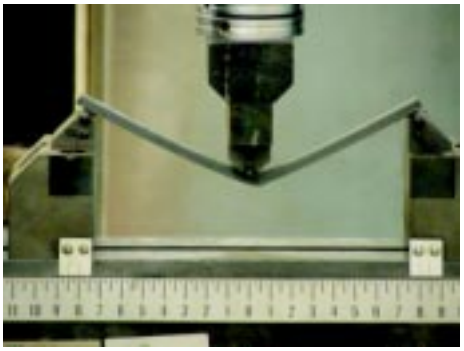


The compression test photograph shows the end treatment of the compression samples. The washers at the ends of the samples reduce or eliminate "brooming" of the sample so that a proper failure can occur. Test samples were 1/2″ x 1/2″ x 1″.

Short Beam Shear (ASTM D2344)

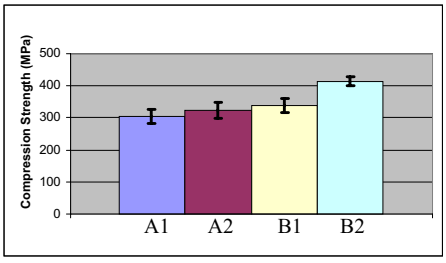
The short beam shear photo shows that test at completion. This test determines interlaminar shear strength. The graph shows that the epoxy samples outperformed the vinylester samples. The samples for this test are 1/2″ x 1/4″ x 1$^{1/2}$″.

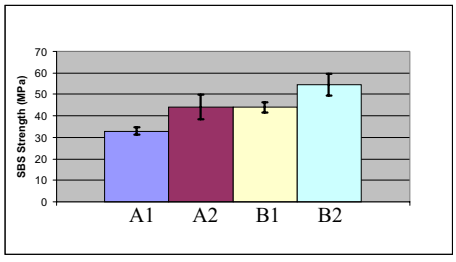
Flexure (ASTM D790)

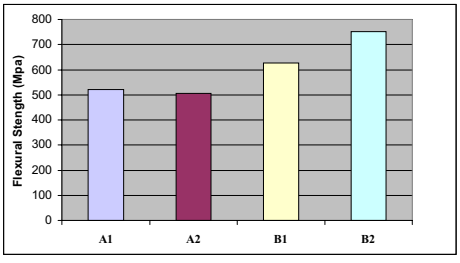


This photo shows a flexure test underway. The graph again illustrates the superiority of epoxy over vinylester in a carbon fiber laminate. Test samples are 1/2″ x 1/4″ x 9″.

A1 Derakane 0° axis **A2** Derakane 90° axis **B1** PRO-SET 0° axis **B2** PRO-SET 90° axis







PRO-SET were post cured at 140°F for 8 hours as specified by Gougeon Brothers literature.

The fiber distribution was not symmetrical, so one set of samples was machined parallel to the x (0°) axis and one set parallel to the y (90°) axis for each resin type. The infused and post cured panels were machined into the requisite sample sizes here in the Gougeon Brothers' shop. Five specimens were made from each panel for each test. This amounted to 20 samples per test. The test samples were sent to the Advanced Materials Engineering Experiment Station at Michigan State University, where they were tested according to ASTM specifications.

The Tg was determined by (ASTM D4065) Dynamic Mechanical Analysis (DMA). This instrument applies a sinusoidal mechanical force to a sample and the resulting displacement is measured. The displacement can be resolved into two fundamental mechanical characteristics: elasticity and flow. It is possible to measure changes in mechanical behavior such as modulus and damping, as a function of temperature, time, frequency, stress or strain, or combinations of these parameters.

Typical sample sizes are 1mm x 20mm x 4mm. The samples are usually mounted in a three-point bending arrangement and subjected to a cyclic stress at frequencies between 0.1Hz - 50 Hz. The system is usually set to operate in the range 20°C to 200°C.

Materials A1 and A2—the samples made with vinylester—exhibited a doublet in the Tan Delta curve indicating a partially cured material. We asked that material A1 be retested, and the subsequent Tan Delta curve had a single peak indicating a complete cure. Even with a 150°F post cure, the vinylester was not fully cured until after the 1st DMA test to 392°F.

The Coefficient of Thermal Expansion (CTE) was measured by Thermal Mechanical Analysis (TMA). TMA testing was conducted on a TA Instruments TMA testing was conducted on a TA Instruments TMA 2940. All composite specimens exhibited very low coefficient of thermal expansion below the Tg because the carbon fiber, which exhibits almost no thermal expansion, dominated the laminate.

These tests confirm there is a fall-off in the strength characteristics of a carbon fiber laminate made with vinylester resin compared to one made of epoxy resin. Three tests were used to evaluate the differences in the performance of the 3TEX carbon fiber pre-form when made with vinylester and epoxy; compression, flexure and short beam shear. The epoxy resin impregnated panels outperformed the vinylester resin panels especially where compression or shear loads were applied. The tests also reinforce our belief that vinylester resin should be post cured for it to reach its full properties. ■

Transition to Epoxy

Tom Pawlak, Technical Services
Gougeon Brothers, Inc.

If you are currently laminating with polyester and are interested in laminating with epoxy, we recommend experimenting on something small before undertaking larger projects. If a big project involving epoxy is looming, be sure to allow you and your crew plenty of time to become familiar with the working characteristics and various fabrication methods available for creating fiber reinforced plastic (FRP) laminates with epoxy. This is important if you hope to maximize the benefits of epoxy and assure that your project is successful. Don't assume that extensive experience with polyester or vinylester guarantees quality epoxy laminates.

Before beginning, you need to know something about the laminate you wish to create. Will it be a solid FRP or will it incorporate a core? Do you plan to contact mold the part(s) or will you be vacuum bagging? Each method has its pro's and con's. Vacuum bagging creates strong lightweight laminates with high fiber-to-resin ratios, but the vacuuming process uses a lot of consumables that are expensive and do not become part of the laminate. Contact laminating is a simpler process, does not require special equipment, and creates a slightly heavier laminate with lower fiber-to-resin ratios. If you are undecided as to which method is the best for your project, consider giving our technical staff a call. We'll be happy to discuss your project and make recommendations including resin/hardener combinations that are ideally suited for any manufacturing method.

The PRO-SET® product line offers a number of resin/hardener combinations. A good place to start is to select an epoxy that cures at room temperature. PRO-SET 125 Resin and 229 Hardener is a good choice. It wets out fabrics quickly, offers about 3 to 4 hours of laminating time at 72°F and can be used to contact mold or vacuum bag laminates. A slightly more viscous resin option (which helps to reduce resin drain out in coarse fabrics) would be 135 Resin with 226 or 229 Hardeners. To find working characteristics and cured physical properties for all PRO-SET products, visit our web site at www.prosetepoxy.com, or refer to our PRO-SET literature. This information can help you decide on a resin/hardener combination for your project.

An ideal surface to experiment on is 1/4″ thick plate glass. It can serve as a flat mold on which to try different laminating methods with different resin/hardener combinations. This will help you determine the best combination of methods and materials for the laminate. Plate glass allows you to create a perfectly shiny surface which helps identify print-through characteristics of the laminates. It also allows you to gauge print-through resistance after gelcoated panels have been exposed to heat lamps with varying resin/hardener combinations that were exposed to different post cures.

If you plan to vacuum bag, it helps to experiment using a number of variables. You can vary the following: mixed epoxy viscosity & gel time, initial resin content, bleeder film patterns and hole size (to optimize resin content). Try different breather fabrics to minimize waste and experiment with how long before the vacuum is applied at different tempera-

tures. It helps to try several variations at the same time on different panels or different variations on the same panel. Don't be afraid to cut up some of your test laminates to verify results. Be sure to label things well and keep good notes so you can duplicate successes.

When you are able to repeatedly create good panels, its time move up in scale. Use this as an opportunity to fabricate structural bulkheads, or create a dingy or transom in an existing mold. Working with a three-dimensional mold creates realistic laminating challenges. One of these with vacuum bagging is to keep the core in place on vertical surfaces. During the experiments, prop your mold up to create vertical situations if you will be faced with this issue in production.

When vacuum bagging, don't assume the results achieved in a test laminate that was created within 15 or 20 minutes will be the same as those achieved in production over a two or three hour period at the same temperature. In production, the epoxy may be gelling after three hours whereas the epoxy in the sample that took only 20 minutes before the vacuum was applied was still fresh and flowing. When you know a job is going to take two hours or more in production, it is best to experiment with that in mind and take the same amount of time in proof of concept samples. Experiments could include incorporating polyester gelcoat and one of the conversion coatings that allow you to switch from polyester to epoxy. You could also try leaving out some of the layers of chopped strand mat. Mat is often used next to the finished side of a part to improve print-through resistance, but is not required between layers of stitched or woven fabrics when using epoxy.

Change is difficult, especially when introducing multiple material and process changes. To be successful at switching to epoxy, it is important to include members of your laminating crew when experimenting. That way they can be part of a successful transition. They will take what they've learned back to the floor and teach others how to successfully build with epoxy. Give us a call to discuss the specifics of your transition. 989-684-7286. ■

Customer Project

50' Crowther Catamaran under construction at Wahoo Composites. The boat is made from carbon fiber, foam and PRO-SET Epoxy.

Port hull being faired.

Center pod ready for paint.

Gougeon Brothers, Inc.
P.O. Box 908
Bay City, MI 48707

PRO-SET®

- laminating epoxies
- adhesives
- process equipment

www.prosetepoxy.com