

Bonding Adhesives for Carbon Foam Tooling Applications

Bonding of GRAFOAM® Carbon Foam

A variety of commercially available adhesives, including epoxy, phenolic, urethane, polyimide-based adhesives, and fluoroelastomeric may be used for bonding. Strength testing results of selected bonding agents are reported here. The optimal adhesive depends on the particular application and its mechanical and thermal requirements. Please consult with a GrafTech representative to discuss bonding alternatives for your particular application.

1. Surface Preparation

The surfaces to be bonded need to be clean, dry, and dust free. For best results the foam block should be prepared with sufficient flatness and smoothness.

- a) Mill the foam as needed to the appropriate surface finish required for your application; making sure there are no surface irregularities. *Note: See GrafTech's, "Machining of GRAFOAM® Product Use Instructions" for further information.*
- b) Remove any dust from foam surface using vacuuming or other appropriate means.
- c) An optional oven drying step is suggested for very delicate applications.

2. Adhesives

To effectively bond **GRAFOAM®** products, different parameters should be considered: Strength required of the bond relative to the foam, temperature to which the bond will be taken, machineability of the bond in the application, and allowable or required penetration into the foam. It is very important to select an adhesive capable of surviving the thermal cycling required in the application. The list below shows some of the different bonding systems available.

Pelseal® 3159 – A 2-part solvent borne liquid fluoroelastomer flexible adhesive with a high solids content (83%). Manufactured by Pelseal Technologies, LLC. The fluoroelastomers offer strong flexible sealing and bonding at elevated temperatures.

Hysol® EA 9394/C-2 – A 2-part high temperature epoxy paste adhesive. Manufactured by Henkel Corporation. Epoxies are operating at the top of their temperature range of around 400°F. The bond is very rigid and strong.

Fluorolast® WB200 – A 2-part water borne liquid fluoroelastomer flexible coating with a low solids content. Manufactured by Lauren Manufacturing.

	Viscosity poise	Temperature Rating	Cure Temp	Cure Time, hrs	Application Coats/surface	Application Tool
Pelseal® 3159	500	400°F continuous 500°F Excursion	Room Temperature	24	1	Spatula
Hysol® EA 9394/C-2	<3,000	>400°F	200°F	4	1	Spatula
Fluorolast® WB200	20	400°F continuous 500°F excursion	Room Temperature	24	3	Brush/Air

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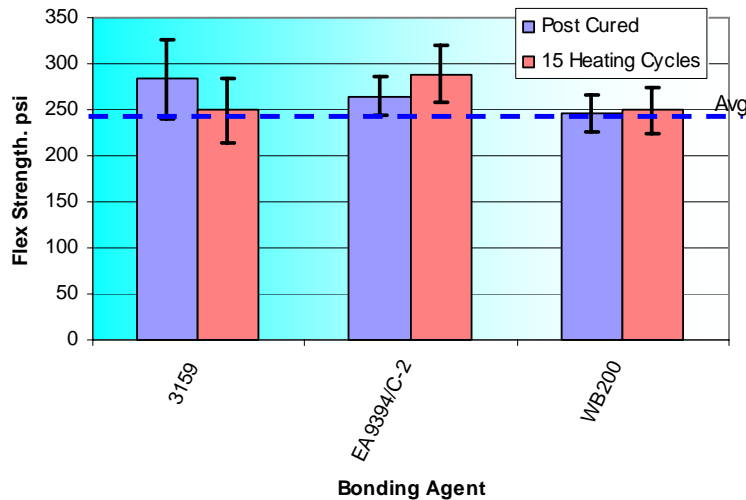


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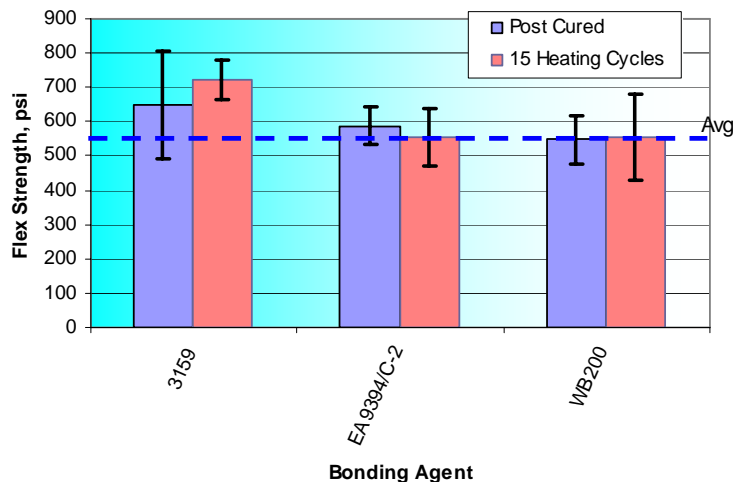
3. GRAFOAM® Carbon Foam – Flexural Testing of Bonded Foam

Flexural strength test results indicate that the bond achieved was stronger than the foam for both FPA-10 and FPA-20. The high temperature epoxy is a very rigid, high strength material. In every case, the foam breaks instead of the epoxy bond in strength testing. The fluoroelastomers, due to their elastomeric nature, allow compliance at the joint prior to flexural failure of the foam.

**Average Flex Strength Vs Bonding Agent
FPA-10**



**Average Flex Strength Vs Bonding Agent
FPA-20**



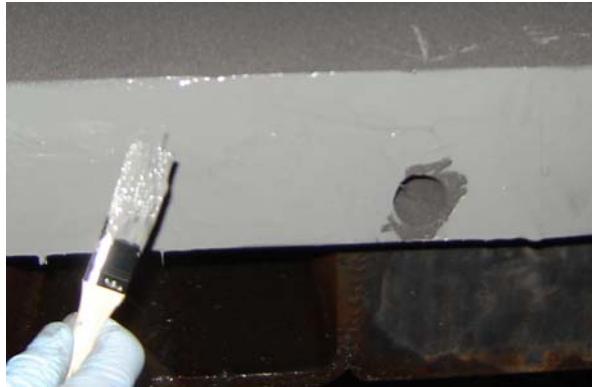
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4. Application

The following describes general bonding techniques for bonding blocks of carbon foam. Techniques must be modified as needed for the specific application and bonding agent. Please review and follow all health, safety and environmental guidelines provided by the bonding agent manufacturer.

- a) Mix bonding agents in separate container (if it contains two or more parts).
- b) With a flexible neoprene tool, natural bristle brush, or spatula, as specified by the manufacturer, apply a layer to the mating foam surfaces. Be careful not to damage the surface. Work the adhesive in as needed to fully wet the foam surface. The strongest bonding will occur with some penetration into the foam's porous structure.



- c) Apply additional coats as needed to obtain complete wetting of both mating surfaces. It is important that the coating remains thick enough after full wetting of the foam surface to assure a sufficient bond thickness, but thin enough so that the surfaces are tightly together. Higher porosity FPA-10 foam will require more coats than the lower porosity FPA-20 foam. The number of coats is also dependent on the viscosity of the bonding agent.



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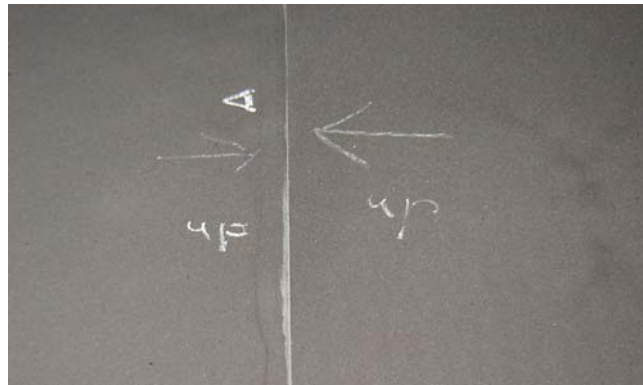
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d) When joining the two mating surfaces, slide the bond line in all four directions. This assures an even bond line.



e) Remove excess adhesive from the joint. Remove as much exuded material as possible from the joint. This will help prevent spalling of the foam surface due to CTE mismatches where the bonding agent sits directly on the foam with no mating piece.

f) Apply 1 to 2 psi pressure and lock the location of the two pieces being bonded to prevent movement of the bond line. As with most adhesives, lubrication of the planes may occur before the bond is fully set.



g) Cure in oven at recommended curing temperature and schedule. Generally, post cure to above the use temperature.

5. Curing

The curing temperature should be **above** the use temperature. The supplier or manufacturer of the adhesive may specify a ramp-up rate. Aggressive ramp-up rates could cause the adhesive to exude out of the joint before it has a chance to set. When curing a bond line, pieces should be held together with pressure to prevent shifting during the curing cycle. Due to the low thermal conductivity of the foam, the required hold time will depend on the thickness and density of the foam. **Note that self-sustained oxidation may occur at temperatures above 200°C in air for FPA carbon foam of substantial thickness. It is recommended that the cure temperature be monitored in these situations. If using an adhesive with a volatile component, i.e. MEK, acetone, MIBK, etc., a non-oxidizing atmosphere such as nitrogen is recommended.**

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