LAST-A-FOAM® Tooling & Molds User Guide

Product Selection
Bonding
Machining
Sealing
Releasing
Curing
Applications

GENERAL PLASTICS
MANUFACTURING COMPANY

Where Great Ideas Take Shape

Introduction To The User Guide

General Plastics prepared this guide to assist you with recommendations, general guidelines and a reference to address common applications using the LAST-A-FOAM® high-density, rigid polyurethane foam product line.

Here you will find information on material properties and performance, application considerations, and helpful tips and resources when using our products. Specific to this guide are the FR-7100 Multi-Use Core and Modeling Board Series, the FR-4700 High-Temperature Tooling Board Series, the FR-4500 Tooling Board Series, and the FR-3700 Performance Core Series.

Our knowledgeable customer service team and product experts are ready and available to answer questions you may have and to help you attain the best possible results using our products. We can provide recommendations on product selection, design, use, and testing services or product literature.

Customer Service and Product Experts
1-800-806-6051 or 1-253-473-5000
Monday-Friday 6:30am-5pm, Pacific Time

All General Plastics material products
are manufactured in the United States and are free of CFCs and VOCs.

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Product Overview

LAST-A-FOAM® high-density polyurethane foam is a popular choice in the tooling industry because it does not outgas during heating, is dimensionally stable, has a predictable coefficient of thermal expansion (CTE), and has a fine/smooth surface finish.

General Plastics Tooling Board comes in a range of densities to match your specific job requirements and in large sheets up to 24" thick. It is available in fire-resistant boards and high-temperature (HT) boards for specific industry uses. Rigid LAST-A-FOAM® products have a long record of success as tooling substrates and have excellent machinability.

Typical tooling board uses include:

- Autoclave Tools
- Bonding Fixtures
- Composite Layup Tools
- Drape-forming Tools
- Fiberglass Mold Plugs
- Foundry Patterns
- Hydroforming Tools
- Inspecting Jigs
- Machining Supports
- Master Molds
- Mold Patterns
- Mold Tools
- Trim Fixtures
- Vacuum-forming Tools

Tool courtesy of Hexcel Corporation and HexTool®

Important: Before You Start, Test Your Materials

Select the material you plan to use for testing, and then test the tooling material under the expected process conditions to ensure it is suitable and stable. This is recommended to ensure good tooling performance, and it should be performed as part of your process before you commit to a larger program.

Product Selection:

How to Choose the Right Tooling Board for Your Job

High density LAST-A-FOAM® materials offer both greater durability and the ability to render fine detail. Select your material accordingly for machine capability, tooling configuration, machine line feed, and desired end results. Refer to Appendix A (Pg. 10) for physical properties data.

Product Line Details

When your requirements call for high strength, great detail, and high resistance to heat and pressure at process temperatures, tooling material with a density greater than 18 pounds per cubic foot (pcf) is your best choice.

Guide to Board Product Codes

F= Fire-resistant, R=Rigid, HT = High Temperature.
Density example: FR-4718 (part of the FR-4700 HT Tooling Board Series with a density of 18 lbs./ft^3)

FR-3700 Performance Core Series

Density covered in this guide: 30 lbs./ft^3 (FR-3730).
Tougher and less "friable" than the FR-6700 aerospace-grade series, this foam enables cutting of crisp edges, making it well suited for machining complex shapes for detailed part profiles.

FR-7100 Multi-Use Core & Modeling Board Series

Densities covered in this guide: 20, 30, 40 lbs./ft^3 (FR-7120, FR-7130, and FR-7140). This uniform foam is easily finished or painted for low-cost core applications as well as use for composite layup tools and for industrial patterns.

FR-4500 Tooling Board Series

Densities covered in this guide: 20, 30, 40, and 50 lbs/ft^3 (FR-4520, FR-4530, FR-4540, and FR-4550). Tough, grain-free, machinable tooling boards are used for styling and design models, master models, masters for composite and layup tools, and for mold and foundry patterns.

FR-4700 High-Temperature (HT) Tooling Board Series

Density covered in this guide: 18 lbs./ft^3 (FR-4718), 30 lbs/ft^3 (FR-4730), and 40 lbs./ft^3 (FR-4740). This board supports prepreg composite layup tooling for high-temperature applications up to 400°F (200°C). Ideal for prototype tooling, master molds, thermoforming, and limited production runs.

General Questions Regarding Thermal Properties

Since most tooling board applications are sensitive to

LAST-A-FOAM® Thermal Properties

Foam Series	Continuous Service Temperature (ºF)	Heat Distortion Temperature (ºF)	Glass Transition Temperature (Tg) (ºF)	Coefficent of Thermal Expansion (CTE) in/in ºF
FR-4500 (20, 30, 40, 50 lbs/ft^3)	195	215	217	29 x 10^{-6}
FR-7100 (20, 30, 40 lbs/ft^3)	215	235	245	35 x 10^{-6}
FR-3700 (30 lb/ft^3)	250	270	280	34 x 10^{-6}
FR-4700 HT (18, 30, 40 lb/ft^3)	350	420	430	26 x 10^{-6}

General Machining Recommendations for LAST-A-FOAM® Tooling Board Grades

LAST-A-FOAM Product Density	Roughing Speed (rpm)	Roughing Feed Rate (ipm)	Finishing Speed (rpm)	Finishing Feed Rate (ipm)
FR-7120 (20 lbs/ft^3)	2,500	120	5,000	200
FR-7130 (30 lbs/ft^3)	2,500	120	5,000	200
FR-7140 (40 lbs/ft^3)	2,500	120	5,000	200
FR-3720 (20 lbs/ft^3)	2,500	120	5,000	200
FR-3730 (30 lbs/ft^3)	2,500	120	5,000	200
FR-4515, FR-4520 (15 and 20 lbs/ft^3)	2,500	120	5,000	200
FR-4530, FR-4540 (30 and 40 lbs/ft^3)	3,000-3,500	120	10,000	160-200
FR-4550 (50 lbs/ft^3)	2,000-2,500	100	10,000	200
FR-4718 (18 lbs/ft^3)	2,500-3,000	220	5,000	350
FR-4730 (30 lbs/ft^3)	2,500	120	5,000	200
FR-4740 (40 lbs/ft^3)	2,500	120	5,000	200

Roughing: Results obtained with a ½-1" four-flute ball-end mill. HSS cutters were used, although carbide-tipped cutters were used on FR-4550 materials. Cutting depths up to 2" deep can be used with 30-40% step-over.

Finishing: Results obtained with ½" two-flute ball-end mill. Cutting depths less than 0.125" with a small step-over produce smoother surface finish results.

CTE Data for Commonly Used Companion Materials with Our Boards

Material	(10^{-6} in/in °F)
Aluminum	12.3
Concrete	8
Epoxy, casting resins & compounds, unfilled	31
Graphite	4
Invar	0.8
Polyester - glass fiber-reinforced	14
Polyethylene (PE)	111
Polyethylene terephthalate (PET)	33
Polypropylene - glass fiber-reinforced	18
Polyurethane (PUR), rigid	32
Porcelain, industrial	3.6
Quartz	0.43-.079
Silicon	1.7
FR-3700	34
FR-7100	34
FR-4500	35
FR-4700	26

dimensional stability, process temperature, prepreg resin cure cycles, autoclave pressures, thermal expansion changes, and material property mismatch problems, constructing tools that always perform as expected can be challenging.

How much heat will the tooling material take?
Refer to the LAST-A-FOAM® Thermal Properties chart on page 2. When designing your tool, also take into consideration its size and shape.

What is the Glass Transition Temperature (Tg)?
Above this temperature, the material will become "rubbery" and can exhibit plastic deformation under low mechanical or autoclave pressure loads.

What is the Heat Distortion Temperature?
At this temperature, when exposure times exceed approximately four hours, the material will begin to deform under load. Under low pressure or mechanical loads, exposure of one to three hours (as in a cure cycle or secondary heating operation) is allowable up to the heat-distortion temperature. If using vacuum-bag or autoclave-cure processes, test the tooling material under process conditions to ensure it is suitable and stable.

What is the Continuous Service Temperature?
This is the temperature at which the product can be used continuously without distortion.

What is the Coefficient of Thermal Expansion (CTE) and why is this important?
As with similar tooling materials, LAST-A-FOAM® products change in dimension with changes in temperature. Because most LAST-A-FOAM® product lines are made with polyurethane resins, their thermal expansion characteristics are typical of most urethane resin products.

TIP: Understanding Dimensional Stability

Testing Example: If you use an unconstrained beam of LAST-A-FOAM® FR-4520 (CTE of $35x10^{-6}$ in/in °F) that is 100 inches long, and heat it from 65°F to 150°F, it will grow to 100.31 inches long. The material will shrink back to 100 inches as it cools. It is important to know the actual temperature range throughout the process, so that the tool is designed to ensure the final part has the desired dimensions.

- Strength and Creep: Applying solid bonds to tooling plates will help restrain the material under heating conditions. Such heating enables lower density LAST-A-FOAM® to creep or relax into its new configuration with appropriate tolerance.
- Avoid unsupported thin cross-sections of tooling material, because heat soaking at high temperature may cause unpredictable movement.

Bonding Recommendations:

Choosing the Right Adhesives

Your specific design and application will drive your particular adhesive need for bonding and sealing. In selecting your adhesive, keep in mind the environment the bonded assembly will have to withstand. Make sure your sealant material is compatible with the mold release and surface coating materials you plan to use when completing the tool.

Consider these important factors:

- Use temperature
- Bond line gap-filling capacity
- Chemical exposure
- Mechanical loads
- Thermal expansion characteristics
- Ease of application
- Pot life of adhesive

All rigid LAST-A-FOAM® products are produced with closed-cell resins. For bonding and sealing, a wide variety of adhesives and coatings can be used. High-density LAST-A-FOAM® is comparatively easy to fill and seal. Be sure to follow the manufacturer's safety instructions when using any bonding, filling or finishing product.

Bonding and Sealing Adhesives

The preferred adhesives are two-part systems that can cure at room temperature or one-part moisture curing formulations. Most polyurethane, epoxy, cyanocrylates, or methacrylate systems will work. See page 16 for recommended adhesives.

NOTE: Neither solvent-based adhesives nor heat-cured adhesives are recommended for bonding tooling board. The solvent in the solvent-based adhesive does not evaporate from the bond line to form a solid bond. Heat-cured adhesives require that the entire tool be heated to the appropriate curing temperature in order for the heat to penetrate the bond line. This is not always practical.

Machining Recommendations:

NOTE: Models, tools, molds, prototypes and CNC-proofing applications depend upon proper machine tooling for quality production. It is recommended you become familiar with the product prior to engaging in a large project.

CNC Routing

LAST-A-FOAM® tooling board machines exceptionally well on a CNC router compared with traditional aluminum tools. It is recommended you do a rough cut first, leaving 1-3 mm of material for finishing. Use caution at edges and tight corners to avoid chipping at the start of a new pathway and when exiting the foam.

Follow these proven guidelines:

- Use four-flute cutters or woodworking router bits
- Use high RPM and slow feed rates
- Use forced air on the drill bit to reduce dust and particle build-up
- Keep a load on the cutter to avoid chatter

Using a Vacuum Hold-Down Method

This approach is ideal for trimming thermoformed and compression-molded parts on a CNC router where it is difficult or inconvenient to use clamps. Because LAST-A-FOAM® products are closed-cell, vacuum methods can be used as a practical hold-down force in many applications, eliminating the need for clamps. Simply drill small holes in the tool and pull vacuum through them. Use silicone or latex seals or masking tape around the part periphery to hold the vacuum.

TIP: Dealing with Dust

Rigid LAST-A-FOAM® products are essentially chemically inert; however, the processes of cutting, planing, shaping, routing and sanding LAST-A-FOAM® products produce dust. When working with these materials, use appropriate safety equipment to prevent inhaling foam dust. Here are some tips:

- Lower spindle speeds and higher feed rates tend to reduce dusting.
- Finish cuts typically produce the most dust.
- To minimize airborne dust, use a dust-collection shop vacuum or system at the cutting head.

Tips for Holding Screw- and Bolt-Threads

Product densities greater than 20 pcf hold screws well if they are installed in pilot holes predrilled close to the root diameter of the threaded fastener.

- For one-time insertion and static loads, choose coarse-thread, self-tapping sheet metal screws, drywall screws or particle board screws.
- To maximize thread retention, use a bonded, threaded insert (ideally with a knurled outside surface) or an epoxy-bonded Heli-Coil® insert.
- Although it is possible to "tap" threads into urethane foams to establish threaded holes, these coarse threads are easily stripped by an over-torqued fastener. Tapped thread strength is not sufficient for repeated insertion and withdrawal of fasteners.
- High-density tooling products (such as FR-4540, FR-4550) hold threads better than other materials, but are not optimal alone. For greater reliability, use inserts with adhesives.
- To direct the location of threaded fasteners more precisely, pot the insert into an oversized hole and fix the insert in its proper location before the potting compound sets.

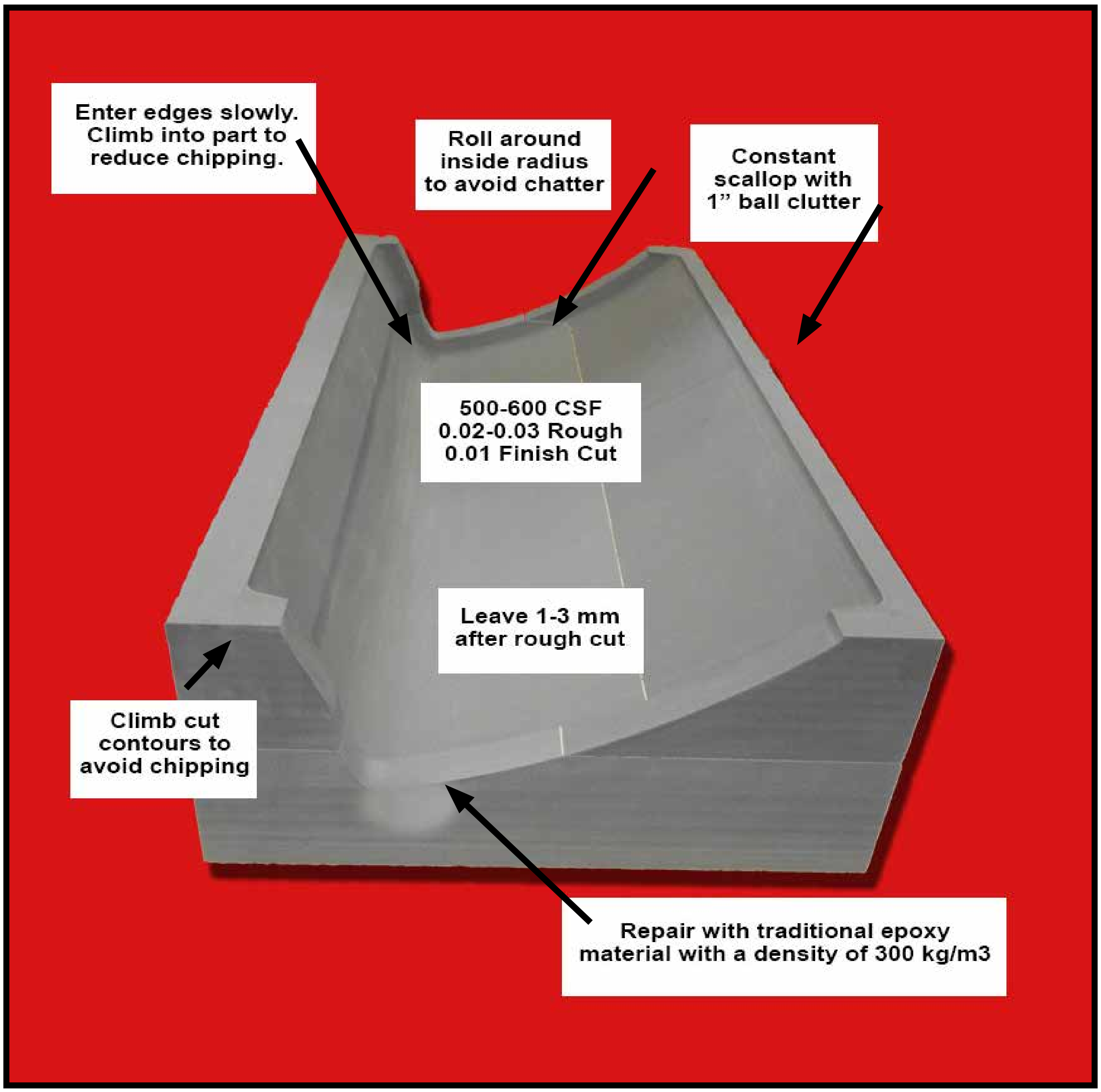


Fig. 1

Sealing and Finishing Recommendations:

Finished Surface Preparation Tips

A good final finish depends on proper surface preparation. Virtually no carrier solvents irreversibly damage LAST-A-FOAM®, so you have great freedom to select finishing materials.

Using Sanding Sealers and Finishing a Bond Line

Most sanding sealers will plug surface cells and fill small voids. You will likely need more than one coat of sealer. For best results, apply at least four coats of sealer and do a light sanding between coats.

To finish LAST-A-FOAM® across a bond line, choose an adhesive with a cured hardness similar to that of the surrounding foam of the material surrounding the bond line, and sand.

NOTE: Our Technical Data Sheets have hardness information to help you match the material to the cured hardness of various adhesives.

Getting the Best Results for Finishing

Prepare the surface for the finish coatings of your choice with light sanding as needed. You may only need a paint primer on high-density LAST-A-FOAM® material. If you prefer a glossy finish, use a high-gloss top coat. Follow manufacturer instructions to achieve the results you desire. See Appendix B on page 16 for recommended sealing products.

Creative Tips for Finish Coat Applications

Finish coatings can duplicate virtually any surface devised by man or found in nature, including wood, metal, rock, fish skin, feathers, and even mirror.

A primer will improve surface quality, but it's usually not needed to improve adhesion or surface sealing. Automotive and woodworking-grade finishes typically generate good results when applied to our rigid LAST-A-FOAM® products.

NOTE: We recommend you test your desired finishes to achieve best results. If you have questions during your process, please contact our product experts in customer service, who are happy to assist.

> **TIP:** Before using any new resin, cure profile, sealant, or tooling board, we recommend you test under the conditions you expect to have in production.

Mold Release Recommendations:

Using Mold Release Agents

A release agent is any chemical that is used to help release a molded part from a mold cavity. Mold release agents are often coated onto polymeric composite surfaces used in adhesive bonding.

A large variety of release agents can be used with LAST-A-FOAM® products. They can be waxes, water-borne, solvent-borne, or aerosols. Please follow manufacturer recommendations and test ahead of time. See Appendix B on page 16 for recommended sealing products.

Curing Processes:

Specific cure cycles (temperature, pressure, dwell times, etc.) depend on the design and type of the tooling material used, as well as the resin used in the composite lay-up.

Achieving Dimensional Stability with Vacuum-Bag and Autoclave Pressures

Dimensional stability is a key consideration in advanced-composite tooling applications where heat cures and laminate-consolidation pressures are applied to the part.

Although all tooling-grade LAST-A-FOAM® is resistant to warping, subsequent machining operations can induce stress on a piece of foam. This may be evident at room temperature, or become apparent only after heating.

Using Low-Temperature Prepregs with Urethane Tooling Materials

All LAST-A-FOAM® products with the proper sealer, release and cure profile can produce high-quality parts. See Appendix B on page 16 for compatible sealers.

Since LAST-A-FOAM® tooling board products are cellular solids, the thermal conductivity is lower than metal or even other plastics. Longer dwell times may be needed for the resin system to reach full cure.

Large-Mass Tools & High-Temperature Curing Cycles

Fabricating tools from large monolithic blocks is frequently desirable, cost effective and problem-free. However, subjecting large-mass tooling to high temperatures and in a long-duration autoclave cure cycle (e.g., 350˚F for 6-plus hours at peak temperature) is an exception.

In this case, there is high potential for heat soaking the entire mass of the tool, which can cause a large temperature difference (ΔT) between the outside and inside of the tool during cool down. This is a large difference in thermal expansion effect and could potentially induce severe stresses within the tool. Sometimes, these stresses can exceed the strength of the tool material, causing the tool to crack or shear.

Rapid heating of a tool may create similar stresses, as when a quick ramp-up in autoclave or oven temperature causes the outside of the tool to heat much more rapidly than its core.

NOTE: Test the predicted cure cycle before production use, including ramp-up and cool-down cycles. We have observed that most cracking occurs during the cooling process.

TIP: The temperature gradient between the core of the tool and the surface should not exceed 30ºF. Care should be taken in the cool-down cycle below 220ºF; there should always be a sufficient step to ensure the tool can equilibrate before cooling to ambient temperature.

Material Handling, Storage and Safety Guidelines

When storing and handling rigid LAST-A-FOAM®, treat it like any other potentially combustible organic solid. The products are essentially chemically inert. Processes used in manufacture will create dust. **See tips for dealing with dust on page 4.**

Tooling & Mold Applications:

Using HDU Materials

Easily machined and far less costly than aluminum and other substrates, they are a practical option for vacuum-forming low-rate and prototype parts. Here are some recommendations to keep in mind with each process method.

Key Factors to Consider When Thermoforming

- Plastic sheet thickness
- Forming temperature
- How often the tooling is "cycled" to form the part

Foams used in this density range have relatively low mass and are poor conductors of heat energy. They absorb heat slowly, but once heat-energy is absorbed, they also release it slowly. Forming many parts in a short time frame using thick plastic sheets typically transfers substantial heat to the forming tool, potentially softening the tool.

High-Temperature Forming Molds

Parts requiring higher forming temperatures are successfully formed with molds made from FR-3720, FR-3730, FR-4718, FR-4730, and FR-4740 using adequate cooling methods of parts and tools between cycles. Flexible and rigid polystyrene, ABS, PVC and polyolefin plastics are easily formed using LAST-A-FOAM® tools.

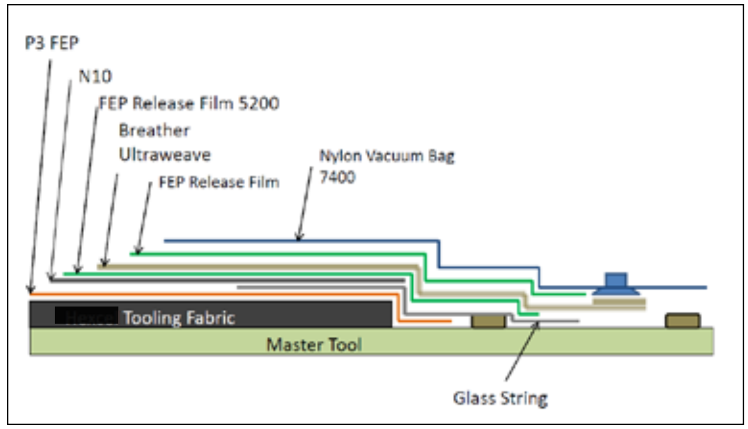
Foundry and Mold Pattern Applications

LAST-A-FOAM® is far superior to wood for pattern making.

BENEFITS INCLUDE:

- Dimensionally stable
- Durable
- Free of grain effects
- Available in large blocks up to 24'' x 80" or custom bonded to larger sizes
- Produced without bond joints that can fail or cause "mark off" on production
- Unaffected by humidity changes that can cause bond joints to fail in wood patterns
- Cost-effective as a pattern substrate, (vs. the labor expense of "blocking up" a large foundry or mold pattern out of small wood pieces)

LAST-A-FOAM® Tool in Bagging Layup Process **Fig. 2**



Bagging Schematic for HT Autoclave Cure **Fig. 3**
Courtesy of Hexcel Corporation and the HexTool®
MGI User Guide.

Resin Infusion, Prepreg Layup & Autoclave Processes

LAST-A-FOAM® FR-7130 and FR-7140

These boards provide ample strength to withstand vacuum infusion, autoclave and vacuum-bag pressures in tooling used for VARTM, SCRIMP, RIFT and other resin-infusion processes. All major American airframe manufactures have relied on LAST-A-FOAM® products from this line, to build process tooling for airworthy composite structures. Manufacturers value the:

- Ease of machining
- Large block sizes
- Predictable high-temperature performance
- Low thermal mass

Fiberglass Molds and Plugs

LAST-A-FOAM® is flame-retardant, making it safer to store than styrene-based foam products. The moderate Tg allows it to withstand the short-term exothermic curing of unsaturated polyester, epoxy and vinyl ester resins. Thanks to its relatively low cost and high strength, FR-7100 is usually the best choice. It is available in blocks up to 35" tall. This foam is highly resistant to tooling gel-coats, styrene monomer, solvents, paints, and the coatings used in the FRP composite industry.

Using Soft Tools up to 400ºF

LAST-A-FOAM® FR-4700 HT Tooling Board

The FR-4700 tooling board is a rigid, high-temperature, hybrid tooling board that is designed for prototype machining, prepreg composite layup tooling, vacuum form tooling, tool proofing, pattern making, and master model making.

Application

FR-4700 Tooling Board is non-abrasive and can be machined and cut with HSS cutters or any standard cutting tool. It can be bonded to itself or other substrates using urethane and epoxy adhesives that are rated for appropriate end-use temperatures.

Key Performance Benefits

- Applications up to 400°F (200ºC) peak temperature
- Continuous use up to 350°F (176ºC)
- Compatible with commercial prepregs
- No outgassing or cure inhibition
- Dimensionally stable
- Large block size reduces bond lines
- Compatible with most surface finishing materials
- Easily machinable

Operating Temperature Profile

FR-4700 tooling board can be used under autoclave conditions up to 400°F (200ºC) at 90 psi. The thicker the cross-section or the longer the dwell time, the longer the cool down will take.

See next page for special FR-4700 user guidelines.

FR-4700 High-Temperature Tooling & Mold Recommendations:

Bonding Adhesive

FR-4700 tooling board will not inhibit adhesive curing or curing of commercial prepregs. Select an adhesive appropriate for the processing temperature. See Appendix C on page 17 for recommended adhesives.

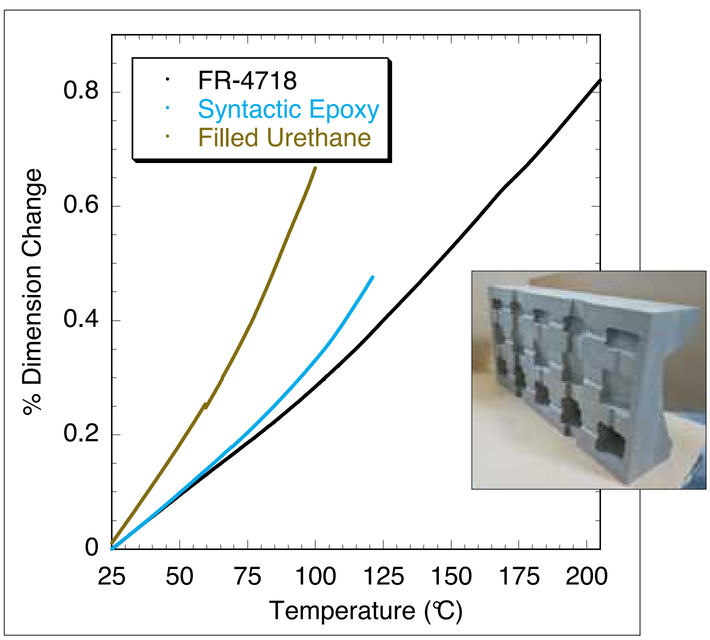
Bonding Process

Surfaces to be bonded must be clean, dust-free, flat, and square. Apply adhesive to both surfaces so they are completely coated. Apply more adhesive in the middle as squeeze-out will occur. For best results, apply even pressure such as a vacuum bag. Good results have been obtained using a 1/4” or 1/8” notched trowel to apply the adhesive.

NOTE: It is best to use a room-temperature cure adhesive. Trying to achieve an elevated temperature cure on a large mass of foam can take a very long time and can result in cracking of the foam if not cooled slowly.

Follow the manufacturer’s recommendation for curing the adhesive.

Coefficient of Thermal Expansion Graph For FR-4700



It is optional to remove extra material to create an “egg-crate” structure. This will reduce cycle times and improve stability of the tool.

CNC Routing recommendations

The FR-4700 tooling board will machine well compared with traditional aluminum tools. It is recommended you do a rough cut first, leaving an extra 1-3 mm for finishing. Use caution with edges and tight corners to avoid chipping at the start of a new pathway. See Fig. 1 (page 5) for basic CNC recommendations.

Follow these additional FR-4700 guidelines:

- Use four-flute cutters or woodworking router bits
- Use high RPM and feed rates
- Use forced air on the drill bit to reduce dust and particle build-up
- Keep a load on the cutter to avoid chatter

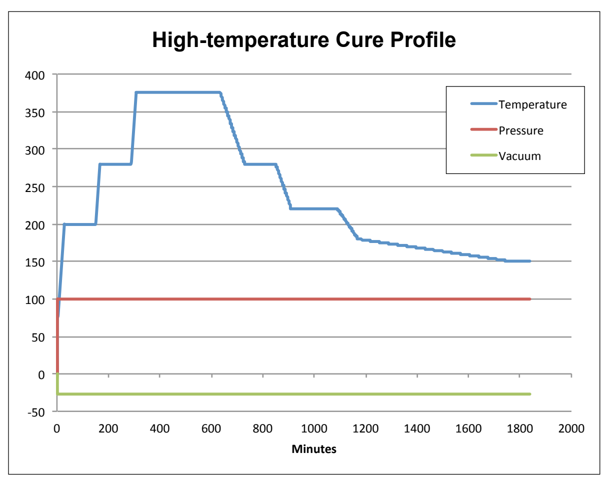
Sealant Compounds

A sealer should be used to fill the cut foam surface cells and provide a hard, smooth finish on the tooling surface. For the FR-4700, a primer is recommended if a very smooth finish is needed. **NOTE: Best results have been obtained using Airtech ToolTec CS5 adhesive release film. This all-in-one product is a sealant, surface finish and release agent.** For curing temperatures lower than 275°F (135ºC), a lower cost solvent-borne acrylic resin or a cross-linking vinyl ester resin will suffice. See Appendix A on page 10 for product recommendations.

Mold Release Agents

A number of mold releases can be used. The end user needs to test compatibility with the resins and temperatures needed in the production process. See Appendix C on page 17 for FR-4700 recommendations.

TIP: High-temperature Curing



FR-4700 tooling board can be used under autoclave conditions up to 400°F (200ºC) at 90 psi. **NOTE:** The temperature gradient between the core of the tool and the surface should not exceed 30°F (17ºC). Care should be taken during the cool down cycle below 220°F (104ºC). There should always be a step sufficient to ensure the tool can equilibrate before cooling to room temperature. See chart. For a recommended cool-down cycle, please contact customer service at (253) 473-5000.

Appendix A - Physical Property Data

All physical property data are subject to revision due to development of and changes to the material. The data is derived from tests and historical usage. The data is an average estimation and should be treated as such. Calculations should be verified by actual tests. The data is furnished without liability for the company and does not constitute a warranty or representation in respect to the material or its use. General Plastics reserves the right to release new data sheets in replacement.

LAST-A-FOAM® FR-3730

LAST-A-FOAM® FR-3730 RIGID POLYURETHANE FOAM			
Property	**VALUE (psi)**	**VALUE (kPa)**	**Test Method**
Density (pcf) (kg/m^3)	30.0	481	ASTM D-1622
Compressive Strength (psi) (kPa)			ASTM D-1621
Parallel to Rise			
-65°F	3942	27180	
75°F	2954	20368	
200°F	1686	11625	
250°F	1091	7522	
Perpendicular to Rise			
-65°F	4200	28959	
75°F	2960	20409	
200°F	1748	12052	
250°F	1125	7757	
Compressive Modulus (psi) (kPa)			ASTM D-1621
Parallel to Rise			
-65°F	55584	383252	
75°F	51486	354996	
200°F	51070	352128	
250°F	37408	257928	
Perpendicular to Rise			
-65°F	58570	403840	
75°F	51059	352052	
200°F	52573	362491	
250°F	38899	268209	
Tensile Strength (psi) (kPa)			ASTM D-1623 Type A Specimens
Parallel to Rise	1838	12673	
Perpendicular to Rise	1907	13149	
Flexural Strength (psi) (kPa)			ASTM D-790 Method 1-A
Rise Parallel to Test Span	2761	19037	
Rise Parallel to Beam Thickness	2505	17272	
Flexural Modulus (psi) (kPa)			ASTM D-790 Method 1-A
Rise Parallel to Test Span	83868	578270	
Rise Parallel to Beam Thickness	84818	584820	

Values shown are average values determined from laboratory tests **07/22/2015**

LAST-A-FOAM® FR-4520

LAST-A-FOAM® FR-4520 RIGID POLYURETHANE FOAM			
Property	**VALUE (psi)**	**VALUE (kPa)**	**Test Method**
Density (pcf) (kg/m^3)	**20.0**	320	ASTM D-1622
Compressive Strength (psi) (kPa)			ASTM-D-1621
Parallel to Rise			
@ 75°F	1236	8522	
@ 160°F	814	5613	
Perpendicular to Rise			
@ 75°F	1312	9046	
@ 160°F	848	5847	
Compressive Modulus (psi) (kPa)			ASTM-D-1621
Parallel to Rise			
@ 75°F	26603	183428	
@ 160°F	24127	166356	
Perpendicular to Rise			
@ 75°F	27946	192688	
@ 160°F	24510	168996	
Tensile Strength (psi) (kPa)			ASTM D-1623 Type A Specimens
Parallel to Rise	882	6081	
Perpendicular to Rise	863	5950	
Flexural Strength (psi) (kPa)			ASTM D-790 Method 1-A
Rise Parallel to Test Span	1335	9205	
Rise Parallel to Beam Thick.	1359	9370	
Flexural Modulus (psi) (kPa)			ASTM D-790 Method 1-A
Rise Parallel to Test Span	50713	349666	
Rise Parallel to Beam Thick.	49809	343433	

Values shown are average values determined from laboratory tests **07/23/2015**

LAST-A-FOAM® FR-4530

LAST-A-FOAM® FR-4530 RIGID POLYURETHANE FOAM			
Property	**VALUE (psi)**	**VALUE (kPa)**	**Test Method**
Density (pcf) (kg/m^3)	**30.0**	481	ASTM D-1622
Compressive Strength (psi) (kPa)			ASTM-D-1621
Parallel to Rise			
@ 75°F	2071	14280	
@ 160°F	1388	9570	
Perpendicular to Rise			
@ 75°F	2264	15610	
@ 160°F	1437	9908	
Compressive Modulus (psi) (kPa)			ASTM-D-1621
Parallel to Rise			
@ 75°F	41037	282950	
@ 160°F	36972	254922	
Perpendicular to Rise			
@ 75°F	46673	321810	
@ 160°F	43269	298340	
Tensile Strength (psi) (kPa)			ASTM D-1623 Type A Specimens
Parallel to Rise	1487	10253	
Perpendicular to Rise	1391	9591	
Flexural Strength (psi) (kPa)			ASTM D-790 Method 1-A
Rise Parallel to Test Span	2121	14624	
Rise Parallel to Beam Thick.	2165	14928	
Flexural Modulus (psi) (kPa)			ASTM D-790 Method 1-A
Rise Parallel to Test Span	80892	557750	
Rise Parallel to Beam Thick.	82572	569334	

Values shown are average values determined from laboratory tests **07/23/2015**

LAST-A-FOAM® FR-4540

LAST-A-FOAM® FR-4540 RIGID POLYURETHANE FOAM			
Property	**VALUE (psi)**	**VALUE (kPa)**	**Test Method**
Density (pcf) (kg/m^3)	**40.0**	641	ASTM D-1622
Compressive Strength (psi) (kPa)			ASTM-D-1621
Parallel to Rise			
@ 75°F	3616	24932	
@ 160°F	2200	15169	
Perpendicular to Rise			
@ 75°F	3891	26828	
@ 160°F	2392	16493	
Compressive Modulus (psi) (kPa)			ASTM-D-1621
Parallel to Rise			
@ 75°F	67604	466130	
@ 160°F	62256	429255	
Perpendicular to Rise			
@ 75°F	69893	481912	
@ 160°F	60137	414645	
Tensile Strength (psi) (kPa)			ASTM D-1623 Type A Specimens
Parallel to Rise	2467	17010	
Perpendicular to Rise	2478	17086	
Flexural Strength (psi) (kPa)			ASTM D-790 Method 1-A
Rise Parallel to Test Span	3909	26953	
Rise Parallel to Beam Thick.	3992	27525	
Flexural Modulus (psi) (kPa)			ASTM D-790 Method 1-A
Rise Parallel to Test Span	137833	950359	
Rise Parallel to Beam Thick.	133283	918986	

Values shown are average values determined from laboratory tests **07/23/2015**

LAST-A-FOAM® FR-4550

LAST-A-FOAM® FR-4550 RIGID POLYURETHANE FOAM			
Property	**VALUE (psi)**	**VALUE (kPa)**	**Test Method**
Density (pcf) (kg/m^3)	**50.0**	801	ASTM D-1622
Compressive Strength (psi) (kPa)			ASTM-D-1621
Parallel to Rise			
@ 75°F	4514	31124	
@ 160°F	2806	19347	
Perpendicular to Rise			
@ 75°F	4896	33758	
@ 160°F	3028	20878	
Compressive Modulus (psi) (kPa)			ASTM-D-1621
Parallel to Rise			
@ 75°F	83381	574912	
@ 160°F	76927	530412	
Perpendicular to Rise			
@ 75°F	88858	612676	
@ 160°F	78726	542816	
Tensile Strength (psi) (kPa)			ASTM D-1623 Type A Specimens
Parallel to Rise	3102	21388	
Perpendicular to Rise	3064	21126	
Flexural Strength (psi) (kPa)			ASTM D-790 Method 1-A
Rise Parallel to Test Span	4804	33124	
Rise Parallel to Beam Thick.	4907	33834	
Flexural Modulus (psi) (kPa)			ASTM D-790 Method 1-A
Rise Parallel to Test Span	170752	1177335	
Rise Parallel to Beam Thick.	167619	1155733	

Values shown are average values determined from laboratory tests **07/23/2015**

LAST-A-FOAM® FR-4718

LAST-A-FOAM® FR-4718 RIGID POLYURETHANE FOAM			
Property	VALUE (psi)	VALUE (kPa)	Test Method
Density (pcf) (kg/m^3)	**18.0**	288	ASTM D-1622
Compressive Strength (psi) (kPa)			ASTM-D-1621
Parallel to Rise			
@ 75°F	1187	8182	
@ 350° F	622	4286	
Perpendicular to Rise			
@ 75°F	1094	7541	
@ 350° F	631	4350	
Compressive Modulus (psi) (kPa)			ASTM-D-1621
Parallel to Rise			
@ 75°F	37308	257237	
@ 350° F	18855	130003	
Perpendicular to Rise			
@ 75°F	29152	201006	
@ 350° F	17527	120849	
CTE: (in/in-°F) (m/m-K)	27×10^{-6}	49×10^{-6}	ASTM E-1824 @ 200°F - 400°F
Glass Transition, Tg (°F) (°C)	428	220	ASTM E-1824
Thermal Conductivity:			ASTM C-518 at 75°F (24°C) mean temp.
(BTU*in/ft^2*°F*h) [(W/m*K)]	0.42	0.06	

Values shown are average values determined from laboratory tests **10/13/2013**

LAST-A-FOAM® FR-4730

LAST-A-FOAM® FR-4730 RIGID POLYURETHANE FOAM			
Property	VALUE (psi)	VALUE (kPa)	Test Method
Density (pcf) (kg/m^3)	30.0	481	ASTM D-1622
Compressive Strength (psi) (kPa)			ASTM-D-1621
Parallel to Rise			
@ 75°F	3045	20993	
@ 350° F	1392	9600	
Perpendicular to Rise			
@ 75°F	2571	17728	
@ 350° F	1366	9416	
Compressive Modulus (psi) (kPa)			ASTM-D-1621
Parallel to Rise			
@ 75°F	0	0	
@ 350° F	94142	649109	
Perpendicular to Rise			
@ 75°F	0	0	
@ 350° F	53155	366504	
CTE: (in/in-°F) (m/m-K)	26×10^{-6}	47×10^{-6}	ASTM E-1824 @ 200°F-400°F
Glass Transition, Tg (°F) (°C)	426	219	ASTM E-1824
Thermal Conductivity:			ASTM C-518 at 75°F (24°C) mean temp.
(BTU*in/ft^2*°F*h) [(W/m*K)]	0.63	0.09	

Values shown are average values determined from laboratory tests **10/13/2013**

LAST-A-FOAM® FR-4740

LAST-A-FOAM® FR-4740 RIGID POLYURETHANE FOAM			
Property	**VALUE (psi)**	**VALUE (kPa)**	**Test Method**
Density (pcf) (kg/m^3)	40.0	641	ASTM D-1622
Compressive Strength (psi) (kPa)			ASTM-D-1621
Parallel to Rise			
@ 75°F	5176	35688	
@ 350° F	2192	15117	
Perpendicular to Rise			
@ 75°F	4161	28691	
@ 350° F	2109	14545	
Compressive Modulus (psi) (kPa)			ASTM-D-1621
Parallel to Rise			
@ 75°F	0	0	
@ 350° F	181038	1248254	
Perpendicular to Rise			
@ 75°F	0	0	
@ 350° F	91047	627771	
CTE (in/in-°F) (m/m-K)	26×10^{-6}	47×10^{-6}	ASTM E-1824 @ 200°F-400°F
Glass Transition, Tg (°F) (°C)	424	218	ASTM E-1824
Thermal Conductivity (BTU*in/ft2*°F*h) (W/m*K)	0.91	0.13	ASTM C-518 at 75°F (24°C) mean temp.
Fire Safety	Pass	Pass	<15s extinguish time, <6 in burn length *via test method shown below

Values shown are average values determined from laboratory tests **10/13/2013**

LAST-A-FOAM® FR-7120

LAST-A-FOAM® FR-7120 RIGID POLYURETHANE FOAM			
Property	**VALUE (psi)**	**VALUE (kPa)**	**Test Method**
Density (pcf) (kg/m^3)	**20.0**	320	ASTM D-1622
Compressive Strength (psi) (kPa)			ASTM-D-1621
Parallel to Rise			
@ 75°F	1066	7350	
@ 200°F	584	4027	
Perpendicular to Rise			
@ 75°F	1012	6978	
@ 200°F	531	3661	
Compressive Modulus (psi) (kPa)			ASTM-D-1621
Parallel to Rise			
@ 75°F	37327	257370	
@ 200°F	19754	136204	
Perpendicular to Rise			
@ 75°F	28246	194756	
@ 200°F	15928	109824	
Tensile Strength (psi) (kPa)			ASTM D-1623 Type A Specimens
Parallel to Rise	749	5164	
Perpendicular to Rise	714	4923	
Flexural Strength (psi) (kPa)			ASTM D-790 Method 1-A
Rise Parallel to Test Span	1020	395228	
Rise Parallel to Beam Thick.	990	6826	
Flexural Modulus (psi) (kPa)			ASTM D-790 Method 1-A
Rise Parallel to Test Span	33163	395228	
Rise Parallel to Beam Thick.	33164	228666	

Values shown are average values determined from laboratory tests **07/23/2015**

LAST-A-FOAM® FR-7130

LAST-A-FOAM® FR-7130 RIGID POLYURETHANE FOAM			
Property	**VALUE (psi)**	**VALUE (kPa)**	**Test Method**
Density (pcf) (kg/m^3)	**30.0**	481	ASTM D-1622
Compressive Strength (psi) (kPa)			ASTM-D-1621
Parallel to Rise			
@ 75°F	2371	16348	
@ 200°F	1189	8198	
Perpendicular to Rise			
@ 75°F	2231	15383	
@ 200°F	1131	7798	
Compressive Modulus (psi) (kPa)			ASTM-D-1621
Parallel to Rise			
@ 75°F	90311	622694	
@ 200°F	34879	240491	
Perpendicular to Rise			
@ 75°F	63174	435585	
@ 200°F	33232	229135	
Tensile Strength (psi) (kPa)			ASTM D-1623 Type A Specimens
Parallel to Rise	1397	9632	
Perpendicular to Rise	1256	8660	
Flexural Strength (psi) (kPa)			ASTM D-790 Method 1-A
Rise Parallel to Test Span	1936	395228	
Rise Parallel to Beam Thick.	1951	13452	
Flexural Modulus (psi) (kPa)			ASTM D-790 Method 1-A
Rise Parallel to Test Span	71762	395228	
Rise Parallel to Beam Thick.	70698	487463	

Values shown are average values determined from laboratory tests **07/23/2015**

LAST-A-FOAM® FR-7140

LAST-A-FOAM® FR-7140 RIGID POLYURETHANE FOAM			
Property	**VALUE (psi)**	**VALUE (kPa)**	**Test Method**
Density (pcf) (kg/m^3)	**40.0**	641	ASTM D-1622
Compressive Strength (psi) (kPa)			ASTM-D-1621
Parallel to Rise			
@ 75°F	4220	29097	
@ 200°F	2134	14714	
Perpendicular to Rise			
@ 75°F	4263	29393	
@ 200°F	2191	15107	
Compressive Modulus (psi) (kPa)			ASTM-D-1621
Parallel to Rise			
@ 75°F	113710	784030	
@ 200°F	55026	379404	
Perpendicular to Rise			
@ 75°F	116176	801034	
@ 200°F	51814	357258	
Tensile Strength (psi) (kPa)			ASTM D-1623 Type A Specimens
Parallel to Rise	2317	15976	
Perpendicular to Rise	2475	17065	
Flexural Strength (psi) (kPa)			ASTM D-790 Method 1-A
Rise Parallel to Test Span	3388	395228	
Rise Parallel to Beam Thick.	3517	24250	
Flexural Modulus (psi) (kPa)			ASTM D-790 Method 1-A
Rise Parallel to Test Span	130251	395228	
Rise Parallel to Beam Thick.	130250	898074	

Values shown are average values determined from laboratory tests **07/23/2015**

Appendix B - Recommended Products

Epoxy Adhesives

- 2216 B/A, 1838 B/A, 3501 B/A (3M Company)
- #320, #363 (Lord Corporation)
- Triggerbond 10-3003, 10-3012 (Epoxies Etc.)
- WB 400/WH150 (Resin Services Co.)
- Epi-Tech 260A (Adhesive Tech.)
- DURABOND E20HP (Henkel Loctite)

Contact Cements

- Fastbond™ 10 (3M Co.)
- 80 Aerosol and Super 77 Aerosol (3M Co.)
- ScotchGrip™ 1357 (3M Co.)
- 7132C + Boscodur 24 (Bostik)
- Methacylate Adhesives #330 Depend® (Henkel Loctite)
- 324 Superbonder (Henkel Loctite)
- 661/6, 662/6, 663/6 (Lord Corp.)
- MA200, MA320, AO420 (ITW Plexus)

Polyurethane Adhesives

- 3532 B/A, 3535 B/A (3M Company)
- 7542, 7545, 7546, 7610 (Lord Corporation)
- EXCEL ONE® (The Ambel Corporation)
- DURABOND 605/610 (Henkel Loctite)
- PL Premium Polyurethane
- Construction Adhesive (OSI)
- ProBond Polyurethane Glue (Borden Co.)
- Titebond Polyurethane Glue (Franklin)
- Gorilla Glue® (The Gorilla Group)

Cyanoacrylate Adhesives

(Note: It is good to use activators for all cyanoacrylate bonds)

- 454 Gel, 409 QuickGel® (Henkel Loctite)
- Pronto Gel CA-50 Instant Adhesives (3M Co.)
- Hot Stuff Special T (Satellite City)
- Zap Gel (Pacer Technology)

Mold Release Agents

- CHEMLEASE® MPP117 (Chemtrend)
- Duratec® Vinyl Ester Hi-Gloss Topcoat (1902) (Hawkeye Industries)
- Duratec® Sealer 823 (Hawkeye Industries)
- Orca Composites Super Clear Additive/Coating
- Orca Composites Vinyl Ester White Surface Primer

Foam Surface Sealants

- MV85LE Mold Sealant + Release (Meguiar's USA)
- ZYVAX Sealer GP (ZYVAX Inc.)
- DURATEC Polyester Sealer (Hawkeye Industries)
- Sanding sealer for wood products (various manufacturers)
- Concrete sealers (both water and solvent-based types)
- Varathane® Diamond Finish (Flecto Company)

Appendix C - Recommended Products for FR-4700

Bonding Adhesives

- Hysol EA 9396 Epoxy Paste Adhesive (ambient cure, low viscosity)
- Hysol EA 9394 Epoxy Paste Adhesive (ambient cure, high viscosity)
- Duralco 4461-SS-2 from Cotronics Corporation
- Reklein Plastics Resin Services HTR-350

Sealant Compounds / Surface Finish Sealing

- CHEMLEASE MPP117 from Chemtrend (FR-4730 or FR-4740)
- Duratec Vinylester primer
- Orca Composites Super Clear Additive/Coating
- Orca Composites Vinyl Ester White Surface Primer

For curing temperatures greater than 250°F (120°C) (Epoxy, BMI, Cyanate Ester), a resin-based filled sealer/primer can be used. It is recommended that the manufacturer's surface preparation and curing instructions be carefully followed.

- ADTECH MR #7 Mold Sealer from CASS Polymers (FR-4740)
- ADTECH ES-221 High-Temp Epoxy Surface Coat from CASS Polymers
- ADTECH ES-215 High-Temp Sealer from CASS Polymers
- ADTECH P-17 (useful for filling larger voids or repairs)
- Hawkeye Industries Duratec® Vinyl Ester Primer
- ZYVAX Sealer GP

Mold Release Agents

- Zyvax Composite Shield
- Frekote® 700-NC
- Frekote® WOLO
- Airtech® ToolTec CS5
- Adtech MR#10 High Gloss (> 300ºF (148ºC))

Glossary for Tooling Board Material Machining

Autoclave - A strong, heated container used for chemical reactions and processes using high pressures and temperatures in manufacture.

Autoclave/Vacuum Bag - Individual sheets of prepreg material are laid-up and placed in an open mold. The material is covered with release film, bleeder/breather material and a vacuum bag. A vacuum is pulled on part and the entire mold is placed into an autoclave (heated pressure vessel). The part is cured with a continuous vacuum to extract entrapped gasses from laminate. This is a very common process in the aerospace industry because it affords precise control over the molding process due to a long slow cure cycle that is anywhere from one to several hours. This precise control creates the exact laminate geometric forms needed to ensure strength and safety in the aerospace industry, but it is also slow and labor intensive, meaning costs often confine it to the aerospace industry.

Carbon Fiber - Carbon fibers are created when polyacrylonitrile fibers (PAN), Pitch resins, or Rayon are carbonized (through oxidation and thermal pyrolysis) at high temperatures. Through further processes of graphitizing or stretching the fibers strength or elasticity can be enhanced respectively. Carbon fibers are manufactured in diameters analogous to glass fibers with diameters ranging from 9 to 17 µm. These fibers wound into larger threads for transportation and further production processes. Further production processes include weaving or braiding into carbon fabrics, cloths and mats analogous to those described for glass that can then be used in actual reinforcement processes.

CNC - Computer Numerical Control Router used in machine tooling.

CFC - CFCs have been widely used as refrigerants, propellants (in aerosol applications) and solvents. A chlorofluorocarbon (CFC) is an organic compound that contains only carbon, chlorine, hydrogen and fluorine, produced as a volatile derivative of methane and ethane, also commonly known by the DuPont brand name Freon. The manufacture of such compounds has been phased out (and replaced with products such as R-410A) by the Montreal Protocol because they contribute to significant ozone depletion.

CFM - Cubic feet per minute is the standard measure used to describe a volume of flow for a material substance.

Compression Strength - The largest compression force a material can withstand before it loses its shape or fails. Testing is governed by BS EN ISO 14126 for standards.

Compression Modulus - Compression modulus is the ratio of foam's ability to support force at different indentation or compression levels. It is determined by taking the ratio of the foam's IFD (indentation force deflection) at 25 percent indentation and 65 percent indentation (65% IFD ö 25% IFD). The ratio of foam that has a 25 percent IFD of 30 pounds and a 65 percent IFD of 60 pounds is 2.0.

Continuous Service Temperature - Temperature at which a product can be manipulated continuously, without material distortion.

CTE - Coefficient of Thermal Expansion. The degree of expansion or change in size divided by the change in temperature is called the material's coefficient of thermal expansion. The material will become "rubbery" above this temperature and can exhibit plastic deformation under (fairly low) mechanical or autoclave-pressure loads. Volumetric thermal expansion coefficient is the most basic thermal expansion coefficient. Linear and area coefficients have also been developed for manufacturing use with materials.

FR - Flame retardant chemicals used in thermoplastics, thermosets and coatings that inhibit or resist the spread of fire.

Heat Distortion Temperature - At this temperature, when exposure times exceed approximately four hours, material will begin to "creep" under the load. Under low pressure or mechanical loads, exposure of one to three hours (as in a cure cycle or secondary heating operation) is allowable up to this heat-distortion temperature. If using vacuum-bag or autoclave material cure processes, test the tooling material under process conditions to ensure it is suitable and stable to this temperature.

HDU - High density urethane, the superior material used to create LAST-A-FOAM. The material density is measured in pounds per cubic foot; the more pounds per foot, the stronger the material. Testing is governed by ISO 1183 for standards.

Infusion Processes (SCRIMP, RIFT, VARTM) - Core materials, resin or fiber are laid up as dry material, and then covered with peel ply and a non-structural fabric. The dry stack is sealed and vacuum bagged and resin is allowed to flow into the material laminate.

Indentation Force Deflection (IFD) - IFD is a measurement of foam firmness. It's taken by measuring the force in pounds required to indent or compress a foam sample a specified percentage of its height across and indenter foot with a surface area of 50 square inches. In the U.S. foams are typically measured at 25% and 65% indentation and in four-inch thicknesses.

Knurling - A manufacturing process whereby a diamond-shaped, crisscross pattern is cut or rolled into metal tools to make them easier to hold and use.

Mandrel wrapping - Sheets of prepreg material are wrapped around a steel or aluminum mandrel. The prepreg material is compacted by nylon or polypropylene cello tape. Parts are typically batch cured by vacuum bagging and hanging in an oven. After cure the cello and mandrel are removed leaving a hollow carbon tube. This process creates strong and robust hollow carbon tubes.

PCF - Pounds per cubic foot, a common U.S. unit of measure of density.

Pot Life - Also called working life, the period of time after mixing during which an adhesive remains suitable for use. The more adhesive that is mixed, the more an adhesive's pot life decreases.

Pre-Catalyzed Resin - Pre-catalyzed resin has the catalyst added at the manufacturer.

Prepreg Autoclave - Fibers are pre-impregnated by the manufacturer under heat and pressure or with a solvent or a pre-catalyzed resin.

Prepreg Out of Autoclave - Low temperature prepregs have resin chemistry that allows curing at 60-120 ºF.

Pressure (PSI) - A unit of pressure, measured in pound force per square inch.

Pultrusion - Fiber bundles and slit fabrics are pulled through a wet bath of resin and formed into the rough part shape. Saturated material is extruded from a heated closed die curing while being continuously pulled through die. Some of the end products of the pultrusion process are structural shapes, i.e. I beam, angle, channel and flat sheet. These materials can be used to create all sorts of fiberglass structures such as ladders, platforms, handrail systems tank, pipe and pump supports.

Resin Transfer Molding and VARI - Vacuum assisted resin injection and resin transfer molding are dual mode clamping procedures whereby resin is injected into the cavity between the molds.

Routing Tools - Used to rough and cut out tool shapes, and to add edge details. Examples are: A CNC-router or a hand-held router.

Roughing & Finishing Feed Rate (IPM) - Inches per minute feed rate for material.

Roughing & Finishing Speed (RPM) - Revolutions per minute speed.

RTM & VARTM - Also called resin infusion. Fabrics are placed into a mold which wet resin is then injected into. Resin is typically pressurized and forced into a cavity which is under vacuum in the RTM (Resin Transfer Molding) process. Resin is entirely pulled into cavity under vacuum in the VARTM (Vacuum Assisted Resin Transfer Molding) process. This molding process allows precise tolerances and detailed shaping but can sometimes fail to fully saturate the fabric leading to weak spots in the final shape.

Short Beam Shear Strength - Standard measure used to determine inter-laminar shear strength of parallel fibers, such as those in composites, plastics and laminates. Testing is governed by BS ENO ISO 14130.

Tensile Strength - The resistance of a material or the force required to break the material under tension. Testing is governed by BS EN ISO 527-5 & 1 for unidirectional material standards and BS EN ISO 527-4 & 1 for multiaxial standards.

Tensile Modulus - Or elastic modulus, is a measure of the stiffness of an elastic material. The modulus of a material can be used to calculate the force it exerts under specific strain. It is defined as the ratio of the stress along an axis over the strain along that axis. It is a formula quantity used to characterize the material.

Thermal Couples (TC) - Thermocouples are a widely used type of temperature sensor for measurement and control in material manufacture. A thermocouple consists of two dissimilar conductors in contact, which produce a voltage when heated. The size of the voltage is dependent on the difference of temperature of the junction to the other parts of the circuit.

Thermal Expansion - Is the tendency of material to change in volume in response to a change in temperature. In general, substances expand or contract when their temperature changes, with expansion or contraction occurring in all directions. This is very important factor in HDU manufacturing.

Tg - Glass transition temperature. The glass transition temperature is always lower than the melting temperature, Tm.

Glossary for Tooling Board Material Machining Continued

Tm - The melting temperature of the crystalline state of a material.

Unicellular - Having one cell. LAST-A-FOAM ® material does and it is consistent, high performance and ideal for prototype machining, vacuum forming, pattern making and tooling.

Vacuum Bagging - This is an extension of the Wet Lay-Up Process; pressure is applied to the laminate material to improve consolidation. This is done by sealing a plastic film over the wet laid-up laminate and onto the tool. Air under the bag is extracted by vacuum pump, applying one atmosphere of pressure.

Viscosity - In primer or paint, the viscosity of a fluid is a measure of its resistance to tensile stress. For liquids it corresponds to "thickness," the thicker the paint the more viscosity.

VOC - Volatile organic compounds (VOCs) are organic chemicals that have molecules that evaporate at room temperature.

Wet Layup (Hand) and Spray Layup Processes - The process is a low-cost way of depositing fiber and resin into a core material. Fiber is chopped and fed into a gun sprayer of catalyzed resin directed at the mold. This also can be done with brushes and rollers.

Wet layup - Wet layup forming combines fiber reinforcement and the matrix as they are placed on the forming tool. Reinforcing Fiber layers are placed in an open mold and then saturated with a wet [resin] by pouring it over the fabric and working it into the fabric. The mold is then left so that the resin will cure, usually at room temperature, though heat is sometimes used to ensure a proper curing process. Sometimes a vacuum bag is used to compress a wet layup. Glass fibers are most commonly used for this process, the results are widely known as fiberglass, and is used to make common products like skis, canoes, kayaks and surf boards.

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