

System Three Epoxy

The Epoxy Book

Scroll to Page 1

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Table of Contents

Section I Introduction	1
Section II Safety and Handling	2
Section III Understanding Chemistry	3
Section IV Measuring and Mixing	4
Section V Boatbuilding Product Evolution	7
Section VI Our Epoxy Systems	8
Section VII Techniques of Epoxy Use	10
Section VII A Coating With Epoxy Resin	10
Section VII B Fiberglassing With Epoxy Resin	12
Section VII C Modifying Epoxy With Fillers	14
Section VII D Bonding With Epoxy	15
Section VII E Filleting, Fairing and Molding With Epoxy Resin	16
Section VIII Painting and Finishing	18
Section IX Areas of Epoxy Use	20
Section IX A Wooden Boat Construction	20
Section IX B Wooden Boat Restoration and Repair	23
Section IX C Composite Cored Construction	24
Section IX D Fiberglass Boat Repair	25
Section IX E Other Areas of Epoxy Use	28
Section X Troubleshooting and Commonly Asked Questions	29
Index	32
Appendix A - Estimated Usage	35



SECTION I - INTRODUCTION

A lot has happened since the last major revision of The Epoxy Book. While we started with marine epoxies - today woodworkers, home repairers, industrial manufacturers, hobbyists and many others who have little interest in boats use System Three Resins' products. Boat building itself has changed: The majority of wooden boats built today are constructed from kits consisting of pre-cut panels. The men and women building these kits want the finished product. They are not pursuing a passion to build boats. Everyone wants the easier-to-use epoxy systems that we now market.

The Internet has come of age and is by far and away the best vehicle for supplying new information to the users of our products. Many of the techniques of epoxy use are timeless or change slowly. Furthermore, the techniques are the same whether one is building a boat, a wooden dashboard for an old sports car, bonding two pieces of metal, or pouring a bar top. This is the information you'll now find in The Epoxy Book. Seek the variable information from our website (www.systemthree.com) or call us if you're not a computer user.

The best way to learn about epoxy resin products is to use them. You have to practice, just as you would if you were learning to snowboard, sail or play the guitar. The best and least expensive way to practice is to get The SilverTip Epoxy Trial Kit, some cheap lumber and try some of the techniques outlined in this book. Nothing beats hands-on learning. Even experienced epoxy users benefit from practice when trying something new. If you get stuck on something, go to our website, become a member if you haven't already done so, look in the FAQ's, glossary, literature, product data sheets, or

MSDS and see if you can find the answer to your question. If you contact us with a question we've already answered we will point you to the information rather than answer your question directly - you'll learn more that way.

We think that part of our responsibility as a manufacturer is to provide quality products to our customers and the information necessary to use them correctly. The Epoxy Book and our published and electronic information have accomplished this. Beyond that, we think it is the customer's responsibility to read the directions and use the products in accordance with the information we provide. Although we have formed a partnership in this fashion, the customer is the one ultimately responsible for the success of the project. So, while you don't need our permission to try something new, we suggest that you first try your idea on some scrap and satisfy yourself that you can accomplish what you desire. If you neglect this important step you will have committed your entire project to the test.

You'll find that The Epoxy Book is organized in sections starting with Safety and transitioning into Epoxy Chemistry. Then we get into Areas of Use, Measuring and Mixing, Techniques of Epoxy Use and finally, Painting and Finishing. Appendix A contains some useful information while the Index can help in quick lookups.

One point though: This is a book about epoxy resin products and their use. It is not about construction. There are many great books about boat construction, furniture making, model construction, home repair and the like and we do not intend to duplicate or summarize them here. If you are looking for this information go to the links section of our website or use one of the Internet search facilities to find what you seek.



SECTION II - SAFETY AND HANDLING

We select our resin and hardener raw materials with the health and safety of our customers in mind. However, it is not possible to make a perfectly safe epoxy resin system. These materials all have health risks, especially if improperly used.

The primary hazard when working with an epoxy system is skin irritation leading to potential skin sensitization from prolonged and repeated contact. Most people who become sensitized are unable to continue working with epoxies without breaking out in a rash most commonly on the inside of the forearms and on the forehead above the eyebrows. The effect appears to be cumulative. That is, you might be able to get away with getting epoxy on your skin for a while, but it could catch up to you and you will be sensitized.

Wear disposable gloves or barrier skin creams when working with products containing epoxy resins. Never use solvents to remove epoxies from your skin. Solvents, in addition to having problems that are as bad as or worse than epoxies, can help drive the hazardous ingredients into your body. Use waterless hand soap and lots of paper towels to remove epoxy from your skin. Then apply a good skin cream to replace the natural oils removed by the hand soap. If you get gummy, half-cured material on your skin let it cure and peel it off the next day. Cured epoxy doesn't stick well to skin or hair. Using a solvent to remove partially cured epoxy from your body is not an acceptable alternative.

If a rash develops when working with epoxy products stop until it clears up. If the rash is bad or persists see a doctor. Take a copy of this book and an MSDS (Material Safety Data Sheet) for the product you have been using. Have the doctor contact us if additional information is needed. Don't continue to work with epoxy if you break out every time you get near it. This is your body's way of telling you to cool it. Pay attention.

Working cleanly and keeping the materials off you are the keystones of epoxy safety. Work in a throwaway mode. Don't try to clean brushes with solvent - toss them out. Tools like putty knives can be wiped with a paper towel then sanded clean after the product cures. Cured epoxy doesn't stick to polyethylene, wax paper or most plastic wrap. Gloves, disposable brushes, and onetime use roller covers are expendable. Your health is not. Think of gloves and dust masks as another part of the cost of the project. Be prepared to spend some money on these items that are designed to help protect you. We like the inexpensive disposable gloves as opposed to heavier, more permanent gloves. The problem with the heavier gloves is that they eventually become contaminated with uncured resin or hardener on the inside long before they wear out. The very thing that you started using to protect you is now a source of contamination. Disposable gloves wear out about the time they become dirty and are replaced.

The vapor pressure of epoxy resin and hardener is so low that vapors rarely cause problems, unless you have already become sensitized. Well-cured resin should cause no problem, as it is largely inert.

Whenever sanding or creating any kind of dust wear a mask to keep the dust out of your lungs. If you sand fiberglass and allow the dust to get on your skin you will probably get an itch from the glass fibers. Shower in cool water to wash the fibers off you. The itch usually goes away after 24 hours.

Two-part epoxy products should be sprayed only by experienced, professional applicators, and then only if impervious coveralls and air-supplied respirator (SCUBA) equipment is worn. Airborne mists of reactive chemicals can exaggerate their health hazards exponentially.

System Three epoxy resin and hardener products have a low flammability risk, generally burning only if exposed to a high heat source. BUT, the solvents found in most shops are extremely flammable and/or explosive in the right concentration. Be smart and avoid any possible source of ignition when using solvents. Be even smarter and eliminate the use of solvents.

Material Safety Data Sheets (MSDS) for all System Three epoxy products can be had for the asking. Current versions are always available on our website (www.systemthree.com) or by contacting us.

Most people never develop health problems working with epoxy resins. If we scared you a little then it's our hope that you'll work with these materials a little smarter and cleaner than you might have otherwise.



SECTION III - UNDERSTANDING THE CHEMISTRY

Thoroughly knowing epoxy resin chemistry is not necessary before using a System Three product, but having a rudimentary chemical knowledge will help you complete any project more effectively, avoiding pitfalls or surprises which may arise when using epoxy containing materials.

The resin that is the basis for all epoxy is the diglycidyl ether of bisphenol A (DGEBA). Bisphenol A is produced by reacting phenol with acetone under suitable conditions. The "A" stands for acetone, "phenyl" means phenol groups and "bis" means two. Thus, bisphenol A is the product made from chemically combining two phenols with one acetone. Unreacted acetone and phenol are stripped from the bisphenol A, which is then reacted with a material called epichlorohydrin. This reaction sticks the two ("di") glycidyl groups on ends of the bisphenol A molecule. The resultant product is the diglycidyl ether of bisphenol A, or the basic epoxy resin. It is these glycidyl groups that react with the amine hydrogen atoms on hardeners to produce the cured epoxy resin. Unmodified liquid epoxy resin is very viscous and unsuitable for most uses except as thick glue. At System Three Resins we purchase the material in this basic form, then modify it using formulae developed by us. The results are the "Part A's" of the various epoxy resin products we manufacture.

Chemical raw materials used to manufacture curing agents, or hardeners, for room-temperature cured epoxy resins are most commonly polyamines. They are organic molecules containing two or more amine groups. Amine groups are not unlike ammonia in structure except that they are attached to organic molecules. Like ammonia, amines are strongly alkaline. Because of this similarity, epoxy resin hardeners often have an ammonia-like odor, most notable in the air space in containers right after they are opened. Once in the open this odor is difficult to detect because of the low vapor pressure of the polyamines. Epoxy hardeners are commonly referred to as "Part B".

Reactive amine groups are nitrogen atoms with one or two hydrogen atoms attached to the nitrogen. These hydrogen atoms react with oxygen atoms from glycidyl groups on the epoxy to form the cured resin - a highly crosslinked thermoset plastic. Heat will soften, but not melt, a cured epoxy. The three dimensional structure gives the cured resin excellent physical properties.

The ratio of the glycidyl oxygens to the amine hydrogens, taking into account the various molecular weights and densities involved, determines the final resin to hardener ratio. The proper ratio produces a "fully-crosslinked" thermoset plastic. Varying the recommended ratio will leave either unreacted oxygen or hydrogen atoms depending upon which side is in excess. The resultant cured resin will have lower strength, as it is not as completely crosslinked. Excess Part B results in an increase in moisture sensitivity in the cured epoxy and should be avoided.

Amine hardeners are not "catalysts". Catalysts promote reactions but do not chemically become a part of the finished product. Amine hardeners mate with the epoxy resin, greatly contributing to the ultimate properties of the cured system.

Cure time of an epoxy system is dependent upon the reactivity of the amine hydrogen atoms. While the attached organic molecule takes no direct part in the chemical reaction, it does influence how readily the amine hydrogen atoms leave the nitrogen and react with the glycidyl oxygen atom. Thus, cure time is set by the kinetics of the particular amine used in the hardener. Cure time for any given epoxy system can be altered only by adding an accelerator in systems that can accommodate one, or by changing the temperature and mass of the resin/hardener mix. Adding more hardener will not "speed things up" and adding less will not "slow things down".

The epoxy curing reaction is exothermic. This means that it gives off heat as it cures. The rate at which an epoxy resin cures is dependent upon the curing temperature. The warmer it is the faster it goes. The cure rate will vary by about half or double with each 18°F (10°C) change in temperature. For example, if an epoxy system takes 3 hours to become tack free at 70°F, it will be tack free in 1.5 hours at 88°F or tack free in 6 hours at 52°F. Everything to do with the speed of the reaction follows this general rule. Pot life and working time are greatly influenced by the initial tem-



perature of the mixed resin and hardener. On a hot day cool the two materials before mixing to increase the working time.

The gel time of the resin is the time it takes for a given mass held in a compact volume to solidify. Gel time depends on the initial temperature of the mass and follows the above rule. One hundred grams (about three fluid ounces) of SilverTip Laminating Epoxy with Fast Hardener will solidify in 25 minutes starting at 77°F. At 60°F the gel time is about 50 minutes. If the same mass were spread over 4 square feet at 77°F the gel time would be a little over three hours. Cure time is surface area/mass sensitive in addition to being temperature sensitive.

What's happening is this: As the reaction proceeds it gives off heat. If the heat generated is immediately dissipated to the environment (as occurs in thin films) the temperature of the curing resin does not rise and the reaction speed proceeds at a uniform pace. If the resin is confined (as in a mixing pot) the exothermic reaction raises the temperature of the mixture, accelerating the reaction.

Working time is about 75% of the gel time for the geometry of the pot. It can be lengthened by increasing the surface area, working with a smaller mass, or cooling the resin and hardener prior to mixing. Material left in the pot will increase in absolute viscosity (measured at 75°F, for example) due to polymerization but initially decrease in apparent viscosity due to heating. Material left in the pot to 75% of gel time may appear quite thin (due to heating) but will actually be quite thick when cooled to room temperature. Experienced users either mix batches that will be applied almost immediately or increase the surface area to slow the reaction.

Although the cure rate of an epoxy is dependent upon temperature, the curing mechanism is independent of temperature. The reaction proceeds most quickly in the liquid state. As the cure proceeds the system changes from a liquid to a sticky, viscous, soft gel. After gelation the reaction speed slows down as hardness increases. Chemical reactions proceed more slowly in the solid state. From the soft sticky gel the system gets harder, slowly losing its stickiness. It becomes tack free and continues to become harder and stronger as time passes.

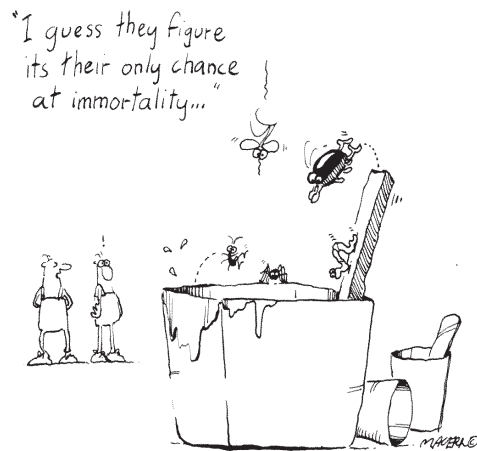
At normal temperatures the system will reach about 60 to 80% of ultimate strength after 24 hours. Curing then proceeds slowly over the next several weeks, finally reaching a point where no further curing will occur without a significant increase in temperature. However, for most purposes room temperature cured systems can be considered fully cured after 72 hours at 77°F. High modulus systems like Phase Two epoxy must be post-cured at elevated temperatures to reach full cure.

It is usually more efficient to work with as fast a cure time as practical for the application at hand if the particular system being used offers this choice. This allows the builder to get along to the next phase without wasting time waiting for epoxy to cure. Faster curing films with shorter tack times will have less chance to pick up fly tracks, bugs, and other airborne contaminants.

A surface film may form on some epoxy systems during the curing process. Technically, this surface film is an amine carbonate that can form in the presence of carbon dioxide and water vapor. More appears on cool damp days than on warm sunny days. This film, often called blush, is water-soluble and should be removed with a sponge and warm water before sanding or painting. Surface blush does not affect the clarity of the cured epoxy film. SilverTip Laminating Epoxy does not form a blush.

Unprotected epoxy resins are not ultimately sunlight resistant. After about six months of exposure to intense sunlight they begin to decay. Additional exposure will induce chalking, yellowing, and eventually the epoxy will disintegrate, losing its mechanical properties. The solution to this problem is to protect the epoxy with paint or with a varnish, which contains an ultraviolet light shield.

Caution must be observed when using epoxy resins along with polyester resins. Observe the general rule that epoxy resins may be applied over cured polyesters that have been dewaxed and well sanded but polyesters should never be used over cured epoxy resins. Unreacted amine in the epoxy inhibits the peroxide catalyst in the polyester causing an incomplete cure at the interface. Sanding does not get rid of unreacted amine. The result is a poor bond even though the surface appears cured. Debonding will be the inevitable result. Our SB-112 epoxy system was designed to get around the "polyester over epoxy" problem. Consult the SB-112 Technical Data Sheet for additional information.



SECTION IV - MEASURING AND MIXING

Measuring and mixing is really easy with most of our epoxy systems because they mix at a 2:1 or 1:1 volume ratio, but this doesn't mean you don't have to pay attention to what you're doing. First, read the label or Technical Data Sheet to see what the correct ratio is for the product you are using. Customers will call our Technical Support line suggesting that something is wrong with the epoxy because it didn't cure properly. We know of no situation where properly-mixed resin/hardener has gone bad or has been contaminated and wouldn't cure. It always resolves that the batch was either improperly measured or insufficiently mixed in the user's shop. Epoxy chemistry just will not allow it to work any other way.

If you're working on a project that requires you mix many small resin batches, develop a measuring technique that is sufficiently

accurate and stay with it. Doing it the same way each time will minimize the chance for error. Measuring errors are insidious and can pop up when least expected. The reasons that errors occur are always because the technique changed, too little time was taken, someone else mixed a batch, or just not enough care was taken.

If using a graduated cup or a straight-sided can, get in the habit of measuring the same way each time. If you pour the resin first, then always pour the resin first. Before adding the hardener, notice how much resin is already in the container, divide this by two (for a 2:1 system) and then add hardener to bring the total to the correct mark. Measuring in the same order each time will avoid the common error of two parts of hardener to one part of resin.

Using a vertically held stir stick marked in a two to one ratio will only work for vertical sided containers. Don't use this method on containers with sloping sides.

If using the "two measures/one measure" method and mixing in a separate container, scrape the sides each time you pour from the measuring cups to the mixing container.

Double check that the graduations on disposable paper cups look right. Some cups are not rolled correctly when made. The first graduation is sometimes too high or too low.

Use the System Three AccuMeasure Kit (see Product Catalog) when working with amounts smaller than three fluid ounces. It's inexpensive and very accurate down to about one half ounce. Many of our customers have completed large projects measuring with just the AccuMeasure Kit and 14-ounce graduated disposable paper cups. You really don't need to invest a lot of money in metering devices to measure a 2:1 or 1:1 volume ratio products successfully. Good technique and common sense go a long way.

System Three Resins offers white plastic plunger pumps for those who want a mechanical device to measure by volume. These fit on the pint, quart, half-gallon, one-gallon, 2.5 and five-gallon containers. These pumps are the kind that you find at the ballpark that are used to get mustard out of the jar to put on your hot dog. They can be used at two squirts to one squirt or the hardener pump can be modified to operate at one squirt of hardener to one squirt of resin. Complete instructions come with each plunger pump kit. They do not work for high-viscosity systems measured at 1:1.

We can refer those willing to invest large sums in fast, accurate mechanical devices to outside vendors. System Three Resins no longer offers these following the advent of low cost digital scales.

Any mechanical device can go haywire, lying to you with a straight face. Valves can stick causing backflow into the reservoirs. Pumps should be checked for accuracy periodically using scales or graduated cups. If you aren't prepared to spend the time to properly maintain these mechanical pumps, then consider measuring by weight. This is the method we use and find it faster and more accurate than measuring by volume.

Excellent reliable digital scales can be had for under a hundred dollars. This is about a third of the cost of lowest price mechanical devices excepting the mustard pumps. A digital scale with a capacity of 500 grams with 0.1 gram divisions can weigh batches of less than one-half fluid ounce reproducibly with confidence that it is dead on each and every time.

Scales offer two other distinct advantages: The old style "chemistry set" approach utilizing powder fillers greatly benefits when the fillers are also weighed. One ends up with consistent mixes each time when thickened batches are needed. Second, the SilverTip series contains products like EZ-Fillet, QuikFair and MetlWeld which, being semi-pastes, cannot accurately be measured by volume since they do not "self-level" and often contain air pockets when plopped into a measuring cup.

Don't make the mistake of using the volume ratio when measuring by weight. We formulate products to be used by simple volume ratios (2:1, for example) as much for packaging purposes as any other reason. Weight ratios are usually expressed in parts of hardener to 100 parts of resin. Volume ratios of 2:1 are often equivalent to weight ratios of 43/100 because the hardener is less dense than the resin. Check the Product Data Sheet to get the correct weight ratio if you measure by weight.

With the resin and hardener accurately measured, mix thoroughly. For batches of a gallon or less, stir well, scraping the container sides, and mix from the bottom to the top. Keep stirring until that mixture is no longer hazy. Don't worry about a few air bubbles. That's normal. Scrape the mixing stick several times on the side of the container. Mixing takes anywhere from 15 seconds to a minute depending on the size, shape of the container, and temperature and viscosity of the mix. A sure-fire way to make sure that material is thoroughly mixed is to use the "two-container method". Mix in one container and then transfer the contents into a second container scraping the first into the second. Then mix again. You will have an absolutely uniform batch if you do this and avoid having partially cured spots in your coating or pour.

Avoid large batches if possible. It's better to make three 12-ounce batches rather than one 36-ounce batch. If your job is big and you must work with large batches then use a Jiffy Mixer. Attached to a drill it will make short work of mixing batches larger than a gallon. Use the two-container method also when mixing large batches, and don't forget to scrape the sides of the mixing container. Keep in mind that large batches take longer to mix, have a much shorter pot

life, and if you get side tracked cost more when they gel in the pot. Epoxy paperweights are expensive.

If you measured or mixed incorrectly and a batch doesn't properly cure about the only thing to do is scrape it off and start over. A hot air gun will help to soften the partially cured material. Then try removing any residual material with lacquer thinner (but not with the hot air gun or source of ignition around). Wear solvent resistant gloves and have plenty of ventilation when doing this. Then examine your technique to find out what went wrong.



If your measuring/mixing error is not apparent do the following gel time test to convince yourself that the product is not at fault.

Accurately measure resin and hardener in the same container, use a total of three to six fluid ounces or at least 50 grams. Mark down the time you started mixing the two components. Mix thoroughly and record the approximate starting temperature of the mixture. Stir occasionally and note the time that the material gels (solidifies). Refer to Technical Data Sheet for the product being tested to see if the gel time is about what it is supposed to be for the given starting temperature. A minute or two either way is not important. If your test material cured properly then the error is in measuring or mixing.

If, after all this, you remain convinced that “something is wrong with the product”, take it back to the store. If your System Three dealer can’t talk you through the problem, call us. Keep in mind that we have tested the batch you are using and lots of other customers are using material from this same batch.

All System Three epoxy products are formulated systems, meaning that we start with basic raw materials produced by large chemical manufacturers, and modify them to make them suitable for our customers’ use. These modifications take many forms, and are the heart of epoxy resin formulating.

For instance, in a clear laminating resin, a modification might include viscosity reduction by the addition of diluents or low viscosity solvents, which are also epoxies. Lower viscosity makes a laminating resin thin enough to wet fiberglass cloth, coat and penetrate wood, coat concrete, stone, or metal, and bind various fillers to produce gap filling glues and putties. Because the diluents we use are also epoxies, they are called reactive diluents, reacting with the amines the same way the basic resin reacts, becoming a part of the cured system. Other reactive materials protect against long-term embrittlement and improve resiliency and impact resistance.

In the case of several of the SilverTip marine epoxy Series products we add various fillers, pigments and thixotropes in a unique process that removes any dispersed air. SculpWood moldable epoxy putty is a “filled” product taken to an extreme: There is so much filler in the product that it is friable rather than wet. It takes specialized equipment to make products like this.

Many of our products use trace materials that are designed to lower surface tension, promote substrate wetting, reduce cratering and “fisheye” formation, aid in breaking bubbles and detaining air. Some additives promote adhesion while others increase toughness.

These modifications are what make our epoxy products unique, different, and we think preferable to our competitor’s products. We not only develop the chemical formulations for both the resin and hardeners, we manufacture our products, giving us ultimate control over the quality of the final system. Every batch manufactured in our factory goes through appropriate quality control testing in the laboratory, depending on its intended end use. Nothing is shipped to a customer that does not meet our high standards. Everything we ship will perform as advertised if properly measured, thoroughly mixed, and applied according to instructions.

System Three Resins is well qualified to formulate and produce epoxy resin products. Our technical staff includes one of the owners, a chemical engineer who has worked with polymers since 1963. He has built a 34-foot wood/epoxy sailboat and more recently a composite kit aircraft, which he regularly flies. We also have a polymer chemist with over 30 years of formulating and manufacturing experience in our employ.

This background gives us the ability to know and apply epoxy technology that is on a par with any other companies in the industry, including the multinational conglomerates. The development, manufacture, and distribution of System Three products is our only business.

The dominant factor in the design, development, and evolution of System Three epoxy resin products has been this:

AN EPOXY SYSTEM SHOULD ADAPT TO THE CONDITIONS OF THE USER - NOT THE OTHER WAY AROUND.



SECTION V - BOATBUILDING PRODUCT EVOLUTION

System Three Resins began manufacturing and selling formulated epoxy resin systems to the marine industry in 1979. Our initial product (now called our General Purpose epoxy) took what we call the “chemistry set” approach. That is, for building or repairing wooden boats, one bought a low viscosity, clear resin and the appropriate speed hardener, along with powdered fillers, thixotropes, wood flour, microballoons and the like. The basic resin/hardener system was formulated to be able to coat wood and wet out fiberglass cloth when used right out of the container. With the addition of various dusty powdered fillers one could make an adhesive, filleting putty or fairing compound.

The “chemistry set” approach requires that the user invest considerable time in order learn how to use the products successfully. While all the various combinations of materials in the “chemistry set” produce adequate materials none are optimized for any particular application. For example, the best epoxy adhesives have qualities that make them unsuitable for use as coating resins. The converse is also true: The best coating resins make marginally adequate adhesives. But, the “chemistry set” approach required that one resin/hardener combination be used for both. So, while compromises were required, coating formulations drove the mix, forcing customers to use only acceptable, not optimized, products for non-coating applications.

The “chemistry set” approach requires the addition of lightweight dusty obnoxious fillers that change the liquid system into non-sagging putties, fairing and filleting compounds. It is impossible to add these without dispersing a lot of air into the mix. Air has the effect of temporarily increasing thixotropy in a putty yet almost always results in a putty that will slump unless enough real thixotrope has been added. Imagine watching a carefully made fillet start to sag as it cures.

In 1999, we recognized the drawbacks of the “chemistry set” approach and began working on a concept that it might be possible to eliminate the use of fillers and achieve a better end result. For example, if we could make a product that would solely be used as a fairing putty we could optimize a resin/hardener system especially for this application. We could then disperse the microballoons and remove the incorporated air in our vacuum equipment. Then all the user would have to do is mix the two parts together and apply the resultant material. By eliminating the requirement that the user add two separate fillers we no longer needed to provide time to add them. This allowed us to make a super fast curing system. The resultant product was SilverTip QuikFair, a microballoon filled fairing compound that can be applied and then sanded three hours later - about five times as fast as what could be achieved via the “chemistry set” approach! As we pursued this concept we discovered technology that allowed a liquid resin and hardener to instantly form a soft paste when mixed. We were able to use this technology to make an optimized wood adhesive (SilverTip GelMagic) and wood-flour based filleting material (SilverTip EZ-Fillet). Separating these from coating resin requirements allowed us to again optimize each product individually utilizing our “soft-paste” discovery.

All this now allowed us to optimize the coating/fiberglassing resin system since it no longer had to perform other functions. We developed an almost colorless easy to use 2:1 system that cures without amine blush, has excellent impact resistance and better elevated temperature properties than other room temperature cured epoxy systems. It has almost twice the working time for the same thin film cure time as our General Purpose “chemistry set” epoxy. The result of nearly five years of development work on this concept is our new SilverTip Series of marine epoxy resin products.



SECTION VI - OUR EPOXY SYSTEMS

What follows is a brief description of the various epoxy product systems we offer along with suggested areas of use. Consult the individual Technical Data Sheets for each product for specific information. These are available online at www.systemthree.com, from your System Three dealer, or by calling us.

SilverTip Series

This product family consists of SilverTip marine laminating resin with Fast and Slow hardener, SilverTip GelMagic wood adhesive, EZ-Fillet wood flour putty, SilverTip QuikFair microballoon fairing putty, and SilverTip MetlWeld for bonding metals and other difficult materials. These products are especially formulated ready to use directly from the container, and do not require the user to make any addition of fillers or other materials.

General Purpose Resin

This was our first formulated epoxy resin product. It is a general-purpose epoxy system that is widely used in wooden boat construction and repair, fiberglass boat repair including gel coat blister repair for fiberglass boats. While our general-purpose epoxy is specially formulated for wooden boat building, it has also been used to repair fiberglass boats both above and below the waterline. It is highly rated in the repair of gel coat blisters on fiberglass boat hulls. It has been used in some exotic non-boatbuilding areas such as the repair of cracked concrete oil well linings in the permafrost zone in Alaska, for lobster tank linings, piano repair, guitar making, sail, surf and snowboards, wind turbine blades, along with numerous other uses. Today this epoxy is successfully being used around the world in every conceivable climatic condition from above the polar circles to right smack on the equator and everywhere in between.

Our general-purpose epoxy has an excellent balance of properties for use with wood, fiberglass and other materials where the substrate carries the major portion of the load and the service temperature is not extreme - the situation with almost all wooden boats, balsa strip boats and similar structures.

Various fillers must be added to our general-purpose resin to make adhesives, filleting and fairing compounds. This resin will blush under conditions of high humidity and temperatures too low for the hardener being used.

Phase Two Laminating Epoxy

Phase Two is an ultrahigh modulus laminating epoxy resin system ideally suited for composite cored (foam, honeycomb and end grain balsa) boat hulls. Many sailboard builders use it to build polystyrene foam cored boards. It has been used to build radar domes and other solid (non-cored) structures like carbon fiber masts, booms and spinnaker poles. With the exception of some balsa strip boats intended to be painted a darker color, Phase Two is not used for wood boat building or fiberglass boat repair.

Most high modulus epoxy systems tend toward brittleness. Phase Two epoxy overcomes this problem by using two-phase morphology to achieve an excellent balance of mechanical and toughness

properties. When Phase Two epoxy cures, a material soluble in the uncured resin precipitates from solution to form discrete particles of matter with vastly different mechanical properties than the high modulus homogeneous first phase. It is the interaction between the first phase and second phase that gives Phase Two epoxy its excellent toughness properties. The overall mechanical properties derive from the first phase. Toughness properties involve fracture behavior and it is Phase Two epoxy's extreme resistance to fracture that gives it great impact and fatigue resistance. Second phase formation causes Phase Two to cure with a milky color. In thick sections it is opaque.

Like all high modulus epoxy systems Phase Two must be heated to finish the cure. This requirement along with its mechanical properties limit its use in wooden boat building to balsa strip boats that will be painted a darker color (more heat). Separate brochures on Phase Two epoxy are available either online or by telephoning.

Clear Coat Epoxy

Clear Coat epoxy is a very low viscosity (thin) almost colorless epoxy system that has a long pot life and cures without amine blush. Unlike some of the so-called penetrating epoxies, Clear Coat contains no solvent. Furthermore, it is a very strong system when cured whereas the penetrating epoxies have little, if any, strength or resistance to moisture. Clear Coat epoxy will cure at temperatures as low as 50°F.

Clear Coat epoxy wets out fiberglass cloth almost instantly and is sometimes used to build furniture grade strip planked canoes and kayaks. Clear Coat epoxy is often used as the base coat in fiberglass gel coat blister repair particularly when the gel coat has been removed exposing damaged and loose glass fibers. It is also used as a base for varnish for front entry doors and outdoor wood furniture. A separate application brochure on using Clear Coat with our spar urethane varnish or WR-LPU Topcoat on outdoor wood projects is available.

SB-112

SB-112 was developed for use in building surf and sailboards. It has practically no color and contains ultraviolet light stabilizers making it a good choice for this application. The UV stabilizers in SB-112 protect it from intermittent sunlight exposure that surf or sailboards might see. They do not protect it from permanent exposure to the sun that is likely to be seen on the bright work of a boat hull. See the Painting Section for more information on UV protection. Polyester finishes may be applied directly to SB-112.

MirrorCoat

MirrorCoat is specially formulated to create glossy, high build resin surfaces on bars, counters and tabletops. MirrorCoat forms a high build durable, smooth, glossy finish on many surfaces such as wood, ceramics, plaster and masonry. MirrorCoat cures to a glossy, smooth bubble free finish that is scratch and stain resistant as well as alcohol and waterproof. A separate application brochure on MirrorCoat is available.

RotFix

RotFix is a very thin 2:1 liquid epoxy system used in the repair of dry rot. It is used in conjunction with SculpWood. The general method is to remove the punky rotted wood. Allow the area to dry if wet. Liberally apply RotFix to the inside of the cavity allowing it to soak into the end grain. Anytime after this and preferably while the RotFix is still at least slightly tacky over fill the cavity with SculpWood. Once cured sand flush with the surrounding area. For the absolute best in rot repair see the section below on EndRot.

SculpWood

SculpWood is a 1:1 kneadable epoxy putty used to replace rotted wood. It is often used in conjunction with RotFix as described above. SculpWood can be sanded, drilled, screwed and nailed when cured. It has about the same density as wood.

EndRot Kit

In addition to RotFix and Sculpwood, the EndRot Kit contains EPA approved sodium borates for killing dry rot fungus. We highly recommend the use of these borates when doing a repair in a home or other structure exposed to the weather. Simply replacing the rotted wood as described above will not stop the dry rot from re-occurring when conditions favor it.

T-88 Structural Adhesive

T-88 has been used for years in the building of experimental wooden aircraft and for woodworkers who desire a clear glue line. More recently T-88 has been approved by the FAA for the repair of certified wooden aircraft on a case-by-case rather than blanket basis. Check with us for the current status prior to use on certified aircraft. T-88 meets the requirements of MIL-A-81236(OS) and CID-A-A-3053.

Mixed T-88 has a viscosity of about 12,000cps and does not require the addition of thixotropes to fill small gaps. Larger gaps can be filled using T-88 gel. Both the liquid and gelled versions are available in dual cartridges that accept static mixers. T-88 is considered an "overnight" cure product and is waterproof.

Quick Cure

Quick Cure is available in 5, 15, and 30-minute gel time versions appropriately called Quick Cure 5, 15 & 30. Quick Cure hardener is mercaptan based. Because of this it should be considered water resistant rather than waterproof. We do not recommend the use of Quick Cure for continuous immersion. Mercaptan cured epoxy resin (so called 5-minute epoxy) typically is a bit more rubbery than polyamide cured products like T-88 and softens more quickly with elevated temperature. Despite these drawbacks their rapid development of strength makes these products extremely useful for the right applications. It is possible, for example, to coat a board with T-88 leaving a few small areas uncoated. The uncoated areas are then coated with Quick Cure 5 and the board is then put in place on an overhead or vertical surface. It is held there for a few minutes while the Quick Cure hardens. Once this happens the board will stay put while the T-88 cures.

Epoxy Paste Pigments

We offer several pigments dispersed in epoxy resin in highly concentrated form. These are basic pigments that the user can blend with each other to make many shades. Since they are dispersed in epoxy resin they are added to the resin portion of the system and then the pigmented resin is used at the correct ratio with the appropriate hardener. Our dispersed pigments include white, black, brown, red iron oxide, toluidine red, phthalocynine green, phthalocynine blue and organic yellow. Do not use these pigments to tint our water reduceable urethane coatings (WR-LPU). The pigments can be mixed with WR-155 Activator to tint the primer to a pastel shade.

PG-101

PG-101 is a moisture-cured MDI based urethane. The attractiveness of these kinds of wood adhesives is that they are "one-part" and ready to use right out of the bottle. The disadvantages include considerably lower cured strength than epoxy adhesives, inability to bond dry non-porous surfaces, poor moisture resistance and limited shelf life. Because of their limitations we recommend PG-101 and other moisture-cured urethanes only for lightly loaded dry applications such as furniture building, cabinet making, etc. We strongly recommend against their use in marine applications.

Infusion Resins

For years, System Three has made resin systems for both pressure (RTM – Resin Transfer Molding) and vacuum infusion of dry fiberglass, carbon fiber and the like. These resins are characterized by their low viscosity and long pot lives. Typically infusion systems must be postcured to reach full strength. The infusion process has become popular in the marine area primarily because it offers a low cost way to reduce styrene emissions when polyester and vinyl ester resins are used. Some builders use epoxy with the infusion process. The chief advantage is a slightly higher glass to resin ratio. Since there is a steep learning curve associated with infusion we recommend it only to boat builders who understand that a better glass to resin ratio more than justifies the "costs" associated with the infusion process. We invite those who have studied this process to contact us regarding System Three's Infusion Resin offerings.

Electrical Potting Resins

Over the years System Three has been a large supplier of electrical and electronics potting and encapsulating resins. Many of these products have been based upon our General Purpose and Clear Coat systems with added pigments. Others are more complex and contain fillers and thixotropes. In most cases our electrical potting resins are custom formulated to mesh as perfectly as possible with the user's production process. Our standard product, EP-2010, is available "off-the-shelf". Those with interest in this area are encouraged to contact us to learn more.

SECTION VII - TECHNIQUES OF EPOXY USE

Epoxy resins are used and applied following one of four basic techniques. These are coating, fiberglassing, gluing, and filleting/fairing. Furthermore, the techniques are pretty much the same whether they involve new wooden boat construction, the repair of fiberglass boats, furniture building, bar top coating or dry rot repair.

What might seem to be other techniques are usually just variations or combinations of the above. Many of our epoxy users discover new variations. We will discuss a number of these variations and the “tricks” that will make the epoxy work go easier and faster. We don’t know everything and are constantly learning something new. We invite you to learn along with us. If you come up with a variation that we don’t mention, model it first to see if it will work. Do this prior to using your whole project as a test. For example, we are often asked if System Three epoxy will stick to stained wood. Most of the time it will regardless of the stain used. However, the only way to be really sure is to conduct your own little test.

Suppose that you are staining a piece of fir that will later be coated with epoxy and have another piece laminated to it. First, stain a scrap piece of the same wood; allow it to dry well (several days). Laminate on two pieces of 3 or 4-inch wide fiberglass tape about five inches long. Leave a “tail” that can be grasped later with a pair of pliers by running the tape a couple of inches up on a plastic squeegee. Let the epoxy cure a day or two. Remove the squeegee and grab the tail with the pliers. Try to peel the tape off the substrate. If the tape tears where the tail starts, leaving the balance of the tape bonded to the surface, then the bond is good. If the whole thing pops off intact then the bond is bad and the stain is interfering with the bond strength. Better find a new stain and repeat the test.

This same procedure can be modified to test the ability of the epoxy to bond exotic woods. If the failure occurs in the wood when two pieces are glued rather than in the glue line then it is safe to assume that the epoxy works on that kind of wood.

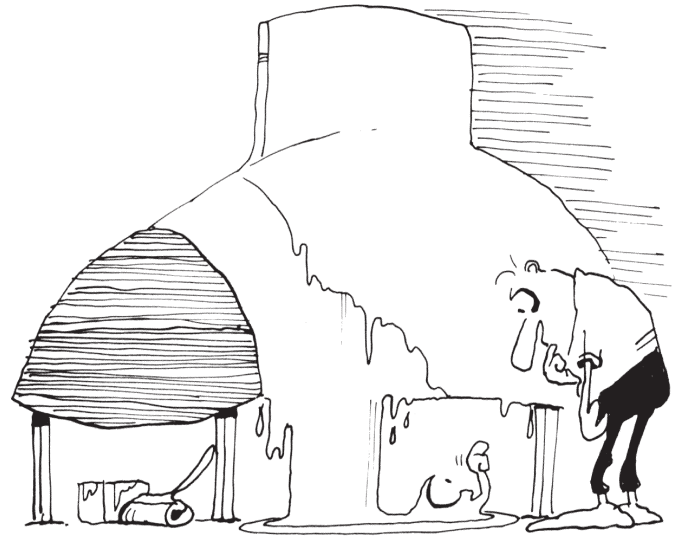
In order to simplify the following discussion of the four main areas of use for our epoxy systems we are going to confine the discussion to using our SilverTip Series products with wood. Where appropriate we will mention the use of our other epoxy systems. We feel that if you can understand and use the following techniques then you will be able to do most kinds of epoxy work regardless of the nature of your project.

SECTION VII A - COATING WITH EPOXY RESIN

Wood is often coated with epoxy to dimensionally stabilize it and provide a barrier which helps to prevent the passage of moisture. SilverTip Laminating Epoxy has a certain amount of flexibility and tough resilience built into the formulation. Because of this, a plywood panel could be coated on the bench, then bent into place without danger of the epoxy cracking. When working flat you’re not fighting gravity and the coated panel is easily sanded on the bench using a disc sander and foam pad. The sanded panels

are then installed and are ready for painting. Coating a 4’x8’ sheet of fir plywood will illustrate this method:

Mix the SilverTip resin and hardener in the correct ratio, referring to Appendix A to estimate the amount you’ll need. Pour this mix on the plywood in a stream of “S” curves starting at one end and finishing at the other, making four or five curves along the eight foot length. Spread the epoxy back and forth with a squeegee into the dry areas, trying to get as even a coating as possible without being too fussy. Use a dry foam roller to even out the coating. When this first coat is cured to at least a soft set tack free stage it can be recoated. Subsequent coatings applied at any time between this soft set stage and 72 hours do not need to be sanded and will chemically bond.



Subsequent coatings may still bond well after 72 hours without sanding but the proposition gets riskier. An amine cured epoxy surface is quite alkaline and can react with any acidic material such as moist carbon dioxide or silicates. Further epoxy coats may not bond well to some of these reaction products. Sanding, in addition to providing some “tooth” for mechanical bonding, also cleans since it exposes new, uncontaminated surface. If in doubt, sand enough to kill most of the gloss.

Working on non-horizontal surfaces is similar except that the mixed resin is poured into a roller pan and applied with a foam roller. To control runs and sags use several thin coats rather than a few thick coats. As with coating the flat panel, just wait until one coat has reached the soft set stage before applying the next.

In boat building use at least two coats for interior wood surfaces and three in areas that may be constantly wet, such as bilges. Darkroom sinks should have at least three coats on the wet side and two on the back. White epoxy paste pigment is a nice addition to an epoxy coating where appropriate. Unlike paint it will not flake off.

Several tricks can be used to improve the appearance of the finished film. Bubbles that persist in the coating can be broken

with a foam brush by lightly dragging it across the surface. Quickly and lightly fanning the uncured surface with a propane torch will accomplish this with greater speed. Avoid overheating an area as this could cause the epoxy film to pull away from the surface creating craters. Overheating will also cause the expansion of any air in the pores of the wood and may result in an epoxy coating full of bubbles.

Sometimes a coating will try to crater. This is most common with recoated surfaces that have been sanded, but may happen on other surfaces as well. While the cause of cratering is quite complex, the solution is pretty simple. Immediately after coating a surface look at it from an angle, sweeping your eyes over the whole surface. Craters will usually form within ten minutes after first applying the coating. Take the heel of the foam roller and really grind it in the area that has cratered. This wets out the dry spots in the crater center. Then, re-roll the area treated to even out the coating.

After 24 to 48 hours (depending upon temperature and hardener used) the coating will be cured enough to sand. When using general-purpose resin first wipe the surface with a damp sponge to remove any water-soluble amine carbonate surface film prior to sanding. It is not necessary to wipe SilverTip Laminating and Coating resin prior to sanding. At this stage of cure the epoxy coating can usually be sanded with a disc sander or random orbital sander. Machine sanding can generate quite a bit of heat, especially when the sandpaper gets dull or clogged, causing gumming of the sanding dust. Keep the sander moving and apply only light pressure. This keeps the heat down. If clogging still happens you'll have to either hand sand, scrape as described below, wet sand or allow another day for the cure to proceed.

Scraping is an alternative to sanding that actually produces a better finish. This shaves off a thin film of epoxy leaving a surface that looks like it was sanded with 600 grit paper. Small parts can be scraped using a single edged razor held vertically. Several companies make wood scrapers for working on larger surfaces. Keep them sharp and be careful not to cut yourself.

Any residual sanding dust should be removed by blowing or brushing it off prior to recoating. The final bit may be removed with a damp rag. Don't use acetone, other solvents or tack rags. They may leave an unbondable surface coating on the sanded epoxy surface.

Try to work at a constant or falling temperature when coating new wood. When the temperature is rising, air trapped beneath the uncured epoxy may expand and cause small bubbles to form in the coating. Avoid working in direct sunlight on new wood for this reason. If you must work in sunlight, coat the wood as the sun is going down. The wood will be cooling and air bubbles should not form. Cover any outdoor work to help prevent dew from forming on the uncured epoxy surface.

Some very porous woods are quite persistent at forming air bubbles. A trick we have used is to heat the whole surface to a temperature at least 40°F higher than room temperature. Use a hot air gun or place the wood in the sunlight for a while. Stop heating and immediately coat the surface. The epoxy will thin on the warm surface and at the same time start to cool it. The air in

small pores will begin to contract pulling the thinned epoxy in to them. Any air that does rise will be going through thinned epoxy and have an easier time of it. In lieu of this you may be able to apply a thin epoxy coating, allow it to soak in and then squeegee and discard any remaining on the surface. Once cured the coated wood now acts as a non-porous surface and rising air bubbles should pose no further problems.

Clear Coat epoxy can also be used for coating wood. Like SilverTip Laminating Epoxy it leaves no amine blush on the surface. It is a much thinner material and, while an argument could be made that this is good for the first coat, it takes over twice as many coats to achieve the film thickness and hence moisture barrier protection of SilverTip or our general purpose epoxy.

SilverTip Laminating Epoxy is an excellent base for varnish. The application of multiple coats of varnish and sanding between coats can be eliminated with two coats of SilverTip with NO sanding between coats. The final epoxy coat is sanded to provide a base, and then one or two coats of varnish are applied. The result appears to have the depth of ten or more coats of varnish and is much more durable. Revarnishing is much easier because the old varnish is just removed down to the epoxy coating. SilverTip Laminating Epoxy may be thinned with up to ten percent lacquer thinner to improve brushing. The use of solvents will retard the cure time somewhat so don't use any more than needed. Add just enough thinner to allow the epoxy to brush easily. Never add solvents to epoxy for gluing or fiberglassing.

Clear Coat epoxy is also used as a base for varnish but has several differences from SilverTip Laminating Epoxy in this application. First, it is thinner and can be easily brushed without adding solvents. Second, it is much slower affording longer working time but at the expense of a longer cure time. Third, it soaks into wood much better. Like SilverTip Laminating Epoxy it does not need to be sanded if recoated within two or three days. Unlike SilverTip Laminating Epoxy it takes over twice as many coats to achieve equal thickness.

Clear Coat epoxy may water spot if water stands on it even though it has been cured for a long time. This is a phenomenon unique to the raw materials used in the Clear Coat hardener. Sanded Clear Coat epoxy will not water spot as the offending surface layer has been removed. SilverTip Laminating Epoxy develops water spot resistance within 24 hours of application.

Epoxy coatings should be sanded before varnishing or painting. These materials stick to the epoxy by mechanical means and must have some "tooth" in order to bond well. Never apply solvent-based coatings to partially cured epoxy. Read the Painting Section before painting or varnishing an epoxy coating.

Materials Required for Coating:

SilverTip Laminating Epoxy (Resin and Hardener)
Foam roller covers/frames
Measuring device
Plastic squeegees
Protective gloves
Brushes, foam and bristle

SECTION VII B - FIBERGLASSING WITH EPOXY RESIN

Outside surfaces of boat hulls are usually epoxy/fiberglassed to create a thicker, stronger epoxy coating. This provides higher abrasion, impact and moisture resistance. In the case of most wooden boats the purpose of reinforcing cloth is to strengthen the epoxy coating, not to reinforce the hull. Chines, keels, bow and transom corners are structurally reinforced with fiberglass tape and epoxy. Fiberglass tape has been judiciously used to great advantage by woodworkers to strengthen unseen edges of complex miter/bevel joints in panels.

Some small, dry-sailed boat hulls made from plywood other than fir don't need cloth. Several coats of epoxy alone are usually all that is needed, though seams should be fiberglassed for structural reasons. Rotary cut fir plywood should always be fiberglassed on outside exposed surfaces or the plywood may check and crack the epoxy coating.

Epoxy resins have all but replaced polyester resins for the fiberglassing of wood. Polyester is a poor adhesive, delaminating when moisture gets between the fiberglass substrate and the wood.

Because the fiberglass is structural to the epoxy coating rather than the boat hull, it's possible to use a lightweight cloth. Six-ounce cloth is sufficient for most surfaces and can be doubled in high wear and impact areas. Don't use cloth that is too heavy for the intended service, you'll use a lot more epoxy and have a heavier boat, gaining little else. Tests show no appreciable difference in peel strength between the two most popular finishes of fiberglass cloth, Volan and Silane. Four and six ounce cloths are nearly invisible when wet out with SilverTip Laminating Epoxy. Heavier weight fiberglass shows the weave pattern under certain lighting conditions.

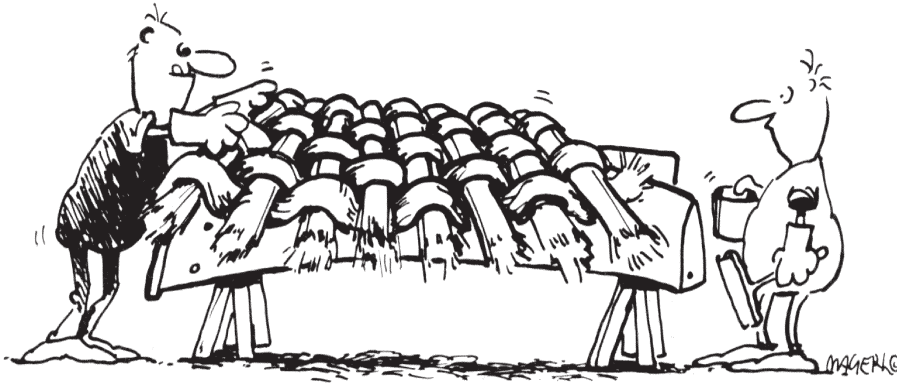
Avoid using fiberglass mat with epoxy resins. The binder that holds the mat together is dissolved by the styrene in polyester resins. Epoxies don't use styrene as a diluent, making it almost impossible to properly wet out the mat. Woven roving is wet out well by epoxy but we know of no reason to use it in building a wooden boat. Clear Coat epoxy due to lower viscosity and higher solvating power will wet out fiberglass cloth faster than other systems.

Regardless of the type of the cloth or resin system used, fiberglassing is done essentially the same way. There is no need to be intimidated by fiberglassing, what you are really doing is gluing the cloth to the surface with a minimum amount of resin. Use just enough epoxy to wet out the cloth, you'll fill the weave of the cloth later. Work on as horizontal a surface as possible. Fiberglassing is much easier if you are not fighting gravity.

The first step to doing a good fiberglass job is to pre-coat the wood to avoid the problem of having unsealed wood soak up too much epoxy, starving the wood/glass bond. Pre-coating doesn't use any more epoxy than the more difficult one step method (for experienced fiberglassers only!) and helps to assure that maximum peel strength is achieved. After the first coat cures fill any holes with SilverTip QuikFair or an epoxy /microballoon mixture to provide a smooth base for the cloth. Sand off high spots and burrs or knock them down with a Surform or body file. Clean the surface with compressed air or brush off and wipe with a clean damp rag to remove any remaining traces of dust. Don't use acetone or similar solvents for this. Much acetone sold today is reclaimed and may have impurities that interfere with secondary bonding by leaving a film of residue on the surface. Avoid the use of tack cloths as they may transfer some of the waxy material on them to the epoxy surface causing secondary bonding problems. Next lay the fiberglass out on the pre-coated, tack free surface, smoothing it out and doing any rough trimming. Masking tape may be necessary to hold the cloth in place if the surface has any slope.

Mix no more than 15 fluid ounces of resin and hardener. Work

with small batches until you get the hang of it. Start at one end and pour the resin out over an area equal to about 1 square foot per fluid ounce (15 ounces does a 3 x 5 foot area). Pour in "S" curves as described in the coating section (on steep surfaces apply the epoxy with a roller cover and roller



tray), spreading lightly into the dry areas with a squeegee (we like the rubber Thalco squeegee for laying down cloth). Let the resin wet the cloth out. Don't try to "force" it through the weave with the squeegee. Notice how the cloth disappears as it wets out.

When this first area has been covered and the cloth has disappeared, take the squeegee and use reasonable pressure to squeeze the excess resin away from the wet cloth. Work it down into the dry cloth area only if the surface will be painted. If you intended to clear finish the part you should discard the frothy squeegeed resin as it may not expel all the microfoam before curing. You can wipe the squeegee edge on a cup or can to remove the resin. Squeegeeing removes excess resin and entrained air, sticking the cloth down right next to the wood surface. The squeegeed cloth should now have a semi-dry look with the weave pattern showing; the cloth itself will be invisible.

Keep on going, section by section, until you are finished. If you are working on a very large area use a dry roller cover on the previous three or four sections to give a final smoothing. On smaller boats the roller cover can be used after the entire hull has been fiberglassed.

Let the epoxy resin cure to the “green” stage where it is pliable but no longer tacky unless pressed really hard. Now is the time to trim the excess cloth. Trim by running a single edged razor blade around where the glass overhangs the edge. Press down any glass that lifted from the surface while trimming.

The selvage edges of the fiberglass have to be feathered before being covered by another piece of cloth. Wait another hour or so and do the feathering with a Surform. Do it while it is in the right state of cure. Too early and the wet fiberglass will lift, too late and it will be too hard to cut. The alternative is to wait a day or so until it is hard enough to sand.

It is not always possible to have a selvage edge on the cloth. Rather than have a cut edge fraying all over the place, which can only be cleaned up by a lot of sanding later, here’s a trick that produces a very neat edge. Run a piece of 2” masking tape so that the inner edge of the tape is where you want to stop the glass. Lay down the cloth so that it runs at least an inch past the outer edge of the tape. Wet out the glass past the inner edge and about halfway across the tape. When the cure reaches the green state run a single edge razor blade right down the inner edge of the tape. Pull off the tape and presto; you have a nice edge right where you cut the fiberglass. If a little of the cloth lifts, press it back down.

The weave of the cloth can be filled once the resin has reached the green state of cure. Don’t try to sand the weave smooth, fill it with epoxy. Apply fill coats the same as discussed in the preceding section on coating. Several coats may be necessary before the weave is filled. If you plan to paint the surface you may fill the cloth weave with SilverTip QuikFair in one coat using a squeegee. Don’t use any filler on surfaces that are to be clear finished.

When the weave has been filled the surface should be sanded to prepare it for painting or varnishing. Sand the epoxy, not the fiberglass. Be sure to wear a respirator or dust mask while sanding. You’ll probably get the fiberglass itch. Take a cool shower after this step and put on clean clothes to minimize the irritation. If you do get the fiberglass itch, don’t worry; it goes away after a few hours.

Applying fiberglass overhead is at best a difficult, messy job. Anyone who has tried it once has no desire to repeat the experience and will do everything possible to try to turn the work over or at least fiberglass on a slant. If this is not possible then here are several suggestions for accomplishing this job:

If you are working on a relatively small area, wet the surface with mixed resin/hardener and lay a rough-cut piece of cloth into the resin. Surface tension will hold it into place without sagging if not too much resin is used. Using a squeegee overhead is a feat no one has yet mastered. Use foam rollers. Once the epoxy has cured you finish the overhead area in the usual manner.

Glassing large overhead areas calls for a different technique and a helper or two. Most successful jobs are done by rolling on a coating, then allowing it to cure to a tacky state. The cloth is then rolled out as smoothly as possible into the tacky coating. This is where you’ll probably need more than one person. Get the

wrinkles out as you go along, you won’t be able to slide them out because the tackiness of the coating will hold the cloth in place. Once you’ve got the cloth where you want it press it into the tacky undercoat with a dry foam roller. Then wet it out using the roller cover and a roller pan. Use just enough epoxy to wet out the cloth. When cured finish in the usual way.

Corners and edges often require several layers of cloth. Giving thought to a “glassing pattern” will allow doubling at edges without going through extra steps. Corners are most easily “patched”. Cut circles of different diameters from cloth scraps. Wet down, dabbing at it with an epoxy soaked brush. Lay down the next larger circle over this wetting it with more epoxy, if necessary. Continue the process until finished. Each larger circle will fray the cut edges of the smaller circle under it. This process is self-feathering. Use the masking tape trick for the last circle and the job will require little sanding to look nice.

Heavy structural seams are best done using biaxial tape. Biaxial means that the fibers run at 45 degrees to the way the tape comes off the rolls. When run along a seam ALL the fibers run across the seam at 45 degrees. In regular plain woven tape half the fibers run parallel to the seam and add nothing to the strength.

Biaxial tape is heavy at 24 ounces per square yard and it won’t be clear like lighter tape when wet out with epoxy so don’t use it for clear finished seams. Rather than feather edge biaxial tape by sanding we prefer to fair the edges using SilverTip QuikFair after sanding off the high spots.

In summary, fiberglassing is a three-step process:

1. Seal the wood to prevent starving the wood/cloth joint. Do filling and fairing on the sealed wood.
2. Stick the cloth down leaving a minimum amount of resin in the cloth.
3. Fill the weave any time after the wet cloth has reached the “green stage” and is stuck to the substrate.

Materials Required for Fiberglassing:

SilverTip Laminating Epoxy and hardener
Roller covers and frame
Fiberglass cloth
Thalco (rubber) squeegee
Measuring device
Protective gloves, dust mask
SilverTip QuikFair
Trimming knife
Surform (Stanley Tool Works)
Sandpaper

SECTION SECTION VII C - MODIFYING EPOXY WITH FILLERS

Epoxies formulated for coating and fiberglassing are too thin to serve as gap-filling adhesives. They can be modified by the addition of thixotropes to form non-sagging pastes very useful as gap filling glues. These pastes can be further modified with the addition of microballoons to form putties for fairing and hole filling. Wood flour can be used to make filleting putty for stitch-and-glue boat construction. All these solid dusty additives are called fillers. Fillers change the flow and density characteristics of the epoxy system. Each filler changes the liquid resin and hardener in ways that make epoxy useful for other applications besides coating or fiberglassing.

You will need to learn how to use fillers if you intend to use our general-purpose epoxy. You can avoid using fillers if you choose to use products from the SilverTip Series. SilverTip GelMagic, SilverTip EZ-Fillet, SilverTip QuikFair, and SilverTip MetlWeld have already been modified and optimized for their particular end uses. You simply measure and mix these products and do not have to bother with fillers. So, if you are using any of the SilverTip Series products, skip this and move on to the next section.

Fillers fall into four general classes: thixotropic agents, bulking agents, fibrous fillers, and pigments. There is some overlapping as to function of certain fillers. For example, plastic minifibers are both fibrous and act also as a thixotropic agent.

Silica thickener (Cab-O-Sil or Aerosil), plastic minifibers and wood flour are thixotropic agents. They turn the epoxy into a thixotropic fluid. These fluids flow under shear stress but do not readily flow once the stress is removed. Ketchup and latex house paints are examples of thixotropic fluids. Adding these agents to the mixed resin and hardener produces a fluid that will easily flow under the spreading stress of a putty knife. Once the stress is removed the thickened epoxy retains its shape. In short, these fillers make the epoxy non-sagging and are added specifically to make gap-filling adhesives.

Phenolic microballoons, quartz microspheres, and wood flour are bulking agents. They "bulk out" the epoxy making a lightweight putty like mix. Although all these thicken the epoxy, only wood flour will also make it thixotropic. Attempting to add sufficient microballoons or microspheres to make a non-sagging fairing putty will result in one that spreads poorly as it becomes dry. These materials should be used along with a thixotropic agent. Silica thickener is the best choice because it produces the smoothest compound.

Chopped glass strands, milled glass fibers, and plastic minifibers are fibrous materials that can be incorporated into structural filleting putties to improve tensile strength, and are listed above in descending order of tensile strength improvement.

White paste pigment (titanium dioxide) and graphite powder are generally used as pigments. Graphite powder added at high loading levels (25%) to coatings, which are then sanded, produce a "slick" racing finish due to the lubricating qualities of the graphite. Graphite is a conductive material and could cause electrolysis problems under the right circumstances. Since it is

the most "noble" of all conductors you should avoid direct contact with other metals under wet conditions. Adding white paste pigment produces a white resin coating that is useful where a light color is desired and painting is difficult. Pigments aren't meant to serve as substitutes for paint in areas exposed to strong sunlight. White paste pigment can be added to the final fill coat when fiberglassing, allowing this coat to serve as a base coat for finish painting.

Our other pigments are pure dry colorants ground into epoxy resin to produce an epoxy paste pigment. Since they are dispersed into epoxy resin they may be added to the resin side of our epoxy systems to produce stable pigmented resin. The volume of the pigmented resin is used to determine the hardener necessary. These pigments are transparent when used in tiny amounts in an epoxy and can be said to act as dyes. In larger amounts they are opaque. Our pigments come in white, black, brown, yellow, red, green and blue and may be blended with each other to produce various hues. They should be used in epoxy systems only and never used in our paints.

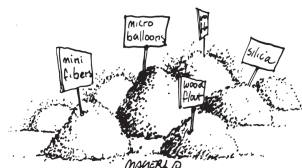
These fillers, pigments and additives may be used with any of our epoxy systems except for SilverTip Laminating Epoxy, which was designed as a coating and fiberglassing resin only. Higher filler loading levels are possible with Clear Coat epoxy because it is much lower in viscosity than our other systems.

Fillers change the mechanical properties of the cured resin. For all practical purposes the builder can ignore these changes. Thixotropic agents have the least effect since they are used in the smallest amounts to produce the desired result. Bulking agents reduce tensile strength in proportion to the amount added. Some will initially increase compressive strength. With increasing amounts of additives, though, compressive strengths will decrease.

Many combinations of filler materials are possible and we have not tested them all. If you have an idea that a certain combination might do something special for you then check it out. Little pieces of scrap plywood are good for this. Think up some destructive tests that will simulate the stresses the material will see in service. Check to see where the failure occurs. If the wood breaks then your combination should work well with wood, at least.

The correct sequence for the addition of filler materials:

1. Correctly measure and mix resin/hardener.
2. Add fiber fillers, if any, and mix well.
3. Add bulking agents, if any, and mix well.
4. Add thixotropic agent and mix well.



SECTION VII D - BONDING WITH EPOXY

The mixed viscosity of coating and fiberglassing epoxies is not high enough to make good gap filling adhesives. Thixotropic agents like silica thickener (Cab-O-Sil, Aerosil), plastic minifibers, and wood flour are used to thicken the epoxy and change the flow characteristics. These fillers will turn the epoxy from translucent to opaque depending on the type and amount used. Silica thickener and plastic minifibers make the epoxy whitish while wood flour turns it reddish-brown. Silica thickener makes a smooth material while epoxy thickened with plastic minifibers or wood flour will be coarse. Microballoons and microspheres should not be used in adhesive formulations as they reduce tensile strength.

Making an epoxy glue joint is quite simple. It is even simpler if SilverTip GelMagic is being used since SilverTip GelMagic "self-thickens" to become a gap filling adhesive. T-88 is thick enough straight out of the bottle to be used as a gap filling glue. Assuming that our general-purpose epoxy is being used first properly measure and mix the resin and hardener, then coat both mating surfaces with this unfilled epoxy to wet them out. It is not necessary to let this coat cure. Next, add the thixotropic agent to the balance of the mixed resin/hardener blend and spread this thickened resin on either of the two surfaces. When using SilverTip GelMagic simply measure and mix the two parts and spread on both surfaces. Then close up the joint. There are some tricks and things to keep in mind.

First, remember that the ultimate strength of any glue joint is a function of the glue surface area. The more surface area, the stronger the joint. This is the reason that scarf joints are made at a minimum 8:1 slope. Fillets increase glue surface area and are used to relieve stress concentrations that build at right angle corners. Stringers, for example, should have fillets where they butt onto the boat hull planking.

Second, make sure that the surfaces being glued are clean, free of grease, oil, wax, and other contaminants that could act as release agents. If the surface is coated with cured epoxy, sand before gluing and wipe the dust off. Prior to sanding wipe away any oil or grease with a clean rag and suitable solvent. Remove paint rather than trying to glue onto a painted surface. Epoxy resins stick well to sanded paint but the overall bond strength will be no better than the paint to substrate bond.

Third, do not over-clamp. Epoxy resins require only contact pressure. Over-clamping can squeeze most of the adhesive out of the glue joint and the epoxy that is left is absorbed into the wood starving the joint. A glue-starved joint is very weak. Use only enough pressure to hold the joint immobile and keep the two surfaces in contact until the epoxy has set overnight at normal temperatures. Nails, screws, clamps, rubber bands, or staples can all be utilized.. Clamp just hard enough to close up the joint.

Fourth, remember that epoxy resins continue to cure and build strength for several days after they solidify. Joints that will be under immediate stress once they are unclamped need more cure time before the clamps are removed. Overnight cures are usually sufficient for most non-stressed joints. In cold weather the time

could stretch out to several days. A common cause of epoxy joint failures is excessive stress before the epoxy has reached sufficient strength. This might occur when a scarf joint is bent too soon. Fifth, protect the finished glue joint from weather degradation. Wood that is allowed to weather will cycle through moisture content extremes. Wood expands as the moisture content increases. This expansion can set up enormous stress concentrations across a glue joint due to uneven rates of expansion on either side of the glue line. These stress concentrations can exceed the strength of any glue, including epoxy resins, causing failure. Protect the joint by epoxy coating all surfaces of the glued wood. This will stop moisture cycling and prevent failure because of weathering. This is not a problem for wood glued with epoxy that will not be subject to deep moisture cycling – indoors, for example.

Most woods can be successfully bonded with epoxy. Teak is not difficult to bond but the bond may fail if allowed to cycle moisture. When epoxy gluing a teak on plywood boat deck, the teak should be less than 3/16" thick. The expansion joints should be of a flexible material like the two part polysulfide rubber mastics. Don't use black-pigmented epoxy between teak boards that will be subjected to strong sunlight or weathering – the epoxy will crack.

SilverTip GelMagic and our general-purpose epoxy are specifically designed for use as an adhesive for wood-to-wood bonds. Both will bond well to sanded polyester and vinyl ester resins. For metal bonding we recommend using SilverTip MetlWeld, our specially designed adhesive for bonding metal and other difficult to bond materials.

Metal to metal bonding success depends upon the type of metals bonded, the surface preparation, and the intended service temperature. Bonds between different metals may degrade over time due to differential thermal expansion, which sets up shear stress that leads to interfacial failure. Potential structural bonding of metals should be thoroughly evaluated before proceeding. We recommend the use of mechanical fasteners for critical applications.

Metal to wood bonding for non-structural applications may be done successfully with epoxy providing that the metal is clean and bright. Don't pot stainless steel bolts in any epoxy resin if the application will be around water. Stainless steel works only in the presence of sufficient oxygen. The epoxy will deprive it of oxygen causing crevice corrosion in the presence of an electrolyte like seawater. Stainless steel fastener failure occurs where the bolt emerges from the epoxy resin.

Bonding to metal alone such as fairings on lead keels will work well with epoxy so long as the lead is bright and free of oxidation. Since lead readily tarnishes there may be benefit from immediately coating the bright lead with SilverTip MetlWeld before fairing with SilverTip QuikFair to fair the keel. The SilverTip MetlWeld provides an almost absolute bond to the lead and SilverTip QuikFair easily bonds to tacky or cured and scuffed SilverTip MetlWeld.

Thermoplastic materials like vinyl plastics or ABS bond reasonably well with epoxy resins. You will get the best results if you first sand the plastic with coarse paper. Before bonding flame treat these plastics by passing the flame of a propane torch across the surface without scorching or melting the surface.

Epoxy will not bond to polyethylene, polypropylene, or Teflon. It bonds well to neoprene and polyurethane rubbers.

There are too many materials and combinations to cover every possibility. Model any questionable materials that you want to bond. Glue some scraps and test them. Try accelerated aging and retest them. If they survive an hour in 160°F water they will probably last for quite a while.

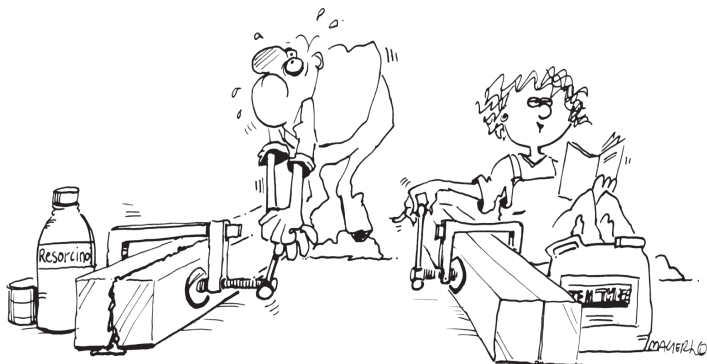
Quick Cure is our 1:1 “five-minute” epoxy. Items glued with Quick Cure can be stressed in as little as 15 minutes. It is very handy to have in the shop simply for this reason. Builders often find that “missed screw hole” when ready to lay down the fiberglass cloth. Mix a little Quick Cure; add some wood flour and you’ve got an instant putty to fill the hole. Quick Cure can also be used in combination with slower epoxies as a “spot welder” where clamping is all but impossible.

Coat the pieces to be bonded with SilverTip GelMagic, except leave several silver dollar size bare areas. Mix some Quick Cure and apply to the bare areas. Push the pieces to be bonded together with enough pressure to cause some “ooze out”. Hold in place for about five minutes until the Quick Cure hardens. Now the Quick Cure will hold the pieces together while the SilverTip GelMagic sets.

Unlike our other epoxy systems Quick Cure (like all similar epoxy products) is water resistant, not water proof. It is fine for intermittent water contact but should not be exposed below the waterline on a boat, for example.

Materials Required for Bonding:

Epoxy Resin and Hardener
Brushes, spreading tools
Silica thickener
Sandpaper



SECTION VII E FILLETING, FAIRING, AND MOLDING WITH EPOXY RESIN

The SilverTip Series contains two putty materials: SilverTip EZ-Fillet, a wood-flour filled putty, and SilverTip QuikFair, a microballoon filled putty. Neither involve user added fillers and powders. As described elsewhere these have other advantages beyond simply eliminating the use of obnoxious, dusty powders. We suggest that most epoxy users will be better off using these rather than whipping up a batch of “homebrew” epoxy putties. Once mixed SilverTip EZ-Fillet and SilverTip QuikFair are used as described below.

For those who choose to homebrew putties we offer the following: Our general purpose epoxy can be mixed with phenolic microballoons (purple), quartz microspheres (white), or wood flour (brown) to make a putty-like material that is used for making cosmetic or structural filleting, fairing, or molding compounds. The use of these materials with the right portions of silica thickener makes a smoother compound than the fillers alone can produce. The amount of these fillers is best determined by experimentation taking into account the desired results, temperature and viscosity of the epoxy being used. For previously stated reasons we neither recommend nor support the use of SilverTip Laminating Epoxy resin with fillers or thickeners.

Filleting is the process of adding an epoxy putty to concave angled corners for cosmetic and structural reasons. Cosmetic fillets are generally “low density” being made by the addition of microballoons, which “bulk out” the epoxy. Structural fillets are “high density” and are thickened with silica thickener, plastic thickener, or wood flour. These fillets sometimes contain glass fiber. Thixotropic agents make the mix non-sagging when sufficient amounts are used. Microballoons and microspheres do thicken the epoxy, but when used in proper loadings do not prevent sagging, and need the addition of a thixotropic agent like silica thickener.

Cosmetic fillets are applied by putting an excess of material along the length of the corner with a putty knife or caulking tube. Be careful not to force big air bubbles into the fillet when putting the putty into the corner. A rounded tool is used to shape the putty by drawing it along the fillet. The sides of the tool should touch both sides of the corner and the radius of the tool is determined by how rounded the finished fillet will be. Almost any material can be used to make a filleting tool. Plywood paddles work well, are easy to make and are inexpensive. The excess putty will be forced out on either side of the tool where it is scraped off with a putty knife.

Once the fillet has cured it may be sanded. A round edged sanding block with coarse (50 to 60 grit) paper works best. Knock off the high spots with the sandpaper and then come back and fill in the low spots with an additional batch of putty. This is much easier than sanding the whole fillet down to a common level. Blow or brush off the sanding dust (wear a dust mask!) Make up some more filleting compound and use a broad putty knife to fill the low spots resting the blade against the fillet parallel its axis. Allow the putty to cure and do a final sanding.

Before microballoons are painted they should be sealed with epoxy or else the paint goes into the tiny hollows in the broken bal-

loons and the finish will appear ragged. Brush or roll on a coat of epoxy on the sanded balloons. Use either Clear Coat or SilverTip Laminating Epoxy thinned with about 10% denatured alcohol or lacquer thinner to make it easier to apply. Treat this cured sealer coat as any other epoxy coating before finishing.

Structural fillets increase the glue joint surface area relieving stress concentration zones that occur at angled corners. They are usually made at the same time that the piece creating the corner is attached. For example, when sheet plywood is glued onto a stringer the excess glue that oozes out can be used to form the fillet. A gloved finger makes a good filleting tool, as these fillets don't need to be large. Once the glue begins to cure it can be smoothed by rubbing with a solvent saturated rag. Wear solvent resistant gloves when doing this.

Large structural fillets are generally made in a separate operation in a manner similar to making cosmetic fillets. The addition of either milled glass fibers or chopped glass strands, improves the tensile strength of structural fillets.

Proper epoxy fillets don't need to be covered with fiberglass cloth. Apply cosmetic fillets after the fiberglassing is finished. This makes fiberglassing easier as the edges of the cloth can be run into the corners; left ragged, and then later is covered by the fillet.

Fillets in stitch-and-glue boat construction are usually fiberglassed. The easiest way to do this is to fiberglass the fillet when it is in a semi-stiff state so that it can still be pushed around with an epoxy-saturated brush. This saves having to sand the fillet after it has cured.

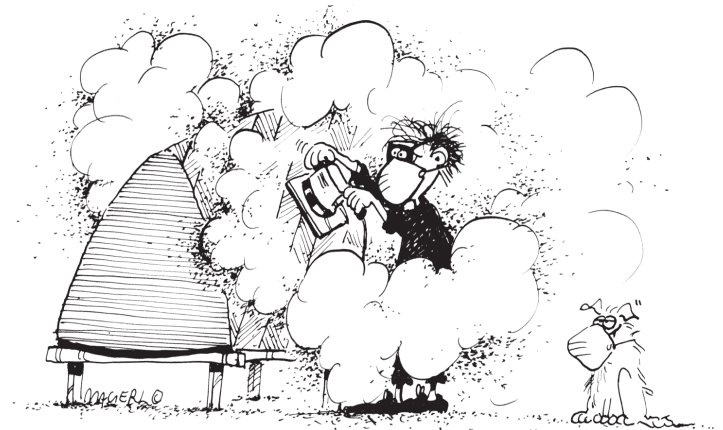
Fairing is the operation of filling the low spots on a boat hull or auto body to the level of the high spots, eliminating waviness and hollows. Use SilverTip SilverTip QuikFair for this or make your own. The compound used is identical to that of the cosmetic fillet and the operation is similar except that large flat areas are involved. Large wallpaper broad knives, stiff boards with taped edges, squeegees, and similar tools are useful for fairing. Once the putty has cured it is sanded with long sanding blocks to a level fair with the surrounding area. On very large areas low spots may appear during sanding that will need a second fairing. After final sanding the fairing compound should be sealed with epoxy prior to painting.

A slick way to fair a large area and avoid a lot of tedious sanding is to use a serrated trowel like the metal one floor tilers use to spread mastic. Apply the fairing putty using this tool leaving a series of parallel ridges that stand proud of the surface. Allow the putty to cure, and then sand the area with a long board. Notice that all you are sanding is the tops of the ridges, about one fourth of the total surface area being faired. Sanding dust falls into the valleys. Once the ridge tops are fair, the area is cleaned of sanding dust and the valleys are filled with fairing compound using a broad knife with a straight edge. Only a light sanding is then required for final fairing following cure. Seal with epoxy before painting.

Molding with epoxy compounds is a very useful technique that can be used to build winch pads, lifeline stanchion, pulpit pads, etc. A high-density compound like SilverTip EZ-Fillet should be used here. The idea is to make a pad on the hull or deck of the proper size and shape to mount the hardware. An example can best illustrate the technique. A six-inch diameter pad is needed to mount a winch. A plywood circle six inches across is cut and transparent cellophane tape is stuck all over it, to act as a release agent. SilverTip EZ-Fillet or a stiff structural putty of epoxy, milled glass fiber and Silica thickener is made and liberally applied to the taped plywood. The plywood is then located at the proper place on the cabin top and the puttied plywood is pushed down onto the deck. The plane of the plywood face is adjusted so that the winch will have the proper sheet lead angle. Tapping the plywood forces the excess putty out. When the plywood has been properly positioned, the excess compound is removed with a putty knife. The molded pad is allowed to cure and the plywood blank can then be knocked off with a hammer. Any voids are then filled with more compound and the pad edges are filleted with SilverTip QuikFair to fair them in with the cabin top.

Materials Required for Fairing, Filleting:

Epoxy Resin and Hardener (SilverTip QuikFair, SilverTip EZ-Fillet)
Spreaders
Microballoons /Microspheres
Sandpaper
Silica Thickener
Fibers



SECTION VIII - PAINTING AND FINISHING

Over the years nearly half of the technical service questions we've asked involve painting and varnishing epoxy coatings. More than anything else this has been the area that has caused most people trouble. We have solved these problems by developing our own paint and clear finish system for epoxy resin surfaces - more on this later.

Epoxy surfaces may be coated either with opaque paints or finished with clear varnishes. The epoxy surface accepts finishes like any other non-porous surface except that it is chemically active to certain materials because of unreacted amines on the surface and throughout the epoxy matrix.

All outside epoxy surfaces exposed to sunlight must be protected from degradation by the ultraviolet rays (UV) in sunlight. This is the invisible short wave length portion of sunlight that causes sunburn. The long-term effect of UV on unprotected epoxy is a dulling of the clear film, followed by chalking and, finally, film cracking and delamination.

The initial effects of UV degradation on most epoxies start after about six months of intense tropical sunlight on horizontal surfaces. Total breakdown will occur after about fifteen months under these same conditions.

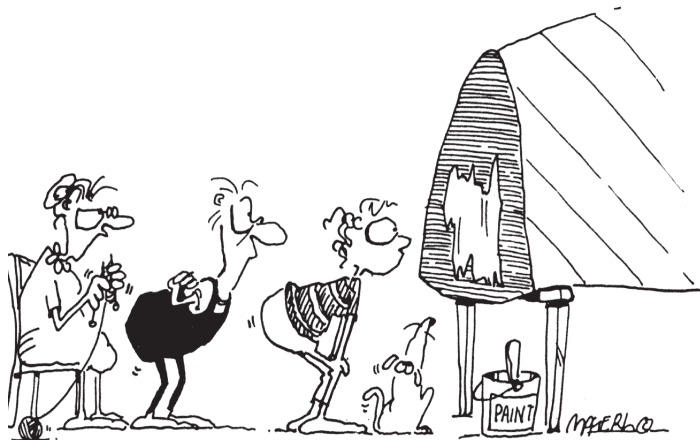
Bright finished boats should be finished with a clear coating that contains a UV inhibitor. This inhibitor is sacrificial so the coating must be periodically renewed if the epoxy is to be protected. When the clear protective coating starts to look dull it's time to refinish. Old coatings are removed by sanding or are chemically stripped with strong solvents. Test patch an inconspicuous area to make sure that the solvent used does not attack the epoxy base. Solvents and removers containing methylene chloride will soften and etch epoxy surfaces. Don't use these. Be sure to observe the usual precautions when working with these solvents.

Opaque paints do not allow the passage of UV light, offering the best protection of the epoxy coating. A primer coat prior to painting over epoxy is quite beneficial because it provides a uniform color base and is easier to sand than epoxy resin. It is generally not necessary to use a primer in order for a suitable top-coat to adhere to sanded epoxy resin. Do the crosshatch adhesion test described below to check for adhesion.

Besides antifouling paint, two broad classes of coatings are commonly used as boat paints. These are "one part" alkyd and modified alkyd enamels commonly called "oil base paints" and two part linear polyurethane (LPU) paints. Two-part epoxy based top coats have fallen into disfavor due to their tendency to chalk. Two-part epoxy primers are recommended as high build sanding base primers for LPU paints, however. Some advocate the use of water-thinned latex paints. While these products bond well to coarsely sanded epoxy they are quite soft and do not wear well on boats.

Be sure that you are getting what you expect when purchasing a marine paint. Paints sold in marine stores today are often a triumph of marketing over technology. Remember the adage: "The big print giveth while the small print taketh away." It is not un-

common to see the pretty face on a paint can staring back at you screaming, "Buy me! I am a one part polyurethane". Yet, when you read the back of the can you find that the ingredients state that it contains polyurethane safflower alkyd resin or some other modified alkyd. If it says alkyd anywhere on the can then it is an alkyd NOT a polyurethane. True polyurethanes (often referred to as LPU paints) are two-part and cost several times what an alkyd costs. If the ingredients are not specified on the can, then ask for an MSDS on the paint - that should provide information on the type of paint you're about to buy.



Alkyd enamels and related one part paints and varnishes are easy to work with but may not properly dry on epoxy resins. They may be brushed, rolled or sprayed and dry to a glossy film that is easy to refinish. Their main drawback as a finish is that they are softer than LPU paints and chalk slowly over a period of time.

LPU paints dry very hard with excellent gloss, are not degraded by sunlight and wear very well. Their main drawback is that they require immaculate surface preparation and can be tricky to apply. Solvent based LPU paints contain some very toxic materials. Consult and understand the MSDS if you plan to use these materials. Solvent based LPU paints can turn dull when curing if the humidity is too high.

Because of the ultra high gloss of LPU paints any imperfection in the substrate will show in the finished coating. The tendency of the alkyd paints to dull to a semi-gloss finish over time can hide some of the flaws that might otherwise mar an LPU finish. However, if your project is perfect and you are willing to spend the time and care required to use LPU paints the results can be spectacular.

Use any color you want so long as it is light. If you paint a wood boat with a dark color and use it in the summer sun you are going to experience a number of problems. First, you'll get "print through". This is the telegraphing of the cloth weave or wood grain pattern to the glossy painted surface. Second, you'll see what appears to be shrinkage of the epoxy resin (microballoon putty over screw holes, for example.) This is caused by the expansion and contraction of the wood fiber due to changing

moisture content rapidly aggravated by excess heat soaked up by your darkly painted boat. Finally, the useful life of the boat will be shorter.

Test patches are advisable prior to painting or varnishing over an epoxy coating. These test patches will give you a feel for how the various coating materials handle and point out any possible incompatibility problems prior to them becoming a disaster all over your boat.

To do a test patch, coat a small area with the painting system selected to make sure that each paint layer dries properly and adheres well to its substrate. One reason for doing this is that epoxy resins, despite sanding and long cure time remain chemically active to certain components of alkyd paint and varnish systems. Generally, epoxy primers and LPU paints are compatible with epoxy resin coatings and may even chemically bond. However, some of the alkyd enamels and other one part paints and varnishes may not properly dry on epoxy resin coatings. The free unreacted amine in the epoxy resin coating interferes with the action of the metallic driers in some of these paints. If this happens the paint may surface dry but remain soft and tacky next to the epoxy resin surface.

A similar chemical phenomenon occurs between the amines in epoxy hardeners and the peroxide catalyst used in polyester and vinyl ester resins and primers. The amines inhibit the action of the peroxide catalyst, preventing cure at the interface. For this reason, it is not possible to "gel coat" finish cured epoxy without specialty barrier coats and it is very risky to use peroxide cured polymers directly over cured epoxy resins. Besides, gel coats don't look all that good when applied to a male form. Their best use is against a polished female mold. For the same reason you should not use polyester based putties over an epoxy.

Be sure to follow the paint manufacturer's instructions when doing the test patch. With the exception of the high build two-part epoxy primers, all finish paint systems should be applied thinly. Thick coats will not dry properly and may take weeks to "through dry". Temperature and humidity play an important role in the speed of alkyd paint drying. The higher the temperature and lower the humidity, the faster the drying.

You can gauge drying by digging your fingernail into your test patch and scratching. If the paint film is still soft below its surface then it has not finished drying. A dry film is hard all the way through. A simple test called the crosshatch adhesion test will show how the new layer bonds to the substrate. Do this test only on paint that has dried thoroughly. To do this test take an industrial razor blade and score the surface with a set of 8 parallel lines about an eighth of an inch apart. Score a similar set at 90 degrees from and crossing the first set. The finished lines look like a giant tic-tac-toe grid. Take some clear packaging adhesive tape and press the sticky side into the grid leaving a tail. Press the tape hard with the back of your fingernail. Grab the tail and jerk the tape off the grid. Examine both the tape and the grid for paint adhesion failures. Except for the grid lines on the tape, no paint should come off on the tape. If it does then you have an adhesion problem and it WILL show up on your boat most likely in the form of paint blisters. Better select a different substrate/top coat combination and test it.

Once you are satisfied that there are no system compatibility or adhesion problems then you can paint your project with confidence.

By now you are probably wondering why we don't just give you a list of what paint brands you can use. We would if we could but because paint makers are free to modify their formulations without notifying System Three Resins we will not recommend a specific brand of paint. The batch we test might have changed by the time information about our results gets to you. It is not possible for us to keep up with all the different brands and lot numbers.

We recommend the use of System Three water reducible epoxy primer and water reducible LPU finish coats. They work, there are no adhesion problems, they thin and clean up with water, they spray, brush or roll, there is no solvent smell so you can use them indoors. These products are extremely durable and fully compatible with System Three epoxy products. Consult the paint literature on our website (www.systemthree.com) or ask for it by mail.



SECTION IX - AREAS OF EPOXY USE

In the Introduction we stated that this is not a book about boat construction and repair. While that is true, we believe that the ways of using epoxy described in Section VII will have more meaning if the prospective user can relate the techniques of boat construction and repair. There are a number of boatbuilding books that go into greater depth than we will here.

These books go in and out of print fairly frequently and new ones are always coming along. In addition to the local library the reader should consult current magazines oriented in this direction.

SECTION IX A - WOODEN BOAT CONSTRUCTION

Sheet Plywood

Plywood is a very versatile material widely used in wood boat construction. It is dimensionally stable and needs only to be epoxy coated to protect it from moisture to become an almost ideal boatbuilding material. Several construction techniques are used to fabricate boats from plywood.

It is not necessary to use marine grade plywood in boatbuilding. Marine plywood is basically exterior plywood with a lower void content. Several years ago the plywood association that sets specifications started degrading marine plywood by allowing a higher void content. We believe that the extra cost for fir marine plywood over A-B exterior is not justified today.

Fir plywood boats that see continuous outdoor exposure should be sheathed on the exterior surfaces. Almost all fir plywood is rotary cut and exposed exterior surfaces will eventually check if unreinforced epoxy coatings are used. Sliced veneer plywood has almost no tendency to check. However, we know of no source of sliced fir plywood so plan to put a light layer of cloth on all exterior fir plywood surfaces. Sliced veneer mahogany plywood is readily available in many coastal areas. This plywood is considerably more expensive than fir. Builders using this for small boats rarely fiberglass the surface. Large boats are commonly fiberglassed if only because repair is far more costly if the epoxy coating is breached in impact. Better to build in the protection during production.

Frame, Stringer, Planking Construction

Plywood was probably first used in this type of construction which came along even before epoxy and polyester resins were developed. This is a simple and straightforward method of boatbuilding.

The builder makes the frames from a set of drawings or table of offsets. Some of the frames may be temporary while others stay as bulkheads in the finished boat. The frames are mount-

ed bottom up on a horizontal ladder-like structure called a strongback. Here the rungs are attached to the rails precisely at ninety degrees to the centerline. Strongbacks are precisely leveled so that plumb bobs may be used to aid in attaching the frames to the rungs. Usually an overhead taut wire will represent the centerline in space. The frames are mounted on the rungs of the strongback so that centerlines and reference lines align precisely. Temporary bracing is often used until the stringers are added.

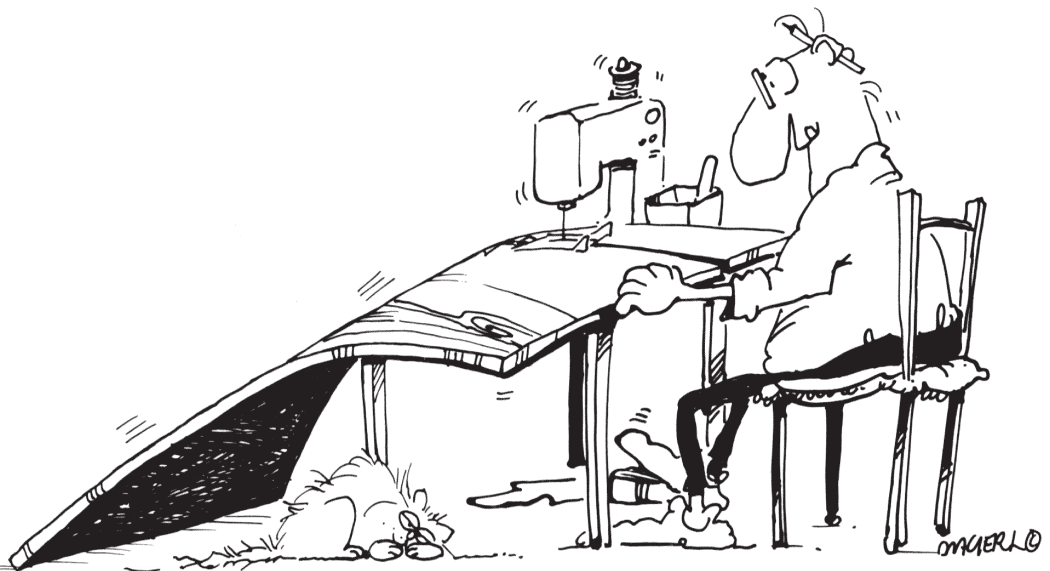
After this notches may be cut into the frames to mount the stringers, which are epoxy glued into place. Once the epoxy has cured the temporary bracing is removed as the frames and stringers are quite rigid. Plywood is fitted and glued to the frame/stringer structure. After this the strongback is superfluous.

The plywood is epoxy coated, faired, and fiberglassed. All the unit operations of epoxy use have been employed so far. There are a number of tricks that can make the epoxy work go easier. For example, the plywood frames could have been coated and sanded even prior to cutting from 4x8 sheets. Plywood planking should have been coated and sanded on the inside before the planking is attached. Some designs use molded chines rather than chine logs. Here, biaxial tape would be ideal to attach adjacent planking.

It is important to remember that there is no one right way to do most anything (except for correct mix ratios!) when boatbuilding. Build it in your head first and you'll think of a lot of short cuts that work.

Stitch & Glue Construction

In a way this uses plywood in hull construction in almost the reverse order of the frame, stringer, planking building method. Here the panels are cut to the correct shape and wired together with soft copper wire through small holes cut in adjoining planking edges. Sometimes a frame or two are used to facilitate in the bending and joining of the panels.



Once wired together the joints are glued by applying large epoxy fillets to the inside edges. The wire is removed and the outside edges are taped with glass cloth and epoxy. Several bulkheads are added and stringers may be glued to the interior panels to increase stiffness.

This construction method, also called sewn seam construction, lends itself very well to small boat construction where the internal structure of frames and stringers are not necessary. Lately several large production boats (56 feet) have been built on the West Coast using this method. The commercial builder of one of these made his own plywood on a 10 by 60 foot vacuum table. Interestingly, many huge fiberglass boats are partially constructed using this method (bows and sterns are still made in a standard fiberglass mold).

Some designing skill is required to take a three dimensional concept and reduce it to a two dimensional drawing that can be laid out on plywood so that edges meet when the panels are cut and sewn together. The first time builder should purchase plans rather than suffer the frustration involved in ruining several sheets of plywood "trying to get it right." The classified sections of the boatbuilding magazines carry ads for these plans. Often, there are also ads for kits where the panels are already cut.

Epoxy coating and perhaps even fiberglassing the panels prior to assembly will save lots of time in this construction method. Learning to make the "no sand" interior fillets described is a must. Removing the copper wire can be tricky. Some builders fillet right over it and then cut it off flush on the outside.

Here it becomes part of the boat. We heard of one builder who hooked the wire up to a car battery for a second or two and then pulled the red-hot wire out with a pair of pliers. We like the idea of making small fillets using Quick Cure 5 and wood flour, or alternately using SilverTip EZ-Fillet wood flour putty every six inches along the inside seam. After a few minutes the wires can easily be removed and the regular fillet applied. Talk to your plans designer and see what he recommends.

Glued Lapstrake Construction

Many people believe that traditional lapstrake construction makes the most beautiful boat of all. They long for a more modern method that produces a light, strong boat without the maintenance problems of the traditional lapstrake boat. Several builder/designers have developed techniques for doing this out of plywood.

Basically, plywood is cut to the proper shape and one edge of each plank is beveled. These planks are attached to temporary mold frames and permanently attached to the stem and transom. The boat is usually built upside down with the very bottom planks applied first. Successive planks are laid on these with about a half-inch overlap. The laps are epoxy glued. Planking continues in this fashion to the gunnels.

The result is a lightweight, stiff boat. The stiffness comes from the doubling at the laps combined with the bent planks. So far, only small boats have been built using this method. A chief aesthetic advantage of this style is that it allows for more roundness in the finished hull than other plywood methods. A possible disadvantage is that it is more tedious than sewn seam construction.

We can't conceive of building a boat in this method without epoxy coating and fiberglassing the plywood panels prior to cutting the planks. The boat would be impossible to fiberglass once assembled. Doing it first means that except for the cut plywood edges the boat is essentially "epoxied" before it is even assembled. We'd seal these after assembly and use fillets to round them into the adjacent planks.

There are several books available on glued lap construction. Check in the various boating magazines to find them. Buy a good design. As much as in stitch and glue construction, cutting and beveling the planks is critical to achieving good results.



Strip Plank Construction

Strip planking has been used to construct boats with lengths from eight feet (prams) to huge power and sailboats. The most common strip planked boats built today are canoes in the fifteen to eighteen foot range. Strip planking readily allows the builder to make compound curved hulls even in shorter lengths.

Strip planking is simply the edge gluing of long strips over temporary mold frames. Most often these are male mold frames although some advantage is possible using female mold frames. The strips are cut somewhat longer than the boat so that they are long enough to be bent around the curve of the mold. Larger boats use scarfed strips to achieve the proper length. Western red cedar is

often used to build canoes and smaller boats. It is lightweight and attractive lending itself well to bright finished hulls. Redwood, Alaskan yellow cedar, Sitka spruce, and fir are also used.

Several companies are now marketing veneer faced end grain balsa strips. This material shows promise for boats over twenty feet. It is lighter than solid material for a given thickness. It is also weaker and much more expensive. Because it is weaker more exotic fiberglass fabrics must be used to build strength. This further adds to the cost of using this material and adds enough additional weight to largely offset its lower density when used for smaller boats. In larger boats where lightweight is the ultimate goal and the money is there to buy it, balsa strip is worth considering.

In a way the smaller strip planked boats may be thought of as wood cored fiberglass composite boats, as the sheathing is structural. Here the strips are thin and edge contact area is low enough that the strips need the structural reinforcement of cloth on the inside as well as the outside. As boats get larger strip thickness and glue surface area increase. The overall strength coming from the glued edges begins to predominate and the structural importance of the sheathing becomes less important. Still, most builders of large strip plank boats use a healthy layer of reinforcing material on the outside of the hull. Some large strip planked boats use a double layer of diagonal veneer planking (see section on cold molding). Except for scarfing and edge gluing not much epoxy is used in strip planking until the hull is completed. One neat trick when canoe building is to use Quick Cure to glue the butt ends to the side strips when closing the "football". The outside of a strip-planked boat is faired and fibreglassed before taking the hull off a male mold. In female molding the inside may be fibreglassed and ribs molded in place prior to demolding the hull. Since the sheathing is an important structural part of strip plank boats the designer's recommendations should be followed when selecting sheathing materials.

Cold Molding

The term "Cold Molding" was coined to differentiate the process from hot molding. In hot molding layers of veneer are glued together under heat and pressure. Plywood is hot molded. In cold molding some pressure is used at least to keep the veneer in contact but heat is not generally used. Boat hulls have been built using the cold molding process long before the advent of epoxy resin adhesives. The development of modern epoxy resins has made cold molding into a viable building technique for the professional one-off builder as well as the serious amateur.

Cold molding is the process where strips of veneer are laid diagonally to the hull's centerline over a male mold or plug. Three or more layers are used with each layer at ninety degrees to the one below it. The net result is a large piece of plywood in the shape of a boat hull.

The length of the strips is sufficient to reach from the keel to the sheer with the thickness and width largely determined by the size of the boat. Many materials have been used for cold molding including veneer, plywood, and door skins. Western red cedar, fir, spruce, Alaskan yellow cedar, mahogany, and redwood have all been used to build successful boat hulls.

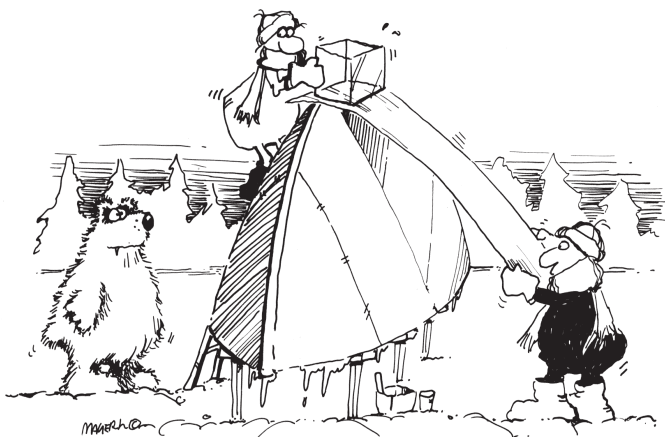
Epoxy resin is the preferred adhesive because of its great gap filling properties. Veneer is often stapled either permanently or with removable staples. Because the "clamping pressure" varies over the surface small gaps result in areas away from the staple. Thickened epoxy like SilverTip GelMagic fills these gaps to make a solid structure. Some builders prefer to use vacuum bagging techniques to clamp the veneer until the epoxy cures.

Vacuum bagging is a very simple process that uses atmospheric pressure to achieve clamping forces. Essentially, a "bag" is created by using the part to be clamped as one side with a polyethylene film as the other. The two sides are joined with some type of mastic sealant and the air in the bag is removed with a vacuum pump. In order to work properly the veneer must be molded on some type of mold that is impervious to air. The bag must totally cover the veneer (which may be stapled at the ends to hold it into place until the bag is evacuated) and be affixed to the mold surface. Obviously, a more elaborate mold must be constructed for vacuum bagging a cold molded boat.

In the past several years many techniques have been developed that allow hull panels to be cold molded using vacuum bag techniques. The hull panels are cut to shape, butted together and joined along the keel line using sewn seam methods. Two of these techniques, Constant Camber and Cylinder Molding, are especially suited for making long narrow hulls of the types used for catamarans and trimarans.

Cold molded boats are epoxy faired and fibreglassed before removing them from the mold. Once removed they are epoxy coated on the inside and frames and bulkheads are added.

Just as some strip planked boats have several layers of veneer cold molded to the outside, some cold molded boats are built by permanently attaching the veneer to a latticework of frames and stringers. Some carvel planked and caulked boat hulls have been preserved using cold molding techniques. The careful reader will have noted that it is possible to combine elements of several building techniques to produce a strong hull.



SECTION IX B - WOODEN BOAT RESTORATION AND REPAIR

Often our technical service people take a telephone call where the question "I bought this old wooden boat and I was wondering if your product can be used to restore it?" The caller often hopes that slathering on a coat of System Three epoxy will turn the boat into a beautiful modern wooden boat. More often than not we end up dashing his hopes for a quick fix simply because there isn't one.

Modern wooden boat construction takes small pieces of wood in some form and uses epoxy resin to laminate the pieces into one large piece in the shape of a boat hull. This so called monocoque (single piece) structure is very different from traditional wooden boat construction wherein the various pieces are mechanically attached to each other in such a way that movement is allowed. Indeed, it is the movement caused by the swelling of wood by water that keeps these boats leak proof.

Jim Brown of trimaran fame uses the analogy that a traditionally built boat is like a woven basket where a modern wood/epoxy boat is like a bowl. To be watertight the basket must be allowed to swell a little when wet so that the strands press against each other. For the bowl to remain watertight it must be sealed to keep water out - the very antithesis of the basket. Therein lies the problem with slathering epoxy on a traditionally built wooden craft. To do it you must first dry the hull, which causes shrinking of the wood planking. At this point it is no longer watertight. Epoxy coating the planking will prevent it from absorbing water and swelling. It will remain leaky.

While it is possible to stuff thickened epoxy into the opened seams of the dry hull, fiberglass the outside and produce a leak proof hull the results are apt to be temporary as the planking will pick up moisture elsewhere and swell probably cracking the fiberglass. Dry wood picks up moisture and swells producing forces that greatly exceed the strength of epoxy resins.

If the boat owner is aware of the risks and is prepared to sink a lot of labor into the project some traditionally built boats can be brought into a modern monocoque condition. The key to success is devising a way that will eliminate or reduce the movement of the various wood members permanently. The problem is that no one possesses the crystal ball that predicts such success. The following will give a rough outline of the techniques involved. Be advised that there are no guarantees and the situation may deteriorate rather than improve.

Plywood Boats:

These pose no problem in restoration as they are essentially built as modern plywood boats. Dry the hull thoroughly. Remove all coatings and take the boat back down to bare plywood replacing any rotten plywood. Make sure that the frames are in good shape and replace any that aren't either by sistering in new frames or building new frames and installing them. Epoxy coat the bare plywood and fill depressions, screw holes, staple holes, etc. With System Three epoxy and microballoons. Sand fair. Lay down fiberglass cloth and reinforce the chines, bow, corners, etc. Finish as described in this book. If possible, the inside should be

taken down to bare plywood and epoxy coated. Remove any oil or grease that would interfere with epoxy adhesion.

Carvel Planked and Caulked:

The important thing here is that the planking has got to be immobilized against both mechanical movement and moisture swelling.

Remove all caulking by using a router or saw blade. Dry the hull thoroughly and remove all outer coatings down to bare wood. Remove any damaged planks and replace. Make sure that the frames are in good shape and replace any that aren't either by sistering in new frames or building new frames and installing them. Refasten any loose planks. Fill the seams with thickened epoxy or glue in wedge shaped battens if the gaps are wide. Fair the hull using System Three epoxy and microballoons.

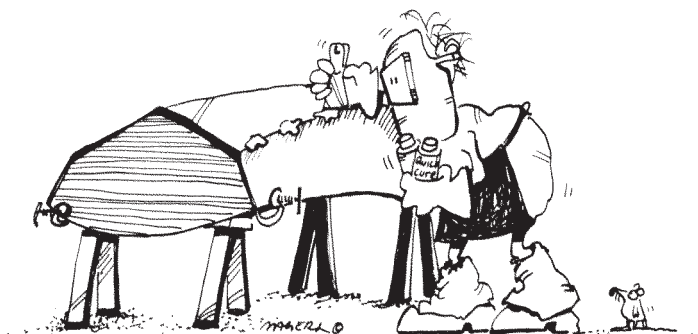
At this point a crucial decision must be made. The planking must be sheathed with an outer layer that is structural. We believe that the best way is to use a double diagonal layer of veneer at 45 degrees to the planking. The veneer is then finished as a new hull. An alternative way is to use a structural fabric and orient the fibers so that they lie perpendicular to the planking. As added insurance the inside of the hull planking should be taken down to bare wood and epoxy coated. This may not be possible without gutting the boat. If you go this far put nice generous fillets in the corners formed by the frames and planks.

Glued Planking:

Restoring these boats is quite similar to carvel planked boats except there is no caulking to remove. Make sure the hull is dry, the planks well fastened to the frames and each other regluing the planking where required. Follow the outline above.

Traditional Lapstrake:

We do not recommend restoring this construction method with epoxy resin. Restore boats built of traditional lapstrake construction using original techniques.





SECTION IX C - COMPOSITE CORED CONSTRUCTION

Many high tech one-off custom boats are built with epoxy resin and exotic fabrics such as Kevlar and Carbon Fiber laminated onto cores of vinyl foam, balsa, or thermoplastic honeycomb. Phase Two epoxy is System Three Resins' preferred material for this type of construction. These boats are built on male or in female molds in a variety of ways.

The chief structural difference between this and more common wooden boat construction is that in wooden boat construction the wood acts as the "core" and is structural. The fiberglass/epoxy skins protect the wood against the elements rather than strengthen the wood core to any great extent. In composite cored construction the opposite is true. The skins carry most of the structural load and the core, by separating the skins, provides stiffness and enables the builder to produce a very strong, lightweight hull. This not so obvious difference dictates very different requirements for the matrix resin used. A resin well suited for a wooden boat will not be good for a composite cored hull. Those who tout their products for both types of construction are robbing Peter to pay Paul and penalizing builders of both types of boats in the process.

Almost all serious racing sailboats and powerboats are composite cored. The materials used to build these boats are expensive. Generally, the lighter the hull the more it costs. Lightness comes at a high price if strength is also a requirement. The reason for the extreme push towards lightness is that with limited horsepower (sail area or engine size) a lighter hull will move faster.

Proper design and engineering of these boats is essential if they are to be lightweight and still hold together. Because the materials used in composite cored construction are exotic and expensive a proper shop with the right environmental control is a must. These hulls are almost always postcured. That is, after the laminate hardens the entire hull is raised to an elevated temperature for several hours to finish curing the matrix resin. Phase Two epoxy requires this post cure to achieve it's ultimate properties and it is folly to use a product like Phase Two unless it will be post cured.

If you are interested in learning more about composite cored construction ask for System Three Resins' publications "Two Phase Epoxy Systems for Composite Cored Construction" and "Using Phase Two Epoxy Resin".

Epoxy resins are increasingly being used to repair polyester/fiberglass boats both above and below the waterline. The usage techniques are identical to those used in wooden boat building and described in Section VI of this book. The only real difference when using wood and epoxy is that wood is porous, at least for the first coat. Fairing and hole filling on a fiberglass hull is no different than doing the same thing on epoxy-coated wood. The same materials and tools are used.

The greatest use of System Three epoxy for fiberglass hull repair is gel coat blister repairs below the waterline. The product is used for many above waterline repairs as well. Polyester gel coats generally are not used as finishes on epoxy repairs. However, it will bond to System Three Resins' SB-112 epoxy system. We recommend the use of this product where the repair will be finished with polyester gel coat.

Above Waterline Repairs:

The first thing before attempting to do any repair is to assess the problem. It is not possible to know how to fix something until you know why and how it broke. Professional repair yards understand this while many boat owners do not. Spend some time understanding the problem.

If, for example, a boat owner discovers that some fiberglassed in wood engine stringers are rotting; it will be necessary to pull the engine to affect a repair. Do this and then poke around to see the extent of damage. Don't get out a grinder and start hacking away at the fiberglass in an effort to remove the cancer that affects your boat. In many cases fiberglass boat repairs using epoxy resin can utilize the existing structure to make a speedy repair. The very top of the fiberglass can be carefully removed and the rotten wood scraped out. A new piece the same size can be fitted, epoxy coated and glued in place using the fiberglass that was bonded onto the sides of the removed wood. The fiberglass top is then epoxy glued on the new wood and, presto! the new engine mounts are ready to go without a lot of realignment problems.

Think the problem through before mucking things up! Each problem and boat has it's own peculiarities. Study the problem on your boat and use the principles of epoxy use described in this book. If you need more knowledge there are a number of books on fiberglass boat repair. You are probably not going to find that your boat fits any of the textbook examples in the repair books so you'll have to make up your own recipe for success. It is doubtful that a can of some glop sold by some marine store will do the job. Study the problem, plot out the solution step-by-step, make a dry run in your head to see if you've missed anything, order the materials, get everything ready and go. This is the way the professional repair people do the new, unfamiliar repairs and you can too!

Much has been written about this increasingly common problem in polyester resin fiberglass boats. It is beyond the scope of The Epoxy Book to go into the "why" of the problem. System Three epoxy is highly rated by one consumer boat repair magazine for this purpose.

Many people and boatyards use our product in the repair of gel coat blisters. This section describes the method of repair. We do not claim that this is either the only method or the best method available. Our only claim is that the method described herein is being used and the track record has been generally good. There have, however, been a few failures using our products just as there have been using others' products and methods. This section has not been written as an inducement to sell our product for this purpose. Blister repair, being an inexact science, is one where you "pays your money and takes your chances." Please read the special warranty at the end of this section before deciding to use our products for gel coat blister repair.

We caution that gel coat blister repair is a dirty labor-intensive job. This is why the price the yard quoted may seem so high. Compared to the labor cost the

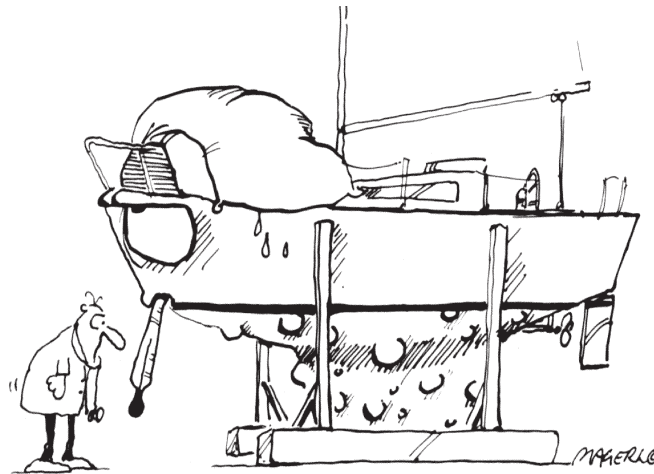
materials are cheap. Unless you have more time on your hands than money in your pocket, you might want to accept the yard's offer and have them do it. Or, you might have the yard do the gel coat removal and you do the rest with some occasional hired help. If you do plan to do the job yourself, make sure your haulout yard knows what you plan to do and allows it.

STEP 1: Clean Hull – Remove Bottom Paint.

Remove all marine growth, scum, barnacles, etc. Your yard may do this upon haulout by hydro blasting or steam cleaning. It may be necessary to use a scraper to get the barnacles off.

If your boat lacks a boot top stripe you'll want to develop a technique for marking the top of the bottom paint line. Running masking tape above the line on the topsides is a good method. It will become frayed when sanding and you'll want to replace it for Step 7. Making small grease pencil marks right above the tape on the topsides every foot or so will serve as a guide for the new tape. These are easily removed with soap and water or paint thinner when the project is finished.

When the hull is dry you've got to make a decision whether you are going to remove the gel coat or merely abrade it by sanding and opening the blisters as discussed below. The decision will largely hinge on the extent of blistering. Removal offers the greatest chance of a complete cure but it also requires great labor to bring the hull back to its original fair condition. Merely sanding but not removing gel coat eliminates a lot of the fairing problems but may



miss some of the small blisters. They may show up on next haulout and you'll have to patch them then.

Sandblasting is the easiest, fastest and most widely available way to remove the gel coat. Several newer methods that work like a power plane or joiner have been developed but the equipment is expensive and not yet widely available. It is worth paying a professional to remove gel coat. Your yard may know of someone who does this. Be sure to check with your yard to see if they even allow sandblasting. Some do and some don't. If sandblasting, be careful to remove only the gel coat and any damaged mat. Digging into the hull with the sandblaster will weaken it as it removes structural fabric.

A 1500 to 2500 rpm sander polisher with an eight-inch foam backed pad is the best way to sand gel coat. Be advised that this is dirty, strenuous and tedious work. You can do it yourself but will get very tired and may spend as much money in time and materials as you'd have paid to have someone come in and sand it for you. Hulls with gel coat removed dry faster than those with the gel coat intact.

Bottom paints contain toxic materials. Avoid breathing dust or getting dust in cuts or open sores. Always wear suitable dust masks. Wash contaminated clothing separately from other clothing.

STEP 2: Open Blisters -Remove Damaged Fiberglass.

If you have elected to remove the gel coat you have already completed this task. Skip on to Step 3. If you have only sanded the gel coat and do not plan to remove it, read on.

Now is the time to open the blisters and clean them out. Use the point of a utility knife to puncture each blister. Insert the knife and with a twisting action, cut out the damaged gel coat and fiberglass. Remove all the "rotten" material. Keep cutting until you get it all out. Don't worry about cutting good fiberglass. It is highly resistant to cutting. Use the knife to get rid of all undercuts, as they will make filling more difficult.

Other tools may be used also. Small rotary files attached to electric drills have been successfully used. The idea, whatever you use, is to open up the blisters and remove damaged gel coat and fiberglass. Blisters generally contain acidic water under pressure. The water may contain dissolved material, which could cause eye irritation or damage. Wear safety goggles and stand back out of the line of fire.

STEP 3: Wash and Dry Boat and Blisters.

Wash the boat thoroughly from the boot top stripe down with fresh water to remove all traces of salt, blister fluid, sanding dust and other dissolved material. Rinse the hull well. Be sure to squirt the water into the exposed blisters to remove any contaminants in the blister. Let the boat drain and air dry for several hours. Look and see if any purple-brown colored vinegar smelling liquid is oozing out of opened blisters. This is blister fluid. If it is, then dig out those blisters even more and rewash. Repeat this step as necessary.

The next step, drying the hull, is the single most critical operation to affect a cure that lasts. It is of paramount importance that the hull be as dry as possible. Start by emptying the bilge of standing water. In 80°F weather at 40 percent relative humidity the average

blistered hull will take three weeks to dry to a steady low level. You may not be able to achieve these conditions without "skirting" the boat and using heat and a dehumidifier. If you plan to do it this way we recommend reading "A Manual for the Repair of Fiberglass Boats Suffering from Osmotic Blistering" by Richard and Roger McLean.

Some people have suggested that the hull drying process can be accomplished by vacuum bagging. We have studied the results of this process and talked with those who have done it. While there is some initial drop in hull moisture content, this method will not properly dry a hull even at safe elevated temperatures. We cannot recommend this method of hull drying.

If you live in an area where boats are hauled in the winter do Steps 1, 2, and 3 in the fall and when the weather starts to warm in the spring, skirt the boat and finish the drying.

STEP 4: Fill the Blisters.

When the hull laminate has completely dried you should roll on a sealer coat of mixed Clear Coat epoxy resin/hardener. Work the mixed resin into each cavity to wet out any damaged fiberglass. Allow it to soak in for an hour or two. Then mix up some System Three epoxy and make a tilling putty by the addition of microballoons and silica thickener. This material makes a non-sagging putty which will replace the material you removed in Step 2. Try to perform this step on the shady side of the hull if possible as you will have longer working time.

Initially, mix small batches until you get the hang of working with QuikFair or an epoxy/microballoon mixture. You can always mix more but once mixed you've got to use it within a short period of time or it will go off in the pot. Fill each blister from the bottom (otherwise you will trap air) using a putty knife or similar tool. Fill flush with the gel coat surface with a slight overfill which will be sanded down later. Finally, use the edge of the putty knife to scrape off any excess around the perimeter of the hole. Get it now before it cures or you will have to sand it off later.

Fill all the blisters and allow to cure at least overnight if the temperature is above 60°F or two nights if the temperature is below 60°F before proceeding to step 5.

If you have had the hull sandblasted then you may not have blister pockets to fill. Your job is to begin fairing. Before beginning, roll on a coat of mixed Clear Coat resin to seal the exposed fiberglass surface. Allow several hours to cure before fairing. The idea in fairing is to restore the surface to the gel coat level prior to removal. You will do this with the same with QuikFair or the microballoon mixture but use a broad knife or similar tool to apply it. In effect you will be plastering the hull with the epoxy microballoon mixture and sanding it to get it fair. A careful job applying the "mud" will save hours of sanding later.

STEP 5: Sand the Hull.

Use 60 grit aluminum oxide paper and sand the filled cavities fair with the surrounding hull. Blocks or sanding pads help avoid sanding the cured putty below the surrounding hull surface. The putty will sand faster than the fiberglass. Refill any concave holes or exposed air bubbles with the putty blend. Allow to cure and resand.

If you removed the gel coat and puttied the entire hull bottom you will now sand it fair. This is best done by two people using a long board. This is just a long sanding block with paper glued to it. The flat part of a straight 2x4 about 3 feet long works well. You may find that the sanding will reveal low spots that require additional microballoon mix. Fill them, resand and continue in this fashion until the entire hull is without ridges, bumps or hollows.

STEP 6: Prepare the Hull for Epoxy Coating.

After the cavities have all been filled and the hull is fair it is necessary to prepare the hull for epoxy coating. It is this coating that will help prevent the hull from blistering in the future as the epoxy coating is much more resistant to water penetration than the polyester resins used to build your hull.

Begin by sanding the entire hull to be epoxy coated with 60-grit paper if you have not sanded it in the filling/fairing process. You may hand sand it or use a vibrating sander. Rotary high-speed sanders should only be used if you are confident about your ability to use them. They are heavy and cut fast and you may end up gouging the hull. Sand the hull until there is no gloss left - sand right up to the old bottom paint line. Avoid breathing the dust.

After the hull has been thoroughly sanded wash it with water to remove the sanding dust. Really get in there and scrub it with a clean brush to remove all traces of sanding dust. Rinse and allow it to dry well - at least overnight.

STEP 7: Coating the Hull with Epoxy.

You will need System Three epoxy resin and hardener, disposable gloves, graduated cups, stir sticks, yellow foam roller covers, roller frame, disposable brushes and a 9" roller paint tray for this step. Use only the roller covers supplied by us. They are designed for our product.

The idea here is to get on a minimum of four coats of epoxy without the runs and sags that will require a lot of sanding later. It is this coating that provides the barrier that help prevent the future intrusion of water into the hull.

First run masking tape around the boat so that the bottom edge of the tape is right at the top of the old bottom paint line. This will help prevent rolling epoxy on the topsides or boot top stripe.

Put on the gloves and mix up about six ounces of resin/hardener. Pour the thoroughly mixed material into the roller pan and "paint" the hull using the yellow foam roller covers. Put on as thick a coating as possible but not so much that it will run and sag. Experience will teach you how much you can get away with. Better to spend the time putting on an extra coat if the previous coats have been a little thin rather than sanding out runs later. If you see a run

developing go back and roll it out. The resin/hardener mix contains no solvent so you won't leave marks if you do this. Brush out any air bubbles with a foam brush using light strokes. Just use enough pressure to break the bubbles and not disturb the uncured epoxy.

Remove the masking tape right after you finish the first coat. Do it before it cures or else it will be difficult to remove later. Wear gloves since the masking tape will be wet with epoxy.

Retape then apply the next coat as soon as the previous coat is set enough so the combination of the two coats will not run and sag. This is about 2 to 3 hours with fast hardener on a 60°F day. Less on a warmer day, longer with slower hardener. You may wait up to 72 hours between coats without sanding as long as the hull does not become contaminated in the meantime.

Put the succeeding coats on the hull right up to the top of the first coat. By catching the light right you'll be able to see where the first coat ended and the new coat starts.

If you wait longer than 72 hours between coats you'll have to give the epoxy a light sanding to give the new coat some "tooth" to tie into the previous coat. Prior to this time the coats will bond chemically to each other.

Allow the last coat to cure overnight before proceeding to the next step - even longer if the temperature is below 60°F during the cure cycle.

STEP 8: Sanding for Bottom Paint.

Hose and sponge the hull with water to remove any oily surface film on the cured epoxy. This is a water-soluble film and will be thicker if you applied the coating in humid weather. It is a by-product of the epoxy curing reaction. Solvents do not remove this film.

Sand the cured epoxy with 80-grit paper to smooth any runs and kill the gloss. A sanding block helps to prevent over sanding when removing cured runs. Be careful not to sand through the epoxy coating and re-expose the gel coat thus losing the epoxy protection. If you desire an even smoother bottom you may want to use finer grades of wet and dry paper. If the sandpaper clogs excessively then the epoxy coating has not sufficiently cured. Wait another day. Wet sanding helps prevent paper clogging and keeps the dust down. Use wet or dry sandpaper and dip it into a bucket of water occasionally.

After sanding, wash the dust off with a sponge and water. Allow the hull to dry. Wipe with acetone, MEK, or the solvent recommended by the bottom paint maker for preparation to applying this paint.

Do not be seduced into believing that bottom paint can be applied to partially cured System Three epoxy. Some would have you believe that this avoids final sanding of the last epoxy coating. If you do this you may find that the bottom paint along with the last coat of epoxy will start to fall off in several months.

STEP 9: Applying the Bottom Paint.

Follow the manufacturer's recommendation when applying bottom paint to the epoxy-coated hull. Most bottom paints will adhere well to the sanded epoxy coated hull with no primer. Keep in mind, however, that bottom paints are formulated for polyester gel coat hulls and some may not work well on epoxy coatings. You should do a small test patch on your hull to make sure that the bottom paint dries properly and adheres well to the epoxy coating.

Estimating Amounts

Figure 0.2 gallons of mixed resin and hardener per coat per 100 square feet of hull surface (500 sq. ft. per gallon per coat) to be coated for the barrier coat. Thus, a 30-foot sailboat with 175 square feet of under water surface will require about 1 3/4 gallon of mixed resin/hardener for the barrier coat. The amount necessary for the filling/fairing will depend greatly upon each boat.

Materials List

The following materials are available from System Three Resins and will be necessary for the completion of a blister repair job.

Epoxy Resin and Hardener	Filler Materials
Measuring Cups	Mixing Sticks
Mixing Pots	Disposable Gloves
Disposable Brushes	Foam Brushes
Roller Covers	Roller Frames
Roller Tray	Squeegees
Masking Tape	Dust Masks
Utility Knife	Sandpaper
Safety Goggles	

In addition to these materials you will need hoses, buckets scrub brushes, clean rags, paper towels, putty knives, a ladder, sanding tools, etc.

SPECIAL WARRANTY FOR GEL COAT BLISTER REPAIR

Because the construction of your hull and the repair of the gel coat blisters are beyond the control of System Three Resins, no representations or warranties are made or implied that future gel coat blistering will be prevented using the techniques and materials described in this booklet. System Three Resins shall not be responsible for incidental or consequential damage as a result of using its materials or the techniques described herein. System Three Resins' sole liability shall be the replacement of defective materials or the refund of the purchase price of these materials.

SECTION IX E - OTHER AREAS OF EPOXY USE

System Three Resins' products have been used in many areas besides boatbuilding and repair. These areas include concrete repair, radar dome fabrication, piano repair, guitar making, art deco projects, jewelry making, pottery repair, golf club repair, outdoor sign production, home and professionally built hot tubs and spas, aircraft manufacture, tooling, electrical potting, home restoration, rock polishing, and sports equipment manufacture to name a few.

At best we are experts on epoxy resin product formulating and students of boat building and repair. If you have an oddball use give it a try. If you call and ask us this is probably the answer you will get. At best we can only give you our honest opinion and maybe tell you why we think it might not work. But don't take our word for it. Give it a try. Just like on a boat, you're the captain of your project.



SECTION X - TROUBLESHOOTING AND COMMONLY ASKED QUESTIONS

Following are questions we are commonly asked when something goes wrong. We hope that you will read them because the answer to your problem may appear below. If it doesn't then call us on our technical line and we'll go over it with you.

The Part A resin has hardened and turned white. Can I still use it?

Yes. The white solid or haziness is a mass of resin crystals. Crystallized resin will not cure properly. These can be melted by heating the container to 120°F. The resin will clear up and be as good as new.

The Part B hardener is darker in color than when I bought it. Can I still use it?

Probably. Hardeners yellow and darken over time due to contact with air and sunlight. This does not affect their performance. To satisfy yourself do a small test and make sure it cures properly.

What is the shelf life of your epoxy resin products?

All solvent-free epoxies have essentially unlimited shelf lives so long as they are stored in sealed containers. The resin may crystallize or the hardener may darken but this does not affect its performance. If the material is more than a year old do a test to satisfy yourself that it cures properly.

Can I put polyester gelcoat over cured epoxy?

In general, polyester resins won't cure properly or bond well to epoxy resin products without a "tie-coat" barrier resin in between. System Three SB-112 resin system can be used as a tie coat in between epoxy laminating or coating resins, and polyester laminating or gelcoat resins. Using this resin allows you to gelcoat an epoxy-built or epoxy-repaired boat.

Can I color System Three® epoxy products?

Yes. The preferred method is with System Three paste pigments. You can add these up to 10% by weight of the Part A resin. You can also use universal paint colorants from the paint or hardware store, but only up to 2% by weight of the resin.

My epoxy resin is taking too long to cure. How can I speed it up?

The only way to speed the cure of our epoxy resin products, once they've been applied, is to heat the room or the area that your project is in. Every 18°F increase in temperature cuts the time it takes for the resin to cure in half.

Which laminating resin is easiest to use for fiberglassing?

There are two main things to consider: how the resin wets out the cloth and how well it fills the weave. The thinner resins, like Clear Coat, will wet cloth easier, but take more coats to fill the weave. With thicker resins, like System Three General Purpose, the opposite is true.

Will the ultimate strength of an epoxy coating be affected if it gets cold while it's curing?

No. As long as the epoxy is completely cured, the physical properties will not be affected.

What solvent can I use to clean up cured epoxy resin products?

Cured epoxy systems are very chemical resistant, and need to be removed with an epoxy-type paint stripper containing methylene chloride, or by a combination of heat for softening followed by scraping. Uncured epoxy resins and hardeners can be cleaned up with ketones, alcohols, or lacquer thinner. White vinegar will clean up unmixed resin components.

Will System Three® epoxy products damage polystyrene or urethane foam?

No. Our coating and laminating resins are designed to go directly over solvent-sensitive substrates without any fear of softening or "melting" them.

Can I stain over cured epoxy resin?

No. Any wood that's been coated with epoxy will be sealed, and when it's cured it won't accept stain. Stain wood first; then apply epoxy resin.

What stains can I use before applying epoxy?

Dye stains are preferable because they leave no surface film. But in general, any stain can be used so long as it is completely cured before applying mixed epoxy resin. However, it is prudent to do a test by staining some scrap and then applying epoxy. Check for appearance and bonding.

What can I use as a material that epoxy won't stick to?

Epoxies will not stick to mold-release compounds recommended for use with epoxy, and polyethylene sheeting, like disposable paint tarps and sandwich bags. Epoxy does not stick to the shiny side of packaging tape or paraffin wax.

I made a small batch and after a week it has not cured. What happened?

It is difficult to measure a batch of resin and hardener less than three fluid ounces by volume. If you need to make a small batch, measure it by weight. System Three offers a small digital scale perfect for this use.

*...Zere iz no
Such sing as
an instant
cure...*



I made a large batch and found a few areas that are still sticky after most of the surface is cured hard. What happened?

The material was probably not thoroughly mixed and unmixed material was scraped from the container onto the surface. When mixing always be sure to mix from the bottom to the top and scrape the sides of the container and the stick. Experienced users dump and scrape the mixed material from the first container into a second and then mix again. This totally avoids the problem described above.

I made a large batch and found a few areas that are still sticky after most of the surface is cured hard. Can I fix it?

Yes. First, scrape off what you can. Then pour or wipe a suitable solvent on the surface. Wear a respirator or provide proper ventilation when working with solvents. Wipe or scrub the resin surface. This will remove residual uncured resin but won't harm any cured resin. Sand the underlying cured resin and apply a fresh coat properly measured and thoroughly mixed. Note: Over bare wood the fresh coat of resin will need to be worked into the wood with a stiff-bristle brush to mix any residual uncured material into the fresh material. This will ensure that the fresh coat will adhere properly to the wood.

I have material that hasn't cured after four days in a warm room. Can I apply fresh resin over the top and have the whole thing cure hard?

No. If the older material has stopped curing, applying more epoxy won't start it up again. The uncured resin must be removed and new material applied to that surface.

Can I use the hardener from one of your epoxy systems with the resin from another?

No. Epoxy resin systems are two-part products where each part is designed to go with the other.

Can I apply mixed epoxy to a piece of wood and then bend it without cracking the epoxy?

Yes, while the cured epoxy may be stiffer than an equal thickness of wood, the epoxy coating is much thinner and can be bent further than the wood it coats without cracking.

I laminated some bent wood strips with epoxy adhesive and clamped them overnight. When I found them the next day the adhesive had cured hard but several strips had sprung open. How can I keep them together?

Leave the clamps on a full 24 hours. The epoxy had not adequately cured when the clamps were removed. The force caused by the bent wood trying to straighten was sufficient to cause the uncured epoxy to fail. It opened up some time after you removed the clamps, but the epoxy continued to cure between the time the clamps were removed and when you saw the laminations the next day.

To avoid the above problem I left the clamps on for three days but the epoxy adhesive still failed at the interface between the strips. The surface appeared grainy or sugary. Why?

Likely you used too much clamping pressure. The clamps squeezed most of the epoxy out of the joints and the wood

absorbed what was left leaving a starved joint. A grainy feel at the interface is symptomatic of a starved epoxy glue joint.

How much clamping pressure do I use for an epoxy glue joint?

Epoxy adhesives, being gap-filling glues, need only enough clamping to close the joint. Unlike other glues epoxy does not require high pressure to make a proper glue joint.

Will epoxy resin adhesives bond all materials together?

Epoxy resin adhesives will bond all woods, aluminum and glass well. It does not bond to Teflon, polyethylene, polypropylene, nylon, or Mylar. It bonds poorly to polyvinyl chloride, acrylic and polycarbonate plastics. The only way to tell if an epoxy will bond to a material is to try it. Generally, epoxy adhesives are the best choice for bonding dissimilar materials together. If epoxy bonds to Material A and to Material B it will bond the two materials to each other. The best thing to do is to try it and see for yourself.

What materials can I put over your epoxy products? What materials will your epoxy go over?

Since epoxy resin system vary in compatibility with materials, there is no single list. In general, if a material is not listed in the product directions or application instructions, the best thing to do is to try it and see for yourself.

Can I use your epoxy products to build or repair a gas tank?

System Three epoxies, when properly cured, are resistant to diesel fuel and aviation fuel, but not gasoline. There are gasoline-resistant epoxy products available, but System Three does not make one.

My question isn't listed here. What are my options?

If we haven't answered your question earlier, send us an e-mail at support@systemthree.com , or give us a call at (253) 333-8118.

Paint Products FAQs

What is the coverage of WR-LPU Topcoat?

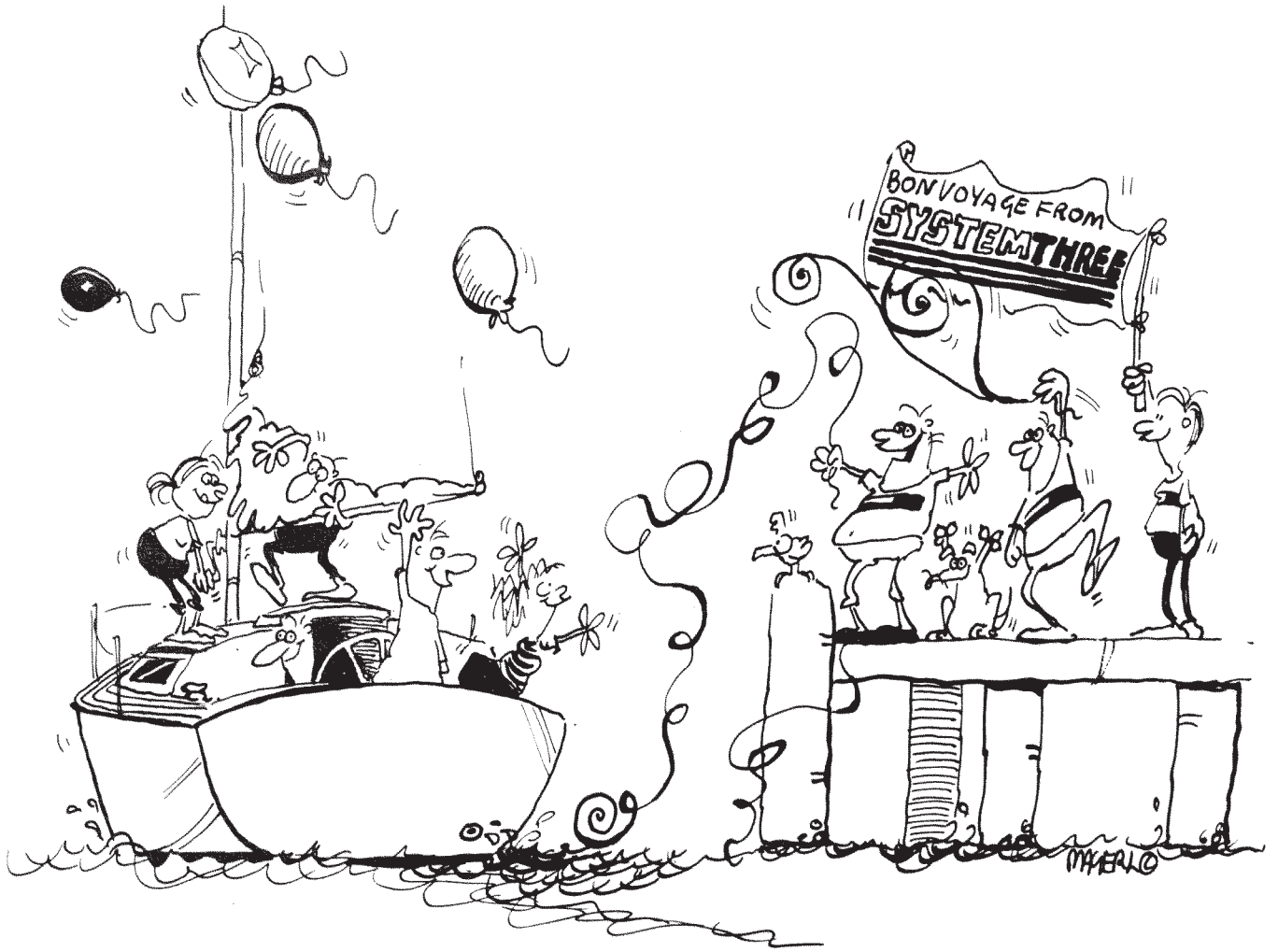
We recommend a spreading rate approximately 400 square feet per gallon. This will give a coating of 2.5 mils(0.0025") dry film thickness.

What is the coverage of WR-155 Primer?

We recommend a spreading rate of approximately 250 square feet per gallon. This will allow for some coating removal from sanding, and still leaving a 2.5 mil dry film thickness.

How long after I finish my wood/epoxy boat can I apply System Three® Spar Varnish?

You should wait a minimum of two weeks for the resin to cure, then sand it, wash it to remove the dust, and apply the varnish.



Index

A

Accelerator 3
Accumeasure Kit 5
Acetone 3, 11, 12, 17, 27
Alaskan yellow cedar 22
Amine blush 8, 11
Amine carbamate 4, 11
Amine groups 3
Amine hydrogens 3
Ammonia 3
Appendix A - Estimated Usage 35

B

Balsa 8, 22
Barrier coats 19
Biaxial tape 13, 20
Bisphenol A 3
Bottom paint 18, 25, 27, 28
Brown, Jim 23
Bubbles 5, 6, 11, 16, 27
Bulking agents 14

C

Cab-O-Sil 14, 15
Canoes 21, 22
Carbon dioxide 4, 10
Carbon fiber 8
Carvel planking 22, 23
Catalysts 3
Catamarans 22
Cedar, Alaskan yellow 22
Cedar, Western red 22
Chalking 4, 18
Chemical reaction 3
chemistry set 5, 7
Chopped glass strands 14
Clear Coat 8, 11, 12, 14, 17, 26, 29, iii
Cold molding 22
Constant Camber 22
Cratering 6, 11
Crevice corrosion 15
Cross hatch adhesion test 19
Cure time 3
Cylinder Molding 22

D

Debonding 4
Dehumidifier 26
Delamination 18
Diluents 6
Disk sanding 11
Door skins 22
Dust masks 2, 26

E

Electrical Potting Resin 9

Electrolysis 14
Embrittlement 6
EndRot 9, iii
Engine mounts 25
Epichlorohydrin 3
Epoxy resin chemistry 3
Exothermic 3

F

Fairing 10, 13, 14, 16, 17, 25, 26, 27, 28
Feathering 13
Fiberglassing 10, 11, 12, 13, 14, 17, 21
Fiberglass boat repair 8, 10, 25
Fiberglass cloth 6, 8, 12, 15, 16, 17, 23
Fiberglass itch 13
Fiberglass mat 12
Fillers 6, 14, 15
Filleting 10, 14, 16, 17
Film cracking 18
Flammability 2
Foam cored 8

G

Gap filling 6, 14, 15, 22
Gel coat 8, 10, 19, 25, 26, 27, 28
Gel time 3, 4, 6
Gloves 2, 5, 11, 13, 17, 27
Glue 3, 10, 15, 17, 21, 22, 23
Glued Lapstrake 21
Gluing 10, 11, 12, 15, 21, 22
Glycidol oxygens 3
Graduated cups 5, 27
Graphite powder 14

H

Hardener #1 3
Health and safety 2
Honeycomb 8
Hot air gun 5, 11
Humidity 18, 19, 26

I

Infusion Resin 9
Interfacial bonding 15

J

Jiffy Mixer 5

K

Kinetics 3

L

Lacquer thinner 5
Lapstrake construction 21, 23
Linear polyurethane paints 18

M

Mahogany 20, 22
Marine paint 18
Masking tape 12
Material Safety Data Sheets (MSDS) 2
Measuring by weight 5
Measuring errors 4
Mechanical bonding 10
MEK 17, 27
Metal bonding 15
Methylene chloride 18
Microballoons 14, 16, 23, 26
Microspheres 14, 15, 16
Milky 8
Milled glass fibers 14, 17
MirrorCoat 8, iii
Mixing pot 3, 5
Moisture resistance 12
Molded chines 20
Molding compounds 16
Monocoque 23

N

Neoprene rubber 16
Nitrogen 3

O

Over-clamping 15

P

Painting 4, 10, 11, 13, 14, 17, 18, 19
PG-101 9
Phase Two 4, 8, 24, iii
Phenol 3
Pigmented Epoxy 15
Plastic minifibers 14, 15
Plunger pumps 5
Plywood planking 20
rotary cut 12, 20
Polyamines 3
Polyester resins 4, 12, 20, 27
Polyethylene 2, 16, 22
Polymerization 4
Polypropylene 16
Polystyrene 8
Polysulfide Rubber 15
Polyurethane 16, 18
Porous Woods 11
Pot Life 3
Precoating 12
Print through 18
Putty 2, 14, 16, 17, 18, 26, 27, 28

Q

Quick Cure 16, 21, 22, iii

R

Reactivity 3
Redwood 22
Respirator 13
Roller covers 2, 11, 13, 27
Roller pan 10, 13, 27
RotFix 9, iii
Rotten wood 25

S

Sailboard 8
Sandblasting 26
Sanding dust 11, 16, 17, 26, 27
SB-112 4, 8, 29, iii
Scarf joints 15
Scraping 5
SculpWood 6, 9, iii
Selvage edge 13
Sewn seam construction 21
Silicates 10
Silica thickener 14, 15, 16, 17
SilverTip 1, 3, 4, 5, 6, 7, 10, 11, 13, 14, 15, 16, iii
SilverTip EZ-Fillet 7, 14, 16, 17, 21, iii
SilverTip GelMagic 7, 8, 14, 15, 16, 22, iii
SilverTip Laminating Epoxy 3, 4, 10, 11, 12, 13, 14, 16, 17, iii
SilverTip MetlWeld 8, 14, 15, iii
SilverTip QuikFair 7, 8, 12, 13, 14, 15, 16, 17, iii
Sistering 23
Sitka spruce 22
Skin cream 2
Skin sensitization 2
Solvents 2, 6, 11, 12, 18
Squeegees 11, 17
Staining wood 10
Stainless steel 15
Starved joint 15
Strip planking 21
Structural seams 13
Styrene 12
Sunlight 4, 11, 14, 15, 18
Surf 8
Surform 12, 13
System Three epoxy 10, 14, 15, 16, 17, 18, 23, 25, 26, 27

T

T-88 9, 15, iii
Tack rags 11
Teak 15
Teflon 16
Telegraphing 18
Thalco squeegee 12
Thermoset plastic 3
Thixotropic 14, 15, 16

Titanium dioxide 14
Trimarans 22

U

Ultraviolet light 4, 8

V

Vacuum bagging 22, 26
Vapor pressure 2, 3
Varnishing 11, 13, 18, 19
Veneer 20, 22, 23
Vinegar smell 26
Vinyl ester 19
Volume ratio 4, 5

W

Waterless handsoap 2
Water reducible paints 19
Wax 2, 15
Weather degradation 15
Western red cedar 22
Winch pads 17
Wooden boat construction 8, 10, 23
Wood flour 14, 15, 16, 21
Working time 3, 11, 26

APPENDIX A

ESTIMATING USAGE

The following will serve as a guide for estimating the amount of SilverTip™ Series product you'll need. The key to any estimate is a reasonably accurate idea of the surface area involved. The numbers given are in square feet of coverage per gallon of mixed resin and hardener except as noted. Divide by 40 to convert figures to square meters per liter.

SILVERTIP COATING AND LAMINATING RESIN

Coating Wood	First Coat	Subsequent Coats
Softwood Plywood/Veneer	250	400
Hardwood Plywood/Veneer	325	400
Vertical Surface-maximum non-sag	500	500
Fiberglassing		
(sealer, wet-out & fill coats)		
4 ounce cloth	150	300
6 ounce cloth	130	250
10 ounce cloth	100	170
Biaxial Tape	32	40

GEL MAGIC ADHESIVE

Glue Lines*	Thickness	Consistency	Soft Wood	Hard Wood
High Pressure	8 mil	Thixotropic Fluid	0.85	0.73
Low Pressure	20 mil	Soft Paste	1.32	1.20

*Figures are in gallons of mixed product per 100 square feet of glue surface area. Both surfaces wet out with GelMagic. High pressure includes vacuum bagging while low pressure includes stapled veneer, loose joints, etc. One mil equals .001 inch or about 1/4 millimeter.

Volume of Fillets:

The amount of filleting compound in gallons per lineal foot of fillet for any practical fillet is equal to about $0.0111r^2$, where r is the fillet radius in inches.

Volume of Fairings:

The amount of fairing compound in gallons per square foot of fairing surface area is equal to $0.623t$, where t is the fairing thickness in inches.

NOTES