THE EPOXY BOOK

A SYSTEM THREE RESINS PUBLICATION

Most boatbuilders already know who we are. That is because for the past two decades System Three Resins' focus has been to provide the highest quality epoxy products to boatbuilders throughout the world. *The Epoxy Book* was written to address the specific things that you need to know to successfully complete a boatbuilding project. However, non-boatbuilders will also find a lot of useful information in this book. For example, there's an easy to understand epoxy chemistry lesson, tips on measuring and mixing epoxy systems, how to safely handle epoxy, and techniques of epoxy use such as coating, fiberglassing, adding fillers to epoxies and using epoxy resins as structural adhesives. After reading this book and trying out our specially formulated epoxy resins and adhesives many different craftsmen from woodworkers to kit airplane builders have become regular purchasers of our products. We welcome every new customer supporting them with accurate product information and straightforward technical advice on using our products for their specific application needs. In so doing, we are continually establishing ourselves as a company that solves problems for its customers. Several years ago we discovered a need for our product formulation and problem solving skills in the industrial epoxy sector. Since then our industrial R&D staff has helped many companies in industries from appliance manufacturing to fishing rod assembly. Today, a large part of our business is done with these industrial accounts. As you read through *The Epoxy Catalog* and *The Epoxy Book* you will see the products and expertise that we have developed while serving the needs of boatbuilders and hobbyists. It is our hope that you will also see that we can supply the epoxy and urethane coating needs of your company as well. Your inquiries are always welcome in our marketing department.

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INTRODUCTION

Time has a way of slipping away and before you know it five years have passed. So it is with *The Epoxy Book*. Our last major revision was in 1995. Since that time epoxy users have become more sophisticated and expect more from the products for which they spend their hard earned money.

No longer is it possible to use one epoxy resin formulation for every conceivable boat building and repair application. Ten years ago, we had two major epoxy resin formulations, System Three epoxy for wooden boat building and repair and Phase Two epoxy for composite cored construction. Today we have twice this number and have developed many specialty formulations for specific purposes.

While this might seem confusing to the newcomer to epoxy resins, our goal was to make life easier. Nowhere is this truer than in our line of epoxy primers and paints. The biggest problem to plague boatbuilders in the past few years has been the painting problem. This problem arose because of changes in paint formulations (banning certain metallic driers and requiring lower volatile organic content), not because our original System Three epoxy formulation was deficient. The painting problem is now solved. We have developed new products to overcome the problem.

The same thing is true of SB-112, our surf and sail board epoxy formulation. As this industry switched to the lighter styrofoam blanks the need for an epoxy laminating resin was necessary. The requirement here was for an ultraviolet light stabilized, clear colorless resin that polyester resins could bond to. This industry was not about to accept current boatbuilding epoxy resin systems because they could meet none of these requirements. Thus, we developed SB-112. Now we find many people use SB-l12 for fiberglass boat repair where the surface will be gel coated.

The major change in this edition is the addition of the new products and the telling of where and how they are used. We've also expanded the section on fiberglass boat repair by outlining a procedure for gel coat blister repair, a major use of our products. The section on wooden boat building and repair has been enlarged. In short, there is something in here for all users of our products.

Our responsibility is to provide quality products to the end user. The information about the use of these products as outlined in this book is merely a distillation of the knowledge we've gained over the years. Some of this knowledge is developed by us, some by others. You, the user, are the captain of your ship even before you launch her. Your responsibility is to make sure that all the products you use, including ours, are properly used. We have no control over how you use our products and can't guarantee that they will work in your application exactly as you want them to. We encourage the testing of new ideas on a piece of suitable scrap prior to committing a whole project to the experiment.

You'll find that this book is organized into sections starting with basic chemistry and safety regarding all epoxies, swinging into System Three Resins products. Proper measuring and mixing techniques are next. Detailed sections follow the basics on the various unit operations of epoxy use. Then we get into wooden boat building and repair, composite construction and fiberglass boat repair including blister repair. There's a section on troubleshooting and we finish with some useful tables and charts in the Appendix.

One point though. This is not a book about boat construction. It is a book about epoxy resin use in boat construction. There are a number of excellent books about boat construction methods that use epoxy resin. Some mention our product, some mention competitive epoxies. Use these books as an aid to boat construction not epoxy resin selection.

In the interest of simplicity and readability we have used American units of measure in this book. For this use we apologize to our friends and customers in the more civilized metric speaking countries. For you we have provided a conversion table in Appendix G.

SECTION II
CHEMISTRY

Thoroughly knowing epoxy resin chemistry is not necessary before building a boat, but having a rudimentary chemical knowledge will help you complete your project more effectively, avoiding any pitfalls or surprises which may arise when using epoxy resins.

The resin that is the basis for all boatbuilding epoxies 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 chemical 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) glycidol 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 glycidol groups that react with the amine hydrogen atoms on hardeners to produce the cured epoxy resin.

Basic epoxy resin is very viscous and unsuitable for use in boatbuilding except as a thick glue for specialized applications. At System Three Resins we purchase the material in this basic form, then modify it using formulae developed by us. The result is the various boatbuilding epoxy resin systems we offer.

Hardeners used with room temperature cured epoxy resins are most commonly polyamines. That is, 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 dead air space in containers right after they are opened. Once in the open this odor is difficult to detect because of the high vapor pressure of the polyamines.

Reactive amine groups are nitrogen atoms with one or two hydrogen atoms attached to the nitrogen. These hydrogen atoms react with oxygen atoms from glycidol 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 glycidol oxygens to the amine hydrogens, taking into account the various molecular weights and densities involved, determines the final resin to hardener ratio. 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.

Epoxy hardeners are not “Catalysts”. Catalysts promote reactions but do not chemically become a part of the finished product. Epoxy 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 glycidol oxygen atom. Thus, cure time is set by the kinetics of the particular amine used in the hardener. Cure time can be altered only by selecting a different hardener, adding an accelerator in systems that can accommodate one, or by changing the temperature and mass of the resin/hardener mix.

The epoxy curing reaction is exothermic. This means that it gives off heat as it cures. The rate at which the epoxy resin cures is dependent upon the curing temperature. The warmer it is the faster it goes. The curing 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 temperature of the mixed resin and hardener.

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 System Three Resin/Hardener #1 will solidify in 15 minutes starting at 77°F. At 60°F the gel time is a little under 30 minutes. If the same mass were spread over 4 square feet at 77°F the gel time would be a little over two 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. Thick, partially cured epoxy is not as effective in wetting out fiberglass cloth and bonding surfaces. 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 boatbuilding purposes room temperature cured systems can be considered fully cured after 72 hours at 77°F. High modulus systems like Phase Two 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. This allows the builder to get along to the next phase without wasting time waiting for epoxy to cure. Faster curing films with shorter tacky times will have less chance to pick up fly tracks, bugs, and other airborne contaminants.

A surface film may form in some epoxy systems during the curing process. Technically, this surface film is an amine carbamate 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 is water-soluble and should be removed before sanding or painting (See Section VII). One of the benefits of System Three epoxy is that this film need not be removed between coats if successive coats are applied soon after the previous coat cures. Clear Coat, SB-112 and Quick Cure do not form this amine blush, Phase Two may under extreme circumstances.

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 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.

System Three Resins has developed several products that enable the user to successfully marry epoxy and polyester resins. These products are described in Section III.

SECTION III
SYSTEM THREE RESINS' PRODUCTS

All of our epoxy systems are formulated systems, meaning that we start with basic epoxy resins manufactured by large chemical companies and modify them to make them suitable for boatbuilding and repair. In the first modification (for most products) we reduce the viscosity by the addition of diluents or low viscosity solvents which are also epoxies. This makes an epoxy system thin enough to wet fiberglass cloth, coat wood 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. Finally, trace materials designed to lower surface tension, promote substrate wet out, reduce cratering and "fisheye" formation, aid in breaking bubbles and detraining air are used to produce the finished product.

These modifications are what make our epoxy unique and different from other epoxy systems. 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 gets tested for both gel time and "thin film set time". Nothing is shipped to a customer that does not meet our high standards. Everything we ship cures if properly measured and thoroughly mixed.

System Three Resins is well qualified to formulate and produce boatbuilding epoxy resins. One of the owners, Kern Hendricks, is a chemical engineer who has worked with polymers since 1963. The other owner, Tom Freeman, has been in the marine business since 1965. Both have built large wood/epoxy sailboats, cruising them extensively in both coastal and international waters. We use the products we sell.

This background gives us the unique advantage of knowing and applying marine epoxy technology far better than others in the business. We have built boats under less than ideal conditions, sailing and using these boats twelve months of the year. The development, manufacture, and distribution of System Three products is our only business, and we take pride in being personally available to all of our customers. The dominant factor in the design, development, and evolution of System Three products has been this:

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

System Three Epoxy Resin

This product, named after our company, is our first epoxy formulation. 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. As epoxy user's knowledge and sophistication have increased so, too, have the epoxy systems offered by our company. The truth is, no single epoxy formulation can be all things to all people. However, our flagship product, System Three epoxy, comes close. It more than adequately fills the needs of ninety percent of our customer's epoxy requirements. Our other formulations take care of the balance.

While System Three 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 System Three 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.

System Three epoxy may be used effectively down to 35°F, maybe used in 100% relative humidity, does not turn milky in thin films, is used in an easy 2:1 volume mix ratio, is measuring error tolerant, and is packaged in rust proof containers. Pot life and cure times can be controlled by blending the hardeners, and the user may expect (and get!) consistent cures from different lots of resin and hardener. Typical physical properties of "neat" System Three epoxy castings are shown in Appendix A. Those familiar with the evaluation of such data will note that System Three epoxy is a medium modulus resin with high resiliency and good elongation. Tensile and compressive strengths are more than adequate for this product's intended purpose. The heat distortion temperature is fully adequate for boats painted light colors but suggests that dark colored hulls subject to intense sunlight might experience some softening of the epoxy coating. The data indicates that System Three epoxy cures to a very tough, hard, resilient film. This film resists star breaks and stress cracking. Long-term test results coupled with water extractables data show that these properties are not lost over time due to environmental degradation. Embrittlement over time can be a problem with high modulus boat building epoxy resins. This embrittlement will lead to micro cracking and the subsequent loss of strength thus defeating the original purpose of the resin. We avoid this problem in the System Three epoxy formulation.

In summary, System Three 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. Foam and end grain balsa cored boats should be built with Phase Two epoxy, our ultrahigh modulus laminating epoxy resin system. Here the skin laminates take almost all the load and the enhanced physical properties are necessary especially at elevated temperatures.

System Three epoxy, when properly mixed with any of the three hardeners, is ready to be used for coating or fiberglassing. For most gluing operations it is mixed with fillers that give it gap filling and flow control properties not available from the neat resin/hardener mixture. For all fairing and filleting work it is mixed with fillers. Section VI will cover these operations in detail.

The System Three name derives from the fact that the epoxy has three hardeners. The hardeners for System Three epoxy are all used at two parts of resin to one part of hardener BY VOLUME. For those who weigh the ingredients the ratio is 44 parts of hardener to 100 parts of resin. ***NEVER VARY THIS MIXING RATIO!*** An incomplete cure with attendant loss of physical properties will result. Our other epoxy systems may have different mix ratios. The measuring error tolerance is about 10% excess hardener and 20% excess resin. Thus, it is better to err on the side of too much resin rather than too much hardener, This tolerance combined with a 21 volume ratio make the purchase of expensive metering equipment unnecessary. However, such equipment is available and may pay for itself through less waste and more convenience over the long haul.

The three hardeners may be mixed with each other by the user to fine tune the pot life and working time to suit his particular application. The resultant mixture is then used in the correct 2:1 ratio by volume. Appendix B lists the gel times of various hardener blends.

A detailed product description of System Three epoxy and hardeners follows:

Epoxy Resin:

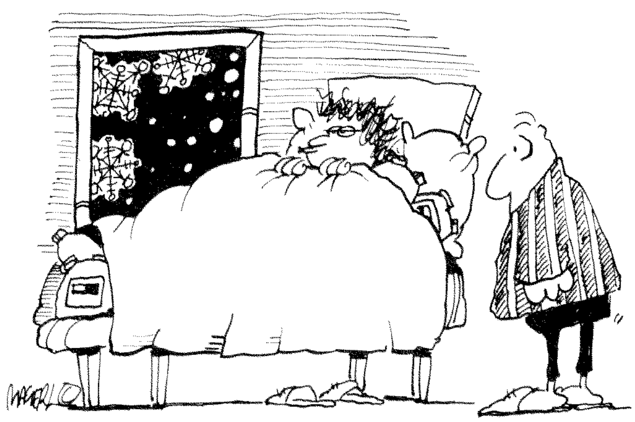
Low viscosity (500-800 centipoise @ 77°F) clear straw yellow modified epoxy resin. Modifications include additives to promote leveling, air detrainment in rolled coatings, resiliency, toughness, high impact resistance, and recoat ability, without removing amine blush or sanding between coats. Shelf life is unlimited in closed containers stored below 90°F. Haziness and crystallization will occur if stored at cold temperatures (below 50°F) for prolonged periods. Immersing the closed container in hot tap water and heating to 120°F or above will bring the resin back to a clear state. Neither crystallization nor heating will adversely affect the product. Crystallization will reoccur if the material is not totally brought back to a clear bright state after heating. Simply warming cold material to room temperature will not melt the crystals. Heat must be used.

Hardeners:

All hardeners are mixtures of aliphatic polyamines, cycloaliphatic polyamines and/or amido amines. Other materials are included to promote extremely low moisture sensitivity during cure, and the ability to form clear, tough, non-milky films. There is no practical shelf life for hardeners stored in closed containers below 90°F. We have used ten-year-old material with no discernible difference between it and fresh lots. Accelerators should not be used with these hardeners.

Hardener #1 – Low temperature use.

Will cure down to 35°F under damp conditions. Pot life at 77°F is 15 minutes. Thin films set and are tack free to the light touch in about 2 hours at 77°F. Uses include coating and glassing at all temperatures and general-purpose use below 70°F. Between 60-70°F work in smaller batches or get it spread out fast to increase surface area/mass ratio.



Hardener #2 – Intermediate temperature use.

Use above 55°F in damp or dry conditions. Pot life at 77°F is 30 minutes. Thin films set and are tack free in about 4 hours at 77°F. General-purpose hardener from 60 to 85°F. For large glue jobs requiring long open assembly times above 80°F it should be slowed with Hardener #3.

Hardener #3 – High temperature use.

Use alone at 75°F and above in damp or dry conditions. Pot life at 77°F is 70 minutes. Thin films set and are tack free in about 9 hours at 77°F. Because it is so sluggish, this hardener is not recommended for use by itself for coating jobs. It works very well for gluing jobs where long open assembly times at elevated temperatures are required. However, the best use of this hardener is when mixed with Hardeners #1 & #2. It will really put the brakes on them. For example, a 70/30 volume blend of Hardeners #1 and #3 will produce the same working characteristics as Hardener #2. (See Appendix B). Many users in colder climates with warm summers use Hardener #1 as a staple and keep some of this hardener on hand to slow it down as needed.

Appendix C gives the pot lives of the three hardeners at various temperatures. The use of Appendix B & Appendix C along with the 18°F change to halve or double the cure rate will allow precise pot life control by the user who wishes this control. However, it is not really necessary to fine tune System Three epoxy to this degree in order to build your boat. Most people select either the Fast (#1) or Intermediate (#2) Hardener and let it go at that. Then if hot weather is anticipated some Slow (#3) Hardener can be ordered to slow the others down for those jobs requiring long open assembly times.

Polyester resin gel coats will not properly cure when used on top of System Three epoxy. Users planning to do fiberglass boat repairs cosmetically finished with polyester gel coat should use SB-112. System Three epoxy is suitable for all other fiberglass boat repairs and is highly recommended for gel coat blister repair.

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). Complete information on the use and physical properties of Phase Two is available from System Three Resins.

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, in any, strength or resistance to moisture. Despite its long pot life (about the same as System Three epoxy with Hardener #3) it will cure at temperatures as low as 50°F.

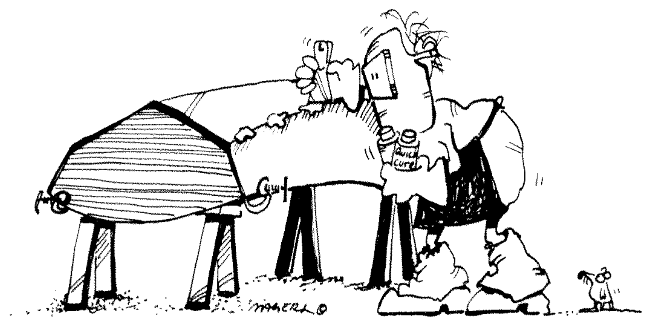
Clear Coat epoxy wets out fiberglass cloth almost instantly and is sometimes used to build furniture grade strip planked hulls. Here it is mostly used to seal the wood and wet out the cloth. System Three epoxy is used to do the bonding and fill the weave. Clear Coat epoxy is often used as the base coat 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.

The Glues

System Three Resins makes 1:1 mix ratio thick epoxy glues. These include Quick Cure, our "five minute" epoxy and T-88 Structural Adhesive, an hour-long pot life glue. Quick Cure is very useful in boatbuilding especially where "wood welding" is desirable. T-88 contains no fillers so it produces a clear glue line. It is useful in finish work where fillers used to thicken a thinner epoxy would detract from the beauty of the wood.

SB-112

This product 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. Polyester finishes may be applied directly to SB-112.



Other Products

Our research and development efforts are aggressive. We are constantly looking for other applications of epoxy chemistry to solve boatbuilding and repair needs. Many of our newer products have come as a result of a request or suggestion by our users. Some have application for wooden boats, most do not. We would like to hear from you if you have a specific requirement that cannot be met by using one of our current products.

SECTION IV
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 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 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 awhile but sooner or later it will catch up to you and you will be sensitized.

Wear disposable gloves or barrier skin creams when working with 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, will help drive the hazardous ingredients into your body. Use a good-waterless- hand soap and lots of paper towels to remove epoxy from your skin. Then apply a good medicated 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 epoxies you should stop until it clears up. If the rash is bad or persists see a doctor. Take him a copy of this book and have him contact us if he needs additional information. Find someone else to

do the epoxy work for you seeing to it that they work cleanly. 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 epoxy 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 epoxy cures. Cured epoxy doesn't stick to polyethylene, wax paper or most plastic wrap. Gloves, disposable brushes, and one time 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 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 high that fumes rarely cause problems, unless you have already become sensitized. Well-cured resin should cause no problem, as it is largely inert.

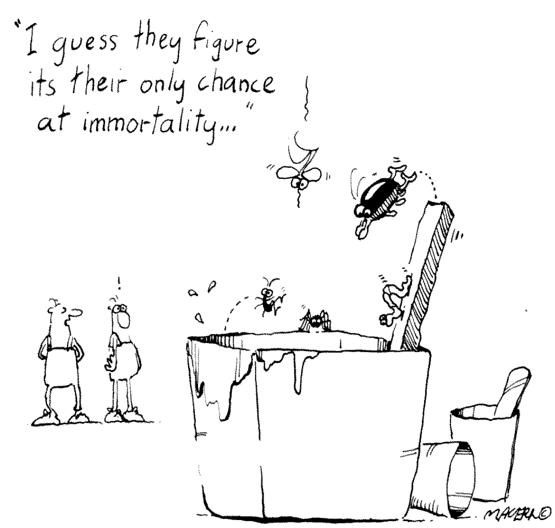
Whenever sanding or creating any kind of dust wear a mask to keep the dust out of your lungs. If you sand fiberglass and allow the dust to get on your skin you will probably get an itch from the glass fibers. Shower in cool water to wash the fibers off you. The itch usually goes away after 24 hours.

None of our epoxy formulations should be applied by spraying or any method that creates a mist or vapor of the epoxy.

Epoxy resins and hardeners 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 System Three Epoxy resin and hardeners appear in Appendix H. MSDS for all other formulations or any of the products we sell are 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. If you're the type of person who can't open a can of paint without slopping it all over you, or if you think that it is macho to get the materials you're working with all over your body and then go have lunch with dirty hands, we'd really prefer that you take your epoxy resin business elsewhere.



SECTION V
MEASURING AND MIXING EPOXY SYSTEMS

Measuring and mixing is really easy with most of our epoxy systems because they mix at a 2:1 volume ratio, but this doesn't mean you don't have to pay attention to what you're doing. Occasionally a customer will call suggesting that something is wrong with the epoxy because it didn't cure properly. We know of no situation where the 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.

Measuring errors are insidious and can pop up when you least expect them. These errors usually occur because you changed your technique, were in a hurry, had someone else mix a batch, or were just not careful. Develop a measuring technique that is sufficiently accurate and then stay with it. Doing it the same way each time will minimize the chance for error. In the interest of simplification the following discussion assumes a 2:1 volume ratio. Refer to Appendix F for specific product mix ratios.

If you are using some type of 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 you add 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 you use the "two measures/one measure" method and mix in a separate pot, be sure to scrape the sides each time you pour from your measuring cups to the mixing pot.
Make sure the graduations on disposable cups look right. Some cups are not rolled correctly when made. The first graduation sometimes is too high or too low. We can't inspect each cup to make sure it was properly made, this is your job.

Use the AccuMeasure Kit 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 built large boats using just the AccuMeasure Kit and 14 ounce graduated cups. You really don't need to invest a lot of money in metering devices to measure a 2:1 volume ratio accurately.

System Three Resins offers two mechanical pump measuring devices for commercial shops and for those who desire the convenience that these devices provide.

Our white plastic plunger pumps fit on the one, 2.5 and five-gallon containers. For those buying in quarts we offer an empty one-gallon jug for pump attachment. These pumps are the kind that you find at the ballpark and use 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.

The Model A dispensing pump is designed for those who use one to six fluid ounces frequently and like a portable device. It is too slow to meter out frequent large batches. This pump is very accurate and dependable when properly maintained.

Be aware that 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 using the other measuring methods described above.

Epoxy systems can be measured by weight as well as volume. The correct ratios are shown in Appendix F. Don't make the mistake of using the volume ratio when measuring by weight. Because the hardener is less dense than the resin you'll use too much hardener and get an incomplete cure.

Large batches (a quart or more) are most efficiently measured by weight. A good five-pound postal scale is usually accurate enough for the larger batches. An O'Haus triple beam balance will allow for the accurate weighing of batches from as little as a few grams to over 5.5 pounds at a cost comparable to the Model A pump.

With the resin and hardener accurately measured, mix thoroughly. 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.

Don't make large batches. 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 a half-gallon batch. 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 acetone, MEK, or 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 epoxy is not at fault.

Accurately measure resin and hardener in the same container, use a total of three to six fluid ounces. 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 Appendix C for System Three epoxy or the specific data sheets for the other systems 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 must be in the way you measured and mixed the batch that gave the trouble.

If, after all this, you remain convinced that "something is wrong with the epoxy", call us. We'll talk you through the problem. Keep in mind that we have tested the batch you are using and lots of other builders are using material from this same batch. In over 20 years we have yet to see a case where the epoxy went bad.

SECTION VI
TECHNIQUES OF EPOXY USE

Four epoxy application techniques are commonly used in boat construction and repair. These are coating, fiberglassing, gluing, and filleting/fairing. Furthermore, the techniques are pretty much the same whether they are involved in new wooden boat construction and repair or fiberglass boat repair including gel coat blister repair. After all, coating with epoxy involves the same technique and tools regardless of whether the substrate is wood or fiberglass.

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 the whole boat 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.

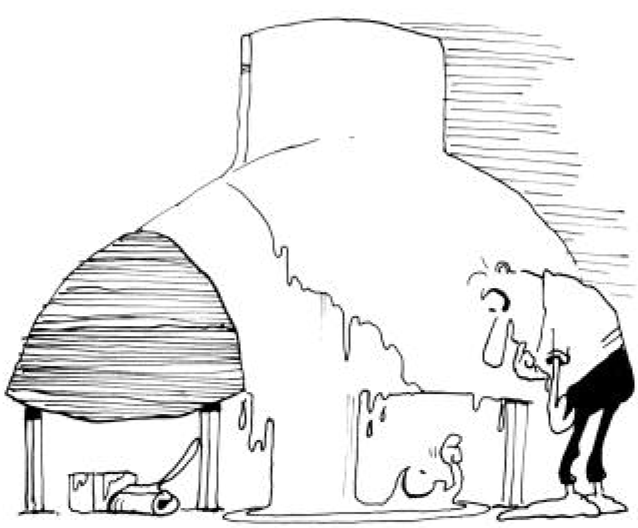
Suppose that you are staining a piece of fir that will later be coated with epoxy and have another piece laminated to it. First, stain a scrap piece of the same wood; allow it to dry well (several days). Laminate on two pieces of 3 or 4-inch wide fiberglass tape about five inches long. Leave a "tail" 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 System Three epoxy with plywood, a common boatbuilding material. Where appropriate we will mention the use of our other epoxy systems. The sections following this will discuss modifications of the four techniques for specific areas of wooden boat building and fiberglass boat repair. 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 kind of boat you have.

SECTION VI A
COATING WITH EPOXY RESIN

Wood is coated with epoxy to stabilize the moisture content and provide a moisture barrier, which helps to prevent the passage of moisture. System Three epoxy has a certain amount of flexibility and tough resilience built into the formulation. Because of this, wood can be coated on the bench, then bent into place on the boat 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, all ready for painting. Coating a 4'x8' sheet of fir plywood will illustrate this method:



Mix the resin and hardener in the correct ratio, referring to Appendix D 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.

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.

Use at least two coats for interior wood and three in areas that may be constantly wet, such as bilges. White epoxy paste pigment is a nice addition to an epoxy coating to improve the visibility in bilge areas. Unlike paint it will not flake off.

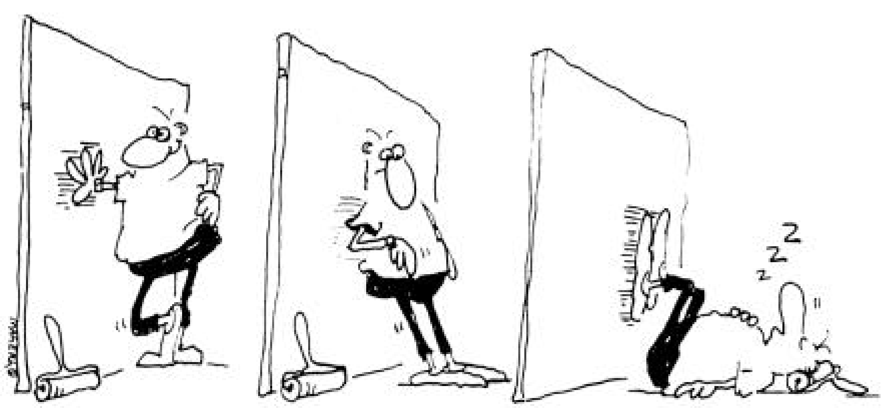
Several tricks can be used to improve the appearance of the finished film. Bubbles that persist in the coating can be broken with a foam brush by lightly dragging it across the surface. Fanning the uncured surface with a hot air gun or hair dryer will accomplish this with greater speed. Avoid overheating 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.

System Three epoxy will bond to wood and cure in thin coatings in cold, damp conditions without any special tricks, but giving it an induction period will help speed things along. After mixing the resin and hardener allow the mix to sit in the pot for a few minutes, just until it begins to feel slightly warm. Then apply it in the usual manner. The use of a hot air gun will help level a cold epoxy coating but is not necessary to aid in the cure.

After 24 to 48 hours (depending upon temperature and hardener used) the coating will be cured enough to sand. First wipe the surface with a damp sponge to remove any water-soluble amine carbamate surface film prior to sanding. At this stage of cure the epoxy coating can usually be sanded with a disc sander and a big foam pad starting with 60 grit paper. Disk 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.



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. Evening dew condensation does not harm the partially cured System Three epoxy coating.

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 awhile. 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.

Clear Coat epoxy can also be used for coating wood. 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 System Three epoxy.

System Three 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 epoxy 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. Mixed resin/hardener may be thinned with up to ten percent acetone, MEK or other suitable solvent to improve brushing. The use of these 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 System Three epoxy for gluing or fiberglassing.

Clear Coat epoxy is also used as a base for varnish but has several differences from System Three epoxy in this application. First, it is thinner and can be easily brushed with out adding solvents. Second, it is much slower affording longer working time but at the expense of a longer cure time. Third, it produces no amine blush. Fourth, it soaks into wood much better. Like System Three epoxy it does not need to be sanded if recoated within two or three days. Unlike System Three epoxy it is significantly more sensitive to moisture during cure and 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.

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. See Section VII before painting or varnishing an epoxy coating.

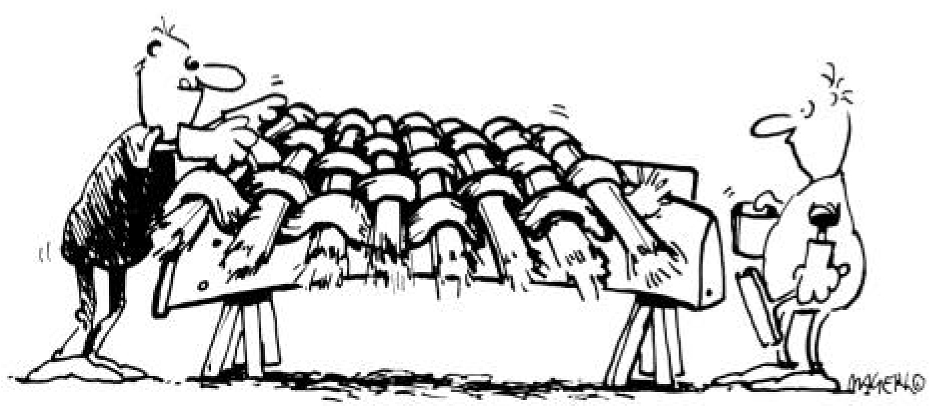
Materials Required for Coating:

Epoxy resin and hardener	Foam roller covers and frames
Measuring device	Plastic squeegees
Protective gloves	Brushes, foam and bristle

SECTION VI B
FIBERGLASSING WITH EPOXY RESIN

Outside surfaces of boat hulls which are epoxy coated usually use fiberglass or other woven cloth material as a reinforcement, or substrate, allowing a thicker, stronger epoxy coating which results in higher abrasion, impact and moisture resistance. In the case of most wooden boats the purpose of this reinforcing cloth is to strengthen the epoxy coating, not to reinforce the hull.

Some small, dry-sailed hulls made from plywood other than fir won'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 the outside or the plywood may check and crack the epoxy coating.



System Three epoxy has all but replaced polyester resin 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. One of our own boats, a 34-foot fir plywood/epoxy trimaran, has only two layers of 4-ounce cloth below the waterline and one above. The decks and cabin top, which get a lot of foot traffic, have only one layer of 4-ounce cloth. This boat has seen over ten years of extended offshore service and the glass/ epoxy coating is in excellent condition. Don't use a 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 run with System Three epoxy 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 clear epoxy resin. Heavier weight cloths begin to show the weave pattern under certain lighting conditions.

Avoid using fiberglass mat with epoxy resins. The binder that holds the mat together is designed to be dissolved by the styrene in polyester resins. Boatbuilding epoxies don't use styrene as a diluent, making it almost impossible to wet out the mat. Woven roving is wet out well by epoxy although 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 in 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 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. We now recommend against using 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.

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 a fair amount of pressure to squeeze the excess resin away from the wet cloth, working it down into the dry cloth area. This 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 state" 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 may be 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 allover 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. It is possible to thicken the epoxy slightly and do it in one coat using a squeegee. Silica thickener (Cab-O-Sil) works best but 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 boat over or at least work 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 too much resin is not 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 as smoothly as possible onto 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. When it is all smushed down, 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 chines and sheers 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 our 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. With 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 bright finished seams. Rather than feather edge biaxial tape by sanding we prefer to fair the edges using an epoxy/microballoon mixture.

In summary, fiberglassing is a three step process:

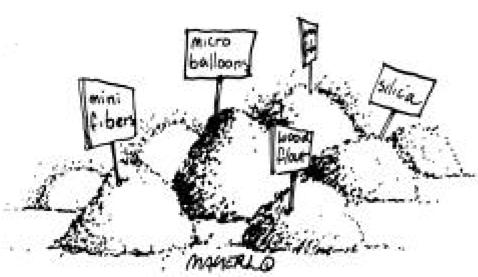
1. Seal the wood to prevent starving the wood/cloth joint. Do filling and fairing on the sealed wood.

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

Epoxy resin and hardener	Foam roller covers and frame
Fiberglass cloth	Thalco (rubber) squeegee
Measuring device	Protective gloves, dust mask
Silica Thickener	Trimming knife
Microballoons	Sandpaper



SECTION VI C
USING FILLERS WITH EPOXY RESIN

System Three epoxy properly mixed is intended for both coating and fiberglassing. When used “right out of the jug”, the mixture is said to be "unfilled" and it is too thin to be used as a gap filling adhesive or for fairing and filleting compounds. For these applications certain fillers are added. These materials change the flow and density characteristics of the epoxy system.

All fillers sold for use with System Three epoxy products are solid materials, falling 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 is both fibrous and acts also as a thixotropic agent.

Silica thickener (Cab-O-Sil), plastic minifibers and wood flour are thixotropic agents. They turn the epoxy into a thixotropic fluid. Most people are not familiar with the term "thixotropic" though everyone is familiar with the properties of these fluids. They flow under shear stress but do not flow once the stress is removed. Ketchup and latex house paints are thixotropic fluids. Adding these agents to the mixed resin and hardener produces a fluid which will easily flow under the spreading stress of a putty knife. Once the stress is removed the thickened epoxy retains shape. In short, these fillers make the epoxy non-sagging, being added to restrict drainage and 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 make it thixotropic. Attempting to add sufficient microballoons or microspheres to make a non-sagging fairing putty will result in one that spreads poorly. 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), graphite powder, and aluminum powder are generally used by boatbuilders as pigments. Graphite powder added at high loading levels (25%) to coatings, which are then sanded, is claimed by some to produce a "slick" racing finish due to the lubricating qualities of the graphite. We have no data on this and caution potential users to be aware that graphite is a conductive material and could cause electrolysis problems under the right circumstances. Addition of small amounts of aluminum powder will produce a gray epoxy and in larger amounts will improve the machineability of the resin. Adding white paste pigment produces a white resin coating that is useful for bilges and other areas 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 is useful when added to the final fill coat when fiberglassing, allowing this coat to serve as a cover 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 a stable pigmented resin. The amount of the pigmented resin is used to determine the amount of hardener required. Used in very small amounts these pigments are transparent in an epoxy and can be said to act as dyes. In larger amounts they are opaque.

These fillers, pigments and additives may be used with Clear Coat and Phase Two epoxy. Higher filler loading levels are possible with Clear Coat epoxy because it is much lower in viscosity than System Three epoxy. Except as a fill coat for fiberglass, Phase Two is rarely pigmented.

Fillers change the mechanical properties of the cured resin, however for all practical purposes these changes can be ignored by the builder. 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.

Numerous 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.

This is a 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 VI D
EPOXY RESINS AS STRUCTURAL ADHESIVES

The mixed viscosity of System Three epoxy is not high enough to make a good gap filling adhesive. Thixotropic agents like silica thickener (Cab-O-Sil), 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 routinely used in an adhesive formulation as they reduce tensile strength. Quartz microspheres may be used as a filler/thickener for cold molding where the surface area to be bonded is large with respect to the mass. Microspheres are acceptable here because of the large glue surface area involved and the low microsphere loading level.

Making an epoxy glue joint is quite simple. 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 to be glued and close up the joint. That's all there is to it. But 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 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. Before 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 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 utilized to do this holding job. Clamp just hard enough to close up the joint.

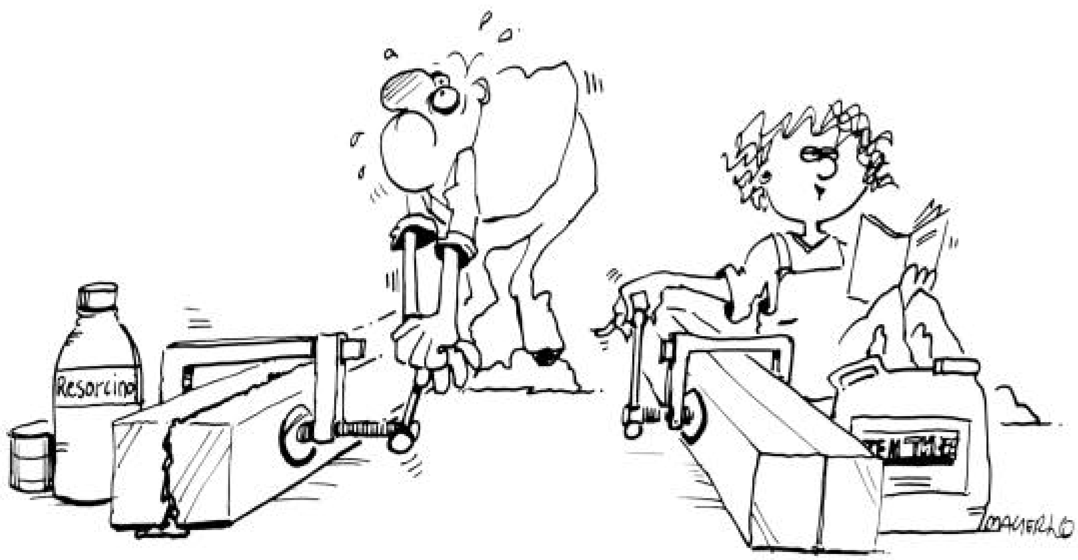
Fourth, remember that epoxy resins continue to cure and build strength for several days after they solidify. Joints that will be under immediate stress once they are unclamped need more cure time before the clamps are removed. Overnight cures are usually sufficient for most non-stressed joints. A common cause of epoxy joint failures is too much stress before the epoxy has reached sufficient strength. Such a case might occur where a scarfed sheer clamp is bent into place too soon. One or more of the scarf joints might open up.

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. Protecting the joint by epoxy coating all surfaces of the glued wood stops the moisture cycling and prevents failure because of weathering. This is not a problem for wood glued with epoxy that will not be subject to deep moisture cycling.

Most woods can be successfully bonded with System Three epoxy. Teak is not difficult to bond but could debond if allowed to moisture cycle. When epoxy gluing a teak on plywood 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 weather.

System Three epoxy is specifically designed for use as an adhesive for wood to wood and fiberglass cloth to wood bonds. When we are asked if it can be used to bond metals and plastics the general answer is that it depends on the materials involved and their intended use.

Metal to metal bonding success depends upon the type of metals bonded, the surface preparation, and the intended service temperature. Generally, we recommend against making structural metal-to-metal bonds with boatbuilding epoxy resins. Our testing shows that these bonds degrade over time due to differential thermal expansion rates setting up shear stress and resultant interfacial failure. For non-structural applications the flexible mastic materials appear to hold better than the more rigid epoxies as they better allow for thermal expansion.



Metal to wood bonding for non-structural applications may be done successfully with System Three epoxy providing that the metal is clean and bright. Structural applications are best when they are mechanically fastened. Don't pot stainless steel bolts in epoxy resin. 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 System Three epoxy so long as the lead is bright and free of oxidation.

Thermoplastic materials like vinyls or ABS generally bond poorly with epoxy resins. If you need to bond any of these test them yourself. You will get the best results if you first sand the plastic with coarse paper. Epoxy will not bond to polyethylene, polypropylene, or Teflon. It bonds well to neoprene and polyurethane rubbers.

Epoxy resins usually bond well with cured thermoset materials like polyester, vinyl ester, and other epoxy resins as long as the cured surface is sanded and wax free. However, you should not try to bond polyester, vinyl ester, or other polymeric materials which are cured with MEKP or other peroxide “Catalysts” to cured epoxy resins with the exception of SB-112.

There are too many materials and combinations to cover every possibility. We suggest that you 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 on your boat. You have the ultimate responsibility for your own work.

Sometimes there's a need for a clear gap filling thickened epoxy. It's not possible to produce such a material using any of the solid thixotropic agents previously discussed. Our T-88 Structural Adhesive is handy for this since it is clear and thick. There is also a way to do this, however, by using System Three epoxy and hardener alone. The technique is to perform a partial cure before applying the glue by using an insufficient amount of hardener. This reaction produces a "thick" epoxy to which the balance of the required hardener is added when the gluing is to be done. The method is best illustrated by example:

Pour six fluid ounces of resin into a suitable container. Normally, you would add three ounces of hardener to produce a complete cure. In this case add one ounce only. Stir well then wait for the reaction to run to completion and allow the material to cool about an hour at normal temperatures. Now all you need to add is two more ounces of hardener to complete the reaction. Seven ounces are in the cup - six of resin and one of hardener. Thus, the correct ratio for a complete cure is now 7:2. The material in the cup is very thick but will thin somewhat with the addition of the hardener. Add the remaining two ounces of hardener or use it in the 7:2 ratio.

This method has potential for confusion. It is useful in that a pre-reacted batch may be made well in advance and used as needed. In addition to gluing it can be used to fill dings in bright finished boats.

As stated, T-88 accomplishes the same thing avoiding all the above chemistry. Plus it is used in a 1:1 volumetric mixing ratio. Pot life for T-88 glue is about like System Three epoxy with Slow Hardener (#3). However, it cures at about the same speed as Medium Hardener (#2).

Quick Cure is our 1:1 "five minute" epoxy. Items glued with Quick Cure can be stressed in as little as 10 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 System Three epoxy as a "spot welder" where clamping is all but impossible.

Coat the pieces to be bonded with thickened System Three epoxy 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 System Three epoxy 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.

Materials Required for Bonding

Epoxy Resin and Hardener	Brushes, spreading tools
Silica Thickener or Mini Fibers	Sandpaper

SECTION VI E
FILLETING, FAIRING, AND MOLDING WITH EPOXY RESINS

System Three epoxy is 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. Rather than supply these compounds in a premixed form, we supply the raw materials so that builders are allowed the versatility of creating customized compounds to fit a specific need.

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.

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 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 to the axis of the corner. Allow the putty to cure and do a final sanding. That's it! Perfect fillets in two easy steps with little sanding.

Before microballoons are painted they should be sealed with epoxy or else the paint goes into the tiny hollows in the broken balloons and the finish will appear ragged. Brush or roll on a coat of epoxy on the sanded balloons. Use either Clear Coat or System Three epoxy which has been thinned with about 10% acetone or MEK 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 they 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. If they aren't going to show in the finished boat there really is no need to make them pretty. 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 be covered by the fillet.

Fillets in sewn seam construction usually are 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 hull to the level of the high spots, eliminating waviness and hollows. 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 large 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. 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 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. 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 an epoxy/microballoon/silica thickener mix to fair them in with the cabin top.

Materials Required for Fairing, Filleting

Epoxy Resin and Hardener	Spreaders
Microballoons /Microspheres	Sandpaper
Silica Thickener	

SECTION VII
PAINTING AND FINISHING

A. General Painting Information:

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

System Three 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 ultraviolet (UV) light. 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 System Three epoxy start after about six months of intense tropical sunlight on horizontal surfaces. Total breakdown will occur after about 15 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 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 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 System Three epoxy with these paints is quite helpful for several reasons.

Besides bottom paint, three broad classes of coatings are commonly used as boat paints. These are the "one part" alkyd and modified alkyd enamels commonly called "oil base paints", the "two part" epoxy and the two part linear polyurethane

(LPU) paints. Since all epoxy based materials eventually chalk in sunlight be careful to consider exposure when using the two-part epoxy paints for exterior finish coats. Two part epoxy primers are recommended as high build sanding base primers for LPU paints.

Be sure that you are getting what you expect when purchasing a marine paint. Paints sold in marine stores today are a triumph of marketing over technology. Remember the adage: "The big print giveth while the small print taketh away." It is not uncommon to see the pretty face of 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 about two to three times what an alkyd costs. If the ingredients are not specified on the can, then ask for an MSDS on the paint.

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. The solvent based LPU paints contain some very toxic materials and are difficult and touchy to apply. They can turn dull when curing if the humidity is too high. We believe that the application of the solvent based LPU paints are beyond the skill of most boatbuilders to properly apply and get good results.

Because of the ultra high gloss of LPU paints any imperfection in the substrate will show in the finished coating. Thus, 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 the boat is perfect and you are willing to spend the time and care required to use LPU paints, she'll even be more beautiful.

Use any color you want so long as it is light. If you paint with a dark color and use the boat in the summer sun you are going to experience a number of problems especially if it is a wood boat. First, you'll get "print through". This is the telegraphing of the cloth weave pattern to the glossy painted surface. Second, you 'II 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.

Except for our own painting system "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 their 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" 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.

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 cellophane 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 boat with confidence.

By this time 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.

B. Our Recommendation:

Having scared you half to death about paints we'll now tell you the simple way to do it: Use System Three Resins water reducible epoxy primers 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, and they don't cost any more than any other paint.

Here’s how to do it:

Sand the System Three epoxy enough to kill the gloss. Brush the dust off and wipe it with a damp paper towel to remove final traces of dust. Apply a coat of System Three primer and allow it to dry. The primer may be applied by brushing, rolling or spraying. Depending upon weather and coating thickness this will be about 2 hours. Apply a second coat if a higher build is needed. Allow to cure for 24 to 48 hours. Sand down to a fair surface and finish with 320 grit paper. The primer sands very easily.

When you are satisfied that the surface meets your expectations remove the dust as above and apply a thin coat of System Three LPU Topside Paint - again by brushing, rolling or spraying. You may want to apply several coats if you see minor scratches in the primer showing through the topcoat. The LPU Topside Paint will dry to touch in about 30 minutes and cure over the next several days to a hard, mar resistant semi-gloss finish. Want that high gloss "wet" look? Apply a coating of System Three LPU Clear over the pigmented Topcoat and it's yours.

There you are. We've made it that simple. No intercoat compatibility or adhesion problems. We like this system so much that we've all but stopped the lab work on painting systems produced by others. So if you still want to use XYZ Brand paint on your boat you are on your own, as we won't have any better idea about its suitability than you.

SECTION VIII
AREAS OF EPOXY USE

In the Introduction we stated that it is not a book about boat construction and repair. While that is true, we believe that the unit operations of epoxy use described in Section VI will have more meaning if the prospective user can relate the techniques described to types 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. We also sell books and our catalogue describes these.

SECTION VIII 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

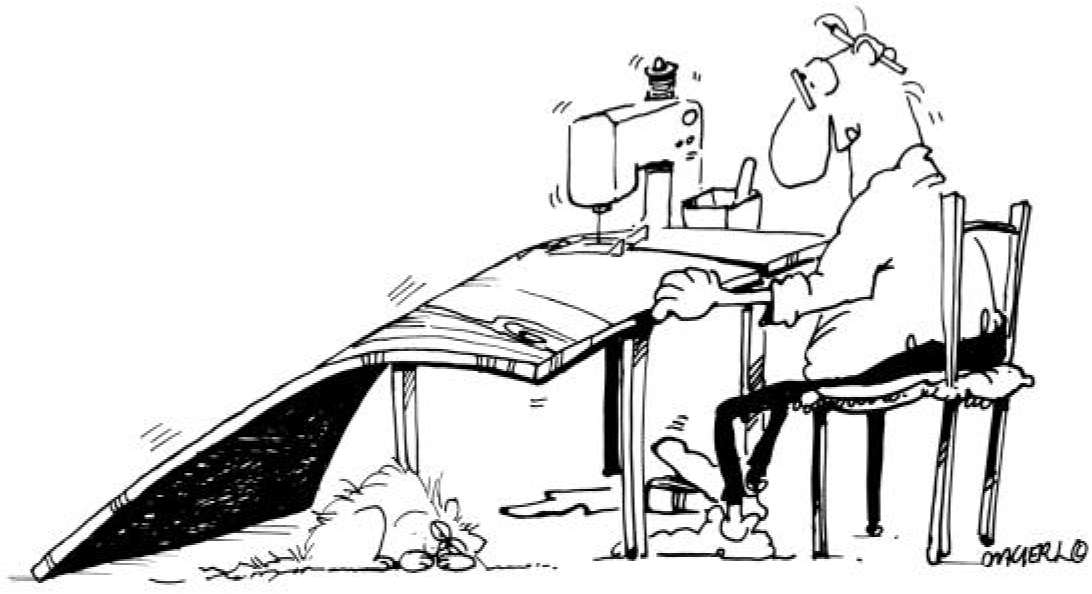
Plywood was probably first used in this type of construction which came along even before epoxy and polyester resins were developed. This is a simple and straightforward method of boatbuilding.

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 mounted 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 (with pigmented resin?) 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 and wood flour 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).

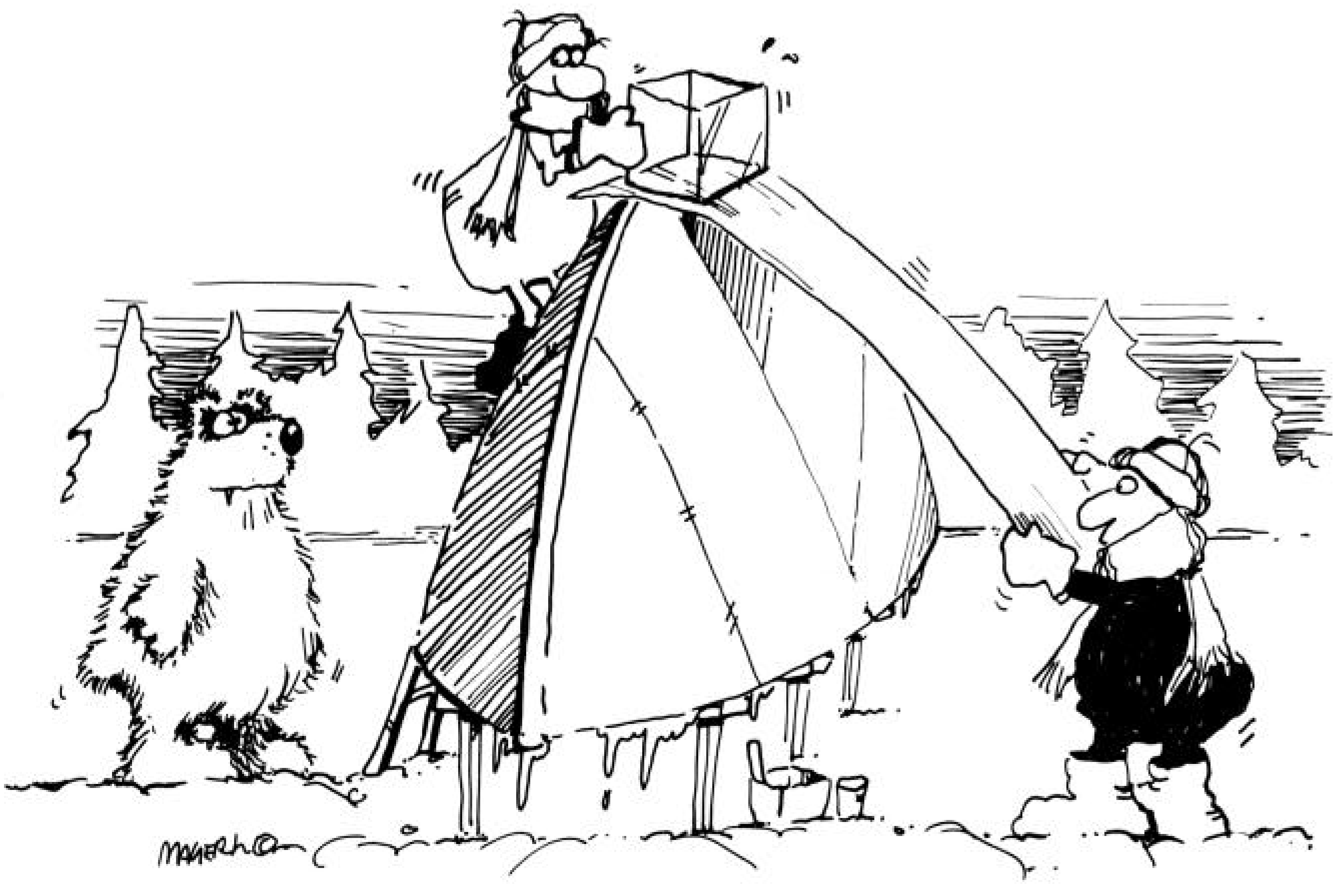
Except for scarfing and edge gluing not much epoxy is used in strip planking until the hull is completed. One neat trick when canoe building is to use Quick Cure to glue the butt ends to the side strips when closing the "football". The outside of a strip-planked boat is faired and fiberglassed before taking the hull off a male mold. In female molding the inside may be fiberglassed 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 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 several 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 fiberglassed 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 VIII 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 VIII 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 post cured. 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 its 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".

SECTION VIII D FIBERGLASS BOAT REPAIR

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 tilling 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.

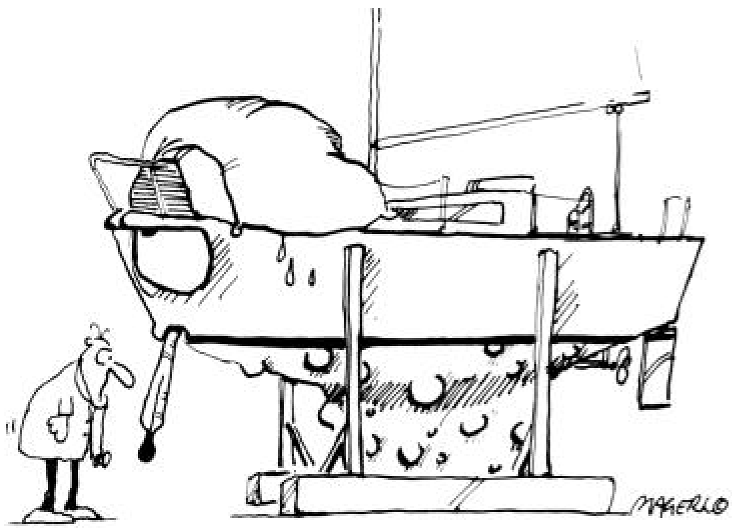
If, for example, a boat owner discovers that some fiberglassed in wood engine stringers are rotting; it will be necessary to pull the engine to affect a repair. Do this and then poke around to see the extent of damage. Don't get out a grinder and start hacking away at the fiberglass in an effort to remove 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. We list several in our catalog. 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!

Gel Coat Blister Repairs

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 has, 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 boottop 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 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 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 boottop 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 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 VIII 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 formulating and students of boat building and repair. We don't pretend to even know what the physical requirements should be for epoxy resins used in these other areas. Most of the use in non-marine areas comes as a result of someone who got hold of our product and was brave enough to try it. 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 IX
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.

Problem: The System Three epoxy has turned hazy and has white material in the bottom of the jug.

Cause and Solution: The epoxy is crystallizing due to storage at too low temperature. See Section III.

Problem: The epoxy isn't curing.

Cause and Solution: It was mixed at the wrong ratio. Resin was mixed with resin or vice versa. Remove the uncured material thoroughly by scraping and solvent washing. Mix at proper ratio and reapply.

Problem: The epoxy keeps going off in the pot.

Cause and Solution: The batch is too big or left too long in the pot. The hardener is too fast for the conditions. Use a smaller batch and get it out of the pot sooner. Change to a slower hardener.

Problem: The epoxy is still gummy.

Cause and Solution: The ratio was wrong. It was inadequately mixed. Not enough time has elapsed at the curing temperature. Make sure that the gumminess is not just the amine blush. Wait and see if the cure proceeds. Apply some heat if possible. If it is still gummy then remove the uncured material thoroughly by scraping and solvent washing. Mix at proper ratio and reapply.

Problem: The epoxy is hard but it clogs the sandpaper.

Cause and Solution: Remove the amine blush. Wait a few more hours for further curing. Use a coarser grit paper or use wet/dry paper with water.

Problem: The top surface of the epoxy coating turned white.

Cause and Solution: It got wet from dew or rain too soon. Apply heat and the whiteness will probably disappear. If not, remove by sanding.

Problem: The glue joints came apart.

Cause and Solution: Too much clamping pressure was used. No filler was used in the epoxy. The joints were stressed before sufficient curing. Use less pressure. Use some filler. Leave the part clamped longer especially if it will be under stress when removed.

Problem: The fiberglass cloth didn't go clear.

Cause and Solution: The type of cloth is wrong. Buy the cloth from us or use an epoxy compatible cloth with a looser weave.

Problem: The paint/varnish won't dry.

Cause and Solution: The wrong type of paint is being used. Read the section on painting to understand and correct the problem.

Problem: Only part of my order arrived.

Cause and Solution: UPS and the Post Office treat each package as a separate shipment. Wait a day more for UPS and longer for the Post Office and then if it doesn't arrive call us on the toll free number.

Problem: I called the toll free number for technical help but couldn't get any.

Cause and Solution: The toll free number is for orders only. Call the technical number for support. We don't price the product for toll free technical support. Most people find the answers they seek in *The Epoxy Book*.


BON VOYAGE FROM
SYSTEMTHREE
MAHERL©

Appendix A
TYPICAL PHYSICAL PROPERTIES*
SYSTEM THREE EPOXY RESIN

MECHANICAL PROPERTIES

Test Method		
ASTM D 638	Tensile Strength, psi	7,500
ASTM D 638	Tensile Elongation, %	11
ASTM D 638	Tensile Modulus, psi	325,000
ASTM D 790	Flexural Strength, psi	12,500
ASTM D 790	Flexural Modulus, psi	350,000
ASTM D 695	Compressive Strength, psi	
	at Yield	12,000
	at Failure	26,000
ASTM D 648	Heat Deflection Temperature, °F	123
	Hardness, Shore D	75
	Water Extractables Content, %	<0.1

TOUGHNESS PROPERTIES

Fracture Toughness, lbs. Inch	850
Critical Strain Energy Release Rate, joules/meter^2	790

PHYSICAL PROPERTIES

	Density, #/gal.	Viscosity, cps
Epoxy Resin	9.14	550
Hardener #1	8.17	1,100
Hardener #2	8.12	900
Hardener #3	7.91	350

Nominal mixed density 8.8 #/gallon
Nominal mixed viscosity 750 cps

* All samples cured for 14 days at 77°F (25°C) prior to testing. Density measured at 68°F, viscosity at 77°F. These numbers are representations, not specifications.

Appendix B
GEL TIMES OF HARDENER BLENDS*

Blend Composition		**Minutes at 77°F**		
% Faster Hardener	**% Slower Hardener**	**1 & 2**	**1 & 3**	**2 & 3**
80	20	16	21	39
60	40	19	32	45
50	50	22	44	51
40	60	26	53	57
20	80	28	61	64

* 100 grams of mixed resin/hardener (about 3 fluid ounces)

Appendix C
GEL TIMES AT VARIOUS TEMPERATURES*

°F	**°C**	**Hardener #1**	**Hardener #2**	**Hardener #3**
35	2	90	NR	NR
40	4	72	NR	NR
45	7	60	NR	NR
50	10	50	>120	NR
55	13	41	92	NR
60	16	33	69	>120
65	18	28	56	106
70	21	22	44	89
75	24	18	35	74
77	25	15	30	70
80	27	14	28	61
85	29	12	24	49
90	32	10	20	41
95	35	8	16	35
100	38	6	13	30
105	41	5	11	26
110	43	4	9	21

* 100 grams of mixed resin/hardener (about 3 fluid ounces) cured at the temperatures indicated.

NR = Not Recommended for use at the indicated temperatures.

Appendix D
ESTIMATING USAGE

The following will serve as a guide for estimating the amount of epoxy 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.

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

Gluing Wood ounces of filler per gallon of mixed epoxy to make:	**Silica Thickener**	**Mini-Fibers**	**Wood Flour**
Thixotropic Fluid	4.3	3.0	14.0
Soft Paste	6.3	5.8	29.0
Firm Paste	9.6	10.1	40.0
Density of Firm Paste (lb./gal.)	7.4	6.4	7.5
Original Gallon Becomes	1.32	1.53	1.67

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 epoxy per 100 square feet of glue surface area. Both surfaces wet out, silica thickened epoxy applied to one surface. High pressure includes vacuum bagging while low pressure includes stapled veneer, loose joints, etc. One mil equals .001 inch or ¼ millimeter.

Filleting/Fairing

Per gallon of mixed epoxy:

Microballoons	1.1 pounds
Silica Thickener	0.4 pounds

Makes 2.4 gallons of putty compound

Per gallon of putty compound:

Epoxy resin	0.3 gallon
Hardener	0.15 gallon
Microballoons	0.46 pounds
Silica Thickener	0.17 pounds

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.

Appendix E
RECIPES USING FILLERS

Basic Glue

1. Properly measure and mix resin and hardener.

2. Add silica thickener, minifibers, or wood flour to mixed resin and hardener to get the proper consistency for your application. The more you add the stiffer the mix will be and the lower the ability of the glue to wet out the surfaces being glued. With really stiff mixes it is best to brush or roll on some unfilled epoxy mixture to wet the surfaces being glued.

NOTE: Be aware of the potential poor gluing characteristics of unfilled low viscosity epoxy systems. This occurs because the epoxy is often leached out of the glue joint as it penetrates the surface being glued. If you wish to use an unfilled epoxy then be sure that the joint has absorbed all it can.

Fairing/Filleting Compound

1. Properly measure and mix resin and hardener.

2. Mix in stages 1.5 to 3 times the volume of above phenolic microballoons or quartz microspheres. The more you add the less dense the compound will be and the stiffer it will become. At this stage the material should be thick but still flow.

3. Add silica thickener to stiffen the compound up to suit your application.

Structural Filleting Compound

1. Properly measure and mix resin and hardener.

2. Add chopped or milled glass fibers (milled will make a smoother fillet). Mix well and allow epoxy to wet out the glass. Up to a point the more glass added the stronger the compound will be and the more ragged it will look.

3. Add silica thickener to prevent resin drainage.

Appendix F
EPOXY SYSTEM MIXING RATIOS

Epoxy System	Hardener to use per 100 parts of resin By Volume	By Weight
System Three epoxy	50 (2:1)	43
Phase Two epoxy	40 (5:2)	33
Clear Coat epoxy	50 (2:1)	44
SB-112	50 (2:1)	44
Quick Cure epoxy	100 (1:1)	95
T-88 Structural Adhesive	100 (1:1)	88

Appendix G
METRIC CONVERSION TABLE

	American	Metric
Length	1 mil	0.0254 millimeters
	1 inch	2.54 centimeters
	1 foot	30.48 centimeters
	1 yard	0.9144 meters
Area	1 square inch	6.45 square centimeters
	1 square foot	929 square centimeters
	1 square yard	0.8361 square meters
Mass	1 ounce	28.35 grams
	1 pound	0.455 kilograms
Volume	1 fluid ounce	29.57 milliliters
	1 cup (8 fl. Oz.)	237.6 milliliters
	1 quart	946.4 milliliters
	1 gallon	3.785 liters
Mixed	1 pound/in^2	70.31 gram/square cm
	1 pound/gallon	0.1198 kilograms/liter
Temperature	Celsius = 0.555555(Fahrenheit - 32)	

MATERIAL SAFETY DATA SHEET

System Three Resins, Inc. 3500 W. Valley Hwy N; Suite 105 Auburn, Washington 98001

SECTION I - PRODUCT IDENTIFICATION

Product Name: **System Three Epoxy PART A**
MSDS Number: 20007

Previous Revision: 3/1/00	Date of Prep: August 18, 2000	**Hazard Ratings:**
Product Type: Epoxy Resin Mixture	Reason Revised: Address Change	**Health 2**
24-Hr. Emergency Phone:	Information: 253-333-8118	**Fire 1**
CHEMTREC: 1-800-424-9300	Prepared By: B. Cowman	**Reactivity 0**

SECTION II - HAZARDOUS INGREDIENTS/IDENTITY INFORMATION

HAZARDOUS COMPONENTS	AMOUNT	CAS NUMBER	OSHA PEL	ACGIH TLV
Diglycidyl Ether of Bisphenol A (DGEBPA)	> 70%	25068-38-6	none established	none established
Alkylglycidyl Ether	< 30%	68081-84-5	none established	none established

SECTION III - PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling Range: not applicable
Vapor Density: Heavier than Air
Evaporation Rate: Slower than Ether
Appearance and Odor: Liquid or paste with little or no odor.

Specific Gravity: 1.1-1.3
Material V.O.C.: None
Water Solubility: Negligible

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

Flash Point: > 300°F
Method: Pensky-Martens Closed Cup
Flammable Limits in Air By Volume - Lower: N/A Upper: N/A
Extinguishing Media: Foam, Carbon Dioxide, Dry Chemical, Water Fog

Special Firefighting Procedures: When fighting chemical fires wear full protective equipment with self-contained breathing apparatus. Water spray may be used to cool fire-exposed containers. Toxic fumes may be evolved when this substance is burned.

SECTION V - REACTIVITY DATA

Stability: Stable.
Incompatibility: Strong oxidizing agents, Lewis and mineral acids.

Hazardous Decomposition Products: Oxides of carbon, aldehydes, acids
Hazardous Polymerization: Will not occur.

Conditions to Avoid: Epoxy resins and epoxy resin hardeners react with each other producing heat. They should not be mixed with each other under uncontrolled conditions or in large mass as the ensuing exotherm may result in heat and smoke resulting in hazardous decomposition products.

SECTION VI - HEALTH HAZARD DATA

EFFECTS OF OVEREXPOSURE:
Acute: Slightly irritating to skin, moderately irritating to eyes. Odor may irritate nose, throat and respiratory tract of some persons.
Chronic: May cause skin sensitization from prolonged and repeated contact.
Carcinogenicity: Early studies with DGEBPA have been negative. The IARC concluded in 1988 that DGEBPA was not classifiable as a carcinogen.

System Three Epoxy PART A (continued)

EMERGENCY AND FIRST AID PROCEDURES:

Eyes: Flush with water for 15 minutes holding eyelids open. Seek medical attention.

Skin: Remove contaminated clothing and shoes and wipe excess off skin. Flush skin with water. Follow by washing in soap and water. If irritation occurs, seek medical attention. Do not reuse clothing until cleaned. Contaminated leather articles (shoes) cannot be decontaminated and should be destroyed.

Inhalation: Remove victim to fresh air and provide oxygen if breathing is difficult. Give artificial respiration if not breathing. Get medical attention.

Ingestion: Do not give liquids if victim is unconscious or very drowsy. Otherwise, give no more than 2 glasses of water and induce vomiting by giving 2 tablespoons syrup of ipecac (1 tablespoon and 1 glass of water for child). If ipecac is unavailable, give 2 glasses of water and induce vomiting by touching finger to back of throat. Keep head below hips while vomiting. Get medical attention.

Medical Conditions Generally Aggravated by Exposure: Other than skin sensitization which appears to be permanent, epoxy resin does not appear to cause long term health effects. Nor, does it appear to aggravate other medical conditions.

SECTION VII - PRECAUTIONS FOR SAFE HANDLING AND USE

If Material is Spilled: Avoid contact with material. Persons not wearing appropriate protective equipment should leave the area of the spill until cleanup is complete. Stop spill at source, dike area to prevent spreading, pump liquid to salvage tank or drum. Remaining liquid may be taken up on clay, diatomaceous earth, sawdust, or other absorbent, and shoveled into disposal containers.

Waste Disposal Method: Waste is not hazardous by RCRA criteria (40 CFR 261). Place in an appropriate disposal facility in compliance with local regulations.

SECTION VIII - SPECIAL PROTECTION INFORMATION

Respiratory Protection: Normally none is required when adequate ventilation is provided. In the absence of proper environmental control NIOSH approved respiratory is required. For emergencies, a self-contained breathing apparatus or full-faced respirator is recommended.

Ventilation: Provide adequate ventilation in work areas. Confine material in sealed containers when not in use.

Hand Protection: Always wear impervious gloves, neoprene, vinyl or rubber.

Eye Protection: Splash proof goggles or safety spectacles with side shields are recommended. Always wear eye protection when sanding cured epoxy resins to avoid dust in eyes.

Other Protective Equipment: Wear clean, body-covering clothing to avoid skin contact.

SECTION IX - TRANSPORTATION REQUIREMENTS

Department of Transportation Classification: Not Hazardous

D.O.T. Proper Shipping Name: Not Regulated

Other Requirements:
This product contains no toxic chemicals subject to the report requirements of Section 313 of the Emergency Planning and Community Right-To-Know Act of 1986 and of 40 CFR 372.

M A T E R I A L   S A F E T Y   D A T A   S H E E T

System Three Resins, Inc. 3500 W. Valley Hwy N; Suite 105 Auburn, Washington 98001

SECTION I - PRODUCT IDENTIFICATION

Product Name: **System Three Hardener #1, Hardener #2, Hardener #3 PART B**
MSDS Number: 20001

Previous Date of Prep: 3/1/00	Revision: August 18, 2000	**Hazard Ratings:**
Product Type: Epoxy Hardener	Reason Revised: Address Change	**Health 3**
24-hour Emergency Phone:	Information: 253-333-8118	**Fire 1**
CHEMTREC: (800) 424-9300	Prepared By: B. Cowman	**Reactivity 0**

SECTION II - HAZARDOUS INGREDIENTS/IDENTITY INFORMATION

HAZARDOUS COMPONENTS	AMOUNT	CAS NUMBER	OSHA PEL ACGIH TLV
Modified Aliphatic Amines (Mixture is trade secret)	50-70%	--------	none established
Nonyl Phenol	30-50%	25154-52-3	none established

SECTION III - PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling Range: N/A
Vapor Density: Heavier than Air
Evaporation Rate: Slower than Ether
Appearance and Odor: Light amber liquid with ammonia-like odor.

Specific Gravity: 0.97
Material V.O.C.: None
Water Solubility: Negligible

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

Flash Point: > 250F° Method: Pensky-Martins Closed Cup
Flammable Limits in Air By Volume: Lower: N/A Upper: N/A
Extinguishing Media: Foam, Carbon Dioxide, Dry Chemical, Water Fog

Special Firefighting Procedures:

When fighting chemical fires wear full protective equipment with self-contained breathing apparatus. Water spray may be used to cool fire-exposed containers. Toxic fumes will be evolved when this substance is burned.

SECTION V - REACTIVITY DATA

Stability: Stable

Conditions to Avoid: Epoxy resins and epoxy resin hardeners react with each other producing heat. They should not be mixed with each other under uncontrolled conditions or in large mass as the ensuing exotherm may result in heat and smoke.

Incompatibility: Strong oxidizing agents, mineral acids.
Hazardous Decomposition Products: Oxides of carbon, nitrogen
Hazardous Polymerization: Will not occur.

SECTION VI - HEALTH HAZARD DATA

EFFECTS OF OVEREXPOSURE:

Acute: May cause burns to skin and eyes. High vapor concentration can cause severe irritation of eyes and respiratory tract. Liquid causes severe damage to mucous membranes if swallowed.
Chronic: Prolonged and repeated skin contact may cause skin sensitization, asthma or other allergic responses.

Carcinogenicity: Results of in vitro mutagenicity tests on ethylene amines have been negative. It is not expected that any of the ingredients are carcinogenic.

EMERGENCY AND FIRST AID PROCEDURES:

Eyes: Flush thoroughly with water for at least 15 minutes. Get immediate medical attention.

Skin: Remove contaminated clothing and flood area with water. Wash affected skin with soap and water. Wash clothing before reuse. Discard shoes. Get medical attention if redness, soreness, or blistering occur or persist.

Inhalation: Remove to fresh air. Administer oxygen if necessary. Get medical attention if breathing is difficult or cough develops.

Ingestion: DO NOT INDUCE VOMITING. Vomiting will cause further damage to throat or respiratory tract. Dilute by giving water or milk to drink if victim is conscious. GET IMMEDIATE MEDICAL ATTENTION.

Medical Conditions Generally Aggravated by Exposure: This material may be a strong skin sensitizer in certain susceptible persons. Once sensitized, most persons are unable to work around amine cured epoxy resins without an allergic reaction. Sensitized persons are not known to have other health problems as a result of sensitization.

SECTION VII - PRECAUTIONS FOR SAFE HANDLING AND USE

If Material is Spilled: Avoid contact with material. Persons not wearing appropriate protective equipment should leave the area of the spill until cleanup is complete. Stop spill at source, dike area to prevent spreading, pump liquid to salvage tank or drum. Remaining liquid may be taken up on clay, diatomaceous earth, sawdust, or other absorbent, and shoveled into disposal containers.

Waste Disposal Method: Waste is not hazardous by RCRA criteria (40 CFR 261). Place in an appropriate disposal facility in compliance with local regulations.

SECTION VIII - SPECIAL PROTECTION INFORMATION

Respiratory Protection: Normally none is required when adequate ventilation is provided. In the absence of proper environmental control NIOSH approved respiratory is required. For emergencies, a self-contained breathing apparatus or full-faced respirator is recommended.

Ventilation: Provide adequate ventilation in work areas. Confine material in sealed containers when not in use.

Hand Protection: Always wear impervious gloves, neoprene, vinyl or rubber.

Eye Protection: Splash proof goggles or safety spectacles with side shields are recommended. Always wear eye protection when sanding cured epoxy resins to avoid dust in eyes.

Other Protective Equipment: Wear clean, body-covering clothing to avoid skin contact.

SECTION IX – OTHER REQUIREMENTS

Department of Transportation Classification: Not regulated

SARA Title III:

This product contains no toxic chemicals subject to the report requirements of Section 313 of the Emergency Planning and Community Right-To-Know Act of 1986 and of 40 CFR 372.

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