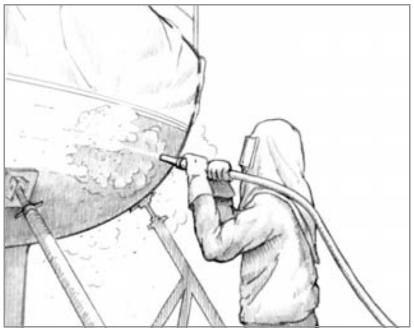
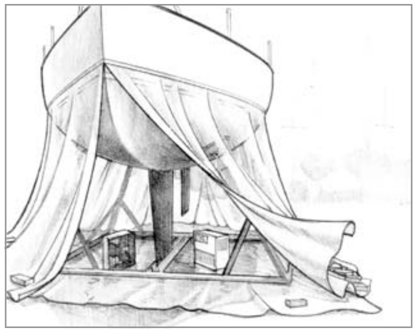
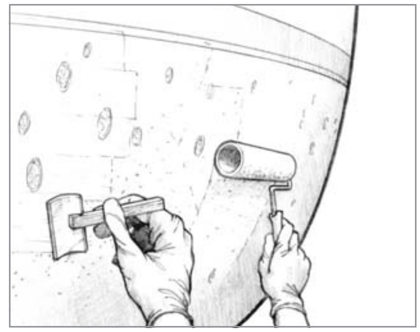
002-650

Gelcoat Blisters
Diagnosis, Repair & Prevention

A guide for repairing and preventing gelcoat blisters in fiberglass boats with WEST SYSTEM® Brand Epoxy.







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WEST SYSTEM® BRAND

Gelcoat Blisters
Diagnosis, Repair & Prevention

9th Edition

Catalog number 002-650

A guide for repairing and preventing gelcoat blisters in fiberglass boats with WEST SYSTEM® Brand epoxy.

The techniques described in this manual are based on the handling characteristics and physical properties of WEST SYSTEM Epoxy products. Because physical properties of resin systems and epoxy brands vary, using the techniques in this publication with coatings or adhesives other than WEST SYSTEM is not recommended. Refer to the current WEST SYSTEM User Manual & Product Guide for complete product information, and safety and handling guidelines.

The information presented herein is believed to be reliable as of publication date, but we cannot guarantee its accuracy in light of possible new discoveries. Because Gougeon Brothers, Inc. cannot control the use of WEST SYSTEM Brand products in customer possession, we do not make any warranty of merchantability or any warranty of fitness for a particular use or purpose. In no event, shall Gougeon Brothers, Inc. be liable for incidental or consequential damages.

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Gougeon Brothers Inc.
Bay City, MI 48707

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1 The Problem of Gelcoat Blisters in Fiberglass Boats

A 1990 *PRACTICAL SAILOR* magazine survey, suggested that one in four boats can be expected to blister in its lifetime. As more is known about blisters and their underlying causes, it is apparent that the problem has become more widespread and runs deeper than just the outward appearance of gelcoat blisters. The extent of blister damage varies from boat to boat. It may appear as a few large isolated blisters or as thousands of small blisters covering an entire hull. In some cases, owners may be unaware that their boats are blistering or that there may be a serious destructive process taking place beneath the gelcoat.

A fiberglass boat is a laminated structure consisting of layers of various reinforcing fabrics and core materials, typically bonded together with polyester resin, and covered with an outer layer of polyester gelcoat. Blisters occur when water that has penetrated the laminate dissolves water soluble materials within the laminate and accumulates in voids or cavities below the gelcoat layer. The solution of water and water soluble materials, through the process of osmosis, attracts more water to the cavities to try to dilute the solution. The pressure of the accumulating water enlarges the cavities to form gelcoat blisters.

When water soluble materials in a polyester resin laminate mix with moisture that has penetrated the laminate, it creates an acidic fluid. This acidic mixture can attack the polyester resin throughout the laminate, severing the chemical bonds that hold the resin matrix together, as well as the resin-to-fiber bonds. This process is known as hydrolysis. Once hydrolysis has started in a polyester hull, the hull's strength has been compromised and the potential for serious additional hydrolysis will never go away. If you own a fiberglass boat built with polyester resin, you should be aware that the potential for this problem exists, and is greater in warmer climates. The extent of damage due to hydrolysis should be included in an assessment of a boat's condition before repairs are made. Gelcoat blisters can often be repaired before the laminate is damaged by hydrolysis. Keep in mind that gelcoat blisters can be an indicator of hydrolysis, and that hydrolysis can occur without the appearance of blisters.

Hydrolyzed laminate and gelcoat blisters can be treated with WEST SYSTEM® Brand Epoxy to limit further damage and in many cases restore a hull's structural integrity. In this manual we will explain the factors affecting blister formation, describe techniques for repairing blister damage and applying an epoxy barrier coating, and offer steps to help prevent future problems. Our recommendations are based on 25 years of experience in the formulation of quality marine epoxies, coupled with extensive laboratory and field testing.

Although WEST SYSTEM epoxy has been used to successfully repair and protect thousands of blistered boats, it is just one of the factors contributing to a lasting repair. Thorough preparation, drying, repairing and coating, as well as preventative maintenance after the repair, are also essential for a successful repair–but do not guarantee it. Other factors beyond your control, such as the amount of water soluble materials in the laminate, the level of existing damage, and the boat's environment also affect the long term success of a blister repair.

1.1 Typical fiberglass boat construction

A fiberglass boat is a composite structure, made of many layers of various reinforcing fabrics and core materials, typically bonded together with a polyester resin. There are as many lay-up schedules as there are boats. A typical hull section might consist of a layer of polyester gelcoat, several alternating layers of mat and woven roving, and in many cases a core material such as end-grain balsa or foam, followed by several more alternating layers of mat and woven roving *(Figures 1-1 and 1-2)*.

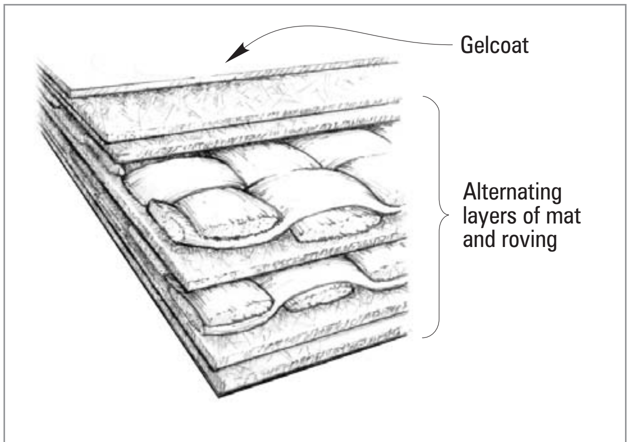

Figure 1-1 *A solid fiberglass laminate is made up of various reinforcing fabrics bonded together with polyester resin.*

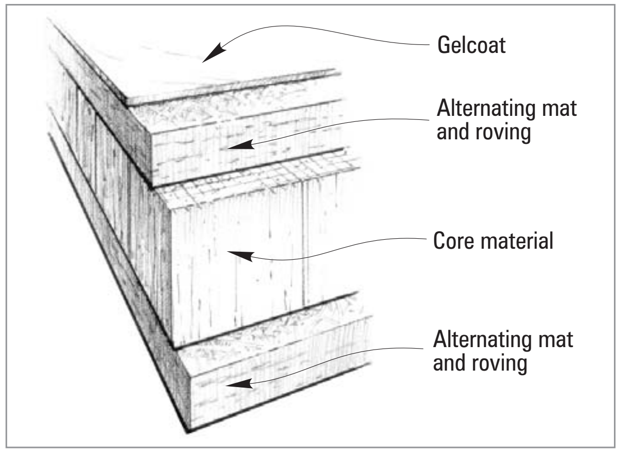

Figure 1-2 *A cored laminate for a typical boat hull consists of end-grain balsa or foam sandwiched between alternating layers of synthetic fabrics.*

Generally, production fiberglass boats are built in a female mold. A release agent is first applied to the surface of the mold, over which the gelcoat material is applied. Gelcoats may be anywhere from 12 to 22 mils (.012"–.022") thick. They start as pigmented, unsaturated polyester resin and are designed to act as a moisture barrier for the underlying laminate, as well as to provide a smooth, glossy cosmetic finish. Subsequent layers of the laminate are laid up over the gelcoat.

Hull thickness may vary from boat to boat. Older boats were often laid up with a solid glass laminate hull thickness of 1" (3.8 cm) to as much as 5" (12.7 cm) in the keel areas of the more heavily-built boats. Today, however, the trend is toward thinner, lighter laminates, a fact that makes the structural integrity of each of the laminate components all the more critical.

The polyester base resin in fiberglass boats is produced by reacting organic acids with glycols to form chains of alternating organic acid and glycol groups. The base resin, consisting of many organic acid/glycol chains of different lengths, is diluted with a reactive monomer, normally styrene, which will eventually react with it. The styrene will induce a cross-linking reaction with the polyester resin causing it to gel. An inhibitor is added to slow down the cross-linking reaction, delaying the reaction between the styrene and base resin, and keeping the system stable for about three months. The addition of a peroxide catalyst, such as MEKP (methyl ethyl ketone peroxide) will overcome the inhibitor and then cause cross-linking of the polyester resin until it is cured. At room temperature, the catalyst does not cause the polyester to cure fast enough so an accelerator has to be used.Typically a metal salt serves as the accelerator and is added to the base resin by the resin manufacturer.The styrene monomer reacts with the base resin, cross-linking the polyester chains together until one solid mass is formed. The result is a hard thermoset plastic.

1.2 Factors affecting blister formation

As a building material, the unsaturated polyesters used in fiberglass construction seem to be a logical choice. They offer relative ease of handling, reasonable cost, and, what appears to be, an acceptable working lifetime. Unfortunately, there are other important characteristics that we now know are working against the polyester structures which lead to problems like blistering and delamination. Many variables affect the formation of blisters including the formulation of the resin for specific applications, manufacturing quality assurance, and the boat's environment.

The chemical stability and moisture permeability of the polymer resin matrix are the key items affecting the durability of the fiberglass hull.

1.2.1 Permeability

The term permeability refers to the ability of a material to permit a substance to pass through it. Polyester laminating resins and gelcoats are not waterproof; they are permeable and will allow water to migrate through the cured resins at a consistent, predictable rate. The permeability of a polymer matrix involves a number of factors.

The thickness of the gelcoat layer, the amount of air or voids in the laminate and the temperature of the laminate affect how much water can permeate the laminate. The warmer the ambient temperature, the higher the rate of Permeation *(Figure 1-3)*. An increase in temperature will boost the rate of permeation through a resin matrix by intensifying the molecular motion of both the polyester and the water. This means boats in the Caribbean are more likely to have problems than those in Lake Superior.

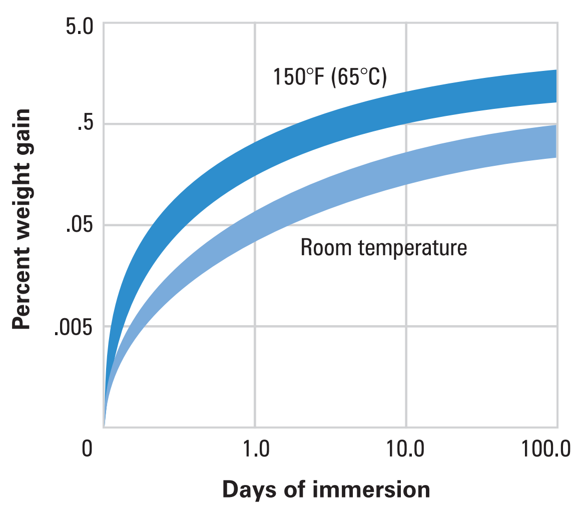

Figure 1-3 *A laminate's susceptibility to moisture permeation tends to increase with higher ambient temperatures.*

1.2.2 Voids

An important factor affecting blister formation is the distribution of free volume (voids) in the matrix. In any laminate, the free volume can be everything from the gaps between and within the molecules of the polymer matrix to manufacturing defects such as entrapped air bubbles, cracks or dry fabric. The cure rate, degree of cross-linking and crystallization all affect this void distribution while also contributing to the overall chemical stability of the cured polymer matrix. When water accumulates in these voids, the formation of blisters is initiated. The acidic fluid that develops may eventually begin to hydrolyze the surrounding resin. Due to manufacturing practices, voids commonly occur at the interface between the gelcoat and the laminate, explaining why a large percentage of blisters develop in this area.

1.2.3 Osmosis and Hydrolysis

Water-soluble materials, or solutes (excess glycols, acids, metal salts, etc.), trapped in voids between the laminate and the gelcoat, or within the laminate, are primarily large molecules. The laminate, meanwhile, is surrounded by relatively pure small water molecules. The small water molecules move from an area of greater concentration to an area of lesser concentration (the voids), and dissolve the solutes to form a blister fluid solution *(Figure 1-4)*. The gelcoat and laminate act as a semi-permeable membrane. They allow the small water molecules in, but do not let the larger solution molecules out. This one-way movement of water into the laminate is known as osmosis. More water is attracted to the voids to dilute the concentration of solutes in the solution *(Figure 1-5)*. The blister fluid continues to accumulate and eventually creates enough hydraulic pressure to result in a blister *(Figure 1-6)*. Research has shown that osmotic forces increase in direct proportion to the concentration of solutes in the water within the laminate.

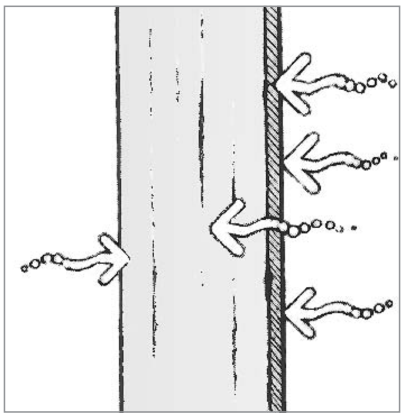

Figure 1-4 *Polyester resins and gelcoats allow water molecules to migrate into the laminate and dissolve soluble materials within the laminate.*

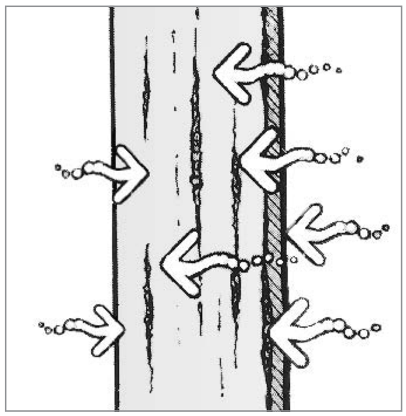

Figure 1-5 *More water molecules are attracted to the voids to dilute the concentration of solutes in the blister fluid solution.*

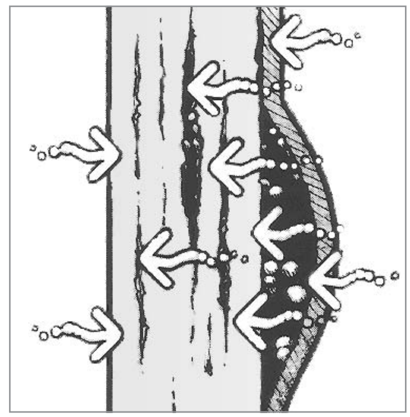

Figure 1-6 *Accumulating fluid creates enough hydraulic pressure in the voids between the gelcoat and laminate to result in a gelcoat blister.*

Under the right conditions, a polymer matrix of polyester resin may degrade when exposed to water. Water in contact with the laminates unreacted resin components (glycols, organic acids, catalyst and metallic accelerator) forms an acid that can breakdown susceptible ester linkages which comprise the majority of bonds in polyester polymers. This chemical reaction is called hydrolysis. Degradation products from the hydrolyzed resin are dissolved by the water within the laminate and increase the solute concentration which promotes osmosis. Water passing into voids and resin-starved pockets within the laminate helps break down more of the polyester molecular chains, which in turn allows more water to pass into the laminate. The process, in effect, feeds on itself, creating more blisters and damaging more resin by hydrolysis.

The higher temperatures of tropical climates and warm damp interiors can cause increased sensitivity to degradation of the ester linkages in the polyester, an increased rate of water permeation, and can accelerate hydrolysis where it is already occurring in the laminate. Keep in mind that standing water and high humidity in the bilge (due to poor ventilation), also permeate the laminate and contribute to blister formation.

Another factor in the water transport mechanism across gelcoat membranes is surface oxidation. Sunlight with its UV degradation potential takes the gloss from gelcoats and destroys some of their water-exclusion capability.

1.2.4 Formulation variables influencing blister formation

A large number of formulation variables influence the susceptibility or resistance of cured polyester laminates to degradation and blistering. Many different types and combinations of glycols, acids and reactive diluents can be used by the resin manufacturer when developing a formulation. Each ingredient alters the basic physical characteristics of the cured resin, including hydrolytic stability, strength and elongation. The mixing process can also have an impact if it leaves improperly mixed and unreacted glycols trapped in the resin after cure.

Particular unsaturated polyester resins, accelerators and catalysts can act as blister initiators in poorly mixed or incompletely reacted matrices. Theoretically, a wide variety of additives (air-release agents, leveling additives, UV-resistant additives, surfactants, abrasion-resistant additives, fire retardants, antioxidants and co-monomers) have the potential to affect blister resistance in the cured laminate. Thixotropic agents, hydrophilic fillers, pigments, color paste vehicles, and the use of solvents as diluents can change the sensitivity to moisture and aid in the formation of blisters. The inclusion of any moisture-sensitive materials could stimulate hydrolysis of the matrix materials and promote the osmotic pressure which causes blisters.

1.2.5 Post construction factors

Poor quality manufacturing practices, material limitations and the rigors of the boating environment can have an adverse effect on the interfacial adhesion between the polyester and fiber reinforcement in the laminate. In addition to poor wet-out during fabrication, high stress or strain in the laminate during use can cause a loss of adhesion or initiate micro-cracking at the interface. Micro-bubbles and multi-phase interfaces within the matrix (due to different cure and shrinkage rates) are all points of stress concentration and, as such, are areas vulnerable to loss of adhesion or cohesion. The resulting voids promote water migration, leading to hydrolysis and the concentration of any soluble materials in the laminate.

Although some older boats seem to be quite sound and many new boats are built to minimize blister potential, with all these variables, it is may be impossible to define a laminate schedule, polyester matrix formulation, and manufacturing plan to create a laminate that is totally impervious to attack.

1.3 WEST SYSTEM® Epoxy for repair and coating

Moisture within the laminate is generally accepted as the common denominator in the gelcoat blister equation. It stands to reason, then, that sound measures toward combating osmotic blistering problems would be drying the laminate thoroughly, keeping the interior of the boat as dry as possible and preventing water from passing through the outside of the hull by providing a water-resistant barrier coating. The critical questions are what is the best available moisture barrier material and how should it be applied.

There are three compelling reasons to use an epoxy resin rather than a polyester resin or other materials to combat gelcoat blistering. Epoxy is more effective as a moisture barrier, has greater resistance to hydrolysis, and is a better structural adhesive.

1.3.1 Choosing an effective moisture barrier

Gougeon Brothers, Inc. has developed a comprehensive test program based on U.S.D.A. Forest Service methodology which has been used for years as an established method to determine the moisture exclusion ability of a coating material. We can test identical samples treated with various coatings and application techniques to compare each coating's relative effectiveness as a moisture barrier. (The complete MEE test procedure is available upon request from Gougeon Brothers Inc.)

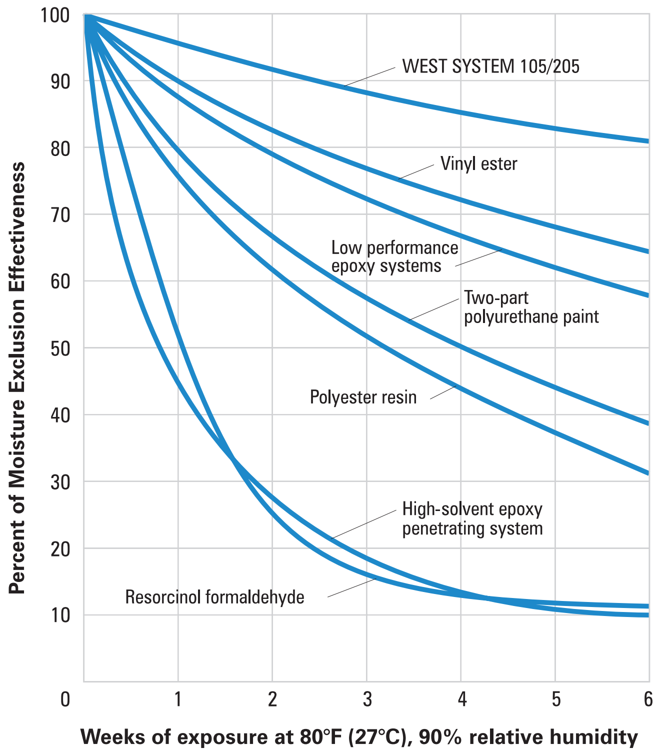

Figure 1-7 *Moisture exclusion effectiveness (MEE) of various marine materials. Comparison of three coats of each material.*

As you can see from *Figure 1-7*, various common finishes have significantly different levels of moisture exclusion effectiveness. At the end of six weeks of exposure to 90% relative humidity at 80°F (27°C), polyester resin is functioning at 30% MEE. Polyurethane paints, on the other hand, are at nearly 40% MEE with one popular brand and 65% MEE with another.

Figure 1-7 also demonstrates that some epoxy formulations, although generally the same or slightly better than paints or varnishes, fall significantly short of a properly formulated epoxy's potential as a moisture barrier. WEST SYSTEM Brand 105/205 and 105/206 epoxies are shown functioning at 82% and 78% MEE respectively after six weeks.

It is also significant to note that the MEE slope for WEST SYSTEM Brand epoxy is relatively flat at six weeks, while the low-performance epoxies, polyurethane paints and polyester resins are suffering from sharply declining curves which indicate that the MEE of these coatings will continue to deteriorate at a rapid pace.

This research has shown that WEST SYSTEM Brand epoxy has a much higher resistance to moisture than most other coatings. This is a critical characteristic in reducing moisture permeability through the resin matrix which could result in gelcoat blistering and/or interlaminate failure.

1.3.2 Hydrolysis resistance

An epoxy matrix is more resistant to hydrolysis than a polyester matrix. In general, the structure of the cured epoxy's ether linkage is more stable than the structure of the polyester's ester linkage. This means that the epoxy matrix will not be broken down by water as easily as the polyester matrix.

Epoxy has a service history proving its excellent resistance to blistering and other moisture related problems. For the custom boat builder, high-end production facility or marine repair yard, the high mechanical and chemical stability of epoxy, coupled with its excellent moisture resistance, make it an excellent choice to battle gelcoat blistering.

1.3.3 Secondary bonding

There is one other compelling reason to use an epoxy resin rather than polyester resin. To effectively repair interlaminate failure, and to repair laminate surfaces damaged due to gelcoat blistering, the repair material must be a superior structural adhesive, capable of bonding to both polyester resin and the glass fiber.

Unsaturated polyester resins perform fairly well during the construction of a structure when all of the layers of resin are applied and allowed to cure together. This type of bond is considered a primary bond. Problems can occur, however, when you try to bond polyester resin to a previously cured laminate as is necessary in blister repair applications. This type of bond is secondary or post-bonding.

WEST SYSTEM epoxy, however, forms a superior bond with cured polyester in secondary bonding. Since the epoxy is stronger and shrinks less than polyester, the epoxy repair may actually be more durable than the original structure.

Moisture exclusion ability, hydrolysis resistance, as well as secondary bonding capability are major considerations in choosing a barrier coating. If you also consider cost, ease and practicality of application, availability, safety and access to technical assistance, WEST SYSTEM epoxy is an excellent choice for gelcoat blister repair.

1.4 Recommendations for the repair and prevention of gelcoat blisters

1. **Inspect beyond the obvious.**
   If you plan to barrier coat your hull after repairing blisters, we feel it is important to inspect the hull beyond the obvious blisters. Before beginning repairs, we recommend grinding through the gelcoat in several small areas. These profile inspection points, 4" to 6" in diameter, can provide valuable information on the condition of the hull laminate. If the laminate shows signs of hydrolysis, consider removing all of the gelcoat and damaged laminate. It is pointless to barrier coat over a hull that has begun to deteriorate. Just as with skin cancer, the more serious problem may lie below the surface.
2. **Thoroughly dry the hull laminate.**
   Open up all blister cavities and excavate damaged material. Insure that the laminate, throughout the hull structure, is as dry as possible. Active drying methods, such as heating and tenting, may be used to accelerate the process.
3. **Repair blisters and delamination with W* EST******* S* YSTEM********®Brand epoxy products.**
   After sealing with a coat of unthickened epoxy, fill the cavities with a WEST SYSTEM Brand epoxy thickened with either 410 Microlight or 407 Low-Density filler. In areas with extensive blister damage, rebuild the laminate with multiple layers of glass fabric bonded with epoxy.
4. **Apply barrier coat of W* EST******* S* YSTEM******** epoxy with 422 Barrier Coat Additive.**
   Thoroughly clean all underwater surfaces and then abrade by sanding, waterblasting or sandblasting. With the hull properly prepared, apply a minimum of 20 mils (0.020") of WEST SYSTEM epoxy to the surface. This can usually be applied in 5–6 coats. Up to 10 ten coats will provide added protection. Apply the first coat without any additives. The remaining coats should contain 422 Barrier Coat Additive, which improves the epoxy's moisture permeation resistance as well as its resistance to scratches and scuffs.
5. **Provide ventilation to all parts of the hull—keep the bilge as dry as possible.**

Good ventilation is a key to the longevity of your boat. Water vapor can penetrate hull laminate faster than water in liquid form. One of the best recipes for creating a high-temperature humidity chamber is to leave your poorly ventilated, tightly sealed boat in the hot sun for weeks on end. Deck temperatures can exceed 130°F (55°C), pushing cabin temperatures toward 100°F (38°C). Such a rain-forest environment provides the necessary elements for gelcoat blistering since moisture can and will pass through either side of the hull laminate. In tropical climates, where heat and humidity are an extreme problem, you may want to consider having a dehumidifier aboard. Bilge water is also an obvious source of moisture, so it is important to keep the bilge as dry as possible. We strongly recommend active ventilation in bilge areas with powered vents, especially on boats that have previously blistered.

6. Maintain the barrier coat's integrity.

Excessive sanding during haul outs, groundings, scrapes and scratches will all undermine the moisture resistance ability of your epoxy barrier coat. Keep a high-quality bottom paint on the hull. Repair scratches, dings or abrasion damage as soon as possible, recoating the repaired area with epoxy to replace the removed barrier coat.

After several haul outs, your barrier coat may have been reduced from repeated sanding. Consider removing the bottom paint and reapplying two or three coats of epoxy as described in this manual.

Do not let blisters go unchecked. As soon as possible, repair the blisters and coat with epoxy to prevent further degradation. Monitor the hull's moisture periodically. Early detection of moisture absorption can save you considerable expense and frustration in the long run.

If you are unfamiliar with or have any questions about the application and handling techniques of WEST SYSTEM Brand epoxy products, read Section 6–Using WEST SYSTEM Epoxy, before proceeding with Section 2. For additional information about WEST SYSTEM Epoxy products, refer to the WEST SYSTEM *002-950 User Manual & Product Guide*.

If you have additional questions after reading the Section 6 or the User Manual, you may write or call the Gougeon technical staff.

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Additional product and dealer information can be found at the WEST SYSTEM web site, www.westsystem.com. ■

2 Hull Preparation

This section covers the procedure for removing damaged gelcoat and laminate, and for abrading the surface to prepare a hull for drying, filling, fairing and final moisture barrier coating.

The probability for the success of this repair, and the prevention of future blistering, depends on a variety of factors, many of which are beyond your control. These include quality control during the hull's manufacture, the quality of raw materials used in construction, the age of the boat, and the climate it was exposed to. Because of factors such as these, it is impossible to absolutely rule out future blistering. You can however, improve the odds of a successful long term repair by conscientiously following the recommendations in Section 1.4.

2.1 Evaluating blister damage

If at all possible, arrange to be present when the boat is first pulled from the water. Blisters tend to shrink quite rapidly once the boat is out of the water, and can actually disappear within hours, only to reappear when the boat returns to the water. After cleaning off marine growth and dirt, scuff the bottom with 80-grit sandpaper. Blisters will show up as light spots against the darker bottom paint. Damage may range from a few large isolated blisters to an entire hull peppered with thousands of blisters no bigger than a pencil eraser. Damage may also vary considerably from one area of the hull to another. Closely inspecting the hull as soon as it's pulled will allow you to more accurately assess the nature and severity of the blistering and choose the best course of repair.

A thorough inspection includes evaluating the laminate below the gelcoat. Grind 4"–6" diameter inspection points in several places on the hull. Use a disk sander to grind shallow concave areas through the gelcoat. Wet the areas with water or alcohol. When wet, a healthy laminate looks dark and translucent. If white fibers are evident, at or below the surface, it is an indication of a manufacturing defect or that resin around the fibers has degraded and hydrolysis has taken place. If there appears to be laminate damage, grind additional profile inspection points to confirm it and determine the extent of the damage and possibly how much laminate will have to be removed.

Isolated minor blisters can be opened individually and the individual blister cavities filled and faired. This method has worked well, especially on older boats. Since older boats have survived for some time with only limited damage, it is often the case that little damage exists beyond the apparent blisters.

Extensive damage on newer boats, however, may indicate a serious material or manufacturing defect. In these cases the gelcoat should be completely removed. This eliminates the obvious damage as well as any blistering in its early stages, and it allows you to inspect the laminate for defects or damage. The gelcoat will then be replaced by the epoxy barrier coat. This option is a good idea, if time and funds allow, even if the blistering is not yet serious.

In either case, open the blisters and abrade the hull or remove the gelcoat as soon as possible. This will allow the cavities, the remaining gelcoat and the laminate to dry much more quickly. Removing the gelcoat will allow the laminate itself to dry out quicker since the moisture will not have to travel though the gelcoat. Thorough drying is an important and often rushed part of the repair. Opening blisters or removing the gelcoat quickly, with frequent washing during the drying process, will get the most out of a limited drying time.

Be sure to wear protective clothing and eye protection when opening blisters. The acidic blister fluid is frequently under as much as 200 psi of pressure. When the blister is punctured, the fluid may squirt out with surprising force.

2.2 Minor isolated blister damage

Keeping in mind that minor blistering may be a symptom of a larger problem, there are many situations where repairing isolated blisters makes sense. You may be able to repair isolated blisters and improve ventilation, and thus avoid the need for a full-blown barrier coat job. You may repair and monitor blisters for two or three years to determine the severity of your problems before decide on the most effective repair strategy. Or, you may simply want to get your boat into the water so you can go boating now.

If your hull has a manageable number of blisters or blistering is limited to a small section of the hull, this technique allows you to repair blisters in a matter of hours prior to applying bottom pant.

1. Mark the individual blisters or blister areas (by scuffing the bottom paint with 80-grit sandpaper) for future reference if you are not able to open the blisters right away, or:
2. Immediately open the blister cavities. Use a small sanding disk (such as 3M's Rolock™ 2" diameter sanding disk) with 60-grit sandpaper, chucked into a variable-speed drill *(Figure 2-1)*. Make sure that you have removed the entire blister, including the edges of the blister dome. *Complete the repair following the procedures in Section 4.1.*

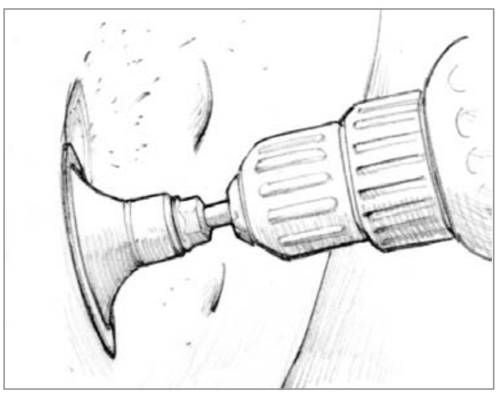


Figure 2-1 *Use a small rotary tool chucked into a variable-speed drill to open the blisters.*

2.3 Extensive blister damage

If you've pulled the boat from the water and find yourself faced with hundreds or thousands of blisters, it may not be practical to open each blister individually. The job of filling and fairing all of the individual blister cavities also takes on monstrous proportions. Grinding, sandblasting or peeling are options that allow you to open all of the blisters and abrade the entire hull (or remove the gelcoat entirely) in one operation. Each method has advantages and disadvantages.

2.3.1 Grinding

Grinding or sanding is the most common method for opening blisters and abrading the gelcoat and is often the only option for boat owners who choose to repair their own blisters. However, grinding is not a pleasant job and, depending on the skill of the operator, may leave the hull uneven and in need of extensive fairing. The operation also creates a lot of dust and a potential health hazard. The equipment required is relatively inexpensive and widely available. It includes a 1000–2000 RPM air or electric polisher, with an 8" foam sanding pad.

Grind the hull to remove bottom paint, open blisters and abrade the surface as follows:

1. Prepare the work area to protect against dust hazards, especially when bottom paint is to be removed. Check local ordinances for restrictions and follow safe waste management practices. It is a good idea to remove all thru-hull fittings.
2. Clean the hull of all marine growth and contaminants like grease or oil.
3. Grind the hull beginning with a coarse grit (24–40) to strip the bottom paint and open blisters. Hold the grinder at a low angle (5°–10°) to avoid gouges. Remove enough of the gelcoat to expose all of the blister cavities or, if the blisters are shallow, continue removing gelcoat until the surface is flush with the bottom of the cavities. Leaving cavities in the surface will require more filling and fairing. In all cases, keep grinding until a solid, undamaged surface is exposed *(Figure 2-2)*.
4. Grind the surface again with a finer grit (50–80) to remove the coarser grit scratches and fair the surface. If sanded fair enough, little filling and fairing will be required. For this operation, an air file or double action (DA) sander may provide more control for fairing than the disc sander. You may chose to sand through all of the gelcoat to the first layer of laminate.
5. Inspect the hull for any further damage after sanding. Sound the hull to detect any interlaminate voids. Repair any voids that are found, following the appropriate procedure in Section 4.3, before beginning the filling and fairing operation.

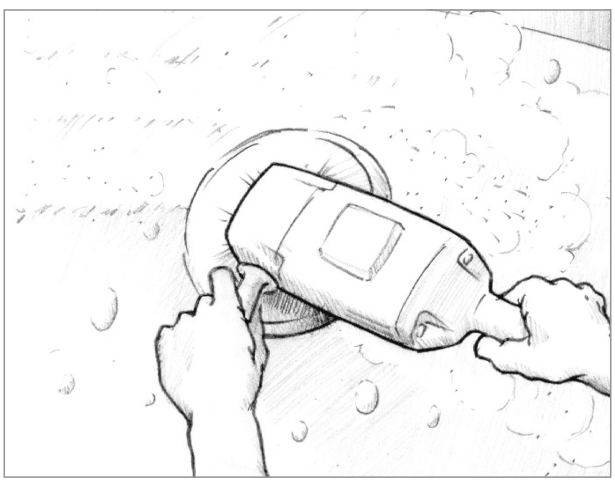


Figure 2-2 *Use an electric polisher with an 8" foam sanding pad to open blister cavities or remove gelcoat.*

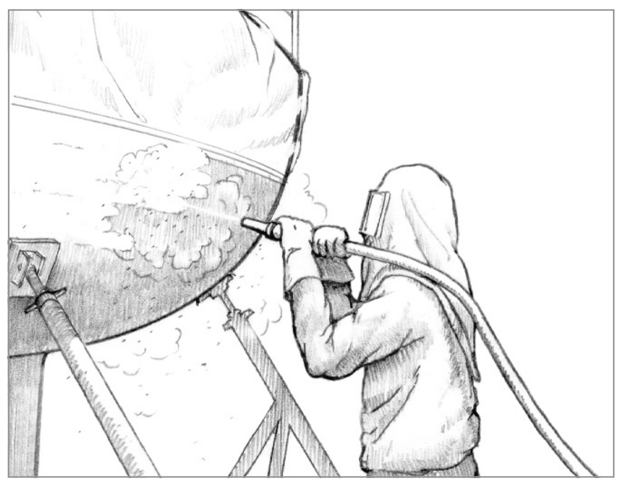


Figure 2-3 *Sandblasting is a common method of opening blisters and abrading the hull.*

2.3.2 Sandblasting

Sandblasting (or water-blasting) involves much more expensive equipment which may be rented *(Figure 2-3)*. Professional sandblasting services are available in many areas. Sandblasting will leave a generally fair but pitted surface. This method is also a potential health problem because of the airborne dust generated. Because sharp sand is blasted into the surface under air pressure, bottom paint should be removed before sandblasting. Failing to do so may result in small particles of paint or contaminates being imbedded in the laminate, a condition which may create bonding problems later on.

When using this method, be very careful not to sandblast too deeply. Do not drive gelcoat coat particles into the softer, underlying laminate nor remove excessive amounts of the laminate. Consider sandblasting 80 or 90% of the gelcoat away, and then finishing the process by sanding. After the gelcoat is removed, inspect the laminate for hydrolysis, delamination or other damage.

2.3.3 Gelcoat peeling

Gelcoat peelers are designed around an electric or hydraulic powered cutting head that shaves the gelcoat down to the appropriate depth in one pass. Peeling leaves a relatively smooth surface, which reveals flaws within the laminate better, and requires much less fairing than a ground or sandblasted surface. Peelers also allow for better waste collection than grinding or sandblasting, minimizing environmental hazards. Gelcoat peelers are relatively new technology and the service, where available, may be the most expensive of the options. However, if you are hiring the labor to sand your hull, peeling the gelcoat can be cost effective, especially if you consider the additional time and expense of fairing the sanded hull. After the gelcoat is removed, inspect the laminate for hydrolysis, delamination or other damage. Wash and sand the surface thoroughly before barrier coating.

2.3.4 Sounding the hull

You may find it a worthwhile investment of time to "sound" the entire hull. Wet or delaminated areas will sound dull or flat when rapped with a small mallet. Dry, solid laminate will have a sharp sound. By tapping the hull in a regular pattern every 3" (7.5cm), you should be able to isolate problem areas *(Figure 2-4)*. Blistering or delamination voids within the laminate may affect the structural integrity of the hull and should be repaired.

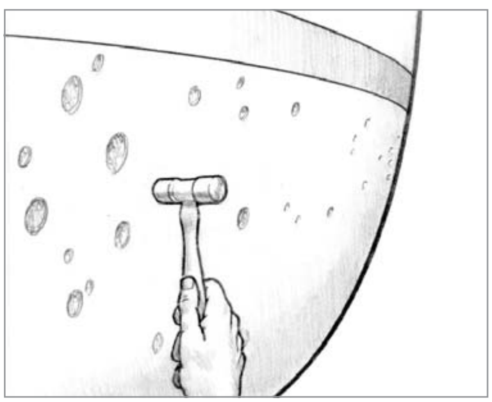


Figure 2-4 *Sounding the hull will reveal interlaminate voids.*

2.4 Exposing and removing interlaminate damage

After grinding or peeling away the gelcoat, wet the surface of the exposed laminate with water will help you to see flaws below the surface. Voids appear as lighter areas within the darker solid laminate. Voids may be the result of hydrolysis or a manufacturing flaw, which may show up in a pattern that reflects the pattern of resin application.Sounding will confirm the presence and extent of the voids. The deeper or more widespread the delamination, the more serious the structural problem. If sounding or visual inspection reveals voids below the outer layer of laminate, open the voids by drilling or grinding to allow the laminate behind the voids to dry out thoroughly before repairs are be made.

2.4.1 Small voids

If the area of a void is limited to a few inches, you can repair it without removing the outer layers of laminate.

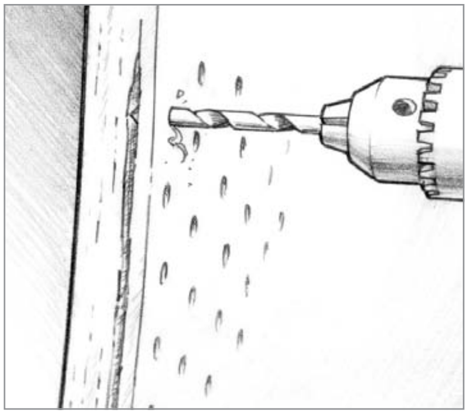


Figure 2-5 *Drill a pattern of $^3/_{16}$" holes through the outer laminate, into the void.*

Drill a pattern of “ diameter holes over the area of the void *(Figure 2-5)*. Drill through the outer laminate without drilling past the void into the laminate below. The holes will allow you to evaluate the size of the void, the soundness of the laminate below the void and help the void to dry out.

Dry the laminate (Section 3) and complete the repair as described in Section 4.3.1

2.4.2 Large voids

If larger areas of delamination are confined to the first layers of laminate or to limited areas of the hull, you can restore the structure by removing the damaged material and bonding in new layers of fiberglass cloth with epoxy.

1. Mark the location and area of all of the voids with a felt marker.
2. Grind out all of the damage, exposing solid undamaged laminate.
3. Bevel the edge of the repair area to a minimum 12-to-1 angle to provide a greater bonding area and reduce stress *concentrations (Figure 2-6)*.
   After drying thoroughly, layers of fiberglass cloth must be bonded (laminated) over the repair area to restore the laminate to its original thickness and strength as described in Section 4.3.2.

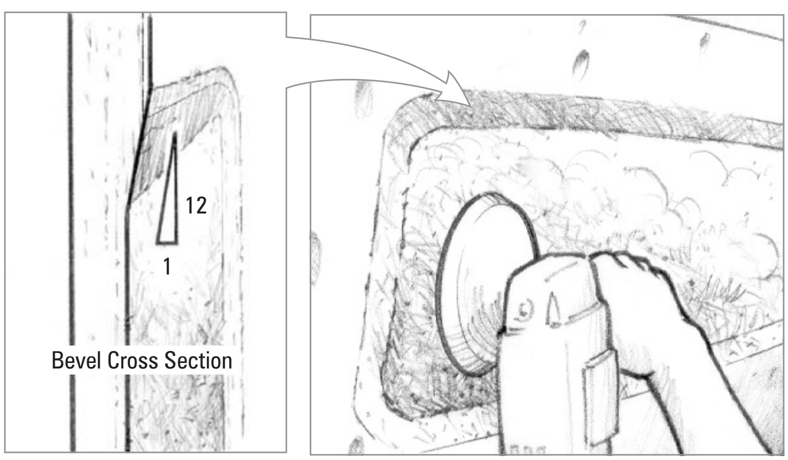


Figure 2-6 *Grind away the laminate over large voids to expose solid laminate. Grind the edge of the repair area to a minimum 12-to-1 bevel.*

2.4.3 Hydrolysis

Evidence of hydrolysis within the laminate may appear as “fiber whiting”. In normal or healthy laminate the fabric fibers below the surface are translucent and unnoticeable. If the resin around the fibers has hydrolyzed, the fibers appear white and are noticeable through the laminate after wetting the surface with water.

1. Inspect the hull to determine the extent of the damage after the gelcoat is removed.
2. Grind or peel to remove all of the hydrolyzed material in the outer layer of laminate. This may include isolated areas or the entire area of the hull.
3. Inspect the layer below the area(s) that were removed and (if necessary) remove all of the hydrolyzed material. Repeat the procedure one layer at a time until all hydrolyzed layers are removed.

   Dry the hull thoroughly (Section 3) and bond on (laminate) new layers of fiberglass cloth to replace any roving or other structural layers that were removed (Section 4.3.2). The outer layer of chopped strand mat is not usually considered a structural layer.

   To repair cored hulls that have delaminated and other structural problems, refer to the Fiberglass Boat Repair & Maintenance manual (Catalog no. 002-550), published by Gougeon Brothers.

Note! If you are unsure of the extent of damage or question the soundness of the hull, it's a good idea to get professional advice before attempting repairs. In severe cases, laminate analysis by a composites lab is advisable. Labs can analyze the laminate layer by layer for resin content, evidence of hydrolysis and moisture content. Contact a local surveyor for help evaluating your hull and locating a lab.

2.5 Special preparations for new boats

An epoxy barrier coating is often applied to brand new hulls to avoid blister problems. New boats, obviously, have no blisters or water in the laminate, but they may require preparation not required by older boats. Check with your boat's manufacturer to be sure this procedure does not negate the hull warranty.

If bottom paint was applied by the boat manufacturer, it must be completely removed by scraping, sanding or chemical stripping before applying the barrier coat. Failure to do so will result in the epoxy bonding to the paint, rather than to the gelcoat. In such instances, the epoxy's bond to the boat is only as good as the bond of the old paint to the hull. The gelcoat must be thoroughly sanded to a clean, dull surface.

When new boats are delivered, provided bottom paint was not applied by the factory, they usually will have mold release agents or waxes on the gelcoat surface. These agents will prevent the epoxy coating from achieving a good bond to the gelcoat and must be removed. Sanding alone is usually ineffective since wax or silicone tends to clog the sandpaper, making it very difficult to remove all traces of the substances.

1. Wipe the gelcoat surface twice, using a quality silicone and wax remover such as DuPont Prep-Sol™ #3919S and clean, white paper towels. (Note: The dyes used in patterned toweling may also contaminate the surface.) Wipe well above the waterline to minimize the chance of contaminating the surface while you're working on the bottom.
2. Abrade the gelcoat below the waterline. This can be done with 80-grit sandpaper on an orbital sander, a double action (DA) sander or an air file, or by waterblasting or sandblasting. The entire hull surface must be dull with no shiny patches visible.

   Proceed to Section 5–Barrier Coating. ■

3 Drying the Laminate

Perhaps the most crucial step of the repair process for a boat which has blistered or absorbed moisture is thoroughly drying the laminate.

3.1 How dry is dry?

True moisture content of a laminate is extremely difficult to determine. In fact, the only accurate measure is to cut a core sample from the hull, weigh it and begin drying it in an oven. Then weigh the sample periodically until it no longer loses weight. The difference between the beginning "wet" weight and the final "dry" weight, expressed as a percentage, is the moisture content of the laminate.

Obviously, this is not a very practical method of determining moisture content. To compound the issue, the moisture content in various sections of the hull can vary dramatically.

The potential for moisture absorption in fiberglass laminates is substantially different from wood, a substance about which a great deal is known. Under certain conditions, a piece of wood may attain 100% moisture content. Moisture is drawn into the wood's cell structure and distributed throughout the sample fairly evenly.

A nearly perfect polyester laminate, with very few voids or resin-dry pockets, will absorb, at best, approximately 3% moisture by weight. And the worst case we've ever seen with a poorly built laminate was 9 or 10%. The principle difference is that a polyester laminate will absorb moisture unevenly in random pockets; the moisture content may be vastly different over a very small section.

3.1.1 Determining moisture content

To monitor drying progress, you'll need to determine the moisture content of the hull. There are now inexpensive, non-destructive moisture meters on the market (see Appendix B). One must be aware, however, that the reading these units give is relative only, and not an accurate representation of the actual moisture content of the laminate.

To monitor the laminate's drying progress using a moisture meter, we recommend taking and recording readings at regular intervals above and below the waterline along the entire length of the boat. During the drying process, periodically take and record new readings at the same locations *(Figure 3-1)*. After a period of time, the drop in relative moisture content will level out. At this point, even though the meter readings may indicate 2 or 3%, it is reasonable to expect that the laminate is as dry as it can be made under the conditions at hand.

A simpler method is to tape a 6" × 6" (15cm × 15cm) square of 6-mil clear plastic to several locations on the hull, above and below the waterline *(Figure 3-2)*. The edges should be tightly sealed, using electrician's or duct tape. As the hull dries, moisture will condense on the plastic. Every three or four days, remove the plastic, wipe the hull and plastic dry, and tape the piece back in place. When the hull is nearing its lowest possible moisture content, very little condensation will appear inside the plastic. There are also outside variables to

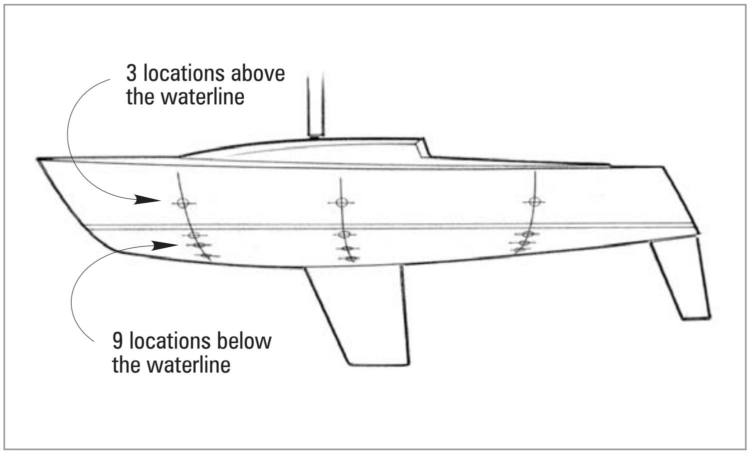


Figure 3-1 *Moisture reading should be taken at various locations, above and below the waterline, during the drying process.*

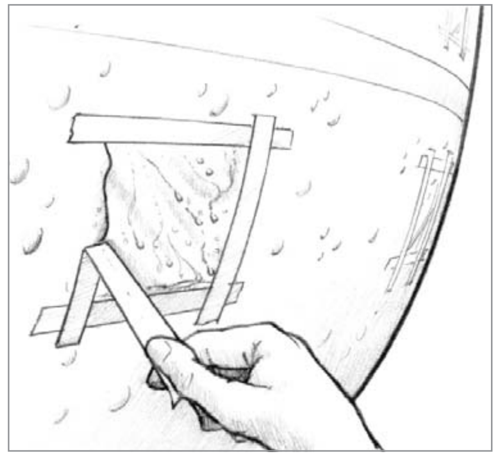


Figure 3-2 *A piece of plastic taped to a wet hull will show condensation on the inside of the plastic.*

keep in mind, such as changing relative humidity and temperature. So, before pronouncing your hull dry enough, allow the patch to stabilize over several days. Keep in mind that, like the moisture meters, this little test is only an indicator of relative moisture content.

3.1.2 Washing the hull

As the hull dries, contaminants such as salts, glycols, and acids will come to the surface and may inhibit the drying process. Steam cleaning, high-pressure washing, or scrubbing with a stiff brush and warm water to remove these contaminants periodically throughout the drying process has been shown to speed the process. The frequency of washing depends on the drying speed, since contaminants will be left on the surface at a faster rate when the hull dries faster. If an active or accelerated drying method is used, washing every 48 hours may be appropriate. If the passive method is used in a cooler or more humid region, washing once a week is more appropriate. In a warmer, drier region, wash more frequently.

A moisture meter will provide a good information on when to wash. If after an initial drop, the moisture level stays constant, wash the hull. After washing, the moisture level should drop then level off again as contaminants build up. Continue washing and monitoring until the hull is dry. If the moisture level remains high after washing it may be an indication of hydrolysis damage. Analysis by a composites lab is recommended.

3.2 Passive drying

Passive drying is simply storing the boat in the driest environment possible, for as long as it takes to reach the optimum moisture level. Drying time depends on the temperature and humidity level. Passive drying is a very practical method for boat owners in temperate climates, who normally store their boat over the winter. Although drying slows down considerably in cold weather, several months of winter usually provides enough time to adequately dry out the laminate. The boat should be protected from the elements and ventilated to dry the interior as well as the exterior. Check the hull with a moisture meter to be sure it is dry.

In tropical climates, passive drying is not always practical. Although it is warmer, high humidity slows drying speed. In areas where the cost of extended storage is a consideration, active drying is often the more economical method.

With either method, open up the blister cavities and thoroughly abrade or remove the gelcoat as soon as possible after your boat is pulled from the water.

3.3 Active drying

When time or the expense of storage space is a factor, several alternatives are available to accelerate drying.

3.3.1 Tenting

One method to accelerate the drying time, particularly if you are in a warmer, humid climate, is to enclose the bottom of the boat in a plastic tent and place dehumidifiers inside the tent. This can be as simple as taping a plastic skirt around the hull, above the waterline, using electrician's tape (it's much easier to remove from the fiberglass surface) and weighting the bottom of the plastic to seal the tent *(Figure 3-3)*. Plastic should also be placed on the ground to *completely seal* the bottom of the boat. Small fans to keep air moving around the hull will also help. If you're particularly industrious, or if you'll be drying out many boats, you may want to construct a full-size, frame-and-plastic drying shed *(Figure 3-4)*. In cooler climates, electric heaters can be installed inside the tent in addition to the dehumidifiers.

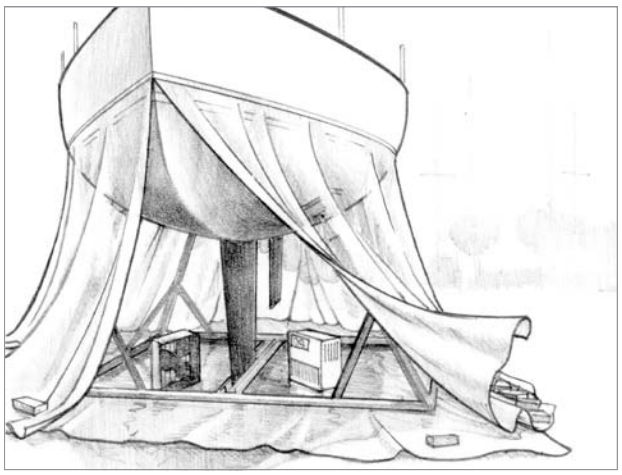


Figure 3-3 *Drying the hull can be accelerated by tenting the hull with a plastic skirt, taped just above the waterline.*

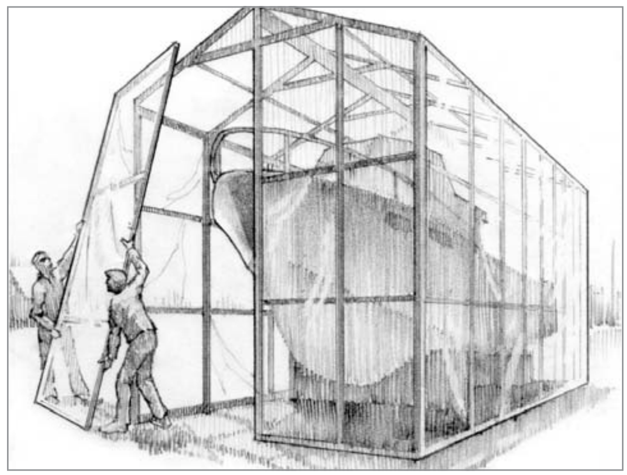


Figure 3-4 *For yards repairing many boats, a drying shed built of lumber and plastic (on the order of a greenhouse) can free up valuable shop space.*

3.3.2 Heaters

Heat is an important factor in accelerated drying. The warmer the temperature, the more water molecules move around and pass through the laminate. Various types of portable heaters may be used to accelerate drying. Electric and catalytic heaters that generate long wave infrared radiation work well and are relatively safe, but use caution to avoid overheating the laminate. Be aware of the dangers of using heaters in an enclosed space and follow all manufacturer's recommendations for the safe use of heaters. Unvented fuel heaters (fuel oil and kerosene) should not be used when tenting. Aside from the dangers of asphyxiation, these types of heaters have been known to contaminate a hull's surface. 100°F temperatures plus dehumidification can dry a hull in as little as two weeks.

3.3.3 Drying the interior

Moisture can penetrate the laminate just as easily from the interior as through the exterior and the bilge is often overlooked when drying the hull. Use sponges to remove all bilge water and provide adequate ventilation within the boat. Open up hatches, cabinets and floor boards to allow free air circulation. To accelerate drying, you may install fans, heaters or a dehumidifier in the boat.

Once the laminate is dried enough to avoid further hydrolysis and provide good bonding, the necessary filling and fairing and coating can proceed as described in Section 4. ■

4 Repairing Blister Damage

This section describes the procedures for filling and fairing minor isolated blister cavities that were prepared in Section 2.2. It describes the repair of extensive blister damage described in Section 2.3 and delamination described in Section 2.4 after the hull laminate has dried out.

4.1 Minor isolated blister damage

The following repair method is specifically tailored to fix minor individual blisters prior to bottom painting. The advantage of this method is that the repair can be completed in a matter of hours and requires no barrier coating prior to bottom painting. It can be used to repair blisters on hulls that have been recently pulled from the water or on hulls that have been out of the water for *some* time. Continue the repair after opening up the blisters as described in Section 2.2.

1. Wipe the cavity clean with an alcohol prep pad or paper towels that have been soaked in rubbing (isopropyl) alcohol *(Figure 4-1)*. Be generous with the alcohol and be sure to change towels frequently so the contaminants are removed rather than spread. Repeat the alcohol wipe/allow to dry process until the laminate is dry to the touch. It is particularly important to repeat the alcohol-wipe process on blisters that were fluid filled at the time they were ground away.
2. Wet out the recently sanded and cleaned blister cavities with an unthickened mixture of WEST SYSTEM® Epoxy *(Figure 4-2)*. Use 205 hardener if you are in a hurry. Allow this initial epoxy coat to gel slightly to lessen the likelihood of the thickened epoxy sliding out of the repair. If you are in a hurry, wipe off most of the initial epoxy with dry paper towel or apply moderate heat to accelerate the epoxy's gel.

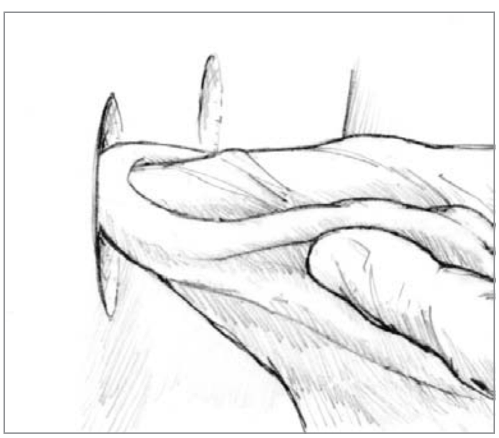


Figure 4-1 *Wipe the cavity clean with alcohol and repeat until the laminate is dry to the touch.*

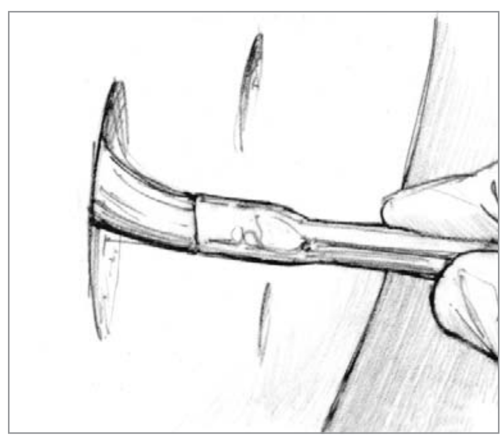


Figure 4-2 *Wet out the cleaned blister cavities with unthickened epoxy.*

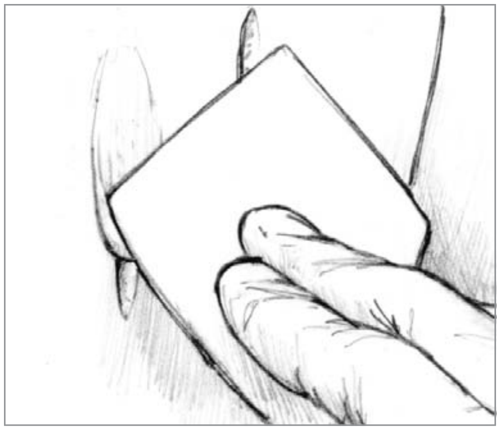


Figure 4-3 *Fill the cavities with epoxy thickened with 406 Colloidal Silica filler.*

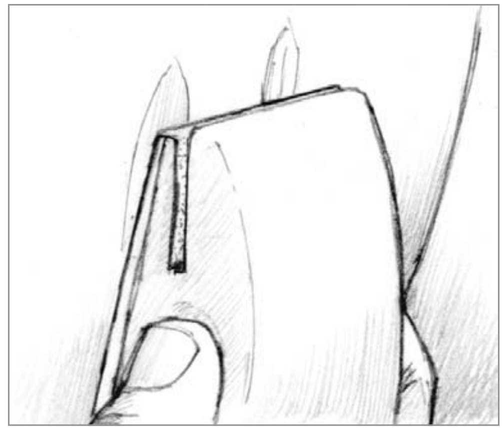


Figure 4-4 *Wash with water and sand with 100-grit sandpaper or wet sand with 80–120-grit .*

3. Fill the cavities with epoxy thickened to a non-sagging consistency with 406 Colloidal Silica filler *(Figure 4-3)*. Avoid overfilling the cavities because 406 thickened epoxy is difficult to sand. On larger cavities where the epoxy may generate exotherm (heat buildup), add more filler to the mix to increase viscosity. The extra filler helps to resist sagging at elevated temperatures caused by exotherm. Allow the epoxy to cure.

Note: Low-density filler is generally recommended for filling blisters because the epoxy/low-density filler mixture sands easily and it will be coated with an epoxy barrier coat. Epoxy thickened with 406 resists moisture permeation better than epoxy thickened with low-density fillers, but it is more difficult to sand. Limiting epoxy/406 to isolated blister repair is more practical that using it on larger jobs that may require a lot of fairing. Use 406 Filler when you will not be applying a barrier coating.

4. Wet sand with 80–120-grit wet/dry sandpaper or wash with water (no soap, no ammonia) and sand dull with 100-grit sandpaper *(Figure 4-4)*. If 105/205 epoxy has been used in warm conditions, sanding and bottom painting can be done later the same day. With slower hardener or in cooler temperatures, allow the epoxy to cure overnight. Apply your bottom paint of choice. Improve the boat's ventilation! See Section 5.4.

4.2 Extensive blister damage

4

Once the blister cavities have been opened, as described in Section 2.3, and the hull has been dried out and cleaned, the cavities must be filled and the surface faired. Drying time may have been anywhere from a week to several months, depending on the drying method and how wet the laminate was. During the drying period, trace particles of solutes may have leached out and remain on the surface. These elements must be removed because they are likely to cause bonding problems. Begin the filling process as follows:

1. Pressure wash, or scrub the surface with an abrasive pad or stiff brush while flushing with fresh water to remove contaminants *(Figure 4-5)*. The brief exposure to the fresh water won't drive up the moisture content of the laminate. Wipe dry with clean paper towels. Avoid washing with solvents, unless a particular contaminant is not water soluble. If you must use solvents, apply and dry with paper towels before the solvent evaporates. Do not use rags to apply or remove solvents

2. Allow the hull to sit overnight to allow the surface to dry completely. Be sure any condensation on the hull has dried before proceeding. Fans or heaters directed at the surface may allow you to start the repair earlier in the day.

3. Wet out the repair area with unthickened epoxy. Doing so will saturate exposed reinforcing fibers, and will provide a good, secondary bond to the cured polyester resin. Each blis-

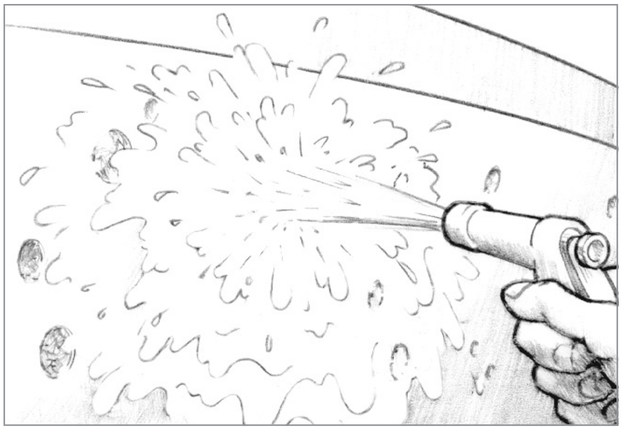


Figure 4-5 *Scrub the surface with a stiff brush while flushing with fresh water to remove contaminants. Allow to dry completely.*

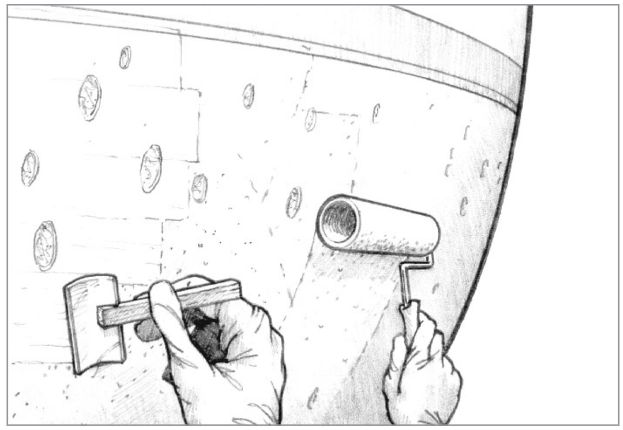


Figure 4-6 *The entire hull or large areas may be wet out with a foam roller. A foam roller brush will remove bubbles and roller marks.*

ter cavity should be saturated with the resin/hardener mixture, taking care to work the epoxy into cracks or crevices with a disposable brush or coat the entire area, applying the epoxy with a foam roller cover. Remove air bubbles by tipping off the surface with a foam roller brush *(Figure 4-6)*. Wet out individual cavities with a disposable brush as necessary to be sure each cavity is well coated. Wait for 30-60 minutes before beginning the next step. This will allow the wet-out coat to cure slightly and prevent the thick fairing mixture from sliding. See Section 6.3 for information on cure times.

4. Prepare a fairing compound by mixing resin/hardener and either 407 or 410 filler to a non-sagging peanut butter consistency.
5. Apply the fairing compound into the blister cavities with a plastic spreader before the wet-out reaches its final cure phase. If the wet-out coat has reached its final cure, wash and sand the surface before applying the compound. Hold the squeegee at a low angle to leave the mixture smooth and filled slightly higher than the surrounding surface *(Figure 4-7)*. Remove any excess epoxy before it cures.
6. Allow the fairing compound to cure thoroughly. For details on cure time see Section 6.3–Handling Epoxy.
7. Sand the surface fair following the procedures outlined in Section 6.4.2 *(Figure 4-8)*. Check for fairness. Reapply fairing compound as needed, repeating the procedure until the surface is fair and smooth.

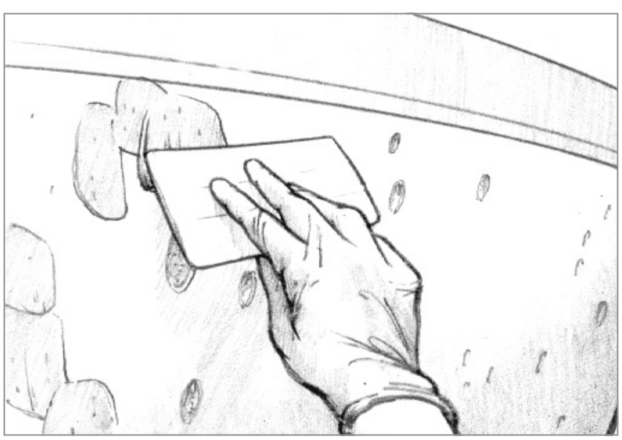


Figure 4-7 *Trowel thickened fairing compound into the blister cavities with a plastic squeegee.*

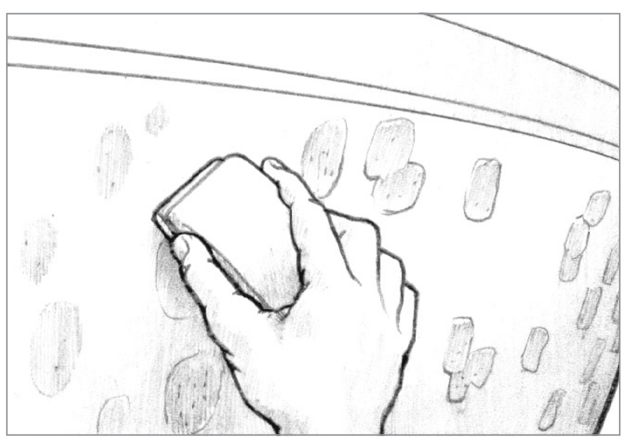


Figure 4-8 *Sand the surface fair after the epoxy/filler has cured thoroughly.*

4.3 Interlaminate damage

Sounding or visual inspection may have revealed voids or hydrolysis below the outer layer of laminate. After completing the preparation described in Section 2.4–*Exposing and removing interlaminate damage*, proceed with the appropriate repair.

4.3.1 Small voids

To repair small voids that have been pattern drilled with the outer laminate left in place as described in Section 2.4.1, first dry thoroughly. Then re-bond the separated laminate by injecting an epoxy mixture into the void as follows:

1. Prepare an 807 Syringe for injecting an epoxy mixture into the voids. Cut 1" off the tapered syringe tip. This will leave a tip diameter of about ", which will fit tight when pushed into the drilled " pattern holes. Adjust the tip length/diameter to fit the hole diameters.
2. Prepare an epoxy mixture of resin/hardener and 406 Colloidal Silica filler to a catsup consistency. Fill the syringe with the epoxy mixture. If the mixture is too thick to draw into the syringe, remove the plunger and pour the mixture in.
3. Inject the mixture into the void through the pattern holes. Force the syringe tip into the lowest pattern hole and inject the mixture until it reaches and begins to ooze from the surrounding holes *(Figure 4-9)*.

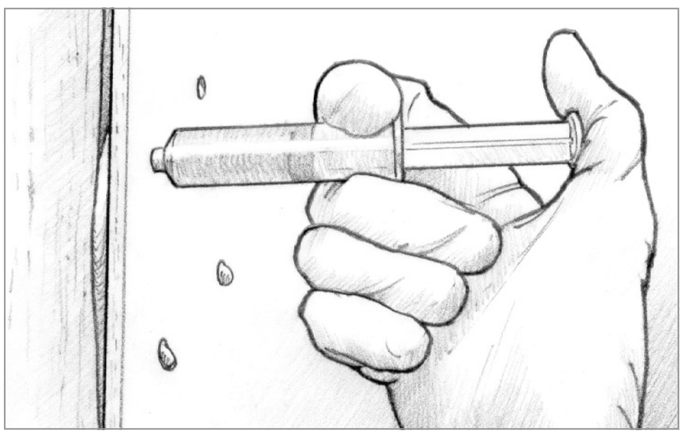


Figure 4-9 *Inject the epoxy mixture until it reaches the surrounding holes.*

4. Move to the next open hole and repeat the procedure. Continue injecting the mixture, filling the void from the bottom up, until all of the air in the void is displaced by the mixture.
5. Allow the epoxy to cure thoroughly. If any small air pockets remain, drill two holes through to the void on opposite sides of the void. Inject additional epoxy mixture into one of the holes. The second hole will allow air to escape.

4.3.2 Large voids

In instances of severe blistering, you may have to excavate large amounts of laminate. In such cases, it is best to restore the hull's structural integrity by replacing the excavated laminate with new fiberglass cloth bonded into place with epoxy. The new skin must be laminated to approximately the same thickness and strength as the original skin. Multiple layers of lightweight cloth will develop the same or greater strength than a single layer of heavy cloth. Use a fiberglass fabric such as WEST SYSTEM® 740, 742 or 745 Episize™ Glass Fabrics.

Grind out all of the damaged area, exposing clean, solid laminate. Bevel the edge of the repair to a 12-to-1 angle, as described in Section 2.4.2, allow the laminate to dry thoroughly and rebuild the excavated laminate as follows:

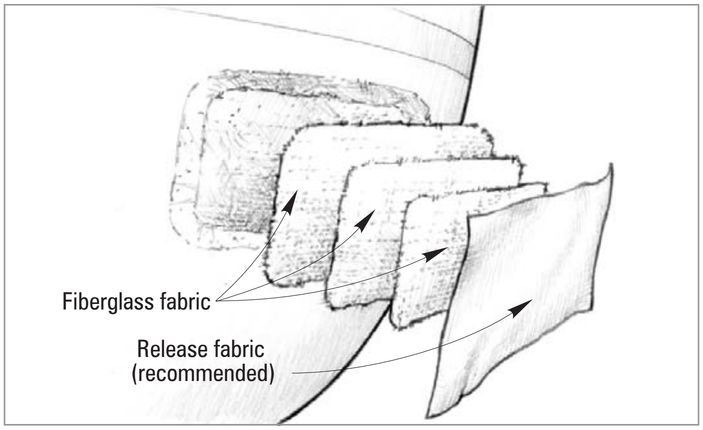


Figure 4-10 *Rebuild the laminate to its original thickness using multiple layers of glass cloth, bonded with epoxy.*

1. Cut an appropriate number of pieces of fiberglass cloth the same shape as the repair area. The first piece should be slightly smaller than the outside of the beveled edge with subsequent pieces gradually getting smaller. The final layer should be the same size as the bottom of the bevel, and the combined thickness of the layers should be slightly thinner than the original panel to allow for final shaping and fairing. Also cut one piece of WEST SYSTEM 879 Release Fabric or peel ply, several inches larger than the repair area. This will be used to smooth the patch into place *(Figure 4-10)*.
2. Wet out the repair area with a resin/hardener mixture *(Figure 4-11)*.
3. Apply a layer of thickened epoxy to the entire repair surface (including the beveled edge) with a plastic squeegee *(Figure 4-12)* after the wet-out has reached its initial cure stage. Mix resin/hardener and 406 Colloidal Silica filler to the consistency of mayonnaise. Apply a thick enough layer to fill any voids or unevenness in the surface and make solid contact with the layers of cloth.
4. Apply the wet-out layers of cloth.

a. Place the largest piece of cloth on a flat, plastic-covered surface *(Figure 4-13)*. Pour a small amount of mixed epoxy in the center of the piece and spread the epoxy into the cloth with a squeegee. As the cloth is wet out, it becomes transparent.

b. Wearing disposable gloves, lift the cloth into position and smooth out bubbles and excess epoxy with the squeegee.

c. Repeat the process for each layer of fabric until you have bonded the smallest piece in place last. Place each piece of cloth in the center of the previous piece. Do not wait for each layer of fabric to cure; you may bond to the still-wet previous layer.

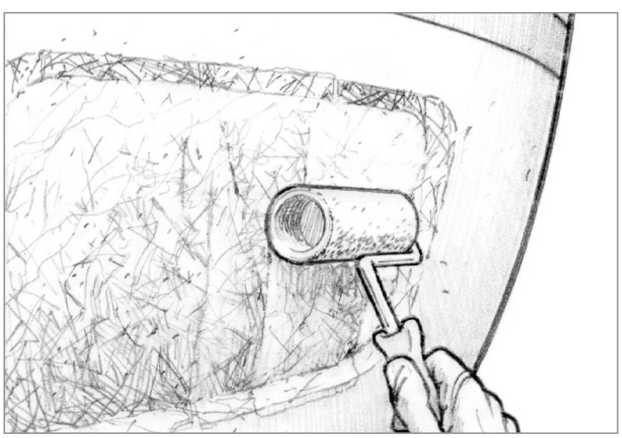


Figure 4-11 *Wet out the repair surface with unthickened epoxy.*

Figure 4-12 *Apply a layer of epoxy/406 thickened to a mayonnaise consistency.*

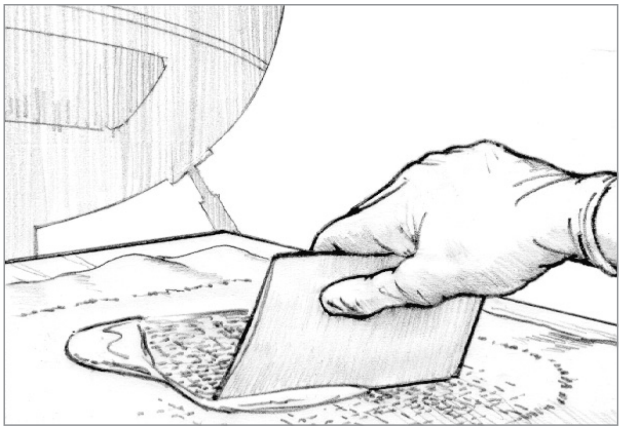


Figure 4-13 *Wet out each piece of cloth with unthickened epoxy and squeegee into place.*

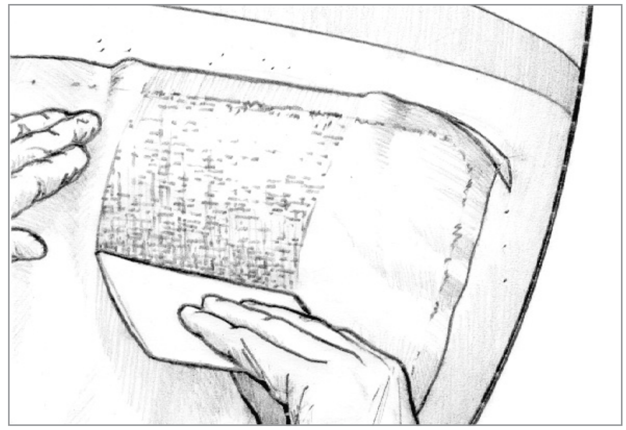


Figure 4-14 *Cover the cloth with a piece of release fabric and squeegee air and excess epoxy from the lay-up.*

5. Cover the repair with release fabric and smooth the patch with the squeegee, squeezing out air and excess epoxy *(Figure 4-14)*.
6. Remove the excess from the surrounding areas with a beveled mixing stick or plain paper towels before the epoxy begins to cure.
7. Allow the patch to cure thoroughly.
8. Peel the release fabric from the cured patch.
9. Sand and fair the surface following the fairing procedures in Section 6.4.2. Begin the final barrier coating operation within 24 hours of the final sanding.

4.3.3 Hydrolysis damage

Hydrolysis most often penetrates to a uniform depth over the entire hull, progressing from the outer layer inward. This means that laminate is most often removed to a uniform depth or specific layer of chopped strand or woven roving. Removal of hydrolyzed laminate usually means peeling or grinding off the outer chopped strand layer if the damage is light and one or more layers of woven roving if the damage is more severe.

Generally chopped strand laminate is nonstructural. If this layer only is removed, the hull can be prepared *(Section 6.4.1)*, faired and barrier coated without replacing it. Woven roving is structural and should be replaced with one or more layers of woven fabric that roughly equals the roving's weight or thickness. For example, if a 24 oz. layer of roving is removed, it can be replaced with two layers of Episize 745 (12 oz.) Glass Fabric, or one layer of 738 Biaxial Fabric (approximately 22 oz.).

Apply the fabric following the procedure in Section 6.4.3. The wet method of application may be preferred when working on the underside of the hull.

After all repairs and fairing are complete, proceed to Section 5–Barrier Coating. ■

5 Barrier Coating

After preparing and drying the hull, and repairing all blister and laminate damage, the next operation is to apply the moisture barrier. A minimum 20-mil (0.020") coating of WEST SYSTEM® epoxy with 422 Barrier Coat Additive is recommended for good protection and can be applied in 5 or 6 coats at room temperature. Note that epoxy is thinner at higher temperatures, resulting in a thinner buildup per coat. At higher temperatures, more than six coats may be required to achieve a 20-mil thick barrier coat.

Additional coats can provide additional protection. However, the benefits of the protection can vary depending on the boat's susceptibility to hydrolysis and its future environment. Boats that will sail in cooler waters and showed little evidence of hydrolysis, will gain little added protection from additional barrier coats. Boats in tropical waters, that showed vulnerably to hydrolysis and blistering, will gain a greater degree of protection from additional barrier coats. In some situations, the additional protection up to 10 coats of epoxy is worth the expense.

See Section 2.5 for information on preparing a new boat for barrier coating.

5.1 Preparation

Avoid starting your epoxy coating application too early in the day. If the boat has cooled substantially during the night, condensation may occur when the ambient air temperature rises faster than the temperature of the hull and keel. Solid lead keels may take considerably longer to warm than the hull. You may want to bring the surfaces up to temperature using heat lamps. Although WEST SYSTEM epoxy will cure at lower temperatures, it will be easier to achieve a uniform coating if the epoxy is applied between 60°F (16°C) and 80°F (27°C).

One objective when applying multiple coats of epoxy is to avoid the necessity of sanding between coats. This is possible if all 5 or 6 coats (or more) can be applied in the same day or if each coat can be applied before the previous coat has reached its final cure phase (Section 6.3.3). You may begin to apply a coat as soon as the previous coat has reached its initial cure phase or has solidified enough to support the weight of the next coat, without sagging. The time between initial cure and final cure will vary with the choice of hardener and the ambient temperature. (See Section 6.3– Handling Epoxy.) If you have no choice over working temperature, chose a hardener that lets you work at a pace you can handle.

Coating a large hull is a big job, one that is ideally handled by two or more people. Before starting, organize your materials, application tools and work area. Decide on everyone's role in the operation and how much of the hull you can efficiently coat in one day. Once you begin, you won't want to stop the procedure.

5.1.1 Planning for one-day coating

A 5 or 6 coat application of epoxy on a small (20' to 30') hull should be a manageable one-day operation for two people. If you have a larger hull or limited help, you can still avoid having to sand between coats or being committed to an unreasonably long coating operation. Rather than applying a few coats to the entire hull on day one and the remaining coats on day two, it would be better to apply all 5 or 6 coats to one half of the hull on day one and all 5 or 6 coats to the other half on day two. Larger hulls may be divided into as many one-day operations as is convenient for you and your crew under your particular working conditions. Only the small area of overlap between one-day coating areas needs to be washed and sanded instead of the entire previous coat.

5.2 Applying the barrier coat

The first coat of epoxy is always applied without additives for maximum penetration or "keying" into the surface. Additives may be added to the second and following coats. Apply the first coat of epoxy within 24 hours of the final sanding.

First coat After all of the above preparations are completed, apply the epoxy barrier coat as follows:

1. Remove all of the sanding dust with a brush or vacuum. Mask the hull at the waterline with electrician's tape.
2. Prepare a batch of resin/hardener, mixing approximately 8 ounces (236ml)–8–10 Mini Pump strokes–at a time. **Stir the mixture thoroughly** and pour into a roller pan immediately after mixing. Do not use additives in the first coat of epoxy.
3. Apply the epoxy to the hull following the coating procedure in Section 6.4.4. Spread the epoxy out to a thin even film with the thin foam roller *(Figure 5-1)*. Continue applying the epoxy, overlapping small coverage areas until the batch is used up.

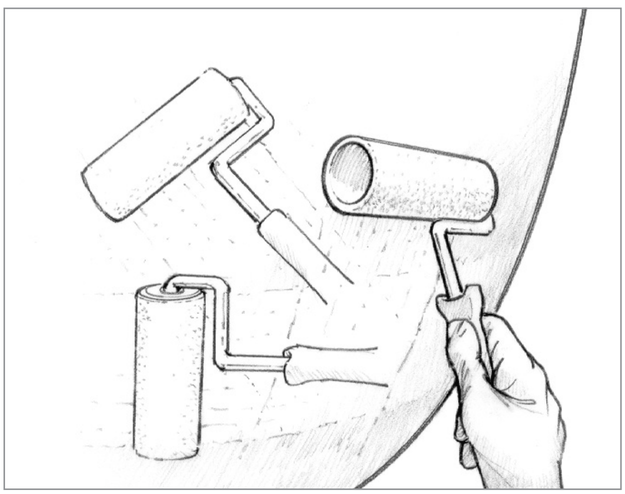


Figure 5-1 *Apply a thin, even film of epoxy with a foam roller.*

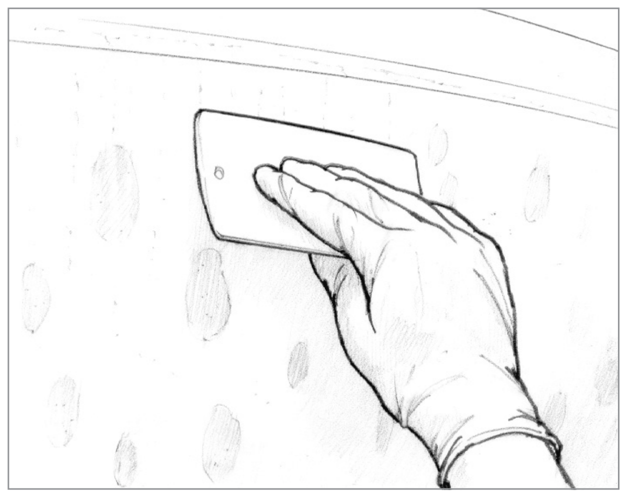


Figure 5-2 *After each batch of epoxy is applied, fill pin holes with a plastic squeegee or spreader. Use firm pressure and hold the squeegee at a nearly flat angle.*

4. Fill pinholes in the surface by squeegeeing the freshly applied epoxy with a stiff plastic or metal spreader. It is important to fill pinholes in the sanded laminate and fairing compound at the first stage of barrier coating. Hold the spreader at a low angle to avoid scraping away epoxy. Press the spreader firmly against the surface and drag the spreader in long, overlapping strokes to "hydraulically" force the epoxy into the pinholes (*Figure 5-2).Fill* the pinholes in each batch area before applying the next batch of epoxy.
5. Apply a second coat of epoxy to the hull before the first coat becomes tack free. Spread the epoxy out to a thin even film with the thin foam roller *(Figure 5-3)*. Continue applying the epoxy, overlapping small coverage areas until the batch is used up.
6. Tip off the freshly applied batch area before you begin applying the next batch. Drag a foam roller brush lightly over the surface in long overlapping strokes, in one direction, to remove

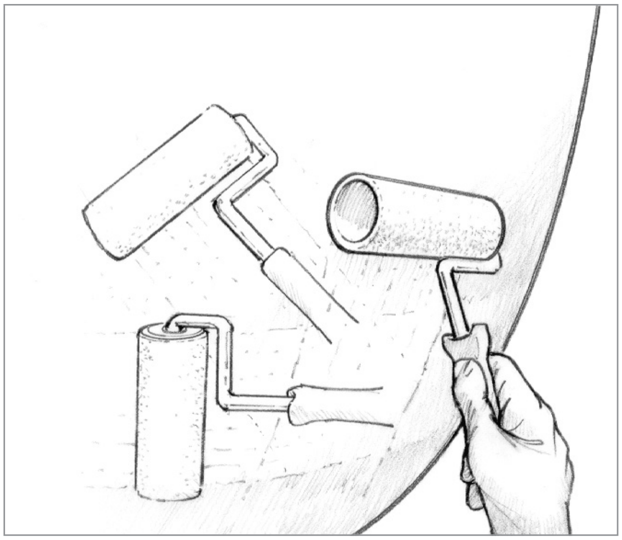


Figure 5-3 *Apply a thin, even film of epoxy with a foam roller.*

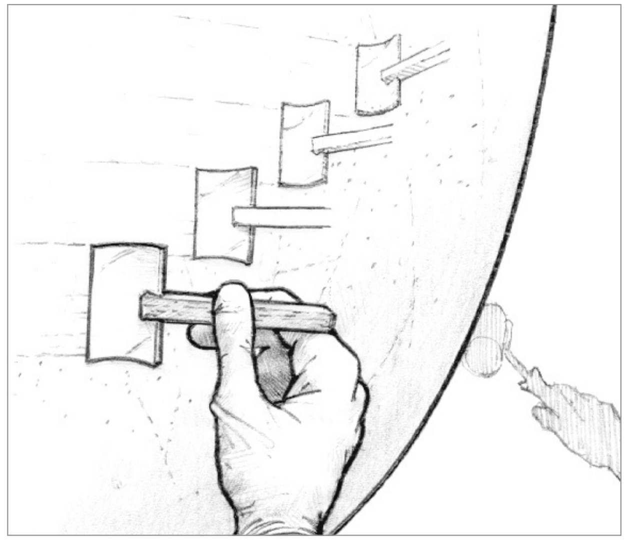


Figure 5-4 *Tip off each fresh coat of epoxy with a foam roller brush to reduce bubbles and roller marks.*

roller marks and air bubbles in the coating. You will find that the thinner the coating, the smoother the finish after tipping off. You may chose to have a helper preparing your next batch of epoxy then tipping off behind you while you continue rolling *(Figure 5-4)*.

It's important that these air bubbles be removed from the surface before the epoxy begins to cure. Our research indicates that an epoxy coating with air entrapment (bubbles) provides significantly less moisture exclusion ability.

7. Continue rolling and tipping off batches of epoxy until your one-day coating area is covered. The batch sizes may be adjusted depending on the amount of working time the hardener and ambient temperature will allow. Mix no more than you can apply and tip off before the batch begins to thicken. (A roller pan cooler box will help to extend the working life of each batch or allow you to mix larger batches. This is especially useful in warmer climates. See Appendix—Tools and Equipment for details.)
   The roller cover and roller cover brush will need to be replaced occasionally as the epoxy saturating the covers from the first batches begins to cure and build up on the cover. Be sure to have enough covers on hand to complete your one-day coating area. Allow two covers per coat per coating area. When you have finished coating, remove the roller cover before it bonds to the frame.

Build up coats You may begin the second coat as soon as the first coat of epoxy has reached its initial cure. To avoid sanding between coats, the second coat must be completed before the first coat reaches its final cure phase. In most cases, by the time you've coated an entire hull, the first section should be ready for the next coat.

1. Prepare an 8-ounce (236 ml) batch of epoxy (approximately 8 to 10 Mini Pump strokes)–**stir thoroughly**. Add approximately 3 tablespoons (56g) of 422 Barrier Coat Additive to the epoxy mixture and stir thoroughly. WEST SYSTEM 422 Barrier Coat Additive performs several important functions. This specially blended, aluminum-based powder further improves the substantial moisture exclusion effectiveness of the epoxy barrier coat and increases abrasion resistance. The additive also turns the normally transparent epoxy opaque, which helps as a visual indicator of coating uniformity during application.
2. Apply this mixture as before, tipping off each batch of epoxy with a foam roller brush as you go *(Figure 5-5)*. Tip off each coat in a direction perpendicular to the previous coat. (i.e. 1st- horizontal, 2nd- vertical, 3rd- horizontal, etc.).

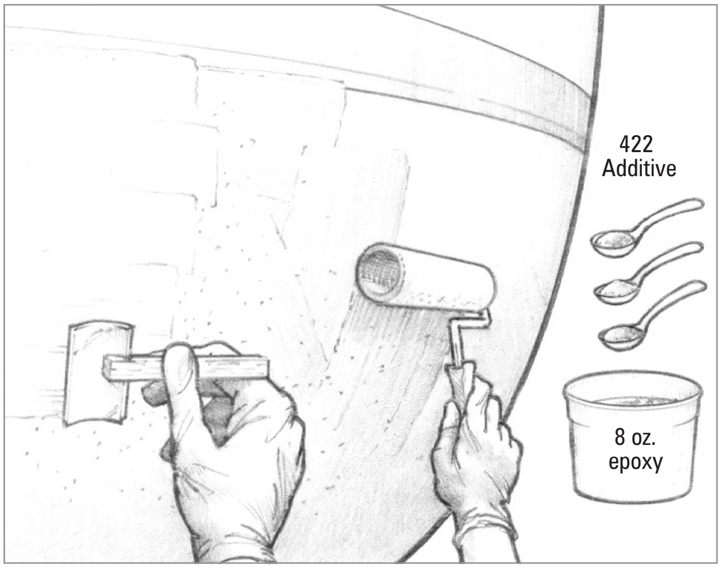


Figure 5-5 *Add 422 Barrier Coat Additive to the second and remaining coats to increase moisture and abrasion resistance. When tipping off, alternate stroke direction with each coat. (i.e. 1st- horizontal, 2nd- vertical, 3rd- horizontal, etc.)*

3. Repeat this process for the remaining five coats of epoxy/barrier coat additive. If you are unable to apply all of the coats in one day, allow the last coat to cure thoroughly. Prepare the surface for bonding (Section 6.4.1) before applying the next coat.

5.3 Bottom paint

Allow the final coat of epoxy to cure for at least 24 hours. Wash the epoxy surface with clean water and a 3M Scotch Brite™ pad to remove amine blush, and then sand (wet or dry) the surface smooth with 80–120-grit sandpaper (refer to paint manufacturer's recommendation). Use caution when sanding; remove only the irregularities in the topmost coats of epoxy. **Do not sand through the top barrier coat.**

Remove sanding dust, and immediately apply a quality, marine-grade bottom paint. Follow the paint manufacturer's instructions for your particular bottom paint.

For a smooth racing finish, after the bottom paint has dried for 12 hours, use a 3M Scotch Brite pad or fine-grit sandpaper to remove minor surface flaws. Additional coats of bottom paint (if desired) can then be applied directly to this surface, again following the paint manufacturer's application instructions.

Note: Most bottom paints tested at Gougeon Brothers have proven to be compatible with cured WEST SYSTEM epoxy surfaces when applied following the procedure described above. However, the reformulation of many bottom paints due to compliance with new environmental restrictions may affect the compatibility of a particular paint. If you have any doubt about the compatibility of a bottom paint, we recommend building a test panel or calling the Gougeon technical staff.

No-sand primers No-sand primers are formulated to prepare a surface so that the need for sanding is eliminated. They work quite well on polyester gelcoat surfaces for bottom paint preparation; however, we've found that their performance is unreliable when used on an epoxy base. Therefore, until our research proves otherwise, **we do not recommend the use of no-sand primers after the epoxy barrier coat has been applied,** and prior to applying bottom paint.

5.4 Recommendations for blister prevention

Section 1.4 listed five recommendations for the prevention and repair of gelcoat blisters. You've invested considerable time, effort and money to complete three of the recommendations. Thorough drying, repair, and the application of a proper epoxy barrier coat will greatly reduce the likelihood of re-blistering. To help protect your investment and further reduce the possibility of blistering, we urge you to follow the two additional recommendations:

1. KEEP THE INTERIOR DRY.

2. MAINTAIN THE BARRIER COAT.

Keeping the interior dry

1. Keep the bilge as dry as possible. Moisture can enter the laminate from the inside as easily as it does from the outside.
2. Check for leaks in water, waste, and fuel tanks. Drain water and waste tanks during the off season to prevent condensation on tank surfaces.
3. Keep the engine sump free of oil that may seal moisture in the laminate. Use a clay-type oil absorber to soak up large amounts of oil and follow up with a degreaser or detergent cleaner. Also keep the sump free of antifreeze which will attract moisture to the surface and can penetrate the laminate.
4. Assure adequate ventilation next to the hull. Provide air movement through lockers and engine compartments, and behind liners, cabin soles, tanks, etc. Condensation will form on boats kept in areas of wide temperature and humidity variation, especially on the cool hull surface below the waterline. Install plenty of appropriate sized louver/vents in panels that trap air and moisture against the hull. Use passive, electric or solar powered electric ventilators, with a flexible vent hose if necessary, to draw moisture from dead air spaces *(Figure 5-6)*.

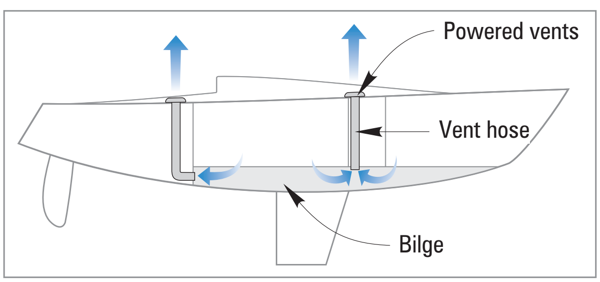


Figure 5-6 *Solar or electric powered exhaust vents can be used to keep the bilge dry. Route a vent hose from the bilge to the deck mounted vent. Air will be drawn from the cabin down through the bilge and carry moisture out through the vent.*

Maintaining the barrier coat

1. Haul the boat and inspect the bottom annually. Check for scrapes or damage to the epoxy barrier coat. Repair and recoat as necessary to maintain a continuous minimum 20-mil coat.
2. If possible, store the boat out of the water during the off season.
3. When sanding or high-pressure cleaning the bottom paint, be careful not to remove the epoxy barrier coat.
4. After several years of use or if your racing hull gets sanded regularly, apply one or two fresh coats of epoxy as necessary to maintain the recommended minimum 20-mil barrier coat thickness. Thoroughly sand the bottom, removing all bottom paint, and apply additional coats of epoxy/barrier as described earlier in this section. Chemical strippers are not recommended for removing bottom paint applied over the epoxy barrier coat. Strippers that contain methylene chloride may soften the epoxy barrier coat if left on long enough.
5. Avoid an excessive buildup of bottom paint. Remove old bottom paint before applying new paint. ■

6 Using WEST SYSTEM® Epoxy

This section is designed to help you understand and safely handle WEST SYSTEM epoxy products and to provide the basic techniques used in most repair and building operations. Refer to the WEST SYSTEM *User Manual & Product Guide* for more complete product information.

6.1 Epoxy safety

Epoxies are safe when handled properly. To use WEST SYSTEM epoxies safely, you must understand their hazards and take precautions to avoid them.

Hazards

The primary hazard associated with epoxy involves skin contact. WEST SYSTEM Resins may cause moderate skin irritation. WEST SYSTEM Hardeners are corrosive and may cause severe skin irritation. Resins and hardeners are also sensitizers and may cause an allergic reaction similar to poison ivy. Susceptibility and the severity of a reaction varies with the individual. Although most people are not sensitive to WEST SYSTEM Resins and Hardeners, the risk of becoming sensitized increases with repeated contact. For those who become sensitized, the severity of the reaction may increase with each contact. The hazards associated with resins and hardeners also apply to the sanding dust from epoxy that has not fully cured. These hazards decrease as resin/hardener mixtures reach full cure. Refer to product labels or Material Safety Data Sheets for specific product warnings and safety information.

Precautions

1. Avoid contact with resin, hardeners, mixed epoxy and sanding dust from epoxy that is not fully cured. Wear protective gloves and clothing whenever you handle WEST SYSTEM Epoxies. Barrier skin creams provide additional protection. If you do get resin, hardener or mixed epoxy on your skin, remove it as soon as possible. Resin is not water soluble—use a waterless skin cleanser to remove resin or mixed epoxy from your skin. Hardener is water soluble—wash with soap and warm water to remove hardener or sanding dust from your skin. Always wash thoroughly with soap and warm water after using epoxy. Never use solvents to remove epoxy from your skin.
   Stop using the product if you develop a reaction. Resume work only after the symptoms disappear, usually after several days. When you resume work, improve your safety precautions to prevent exposure to epoxy, its vapors, and sanding dust. If problems persist, discontinue use and consult a physician.
2. Protect your eyes from contact with resin, hardeners, mixed epoxy, and sanding dust by wearing appropriate eye protection. If contact occurs, immediately flush the eyes with water under low pressure for 15 minutes. If discomfort persists, seek medical attention.
3. Avoid breathing concentrated vapors and sanding dust. WEST SYSTEM epoxies have low VOC content, but vapors can build up in unvented spaces. Provide ample ventilation when working with epoxy in confined spaces, such as boat interiors. When adequate ventilation is not possible, wear a NIOSH (National Institute for Occupational Safety and Health) ap-

proved respirator with an organic vapor cartridge. Provide ventilation and wear a dust mask when sanding epoxy, especially uncured epoxy. Breathing uncured epoxy dust increases your risk of sensitization. Although epoxy cures quickly to a sandable solid, it may take over two weeks at room temperature, or post-curing, to cure completely.

4. Avoid ingestion. Wash thoroughly after handling epoxy, especially before eating or smoking. If epoxy is swallowed, drink large quantities of water—DO NOT induce vomiting. Because hardeners are corrosive, they can cause additional harm if vomited. Call a physician immediately. Refer to First Aid procedures on the Material Safety Data Sheet.
5. KEEP RESINS, HARDENERS, FILLERS AND SOLVENTS OUT OF THE REACH OF CHILDREN.

For additional safety information or data, write to: EPOXY SAFETY, Gougeon Brothers, Inc., P.O. Box 908, Bay City, MI 48707 USA.

6.1.1 Cleanup

Contain large spills with sand, clay or other inert absorbent material. Use a scraper to contain small spills and collect as much material as possible. Follow up with absorbent towels. Uncontaminated resin or hardener may be reclaimed for use. DO NOT use saw dust or other fine cellulose materials to absorb hardeners. DO NOT dispose of hardener in trash containing saw dust or other fine cellulose materials—spontaneous combustion can occur.

Clean resin or mixed epoxy residue with lacquer thinner, acetone or alcohol. Follow all safety warnings on solvent containers. Clean hardener residue with warm soapy water.

Dispose of resin, hardener and empty containers safely. Puncture a corner of the can and drain residue into the appropriate new container of resin or hardener. DO NOT dispose of resin or hardener in a liquid state. Waste resin and hardener can be mixed and cured (in small quantities) to a non-hazardous inert solid.

CAUTION! Pots of curing epoxy can get hot enough to ignite surrounding combustible materials and give off hazardous fumes. Place pots of mixed epoxy in a safe and ventilated area, away from workers and combustible materials. Dispose of the solid mass only if curing is complete and the mass has cooled. Follow federal, state or local disposal regulations.

6.2 Epoxy products

This section provides a short description of WEST SYSTEM resin, hardeners and fillers. Refer to the current *User Manual & Product Guide* for complete information on all WEST SYSTEM products.

6.2.1 Resin and hardeners

Resin

105 Resin—A clear, light-amber, low-viscosity, epoxy resin that can be cured in a wide temperature range to yield a high-strength, rigid solid which has excellent cohesive properties and is an outstanding bonding adhesive and moisture vapor barrier. WEST SYSTEM 105 Resin is formulated for use with four different WEST SYSTEM hardeners. The chart *(Figure 6-1)* on the following page describes the general use and cure speeds of the four hardeners. Use the chart to select the hardener most suited for your application.

Hardeners

205 Hardener—Used for general bonding, barrier coating and fabric application. Formulated to cure at lower temperatures and to produce a rapid cure that develops its physical properties quickly at room temperature. 5:1 mix ratio.

206 Slow Hardener—Used for general bonding, barrier coating and fabric application. Formulated for a longer working and cure time or to provide adequate working time at higher temperatures. 5:1 mix ratio.

Note: 205 Fast and 206 Slow Hardener may be blended for intermediate cure times. Always maintain the proper 5 part resin to 1 part hardener ratio. Do not mix 205 or 206 (5-to-1 ratio) Hardeners with 207 or 209 (3-to-1 ratio) Hardeners.

207 Special Coating Hardener—Formulated specifically for barrier coating and fabric application where *clear finish* is desired. 207 contains a UV stabilization additive, but still requires long term UV protection with paint or varnish. It provides good physical properties for bonding, but it is more difficult to thicken and less cost effective for this purpose than 205 or 206 hardener. 207 is a light amber color that will tint wood slightly darker and warmer, similar to varnish. 3:1 mix ratio.

209 Extra Slow Hardener— Used for general bonding, barrier coating and fabric application in extremely warm and/or humid conditions. Provides approximately twice the pot life and working time as 206 Slow Hardener and adequate pot life up to 110°F (43°C). Also used at room temperatures when a long pot life and working time are required. 3:1 mix ratio.

Hardener Selection Guide

Figure 6-1
Select a hardener for its intended use and for the cure speed best suited for your job, in the temperature range in which you are working.

HARDENER	RESIN/HARDENER USE	HARDENER TEMPERATURE RANGE (°F)* Room Temp. 40° 50° 60° 70° 80° 90° 100°	CURE SPEEDS at room temperature* POT LIFE 100g cupful	OPEN TIME thin film	CURE TO SOLID thin film
205	General bonding and coating		9–12 minutes	60–70 minutes	6–8 hours
206	General bonding and coating		20–25 minutes	90–110 minutes	10–15 hours
207	Clear coating		22–27 minutes	110–130 minutes	12–18 hours
209	General bonding and coating		40–50 minutes	3–4 hours	20–24 hours

*Epoxy cures faster in warmer temperatures and in thicker applications.
Epoxy cures slower in cooler temperatures and in thinner applications.

6.2.2 Fillers

Throughout this manual, we will refer to *epoxy* or *resin/hardener mixture*, meaning mixed resin and hardener without fillers added; and *thickened mixture* or *thickened epoxy*, meaning resin/hardener with one of six fillers added.

Fillers are used to thicken the epoxy for specific applications. They are categorized as either **Adhesive Fillers**—used for structural bonding or gluing, and gap-filling; or **Fairing Fillers**—used for cosmetic surface filling. Although each filler has unique handling and cured characteristics that make it more suitable for some jobs than others *(Figure 6-2)*, for *most* bonding applications any of the adhesive fillers can be used. And for *most* surface filling, either of the fairing fillers can be used. Fillers may also be blended for intermediate characteristics.

Adhesive fillers

403 Microfibers—For general bonding and gap filling. Epoxy/403 mixtures have superior gap-filling qualities and good strength for most bonding applications while retaining wetting/penetrating capabilities. Works especially well with porous woods. Cures to an off-white color.

404 High-Density Filler—For hardware fastener bonding and applications that require maximum physical properties and where high-cyclic loads are anticipated. Also used for gap-filling where maximum strength is necessary. Cures to an off-white color.

405 Filleting Blend—For use in bonding and filleting on naturally finished wood projects. A strong, wood-toned filler that mixes easily and spreads smoothly. Cures to a brown color and can be used to tint other fillers.

406 Colloidal Silica—For general bonding, gap-filling, high-strength bonds and fillets. A practical and versatile, smooth-textured filler. Can be used alone or mixed with other fillers to improve workability and smoothness. Cures to an off-white color.

Fairing fillers

407 Low-Density Filler—A blended microballoon-based filler used to make a fairing compound that is easy to sand or carve while still being reasonably strong on a strength-to-weight basis. Cures to a reddish-brown color.

410 Microlight™—A very low-density filler for creating a light, easily-worked fairing compound. 410 spreads smoothly and sands very easily when cured. Not recommended under dark colored paint or on other surfaces subject to high temperatures. Cures to a light tan color.

See Appendix —Estimating Guides for WEST SYSTEM* products*, for additional filler selection information.

Filler Selection Guide

USES Resin/Hardener mixture thickened with a Filler Use description—Desired characteristics	**ADHESIVE FILLERS** Highest density Highest strength ⟷				**FAIRING FILLERS** ⟷ Lowest density Easiest sanding	
	404 High-density	**406** Colloidal Silica	**403** Microfibers	**405** Filleting Blend	**407** Low-density	**410** Microlight™
Bonding Hardware—Increased fastener interface and hardware load capability—Maximum strength	★★★★	★★★	★★★	★★		
General Bonding—Join parts with epoxy thickened to create a structural gap filler—Strength/gap filling	★★★	★★★	★★★	★★	★	
Bonding with Fillets—Increase joint bonding area and create a structural brace between parts—Smoothness/strength	★★	★★★★	★★	★★★	★★★	
Laminating—Bond layers of wood strips, veneers, planks, sheets and cores—Gap filling/strength	★★	★★★	★★★★	★★	★★	
Fairing—Fill low areas and voids with an easily shaped and sanded surface filler/fairing compound—Sandability/gap filling					★★★	★★★★

Filler suitability for various uses
★★★★=excellent, ★★★=very good, ★★=good, ★=fair, (no stars)=not recommended.

Figure 6-2 *Selecting Fillers—As a rule, use **higher-density fillers** when bonding **higher-density materials** such as hardwoods and metals. Any of the adhesive fillers are suitable for most bonding situations. Your choice of a filler for general use may be based on the handling characteristics you prefer. Fillers may also be blended to create mixtures with intermediate characteristics.*

6.3 Handling epoxy

This section explains the fundamentals of epoxy curing and the steps for proper dispensing, mixing, and adding fillers to assure that every batch of epoxy cures to a useful high-strength solid.

6.3.1 Understanding epoxy's cure stages

Mixing epoxy resin and hardener begins a chemical reaction that transforms the combined liquid ingredients to a solid. The time it takes for this transformation is the **cure time**. As it cures the epoxy passes from the liquid state, through a gel state, before it reaches a solid state *(Figure 6-3)*.

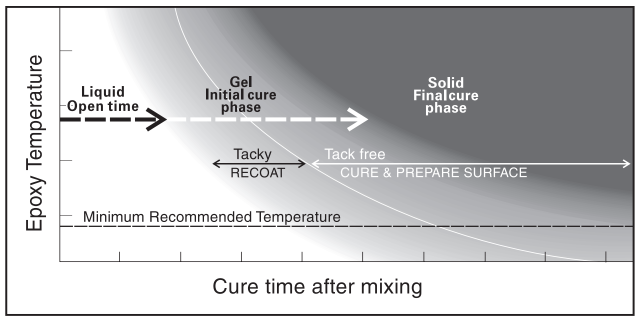


Figure 6-3 *As it cures, mixed epoxy passes from a liquid state, through a gel state, to a solid state. Cure time is shorter when the epoxy is warmer. Cure time is longer when the epoxy is cooler.*

1. Liquid—Open time

Open time (also working time or wet lay-up time) is the portion of the cure time, after mixing, that the resin/hardener mixture remains a *liquid* and is workable and suitable for application. All assembly and clamping should take place during the open time to assure a dependable bond.

2. Gel—Initial cure

The mixture passes into an initial cure phase (also called the green stage) when it begins to *gel*, or "kick off". The epoxy is no longer workable and will no longer feel tacky. During this stage it progresses from a soft gel consistency to the firmness of hard rubber. You will be able to dent it with your thumb nail.

Because the mixture is only partially cured, a new application of epoxy will still chemically link with it, so the surface may still be bonded to or recoated *without special preparation*. However, this ability diminishes as the mixture approaches final cure.

3. Solid—Final cure

The epoxy mixture has cured to a *solid* state and can be dry sanded and shaped. You should not be able to dent it with your thumbnail. At this point the epoxy has reached about 90% of its ultimate strength, so clamps can be removed. It will continue to cure over the next several days at room temperature.

A new application of epoxy will no longer chemically link to it, so the surface of the epoxy *must be properly prepared and sanded* before recoating to achieve a good mechanical, secondary bond. *See Surface Preparation 6.4.1.*

6.3.2 Understanding and controlling cure time

Open time and cure time govern much of the activity of building and repairing with epoxy. Open time dictates the time available for mixing, application, smoothing, shaping, assembly and clamping. Cure time dictates how long you must wait before removing clamps, or before you can sand or go on to the next step in the project. Two factors determine an epoxy mixture's open time and overall cure time—*hardener cure speed* and *epoxy temperature*.

Hardener speed

Each hardener has an ideal temperature cure range *(Figure 6-1)*. At any given temperature, each resin/hardener combination will go through the same cure stages, but at different rates. Select the hardener that gives you adequate working time for the job you are doing at the temperature and conditions you are working under. The product guide and container labels describe hardener pot lives and cure times.

Pot life is a term used to compare the cure speeds of different hardeners. It is the amount of time a specific mass of mixed resin and hardener remains a liquid at a specific temperature. (A 100g-mass mixture in a standard container, at 72°F). Because pot life is a measure of the cure speed of a specific contained mass (volume) of epoxy rather than a thin film, a hardener's pot life is much shorter than its open time.

Epoxy temperature

The warmer the temperature of curing epoxy, the faster it cures *(Figure 6-3)*. Curing epoxy's temperature is determined by the *ambient temperature* plus the *exothermic heat* generated by its cure.

Ambient temperature is the temperature of the air or material in contact with the epoxy. Air temperature is most often the ambient temperature unless the epoxy is applied to a surface with a different temperature. Generally, epoxy cures faster when the air temperature is warmer.

Exothermic heat is produced by the chemical reaction that cures epoxy. The amount of heat produced depends on the thickness or exposed surface area of mixed epoxy. In a thicker mass, more heat is retained, causing a faster reaction and more heat. The mixing container shape and mixed quantity have a great affect on this exothermic reaction. A contained mass of curing epoxy (8 fl. oz. or more) in a plastic mixing cup can quickly generate enough heat to melt the cup and burn your skin. However, if the same quantity is spread into a thin layer, exothermic heat is dissipated, and the epoxy's cure time is determined by the ambient temperature. The thinner the layer of curing epoxy, the less it is affected by exothermic heat, and the slower it cures.

Controlling cure time

In warm conditions use a slower hardener, if possible. Mix smaller batches that can be used up quickly, or quickly pour the epoxy mixture into a container with greater surface area (a roller pan, for example), thereby allowing exothermic heat to dissipate and extending open time. The sooner the mixture is transferred or applied (after thorough mixing), the more of the mixture's useful open time will be available for coating, lay-up or assembly.

In cool conditions use a faster hardener or use supplemental heat to raise the epoxy temperature above the hardeners minimum recommended application temperature. Use a hot air gun, heat lamp or other heat source to warm the resin and hardener before mixing or after the epoxy is applied. At room temperature, supplemental heat is useful when a quicker cure is desired.

CAUTION! Heating epoxy that has not gelled will lower its viscosity, allowing the epoxy to run or sag more easily on vertical surfaces. In addition, heating epoxy applied to a porous substrate (soft wood or low density core material) may cause the substrate to "out-gas" and form bubbles in the epoxy coating. To avoid outgassing, wait until the epoxy coating has gelled before warming it. Never heat mixed epoxy in a liquid state over 120°F (49°C).

Regardless of what steps are taken to control the cure time, thorough planning of the application and assembly will allow you to make maximum use of the epoxy mixture's open time and cure time.

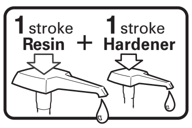
6.3.3 Dispensing and mixing

Careful measuring of epoxy resin and hardener and thorough mixing are essential for a proper cure. Whether the resin/hardener mixture is applied as a coating or modified with fillers or additives, observing the following procedures will assure a controlled and thorough chemical transition to a high-strength epoxy solid.

Dispense the proper proportions of resin and hardener into a clean plastic, metal or wax-free paper container. Don't use glass or foam containers because of the potential danger from exothermic heat buildup. DO NOT attempt to alter the cure time by altering the ratio. An accurate ratio is essential for a proper cure and full development of physical properties.

Dispensing with Mini pumps

Most problems related to curing of the epoxy can be traced to the wrong ratio of resin and hardener. To simplify metering, we recommend using calibrated WEST SYSTEM 300 Mini Pumps to dispense the proper working ratio of resin and hardener.



Pump one full pump stroke of resin for each one full pump stroke of hardener. Depress each pump head fully and allow the head to come completely back to the top before beginning the next stroke *(Figure 6-4)*. Partial strokes will give the wrong ratio. Read the pump instructions before using pumps.

Before you use the first mixture on a project, verify the proper ratio according to the instructions that come with the pumps. Recheck the ratio anytime you experience problems with curing.

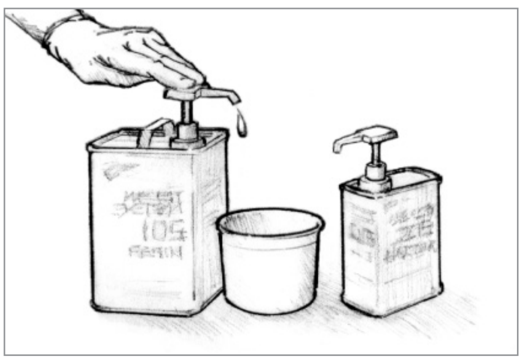


Figure 6-4 *Dispense the proper proportions of resin and hardener.*

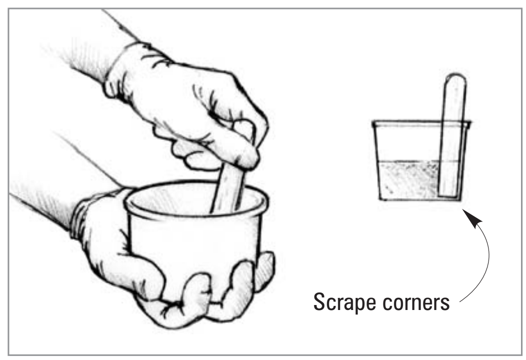


Figure 6-5 *Stir resin and hardener together thoroughly, at least one minute—longer in cooler temperatures.*

Dispensing without Mini Pumps—Weight/volume measure

To measure 105 Resin and 205 or 206 Hardener by weight or volume, combine 5 parts resin with 1 part hardener. To measure 105 Resin and 207 or 209 Hardener by volume, combine 3 parts resin with 1 part hardener (by weight, 3.5 parts resin–1 part hardener).

First time users—If this is the first time you have used WEST SYSTEM epoxy, begin with a small test batch to get the feel for the mixing and curing process before applying the mixture to your project. This will demonstrate the hardener's open time for the temperature you are working in and assure you that the resin/hardener ratio is metered properly. Mix small batches until you are confident of the mixture's handling characteristics.

Mixing

Stir the two ingredients together thoroughly, at least one minute—longer in cooler temperatures *(Figure 6-5)*. To assure thorough mixing, scrape the sides and bottom of the pot as you mix. Use the flat end of the mixing stick to reach the inside corner of the pot. If you are using a power mixer, occasionally scrape the sides and corners of the mixing pot while mixing.

If you are going to be using the mixture for coating, quickly pour it into a roller pan to extend the open time.

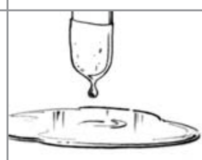
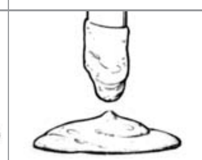
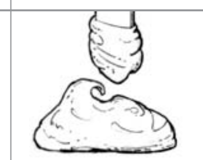
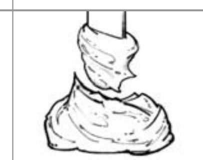
WARNING! Curing epoxy generates heat. Do not fill or cast layers of epoxy thicker than ½"—thinner if enclosed by foam or other insulated material. Several inches of mixed epoxy in a plastic mixing cup will generate enough heat to melt the cup if left to stand for its full pot life. For this reason, do not use foam or glass mixing containers. If a pot of mixed epoxy begins to exotherm (heat up), quickly move it outdoors. Avoid breathing the fumes. Do not dispose of the mixture until the reaction is complete and has cooled.

6.3.4 Adding fillers and additives

Fillers

After selecting an appropriate filler for your job *(Section 6.2.2)*, use it to thicken the epoxy mixture to the desired consistency. The thickness of a mixture required for a particular job is controlled by the amount of filler added. There is no strict formula or measuring involved—use your eye to judge what consistency will work best. Figure 6-6 gives you a general guide to the differences between unthickened epoxy and the three consistencies referred to in this manual.

Figure 6-6 *Epoxy can be thickened to the exact consistency needed for a particular job. The procedures in this manual refer to four common consistencies; syrup, catsup, mayonnaise and peanut butter.*

CONSISTENCY	Unthickened mixture.	Slightly thickened.	Moderately thickened.	Maximum thickness.
	SYRUP	CATSUP	MAYONNAISE	PEANUT BUTTER
GENERAL APPEARANCE				
CHARACTERISTICS	Drips off vertical surfaces.	Sags down vertical surfaces.	Clings to vertical surfaces–peaks fall over.	Clings to vertical surfaces–peaks stand up.
USES	Coating, "wetting-out" before bonding, applying fiberglass, graphite and other fabrics.	Laminating/bonding flat panels with large surface areas, injecting with a syringe.	General bonding, filleting, hardware bonding.	Gap filling, filleting, fairing, bonding uneven surfaces.

Always add fillers in a two-step process:

1. Mix the desired quantity of resin and hardener thoroughly before adding fillers. Begin with a small batch—allow room for the filler.
2. Blend in small handfuls or scoops of the appropriate filler until the desired consistency is reached *(Figure 6-7)*.

   For maximum strength, add only enough filler to completely bridge gaps between surfaces without sagging or running out of the joint or gap. A small amount should squeeze out of joints when clamped. For thick mixtures, don't fill the mixing cup more than 1/3 full of epoxy before adding filler. When making fairing compounds, stir in as much 407 or 410 as you can blend in smoothly—for easy sanding, the thicker the better. Be sure all of the filler is thoroughly blended before the mixture is applied.

Figure 6-7 *Blend in small handfuls or scoops of the appropriate filler until the desired consistency is reached.*

Additives

Additives are used to give epoxy additional physical properties when used as a coating. Although additives are blended with mixed epoxy in the same two-step process as fillers, they are not designed to thicken the epoxy. Follow the mixing instructions on the individual additive containers.

6.3.5 Removing epoxy

Removing uncured or non-curing epoxy. Removed uncured epoxy as you would spilled resin. Scrape as much material as you can from the surface using a stiff metal or plastic scraper—warm the epoxy to lower its viscosity. Clean the residue with lacquer thinner, acetone, or alcohol. Follow safety warnings on solvents and provide adequate ventilation. After recoating wood surfaces with epoxy, it's a good idea to brush the wet epoxy (in the direction of the grain) with a wire brush to improve adhesion. Allow solvents to dry before recoating.

Removing fiberglass cloth applied with epoxy. Use a heat gun to heat and soften the epoxy. Start in a small area near a corner or an edge. Apply heat until you can slip a putty knife or chisel under the cloth (about 200°F). Grab the edge with a pair of pliers and pull up on the cloth while heating just ahead of the separation. On large areas, use a utility knife to score the glass and remove in narrower strips. Resulting surface texture may be coated or remaining epoxy may be removed as follows.

Removing cured epoxy coating. Use a heat gun to soften the epoxy (200°F). Heat a small area and use a paint or cabinet scraper to remove the bulk of the coating. Sand the surface to remove the remaining material. Provide ventilation when heating epoxy.

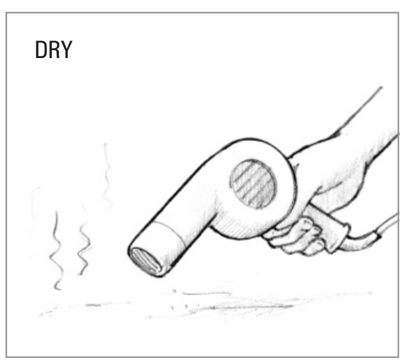
6.4 Basic techniques

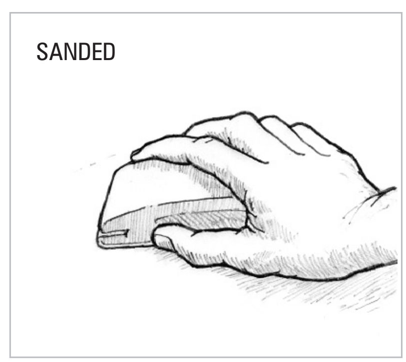
The following basic techniques are common to most repair or building projects, regardless of the type of structure or material you are working with.

6.4.1 Surface preparation

Whether you are bonding, fairing or applying fabrics, the success of the application depends not only on the strength of the epoxy, but also on how well the epoxy adheres to the surface to which it is being applied. Unless you are bonding to partially cured epoxy, the strength of the bond relies on the epoxy's ability to mechanically "key" into the surface. That is why the following three steps of surface preparation are a critical part of any secondary bonding operation.

For good adhesion, bonding surfaces should be:





6

1. Clean

Bonding surfaces must be free of any contaminants such as grease, oil, wax or mold release. Clean contaminated surfaces with lacquer thinner, acetone or other appropriate solvent. Wipe the surface with paper towels before the solvent dries. Clean surfaces *before* sanding to avoid sanding the contaminant into the surface. Follow all safety precautions when working with solvents.

2. Dry

All bonding surfaces must be as dry as possible for good adhesion. If necessary, accelerate drying by warming the bonding surface with hot air guns, hair dryers or heat lamps. Use fans to move the air in confined or enclosed spaces. Watch for condensation when working outdoors or whenever the temperature of the work environment changes.

3. Sanded

Sand smooth non-porous surfaces—thoroughly abrade the surface. For most surfaces, 80-grit aluminum oxide paper will provide a good texture for the epoxy to "key" into. Be sure the surface to be bonded is solid. Remove any flaking, chalking, blistering, or old coating before sanding. Remove all dust after sanding.

Special preparation for various materials

Cured epoxy—Amine blush can appear as a wax-like film on cured epoxy surfaces. It is a byproduct of the curing process and may be more noticeable in cool, moist conditions. Amine blush can clog sandpaper and inhibit subsequent bonding, but it can easily be removed. It's a good idea to assume it has formed on any cured epoxy surface.

To remove the blush, wash the surface with clean water (not solvent) and an abrasive pad, such as Scotch-brite™ 7447 General Purpose Hand Pads. Dry the surface with paper towels to remove the dissolved blush before it dries on the surface. Sand any remaining glossy areas with 80-grit sandpaper. Wet-sanding will also remove the amine blush. If a release fabric is applied over the surface of fresh epoxy, all amine blush will be removed when the release fabric is peeled from the cured epoxy and no additional sanding is required.

Epoxy surfaces that have not fully cured may be bonded to or coated *with epoxy* without washing or sanding. Before applying *coatings other than epoxy* (paints, bottom paints, varnishes, gelcoats, etc.), allow epoxy surfaces to cure fully, then wash and sand.

Hardwoods—Sand with 80-grit paper

Teak/oily woods—Wipe with acetone 15 minutes before coating. The solvent dries the oil at the surface and allows epoxy to penetrate. Be sure the solvent has evaporated before coating.

Porous woods—No special preparation needed. If surface is burnished, possibly by dull planer blades, sand with 80-grit paper to open pores.

Steel, lead—Remove contamination, sand or grind to bright metal, coat with epoxy then sand fresh epoxy into surface. Recoat or bond after first coat gels.

Aluminum—Sand and prepare with 860 Aluminum Etch Kit.

Polyester (fiberglass)—Clean contamination with a silicone and wax remover such as DuPont Prep-Sol™ 3919S. Sand with 80-grit paper to a dull finish.

Plastic—Adhesion varies. If a plastic is impervious to solvents such as acetone, epoxy generally will not bond to it. Soft, flexible plastics such as polyethylene, polypropylene, nylon, Plexiglas and polycarbonate fall into this category.

Hard, rigid plastics such as PVC, ABS and styrene provide better adhesion with good surface preparation and adequate bonding area. After sanding, flame oxidizing (by quickly passing propane torch over the surface without melting the plastic) can improve bonding in some plastics. Its a good idea to conduct an adhesion test on a plastic that you are uncertain about.

6.4.2 Fairing

Fairing refers to the filling and shaping of low areas so they blend with the surrounding surfaces and appear "fair" to the eye and touch. After major structural assembly has been completed, final fairing can be easily accomplished with WEST SYSTEM epoxy and low-density fillers.

1. Prepare the surface as you would for bonding (Section 6.4.1). Sand smooth any bumps or ridges on the surface and remove all dust from the area to be faired.
2. Wet out porous surfaces with unthickened epoxy *(Figure 6-8)*.

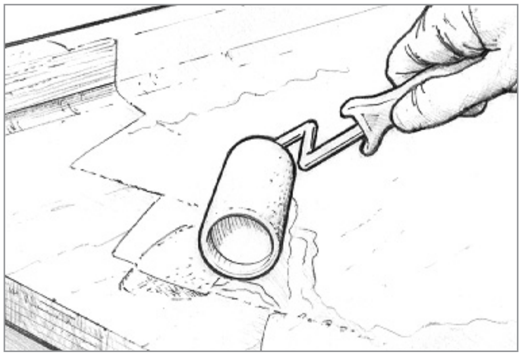


Figure 6-8 *Wet out porous surfaces before applying thickened fairing compound.*

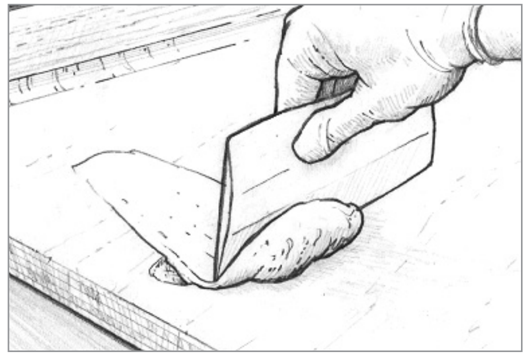


Figure 6-9 *Trowel the thickened epoxy fairing compound into the voids and depressions with a plastic spreader.*

3. Mix resin/hardener and 407 Low-Density or 410 Microlight™ filler to a peanut butter consistency.
4. Trowel on the thickened epoxy mixture with a plastic spreader, working it into all voids and depressions. Smooth the mixture to the desired shape, leaving the mixture slightly higher than the surrounding area *(Figure 6-9)*. Remove any excess thickened epoxy before it cures. If the voids you are filling are over ½" deep, apply the mixture in several applications or use 206 Slow Hardener or 209 Extra Slow Hardener, depending on ambient temperature.
5. Allow the final thickened epoxy application to cure thoroughly.
6. Sand the fairing material to blend with the surrounding contour *(Figure 6-10)*. Begin with 50-grit sandpaper if you have a lot of fairing material to remove. Use 80-grit paper on the appropriate sanding block when you are close to the final contour. ***CAUTION!*** Don't forget your dust mask. Remove the sanding dust and fill any remaining voids following the same procedure.

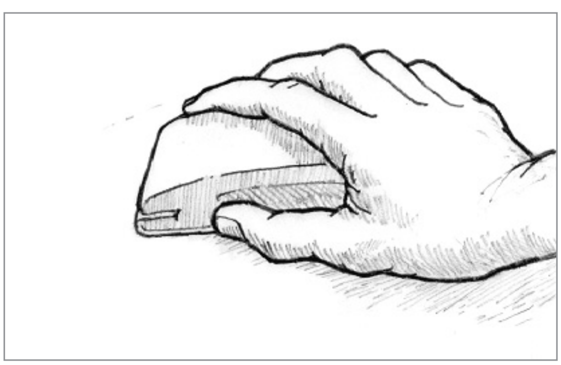


Figure 6-10 *Sand the fairing material to blend with the surrounding contour.*

7. Apply several coats of resin/hardener to the area with a disposable brush or roller after you are satisfied with the fairness. Allow the final coat to cure thoroughly before final sanding and finishing.

6.4.3 Applying woven cloth and tape

Fiberglass cloth is applied to surfaces to provide reinforcement and/or abrasion resistance, or in the case of Douglas Fir plywood, to prevent grain checking. It is usually applied after fairing and shaping are completed, and before the final coating operation. It is also applied in multiple layers (laminated) and in combination with other materials to build composite parts.

Fiberglass cloth may be applied to surfaces by either of two methods. The “dry” method refers to applying the cloth over a dry surface. The “wet” method refers to applying the cloth to an epoxy-coated surface often after the wet-out coat becomes tacky, which helps it cling to vertical or overhead surfaces. Since this method makes it more difficult to position the cloth, the dry method is the preferred method especially with thinner cloth.

Dry method

1. Prepare the surface as you would for bonding (Section 6.4.1).
2. Position the cloth over the surface and cut it several inches larger on all sides. If the surface area you are covering is larger than the cloth size, allow multiple pieces to overlap by approximately two inches. On sloped or vertical surfaces, hold the cloth in place with masking or duct tape, or with staples.
3. Mix a small quantity of epoxy (three or four pumps each of resin and hardener).
4. Pour a small pool of resin/hardener near the center of the cloth.
5. Spread the epoxy over the cloth surface with a plastic spreader, working the epoxy gently from the pool into the dry areas *(Figure 6-11)*. Use a foam roller or brush to wet out fabric on vertical surfaces. Properly wet out fabric is transparent. White areas indicate dry fabric. If you are applying the cloth over a porous surface, be sure to leave enough epoxy to be absorbed by both the cloth and the surface below it. Try to limit the amount of squeegeeing you do. The more you “work” the wet surface, the more minute air bubbles are placed in suspension in the epoxy. This is especially important if you plan to use a clear finish (see note below). You may use a roller or brush to apply epoxy to horizontal as well as vertical surfaces.

   Smooth wrinkles and position the cloth as you work your way to the edges. Check for dry areas (especially over porous surfaces) and re-wet them as necessary before proceeding to the next step. If you have to cut a pleat or notch in the cloth to lay it flat on a compound curve or corner, make the cut with a pair of sharp scissors and overlap the edges for now.

   Note: For clear wood finishes, an alternative wet out method is to lay the epoxy onto the fabric with a short-bristled brush. Dip the brush in the epoxy and lay the epoxy on the sur-

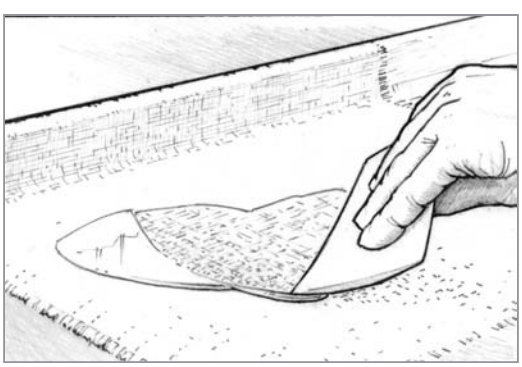


Figure 6-11 *Spread the epoxy from the center of the fabric toward the edges with a plastic spreader.*

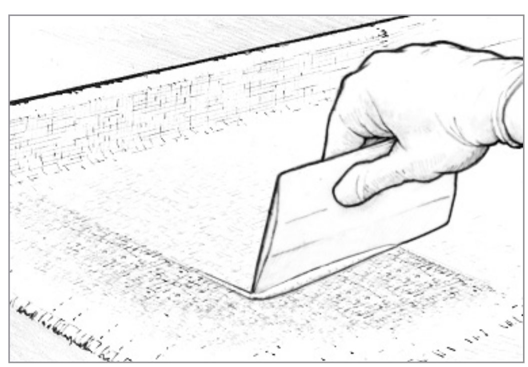


Figure 6-12 *Squeegee away excess epoxy before the first batch begins to gel.*

face in a light even stroke. Don't force the epoxy into the cloth,which may trap air in the fabric and show through the clear finish. Apply enough epoxy to saturate the fabric and the wood below. After several minutes, lay on additional epoxy to dry (white) areas.

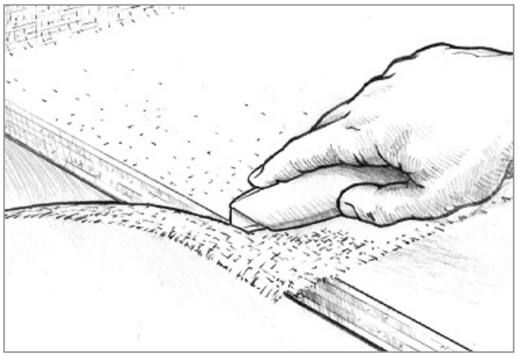


Figure 6-13 *Trim excess cloth when the epoxy reaches its initial cure phase. The wet-out cloth will be dry but flexible and will trim easily with a sharp utility knife.*

7. Squeegee away excess epoxy before the first batch begins to gel *(Figure 6-12)*. Drag the spreader over the fabric, using even-pressured, overlapping strokes. Use enough pressure to remove excess epoxy that would allow the cloth to float off the surface, but not enough pressure to create dry spots. Excess epoxy appears as a shiny area, while a properly wet-out surface appears evenly transparent, with a smooth, cloth texture. Later coats of epoxy will fill the weave of the cloth.
8. Trim the excess and overlapped cloth after the epoxy has reached its initial cure. The cloth will cut easily with a sharp utility knife *(Figure 6-13)*. Trim overlapped cloth, if desired, as follows:

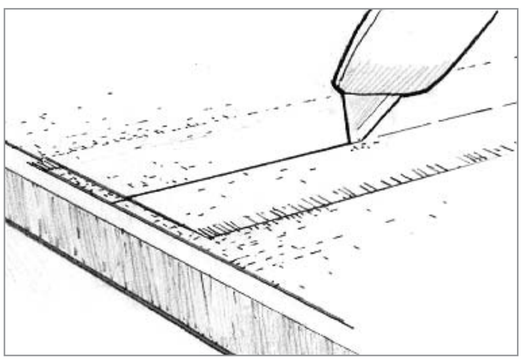


Figure 6-14 *Trim overlapping fabric using a metal straightedge and a sharp utility knife, for a flush butt joint.*

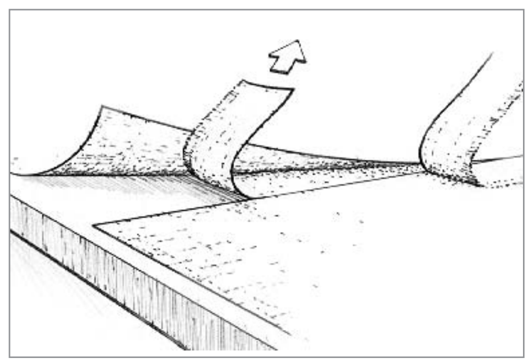


Figure 6-15 *Remove the topmost trimming. Then lift the opposite cut edge to remove the overlapped trimming.*

a) Place a metal straightedge on top of and midway between the two overlapped edges. **b)** Cut through both layers of cloth with a sharp utility knife *(Figure 6-14)*. **c)** Remove the topmost trimming and then lift the opposite cut edge to remove the overlapped trimming *(Figure 6-15)*. **d)** Re-wet the underside of the raised edge with epoxy and smooth into place.

The result should be a near perfect butt joint, eliminating double cloth thickness. A lapped joint is stronger than a butt joint, so if appearance is not important, you may want to leave the overlap and fair in the unevenness after coating.

9. Coat the surface to fill the weave before the wet-out reaches its final cure stage *(Figure 6-16)*. Follow the procedures for epoxy barrier coating under Section 6.4.6. It will take two or three coats to completely fill the weave of the cloth and to allow for a final sanding that will not affect the cloth.

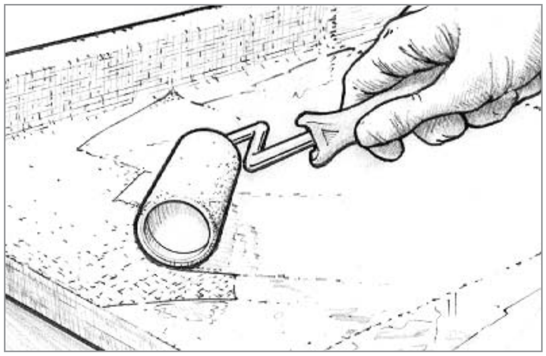


Figure 6-16 *Apply the first coat of un-thickened epoxy to fill the weave of the cloth before the wet-out coat reaches its final cure phase.*

Wet method

An alternative is to apply the fabric or tape to a surface coated with wet epoxy. As mentioned, this is not the preferred method, especially with large pieces of cloth, because of the difficulty removing wrinkles or adjusting the position of the cloth as it is being wet out. However, you may come across situations when this method may be useful or necessary.

1. Prepare the surface (Section 6.4.1).
2. Pre-fit and trim the cloth to size. Roll the cloth neatly so that it may be conveniently rolled back into position later.
3. Roll a heavy coat of epoxy on the surface.
4. Unroll the glass cloth over the wet epoxy and position it. Surface tension will hold most cloth in position. If you are applying the cloth vertically or overhead, you may want to wait until the epoxy becomes tacky. Work out wrinkles by lifting the edge of the cloth and smoothing from the center with your gloved hand or a spreader.
5. Apply a second coat of epoxy with a foam roller. Apply enough epoxy to thoroughly wet out the cloth.
6. Remove the excess epoxy with a spreader, using long overlapping strokes. The cloth should appear consistently transparent with a smooth cloth texture.
7. Follow steps 7, 8 and 9 under the dry method to finish the procedure.

Any remaining irregularities or transitions between cloth and substrate can be faired by using an epoxy/filler fairing compound if the surface is to be painted. Any additional fairing done after the final coating should receive several additional coats over the faired area.

Note: A third alternative, a variation of both methods, is to apply the fabric after a wet out coat has reached an initial cure. Follow the first three steps of the Wet Method, but wait until the epoxy cures dry to the touch before positioning the fabric and continuing with Step 3 of the Dry Method. Apply the fabric before the first coat reaches its final cure phase.

6.4.4 Epoxy barrier coating

The object of final coating is to build up an epoxy coating that provides an effective moisture barrier and a smooth base for final finishing.

Apply a minimum of two coats of WEST SYSTEM epoxy for an effective moisture barrier. Apply three coats if sanding is to be done. Moisture protection will increase with additional coats, up to six coats or about a 20 mil thickness. Additives or pigments should not be added to the first coat. Mixing thinners with WEST SYSTEM epoxy is not recommended.

Disposable, thin urethane foam rollers, such as WEST SYSTEM 800 Roller Covers, allow you greater control over film thickness, are less likely to cause the epoxy to exotherm and leave less stipple than thicker roller covers. Cut the covers into narrower widths to reach difficult areas or for long narrow surfaces like stringers.

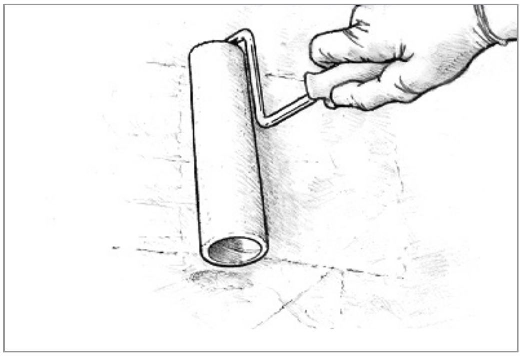


Figure 6-17 *Apply the epoxy in thin even coats using a thin foam roller.*

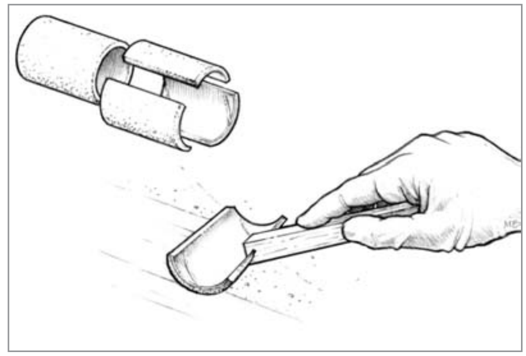


Figure 6-18 *Tip off the fresh coat of epoxy with the grain, using a foam roller brush to remove bubbles and roller marks.*

Complete all fairing and cloth application before beginning the final coating. Allow the temperature of porous surfaces to stabilize before coating. Otherwise, as the material warms up, air within the porous material may expand and pass from the material (outgassing) through the coating and leave bubbles in the cured coating.

1. Prepare the surface as necessary (Section 6.4.1).
2. Mix only as much resin/hardener as you can apply during the open time of the mixture. Pour the mixture into a roller pan as soon as it is mixed thoroughly.
3. Load the roller with a moderate amount of the epoxy mixture. Roll the excess out on the ramp part of the roller pan to get a uniform coating on the roller.
4. Roll lightly and randomly over an area approximately 2 ft x 2 ft to transfer the epoxy evenly over the area *(Figure 6-17)*.
5. As the roller dries out, increase pressure enough to spread the epoxy into a thin, even film. Increase the coverage area, if necessary, to spread the film more thinly and evenly. **The thinner the film, the easier it is to keep it even and avoid runs or sags in each coat.**
6. Finish the area with long, light, even strokes to reduce roller marks. Overlap the previously coated area to blend both areas together.
7. Coat as many of these small working areas as you can with each batch. If a batch begins to thicken before it can be applied, discard it and mix a fresh, smaller batch.
8. Drag a foam roller brush lightly over the fresh epoxy in long, even, overlapping strokes after each full batch is applied. Use enough pressure to smooth the stipple, but not enough to remove any of the coating *(Figure 6-18)*. Alternate the direction in which each coat is tipped off, 1st coat vertical, 2nd coat horizontal, 3rd coat vertical, etc. A WEST SYSTEM 800 Roller Cover can be cut into segments to make a tipping bush.

Recoating Apply second and subsequent coats of epoxy following the same procedures. Make sure the previous coat has cured firmly enough to support the weight of the next coat. To avoid sanding between coats, apply all of the coats in the same day. *See Special preparation—Cured epoxy in Section 6.4.1.* After the final coat has cured overnight, wash and sand it to prepare for the final finish.

6.4.5 Final surface preparation

Proper finishing techniques will not only add beauty to your efforts, but will also protect your work from ultraviolet light which will break down the epoxy over time. The most common methods of finishing are painting or varnishing. These coating systems protect the epoxy from ultraviolet light and require proper preparation of the surface before application.

Preparation for the final finish is just as important as it is for recoating with epoxy. The surface must first be clean, dry and sanded (Section 6.4.1).

1. Allow the final epoxy coat to cure thoroughly.
2. Wash the surface with a Scotch-brite™ pad and water. Dry with paper towels.
3. Sand to a smooth finish. If there are runs or sags, begin sanding with 80-grit paper to remove the highest areas. Sand until the surface feels and looks fair. Complete sanding with the appropriate grit for the type of coating to be applied. Paint adhesion relies on the mechanical grip of the paint keying into the sanding scratches in the epoxy's surface. If a high-build or filling primer is to be applied, 80–100 grit is usually sufficient. For primers and high-solids coatings, 120–180 grit may be adequate. Finishing with 220–400 grit paper will result in a high-gloss finish for most paints or varnishes. Grits finer than this may not provide enough tooth for good adhesion. Wet sanding is preferred by many people because it reduces sanding dust and it will allow you to skip Step 2.
4. After you are satisfied with the texture and fairness of the surface, rinse the surface with fresh water. Rinse water should sheet evenly without beading or fisheyeing. If rinse water beads up (a sign of contamination), wipe the area with solvent and dry with a paper towel, then wet sand again until beading is eliminated.

Proceed with your final coating after the surface has dried thoroughly. To reduce the possibility of contamination, it is a good idea to begin coating within 24 hours of the final sanding. Follow all of the instructions from the coating system's manufacturer. It may be a good idea to make a test panel to evaluate the degree of surface preparation required and the compatibility of the finish system. ■

Estimating Guides

Filler/epoxy proportion guide

Approximate quantity of mixed epoxy required to produce a "catsup", "mayonnaise" or "peanut butter" consistency for the various sized filler products at 72°F. Mixtures will be thinner at higher temperatures.

Filler	Package size	Quantity of mixed epoxy required for "catsup" consistency	"mayonnaise" consistency	"peanut butter" consistency
403-9 403-28 403-B	6.0 oz 20.0 oz 20.0 lb	3.8 qt 3.2 gal 48.0 gal	2.5 qt 2.0 gal 32.0 gal	1.0 qt .9 gal 15.3 gal
404-15 404-45 404-B	15.2 oz 43.0 oz 30.0 lb	1.2 qt 3.6 qt 9.4 gal	.9 qt 2.8 qt 7.4 gal	.7 qt 2.0 qt 5.3 gal
405	8.0 oz	.9 qt	.7 qt	.6 qt
406-2 406-7 406-B	1.7 oz 5.5 oz 10.0 lb	1.3 qt 1.1 gal 27.0 gal	.9 qt 3.0 qt 16.0 gal	.5 qt 1.7 qt 6.0 gal
407-5 407-15 407-B	4.0 oz 12.0 oz 14.0 lb	.5 qt 1.7 qt 6.0 gal	.4 qt 1.3 qt 4.8 gal	.3 qt 1.0 qt 3.7 gal
410-2 410-7 410-B	2.0 oz 5.0 oz 4.0 lb	1.2 qt 3.0 qt 8.9 gal	.9 qt 2.4 qt 7.2 gal	.7 qt 1.8 qt 5.6 gal

Estimating guide for gelcoat blister repair & coating products

Estimates are based on a moderate displacement sailboat. For full keel boats or power boats, add approximately 10% to the product quantity. Quantities assume a 5 or 6 coat buildup. You may find it more economical to purchase supplies in larger quantities. Your actual usage may vary.

Product	*	Length of Boat 20 ft (100 sq ft)	25 ft (200 sq ft)	30 ft (300 sq ft)	35 ft (400 sq ft)	45 ft (500 sq ft)
Gallons of resin, plus hardener (Group Size B's)		1	2	3	4	5
Mini Pumps		1 pr	1 pr	1 pr	1 pr	1 pr
407 Low-Density	1	-0-	-0-	-0-	-0-	-0-
407 Low-Density	2	18 oz	27 oz	36 oz	54 oz	108 oz
407 Low-Density	3	36 oz	54 oz	72 oz	108 oz	216 oz
or 410 Microlight	1	-0-	-0-	-0-	-0-	-0-
or 410 Microlight	2	6 oz	9 oz	12 oz	18 oz	36 oz
or 410 Microlight	3	12 oz	18 oz	24 oz	36 oz	72 oz
Solvent		1 qt	1 qt	2 qt	3 qt	1 gal
422 Barrier Coat Additive		32 oz	64 oz	96 oz	128 oz	160 oz
Gloves		12 pr	12pr	24 pr	24 pr	36 pr
Roller Covers		6	6	12	12	24
Roller Frames		2	2	2	4	4
Squeegees	1	-0-	-0-	-0-	-0-	-0-
Squeegees	2	2	2	2	4	4
Squeegees	3	4	4	4	4	4
Mixing Pots		6	6	6	6	6
Mixing Sticks		12	12	24	24	36

*Bottom Condition
1 No Blistering—fairing not required
2 Moderate Blistering—minor fairing required
3 Severe Blistering—extensive fairing required

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Epoxy group size quantities and coating coverage

WEST SYSTEM epoxy resin and hardeners are packaged in three “Group Sizes.” For each container size of resin, there is a corresponding sized container of hardener. When purchasing resin and hardener, be sure both containers are labeled with the same Group Size letter (A, B or C).

Package size/quantity				Coating coverage	
Group Size	Resin quantity	Hardener quantity	Mixed quantity	Saturation coat porous surfaces	Buildup coats non-porous surfaces
A	105-A 1 qt (.94 L)	205-A or 206-A .43 pt (.20 L)	1.2 qt. (1.15 L)	90–105 sq. ft. (8.5–10m^2)	120–135 sq. ft. (11–12.5 m^2)
		207-A or 209-A .66 pt (.31 L)	1.3 qt. (1.26 L)	90–105 sq. ft. (9–10 m^2)	120–135 sq.ft. 11–13 m^2)
B	105-B .98 gal (3.74 L)	205-B or 206-B .86 qt (.81 L)	1.2 gal. (4.55 L)	350–405 sq. ft. (32–37 m^2)	462–520 sq. ft. (43–48 m^2)
		207-B or 209-B 1.32 qt (1.24 L)	1.3 gal. (4.98 L)	370–430 sq. ft. (35–40 m^2)	490–550 sq. ft. (45–50 m^2)
C	105-C 4.35 gal (16.47 L)	205-C or 206-C .94 gal (3.58 L)	5.29 gal. (20 L)	1530–1785 sq.ft. (142–165 m^2)	2040–2300 sq.ft. (190–213 m^2)
		207-C or 209-C 1.45 gal (5.49 L)	5.8 gal. (21.9 L)	1675–1955 sq.ft. (155–180 m^2)	2235–2520 sq.ft. (207–233 m^2)

Estimating the number of layers of reinforcing fabric

To determine the number of fabric layers required to achieve a specific laminate thickness, divide the thickness desired by the Single Layer Thickness of the tape or fabric you intend to use.

WEST* SYSTEM Product number	740	742	702	713	729	745	737	738
Fabric weight	4 oz	6 oz	11 oz	11 oz	9 oz	12 oz	15 oz	22 oz
Single Layer Thickness*	.008"	.010"	.015"	.012"	.017"	.020"	.033"	.040"

*Average of multiple layers applied by hand lay-up

Epoxy tips

Thinning epoxy

There are epoxy-based products specifically designed to penetrate and reinforce rotted wood. These products, basically an epoxy thinned with solvents, do a good job of penetrating wood. But the solvents compromise the strength and moisture barrier properties of the epoxy. WEST SYSTEM epoxy can be thinned with solvents for greater penetration, but not without the same compromise in strength and moisture resistance. Acetone, toluene or MEK have been used to thin WEST SYSTEM epoxy and duplicate these penetrating epoxies with about the same effectiveness. If you chose to thin the epoxy, keep in mind that the strength, especially compressive strength, and moisture protection of the epoxy are lost in proportion to the amount of solvent added.

There is a better solution to get good penetration without losing strength or moisture resistance. We recommend moderate heating (up to 120°F) of the repair area with a heat gun or heat lamp before applying epoxy. On contact with the warmed wood, the epoxy will thin out, penetrating cavities and pores, and will be drawn even deeper into pores as the wood cools. Although the working life of the epoxy will be considerable shortened, slower hardeners (206, 207, 209) will have a longer working life and should penetrate more than 205 Hardener before they begin to gel. When the epoxy cures it will retain all of its strength and effectiveness as a moisture barrier, which we feel more than offsets any advantages gained by adding solvents to the epoxy.

Epoxy storage/shelf life

Store at room temperature. Keep containers closed to prevent contamination. With proper storage, resin and hardeners should remain usable for many years. Over time, 105 Resin will thicken slightly and will therefore require extra care when mixing. Hardeners may darken with age, but physical properties are not affected by color.

Mini Pumps may be left in containers during storage. After a long storage, it is a good idea to verify the metering accuracy of the pumps and mix a small test batch to assure proper curing.

Repeated freeze/thaw cycles during storage may cause crystallization of 105 Resin. Warm resin to 125°F and stir to dissolve crystals.

Tools and Equipment

Moisture Meters

There are several non-destructive meters available to measure the relative moisture level in fiberglass laminate. These meters work by measuring the resistance of electrical signals transmitted through the laminate. The level of moisture within the laminate affects the level of resistance. Keep in mind that these readings can indicate relative dryness at different locations, and not accurate true measurements of the moisture content throughout the laminate. Moisture meters are available from:

J.R. Overseas Co.
P.O. Box 370
Kent, CT 06757, USA
(860) 927- 3808
www.jroverseas.com

G E Protimeter
500 Research Dr.
Wilmington, MA 01887
(800) 321-4878

Roller cover brushes

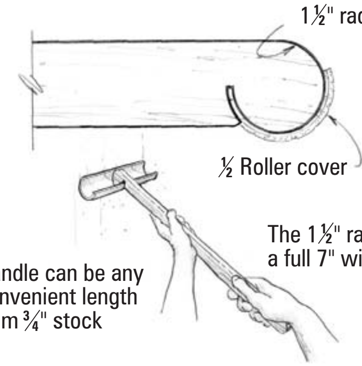
Used to tip off fresh coats of epoxy

A 3½" wide roller cover brush for small areas

Cut an 800 Roller Cover into segments and attach to a handle. Drag the brush over fresh epoxy with light, even pressured, overlapping strokes.

A 7" wide roller cover brush for large areas

Cut an 800 Roller cover into two segments and attach to a long handle.



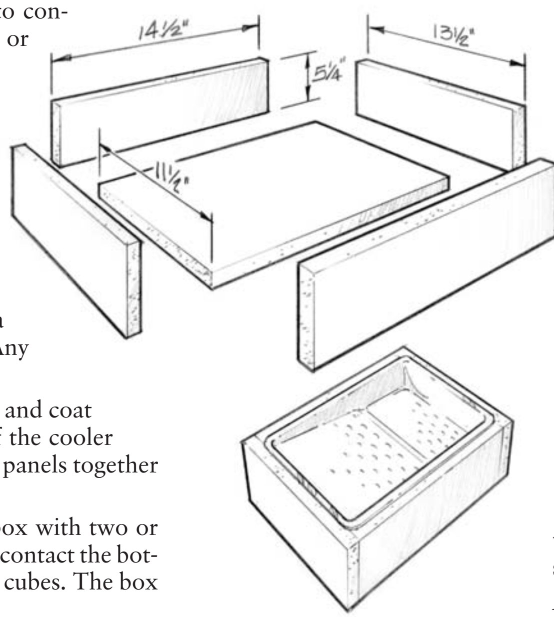
Cooler box—pot life extender

This insulated box is designed to control the pot life of a roller pan or mixing cup full of epoxy by removing excess heat generated by the epoxy's exothermic reaction. In warm climates the cooler can extend the working life of a batch of epoxy.

All parts are 1" Styrofoam™ building insulation bonded together with epoxy thickened to a "peanut butter" consistency. Any available filler may be used.

Apply fillets at all inside corners and coat with epoxy to extend the life of the cooler box, after the bonds holding the panels together have cured.

To use in hot weather, fill the box with two or three inches of water (enough to contact the bottom of the pan) and a couple ice cubes. The box is designed to absorb excess heat rather than chill the epoxy and can extend the working life of a batch of epoxy up to 10 times longer than what would be expected at high temperatures. This allows 205 Fast Hardener to be used in temperatures that normally would have required you to use 206 Slow or 209 Extra Slow Hardener.



In cool weather, fill the box with warm water to keep the viscosity of the epoxy thin and easy to apply.

Alter the dimensions as necessary so your particular roller pan fits within the sides of the box and the lip of the pan rests on top of the side panels.

Designed by John Koeck

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Cold Temperature Bonding

Techniques for Bonding and Coating at Low Temperatures

Epoxy can be used under cold weather conditions, but you must use special application techniques. These precautions are not elaborate or difficult, but they are necessary to achieve acceptable long-term epoxy performance. These precautions do not apply to WEST SYSTEM® epoxy alone; any epoxy used in critical marine structural situations may have its capabilities and performance affected by cold weather. In fact, due to differences in formulation, not all epoxies possess the necessary characteristics to ever cure well under cold weather conditions.

Chemical characteristics

When you mix an epoxy resin and hardener together, you start a chemical reaction which, as a byproduct, produces heat. This is called an exothermic reaction. The ambient temperature in which an epoxy chemical reaction takes place affects the rate of reaction. Warmer temperatures accelerate the reaction time, while cooler temperatures retard it.

Duration of reaction, among other variables, influences inter-bonding of the epoxy molecules. If the reaction is too slow, even though the epoxy may harden, it may not cure completely and possibly never achieve its designed physical properties. This is where danger lies, for improperly cured epoxy may possess enough strength to hold a structure together, yet it may fail after repeated loadings during normal operation.

Working properties

Temperature has a profound effect on the working properties of uncured epoxy. Ambient temperature changes will drastically change the epoxy's viscosity (thickness). Viscosity of water varies little with temperature changes until it either boils or freezes. Epoxy, however, is made of heavier molecules and temperature can have a 10 times greater effect on epoxy molecules than on water molecules over a temperature change of 30°F (16°C).

The colder it gets, the thicker the epoxy becomes, reducing its ability to flow out. This kind of change has three important consequences for working with epoxy under cold conditions.

First, it is more difficult to mix the resin and hardener thoroughly: the resin flows through the dispensing pumps and out of containers with greater difficulty; the cold epoxy and hardener are prone to clinging to the surfaces of the pumps, containers and mixing tools; and they resist being completely blended unless mixed very thoroughly. Remember, because of the low temperature, the chemical reaction isn't going off as well either. Compounding a less efficient exothermic reaction with potential for incomplete and/or inaccurate mixing, you have the recipe for a permanently deficient bond.

Second, the mixed epoxy is much harder to apply. If you've ever tried to spoon honey right out of the refrigerator instead of at room temperature, you know just what we're referring to: the chilled mixture has become stiff. When cold temperatures make epoxy stiff, it's extremely difficult to coat and wet out surfaces.

Third, air bubbles may be introduced when mixing and held in suspension due to the chilled epoxy's increased surface tension. This can be especially troublesome in clear-finish applications.

Cold weather techniques

Up to this point, we've told you all of the reasons why cold weather epoxy usage is difficult and potentially dangerous. However, with a little advance planning and certain simple precautions, all of these problems can be addressed and their consequences avoided. The following are six basic cold weather rules. We've used these guidelines for over 20 years and have yet to experience a cold weather curing problem with WEST SYSTEM epoxy.

1 Use WEST SYSTEM* 205 Fast Hardener.

WEST SYSTEM 205 Hardener has been designed with a chemically-activated polyamine system which exhibits a good cure as low as 35°F (1.5°C). It exhibits a faster cure characteristic than 206 Slow Hardener and offers less uncured exposure time which reduces the chances of incomplete cure due to cold temperatures.

2 Dispense resin and hardener in the proper mixing ratio.

All epoxies have been formulated for a specific mixing ratio of resin to hardener. It is important to mix your epoxy in the precise ratio recommended by the manufacturer. Increasing the amount of hardener will not accelerate cure, but it will seriously compromise the epoxy's ultimate strength. WEST SYSTEM Mini Pumps are designed and calibrated to dispense the correct ratio with one pump stroke of resin for every one pump stroke of hardener.

3 Warm resin and hardener before using.

As we discussed above, the warmer the resin and hardener, the lower the viscosity. And thinner resin and hardener will flow through mechanical pumps better, cling less to containers and mixing equipment, and exhibit superior handling and wet-out characteristics. The epoxy can be warmed using heat lamps or can simply be kept in a warm area until you are ready to use it. Another simple method of warming the resin and hardener is to construct a small hot box out of rigid sheets of foil-backed insulation. Place a regular light bulb or an electric heating pad inside to maintain a temperature of no greater than 90°F (32°C).

4 Stir the resin and hardener thoroughly.

Use extra care when mixing the resin and hardener, and mix for longer than normal periods of time. Scrape the sides and bottom of the mixing container, using a flat-ended mixing stick to reach the corners. Using a smaller diameter mixing pot will also improve the chemical activity because the limited surface area will not dissipate heat produced by the reaction.

5 Warm working surfaces.

Applying warmed epoxy to a cold structure will quickly retard the molecular bonding activity of the epoxy. Be certain the structure, as well as the area surrounding the structure, is brought up to temperature. A hull, for example, which is colder than the surrounding air may experience condensation and result in water contamination to epoxy applied on it. Warm the structure as much as possible. This can be done by constructing tents around small areas and heating with portable heaters or warming the area with hot air guns or heat lamps. Small components or materials (such as fiberglass cloth) can be warmed before use in a hot box as described above.

6 Prepare surfaces carefully between applications.

When coating under cold conditions, a thin film of epoxy often dissipates any exothermic heat generated by the reaction. When heat is dissipated quickly, the epoxy may not cure for an extended period of time. Some reaction with water may occur, resulting in the formation of an amine blush on the surface. Immediately prior to applying subsequent coatings, wash the surface with clean water and allow it to dry thoroughly.

Cold weather storage

It is best to store WEST SYSTEM materials above 35°F (1.5°C) with the container caps screwed down tightly. Storing epoxy in extreme cold may cause crystallization. The formation of crystals does not compromise the epoxy and they can be remedied. Boil water in a pot large enough to hold your epoxy containers. Remove each container's lid to avoid pressure buildup, which may cause the cans to burst, and place the cans in the hot water. Continually stir the epoxy with a clean stick until the liquid regains clarity and all crystals have melted. Remove from the water, replace the lids tightly and invert the container to melt any crystals which may be clinging to the top of the container. If the resin pump has crystallized, pumping warm resin through it should dissolve the crystals. ■

Problem Solving

This guide is designed to help identify and prevent potential problems you may encounter using WEST SYSTEM Epoxy. If the solutions described here do not resolve the problem, call the Gougeon technical staff.

PROBLEM	POSSIBLE CAUSES	SOLUTION
The epoxy mixture has not cured after the recommended cure time has passed.	Off ratio—too much or too little hardener will affect the cure time and thoroughness of the cure.	1. Remove epoxy. Do not apply additional material over non-curing epoxy. See Removing epoxy, page 37. 2. Check correct number of pump strokes-use equal strokes of resin and hardener. DO NOT add extra hardener for faster cure! 3. Check for correct pump (5:1 or 3:1 ratio) and pump group size (Group B resin and Group B hardener). 4. Check pump ratio (see pump instructions). See Dispensing, page 35.
	Low temperature—epoxy mixtures cure slower at low temperatures.	1. Allow extra curing time in cool weather. 2. Apply heat to maintain the chemical reaction and speed the cure. NOTE! Unvented kerosene or propane heaters can inhibit the cure of epoxy and contaminate epoxy surfaces. 3. Use a faster hardener, designed to cure at lower temperatures. See Understanding cure time, page 33.
	Insufficient mixing.	1. Remove epoxy. Do not apply additional material over non-curing epoxy. See epoxy removal note, page 37. 2. Mix resin and hardener together thoroughly to avoid resin rich and hardener rich areas. 3. Add fillers or additives *after* resin and hardener have been thoroughly mixed. See Mixing, page 35.
	Incorrect products.	1. Remove epoxy. Do not apply additional material over non-curing epoxy. See epoxy removal note, page 37. 2. Check for proper resin and hardener. Resin will not cure properly with other brands of hardener or with polyester catalysts.
Bond failure.	Insufficient cure.	See above.
	Resin starved joint-epoxy has wicked into porous surfaces leaving a void at the joint.	Wet out bonding surfaces before applying thickened epoxy. Re-wet very porous surfaces and end grain. See Two-step bonding, WEST SYSTEM User Manual & Product Guide, page 7.
	Contaminated bonding surface.	Clean and sand the surface following the procedure on page 6. Sand wood surfaces after planing or joining.
	Bonding area too small for the load on the joint.	Increase bonding area by adding fillets, bonded fasteners or scarf joints.
	Too much clamping pressure squeezed epoxy out of the joint.	Use just enough clamping pressure to squeeze a small amount of epoxy from the joint. See Clamping note, User Manual & Product Guide, page 7.
Clear coating turned cloudy.	Moisture from condensation or very humid conditions reacts with components in uncured hardener.	1. Apply moderate heat to partially cured coating to remove moisture and complete cure. See out-gassing caution, page 4. 2. Use 207 Hardener for clear coating applications and for bonding thin veneers where epoxy may bleed through to the surface.
	Entrapped air from aggressive roller application.	1. Apply coating at warmer temperature–epoxy is thinner at warmer temperatures. 2. Apply epoxy in thin coats. 3. Apply moderate heat to release trapped air and complete cure. See out-gassing caution, page 34.
Waxy film appears on surface of cured epoxy.	Amine blush forms as a result of the curing process.	Blush formation is typical. Remove with water. See Special preparation—Cured epoxy, page 38.
Hardener has turned red after several years storage.	Moisture in contact with hardener and metal container.	Red color is a normal condition. It will not affect epoxy handling or cured strength. Avoid using for clear coating or exposed areas where color is not desired.

PROBLEM	POSSIBLE CAUSES	SOLUTION
Runs or sags in coating.	Epoxy applied too thick.	1. Use 800 Roller Covers and roll the coating out into a thinner film. A thin film will flow out much smoother than a thicker film after it is tipped off with the foam roller brush. 2. Warm the epoxy to thin it or apply the coating at a warmer temperature. See barrier coating, page 24.
	Coating curing too slowly.	1. Apply the coating at a warmer temperature. 2. Warm the resin and hardener before mixing to speed the cure in cool weather. 3. Switch to a faster hardener if possible. See controlling cure time, page 33.
Fairing compound (epoxy/407 or 410 mixture) sags and is difficult to sand.	Fairing material not thick enough.	1. Add more filler to the mixture until it reaches a "peanut butter" consistency–the more filler added, the stiffer and easier it will be to sand. 2. Allow the wet-out coat to gel before applying the fairing material to vertical surfaces. See Fairing, page 39.
Paint, varnish or gelcoat will not set up over epoxy.	Epoxy not completely cured.	Allow the final epoxy coat to cure thoroughly. Allow several days if necessary for slow hardeners at cooler temperatures. Apply moderate heat to complete the cure if necessary. See Controlling cure time, page 33.
	Paint incompatible with epoxy.	1. Use a different type of paint. Some paints and varnishes may be incompatible with some hardeners. If unsure, test for compatibility on a coated piece of scrap material. 2. Use 207 Hardener. It is compatible with most paints and varnishes.
	Epoxy surface not thoroughly prepared.	Remove the amine blush and sand the surface thoroughly before applying paints or varnishes. See Final surface preparation, page 37.
Epoxy became very hot and cured too quickly.	Batch too large.	1. Mix smaller batches. 2. Transfer the mixture to a container with more surface area, immediately after mixing. See Understanding cure time, page 33, Dispensing and mixing, page 35.
	Temperature too warm for the hardener.	Use 206 Slow or 209 Extra Slow Hardener in very warm weather.
	Application too thick.	Apply thick areas of fill in several thin layers.
Bubbles formed in coating over porous material (bare wood or foam).	Air trapped in the material escapes through coating (out-gassing) as the material's temperature is rising.	1. Coat the wood as its temperature is dropping– after warming the wood with heaters or during the later part of the day. 2. Apply a thinner coat, allowing air to escape easier. 3. Tip off the coating with a roller cover brush to break bubbles. See out-gassing caution, page 34.
Pinholes appear in epoxy coating over abraded fiberglass or epoxy.	Surface tension causes epoxy film to pull away from pinhole before it gels.	After applying epoxy with 800 Roller Cover, force epoxy into pinholes with a stiff plastic or metal spreader held at a low or nearly flat angle. Recoat and tip off coating after all pinholes are filled.
Fisheyeing in coating.	Contamination of the coating or surface or improper abrasion for the coating	1. Be sure mixing equipment is clean. Avoid waxed mixing containers. 2. Be sure surface is properly prepared. Use proper grit sandpaper for the coating, e.g. 80-grit for epoxy. See paint or varnish manufacturer's instructions for proper surface preparation. After surface is prepared, avoid contamination—fingerprints, exhaust fumes, rags with fabric softener (silicone). Coat within hours of preparation.After wet sanding, rinse water should sheet without beading (beading indicates contamination). Wipe with appropriate solvent and re-rinse until rinse water no longer beads. Contact Gougeon Brothers Technical staff if you have additional questions.

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