

The Real Story of Osmosis Blistering Treatment, Cure and Prevention

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by

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There are two fundamental causes of GRP [Glass-Reinforced Polyester] blisters [osmosis blisters, The Pox, etc.].

One is poor workmanship in the original manufacture. The other is water getting into the laminate.

There is one way to stop, repair and prevent this from happening, and that is to keep the GRP and water away from each other.

With every boat yard in the world having its own GRP repair/salesman/expert, why should you believe me?

I am a chemist and a physicist and accidentally got into the paint-and-glue business in the early 1970s. I am the guy who discovered what was causing gel-coat blisters, when the boat manufacturers were denying that there was any such thing. I invented the barrier-coat technology that is now in common use to prevent and repair blister damage.

The outline of this article is as follows: First we shall discuss the issue of poor workmanship; then we shall discuss how to keep water away from the hull.

Keeping water away from the hull will consist of two types of actions; first, reducing the rate at which water enters the hull, by diffusion or direct immersion, and second, facilitating the departure of water which does get in or has already gotten in.

WORKMANSHIP

We may as well begin the discussion of poor workmanship with the statement that the boat never should have been made of GRP in the first place because all polyesters eventually decompose in the presence of water. The short reason for that is that an ester is made by reacting two things together and eliminating water as a reaction byproduct, or waste. When put back in the presence of water, the reaction goes the other way, although it may do that very slowly. This will be discussed in MUCH MORE detail later.

The hull should have been made of some epoxy resin system, as they are inherently stable against reversion from excess water exposure. Why, then, are polyesters used? The simple answer is cost. Epoxy resins cost \$1.50-\$2.00 (U.S.)/pound, whereas polyesters cost fifty to seventy-five cents per pound, roughly a third the cost.

So, there we are. The boats will be, are and have been made of polyester resin for all except the wealthiest, and that is the beginning of poor workmanship.

Why, exactly is it that polyesters are not stable in the presence of water, and why do GRP hulls have all those problems?

The word "polyester" means "many esters" and an ester is a chemist's name for something made by reacting an organic acid with an organic base and eliminating the resulting water. When you put esters in water the reaction goes backwards, with ester-plus-water disassociating back into acid-plus-base.

It's just chemistry. It's the way things work.

The bases used in polyester resins may be small molecules such as are ethylene glycol or neopentyl glycol or similar water-soluble-molecules, and these diffuse out and away, leaving the large acid molecules as an acid-rich residue in the laminate. The polyester resin laminate slowly develops porosity, and the diffusion of water through the gel-coat (colloidal-silica-reinforced and more resistant to this degradation) and into the laminate behind it creates excess pressure (osmotic pressure) and blisters result.

The "catalyst" used to cure polyester resins is a 40% solution of Methyl Ethyl Ketone Peroxide in Dibutyl Phthalate. This material, imperfectly mixed in the spray from a chopper gun, will rapidly wick into glass fiber bundles where it is not mixed with the resin.

Methyl Ethyl Ketone [the remaining material after catalyst decomposition to donate oxygen to cure the polyester resin] is soluble in water and its presence in the cured laminate will create osmotic pressure, drawing in water and contributing to blister creation.

The Dibutyl Phthalate is itself another ester, and will decompose into Phthalic acid and Butyl alcohol.

The cold-set promoter, cobalt naphthenate, is a soap (esters with metal hydroxides are called soaps) of cobalt hydroxide and naphthenic acid. It will similarly decompose under conditions of extreme chemical stress caused by the decomposition of other components of the GRP laminate.

Water is drawn into such areas, creating more osmotic pressure and resulting in blisters wherever there was a contaminant or microscopic void. Even a failed chemical bond between the polyester resin and a glass fiber is a void in which a blister can start.

The use of a chopper gun in and of itself can be considered poor workmanship.

There is a small percentage of water that will dissolve in the laminate, with a higher amount going into chopper-gun-sprayed laminates due to the inherent lack of full wet-out of glass fiber bundles by the chopper-gun manufacturing process, creating microscopic voids in glass fiber bundles throughout the laminate. This diffusion of water into these void structures can be mistaken for water dissolving" in the resin.

There is a web site with an unbelievably long and detailed "explanation", in the most excruciatingly technical terms, of this whole phenomenon, based on the premise that polyester curing reactions are incomplete at room temperature and require a post-cure bake at eighty to ninety degrees centigrade, in order to be fully cured. This statement is not correct, and thus everything that follows from it goes up the wrong alley. Polyester resins decompose in the presence of water, regardless of how fully cured they are. The fully-cured-and-baked ones just take longer. The explanation is as follows:

There are two fundamental types of chemical reactions. One is the addition-type and the other is the free-radical type (there are other types and special cases, but they are not relevant to this simplified discussion).

Addition reactions, such as epoxy curing reactions, go at a certain rate as part A adds to part B. Different kinds of materials have different reaction rates, and accelerators can be added, but there will be some characteristic rate at which a small mass cures. The further the extent of cure, the fewer of part A molecules there are, and the more difficult it is for those A and B molecules to find each other. Thus, the further along the curing reaction goes, the more slowly it goes. This rate is characteristic of addition-type reactions.

The free-radical curing mechanism proceeds by something reacting with itself or another, mediated by a broken molecular fragment called a free radical. The reaction that consumes a free radical generates another upon its completion, and so the reaction propagates rapidly, turning a liquid into a solid quickly, (after some initial dormancy or latency time) and liberating all of its reaction energy as heat in a short period of time. This is characteristic of polyester resins, which may be liquid for twenty minutes after mixing and then fully cure in the next ten minutes.

The "post-cure" baking process which results in a more water-resistant laminate, is actually evaporating a water-soluble solvent, methyl ethyl ketone, [MEK] out of the laminate. That is the same methyl ethyl ketone mentioned earlier, left over from the catalyst. That water-soluble material, in conjunction with any microscopic void, will start the osmotic blistering process.

All one needs are a non-homogenous laminate and a region [a void, improperly mixed resin, or a spot of dirt] containing something soluble or its vapor [such as MEK] or a void space from improperly wetted-out glass fiber bundles, into which water-soluble material can diffuse. Water is then attracted to such a region. Perhaps the laminate and resin in that vicinity will be strong enough to withstand the osmotic pressure, perhaps not. Eventually the polyester will begin to decompose, weakening that little region. Eventually a blister will form. Even in the absence of residual MEK, or the use of a different catalyst which does not contain it, the polyester will eventually decompose, and some of the water-soluble glycol molecules generated by that decomposition reaction will migrate into void spaces, and that will attract more water and the osmotic blistering process begins. It may take fifty or three hundred years but it will happen because the polyester/water hydrolysis reaction exists.

The use of glass fiber mat held together with something that does not readily dissolve in the resin or alters its properties when dissolved will also cause the appearance of osmotic blistering. This is a combination of resin decomposing, resin swelling from water absorption, and the release of the resin from the fibers or fiber bundles. Water can then migrate along the opened capillary space, spreading the resin/fiber decomposition over a great area.

The use of a chopper gun to spray a resin/catalyst droplet mixture onto a surface along with chopped lengths of glass fiber bundles without a doubt contributed more to the production of low-quality laminates that decomposed early, than any other workmanship issue in the manufacture of GRP hulls. Those hulls made with batches of resin premixed and applied by hand to layers of cloth or mat in a mold (the early way of doing it) should hold up far better, and did.

Failed repairs consist of some or all the above issues. Even epoxy fillers, insufficiently mixed, will soften on immersion in water. The fault is not with the epoxy but rather with the mixer.

That pretty well covers the workmanship issue. We could go into the chemistry in more detail, but the words get technical and the chemical reactions are only understandable by chemists and do not change the basic facts: Polyester resins decompose in water and fast-and-sloppy construction methods just make it worse.

THE BARRIER THAT KEEPS WATER AWAY

If blisters develop and are ignored, your hull will develop major structural damage. I believe blistering of fiberglass hulls can be prevented for decades, depending on hull condition and repair workmanship.

I developed the Barrier Coat Technology in 1975 and hulls correctly done since that time have shown no further damage.

The essence of the problem is that water permeates the resin system and then causes what damage it can because polyester resin and its additives inherently decompose in water.

The essence of the solution is this: If one can put a totally impermeable barrier between the water and the hull, then the damage could not occur, regardless of how susceptible the resin of the laminate might be.

There is no such thing as a totally impermeable moisture barrier, but the U.S. Navy has, over the last fifty years developed a great deal of coating systems technology. Further improvements by Smith & Co. have led to our HIGH-BUILD BARRIER COATINGS. Their remarkable moisture resistance comes partly from the blend of mineral fillers used in the system, which increase the diffusion path length to several times the coating thickness, and partly from the unusually dense and water-repellent molecular structure of the resin system. This reduces the concentration of water in the hull.

The rate of the decomposition chemical reactions depends on water concentration in the laminate. The probability of blistering occurring depends on the rate of the chemical decomposition reactions.

This is the fundamental principle: If water evaporates off the inner hull surface of a fiberglass hull boat faster than it can diffuse through the barrier paint coating, this results in a very low moisture content in the laminate. Theoretically, if it leaves faster than it comes in, the resulting water concentration in the laminate should approach zero, EVEN WITH THE BOAT SITTING IN THE WATER! With the water concentration so low, the probability of blisters developing moves out in time perhaps ten times farther, to many decades or even hundreds of years, making it no longer a concern. The factors that will prevent blistering in all but the most egregious cases are, first, the barrier on the outside, and second, some positive means of ventilation throughout the bilge, and any part of the hull that is below the waterline.

This implies that the bilge should be kept dry.

Sometimes it is impossible to keep the bilge dry due to inevitable water leakage around the shaft. In that case use that same moisture-diffusion barrier coating to coat the inside ONLY WHERE THE WATER RUNS down into a sump where the bilge pump sits. That way the part of the bilge that is inevitably wet does not feed water into the laminate, and water vapor is free to diffuse out of the laminate on the inside, where the ventilation can carry it out and away.

*A Brief History of Osmosis Blister-Handling Technology *

The barrier coat technology for stopping osmotic blisters on GRP (Glass Reinforced Polyester) hulls was invented by myself in the middle 1970s. Much of the technology was developed at that time with little or no practical experience, but simply as a series of logical deductions from an initial premise "If we reduce the concentration of water then the chemical reaction whose rate depends on water concentration should proceed more slowly" which follows from the most fundamental scientific principles.

In order to reduce this abstract idea to something workable it was necessary to take the first step of "Assume something that ought to work, try it and see if it does the expected." This first step was in the design of the barrier. Even though liquid organic resins (epoxy, polyester, etc.) are readily available, can be easily spread over a surface and can cure quickly, they are not the ideal material from which to construct a barrier to water molecules.

Minerals, particularly those which do not chemically react with or dissolve in water should be the ideal barrier. There are two reasons for this. First, if the barrier can dissolve in water then a water solution of those mineral salts can obviously migrate through the barrier. Second, water molecules are very small. Minerals of certain types have much smaller spaces between their atoms than those through which water molecules can pass, and have many fewer "polar groups of atoms" which can attract and hold water molecules compared to organic resins, including polyester, vinyl ester, acrylic, epoxy or others.

The ease with which water can move through mineral versus resin barriers may be likened to the ease with which a motorist may travel a five hundred mile highway through mountains with no rest stops nor gas stations, compared to a highway with not only rest stops and gas stations but restaurants, five-star hotels and entertainment every mile.

It was recognized at the beginning that it would be impossible to mold a sheet of glass or ceramic around the outside of a boat, and so a mixture of glass and ceramic minerals was chosen for their ability to fit together as small particles between the spaces of the larger particles. An epoxy resin system was chosen which did not contain any small unattached molecules ("water-soluble molecules" [WSM], to use a buzzword popular in the U. S.) and which was "water-repellent", much as oiled cloth repels water. The popular epoxy and polyester resin systems are not made this way because their manufacturers design the products for different market applications and at different raw material costs. Much research and experimental work eventually led to the formulation of the

barrier coat and the complete solving of all its performance limitations, and the development of supporting products and a coordinated technology for their use.

When all this was tested in the field it was found after ten years of use by professional boat repair contractors and talented amateurs that the technology did indeed seem to work, arresting deterioration, stopping further blistering and repairing damage done.

Occasionally it would be found that something would not work right, blisters turning up in the middle layers of a repair being the most common failure of the technology. Knowing the fundamental principles of the technology were correct, it was then only necessary to find the exact departure from the ideal scene of "technology correctly applied" to remedy the failure. This was not necessarily the fault of anyone but sometimes a learning process for all.

An example of this was the discovery that if one did not rub down the hull with an abrasive pad before applying the barrier coat, [and again, after a coat or two of the barrier coat], microscopic glass fibers which were sticking straight up because of the previous grinding and epoxy impregnation steps would stick through the barrier coat, acting as tunnels or wicks for water to travel down, creating a small blister at the base of each. Other discoveries, such as the possibility of incomplete filler mixing, led to the distribution of a black pigment in a small "salt shaker" to be used to give increased color contrast in the filler and thus ensure complete mixing.

Eventually it appeared that all the inherent imperfections of the technology had been isolated, identified and all barriers to its application handled with standard, workable and reproducible technology.

In 1993 a new discovery was made. Some boats, a very few, did not get better and stay better even when everything appeared to be done right (or, at least, close enough to right that it should not have made so dramatic a difference). More research was done, based on the theory that if the technology was workable (as had been seen in so many cases) then there must be something, heretofore invisible or only rarely present, which causes such failures or creates a predisposition to failure in some cases. After reviewing the technology and its application it was decided to examine the GRP hull of the boat itself on the theory that that had never been exhaustively analyzed in the past and perhaps, by looking at the molecular structure and atomic makeup of the GRP material in these cases, one might find something illogical and, through investigation discover the failure mechanism.

An analysis of a sample of GRP laminate was done and it was discovered that there was an unusual amount of certain mineral elements which could not be explained by the assumption that the material consisted only of Glass-Reinforced Polyester resin. The analytical method used is somewhat like spectrographic analysis in that it can identify the presence of most atomic elements and determine the amount of each present. It is known as X-Ray Fluorescence Spectroscopy, or XRF for short.

This was done, and it was found that there were abnormal amounts of the element Calcium in one hull, and of Magnesium and Silicon in another. The calcium, far more than in the minerals of sea water or in glass, had to have come from limestone, and the Magnesium and excess Silicon would be from Magnesium Silicate, also known as Talc.

A bit of thought led to the amazing realization that some manufacturers of GRP boat hulls had actually added fillers or extenders into the polyester resin in an effort to reduce costs, and/or added fire-retardant minerals in an incompetent effort to make a GRP laminate fire-retardant without purchasing expensive fire-retardant resins.

The net result of adding talc, limestone or other mineral fillers or pigments would be a dramatically enhanced tendency of the hull to show GRP laminate deterioration of the type commonly referred to as osmosis. There are three reasons for this. First, special mixing equipment is required to mix powders with liquids without mixing in fine air bubbles. This is routine for paint manufacturers but not for boat manufacturers, thus many fine bubbles in the resin would be expected. These bubbles are additional voids into which water can diffuse, thus creating osmotic blisters. Second, adding mineral fillers would interfere with the ability of the resin to wet out bundles of glass fiber, allowing voids in which water

accumulates, hastening chemical decomposition of the GRP laminate. Third, mixing limestone (calcium carbonate) or other water-soluble minerals will cause osmotic blisters as the limestone dissolves in the water that is drawn to diffuse through the laminate.

Normally, no manufacturer is likely to admit to anyone they are doing this, much less doing it only to save money. There is no good reason for it.

This is comparable to taking a recipe for bread that calls for three cups of flour and using instead two cups of flour and one cup of fine sand or sawdust.

The chemical consequence of mixing powdered limestone, or any water-soluble mineral for that matter, into GRP in a boat hull is to guarantee that there will be osmosis blistering and deterioration, as the water diffusing into the GRP will dissolve the limestone just as underwater seepage dissolves limestone, creating caverns with stalactites and stalagmites.

The physical consequence of mixing powdered pigments, fillers or extenders of any sort into a resin which is then applied to cloth, mat, roving or glass fiber bundles will be that the capillary forces around each small bundle of glass fibers will draw in the liquid resin while filtering out the powder fillers, which will accumulate as a dense filter cake around the surface of each incompletely wetted bundle of glass fibers. This will create an extensive micro-void structure throughout the hull, which is to say that there will be lots of empty space inside glass fiber bundles that should have been thoroughly impregnated with resin as is the case with ethically manufactured GRP hulls. Water will diffuse into these void regions, extract and dissolve the polyester resin itself over time, and by this mechanism also cause dramatic and persistent osmotic blistering.

The manufacture of such a product, embodying an abnormal and concealed intrinsic liability, may be compared to a person being born with terminal cancer. A sensible diet, vitamins and the usual rules of good living conducive to health and a normal life expectancy do not apply in such a case. If the fact of terminal cancer is hidden from view, then the health of the person would seem to fail for no apparent reason.

To detect such "poor risk" jobs before the yard quotes on repairs or before a prospective owner undertakes a job of blister repair on a hull which has already had many such repairs, use X-ray Fluorescence Spectroscopy [XRF] to analyze the sample, which should be a minimum of ten grams of drill shavings. Be sure to grind off any paints or pigmented gel-coat overlying the GRP laminate. Compare that with an XRF analysis of plain glass fiber from fiberglass or mat such as the hull was made of. The carbon, hydrogen and oxygen of polyester resin do not show up on XRF analysis, but the minerals such as are in silica, talc, limestone or other extender fillers do.

The boat need not be removed from the water to take such samples. The drill shavings may be obtained from the inner surface, holes drilled halfway through the hull and filled with any good epoxy filler.

By way of estimating the ten-gram quantity, a one-centimeter drill, drilling a hole one centimeter deep, will produce about one gram of shavings. In American measure, a 3/8" hole, 3/8" deep, will do. You will need about ten of these. Catch the shavings in a small container held below the drill, and shield the activity from the wind. Pack them in a zip-lock plastic bag, put in a heavy paper envelope and send by air-mail. The analysis is usually done within a few weeks, but it depends on the backlog of the laboratory to which you send the sample. Analytical laboratories are listed in the classified [business] section of a telephone book, and some of those have this sort of equipment.

I wish to emphasize that this is not a usual procedure, and there were only a few brands of boats in the U. S. who, in the 1970s, were notorious for blister and other deterioration problems. Most of the chronic osmosis problem boats were seen in Europe in the 1980s and 1990s and were made ten to twenty years earlier.

Epoxy paints [not anybody's "epoxy resin"] designed as moisture diffusion barriers are appropriate, with degreasing and sanding first to ensure a clean surface. I make one such. You may not conveniently be able to get it, depending on where in the world you are. There are many, around the world, that will do this job. The really important factors are those others, mentioned above.

The implementation of the GRP blister prevention technology should proceed along these lines, since it logically follows from what has been discussed previously.

Residual salt in the hull has, historically, not been an issue in blister recurrence. One might expect that water-soluble sodium chloride would attract water and cause osmotic blistering. The fact is that it does not appear to happen. One could speculate on the reasons, and there is certainly room for further development of understanding.

DRYING THE HULL

One significant feature of my discoveries in the refurbishment of older GRP hulls is that it is utterly unnecessary to dry the hull for months with a dehumidifier tent, etc., etc. For mild blistering where removal of the gelcoat is not necessary, one to two weeks drying in warm weather (once the hull is sanded to bare gelcoat) is sufficient. If the gelcoat were stripped from a seriously damaged hull, a week in warm weather is adequate for the hull to dry sufficiently that the first (moisture-dissolving) coating may be applied. If the damaged laminate is not dry, but rather suppurating strange-smelling liquids, the gelcoat will need to be stripped and the hull re-launched for a week, hauled out again and then rinsed and allowed to dry.

Drying should not be necessary if there is no damage. A decent moisture-diffusion barrier coat is a wise idea, in that case. Once back in the water, less water will diffuse into the laminate from the water outside the hull, and so the laminate will slowly dry out on its own (with adequate ventilation through the bilge area).

The drying is part of blister prevention. If one does not take effective action, then the need to repair more and more blisters will continue. I personally believe in fixing it once. A person's labor to fix their boat is usually worth more than the cost of even fancy materials. Drying of a hull needs to be done externally as well as internally. On the outside, a number of those three-foot-square, six-inch thick fans that blow up a storm are what you want, aimed to move the prevailing winds to and past the hull, as well as something to move inside air through the bilges and compartments, and out. Inside ventilation is even more effective than outside, where the gel-coat is largely intact.

Moving air evaporates water faster than anything else, and the removal of excess water in the laminate is the key to a more successful blister repair, whether one uses the fanciest epoxies or the cheapest polyester.

With adequate ventilation, most hulls are adequately dry in a few weeks, but there are exceptional situations.

Stripping the gelcoat with a "peeler" will give a hull that dries the fastest, all other things equal.

Measure the laminate with a non-contact moisture meter (meaning do NOT use the ones with sharp pins that stick into the surface being measured) in an area under the waterline, where blisters are worst, and compare with an area always dry, usually near the topsides. That will give you a clue as to relatively how dry the whole hull is. The recommended meter is a Wagner L606.

A typical turn-around time for a franchisee in Europe was three to five weeks, depending on weather and hull condition.

Smith & Co. products for blister repair

The products used in GRP blister repair are only as reliable as the personnel that apply them.

The "product" for the repair of damaged GRP, whether minor gel-coat blisters or major laminate deterioration, is actually a technology involving the use of several products in a specified procedure. Like any technology for the repair of poor work of others, it has its limitations. Some hulls should not be considered repairable.

Originally, technicians were trained in the U. S. and then went to Europe to train the franchises and their yard workers in the methods of refurbishment which I developed twenty-five years ago when I first developed the barrier-coat technology for arresting osmosis damage to GRP laminate. The warranty program (backed by Lloyds of London) was implemented about twenty years ago, when our search of the historical records of Smith & Co. customers showed that GRP hulls repaired by their owners with Smith & Co. materials according to Smith & Co. instructions showed no further damage. There were a few instances of further

deterioration over the years, but in each case, this was traced to some deviation from the standard technology. Further repairs were done in those cases and there were no further recurrences. The standard technology for GRP laminate repairs has been developed from the understanding of the exact chemical mechanism of polyester resin decomposition, and the discovery of how workmanship can accelerate it. This article documents that technology. Much of this material was considered proprietary, but the training/franchising program no longer exists and there is no reason now not to place the data in the public domain.

It is important to note that while much of this technology has become common knowledge among boat yards and manufacturers, there is a mixture of false data, irrelevant data, omitted data and altered importance of data mixed in to what the boating publishing media reports, what "everybody knows" about this problem and the solutions promoted by various manufacturers and experts.

General repair instructions

1. Grind out or sandblast all blisters down to sound laminate. Get under all of the loose material. Some blisters may have a colored liquid in them. Don't get any of this in your eyes or on your skin - it may be very caustic. Some hulls may have an advanced state of chemical decomposition. This may be recognized by a strong chemical smell such as vinegar or a solvent, which may be noticeable after peeling the gelcoat or grinding down the hull. An advanced state of chemical decomposition may also be recognized by liquid, apparently water, oozing out of the laminate where a blister has been ground out, and leaving a visible residue which dries on the surface. Such hulls should have the entire gelcoat ground off or peeled to expose the underlying laminate containing chemical decomposition products. This may also require removal of some laminate. Chemical cleaning may then be accomplished in any of several ways: the hull may be hosed down with water every hour for a few days; a garden hose with many small holes such as is used to slowly water a garden may be draped around the hull to slowly and continuously rinse the hull with water; or the hull may be launched and left in the water for a few days to a week and then hauled out again. Some fresh water rinsing and a week or three to dry out (depending on weather and temperature) should then give a hull sufficiently dry to continue.

Simple moving air from fans evaporates water more efficiently than complex dehumidifiers, etc. The mobility of dissolved water through the GRP laminate is relatively slow, and when water reaches the laminate surface the fans quickly carry it away.

2. If the gelcoat is not to be entirely peeled, sand it all down to clean gel-coat. Sand any gelcoat that is left. You must get past the gloss surface of the gelcoat. It is a wax-rich surface, and it may also be degraded by exposure to the water. With many large blisters, it will be necessary to strip off the gelcoat and treat as discussed above. Then, inspect closely. Then let it sit a week outside with good ventilation inside and out, and see if any small blisters on the surface have now become visible as they dried. If there are no visible signs of blisters, then a good epoxy moisture-diffusion-barrier coat (there are products designed specifically to do that) will offer long-term protection if the boat stays in the water all or most of the time. If there are blisters, then follow my advice if you use my products.

Follow the advice of the manufacturer of whoever's products you use, generally. Try to make sense of conflicting advice if you have it, based on a fundamental understanding of what is going on, which my literature should give you. Cope as best you can with local materials if you have no alternative.

3. Allow a week or two in warm dry weather for the excess water to evaporate out of the hull.

4. Apply Clear Penetrating Epoxy Sealer™ to saturate the laminate. The Cold Weather Formula™ applied late in the day is recommended in all but the warmest climates, where the Warm Weather

Formula may be used. This product contains solvents and the choice of which version to use is a solvent evaporation issue. Allow a few days to perhaps a week to dry and cure; then apply a second coat of which little should soak in. In extreme cases, a third or even fourth application may be necessary. Allow sufficient time between each application that the hull no longer smells strongly of solvents before continuing; this may take a few days to a week in moderate weather. In cold weather, the Cold Weather Formula™ of our Clear Penetrating Epoxy Sealer should be used.

5. Apply two roller coats of Smith & Co. High-Build Epoxy Paint™. Use the red for the first coat and any other of our standard colors for succeeding coats. Use contrasting colors so that no areas are missed when applying successive coats, and so that the depth to which one has sanded is visible and control-label. Allow 4 hours drying time between coats, and apply no more than two coats in two days. Allow a day or two for the epoxy paint to fully cure so it can be sanded without dusting. Then rub the entire surface down with an abrasive pad. This is a necessary step. It breaks off the microscopic stubs of glass fiber sticking up through the paint, that would otherwise act as water-wicks and create recurring blisters in the finished job.

6. Fill all holes with Smith & Co. Fill-It™ Epoxy Filler. Mix thoroughly according to the application note for thoroughly mixing fillers. Allow to cure overnight, then sand. Stop sanding when you expose the red layer.

7. Apply three more coats of contrasting colors of High-Build Epoxy Paint. 4 mil wet film thickness per coat is equivalent to 400 sq. ft/gal/coat.

8. Several days further drying time should be allowed to reduce the possibility of solvent blistering. The Antifouling Paint may then be applied below the waterline, and topcoat and bootstripe above.

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