Failed Blister Repairs

A Case History and Solutions

by David Pascoe

John Williams is the proud owner of a ten year old 35' sloop. Prior to his purchase, he spent nearly a year searching around the country to find this particular yacht because it ideally suited his needs. When the survey was conducted, there was only one significant problem with it: it had a scattering of small blisters on the bottom, which I usually refer to as "pimple rash" to differentiate this condition from considerably larger blisters. The blisters in this case were no larger that 1/4" in diameter and had a density of about 2-3 blisters per square foot if averaged over the entire bottom area.

John lived in California and eventually moved to boat from these cool waters to Florida. Suddenly the 90^o waters of Florida's waterways caused the number of blisters the number of blisters to blossom from perhaps a few hundred to several thousand. Not liking what he saw, he decided to have them repaired. Obtaining three estimates on the cost, he finally settled on the Ace Boatyard, in part because they used the West Epoxy system and Williams had heard that this material was highly successfull at solving the blistering problem. The cost was $7,000 and he was given a 5 year guarantee. He was also told that the repair would eliminate his blistering problem, although the yard manager did tell him that it was possible that "a few" blisters could possibly reappear.

The repair method included stripping off all the paint and old gelcoat with a specially designed machine by an outside contractor. This was followed by "fairing" and recoating the bottom according to the instructions provided by the manufacturers of the West System. In addition, it also included "hot coating" the bottom, a method described to me as as applying the antifouling bottom paint to the bottom while the last coat of West System epoxy was still wet.

The job was completed, Mr. Williams paid his bill and went on his way, pleased that his blistering problem had now been repaired and solved. At least until a year later when the yacht was hauled and he discovered that about 50% of the blisters had reappeared. Returning to the yard that did the work, his complaint was greeted with a response somewhat different than what he was told prior to giving the yard his $7,000. Now the blister job was no longer a cure for the problem but simply a repair of the existing blisters. Moreover, all of the blisters that reappeared were new ones they said, unrelated to the ones just recently repaired. That meant that, although Ace Boatyard did indeed warrant that the blisters they repaired would stay fixed, the new blisters were not a reappearance of the old blisters, and therefore not covered by their 5 year warranty.

Mr. Williams estimated that about 1/3rd of all the blisters returned within one year, and he wasn't buying Ace's revision of their warranty. He was told that the repair would end his blistering problem, but it did not. The yard showed no sign of wanting to compromise the matter so he sued.

The yard's defense counsel hired a surveyor to look at the boat, and after doing so pronounced that the entire hull had severe delamination problems, determined by "sounding with a phenolic hammer." Nothing else was done to verify the "delamination." The yard then hung their defense on the premise of preexisting manufacturing defects as the reason why the repair wasn't successful and blisters recurred.

Called as experts for Mr. Williams, we examinated the yacht after the newly applied bottom coating had again been removed, the bottom being stripped down to the skin out mat and in some cases right down to roving. Our sounding of the hull produced not the slightest indication of even possible delamination of the hull.

After removal of the newly applied barrier coatings, this is what Mr. Williams hull looked like. Knife blade is inserted into the void spot caused by the old blister. Most, if not all, of the original blister voids remained. At right, the new resin can be seen to have been applied directly over the old blisters.

Note: The term "mat" or "skin out mat" refers to a fiberglass fabric made up of chopped fiberglass fibers that are quite short, usually about 3-4" long. These fibers are oriented in all directions and are not interwoven or interlocking, which is what mades the material relatively weak compared to woven fabrics. Mat is laid against the gel coat that is sprayed into the mold precisely because it does not have a weave pattern which would telegraph through the gel coat to give the hull finish the same texture as the fabric. The downside of its use is that it is very difficult for the laminators to make sure that the material is fully impregnated with plastic resin.

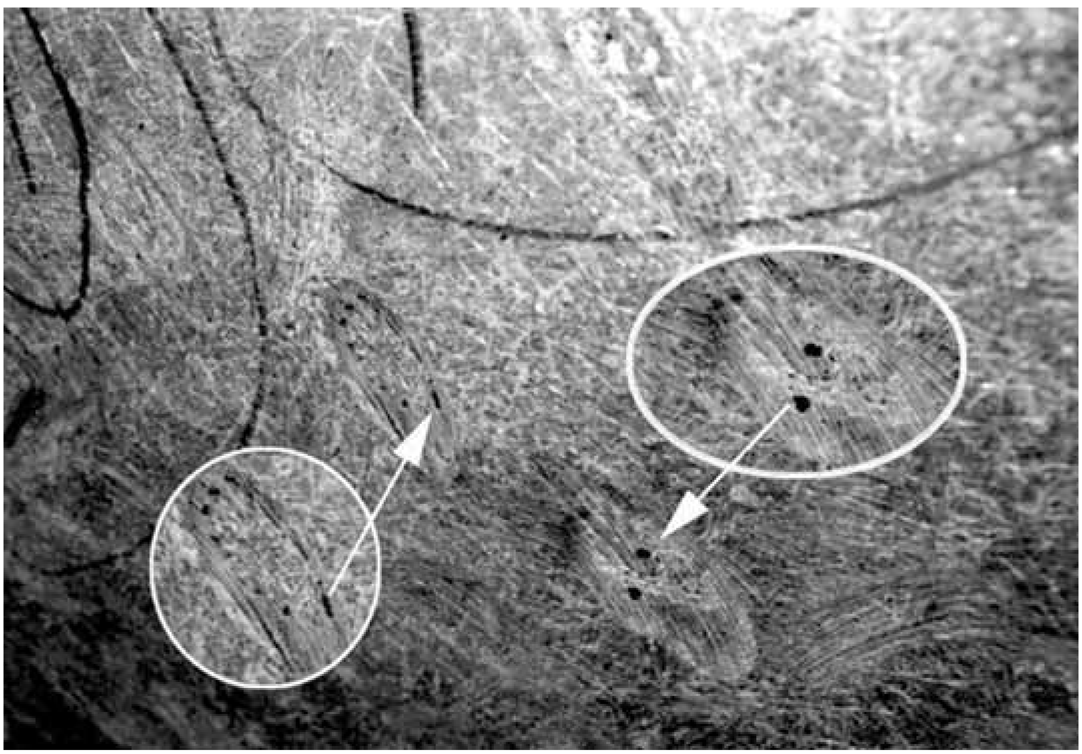
Multiple causes for the reappearance of the blisters became immediately apparent. These are as follows:

- As shown in nearby photos most, if not all, of the old blister cavities were still present. As far as we could determine, no effort was made to grind away the cavities or void areas and fill them.
- Scattered and random areas of the original skin out mat, as part of the original lay up, had significant areas of unsaturated fibers and minute voids, i.e. air bubbles in the original lay up.
- Some areas which had been faired with an unknown filler, but looks like two-part epoxy, were very soft and pliable, giving the appearance that it had not been mixed in proper ratios and did not cure properly. Since some of this material was

hard, and some soft, we do not consider it likely that the material softened of its own accord.

- Judging by the coloration, it was apparent that two applications of a clear resin (although a few areas showed three) and one layer of a fairing material had been applied, the former by roller without being brushed out. In most areas where the barrier coating remained, it was usually found to be very thin, notably thinner than a typical gel coating. We estimate this at about 10 mils. A thick gel coat would be 30 mils, a thin one 20 mils.

The failure to correct these imperfections provided the basis for the reformation of both the old and new blisters. Bearing in mind that the movement of the yacht from cool waters to the 90^{o} waters of the canals of Ft. Lauderdale resulted in a very rapid development of blisters, the yard had every reason to believe that the blistering of this hull was likely to continue at a rapid rate since Mr. Williams had explained all of this to them.



Although these blisters were ground away, the void spots or air bubbles within the skin out mat that initiated the blisters are clearly evident in this photo. The circled insets are enlarged for clarity. The polyester plastic here is not hydrolyzed (disolved) as some researchers claim is the cause of the problem. The plastic is hard and unaffected. If these voids are not removed, then the potential for reformation remains. Also note how dry some of the fibers are.

Assuming that the moisture meter used to determine that the hull had indeed dried out prior to recoating was accurate, this case, and many others like it, seem to belie the common notion that epoxy resins are significantly less permeable than polyesther.

Otherwise, its difficult to explain why large numbers of blisters reappeared so rapidly. Either the hull was never really dry, or somehow it once again absorbed water.

Another shortcoming in the repair process was found, that being that the new coating had been applied with a paint roller and never leveled out. This left a surface texture that was quite rough, resulting in a surface mill thickness that was very irregular. Whether this had an affect on the reblistering hasn't been empirically determined, but if barrier coat thickness has anything to do with the rate of permeability, then its certainly reasonable to assume that it did.

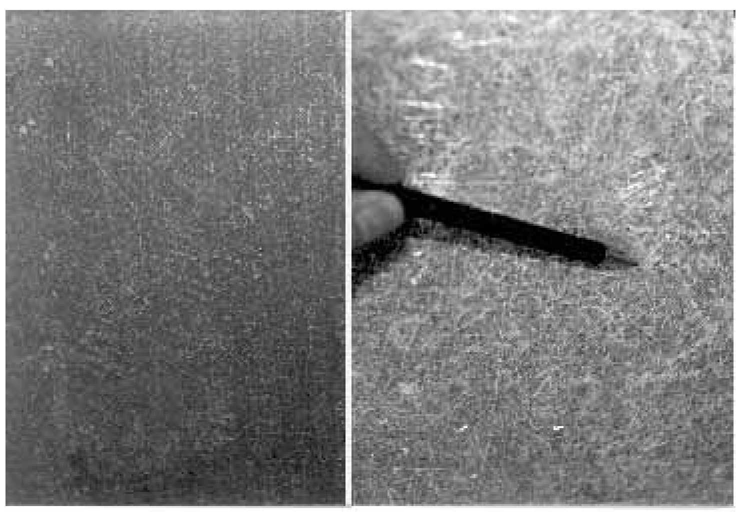
Fairing material that either turned soft or was not properly mixed and catalized. Scrape marks were made with the end of a ball point pen to indicate how soft is is, a perfect environment for blister formation. This is the poinit where the bottom was faired into the old gelcoat at the boot stripe. Note blister voids at lower center.

It also appears that a two-part epoxy filler was used in the fairing process that amounted to no more than 25% of the bottom area. This included spot filling depressions of what might have been larger blisters, as well as fairing around through hull fittings, fairing the waterline into the removed bottom gelcoat, as well as just general fairing. The fairing process was poorly accomplished, resulting in a "lumpy" appearance to the finished job. Most significantly, as we have found in a large number of other failed blister jobs, the fairing material, whatever it is, was found to be soft and pliable. Whether this resulted from improper mixing and incomplete curing, of if the material softened from water exposure or resultant chemical reactions, was not precisely determined. However, it would certainly be difficult to sand a filler that was not completely cured, and the fact of the lumpy appearance of the bottom suggests this possibility. On the other hand, our finding of so many other fillers that turn soft also suggests the likelihood of problems of (1) incompatibility of materials being combined, or (2) that these materials are severely affected by contact with sea water. All we can say for certain is that it is a two-part mix and that the material in many areas, although not all, was very soft.

A final flaw was discovered in that many of the blisters (we don't know what percentage because 90% of the bottom paint was removed) had occurred not under the new epoxy coating, but between the new coating and the new application of bottom paint. In other words, they were bottom paint blisters. And paint blisters are often misinterpreted as barrier coat blisters.

Since there was only one type and coating of bottom paint on the hull, this can't be attributed to incompatibility of bottom paints which, as we know, is usually the cause of paint blisters. So why would a brand new antifouling coat blister like this? Did it have something to do with the "hotcoating?" We would have to conclude that it must have, for there would seem to be no other explanation. Examination under magnification suggested a possible answer, since each blister that we dissected and examined revealed a pit, or indentation extending into the new epoxy barrier coat. The presence of the pit would suggest that a chemical reaction did indeed take place to cause the erosion that created the small pits and blisters in the paint.

Obviously, this begs the question of whether applying an antifouling coat to a wet epoxy barrier coat is a good idea. It may save the boat yard the task of sanding the bottom before painting, but it certainly didn't make the paint adhere any better.



Comparison view of fully saturated skin out mat at left, poorly saturated mat at right also showing numerous void spots or air bubbles. Notice that no blisters appear in the fully saturated laminate. These two areas are the same boat hull. Doesn't this tell the real story of how and why blistering occurs? If the laminate is fully saturated, blisters CAN'T develop.

As we have stated in other articles, blister repair failures like these are becoming commonplace. One reason is due to the fact that there is such a great deal of misinformation floating around out there about the nature of the problem. Over the last decade, I have looked at thousands of blistered boat bottoms and I know one thing for certain. I have never seen blisters occurring in a laminate that did not have voids or unsaturated fibers. It can't happen because there must first be a void space of sufficient size to collect water in sufficient volume to initiate the blistering process. I am convinced that, lacking the voids, blisters cannot form.

The significance of this is twofold. First, for builders it means that if one ensures that there is a thorough wet out of the skin out mat, resulting in fully saturated fibers and minimal voids between gel coat and mat, and between mat and first structural layers, blisters will not form unless you are using third rate materials.

This photo, not this essay's subject vessel, shows a boat bottom with at least two dozen grind spots in little more than one square foot area. Despite all the grinding, hundreds of voids and areas of unsaturated fibers remain. When the condition of the skin out mat is this bad, it cannot be successfully repaired. It must be removed completely. Unfortunately for the owner, the yard simply filled the holes and recoated it, with a high probability that the repair will fail.

Secondly, the same point applies to repairs. The uncorrected problems associated with Mr. William's failed blister repair are common to nearly all others. If the repairer eliminates the voids that help initiate the problem in the first place, he eliminates most of the potential for recurrance. Most repairers are knowledgeable enough to know that they have to remove the existing blister voids, and do so. Yet from touring boat yards and watching their process, it is clear that most are not dealing with the problem of poorly saturated fibers from the original construction. Recoating over a pooly saturated skin out mat occurs again and again.

This presents the repairer with something of a problem because to eliminate the unsaturated fibers in the skin out would mean that a lot of it has to be stripped away and replaced. The problem here is that this would significantly increase the cost to the customer that is likely to meet with resistance. There is a solution to this that will be explained further on.

While there is a great deal of myth about blisters, we have learned so far that:

- The vast majority of blisters occur between the skin out and the gel coat.
- A slightly smaller percentage occur within the skin out mat, or between the skin out and the first structural laminate.
- Blisters occurring within the structural laminate, particularly woven fibers, are extremely rare.
- Hydrolysis, or dissolution of the plastic, is not an initiator, but a secondary reaction of water in the laminate. Softening of the plastic does not usually occur until blistering is well advanced, and often doesn't occur at all.

There are a number of factors involved in why this is so:

1. Chopped strand mat is difficult to fully saturate and a very high percentage of all boats have unsaturated mat. That some do not blister suggests the use of far less permeable gelcoats and resins, or that some resins are more chemically stable than others.

2. The formation of blisters is associated with the softening of the barrier coat due to the presence of precipitated solvents from the resin (styrene) in a void space, and the build up of slight gas pressure sufficient to form the blister. But the pressure build up has been found to be very weak, so that the deformation of the blister may be less due to pressure than the effect of expansion of the gel coat caused by solvent softening. The mechanism is much the same as pouring acetone on cured paint, causing it to wrinkle.

3. Blisters do not form in the structural laminates if only because these heavy fibers are too strong to permit deformation of the laminate. On the other hand, gel coats and barrier coats are not fiber reinforced and are thus far more prone to surface deformation. For a blister to develop from a tiny air bubble between layers of roving, for example, would require a very high pressure indeed to result in deformation. On the other hand, random directional mat fibers are quite weak.

4. These points lead to the seemingly inescapable conclusion that poor saturation of skin out mat has to play a pivotal role in blister formation. If anyone has any doubts about this, try taking a tour through the boat yards and see if you can find blisters occurring within thoroughly saturated laminates. I can tell you in advance that you won't.

It is reasonable to conclude from this that, while epoxy and vinylesther resins are still sufficiently permeable to fail to prevent blistering, the elimination of most of the unsaturated fibers in the skin out mat will preclude most of their reformation when combined with higher quality resins.

It is foolish for a boat yard to give a 100% guarantee on blister repairs, for it is not possible to eliminate all voids close to the surface. Yet it is possible to remove 90% of the voids through careful preparation. Bear in mind that if it requires completely stripping the skin out mat, then there's no reason not to do so. It doesn't have to be put back on since the only reason for it's presence is to prevent telegraphing of roving pattern to the gelcoat, and that's not a consideration on the bottom of a hull. If the structural layers prove to be well-saturated, as they usually are, then the problem is going to be 90% solved.

Here is a particularly good shot of unsaturated fibers in a skin out mat. These really stand out because the layup resin in this hull is tinted dark blue. In most cases, the poorly saturated fibers do not stand out this well. In this case, as in so many others, the repairer simply applied a new barrier coat on top of this mess and the blisters reappeared with six months.

The bottom line to blister repairs is that there are far too many people in the business who don't know what they're doing. They apparently are not aware that for the repair to be successful, they must eliminate the defects that caused the blisters in the first place. Yet it is not possible to determine all of the factors that cause blistering, especially the cause of water getting into the laminate. The buzzword is "osmosis," as if permeability of coatings is the only means of water saturation. The reality is that we can identify a half-dozen ways that water can get into a laminate that have nothing to do with exterior coatings. So even if there were a totally effective, non-permeable coating, it would not solve the problem, for you can't prevent the absorption of water from the interior of the hull, or around through hull fittings and so on.

But the one method that offers the greatest possibility of a cure is to eliminate the voids within the outer laminations where blisters commonly form. And if that means stripping the chopped strand mat from the hull, then that is what has to be done. Otherwise, its just money down the drain.

http://www.yachtsurvey.com/BlisterRepairFail.htm

Blister Repairs Part II

The Alchemist Still Hasn't Found the Philosopher's Stone

by David Pascoe

http://www.yachtsurvey.com

Over the course of the last several months it almost seems that I've been under siege by used boats with failed blister repair problems, some of which are illustrated by the photos below. Reading the magazines and surfing around the web, you probably get the impression, as I have, that the blister problem is abating. But taking a tour of the boat yards I come away with an altogether different impression: the problem is now worse than ever. Much worse. And so is the problem with the failure of repair efforts.

During the survey, I'm usually asked by my customer for an interpretation of what we see on the bottom after its hauled. These photos show why its impossible for me to answer the question; there's no way of knowing what's under the bottom paint until you start removing it. As often as not, what we find is an accumulation of years worth of hap-harzard attempts at repair. What we see here is akin to kids trying to do autobody work on their cars with no knowledge about what they are doing. The methods and materials being applied are just a bit of anything and everything.

It is true, of course, that blister repair is now big business for boat yards. With repair costs typically running in the $4,000 - $7,000 range for small boats, for those yards that promote the business, its something of a bonanza for them. Even more so for the manufacturers of materials who are now doing a land office business selling their chemical prescriptions. But from what I can see in just looking around the yards, its clear that more than 50% of the repair work that I see in yards is on a do-it-yourself basis. And what is being done is only making a bad situation worse.

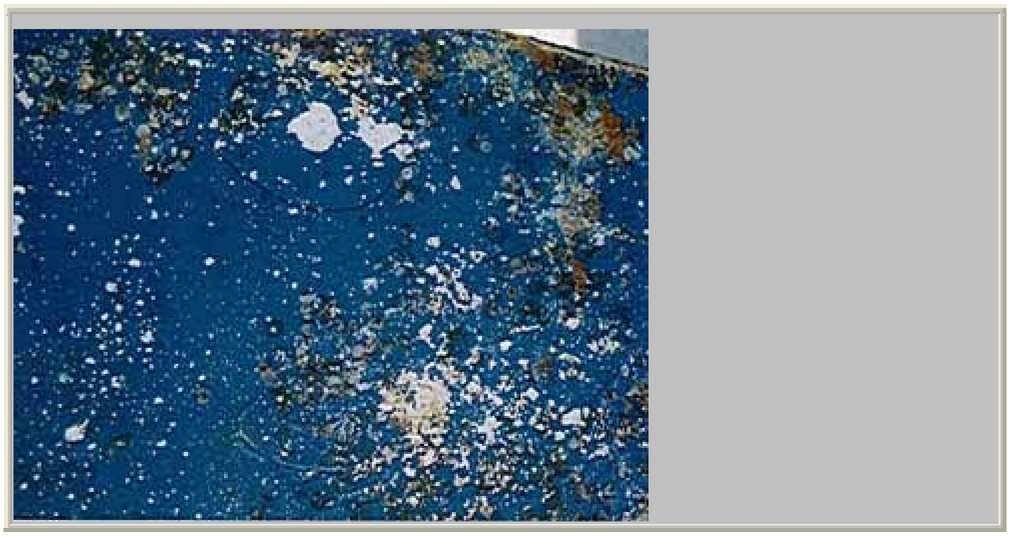
Another failed repair job. This one looks like the so-called "hot coating" where the bottom paint is applied over a wet barrier coat. At left are two larger blisters to which a grinder was applied. The skin out mat layer is plainly evident, is around 3/16" thick and is completely opaque, in addition to having a faulty bonding surface to the structural layers. Under the white layer, which you might think to be gel coat, is a black layer. We can't even imagine what that might be. What has been done to the bottom of this boat over the years (it is 15 years old) is beyond even guessing, but the one thing that is certain is that it there is no hope of successfully repairing it, even though the owner is going to try again. Applying a new coating over this mess is like painting over dirt.

Which leads me to the subject of this essay, the growing problem of failed blister repairs. In the last two months, more than half of the boats we have surveyed that have blister problems involving failed repairs. The owners who were selling these boats, as one might expect, were less than forthcoming about what had been done to their bottoms. In fact, NOT ONE was willing to explain to me the procedure or materials that were used. Many feigned ignorance that anything was done at all, even though it was plainly evident by the number of coats of paint on the bottom (which are easy to count) that the repairs had taken place within a year or two. (A 10 year old boat with only one coat of paint and lots of grinder marks on the bottom tends to get my attention.) Clearly they were upset that whatever had been done wasn't working.

Doing it yourself can save a lot of money, at least initially. But it can present a big problem for the seller and the buyer a little further down the road: Many of the failed blister repairs we've seen over the last 60 days involved not complete recoating of the bottom, but spot or patch up repairs. Several more involved applying "barrier coats" over improperly prepared substrates. Naturally, we cannot completely reconstruct what was done short of doing a lot of probing to the underlying surfaces. But all we have to do is watch what is being done to so many of the other boats in the very same yards in which we are doing the surveys, to see what the nature of the problem is.

To make a long story short, its amateur repairs, or repairs by commercial yards who don't know what they're doing. Its people attacking boat bottoms with grinders and sandblasters and God knows what other kind of devices (sometimes even torches) and causing more damage than they are fixing. Its people applying an apparently endless variety of glop and goop to the bottom of these hulls in the name of "fixing it." But what they are really doing is just making a bad situation worse. They are grinding and sanding and filling and painting and trowling and brushing, patching up the bottoms of their boats with a variety of materials whose colors span most of the spectrum. There is no consistency in what any of them are doing; they use different methods and different materials. We even saw, in a number of cases, boat owners applying fillers and barrier coats directly on top of antifouling paint.

What we are finding on our surveys comports with what we see boat owners doing. They are applying a hodge podge of materials to the bottoms, often year after year, to the point where the boat bottom becomes a veritable chemical stew. I use that phrase "chemical stew" intentionally because what is happening is that the morass of materials being applied to boat bottoms are reacting chemically and erupting into boiling cauldrons of alchemy. Its getting to the point where I don't want to touch a bottom without latex gloves on my hands.



***Top*: What you see here may look like gel coat blisters but actually the white spots are a chemical reaction between a variety of gunk that was smeared on the hull. There was almost no gel coat left. *Below:* This is what it looked like after some kind of machine was used on the bottom. Here we can count four different kinds of filler, in addition to the black stuff that is now being applied on top of all the others, another patch up job. After he's done, he is going to seal all this mess over with a barrier coat. This owner's efforts are a complete waste of time and money.**

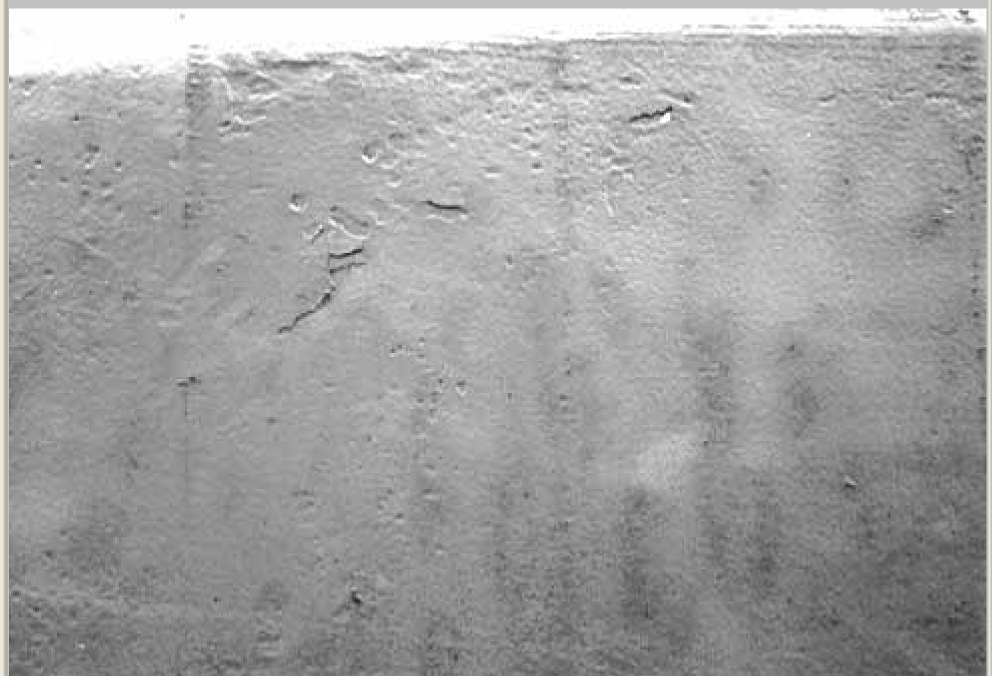
One boat I looked at recently was the real clincher. There was only one coat of anti fouling paint on the bottom, which indicated that whatever had been done most recently was probably only a year ago. Cutting into some of the bottom layers, I found six different colored materials under the antifouling. SIX! In some areas material had been applied over the antifouling. And it was clear, by this variety of multicolored materials, that blister repair had been an on-going patch up process. The fact that the bottom had broken out, not in thousands, but millions of tiny blisters on the surface, just under the paint, is what caught my attention. But what held my attention was that these bottom coatings had turned to mush. Virtually all of the materials applied to the bottom were as soft as day-old paint. Moreover, the stuff was saturated with water and styrene, which has a strong vinegar-like smell. Pick any spot on the bottom and prick it with a sharp knife and this styrene based fluid would start to seep out. Anywhere.

What's happening here is that boat owners are reading stuff in magazines and on the web and then attempting to repair the blisters themselves, either taking advice from people who don't know what they're talking about, or they're just winging it. Whatever the case, they're just making a bad situation worse. Often much worse. They would have been much better off had they just left well enough alone. For instead of blisters, what they end up with is a festering wound.

While there's no way for us to know exactly what's been done and why it went wrong, I have found some common factors.

- The bottom had been sandblasted, attacked with a grinder, or some other method employed that eroded the gelcoat, leaving a pock-marked surface like the face of the moon.
- Materials were used that were either incompatible or inappropriate, particularly fillers or fairing material.
- The materials hawked as being water resistant are not styrene or acid resistant, and were softened or partially dissolved.
- Heavy layers of poorly saturated chopped strand mat continues to be one of the predominant factors in both initial and secondary blistering. The worst cases invariably involve heavy layers of mat on the exterior, as revealed in the top right photo where two ground out blisters reveal a mat nearly 1/4" thick.

The effects of rotary pressure stripping. This process does not remove the gel coat but merely errodes it, leaving it in worse condition than ever. A barrier coating applied to a surface like this is an exercise in futility and a waste of money. This is not the first time around for this boat: notice the prior repaired area at right. This is the third time around for this boat.



This bottom was barrier coated after sand blasting. The craters in the gel coat still remain and the surface is now more porous than ever. The blisters returned with a vengence. They didn't even bother to fair out the craters. Unfortunately, this kind of repair work has become common.

Advice for Buyers Once a blister repair job has been botched, it only gets worse from there. For now the owner has introduced a witches' brew of new chemicals into the equation with all the additional layers he's added. Even worse, he's probably made the hull more porous than it was before, meaning that the poorly saturated mat is going to absorb water faster than ever. There's no way what you see illustrated in these photos can be "sealed." Its like trying to seal a sponge. At this point, the only thing left to do is to strip the entire bottom right down to the structural laminate, which is what should have been done in the first place.

The problem that this poses for the used boat buyer is that the botched repair job is far worse than a boat that merely has blisters. This is not the kind of situation that you want to buy into; in many cases, the botched repair job now will no longer even hold antifouling paint on the bottom because it, too, is reacting chemically and bubbling off. And if you can't keep the bottom paint on, you really do have a problem, one that's a lot worse than just blisters.

This situation is becoming so commonplace that the best advice we can give used boat buyers is to not even consider buying such a boat. And you might just as well inform the broker or seller in advance, before you go the trouble of signing a contract and getting a survey, that you will reject the boat if it has a failed repair job. You should also be aware that the boats built in the orient are the absolute worst for these kinds of problems, with many of the other imports following as close seconds. Moreover, there is a direct correlation to the amount of chopped strand mat on the exterior and where it was built. Its not unusual to find Chinese boats where the mat is 1/4" thick and over. We are happy to report that the incidence of severe blistering with US built boats is considerably less, although far from non existant.

Is There a Right Way? The first thing you have to understand (and accept) is that some boats are not repairable. That's because the quality of materials and workmanship used to build the boat is so bad that what you have is an unstable hull laminate. Adding a barrier coating is not going to prevent the chemical reactions from continuing to occur. You can coat the bottom, but its going to absorb water above the water line and from the interior.

The relationship between boats with severe blistering and boats with excessive chopped strand mat on the exterior can be proven beyond any reasonable doubt. So, too is the problem of hulls where the gel coat is not thoroughly bonded to the mat. Add to that the fact that blisters always occur under the gel coat or with the mat, but almost never within the structural laminates (such as roving or other woven fabrics), and we know for certain that the problem lies within these two outer layers. It stands to reason, then, that if it is possible to remove these offending materials, its is possible to solve the problem. Unfortunately, if the hull has 1/4" of chopped strand mat on the exterior, that mat comprises so much of the thickness of the hull that removing it means removing half the hull. If that's the case, then removing it is no longer an option, so that the hull is then essentially unrepairable.

If the mat layer is thin, say 1/8" - 3/16" then it can be removed without significantly reducing the hull thickness. Of course, there is always the option of stripping a heavy mat layer, and relaminating with a heavy fabric, bearing in mind that fabrics are too strong to allow blisters to form. But that would be rather costly.

We draw a distinction between a bottom that had thousands of pimples and those that have larger blisters. Pimpling is a different phenomenon than a hull that develops just a few larger blisters. While we do not know what the cause is, we can say that it is often associated with solvent softening of the gelcoat. In many cases of pimpling we find the gel coat to be soft and pliable. With larger blisters the gel coat is usually brittle.

Boats with a relatively small number of larger blisters (1" for example) are amenable to spot repairs, which are often successful. If the bottom of your boat has, say, 100 blisters on the bottom, we would recommend spot repairs over stripping and recoating the bottom. We would not recommend barrier coating after spot repairs. Spot repairs are inexpensive, and if they do fail, at least you won't be out a lot of money.

Repair Tips We continue to recommend that the best way to solve the problem of extensive blistering is with complete removal of the chopped strand mat. This material is the primary source of the problem. The most badly blistered boats continue to be those with heavy external layers of mat, and it is our opinion that the blistering cannot be stopped until the material is removed.

- Under no circumstances should you ever sand blast or sand sweep a bottom. Sandblasting shatters the plastic and exposes the fibers far more than they already are. In addition, it craters the gel coat with millions of craters that only worsens the problem when it is sand swept.

- Virtually the same result occurs when these rotary water pressure strippers are used. The end result is as bad as sandblasting. It pocks the gel coat and shreds the exposed fiber bundles, opening up more channels for water ingress.

- The recommended method for removal of gel coat and mat is the planing machine with carbide cutters. This machine will cut off gel coat and mat with minimal damage to the plastic or shredding of the fiber bundles, leaving a clean, smooth surface suitable for recoating. Yes, its more expensive, but it does the job right.

- For spot repairing blisters, we recommend the use of two part epoxy paste ONLY. Do NOT use microballons or fairing material of any kind. You should purchase only the highest quality epoxy, which means the most expensive, and usually one with a recognizable name brand.

- If you do not know how to use a grinder to grind out blisters, DO NOT DO IT. Either learn how or get some one who does. The odds are very high that you will only make matters worse. This is not a job for amatuers. Very few professional yards even know how to do it right.

- Before considering whether to engage a yard to make repairs, determine how thick the skin out mat is. If it is more than 1/8" the odds of success are slim. You will be applying your epoxy or vinylester on top of a sponge.

- Determine how porous the mat is. The better the saturation of the mat with resin, the higher the odds of success. The mat should appear translucent, NOT OPAQUE. If it is opaque or whitish looking, the chance of success if slim. If the mat shows numerous small voids, these are the propagation points for new blisters and the repair is likely to fail.

- If you see blister voids deep within the mat (small, round, opaque areas), the mat has to come off. Coat over this kind of surface and the blisters will come right back again.

- If you are unwilling to pay the cost of stripping off heavy layers of mat, consider whether the blister repair is really necessary. You may be better off just leaving it alone.

Finally, the situation has become so severe that we can only counsel against buying a boat with a botched blister repair job. The ulcers on the bottom of the boat are likely to end up in your stomach.

Here's a 22 year old Bertram with about 100 blisters on the bottom. It has never had any kind of repairs. Is it worth tearing up the bottom and risking making the situation worse? Or would the owner just be better off leaving it alone? We'd opt for the later.

About Barrier Coating The idea of barrier coating is to replace porous gel coat with a more water resistent material such as vinylester or epoxy resin. In theory, its a good idea; in reality it doesn't always work out that way, for the problem is WHAT you are applying that coating to, and whether the coating can be made thick enough to really keep the water out.

For some answers we looked to Hatteras Yachts which, as many of us know, has had enormous blistering problems in the past, and which dealt with it by repairing many of their boats under warranty. So we started wondering how did those repairs hold up? As near as we can tell, by checking on the number of boats built in the 1980's, the answer is fairly well. Its very easy to determine whether a hull has been repaired just by scratching the surface to see if there's gel coat under the paint. If not, then you know its been recoated. The number of Hatterases we see with reemerging blisters is very few. But bear in mind that these are very expensive, larger yachts (50, 60, 70 footers) where the job was probably done right. Usually with the outer layers being removed by hand grinding. The other factor we see is that these coatings are usually quite thick and don't involve any fairing material (like microballons) at all. In other words, the repair is a combination of epoxy paste filler and epoxy or vinylester coating. And nothing else.

The chopped strand substrate on a Hatteras is usually quite thick and porous, but when we see the jobs done at yards like Derector-Gunnell and other high end yards, (I'm talking here over a period of a decade or more) we usually see most of the mat removed and the roving showing through in many places. For the most part, these repair jobs are either completely successful, or fail completely. Very rarely do we see reemergence of only a few blisters. Contrast this with the massive failures that are found on smaller boats. Obviously, with high the cost of a repair job on a million dollar yacht, there is considerable motivation to do it right, as the cost of failure could seriously hurt a yard.

Considering these factors, its hard not to draw some conclusions about the relationship between the dollar value of the repair versus the success rate. The bigger the yacht, the greater the success rate. So what's going on here? Is barrier coating working? Or when it fails, why does it fail? Well, I think the answer has already been given in what has been said so far. The answer is in knowing what works, and the knowledge of how to do it right. But ultimately that boils down to an issue of COST. Successful blister repair is expensive. Barrier coating only works up to a point. That point is predicated on applying the coating to a surface that is not highly porous, such as with a heavy layer of mat. Barrier coatings are not completely water proof, nor can all the water in the hull laminate be eliminated, or prevented from returning. Water can be absorbed from above the water line, and from the hull interior. To be successful, the voids where blisters propagate have to be eliminated. And that usually means removing the chopped strand mat.

Why Are There No Absolute Answers? I am often asked this question, but the answer is difficult to comprehend if you don't understand the nature of boat building. It goes back to the fact that boats are hand made items, usually by companies that are quite small and are sorely lacking in resources and production controls. One day they use this kind of material, the next day something else. In other words, most boat hulls are different, even among the same models by the same builder.

Because there are tens of thousands of different boats all built somewhat differently, no one has even bothered to attempt to study the problem. Besides, how could anyone go around chopping up peoples boat's to study the problem? Even if someone were willing to invest the millions that such a research study would require, the resulting answers would probably be very unsatisfying. It would likely end up with dozens of explanations and mitigating factors that would leave us just as confused as ever. In fact, some of the chemical companies have done some in-house research, including the one I was involved with back in the early 1980's (Uniflite). While I never saw the entire results of that research, I do know that a large number of factors were identified, far more than are common knowledge today. If a complete dissertation on the subject were published, it would be so complex that no one would want to read it. It would just make your head swim with possibilities. It may be just as well that that research, utilized in the Uniflite class action lawsuit, was ultimately sealed in the court settlement, never to be revealed.

The only thing we know for sure is that it is quite possible to build boats that don't blister by using quality materials and methods. As long as the boating public is willing to foot the bill for this terribly expensive problem, without holding the builders feet to the fire, then we'll just have to suffer with it.

Posted July 21, 1998

My Wet Hull Won't Dry

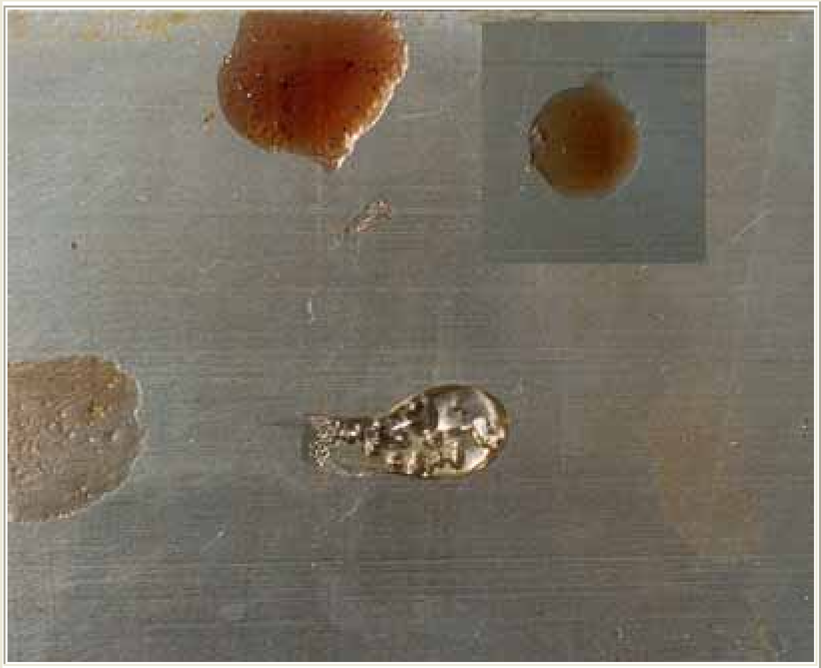
The 8 Grand Conundrum.

by David Pascoe

www.yachtsurvey.com

People with boats undergoing blister repairs often write us to say, "My boat has been drying out for six months now, and it still will not dry. The moisture meter readings are still as high as ever." The usual procedure is to just let the boat sit and "dry out" naturally by a process of evaporation. Still others are erecting tents and what not and installing heaters or dehumidifiers to try to accelerate the process. And still they report that it's not "drying."

No, it's not drying. And the reason why is a very simple one. The wetness you are attempting to dry is not water, but something else. In many cases, it can sit there forever and never go away. You can prove this for yourself by performing a simple test. Collect some fluid samples from blisters on any boat. Rupture the blister with a sharp knife point, then press against it and let it spray into an empty film canister. Then place droplets of the sample on a piece of clean metal or glass. Take it home and put it in a cool, dry place for two weeks.



These are samples of blister fluid after 2 weeks of air drying. The three at top and right are hardened to the touch and have shown almost no shrinkage due to evaporation. The large one at the tops is roughly 2mm in depth. The volume of fluid placed on the plate remained

essentially the same. Water has been added to the sample on the left. Note that it has dissolved completely, dried up and left the residue spread around. The one at bottom center developed those large bubbles when placed in the sun. The one at the top also developed bubbles, but most of them dissolved after removal from sunlight.

When you return to your samples you will find that it has not evaporated, but has hardened into a droplet of near solid clear plastic with no detectable loss in volume or size. It may remain somewhat sticky, or it may fully harden to the touch. If you now take that sample and put it outside in very damp or humid weather, you will find that it will soften up again. In other words, that material is hydroscopic and will absorb water right out of the atmosphere. Now add a drop of water to the sample. Surprise! It will dissolve the solidified material very quickly. And if you take a moisture meter reading of the solidified material on a piece of glass, you'll get a high reading.

What you will have just demonstrated is the reason why your hull won't dry, and the answer on how to dry it. What is migrating out of your exposed hull laminate is a combination of hydrolyzed polyester resin, salts and other chemicals. These sometimes migrate to the surface where exposure to air causes the fluid to naturally cure. But it doesn't go away. It just stays there alternately curing and softening with the changing atmospheric conditions. On a rainy day, it will probably become nearly fluid. After a few days of cool, dry weather it cures again.

Now that you know this gook is water soluble, you know how to get rid of it. Yep, just take a hose and wash it away! But while the hull is wet, be sure to give it about 30 minutes to completely dissolve.

"But won't I just be making my hull wetter by putting water on it?"

Yes, but only temporarily. We've already discovered that the fluid weeping out of the hull is NOT water and will NOT evaporate. As you know, water evaporates very quickly, and the water you use to rinse the hull down will too. Wet the entire hull down and keep it wet for about thirty minutes. Then come back with a hose nozzle and spray it with a bit of pressure to remove the remaining traces since some of this stuff may take longer to dissolve.

On some boats you will actually see the accumulations of fluid on the surface, most often in isolated spots that are little weep holes. This indicates that there is likely a concentration of fluid under the surface and it is finding its way to the surface through a capillary. Most likely you will need to wash the hull down at least three times depending on the condition of the hull. In any case, this will greatly advance the "drying" process and your meter readings should begin to drop significantly, only to start rising again.

Take note of the fact that some hulls actually do have plain old water saturation with only very small traces of hydrolyzed resin. In this case, you may find that the hull starts to dry quickly, but then an odd thing happens. The readings start to rise again. If that happens, it's because the water is migrating to the surface, and then leaving deposits of dissolved material as it evaporates, possibly including salt (which is also hydroscopic), so that the readings again start to rise. Again, simply wash down the hull with water to remove it. If you have any doubts about this, then only try a test area to see if it really works.

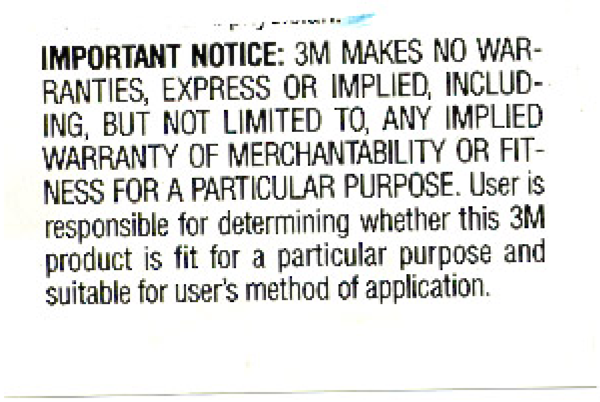
Also, if you are located anywhere near the ocean, make certain that wind-blown salt is not accumulating on your hull. Salt is hydroscopic and will condense water out of the atmosphere. If you are anywhere near a shore with surf, keep in mind that salt can easily be blown inland several miles, and it collects on everything. It will, for example, accumulate on the topsides of your boat, and then be washed downwards by rain.

Keep in mind that hydrolyzed resin may or may not contain other chemicals such as salt. This means that there is no consistency to how a moisture meter will read the stuff. Plastic and glass fibers are not conductive, and since moisture meters operate by metering conductivity, it will all depend on the water and salt content of the hydrolyzed resin. It may be zero or it may be 30.

But there is one thing you can be sure of, which is that if the hydrolyzed resin is not removed from the laminate, it will once again absorb water and start the blistering process all over again and your expensive blister repair job will fail. No, despite all the hype about "barrier coats," there isn't anything that is going to keep water out of the hull laminate completely.

* * * * * *

If you haven't already started a repair job, but are thinking about it, we'd strongly suggest you stop to consider whether it is really possible to cure "boat pox." Shown below is the disclaimer from a 3M product that is sold as a blister repair material.


IMPORTANT NOTICE: 3M MAKES NO WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. User is responsible for determining whether this 3M product is fit for a particular purpose and suitable for user's method of application.

This product is advertised in boating magazines as a repair for blisters. It does not say so directly, but rather suggests that it is. Then, in small print on these cans of extremely expensive materials, we read that the manufacturer is telling us that the stuff is not intended for ANY particular purpose. It is up to YOU to decide if this stuff is any good for anything because 3M does not imply or warrant that it is.

So, if you wonder why we tend to be a bit cynical about the booming business of blister repair, there's graphic reason why.

Illustration of
Water Absorption From a Hull Interior

Many Water Saturated Hulls Don't Blister

by David Pascoe

www.yachtsurvey.com

Quite a few people have written or called to tell us that they know of some proven methods of repairing bottom blisters that constitute a full and final solution. Each of the systems and products offered by West, Ashland Chemical and International Paint were mentioned. These, of course, are the most widely used products, but are also the most frequently involved in the failures, if only by virtue of their widespread use.

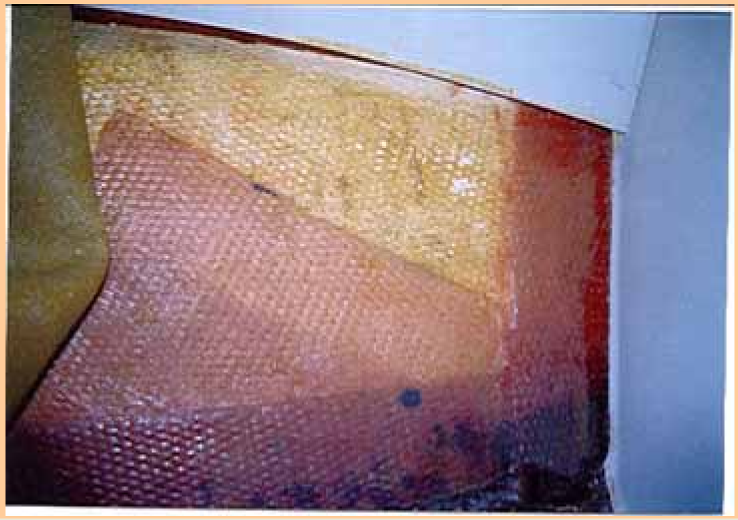
Some of the people who suggested that the information offered on this site was incorrect were surveyors, stating that they were sure that these methods and products worked. We pointed out that not ALL blister repair jobs fail, nor did we suggest that to be the case. Only that far too many do fail. To those who stated that they knew of foolproof repair methods, we posed the question, "How long after the repair jobs did you conduct follow-up inspections to ensure that the repair was, in fact, effective?"

This threw quite a wrinkle into their arguments. It is time-consuming and costly to perform follow-up studies and, as expected, none of those who differed with our views had done so. They were basing their opinions merely on the fact that they hadn't heard about the repairs failing, and so their assumption was that it worked out fine. This is rather typcial of what passes for knowledge in the boating business - mainly a lot of hastily conceived conclusions generated from hearsay and assumption.

It was stated in another essay on this site that effective blister repairs could not be guaranteed because coating the hull from the *exterior* could not insure that it would not once again absorb water from the *interior*. At the time that essay was written, we hadn't yet any good photos revealing just how much water can be absorbed from inside of a hull. That has now changed. Just recently we came across a boat that yielded up some pretty good photographic evidence. Now we have the photos and they're shown below.

Background The boat in this example is a Trojan International 10.8 meter, ten years old and a one-owner boat that had never had blisters on the bottom. It had spent its entire life docked on a canal in South Florida where summertime water temperatures are as high as 92 degrees. This is a very well built hull of solid laminate, of conventional roving reinforcement. It was so thick and hard that when we sounded it with a steel hammer, the hull "rang." No dead, dull thumps on this one. And there was not one blister on the bottom. Now take a look at the photos we took of the interior hull.

1.



2.

3.

As with most hulls, its painted or gel coated throughout most of the interior. But up in the bow section we found some areas that weren't. Here's what we found:

Photo #1. This photo is taken in the forward cabin just above the point where the sole is taped into the hull sides and below the waterline. When I first lifted the carpet here, I was taken aback because my first impression was that the cabin sole tabbing had been laid over painted fiberglass, since the aft section of the interior hull was painted. As you can see, the tabbing is a pink color while the hull laminate seen at the top of the photo is not translucent like the tape but completely opaque. (Tape or tabbing are the strips of fiberglass used to join parts together, such as a bulkhead to the hull in this case.)

Photo #2. This is one of the most graphic illustrations you will ever see of differing rates of water absorption in various areas of one hull. This is looking straight down at the centerline bilge in the forefoot where a bit of black water lies at the bottom of the vee (the black vertical line). The yellow section at the center is a separate layer of fabric which has absorbed far more water than the surrounding laminate and turned yellow. Whereas in the upper part of the photo, you can see a different layer of fabric that is pinkish and is not as opaque, meaning that it has absorbed less water.. Notice that the coloration is the exact opposite of that in photo #1, where it is only the tabbing that remains pink and translucent. Since both sections of laminate are equally hard, most likely what this is telling us that two different kinds of resin were used in this lay up. Because of the hardness, cure rate does not seem to be a factor as it is in many cases.

Photo #3. This photo was taken a few feet further aft. Its the hull bottom between the keel and the stringer (top of photo). Here the laminate has a blotchy appearance - its whiter toward the left and center, while a more translucent area is seen at right. At the bottom is an oily bilge high water line. The stringer has absorbed very little water and remains translucent, whereas the bottom laminate has turned opaque. The differing colors, which are not just surface contamination, suggest that chemicals in the bilge water have also played a role in the discoloration.

What is most distinguishing about this photo (#3) is the progressiveness in the change of color of the laminate down toward the keel; the deeper in the bilge, the more opaque the laminate. When a laminate, or plastic, absorbs water it turns cloudy or opaque. We take this as clear evidence of just how much water a hull can absorb from the interior.

We don't often get to see examples like this because the interior of most boat hulls are painted. So what is the meaning of these examples of differing laminate layers absorbing more or less water? For one thing, it is a dead giveaway that different batches of resin were used, or that the same resin was handled differently, such as catalyzing, accelerating or hardnening agents. Secondly, that some laminates absorb more water than others, some from the interior and some from the exterior.

Further, these photos also demonstrate (as we already know) that water migration through a laminate follows the fiber bundles via the capillary effect. And that there is much less tendency for water to pass from one layer or lamination to another. Why is that so? Because the fibers don't extend from layer to layer, but only horizontally within a layer.

Summary

Here we have an excellent example of a hull that is fully saturated with water and yet it has not blistered. Not one. It also proves that hulls can absorb a great deal of water from the interior, and the reasons why recoating the exterior so often fails to solve the blistering problem IF a hull is prone to blistering.

So why didn't this boat blister? We have less than a complete answer to this question, but we did obtain some indicators. One is that the resin used is not so superior that it resists water absorption*, yet it has displayed no tendency to blister. Another is that the layup quality is well above average - we found no evidence of void spots or incomplete wet out at any point where the laminate was not painted. As you can see in these photos, there are no areas of unwet fibers visible, nor did we find any in other areas.

Although this boat was in the process of being sold, and we could not attack the bottom with a grinder, a little digging with a knife determined that the skin out mat on the exterior is very thin, probably less than 1/8". What this means is that it does not have a thick layer of mat (which is very difficult to wet out) that is full of voids and unsaturated fibers. This would tend to confirm our belief that incomplete wet out is a primary factor in the blistering process.

This is yet another example that leads us to conclude that the quality of workmanship in the layup process plays a major role in blister prevention. Yet that alone cannot explain why this boat did not have any blisters, for it is entirely unreasonable to assume that there are no voids or unsaturated fibers in the bottom outer laminate: that is impossible. Even though the resin is highly permeable, no chemical reactions occurred to result in blisters. Clearly, there must be something about the quality of the resin that prevented this.

But it is equally clear that, if a hull can absorb water from the interior, recoating the exterior is no fool proof solution to blister repair. Due to the fact that water does not migrate as easily *through* a laminate as along its length *****, recoating with a less permeable resin can have a major effect on the extent of blistering that can occur. But these examples should make it pretty obvious that no repair process is going to guarantee a permanent fix.

* Laminates tend to conduct water along the longitudinal axis becasue the fiber bundles, which are never completely wetted out, conveys water readily via the capillary effect. Water absorption by the plastic resin is a much slower process, possibly involving hydrolysis. The term "water absorption" means the induction of water into the laminate by any means.

Useful Terms

Capillary Effect: The tendency of a fluid to conduct itself or flow through narrow passages, e.g. a capillary. Adsorption, absorption, catalysis, diffusion, osmosis and permeability are all terms that are closely related.

Permeable: The ability of a fluid to pass through or penetrate a solid; porous, porosity, passable, penetrable.

Hydrolysis: A chemical reaction in which water reacts with another substance to form two or more new compounds.

Osmosis: The flow or diffusion of a fluid through a semi-permeable membrane, initiated by differing concentrations of that solution on each side of the membrane. It should be noted that osmosis does not occur through a membrane where the solution exists only on one side. The membrane, or material, must first be permeable for osmosis to occur.

Permeate: To pass through pores or interstices.

Semipermiable: Partially but not freely or wholly permeable; of or constituting a natural or artificial membrane that is permeable to some, usually small molecules (as of water or inorganic salts) but bars the passage of other, usually larger particles.

1997

BLISTERS AGAIN?

The Wonderful World of Hull Blistering and Other Interesting Scams

by David Pascoe, Marine Surveyor

www.yachtsurvey.com

Not long ago a marine surveyor wrote a letter to the editor of a boating publication. In that letter he indicated that it was his experience that prior to around 1970 he had encountered very few fiberglass boats with bottom blisters. Then, suddenly in the mid 1970's, bottom blistering seemed to blossom into a chronic problem throughout the boat building industry.

He further wondered if the 1973-4 Arab oil embargo, which dramatically raised the price of oil (and therefore the price of plastics) for a year or so, didn't lie at the heart of the problem. Since then other writings on the subject have appeared, and other surveyors have been heard to make similar comments. Indeed, hull blistering was not a major problem since the first fiberglass hulls were built in the late 1940's, until the advent of mass production on a large scale beginning around 1970.

Mass production of small boats began in the mid 1950's, larger boats starting in 1960 with the advent of Bertram, Hatteras and Hinckley. The transition from wood construction to fiberglass was nearly completed by 1970, at which time very few wooden boats were being built.

These comments caught my attention because it had also been my perception that very few boats ever developed hull blisters prior to the mid 70's. This is not to say that hull blisters never occurred prior to this time, because they did. In fact, one of the very first reinforced plastic hulls built in the 1930's developed all sorts of problems, including what has been described as blistering. But those problems have long since been solved and there is no excuse for the wide scale blistering of hull bottoms that occurs today, despite the absolute knowledge of every boat builder of what materials to use to avoid blistering.

Left: Photo of hull with gelcoat removed, revealing that the mat is very poorly wetted. **Right:** photo of same area prior to removing gelcoat. Pimple blisters are all beneath gelcoat and not under the mat, none of which grew to any significant size.

See Additional Photos Below

The fact is that boat bottoms blister because builders knowingly make the decision to the cheapest possible resins to reduce their costs. Build a boat with better quality resins, resins that are not water permeable, and they will not blister, barring other major production faults. This is the reason why some boats blister while others do not.

Some surveyors have been insightful enough to ask why it is that some boats of a particular builder blister, while others of the same builder do not. Or even why it is that someboats in a model line will blister and others not. Here the answer is a little more complex. One answer is that because resin constitutes such a major part of the overall materials cost in building a boat, many builders - if not most - are constantly in the process of shopping price and changing their resin suppliers based on the best available price.

Another part of the answer is based on a process that was once known as "tank coating." This was a process borrowed from the fiberglass tank industry, the people who made underground storage tanks for things like gasoline storage at gas stations. In the days before fiberglass tanks, the use of steel tanks underground was a major problem because of ground water that would rust them out. Thus, the fiberglass tank industry was the very first major use of fiberglass reinforced plastic. And it was here that blistering first became a problem.

If you're old enough, you may remember a time in the 1960's when every gas station in town seemed to be digging up their tanks and replacing them with fiberglass. That's because leaking gas tanks mean big trouble. But then there was a period when they were digging them up again, this time to replace leaking tanks caused by blistering of the tanks. Interestingly enough, the first fiberglass tanks that were built did not leak. But then the cost of the plastic resin was high and the tanks expensive. Naturally, to reduce the cost, cheaper resins were developed and sold. So now the trouble begins.

By the mid 1960's tank manufacturers found an agreeable compromise. They would use the high quality resin on the outside of the tank (the part exposed to ground water) and the cheaper resins for the inner layers of the laminate, hence the term "tank coat." A decade later, the plastic pool and spa industry encountered the very same problem and solution. Unfortunately, when applied to boat building, tank coating generally causes more problems than its worth. It makes the process of layup more complicated and prone to error. When only a limited number of boats in a builder's line develop blisters, it is the result of an error, i.e. the lay up crew using the wrong resin.

Now comes an interesting aside. Since Bertram, Hatteras, Chris-Craft and Hinckley were the first large fiberglass boat builders, the history of these builders on the subject is interesting. For the most part, Bertram and Hinckley boats did not develop blisters.

Hinckley is reported to have had none, while Hatteras, as we know so well, has had chronic blistering problems for nearly 30 years. Chris-Craft, on the other hand, only had occasional boats with blisters, but those that did were often extremely severe. I know of three cases where the blisters were so bad that they nearly destroyed the hull. Interestingly, the Bertram line rarely had blisters, and those that did were never known to be severe.

Both Bertram and Chris-Craft used the "tank coating" method of applying high and low quality resins strategically in hull construction, as decribed previously. In contrast, Hatteras had long been known to use both low quality gelcoats and resins because it was their method to paint their boats rather than use the gelcoat for the finish. Now consider which company has the worst track record on hull blistering.

But boat builders, a decidedly peculiar bunch of people who seem to insist on the notion that knowledge and education are not essential elements of their industry, went merrily on their way using inferior materials in the construction of their boats, just as large numbers continue to do so up to this very day. And so here it is in 1997 that we still have millions of late model boats continuing to develop blister problems. (To those of you who wrote me regarding prior articles telling me that I was full of horse manure, please tell me why outfits like Bertram and Hinckley have built boats for over 30 years that did not blister. Please, I'm eager to know your answer!)

Now come those very same chemical companies who manufactured and sold those inferior resins to the boat builders, selling to boatyards some solutions to the very problems that they created in the first place. What has prompted me to write this article is the growing number of failures of blister solutions that I have been recently encountering. No, I'm not talking about do-it-yourself jobs, but repair jobs performed by professional boat yards costing $10,000 or more. In the first three months of this year alone I have encountered four yachts of over 50' that have failed blister repair jobs that involve the materials and systems of the major chemical and paint companies. These are not isolated incidents, but a major trend in the business of blister solutions.

In three of the four instances, the new bottom coating system literally turned to mush. The material turned so soft that it could be peeled off with a knife. I stress that these were reported to be the systems of well known manufacturers applied by professionals. The owners stated that these were the materials systems of major chemical or paint companies. Moreover, the rates of failure of repair jobs on smaller boats, most of which I was not much interested in investigating finding out who and why, is actually becoming commonplace. However, many of these problems have to be attributed amatuer or cut-rate repair jobs of the grind-and-fill variety.

The question we have to ask is what the heck is going on here? How is it that the solutions are beginning to appear worse than the problem itself? No doubt that a large number of these failures were the result of less than professional workmanship, driven by the desire for low cost. This does not, however, explain the failure of very costly, professionally applied solutions.

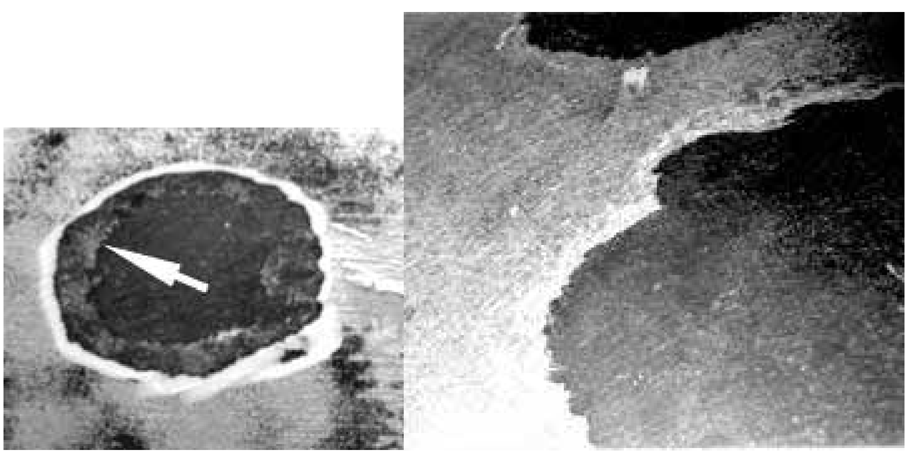
Since I don't have a few million dollars to spend on performing thorough research (as the chemical companies do), I certainly don't have all the answers. But my investigations have turned up some very interesting evidence:

- It is not possible to effectively solve the blistering problem of a hull that is water permeable.
- Water permeability of a laminate is not the function of a resin alone, but how well the glass fibers are saturated or wetted out with resin. If a hull is permeable from the outside, its also permeable from the inside. What is the point of recoating the outside when the inside is also exposed to water?
- Blistering on above the waterline structures proves that immersion is not necessary to cause blisters.
- We learned from the Uniflite class action suit in the early 1980's that continuous strands of glass fiber are capable of conducting water along their entire length by means of the capillary effect. For example, if a roll of roving is laid out from one end of the hull to the other, and the wet out is not good or complete, those fibers can wick water along the entire length of the sheet of glass.
- We also learned that engine vibration transmitted to the hull is one of the major means by which water is transmitted through unsaturated strands. Capillary effect alone is not responsible.
- In a four year casual study that involved examining every hull that I ran across that had the outer coatings removed (involving hundreds of boats), the lack of complete wet out was appallingly bad in well over 50% of all boats that I looked at. The nearby photo typifies the lack of wet out found in most boat hulls. There is a direct correlation between low quality resins and poor wet out on blistering.
- The use of chopped strand mat as a skinout layer to prevent telegraphing of weave patterns through the gelcoat is a major source of the problem of water absorption of the hull. This is because mat does not wet out well. Further, because the fibers are short, there are millions more exposed ends of fiber bundles capable of wicking and conducting water through the laminate. Heavy layers of mat are very hard to fully saturate with resin. It is also responsible for causing millions of small voids that ultimately fill with water. Its almost like a wood boat that has millions of tiny worm holes.
- Exposed fibers on the inside of the hull are also responsible for wicking water into the laminate. There is a definite correlation between where blisters most commonly occur and where bilge water lays within a hull. There is also a correlation of the predominance of blisters and the edges of sheets of glass fabric.
- Major blistering problems are often related to bonding failures of both gelcoats and skin out mats. I was not aware of this until about a year ago, when, one day, I watched a blister repair contractor stripping the gelcoat from a hull. Not only was the gelcoat coming off, but the entire skin out mat was peeling off (see actual

photo of this boat). On closer examination I found that major areas of the skin out mat had never achieved bonding and could be peeled off by hand. As I continue to examine boats for this condition, I am finding more and more of them.

- Examining the process that yards use to remove the blisters, it is found that most keep grinding away until they stop seeing any evidence of delamination. The problem that they often run into is that the delamination never stops. The nearby photos reveals some of the conditions I have found in the vast majority of all blisters that I have examined (thousands). That is that most blisters involve ply separations that seemingly never ends. They grind and grind and grind, but there's always separation around the circumference of the blister.
- When ply separations or incomplete bonding exists, blistering is a problem that cannot be solved. That's because the void areas are going to fill up with water all over the bottom. Repair the blisters and they will reappear because its not possible to keep water out of a hull that's constantly immersed in water.

Why Bonding Failures Occur There are two types of bonds that occur in the laminating process, mechanical and chemical. The former occurs when a wet laminate is laid over one that is dry or cured; the later when the new laminate is applied over one that is wet or at least tacky. In the later case the resins "fuse" together to form a whole. A mechanical bond is simply a glue joint and is based entirely on adhesion and is not nearly as strong. In the normal course of laying up a hull, there is a natural stopping point in the process, this being just after the skin out is laid in (a "skin out" is the first layer, usually mat, laid up against the gelcoat sprayed into the mold). Not always, but it does occur frequently because it is not perceived as being very important to have a chemical bond at this point. After all, the builder reasons, this part is not considered as structural: it just has to do with the finish. Particularly in small companies, the lay-up often occurs in a dirty environment, not infrequently with the carpenter shop nearby and saw dust filling the air. In other words, the bonding surface becomes either completely dry, contaminated or both, thereby resulting in an eventual bonding failure.



Left: In this ground away blister, the ply separation is clearly evident around the perimeter as shown by arrow. When it is repaired, the void or incomplete bonding will remain. **Right:** The skinout mat on this hull never was fully bonded. This is the result after six inch blisters were peeled away. This large section was peeled off with a screwdriver. Note that the mat is less than 50% saturated.

Because it is a weak glue joint, this bond failure may not occur until years later when the hull has been stressed hundreds of times. Certainly the effects of heating and cooling will play a major role in this as differing fiber configurations will cause differing rates of expansion and contraction.

These separations or incomplete bondings are otherwise undetectable in any other way. Sounding out the hull will not detect it unless the separation is complete, which it usually is not. Perhaps a better way to describe it is as a "partial ply separation" because there are many small areas where the glue joint is intact. Its rather like sprinkling sand on a piece of plywood and then trying to glue another piece to it. Parts will stick and parts won't and there's no rhyme or reason where or why except for the sand.

It follows then that a blister repair job on a hull where the skin out layer is not completely bonded is not going to be successful because the whole thing is a porous mess. Just take a look at any hull that has had the gelcoat removed and the reason will be obvious. All those millions of white spots are voids or unsaturated fibers, all of which are going to conduct water via the capillary effect. And if most hulls have this condition (which they do), then we have a very good explanation for why so many blister repair jobs fail. It doesn't explain why the new coating systems turn to muck, but that's another story.

If you're a boat owner who has shelled out a lot of bucks to get your blisters fixed, and you're asking yourself why didn't anyone tell me this, then you're asking the right question.

The answer is that, like the boat builder who built your boat using lousy resin and layup techniques in the first place, the boat yard doesn't know because they're more interested in getting your ten grand than in knowing what it is that they're doing. After all, if they knew they couldn't fix it, they'd have a more difficult time explaining why they took your ten grand. So ignorance is bliss unless you decide to sue them, which you probably won't do because it will cost you more than the value of the problem and if you loose, you're out even more. And so the yard is fairly safe in continuing their ignorance because they can blame it all on the materials manufacturer anyway, who will point the finger back at them and you'll have to sue them both and hire a lot of expensive experts, if you can find any.

And so it is that after 50 years of boat building the blister problem just keeps rolling on and on, keeping surveyors like me in business telling people things they don't want to hear.

No, the moisture meter isn't going to tell you whether a boat is likely to get blisters or not simply because most boat hulls are saturated with water. The reason why some blister and some don't is basically a matter of quality materials and good techniques. Even when saturated with water, quality hulls are far less prone to blistering.

If a hull is 5 years old or more and has no blisters whatever, there's about a 95% probability that it never will. If it has even one blister, the chances are very high that it will continue. The more blisters it has in inverse proportion to it's age, the more likely that the problem will worsen at a progressive rate. Here's why.

Even though a hull may be built with inferior resin, osmotic pressure is not normally sufficient to force a separation between plies that are completely chemically bonded. If it can't force a ply separation, then the blister can't form. In this case, if there are sufficient numbers of voids directly under the gelcoat (which softens with age), small blisters, or what I call pimple rash, will develop that will extend only to the general area of the void. The osmotic pressure is sufficient to raise the gelcoat, but not to cause a ply separation. It is particularly insightful here to note that pimple rash almost never occurs in conjuction with larger blisters. Obviously, then, entirely different factors are at work in this case.

Larger blisters almost always occur <u>under the skin out mat.</u> This is also a point of great significance. If there are larger voids, or poor bonding generally, then, and only then, will serious blistering develop. If the wet out is very good (which is rather rare) then blisters are not likely to develop at all because there are no voids to help get it started.

If you're looking to buy a boat that's three years old and has ten blisters, figure that the problem will gradually worsen, possibly at a very rapid rate. On the other hand, what effect do the blisters really have? Are they going to destroy the hull as so many horror stories told by people wanting to take your money? No, hull blistering rarely causes structural problems unless it is unusually severe.

Can blistering cause problems in resale? Yes, but even that is fairly rare. Its possible that a buyer will try to negotiate for the cost of a fix, but I haven't seen one in fifty sales rejected because of blister problems, and these have always been severe, and usually involving a prior failed repair.

- Don't rely on moisture meter checks to determine whether a hull is prone to blistering.
- If blistering bothers you, don't buy a boat that has them.
- If you own a new boat that's developed even just a few blisters, file a warranty claim immediately. Don't wait for it to get worse and the warranty to expire.
- If the hull does have blisters, the existence of a bonding problem can be determined with a little destructive testing. This can be done by using a long, thin-bladed knife. Slide it in beneath the surface of the blister and see if it slips in beyond the circumference of the blister. If the outer surface is loose all around, then there's a bonding problem.
- Don't be sold a "fix" until you know the source of the problem. Small areas of the gelcoat need to be removed and determined whether there are excessive voids or poor wet out of the skin out mat. If there is, the usual "fix" isn't going to work.

- If there is evidence of poor bonding, a permanent solution may involve peeling the skinout mat off the entire hull.

As you can see, causal factors of hull blistering is myriad and complex, all of which makes coming up with neat, tidy explanations impossible.

Ultimately, those surveyors who thought they saw a link between the oil price increases of the 1970's and hull blistering are half right. The price of oil does does provide additional motivation for builders to use inferior resins, but that started long before 1973, and in industries other than boat building. The problem is not going to go away because that motivation will always be there, combined with the fact that boat owners haven't been willing to hold the builder's feet to the fire. As long as the market is willing to accept the problem, there's not much incentive to change.

For any surveyors who might be reading, here's another interesting question: When was the last time you saw a 24' runabout with hull blisters? How come big boats get them and small ones don't?

Caveat emptor.

Avoiding the Blister Blues

Good Detection and Communication Techniques Critical to Avoiding Complaints

by David H. Pascoe, Marine Surveyor

www.yachtsurvey.com

Hull blistering is a problem that has been with us for a quarter-century. One might think that over a period of twenty-five years this problem would have long since been solved, and no longer be much of a problem for surveyors. Unfortunately, our research reveals that the blistering of boat bottoms continues to be a growing source of complaints and lawsuits against surveyors. It seems to be one of those pernicious problems that just won't go away. In fact, the number of lawsuits against surveyors has actually increased dramatically in the last several years.

One of the reasons for the increasing numbers of complaints is clearly the result of both yards and independent contractors having stepped up their efforts in marketing blister repair solutions. Blister repair has become a big business and repairers are roaming around boat yards looking for blistered boats, seeking repair work. That can mean that if the surveyor doesn't find the blisters on a hull, these people probably will.

A Problem With a Solution Despite the numerous studies, research reports and magazine articles on the subject, there is not much concordance on the cause and effect of blistering. Most of the literature seems directed at repair solutions rather than how to prevent blisters from occurring in the first place.

The simple fact is that hull blistering is caused by the use of inferior materials and shoddy layup. As Lee Dana, former head of engineering at Bertram Yachts told the audience at the annual conference of the National Association of Marine Surveyors in 1985, hulls built with high quality resins don't blister. If builders want to build hulls that don't blister, all they have to do is "spend another ten dollars per gallon for resin," he said

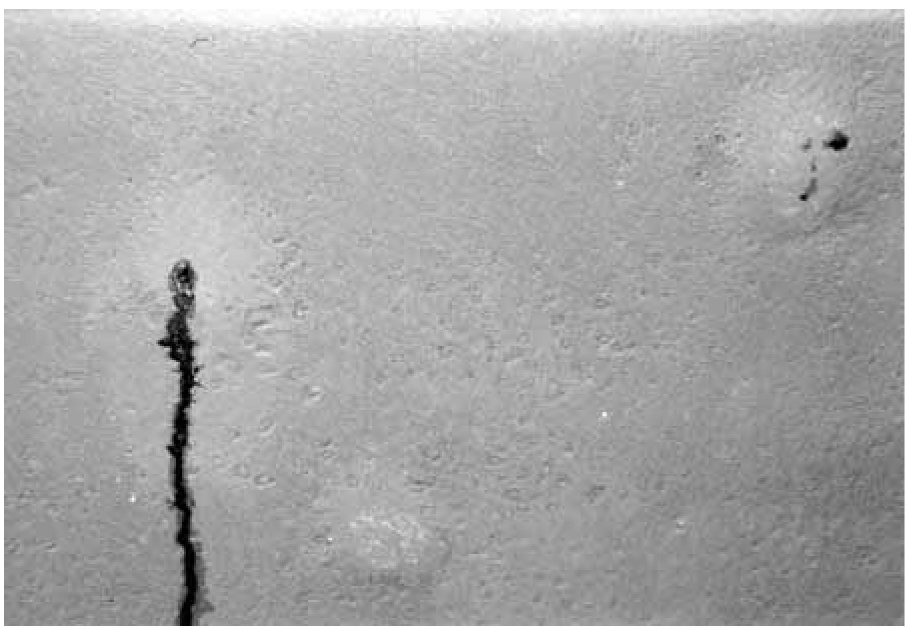
This fact is well known, but rarely considered by surveyors or the boating public. If boat builders wish to build hulls with inferior resins, then they, not surveyors, should be the ones who pay the price with warranty complaints and law suits. Unfortunately, most complaints and lawsuits against surveyors occur with older vessels which are either out of warranty or the builder is no longer in business. Moreover, most warranties only warrant the first vessel owner, leaving the next buyer in the lurch, which explains why the surveyor ends up in a particularly vulnerable position.

The good news is that there are a number of things that surveyors can do to protect themselves. And, if you're not already doing them, this article offers some highly effective methods for protecting yourself against problems that rightfully belong to the boat builder.

The Genesis of Trouble My review of nearly a dozen complaints against surveyors shows that nearly all of them got into trouble because they (1) failed to locate existing blisters, or (2) failed to give adequate advice to the client. Most allege that the surveyor either did not inform the client of the presence of blisters at all, or that he merely mentioned their existence, but downplayed their significance.

In at least three cases, the client maintained that blisters got substantially worse shortly after the survey was conducted, a clain which is dubious at best. In one case, a client claimed that blisters appeared on an older vessel a year after a survey revealed that there were no blisters, the so-called "mystery blister syndrome." In another, it was claimed that blisters appeared only a few months later.

Frankly, it is hard to put much stock in the mystery blister syndrome. Although its well known that blisters will change their profile considerably as a result of changing environmental conditions such as temperature, humidity and drying out after being hauled for a period of time, I've yet to see a case of deflated blisters that wasn't readily observable under proper conditions. Nor have I heard of any documented cases where blisters developed rapidly (The lone exception to this was Hatteras yachts which was known at one time to have used a grossly inferior gelcoat because they painted their hulls). The minimum development time in new vessels seems to be around three years but usually much longer.



There are three blisters appearing in this photo of a boat bottom which is very clean and smooth. Two of them are easily revealed by the fluids that leaked out after the boat was sitting for many weeks. But the blister at lower center is barely visible. All of these blisters were highlighted by good artificial lighting used to take the photo. Without that lighting, and absent the weeping, it would have been very difficult to locate these blisters. After wetting down with water, they became much easier to see. If the bottom were dirty, its not likely that they would have been located.

One way or another, unless they don't mind footing the bill for what should be a boat builder's problem, surveyors need to take some well defined steps to protect themselves from becoming convenient targets for recovery of repair costs.

Obligation to Inform The failure to properly advise or inform a client can certainly be construed as malfeasance or negligence. This means that the surveyor is charged with the responsibility of making every reasonable effort to determine the presence of blisters, be they inflated or deflated, and advise the client accordingly. This does not mean, however, that under the definition of a survey, surveyors are charged with making a technical analysis of cause and effect. It does mean that they have duty to report on conditions that are discoverable or apparent to any other surveyor or expert who would be likely to find such conditions.

Economic Impact Regardless of the prevailing wisdom of the effects of blisters, whether they cause structural damage or not, it is well known that blisters are likely to cause an economic loss to the client, for which the surveyor can be held liable in the event that he fails to detect and advise. Yet a client may exhibity no concern for the existence of blisters, nor be interested in repairing them. The problem usually arises when the client goes to sell the boat. The new buyer may demand that the your former client reduce his price by $6,000 to allow for blister repair. Or he may be approached by a hungry yard manager or repair outfit and given a litany of horrors on how blisters are destroying his boat. Either way, this is how a formerly unconcerned client can suddenly become a hostile adversary.

Without the dark weephole to announce its presence, this blister is not visible under ordinary conditions. It has very little raised contour and is only slightly revealed by a strong light played across it at a low angle. Yet tapping it with a coin clearly reveals the separation of the gelcoat by sound.

The Working Environment Many surveyors get in trouble because they encounter conditions that inhibit their ability to perform their work. For the most part, surveyors get so conditioned to working under extremely poor conditions that they no longer are even aware of how badly their work is hampered by a poor work environment.

We should first understand that courts rarely award judgments to plaintiffs for conditions that are entirely beyond the control of the defendant. They award judgments simply because the defendant failed to properly advise the client about what he could, or could not do. It is not too much for the client to expect the surveyor to advise him of the limitations of his service, particularly when it involves dangerous or costly conditions. Therefore, the principle to be applied under all such limiting conditions is to make sure that the client is properly advised of any factor that adversely affects the surveyor's ability to perform his function as the client expects him to do.

Secondly, surveyors run into trouble as a result of a failure to fully and accurately inform the client of the full import of any negative condition, whether by omission or misconstruction of any material fact. An example would be to say that blisters on a boat bottom are of no significance when, in fact, they may cost thousands to repair.

Third, surveyors also fall victim to the failure to give *timely* advice. As we know so well, brokers are eager to close the sale as rapidly as possible and clients often close a sale long *before* the survey report is even written. It is not enough to merely advise him of defects or limitations only by means of the written report. Whenever serious and costly defects are discovered, or the surveyor is seriously hampered in performing his work, it is imperative that the client be advised as soon as possible. Unless the surveyor does this, the client may have a legitimate complaint that he suffered a loss as a result of the failure to give timely advice.

How Blisters are Concealed I have yet to see a case of blistering that could not be detected by nondestructive methods, which is not to say that there aren't conditions that disguise them. Two of the most common hindrances are heavy paint buildup and dirty bottoms.

Once blistering occurs, the outer skin or gel coat becomes stretched and will never fully return to its original contour. The "hump" may be very slight, but if you are looking for it, you will find it. But to do so, the bottom needs to be clean and smooth. A bottom that is dirty and rough is not capable of giving off enough reflected light to show up the changes in contours so that the blister is likely to be obscured. If the bottom is not cleaned, or is extremely rough, the surveyor cannot do his job and therefore he must make this situation clear to the client, verbally and in writing.

A heavy buildup of paint that has a lot of flaking yields a very rough surface that is ideal for hiding blisters. Even so, this does not mean that if blisters exist they cannot be found. It just means that the surveyor has to look very close. Wet bottoms reflect more light and will show up blisters much better than a dull, dry bottom. You can visually sight the bottom immediately after it is pressure washed to take best advantage of this. Since boats that have been out of the water for a while are reported as most likely to have deflated blisters, get a hose and wet the bottom. If the bottom is clean, no matter how shallow they are, the blisters will show up if you sight it carefully.

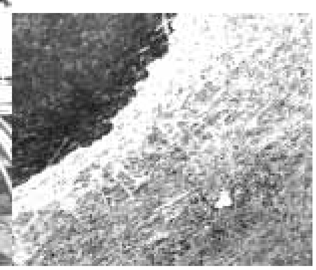
A third factor is the positioning of the vessel at the time of the survey. If the vessel is sitting too close to the ground, it becomes very difficult to get a good look at it. Another problem is when boats are hauled out inside of covered buildings where there is an inadequate light source. When encountering these conditions, its time to be extra cautious. One way or another, the surveyor has to overcome these obstacles or risk the consequences.

This is an example of severe ply separation. The peeled away ply here measures about 3 feet across. In this case the skin out mat was so dry that there was little bonding to the inner structural laminates. The whiteness clearly indicates how dry it is. This allowed the interface between the two plies to fill with water. While this is an extreme example, incomplete bonding to lesser degrees is commonplace. To make matters worse, it was not detectable by sounding, although there was a bit of a warning sign in that the whole hull sounded somewhat "dead." These were not blisters but water filled ply separations that do not appear to have been initiate d by osmotic pressure but rather enhanced by it. Scraping with a knife below the gelcoat easily revealed the dryness of the fibers.

Sighting Careful sighting is a must. To sight the bottom in such a way as to best locate blisters, it is necessary to view the hull from many angles. This is not difficult, but it may mean a lot of duck-walking around so that one can use the available light to best advantage. A casual look at the bottom just won't do.

Weepholes and Deposits Some gelcoats are so weak that they are unable to sustain the buildup of pressure and the blisters rupture either before, or after they reach a significant size. Under these conditions, styrene fluids usually weep out of the laminate, leaving a telltale stain or bubbling deposit as shown in the nearby photos. The important point to bear in mind here is that the breach in the gelcoat is also allowing water to penetrate the laminate, so that blistering is likely to be progressive. Since these are actually ruptured blisters, these telltale signs should not be ignored but rather reported as broken blisters that are just as significant as unbroken blisters.

Sounding Sounding a hull is an audible technique that requires a high degree of skill and finesse. We've seen surveyors attack hulls with a plastic hammer as though they were driving nails. That may turn up a severe delamination, but its not likely to reveal a small blister. Our experimentation with plastic hammers have determined that these are far from the best instruments to use to detect smaller flaws. For one thing, the impact surface is too wide. For another, plastic against plastic is not a very good combination for getting the best audible result. Blisters are most responsive to a small piece of metal, preferably steel, about the size of a silver dollar. Very light tapping with an instrument of this sort will do a much better job of audibly revealing differences in laminate thickness, particularly blisters.

Notice on this hull how the blisters run along a band about one foot below the waterline. Also note how they appear in clusters lower down on the bottom, and that some areas between clusters are not affected. Examples like these prove once and for all that blistering is not merely a function of material, but also a matter of the quality of the layup. On this boat, the areas of blistering are not random but area-specific and directly related to permeability of the laminate due to imperfections. Once again, the skin out mat was found to be poorly saturated. Photo at right contrasts the dry mat against the fully wetted out structural laminate.

Destructive Probing Should the surveyor break open, probe or scrape blisters? Certainly its useful to determine whether the underlying plastic has dissolved or whether there are substantial ply separations. But doing this falls in the category of destructive testing. Complaints have been made against surveyors who have gone too far in doing this. Its best to get the owner's permission before proceeding.

Because secondary bonding failures have been identified with large blisters, the surveyor can take one of two approaches. If he does not, or cannot engage in destructive testing, he can simply warn the client of the possible implications. However, if he breaks the surface at all, at that point he needs to go all the way. Sliding a short, very thin blade such as a cheap steak knife or pallet knife into the blister and probing the circumference for ply separation will usually do the trick. If you can continue to force the blade under the skin out mat beyond the circumference of the blister, there is definitely a bonding problem.

On the other hand, if you cannot force it, that does not necessarily mean that there is not a secondary bonding problem. It could not exist at one location but appear in others. And since this cannot be done for all the blisters, this test can only be used to confirm positive results.

Lamination Problems Boats that display extreme numbers of, or numerous and very large blisters may be suffering from more than just water permeation through the surface coating. My studies of hundreds of blistered boats reveals that many boats that display very large blisters are also suffering from secondary bonding failures. Bonding failures that result in blisters usually occur between the gelcoat and skinout mat, or the skinout mat and the first layer of structural fabric, usually roving. The failure to bond can be due to environmental conditions (temperature and humidity), contamination, or excessive delay in the layup process. Whatever the cause, the result is an incomplete bond that provides and ideal environment for very large blisters to develop. When a vessel has numerous large blisters, secondary bonding problems should be suspect. For a more complete discussion of bonding failures, see article titled *Blisters Again?* on this site.

If the bonding of laminate is weak, you may be able to separate the skinout mat for very long distances, in which case you've got a serious bonding problem that no commonly accepted method of blister repair will solve. To remedy the situation, all of the loose laminate will have to be stripped off.

Describing Blistering It is important that the general parameters of blistering be adequately described. One way to describe blistering is to again use a grid and literally measure and count the number of blisters. Using a tic-tac-toe grid of one foot squares will yield nine squares that make it quite easy to count the number of blisters per square foot.

Since blisters do not always show up evenly over the bottom surface **,** but can appear in clusters or bands, it is probably best not to attempt to give an exact count, but rather to determine the density and state the condition in terms of *maximum density*, but not attempt to indicate specific sizes or locations. Attempting to describe the size of the area and specific density can be difficult and dangerous. This way, if the blistering spreads rapidly to other areas **,** the surveyor won't get caught short. In other words, its better to overstate than understate.

Use a Camera If you're not carrying a camera and using it, you're missing out on a better insurance policy that you could ever purchase. Good photographs will stop most misinformed complaints dead in their tracks. Using a piece of chalk, write the boat name and date on the area to be photographed, and then snap a couple shots from a variety of angles.

If you are not expert at using a camera, then you need to practice until you become so. Bad photos won't help you much. Take multiple shots using different angles and lighting and learn which techniques work best. Use a flash in virtually all conditions except direct sunlight, especially when a subject is half-in, half-out of direct sun. Make sure your flash is illuminating the subject. With good quality modern cameras, auto exposures will work perfectly; there's no need to play with timing and f-stops anymore. But I would suggest avoiding using autofocus which does not always work well. Get in the habit of focusing manually.

Photos won't do you any good when, several years later you can't find them. Storing them in a file is not a good idea because they often fall out and get lost. I store photos and negatives in the lab's original envelope and then file them chronologically in shoe boxes, which are then labeled with the year. This makes for a very convenient method of locating them quickly.

Reporting One good approach is to develop a more or less standard statement dealing with the issues of blisters for every report on fiberglass boats, one which is modified to fit individual circumstances. A good statement is one which first informs the client that reinforced plastics are known to be unstable. It should state that the surveyor is not able to determine the nature of the plastics and reinforcements of which the hull is made, and therefore he cannot guarantee the stability or the performance of the laminate.

To make assumptions about a laminate is to take risks that we ought not take. To look at a hull and say, "Ah, fiberglass," is making an assumption that is not based on anything we really know. In truth, we have no idea of what that hull is made of, and could be an endless array of materials. Nor can we give any assurance of the quality of those materials.

It should be clearly stated that warranties of the hull are provided by the builder only, and that if there are any questions about existing warranties, the manufacturer should be consulted. It should go on to state that the surveyor has made every effort to determine the presence of blisters short of destructive testing, and that blisters were, or were not found. This, however, does not mean that blisters won't develop at a later date. It should be made clear that changing conditions may result in the sudden appearance of blisters where previously there were none. Finally, one should point out that latent blisters, or blisters in the very early stages of formation, or blisters which are depressurized and deflated may also exist, and which are not detectable by any means available to the surveyor.

When sighting the bottom, be alert for evidence of prior blister repairs which are often done shortly before the boat is sold. The reason for this is that the surveyor has no idea of whether a proper repair has been made. Often as not, and owner has just ground out the blister and filled the void with epoxy. In this case the blistering is very likely to continue and may come back to haunt the surveyor. The best way to protect yourself is to report all evidence of prior repairs and disclaim any guarantee that the blistering will not continue.

Interpretation Unless a surveyor is going to engage in some serious destructive testing and analysis, he really doesn't have any way of knowing what the presence of blisters means. And for clients, the significance of blisters is an entirely subjective judgment. We've seen sailboat buyers go ballistic at the mere mention of blisters, while others may not care in the least.

When clients question the surveyor about the significance of blisters, the wise surveyor is one who knows that he doesn't know, and resists the temptation to speak when he shouldn't. In my view, the best approach is to advise the client that only a technical analysis based on destructive testing can answer that question, and that this is not included in the survey service. It is best to advise the client that a prepurchase survey is a condition and not an engineering analysis. If you wish to get involved in destructive testing, separate this service from the survey and set it up as a consulting service. Start a separate file and issue a separate report and billing, even if you end up doing it generally at the same time. This will help protect the surveyor from claims of a negligent survey.

Communications Learning to communicate fully and effectively with the client is a very good form of insurance. But there is a fine line to be walked between communicating facts and engaging in idle speculation. Engaging in speculative conversation may lead the surveyor to say things he didn't intend to say. On the other hand, several complainants told us that they were particularly miffed by a surveyor's lack of communication. Doctors are notorious for this and we all know what its like to visit a doctor with lock jaw. We feel cheated because our desire for information wasn't fulfilled. Our opinion of the doctor drops dramatically. Its very easy for the surveyor to fall into the same trap because his work is strenuous and he's usually exhausted by the time he's finished, thereby diminishing the effectiveness of his communication.

Obviously, the best way to communicate a blistering problem is to physically show the client what is there. Even if he doesn't want to, make him look at it with his own eyes. Make it standard operating procedure to show him the entire hull bottom. There is nothing like direct client involvement in a problem to head off disputes.

Remember that a client who seems unconcerned about blisters at the time he is purchasing a boat that has them, may develop other ideas later on. If he decides to sell a short time later, and is faced with a $6,000 repair bill, its pretty obvious what is likely to happen if the surveyor hasn't adequately covered himself.

Keep Good Records Any time a problem case ends up going to litigation, nearly all experienced surveyors will tell you that they often end up falling victim to a universal shortcoming - the failure to keep good notes. Litigation usually occurs years after the surveyor's initial involvement, and long after his memory has faded. Thus, when a subpoena is shoved under his nose, he retrieves his file only to find that there's not much there to help him.

Because hull blistering is such a universal problem, any surveyor whose been in the business long enough is eventually going to be hit with some sort of complaint. Every one has bad days and makes mistakes, often as a result of circumstances beyond the surveyors control, such as being rushed or hindered by bad weather. Sooner or later, the surveyor will find himself caught short.

A marine surveyor can get no better liability insurance policy than by training himself to keep good notes. Of course its very difficult to do that on the job when there are so many distractions and difficulties. He can't take good notes while standing in the rain or on the deck of a bouncing boat. But he can train himself at every instance to review his work once back at the office, and to fill in or expand on those notes he did take while on the job. This is why photography can be so useful. It only takes moments to snap a picture of a condition that might take ten minutes to attempt to write up on paper or, worse yet, can't be written up at all because of adverse conditions.

We should bear in mind how lame our excuses are likely to sound when sitting in front of a jury

Fiberglass Blisters – Effective prevention and treatment

by Chris Caswell
Boating World

http://www.boats.com/news-reviews/article/fiberglass-blisters

Fiberglass blistering seems to have become an increasingly common problem in the past several years. For most boats, it has been primarily a cosmetic problem, albeit a vexing one, but there have also been instances of hulls so damaged by blisters as to be rendered unseaworthy, which is the reason the Coast Guard funded a study of the problem. The American Boat Builders and Repairers Association also provided a grant, and the Department of Chemical engineering at the University of Rhode Island was selected to conduct the research, which began in 1985.

An initial report from URI, issued in 1986, identified the principle cause of blisters as the presence of water soluble materials in the hull laminate — from chemicals in the resin or from dust, dirt or sawdust — that set the stage. As water molecules penetrate the laminate they combine with these materials to form a droplet of solution. Because of osmotic pressure, more water molecules combine with this droplet, eventually expanding enough to cause a blister.

The solution formed by water mixing with the water soluble materials in the laminate is acidic, and more concentrated than pure water. Osmosis is the tendency of two liquids of different concentration, when separated by a semipermeable membrane, to mix. Thus water molecules pass through the membrane to combine with the more concentrated liquid. (The semipermeable membrane in this case is the fiberglass laminate). The new mixture attracts more water, expands, and causes the blister.

Stress, whether from water absorption in the gel coat or from the rigors of the sea, was also found to be a culprit, with water soluble materials concentrating in microscopic cracks or at interfaces between layers of laminate. A third kind of blister was also deemed possible: the long-term effect of water saturation of the laminating resin. Most of us don't think of our fiberglass hulls as having the characteristics of a sponge, but the URI study has demonstrated that fiberglass laminates do indeed absorb water.

The most recent report from URI has proven to be controversial within the marine industry, and it breaks with the traditionally accepted methods of both preventing and repairing blisters.

A "barrier coat" generally has been considered to be the best preventive medicine against boat pox, and most major paint manufacturers have a "high build" epoxy coating that offers a high level of resistance to water penetration. These high build coatings, which add about 5 mils of thickness per coat, are usually used in two or sometimes three coats below the waterline, followed by the normal application of bottom paints.

Most modern gel coats use an isophthalic resin base, which has shown to be more water resistant than the orthophtalic resin used in the hull lamination. Care must be taken to keep from damaging the gel coat surface when prepping the surface because, though it is known to be fragile and water permeable, it is still far more protection than the primary laminates of the hull. Don't gouge or chip the gelcoat, and rely on an even sanding to provide adhesion for the barrier coat.

The URI study indicates that most fiberglass hulls are vulnerable to blistering or internal water damage as a result of long periods of immersion. It suggests that the hull should be sanded and coated below the waterline every one to three years, depending on water temperature and the length of time afloat each year. If the boat is in cold water for only six months per year and the bottom is carefully inspected every year, renewing the bottom coating every three years may do the job. If the boat is afloat in warm water 12 months per year, the coating should probably be renewed annually.

The process of re-coating the hull involves sanding off all previously applied paint (but not the gel coat!), and then allowing the hull to dry for two or three days to reduce the moisture content of the gel coat. The drying is so important that the URI report suggests that the sanding be done in the fall and the recoating in the spring, if possible.

The URI study mentions the traditional epoxy barrier coat but, in a finding that is a bone of contention within the industry, also suggests that a common alkyd-urethane-silicone marine paint — such as is used on topsides — is a better protection because there is a chemical interaction with the gel coat.

The report also indicated that epoxy coatings do a good job as a water barrier, but "may result in more severe blistering once it starts". Why this occurs is unclear, but the researchers suspect that curing agents in the epoxy may be the culprit.

Whichever prevention method is chosen, all blisters must first be repaired, and three degrees of blistering have been defined by the report:

Type I: Near-surface blisters. Type II: Deeper blisters and cracks extending through resin rich surface layers but not reaching half the hull thickness. Type III: Severe, deep-seated blistering, cracking and delamination that extends through most of the hull thickness and jeopardizes the structural integrity of the hull.

For Type I damage, the first step is to open and drain all blisters, then dig out the damaged fiberglass. The gel coat should be removed from the entire bottom by careful sandblasting or using a power sander with 20 grit aluminum oxide or silicon carbide paper. The URI report emphatically urges frequent changes of sandpaper, to avoid moving the dirt around.

The entire bottom and the damaged areas must then be washed with a stiff nylon brush and fresh water. If you have access to a high-pressure washer, that's even better.

Following this, it's a good idea to inspect the surface (and particularly the damaged areas) with a magnifying glass, to be certain all the dirt and debris has been removed. These impurities can quickly cause reblistering.

The hull must then be dried, to get the saturation of the laminate below 50 percent, which can take considerable time, as reflected by the following table:

Temperature	50% Relative Humidity	25% Relative Humidity
100 F	l6 days	9 days
83 F	32 days	18 days
65 F	64 days	36 days
47 F	128 days	72 days

One of the best ways to be certain that the hull has fully dried is to use a moisture-meter, available at many major boatyards which handle blister repairs.

The URI report recommends repairing the pitting with a compound made up of polyester resin, chopped glass, and colloidal silica. The report also mentions that it's best to do as much fairing as possible while the filler is in the liquid state, because sanding will be difficult. It will indeed: colloidal silica is actually fine sand, and it rapidly destroys sandpaper.

The generally accepted industry method of blister repairs has been to use epoxy resins mixed with chopped glass or powder, after first making sure that the epoxy is compatible with the polyester used in the hull laminates.

For Type II damage, an additional step is necessary before final coating an extensively blistered hull. The entire bottom must be covered with a 1/8-inch layer of fiberglass, which can be done by rolling or spraying isophtalic resin into one or two layers of E-glass "veil mat," a light reinforcement. This must be done in one continuous operation and, when cured, the bottom must be carefully washed, sanded, and washed again before the final coatings.

The good news about Type III damage is that it is quite rare, but the bad news is that the hull is useless and irreparable.

There is a clear message for anyone intending to buy a fiberglass boat. With a new boat, the bottom should be sanded and washed as for Type I blistering, and then a barrier coat of either epoxy or the URI-recommended finish should be applied.

Anyone buying a used boat should certainly have a careful survey, including an assessment of the amount of water absorbed into the hull laminate.

Most boat builders have faced the blistering crisis in varying ways, and Beneteau is an outstanding example of a company responding quickly and honestly to the problem. In the mid-1980s, it was discovered that some boats from one of their four plants were developing blisters, which set off a massive research effort to discover the cause. The culprit turned out to be an unannounced change by a supplier to a water soluble catalyst.

Beneteau corrected the problem and then directly contacted all owners of flawed yachts to have the underwater gelcoat removed and replaced. The process is neither simple nor inexpensive, but the result for each Beneteau owner has been a completely blister-free yacht and a renewed faith in the company.

You'll have to wash the whole hull with acetone before starting. This will clean the surface and remove any residual un-reacted or decomposition products that were retained under the original surface. You'll most likely see some small crusty yellowish mounds form on the hull surface after your first wash. They'll appear at random; not just at your pockmarks.

That yellow stuff is minor amounts of styrene coming out of the original resin. If you rinse the hull with acetone again it will dissolve them. More, smaller bumps of styrene will appear after a day or so meaning you'll have to rinse again. Don't fuss endlessly over them because you'll never completely eliminate them.

If your moisture reading is still to high try spraying the hull with alcohol, about a gallon would do your boat. The alcohol forms an azeotrope with the residual water that has a higher vapor pressure and lower surface tension than water alone. This will cause the water to migrate and evaporate much more quickly. If you have the time you might consider doing this a couple of times long before you start your final prep; say at 1 week intervals. Remember the warmer the weather the better and you just have to wet the surface, not rinse it. Those pump up garden sprayers work great for this.

If you intend to just coat the bottom (no cloth) first coat the whole bottom with West Epoxy. When it hardens sand with 80 grit. Fair with West Epoxy and Cabosil. Again don't fuss too much. Use a rubber trowel and an "artsie" approach; just make sure nothing builds "proud" i.e. beyond a fair line; sand these spots. Put on your first barrier coat. When the hull is all one color you'll easily be able to spot any deficiencies in your initial fairing. When you mix the second batch of barrier coat add some Cabosil to part of it and use that as fairing compound for those spots.
Since you need 5-7 coats of the barrier coat, this gives you lots of opportunities to fine tune your fairing. Your bottom will finish out as slick as a seal. You don't have to start with the West Epoxy and Cabosil at all if the imperfections are minor. But remember that once you start applying the barrier coat you are locked into completing it if you don't want to sand between coats; so if you're not real confident regarding you "artsie" abilities I'd fill any large voids with West and fine tune with barrier/Cabosil.

BTW a couple of hints: Be sure to have one of those "electric drill wall board mud mixers" to mix the barrier coat, it's almost impossible to mix it thoroughly by hand. Get the mixer they use for 5 gallon cans (I know the barrier coat comes in 1 gallon cans), turn it slowly with the can on the ground held between your feet. When it's mixed spin the excess paint off the mixer by spinning it in an empty can.

You can mix the Cabosil into the paint right in your roller pan as you happen to need it. If you come upon a spot that needs therapy and you think you have too much paint in the pan just paint around that spot until the paint level drops in your pan then add the Cabosil and go back and fair. This works best because the paint stiffens up pretty quickly and its consistency is changing so the amount of Cabosil required will change.

These may sound like frivolous hints, but remember you're working on the fly here…coat on coat until you're done. Anything that saves you time and extends your fairing options over many coats should be a help….especially if it extends your rest periods between coats.

've barrier coated my boat three times. First with West epoxy. That coating failed and West had a rep looksee, but no conclusion was reached about the failure.

Second with the Interlux product. Although it showed no sign of deterioration after 5 years, I planned to put the boat on the hard and decided to remove the coating and allow the hull a good opportunity to dry for an extended period. Moreover, the surveyor found fewer than five small blisters, an even better testament to its success (but more were found beneath the Interlux coating, attributable to insufficient drying before coating the hulls). I gave up sanding/grinding the Interlux surface and had it peeled. A very good decision and well worth the cost. (Wish my insight regarding labor vs. cost/progress had been better for other tasks.)

Third, the hulls have been recoated with the Interlux barrier coat, although the boat remains on the hard. IMO the Interlux product builds up better than West on the underside of horizontal/overhead surfaces, as well as on vertical surfaces. Interlux is available in gray and white, which can be alternated to verify coverage. (Color additives can be added to West epoxy, but they aren't recommended in barrier coating.) The Interlux barrier coat is accomplished with about the same effort as mixing and rolling on bottom paint. Really.

I have done extensive repairs and new construction on the boat with West epoxy, and I'm very satisfied with the results. It is a superior product over poyester for these tasks. I'm very comfortable with its various additives and hardeners. I would not, however, use West for barrier coating a hull: the surface area is too great, too many variables for hardening, and tedious mixing of multiple small batches to avoid "going off" too soon. The Interlux product is much, much easier to work with, especially its extended working times between coats before sanding is required.

A bad weather day or an unforeseen distraction could result in having to wash and then sand the West job. Lots of extra labor vs. progress. Not a good thing.

If you choose to use West, be sure to follow West's instructions to WASH and SCRUB hardened epoxy with plain water to remove the amine blush created by the hardening process. The amine blush, which, depending on temperature, humidity and hardener used, can sometimes be felt as a very oily substance; even if it can't be felt, some amine blush will be present. This coating MUST be removed between coats and before sanding (also required between hardened epoxy coatings). If not, this substance prevents chemical bonding of overcoats of epoxy and paint.

Re: Fairing. If a blister hole is larger than a quarter, repair it with cloth and epoxy. Fill smaller holes with a silica-epoxy mix. Over fill both types of repairs and knock them down with a grinder. Minimal fairing should be required, but if the blister repairs are numerous, use epoxy with a more easily sanded fairing additive mixed to peanut butter consistency. Apply it with a large sheetrock trowel with ample coverage and slightly overfill. On curved surfaces, use a flexible fairing board (3M makes one) to get smooth and even surfaces. A palm sander will work okay, but that requires a bit of practice to develop an eye for not sanding too much. A bare hand is handy to "feel" the surface. The edges - where the fairing compound meets the hull - should be sanded for a "seamless joint." Perfection is not necessary, because the barrier coaing can resolve a wide variety of imperfections.

Interlux and West provide excellent instructions on using their products. Take a gander to get the nitty gritty details in taking your decision on which product to use.

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moisture meters,

Through too many seasons in the boatyard, I had the opportunity to compare my expensive meter with a variety of others. IMO the most important attribute of a moisture meter is consistency, that is, if I take ten readings 15 minutes apart on the same spot, the meter will provide the same reading each time. Some meters I used were not consistent, and therefore were unreliable. Some provide a digital numerical display, while others provide an analog meter indication. I prefer the digital display, because it is much easier to see small changes and maintain consistent readings for comparison.

Some meters are less sensitive than others, that is, they indicate no moisture (or much lower moisture) than other meters.

These devices only provide a relative reading, based on a known baseline. That is, take a reading on the side of the hull above the waterline and use that reading as the ideal "dry" baseline. I have seen boats that indicated significant moisture well above the waterline, so you want to identify a spot that is relatively "dry." Of course, any boat that has been in the water and the weather will have absorbed some moisture.

I ran some vertical lines with a magic marker down the hulls and measured specific test spots, which were checked periodically (days, weeks, then months), and wrote the numbers in a notebook to track the changes in moisture. In general, my data showed that the lower the test spots under the waterline, the higher the moisture indication. Specific blisters, through hull penetrations or larger areas of moisture indication (delamination suspects) are easily outlined using the meter. Changes were glacial, but were dramatic at the end of 18-months. Beyond that period, the changes were minimal. (Wet bilges and and integral water tanks are readily identified, in addition to blisters.)

IMO the most important step in a repair is allowing the hull to dry as long as possible before completing repairs/applying the barrier coats (open blisters, but don't repair them until shortly before applying the barrier coats).

Perhaps the boat yard has a meter that you could borrow to make some moisture measurements. If not, with a project already underway, I doubt that the meter would be worthwhile, except to make you crazy.

Probably the BEST info on 'blisters' and bottom jobs is found at: yachtsurvey.com/blisters.htm

Baba's typically have 'resin rich' laminate lay-ups and the 'blisters' you find will most probably be only cosmetic . superficially down into the upper layers of the matting layer. The very best method is to perform a destructive analysis of the structure by coring and sending the core to a materials lab to analyse for 'hydrolysis' depth and penetration, then you can correctly affect a proper repair (need a new thruhull somewhere?) . For me personally Its a 'deal breaker' when buying a boat if the PO had affected any significant DIY 'blister repair' as many such DIY (and 'yard') jobs eventually wind up as a disaster. For me its better to see all the faults from a blistered hull than to 'redo' someones errors.

Tips:
•Whatever the thickness schedule of barrier coat by the manufacturer states ... apply at least 30% more thickness as over the years these 'specifications' seem to be getting thicker and thicker ... you dont want to do a bottom job 'twice'.
•Calculate the exact amount of hull surface versus the layup schedule of barrier. Apply first coat with a roller so that the 'roller pimples' are GREATER than the thickness schedule, allow

to partly cure (not full cure) and SAND the tops of the pimples down so that you have the 'exact' thickness of barrier. Then immediately apply the balance of the barrier with a large polyethylene TROWEL --- laying up the balance of the barrier as one would be applying resin to a 'male plug mold' ... the troweling will precisely fill in the 'valleys' to the proper depth and result in a barrier coat that is very fair and smooth as a baby's ass .... and require very little sanding or fairing !!!!! It may take two or three 'fills' to fair in the 'pimples'. Once totally fair immediately and without letting the barrier totally cure, apply bottom paint (called 'hot-coating' ... will prevent amine blush from fully cured epoxy based barrier and will promote significant adhesion of the bottom paint to the barrier). Once you start to apply barrier (and bottom paint) do not let any coat fully cure but keep applying layers until completed. Apply barrier, sleep for 3 hours, apply more barrier, sleep for 3 hours, etc. until totally finished. Do this and you wont be 're-doing' the bottom job in a few hears ... and you will have a smooth, faired, and 'fast' hull .... and the bottom paint wont come off in 'large chunks' in later years.

• BTW ... apply only the first coat of bottom paint with a roller, apply all the remaining coats by the 'trowel' method (as above but no need to allow a full cure between coats) for a perfectly smooth bottom paint job .... extremely good for those windless summer days on the Chesapeake. If you use an ablative bottom paint ... troweled-on will last much longer, have less drag, and will easily release any 'slime' that you accumulate.