BLISTERS & LAMINATE HYDROLYSIS

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Gelkote blisters and more importantly, deterioration of the laminate caused by water is, by now, a well established phenomenon. We have seen thousands of affected boats over the last twenty years and continue to see new cases every week. Zahniser's has many years experience in diagnosis and repair of these problems. We publish this paper to assist you in understanding this complex problem and it's repair. You will find a glossary of terms at the back.

THE PROBLEM:

Commonly called blisters, the raised bumps on the bottom of the boat are the visible symptom of a condition that is commonly known as hydrolysis of the laminate . It has become obvious that hydrolysis is the real problem and that blisters are an unsightly and destructive by-product of the hydrolysis of the polyester resin in the gelcoat and laminate. As you will see, not all bottoms with hydrolysis damage have blisters, but all bottoms with blisters have some degree of hydrolysis damage.

The cause of the problem was well established in the 1987 University of Rhode Island study by Thomas Rocket and Vincent Rose, The Causes of Boat Hull Blisters. In simple terms, what happens is this. Water penetrates the gelkote both as water vapor and as liquid water. Water is particularly good at this due to the small size of the H2O molecule. The gelcoat is a rather poor barrier against water penetration when constantly immersed. The glass fibers assist by acting as capillary tunnels to transport the water molecules into the laminate. Once adjacent to the resin in the gelkote and laminate, the water goes into chemical solution with what are known as "water soluble materials (WSMs)" in the resin in the gelkote and laminate. These WSMs include phthalic acids, glycol, cobolts, mekp and styrene which have not gone to full cure in the hardening process. To varying degrees they are present in all cured polyester resins. Five percent is an excepted norm. In some rare cases the quality of the materials or their application may be inferior causing a higher than normal percentage of water soluble elements.

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Though this all sounds rather like it is taking place on a "micro-chemical" scale, the affects of hydrolysis of the laminate are visibly apparent. It appears to be effecting all conventionally built polyester fiberglass bottoms that are continually immersed. It is our experience that all boats built with conventional polyester resin and gelkote, show signs of hydrolysis deterioration of the outer laminates after 5 to 10 years of immersion. These signs include "sediment piles" where hydrolysis fluid is exiting the hull, increased moisture content in the outer laminates, reduced resin and glass fiber clarity, reduced resin hardness as well as the obvious and well documented blisters. It should be noted that in the last five years, real progress has been made by some manufacturers in addressing the problem. A switch to using vinylester resin for all or a substantial part of the outer layers of the bottom seems to have been one of the most successful methods to date.

So what about these blisters you might ask. Well, blisters form when the flow of water into the laminate exceeds the flow of hydrolysis fluid back out. It is that simple, FLOW IN EXCEEDS FLOW OUT. To understand technically what happens, we have to understand osmosis and osmotic theory.

Osmosis: If there are two fluids separated by a semi-permeable membrane and one is more concentrated than the other, the more concentrated will draw the less concentrated solution through the membrane until the two are of equal concentrations. The force that does the "drawing" is called "osmotic force" and it can be substantial as we will see.

The acidic solution that is a by-product of hydrolysis collects in an available space in the resin, perhaps a small air bubble trapped in the original layup. This solution cannot pass back through the gelcoat (the semi-permeable membrane) as readily as the water came in because of it's increased molecular size. The hydrolysis fluid is more concentrated than the water the boat floats in, so the hydrolysis fluid draws the water in through the semi-permeable membrane (gelkote) in order to reach equilibrium. As fluid builds up, pressure builds up from the osmotic force and blisters start to form. With time they grow larger and slowly start delaminating the outer layers of laminate, that is, a blister. If enough blisters form, severe delamination can occur.

As time goes on, the blisters may break from the internal pressure and form a pinhole or a crack in the exterior surface. This rupture allows the blister fluid to rapidly leak out and sea water to flow into the laminate much faster. Now hydrolysis can continue more rapidly, working deeper into the laminate. New blisters form at a deeper level, eventually rupturing and the process continues.

Sometimes we find a gelcoat which is cracked, crazed or otherwise quite porous. If the gelcoat is sufficiently porous, small blisters may never occur because the blister forming fluid is not contained and can freely flow back out of the laminate and gelcoat. Sometimes in this instance, large blisters will form at deeper levels in the laminate after many years of immersion. Sometimes blisters do not form at all, but the damage to the laminate is taking place just the same. We often see small piles of sediment on surface of the bottom when the laminate is being hydrolyzed. This sediment is the laminate resin solids precipitating out of the fluid flowing out from the laminate through cracks or pinholes. Such sediment piles are evidence of a hydrolyzing laminate even when there are no blisters visible.

One great paradox is that the efforts of many of well intentioned boat builders to make their gelkotes less porous has actually results in more rapid blistering of the bottom. By "tightening" up the gelkotes to a considerable degree but not enough to fully stop water flow they have increased the difference between flow in and flow out. Hence, as little bit of water makes a lot of blisters. It is important to understand in this situation, that considerably less water has entered the laminate and so though blistered, the underlying laminate tends to be in better condition. Boats that blister in the first six years seldom have serious laminate damage.

One of the most asked questions is "Why did the old boats have fewer blister problems than the boats of the 80's. My old Pearson (or whatever) is 20 years old and never had a blister." Well, we have looked at some of those old boats and what we find is the gelkotes are so porous that "flow out" equals "flow in". The gelkote is not a semi-permeable membrane, rather is a fully permeable membrane. The result is severe hydrolysis but no blisters. Some modern boats have tighter gelkotes which the boat builders had hoped would stop blistering and hydrolysis. Though hydrolysis is greatly reduced, blistering occurs sooner and more dramatically.

People often ask if the whole bottom is affected or if the problem could be a "local" one. Our observation is though blisters may seem more concentrated in certain areas, the hydrolysis of the bottom is very uniform at equal depths. Remember, blisters are a very small, local phenomenon which is a by-product of hydrolysis. We have looked at hundreds of cases of hydrolysis over the years and one of the consistent observations has been the uniformity of the hydrolysis both over the immersed area and in depth. It is also noted that hydrolysis is very layer specific and the effects will vary from layer to layer of glass fabric and that the affect on a specific layers will be uniform throughout the layer and throughout the bottom. It should be obvious by now that the areas between the blisters are being effected by hydrolysis as well as at the blister site.

On rare occasion, say one time in a hundred, there is a local phenomenon. It is important to recognize this but testing for it is difficult and it may not be until the boat is stripped that the lack of uniformity is noted. This may be a good place to note there are often local blisters around keel joints, fittings, rudders, etc. where fairing compounds have been used. This is a completely different problem from laminate hydrolysis, is far less serious and is easily recognizable to the experienced.

Besides the normal reaction of water and a well constructed laminate, there are numerous potential pitfalls in the original hull construction process that may exaggerate the problem as well. Normal construction technique involves applying a gelcoat to a mold. Then, several layers of fiberglass matt are laid into the mold followed by alternate woven roving and matt layers. The layup work is often halted to permit the resin to cure up so that to successive layers can be applied without damaging the layers already in the mold. Working around lunch and quitting times can also be a factor. The interface between cured resin and new resin is a boundary layer which contains a higher concentration of water soluble elements. These boundary layers are often associated with blisters of the larger variety and delamination.

The fiberglass matt that is just below the gelcoat is also believed to be a contributing factor. The short, random, non-woven nature of the glass fibers orients many fiber ends against the gelcoat. These fibers act as capillaries for moisture into the laminate. The sizings used to hold fiberglass mat together in sheet form are also considered to be part of the problem. The incidence of blisters and hydrolysis in the woven fabric portions of the bottom laminates is considerably less than in matt fabrics or chopper gun applied matt.

Laminates with a relatively higher percentage of air bubbles in the laminate seem to be related to a higher incidence of hydrolysis. Both matt sheet goods and chopper gun applied matt fibers have an inherently higher percentage of air bubbles than occur in woven laminates. It is believed that air bubbles provide space for hydrolysis fluids to collect and concentrate.

Resin formulation, age, storage, catalyzation rate, and application as well as application temperature and moisture conditions all seem to play a part in the ultimate solubility of the finished resin. Most boat builders strive to produce a high quality product, but the number of variables and the fact that the polyester material is still soluble under the best of conditions make one wonder about it's suitability for building boats. Boatbuilders are using a variety of new materials and barrier coats and it would appear with some degree of success.

So why are blisters and hydrolysis a problem? Well, the blisters themselves slow the boat and are unsightly. The blisters slowly delaminate the fiberglass laminate locally and if there are sufficient number of blisters, may direct affect the structural integrity of the laminates. Nothing seems to scare off a potential buyer faster than blisters though this is changing as the buying public becomes more familiar with the problem and the effectiveness of well done repairs. The affects of hydrolysis on the resin, however, are of more concern than blisters. The hydrolysis process softens, weakens and removes the resin from the laminate, thus reducing the rigidity of the laminate. As rigidity is reduced, the amount of flex experienced in portions of the bottom increases. With increased flexure comes increased risk of fatigue failure. Most yacht hulls have a safety factor of 2-4 to 1, leaving quite a bit of room for deterioration. These safety margins, however, vary widely and are constantly under pressure to be reduced in the name of performance. If a hull is of cored construction, structural damage can occur quite quickly. Large scale core saturation is largely irreparable at a reasonable cost. It should be noted that the presence of water alone in a glass laminate, even when no hydrolysis damage has been done, significantly decreases laminate's resistance to structural fatigue.

You might ask how long might it take for the deterioration to become a structural concern? This cannot be answered categorically. The truth is, to date, little research has been done to establish deterioration rates and quantitative strength losses over time. Complicating factors include the thickness of the hull structure, the intended use, the surrounding water temperature, the degree of water absorption, the degree of blistering and hydrolysis, the age of the laminate at the time of blister onset, the materials used in construction and the design of the vessel all have a bearing on the rate of deterioration and the effect of deterioration on the structure.

In 1991, Zahniser's commissioned Comtex Laboratories to analyze the physical properties of laminate panels removed from the bottom of Gulfstar 50. The laminate was highly hydrolyzed. The bottom was clearly deforming from water pressure due to immersion suggesting low laminate rigidity.. Test results on these panels showed a fifty percent reduction in rigidity from the new condition. Tensile strength, however, was not greatly effected. The loss of rigidity is significant as the bottom will flex ("oil can") more over bulkheads and other hard spots and eventual time to fatigue failure will be shorter. We also tested a "repaired" panel, using the methods discussed in this paper and achieved rigidity approximately 130% of the theoretical new condition.

In real life, we are starting to see failures in hull bottoms we think are directly related to hydrolysis damage to laminate resin. In six separate cases, we have seen serious, though the hull fractures at the keel roots on fin keeled sail boats. In each case, the laminate resin was severely hydrolyzed. We have seen two cases of laminate fracture across bulkhead hard spots in two powerboats which we thought were related to hydrolysis of the laminate resin. The good news is that eight boats is not a lot of boats, but consider that these are only the ones that we have seen. Surely there are more out there and surely there have been boats lost for these reasons as well. Accident investigation on sunk boats is not like aircraft crash investigation. Unless the boat is in the way, it is usually not raised and the cause of sinking investigated.

We can suppose a lot from these tests and experiences, but we still cannot establish specific strength data for an individual boat in the field. Suffice it to say that hydrolysis weakens the bottom and we are seeing failures. This alone should be sufficient reason to undertake repairs to hydrolyzed laminates as preventative maintenance as soon as possible.

Preventative maintenance is simple in principal: KEEP THE WATER OUT OF THE POLYESTER LAMINATE!!!

DAMAGE ASSESMENT:

There are several stages of inspection one can use to assess hydrolysis damage to the laminate resin.

The first is to have a look at the exterior:

- Identify the size and frequency of blisters. Blister diameter is often associated with the depth of the blister and thus a rough gauge of the depth of the hydrolysis. Though it is risky to place too much emphasis on blister size, bigger blisters mean bigger problems.
- Look for cracks, crazing and pin holes. These may be letting lots of water into the laminate and accelerating hydrolysis.
- Look for sediment piles. These typically indicate active hydrolysis, even though there may be no blisters
- Look for hull distortion. Distortion may be the result of lower laminate rigidity from hydrolyzation
- Take moisture meter readings. It is hard to draw conclusions from high moisture readings on the surface, but low readings usually rule out the possibilities of ongoing problems.

One cannot, however gather sufficient information from the exterior to define the extent of the hydrolysis damage or to design a repair. For this, one has to look into the laminate interior.

THE "WINDOW" INTO THE LAMINATE:

To look into the laminte, we need a "window". The window is a shallow grind, about 6" - 8" in diameter through the bottom paint and gelkote, into the laminate structure of the boat. .

First the repairer chooses a site for the window. The site should be in an unreinforced area, usually 1-2 foot below the waterline. A small hole is drilled all the way through to determine the full thickness of the unreinforced laminate.

The repair then grinds away the bottom paint to expose the gelkote. He visibly inspects the surface, takes a moisture meter reading, a BarCol hardness reading and zeros out a depth gauge. He then grinds through the gelkote, exposing the first layer of fiberglass laminate. Again the surface is visibly inspected. A dry laminate in good condition is clear, dense and bright. White glass fibers, porosity and opaque resin are associated with hydrolysis. Blisters can be clearly seen if present. Moisture and hardness are again tested. The depth gauge is used to give the thickness of the successive layers. The process of grinding and inspection continues until a layer is reached that is considered in good condition, unaffected by water.

The repairer analyzes the data, using his experience and understanding of the repair process to design a repair. Primarily, the repairer is trying to determine how much damage has occurred to the laminate and how far he will have to go into the laminate to make a repair.

The depth of laminate removal is a critical decision point in the repair process. As a general rule, the laminate will be of poor quality at least to the base of the deepest blisters. Usually, there is some hydrolyzed laminate below this level, but eventually, a solid, resin rich, laminate with little residual moisture is usually (but not always) reached. We often see all of the exterior matt (outside of the first woven roving) is in poor condition.

REPAIR DESIGN CONSIDERATIONS:

There is a wide divergence amongst both repairers and owners as to the best way to repair blisters and hydrolysis. On the simplest level, one simply pops blisters and fills them. This completely ignores the problem of water continuing to get in to the laminate and cause more blisters and hydrolysis.

A popular but less than successful approach has been to remove the bottom paint and gelkote and a slight amount of the outer laminate. Deeper blisters are ground out, the hull is "dried" out and a barrier coat is applied. In my experience, providing the barrier coat is 20-30 mils thick, this method will work for 2-5 years, maybe a little more if the boat is dry storage every winter. The barrier coat usually fails by blistering due to the high percentage of water soluble materials left behind by the "drying" process and the moisture that passes through even a good barrier over time. The repairer has not changed the nature of the resin the boat was built with. If the original polyester laminate absorbs sufficient moisture again, it will blister again and the resin will continue to hydrolyze.

This is probably a good time to talk about "drying out". This term is thrown around a lot in this field and it is important to understand what it really means. It implies that all the water that is in the laminate is removed and the laminate goes back to its like new condition. Nope, what happens is that IF you get MOST of the water out, which is the best you can hope for, what you have left is dehydrated hydrolysis fluid. The laminate resin has regained none of its strength, rigidity or density and it contains a high percentage of water soluble material. In my opinion, "drying out" the laminate is a misnomer. Though I would agree it is foolish to install a barrier coat over a "wet hull", drying out does not solve all the problems the term might imply. The other thing to keep in mind is that drying out takes a long time. The use of heated tents, heat blankets, etc. are an attempt to accelerate the drying process and to some degree do so at some added cost.

In my opinion, the most successful repair of blisters and hydrolysis on the simple concept that hydrolyzed laminates are not redeemable. The repair removes the hydrolyzed material, replaces the removed material using materials that will resist hydrolysis and keep water from getting in again by application of a barrier coat. This method side steps the "drying out" problem and deals directly with the deteriorated laminate

The relaminating with new material serves two important functions. It returns removed laminate to the boat and if laid up with a hydrolysis resistant resin like vinylester, it substantially increases the thickness of the portion of the bottom exterior that is very resistant to water damage. In fact, relaminating has been so successful, we recommend a layer of 18 oz. cloth be added to the barrier coat even in cases where little glass has been removed. This represents a premium repair and is more costly, but for those who are looking for the utmost protection, there is little doubt the added cloth and thickness of barrier coat resin makes for a more durable barrier.

By consulting the data gathered from the "window", it is possible to establish what layers are damaged by hydrolysis, which are not and their relative depths. The best repair is made by removing all the hydrolyzed laminate and exposing the undamaged laminate as the start of the repair. The amount of repair laminate should be at least the same as that removed. The replacement laminate fabrics used will vary depending on the repair design, but in general, a high percentage of woven and uni-directional type fabrics is preferred to all matt layups because they are more resistant to water incursion and because they are stronger and more rigid than matt laminates.

There are practical limits to how much one can take off the bottom and successfully relaminate. The primary problem is structurally connecting the new laminate to the topsides. When the bottom laminate is damaged deeply and you wish to remove it, the only place to match the connection is at the waterline. Thick laminates require wide joint areas and the repair ends well up into the sides of the hull. Structurally, this is great but cosmetically a disaster. To deal with the cosmetics, it is necessary to fair in the repair and paint the sides. This is a very costly addition. The final decision of how much can be safely removed from the bottom is dependent overall laminate thickness, cost considerations and the details of dealing with the cosmetics. In general, we would not take more off than we could reapply with three to four layers of 1708 Nytex Stichmatt and one layer of cloth, approximately 1/4".

THE REPAIR BEGINS WITH PEELING AND PREP FOR NEW LAMINATE:

To begin the repair itself the boat is hauled. If any portion of the work is to be done indoors, sailboats will have their masts unstepped. If the "window" has not already been ground and inspected (we call this inspection process a Profile), it should be done now so the repair can be designed and quoted.

Once the amount of laminate to be removed has been established, the removal process begins. In the distant past this was laboriously done by grinding and sandblasting. When more than an 1/8" of laminate had to be removed we used a tool called a "stripper"; a chisel welded to a pipe. The stripper was worked into the interface between two delaminating layers of laminate, wedging the top layer off. If all this sounds a little primitive, it sure felt like it when we were doing it. In fact, it felt stone age. "We sent our heroes out with clubs and rocks and beat on the bottom until it gave up it's worthless hide." What is sandblasting if it isn't throwing rocks?

We now use a tool that has become commonly known as a Peeler. It cuts the gelcoat and laminate off like an electric planer. It is a hand held tool that can take off measured thickness plus or minus .010". The hull after laminate removal is left quite smooth, requiring only moderate sanding. The cutting tool is a much cleaner operation in comparison with grinding and sandblasting, both for the boat and interior as well as for the environment. The removed fiberglass is captured beneath the boat in a water slurry, strained and disposed of safely. The advent of the modern "peeler" tool was the final piece in the repair puzzle and revolutionized the repair process. It made it possible to remove laminate precisely and translate the information determined in the PROFILE into a repair reality.

The peeler crew carefully works to specifications established in the Profile, uniformly removing the deteriorated laminate. Following peeling, areas that could not be reached by the peeler are taken down by hand with grinders. .

We are often asked about removing thru-hulls prior to peeling and relaminating. Though fine in principal, the actual work is far more expensive than is justified by the results. Removal and reinstallation of thru-hulls runs $30-$40/ft plus materials (parts are often broken during disassembly). We have seen no evidence that not removing thru-hulls results in failure around thru-hulls and considering the high cost, removal seems a superfluous luxury.

RELAMINATING:

Assuming the laminate removal has taken off all the hydrolyzed laminate, the hull is now ready for relaminating. In cases where it has not been practical to remove all the hydrolyzed laminate, that which has been left will need to dry out. This can vary considerably weeks, months, but assuming the worst of it has been removed, in practice, the drying time of the remainder is usually fairly short. The resin used in relaminating can be epoxy, polyester or vinylester resin. Isophalic polyester resin is cheaper and easier to work with,. Epoxies, if done well, offer much higher resistance to moisture but are less compatible with the original hull resin and are very costly and hard to work. Vinylester resins offer a high degree of durability at a cost in between epoxies and polyesters and though harder than polyester to work, experience permits us to use vinylester for all our layup work these days.

THE BARRIER COAT:

Following removal of hydrolyzed material, drying and replacement of glass as necessary, a barrier coat is applied. Until 1988, epoxies were generally used for this because of their high physical strength and waterproof qualities. In practical use, however, epoxies were less than ideal. Their application is difficult, requiring exact measuring and mixing habits, warm temperatures and dry atmosphere to achieve claimed physical properties. In the field, it has been noted that epoxies are only marginally tolerant of polyester substrates and seem to reject acidic laminates over time. The results are often blistered barrier coats and reduced protection and durability.

Vinylester resins have increasingly become the standard barrier coat used for blister repair, in the mid-Atlantic region at least. Designed for high corrosion resistance and high physical strength, they combine the good water proof lab specs of epoxy with the ease of application of a polyester resin. The theoretical "waterproofness" for equal skin thickness is marginally less than epoxy but because of it's flexibility and lower cost, vinylester resin can be applied in thicker skins, greatly increasing waterproofness. Thickness is an important factor in a barrier coat. Vinylester is much more compatible with the polyester than epoxies. The bonding strength of vinylesters to the original polyester is better than either polyesters or epoxies. We have used vinylester for barrier coasts exclusively now for over seven years.

As a barrier coat, we apply six rolled coats to arrive at a thickness of .030". This is two - three times the thickness of most epoxy systems. On top of the barrier coat, a vinylester sanding primer is applied and largely sanded off to smooth the bottom. By using the gelkote and laminate removing tool initially and careful filling and sanding, the bottom fairness is quite good and meets most owner's requirements. If race quality finish is required, this is accomplished by many hours of hand fairing.

Once fair, two coats of antifouling completes the repair. The boat is cleaned and launched.

FINAL CONSIDERATIONS:

After the repair is made, several points should be kept in mind. The coating should be inspected annually for evidence of failure. Failure will usually be evidenced by blistering of the barrier. Barrier coats, because they are much less porous than gelkotes will blister with less moisture. Deterioration is a function of exposure to water by immersion. Dry storage reduces exposure.

Zahniser's offers limited warranties on all bottom repairs. In our opinion, a repairer who does not warrant his repairs lacks experience and confidence in his work. Warranty terms will vary depending on the type of repair done and are defined at the time of contracting the repair. Most of our work carries a ten year warranty. Note that we offer NO warranty on simple barrier coats without relaminating. In our opinion, their performance is not predictable enough to warrant.

BARRIER COATS AS PREVENTATIVES:

We are occasionally asked about preventative use of barrier coats over an existing, unblistered gelcoat. Unless the boat has only been in the water for a few years, getting the bottom sufficiently dry without removing the gelkote is a very slow process, often 12 to 18 months. The gelkote, while not sufficiently waterproof to prevent blistering, is still dense enough to slow drying down to a snail's pace. Most boat owners are not willing to give up their boat for a year for a preventative measure. Considering the work will cost half of a blister repair, most owners opt to wait until the bottom blisters. Never the less, a properly applied barrier coat will greatly reduce hydrolyzation over the years. The cost of maintenance of this barrier coat will, however, be rather high.

In the case of a new boat, however, if the manufacturer has not applied a barrier or built the boat out of a non-blistering material such as vinylester resin, a barrier coat is highly recommended before the first immersion. It won't last forever, but it will forestall hydrolysis and blister formation. This is especially important if the boat builder does not have a definite, long term, written policy on blister repair warranty.

REPAIR COSTS:

Simple barrier coats, that is simply removing the gelkote and applying a barrier without relaminating can run $200/ per foot. For reasons listed above, however, we seldom perform this kind of repair these days. Relaminating is much preferred. The cost over relaminating is $300 to $500 per foot of boat length (LOA) depending on a variety of factors including the area of the underwater portion of the hull, whether the keel is glass or exposed metal, the quantity of laminate to be removed and replaced, etc.

CONCLUSION:

Repair methods and costs have largely stabilized, with each yard having adapted the method that works best for them. Ten years ago, it was fashionable among many repairers to admit they knew little about the blister/hydrolysis problem and its repair. Price variations were substantial and written contracts were often avoided. Failures of expensive repairs were common and warranties were conspicuously absent. Yards like Zahniser's helped bring a scientific approach to the repair and have developed methods that offer predictable, consistent results. Written warranties are now the standard. As time goes on, new boat building techniques will outdate the need for these repairs. In the meantime, we will continue to refine our repair techniques and to update this paper from time to time so you can have the latest information available.

Blistering & hydrolysis are complex subjects. Much of the language is technical and has evolved specifically for the field. If you have questions after consulting this report and the enclosed BLISTER & HYDROLYSIS paper, we would like to assist in your understanding. Please feel free to call. Ask for Craig Bumgarner. Not only do we want you to understand the problems with your boat, but we also want to continue to improve our paper and reports.

GLOSSARY

Resin: A generic name for any plastic material that starts out as a liquid and becomes solid through a curing process. Epoxies, polyesters, and vinylesters are all resins.

Polyester: A form of resin based on a phallic acid and glycol commonly used in fiberglass construction. Most boats are built with resin based on orthophthalic resin.

Orthophthalic: A form of polyester resin commonly used in yacht construction. Unfortunately, it is also the most likely to blister and suffer from the hydrolysis process.

Isophthalic: A higher grade of polyester resin based on Isophthalic acid. Though it less soluble than orthophthalic resin, it hydrolyzes and blisters as well. It is more expensive and somewhat harder to work with compared to orthophthalic resin.

Laminate: (verb): To build up a solid sheet of material by successive layers of fiberglass cloth and resin. (noun): The resulting final product of laminating fiberglass cloth and resin. The laminate is distin-guished from the gelkote or core material.

Hydrolysis: A chemical process of decomposition involving splitt-ing of a bond and addition of the elements of water (Webster's). When used in reference to the polyester bottom blister problem, the bond being broken is the ester linking molecule between the phallic acid and the glycol in the polyester compound.

Hygroscopic: A adjective referring to a material which absorbs water readily. Talc for instance is an extremely hygroscopic filler used in conventional polyester autobody putty and accounts for the rapid deterioration of this material when immersed.

Osmosis: Diffusion through a semi-permeable membrane separating a solvent and a solution that tend to equalize their concentration (Webster's). Osmosis is believed to be the process by which water is drawn into the laminate. The membrane is the gelcoat, the solvent is water and the solution is the acidic solution that forms when water and the "water soluble elements" in the polyes-ter resin are combined. Osmosis is why the small con-centration of acidic solution grows into a blister.

Vinylester: A modified epoxy resin in a ester linking system. High physical properties and outstanding corrosion resis-tance. To our knowledge, there has never been a blister in a boat built with vinylester resin.

Epoxy: A form of resin based on coal tar. Very high physical properties and corrosion resistance. The highest in water proof characteristics, but difficult and expensive to use and only marginally tolerant of polyester resins, especially polyester laminates that have been damaged by hydrolys-is. Boats built entirely of epoxy resin do not blister but cost a small fortune.

Gelcoat: The solid, hard, pigmented polyester resin used on the vast majority of fiberglass boats as the protective outer coating on the bottom, sides and deck. Works well on the sides and deck, but is not waterproof enough on the bottom to prevent hydrolysis.

Barrier Coat: A protective outer coating applied to the bottom to reduce the ingress of water into the bottom laminate. Typically an epoxy or a vinylester resin, the barrier coat can be applied over an existing gelkote as a preventative measure or as a replacement after removal of the damaged gelkote and laminate.