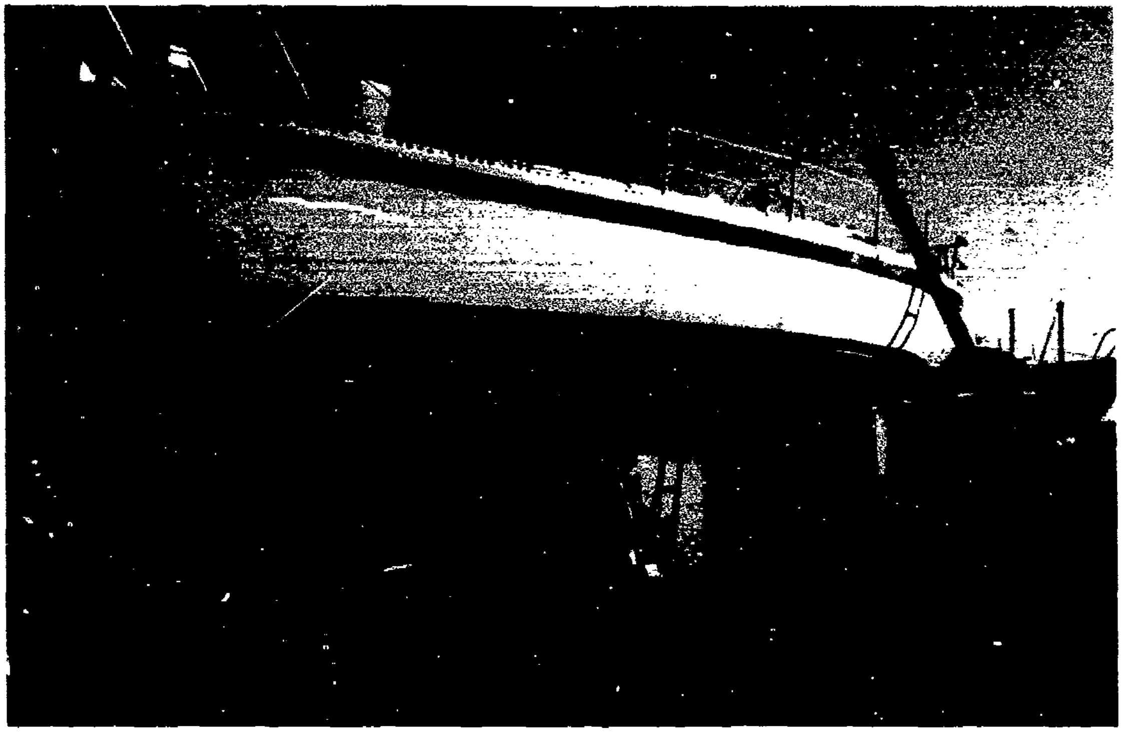
The Prevention and Repair of Gel Coat Blisters



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Abstract of "The Prevention and Repair of Gel Coat Blisters"

This is a brief summary in layman's language of an in-depth, impartial, scientific study to determine the best methods of repairing blister damaged fiberglass boats. Preventive Maintenance and Blister Repairs are the two topics discussed in this report.

The much more detailed report is entitled "Boat Hull Blisters: Repair Techniques and Long Term Effects on Hull Degradation" is also available through NTIS.

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The Prevention and Repair of Gel Coat Blisters

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NOTICE

FORWARD

The following is a brief summary in layman's language of an in-depth, impartial, scientific study to determine the best methods of repairing blister damage to fiberglass boats. Our association, the American Boat Builders and Repairers Association, Inc., has long been concerned with the lack of knowledge regarding a problem that has numerous serious ramifications for our industry, the prevention and cure of which were both unknown. The Coast Guard was concerned because of the potential for life threatening structural failures. The research grant provided by the directors of ABBRA and the two provided by the Coast Guard, we feel, have gone a long way in answering the questions which have plagued numerous members of our industry as well as the boating public.

ABBRA wishes to express its deep appreciation to the U.S. Coast Guard for the financial grants that made the research possible and to the members of the Department of Chemical Engineering at the University of Rhode Island for their dedication in pursuing all aspects of this most perplexing and serious problem.

Thomas Hale

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October 1988

INTRODUCTION

These recommendations, prepared by Dr. Thomas Rockett, Dr. Vincent Rose and Miss Andra Kirsteins of the University of Rhode Island, are based on five years of research work conducted for ABBRA under the sponsorship of the United States Coast Guard. The work was overseen by Mr. Donald Ellison of the Coast Guard Office of Recreational Boating Product Assurance Branch and Mr. Thomas Hale of ABBRA. While no guarantees are implied or intended, the recommendations are based on the most current knowledge of the blister problem. The detailed technical description and results of all experiments conducted are available at the Coast Guard Headquarters, Washington, D.C.

THE PREVENTION AND REPAIR OF GEL COAT BLISTERS

Preventative Maintenance

Most fiberglass boat hulls are susceptible to blistering or internal water damage after long periods of immersion. To prevent or greatly delay the onset of blistering, the following two procedures are recommended.

1. The below water portion of the hull should be sanded and coated every one to three years depending on the extent of use and water temperature. Any previously applied antifouling or marine paint should first be removed, and then fresh antifouling paint should be applied over the new coating. Between sanding and coating, allow two or three days of air drying to reduce moisture in the gel coat. If a boat is land stored in the winter the best procedure is to sand to the gel coat in the fall and coat in the spring. For this application, two coats of a modern alkyd marine paint is not only sufficient but protects better than an equal thickness of some epoxies. Best results were obtained with an alkyd-urethane-silicone blended marine paint. Sand lightly between layers. A major source of protection comes, not from the paint layer itself, but rather because a constituent of the paint interacts with the gel coat polyester making the gel coat a more effective water barrier. Small paint blisters may develop on the paint surfaces but these will not destroy the protective effect of the paint. Also, for the preventative purpose, a high build epoxy may be used and at least a 10 mil coating should be applied. Epoxies reduce blisters because of their barrier properties — not because of their interaction with polyester.

2. The bilge of the boat MUST be kept as dry as possible. A totally dry bilge is impossible, but one should never leave the boat sitting for long periods with water in the bildge. When storing the boat, dry the bilge by sponging the water not removed by the bilge pumps or by using a forced air dehumidifier system to dry the bilge area. Deep seated blistering and delamination of the hull can not take place unless the polymer in the hull is saturated. Saturation can only occur if the inside of the hull is in contact with water or 100% relative humidity air which results if free water is allowed to remain in the bilge. Since there is normally no inside gel coat protection, a wet interior surface will combine with normal water diffusion from the gel coat to produce a disasterous saturation, which can lead to deep blistering, delamination and deterioration of inner hull strength.

Normally, water diffuses slowly through a fiberglass hull, and can not be stopped. As long as the bilge side is dry, saturation is reached only in material near the gel coat and the blistering process begins. Deep seated damage is highly unlikely with a dry bilge. This is because saturation in the polymer is controlled by saturated conditions outside the polmer. If one side of the hull is in contact with water it becomes saturated. If the other side is in contact with water, the entire hull thickness becomes saturated and subject to blistering. However, if the bilge side is dry, the material near it is well below saturation. Across the thickness of the hull the water concentration will fall from saturated to below saturation in a linear manner. Normally hull material below saturation will not blister. Obviously all bilges become wet. A soaked bilge for several days probably presents no problem. However, prolonged stagnation of bilge water is the surest method for destroying hull integrity. Boat designers and builders should consider bilge dryness in new boats, and an interior gel coat or paint coating will add protection.

Blister Repairs

For repair of fiberglass polyester hulls which show blisters, the following steps are recommended. The good news is that acceptable techniques can be recommended, but the bad news is that all the methods of repair described may be only temporary. The repair will stop the process only until water re-enters the hull which will happen sooner or later depending largely upon water temperature and the length of continuous immersion.

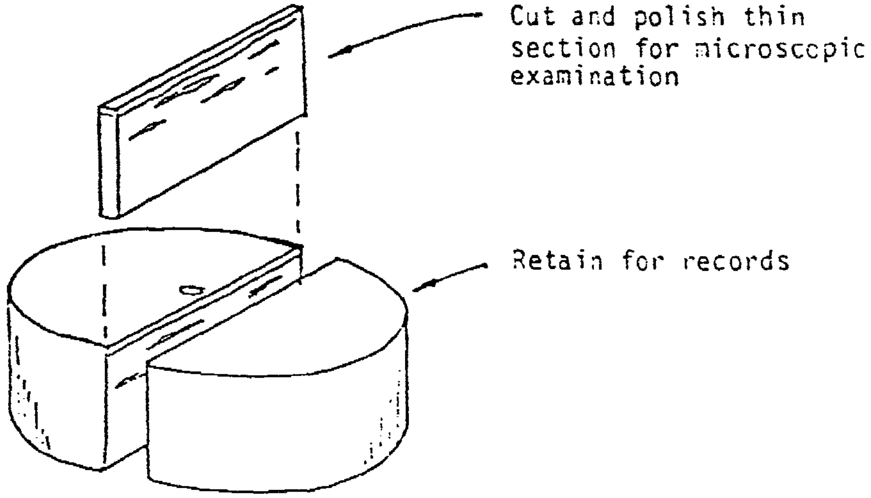
Assessment of Damage

A core plug sample must be taken in a representative area. This plug may then be sectioned by making two parallel cuts, one to two millimeters apart, so that a thin cross section of the hull can be obtained for microscopic study. While this is the best method, an alternative is to cut the plug in half and sand the plug perpendicular to the hull surface to expose a flat cross-section. (See Fig. 1) After sanding, a red dye penetrant (such as Spotcheck, Magnaflux Corporation, Chicago) should be sprayed on the surface. Let the surface dry and sand to remove superficial red dye. Observe the cross-section and the damage (blisters, osmotic disk cracks, delaminations, and extensive glass debonding) will be strongly marked in red.

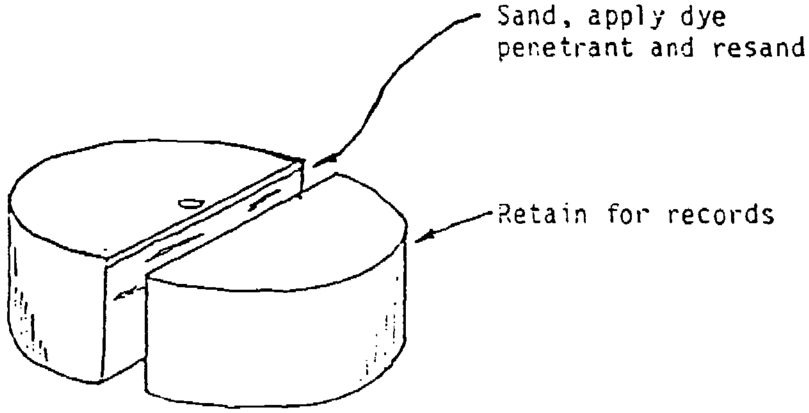
The hull damage can now be classified into three types. Type I damage is near surface blistering. Type II damage will show deeper blisters and cracks extending through resin rich surface layers but not reaching half the hull thickness. Type III damage is severe deep seated blistering, cracking and delamination which extends through most of the hull thickness and jeopardizes the structural integrity of the hull. Each of these classes requires different repair procedures and therefore classification of the damage is essential to repair. The damage may be uniform or it may be localized in one or more areas. The following repair procedures apply to both situations, but in the case of localized damage only the affected area should be repaired.

Repair of Type I Damage

Step 1: Remove gel coat and all damaged material. Exisiting blisters MUST be opened and adjacent damaged material removed or reblistering will be rapid. A power sander using 20 grit aluminum oxide or silicone carbide paper works well. Sand blasting is an alternative, but the nozzle



A. Thin Section Test



B. Dye Penetrant Test

Figure 1. Preparation of core samples for damage evaluation

must be kept at a low angle to the surface (less than 30 degrees) to prevent damage of the underlying fiber glass. This procedure should be attempted only by an experienced operator.

Step 2: Rinsing and cleaning. The purpose of this operation is to remove loose debris and wash off blister fluid. Rinse well with fresh water from a hose and scrub surface with a stiff nylon brush. A mild detergent may be used but be certain the hull is well rinsed after use. Examine the surface with a 10x magnifying lens to be sure debris has been dislodged from the air bubbles in the resin.

Step 3: Drying. Allow the hull to air dry for 48 hours and check for weeping. If a sticky liquid is seen to weep from the hull, the blisters have not been removed and the sanding step must be repeated. Continue the drying process. All water will not be removed by this treatment, but the degree of saturation of the hull will be below 50% which is well in the safe zone for the hull. Use the following table for a guide for drying.

Drying Time in Days for Various Air Temperatures
and Relative Humidities to Reach an
Acceptable Water Level for Repair

TEMPERATURE	50% RELATIVE HUMIDITY	25% RELATIVE HUMIDITY
100 degrees F	16 days	9 days
83 degrees F	32 days	18 days
65 degrees F	64 days	36 days
47 degrees F	128 days	72 days

This table is based on extensive experimentation with 1/4" hull sections and is only applicable if both sides of the hull are exposed to the drying air. The bilge <u>must</u> be completely dried. Since the bilge must be examined thoroughly at this point, recommendations to the owner regarding future bidge dryness should be made. A perfect repair job can be ruined if, after relaunching, stagnant bilge water is allowed to resaturate the hull.

Step 4: Recoating of the fiberglass/polyester hull. The repairer must choose between three different coating methods. The repairer may opt for a thick marine epoxy which will keep water out of the hull for a longer period but may result in more severe blistering once it starts. The second choice is a thinner coating of marine paint which may reblister sooner, but which will not make blistering more severe. Finally, one could choose to repair the hull using a gel coat designed to cure in air. All give good protection. Since different hulls have different blister characteristics, the only certain way of selecting the best repair method is to test the coatings over a repaired plug section. This is both time consuming and expensive. Thus a calculated risk will usually be taken. Both paints and epoxies introduce a constituent from the uncured coating into the polyester/glass hull materials. In the case of almost all paints tested, this interaction protects the hull material and is largely responsible for the protective role of paints. The interaction of the epoxy with the hull material makes the hull material more susceptible to blistering but keeps the water away from the blister site longer because of good water diffusion properties and because epoxy coating can be applied thicker than paint.

If fairing is necessary and the epoxy coating will be used, fair the surface with layers of high-build epoxy. If using paint or gel coat, add to a polyester laminating resin, chopped glass and colloidal silica to make a thick fairing material. Catalyze and spread with a non-stick roller or spatula. Since sanding is difficult, fair in the liquid state as much as possible. Avoid using any hollow type of filler for the fairing compound.

The Epoxy Method

Of the six epoxies tested, good results were obtained with the four pure epoxy systems (as opposed to blends). A filled and pigmented epoxy gave slightly better results than a clear unfilled epoxy. A two layer system with clear epoxy on the hull and filled epoxy over it also gave good results. Follow the manufacturers instructions for application. If more than two hours elapse between adding layers during the build up, be certain to sand the surface to remove any tacky blush. Aim for at least 10 mils of cured coating or the manufacturers recommended thickness if that is greater. This can be achieved with two or three coats of a high build epoxy but may require five or more layers of the thinner materials.

Marine Paints

All paints protected much better than expected. Several modern alkyds performed as well as epoxies on the samples tested. Best results were obtained using an alkyd/urethane/silicon blend, and a two part marine polyurethane paint also performed well. In both cases, these were applied directly to the fiberglass/resin without a primer coat. Three layers are recommended with light sanding and washing to remove sanding debris between layers. After immersion, some small paint blisters can be expected, but these do not stop the protection of the hull material. Some of these coating blisters formed because the paint does not stick well to exposed glass. Apply antifouling paint over the marine paint. This technique will not give as smooth a finish as a gel coat and the sanding job will largely determine the smoothness.

Gel Coat Method

Our test on gel coats gave excellent results if at least 20 mils of the dry gel coat was applied. Use as rapid a curing method as possible. If the manufacturer recommends one to two percent catalyst, go with the higher value. Manufacturers will recommend formulations for use in air curing. If no air inhibition additive is used, a thin tacky water soluble layer will remain on the surface and this must be removed. Wet sand to a hard surface. If wax additives are used to prevent surface tackiness, the wax must be sanded off. Wet sanding is best but change the paper often to prevent clogging. After sanding, apply two coats of marine paint and then add antifouling coating.

Step 5: Inspection. These methods should give one to three years of protecion if all previously blistered material has been removed. Inspection should take place annually. At the first sign of blistering, repair should be repeated because the repair of surface blisters is much less expensive than the repair of type II damage. In the absence of blisters, the maintenence step of repainting every other year will make the repair last longer. The boat must be hauled for proper inspection and pressure hose cleaning is recommended. Lighting is extremely important. A high intensity light must be used at a very low angle to make the blisters visible by shadowing.

Repair of Type II Damage

Step 1: Remove gel coat and affected area as for type I damage. The amount of material removed will be far greater.

Step 2: Rinse and clean as for type I damage.

Step 3: Drying. Follow recommendations for type I damage.

Step 4: Restoration of hull strength and resin rich zone. On the clean, dry, prepared surface apply at least 1/8" of glass reinforced polyester. The reason the layer must be this thick is that water can cause debonding of a new fiberglass layer over an old one. If the layer is too thin, diffusing water could reach the interface, saturate the area and cause debonding. The layer can be applied by spraying (use airless gun) or rolling an isophthalic polyester resin or a high quality orthophthalic resin on one or two layers of veil mat or using a chopper gun to apply chopped glass with the resin. There may be other materials, such as vinyl esters, which may be acceptable, but we cannot recommend them at this time because we have not produced or seen data to prove their efficacy. If the airless spray gun is used the resin must still be rolled into the surface and glass. The layer must be added in one continuous operation. Do not allow part of the thickness of the layer to cure completely before adding a second layer to it. Additional resin can be added up to half an hour after the first application, but if part of the layer cures completely before more resin is placed on top of it, an interface is introduced which could cause problems.

The type of glass used is critical. It must be E-glass or a corrosion resistant glass, and it must be free of a soluble binder. Veil mats must be lightly powder bound and chopped glass must be clean. If there is any question don't use the glass without having tested it. It is often helpful to use a chopped glass with red fibers in the bundle to aid in applying a uniform coat.

Step 5: Preparation of new fiberglass for surface coat. When the polyester added has a wax added to prevent air inhibition or is allowed to cure with an air inhibited tacky surface or is sprayed after roll on with a water soluble PVA layer to prevent air inhibition, the surface must now be sanded into the hard and well-cured polyester. This step is difficult and requires care, patience and lots of sand paper. If any of the PVA, the wax or the air inhibited material is left on the repaired surface it will blister at this interface in a matter of months. First, use a nylon brush and scrub the surface with lots of water. Then sand, replacing the sand paper as it fills. Don't redistribute the water solubles or the wax on the surface. Get it off. Finish by scrubbing with water and a mild detergent to remove all loose debris. Let repaired area dry thoroughly.

Step 6: Recoating of the hull. Follow step 4 for type I damage. Apply three coats of marine paint, the thick expoxy coating, or re-gel coat.

Repair of Type III Damage

In this situation the hull is virtually useless. The following recommendations are aimed at removing as much of the hull as is possible without having the boat collapse. The remnant shell is then used as a male mold for construction of a new hull. The collapse possibility is a real one and care must be taken when placing the bilge post or poppets during the removal of the damaged hull material. This procedure should only be attempted by experienced boat builders and repairers.

Step 1: Removal of damaged zone. This step should be done by sand blasting. It is virtually certain that areas of the hull will be penetrated. Care must be taken to protect the equipment inside the hull.

Step 2: Wash and scrub the surface.

Step 3: Reconstruction of the hull. Follow recommendations in step 4 of damage type II. Rebuild hull to at least the original tickness. Three layers of heavy woven roving (E-glass powder bound) with a veil mat or a chopped glass layer will give approximately 1/4" of hull thickness. Without a veil or chop glass layer, four layers are necessary to yield 1/4" of thickness. Finish with the veil mat or a light chop layer or both. Again (see step 4 - type II) the fewer interruptions in the build-up, the better. Never interrupt the resin rich surface layers. Sanding is a must between interrupted layers.

Step 4: Preparation of the surface for coating. Follow the instructions for step 5 - type II.

Step 5: Surface coating. Again the repairer must choose paint, epoxy or gel coat as described in step 4 of type I damage.

These procedures for repairing blister-damaged hulls, if followed carefully, should give added life to blistered fiberglass boats.