

Repairing Royalex Canoe Hulls

by Nelson Highley

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INTRODUCTION: THEY DON'T MAKE 'EM LIKE THEY USED TO

The canoe hull material, Royalex, revolutionized white water canoe paddling. The material proved to be more durable than aluminum with less of a tendency to dent and to stick on rocks. It also had a limited lifetime. Eventually, it would begin to crack, usually in areas of heaviest abuse. Modern hulls are quite a lot thinner than those original ones to save weight and are even less durable in this aspect.

Even though at least one of the canoe manufacturers still recommends it, anyone who has tried to repair a damaged Royalex hull with fiberglass or Kevlar has discovered that this approach doesn't work. Either the patches come off quickly or, worse, they crack and cause the Royalex under them to crack too and the hull ends up in worse shape than when you started.

The Basic Black Ugly Patch: What I am sharing here is a set of techniques that does work and it seems to work well! I have patches done this way that are over four years old and still in good shape. One of those is directly under my saddle and gets bashed regularly.

These are only the basics; a black, kind of ugly patch on the hull, but it's a *good*, ugly patch. There are many elaborations and variations on this basic process that are not discussed here in the interests of keeping this as short as possible.

Credits: A lot of people are trying a lot of different things out there all the time. This is just some things, passed on to me over several years, (brain-picked from other paddlers, actually), that are effective.

In that light, I'd like to thank as many people as I can remember from whom I have learned these techniques: James Jackson of the NOC, Nolan Whitesell, one of Nolan's technicians who wishes to remain anonymous, Maurice Blackburn, Charlie Whittle, a bunch of Georgia paddlers, and finally Tanda Druding who introduced me to Goop the, (almost), wonder glue!

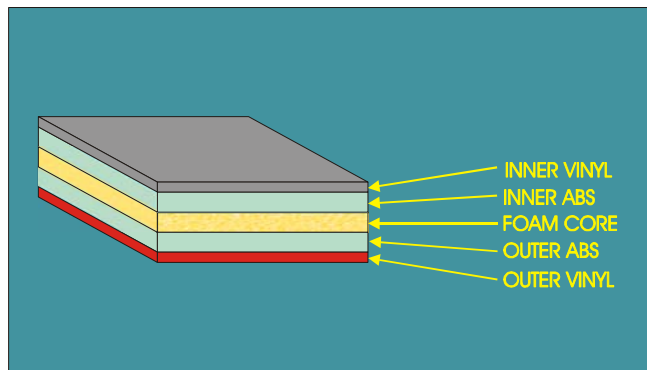
THE BASIC PROBLEM: THE LIMITATIONS OF ROYALEX

Composite Materials: Royalex is what is known as a *composite* material. It is actually three different materials which when combined in a "sandwich" of five layers, has properties superior to any of them alone.

The strength material of this sandwich is a plastic known as ABS which stands for acrylonitrile-butadiene-styrene. (Now you know why they call it ABS). ABS has one of the best impact resistances of any material known, far superior to most metals. It also has almost no shear strength; you can cut 1/16" sheet with heavy shears. The designers of Royalex overcame this limitation by placing two sheets of ABS around a foam core with a vinyl skin bonded to the outside of each ABS sheet.

The Royalex Composite

This "sandwich" makes a material that has better characteristics than any of its components alone.



Damage to Royalex usually involves a breakdown of the composite by *delamination* where the ABS layers separate at the foam core. Delamination is progressive - that is, once started the damage gets progressively worse until deliberate action is taken to make it stop. With Royalex this involves restoring the material's composite nature, not just slapping on a patch.

Royalex Resists Punctures.

The foam core "pads" the ABS sheet thus minimizing shearing forces.

ABS Alone Punctures Easily.

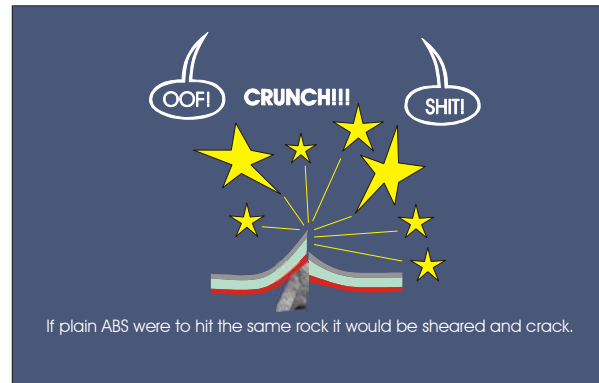
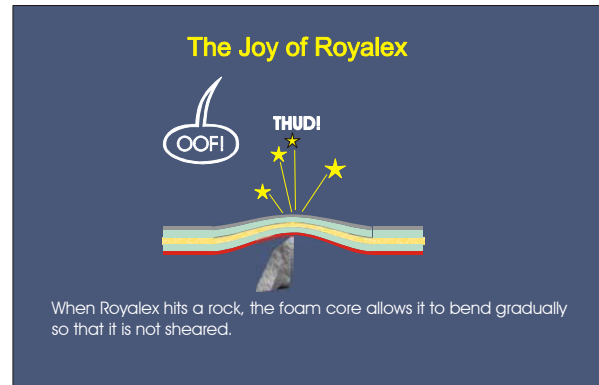
With no foam core, almost any impact produces shearing.

Abrasion is also a shearing condition so ABS alone also has little abrasion resistance and a tough vinyl outer "skin" is needed to protect the ABS from abrasion. This skin is made from PVC, "vinyl", similar to that used for automobile tops. It also helps resist shearing forces on the ABS by stiffening it somewhat. The vinyl's most important contribution though, is protection from the ultra-violet from sunlight. ABS has little UV resistance and will become brittle with exposure.

That Old Devil Delamination: Almost all Royalex damage starts with *delamination*. Once delamination begins, the ABS sheets are no longer protected by the foam core and they will begin to crack as they are bashed. These cracks let water into the foam core where it acts as a lubricant as the hull works, encouraging further delamination. In the winter, this water freezes and expands causing still more damage. This

Why Royalex? If a boat were made of ABS only, each time it hit a rock it would be subjected to shearing forces with obvious consequences.

The foam core acts as a cushion to minimize any shearing effects on the ABS by allowing it to "round" at the point of impact.



process will go on getting worse until you take steps to stop it.

FUNDAMENTAL HULL REPAIR:

The two basic tasks needed for repairs are described here;

1. Stopping and repairing delamination.
2. Applying a patch.

The exact sequence of tasks varies slightly depending on the extent of the damage.

- For damage that does not penetrate the inner layer of ABS, you repair any delamination then add an outside patch.
- For damage that does affect the inner layer, you patch the inner hull first then repair the delamination from the outside and then apply an outer patch.

MATERIALS:

Patch Material: The best Royalex patching material is ABS! ABS sheets can be found at most plastics supply distributors. I recommend 1/16" sheet for all outside patches. (Anything thicker tends to catch on rocks and water drag on it can make a noticeable difference in the hull's performance.) Thicker ABS can be used on any inside patches if strength is needed.

You will find that there is a considerable variety in the kinds of ABS available. When given a choice select by:

- **Color:** Black is best. It resists UV better than any other color.
- **Impact resistance:** It comes graded by impact resistance. The more the better, naturally.
- **Cost:** Whatever is on hand at the distributor's warehouse is usually the least costly especially if they have partial sheets. Recycled ABS is a lot cheaper than virgin grade and, as far as I can tell, it's just as good.

Adhesive: The perfect hull repair adhesive will grip well, remain somewhat flexible after it cures, and is two-part so that it does not need contact with the air to cure. It actually exists! Three-M makes a two-part urethane adhesive that fills the bill. It also costs \$5.00 to \$7.00 an ounce and you will need twelve to eighteen ounces for the repair of a moderate-sized area.

I compromise, (OK, maybe I'm just a little cheap), and substitute a two part epoxy resin for delamination repairs and an evaporation-curing urethane adhesive for the patches.

Epoxy Resin: I inject a two-part epoxy resin in-between the ABS layers to stop and repair delamination. Unless you have six months for curing time, a two-part adhesive is absolutely necessary for the spaces inside the hull where air cannot possibly reach. The cured epoxy leaves a hard spot in the hull but there is a work-around for that. Most epoxy resins are also thin enough, when liquid, to allow all the air bubbles to be worked out from between the laminations as they are injected.

Be careful to get epoxy fiberglass resin. **It must say "Epoxy" on the label.** If it does not say epoxy, it is not epoxy and should not be used. Even though I have had several sales clerks tell me that there is no difference between fiberglass resins, there is in fact a considerable one. Don't take it unless it says "epoxy".

PC-7: PC-7 is a high strength epoxy putty. It's excellent for filling voids that are too small to fill with ABS sheeting. It may or may not be needed it but if you do need it, it's pretty handy.

Goop: Goop is an evaporation curing urethane adhesive. I use it under the patches. It has superior hold and remains somewhat flexible when cured. The downside is that it takes a *long* time for the solvent to work its way out through the adhesive under the patch. Curing times can be measured in weeks!

Goop is available in a variety of types at most hardware stores. There's "Plumber's Goop", and "Hobby Goop", and "Automotive Goop", among others. In truth, there are only two kinds of Goop; UV resistant and non-UV resistant. Everything else is nothing but labeling. Since it all costs about same, why not?

The UV resistant kind may be a little more costly and is probably not really needed since the majority of the bond is protected from sunlight by the patch.

Gloves: Get a whole box of vinyl disposable gloves.

Solvents:

- Get a can of whatever solvent is recommended for the epoxy resin you use. Use this solvent for cleanup - before the epoxy cures.
- Goop uses toluene for clean-up - before the Goop cures.
- For either type, after these adhesives cure, *nothing* works.

Dust Mask: Some of the dust from sanding is not good to inhale. If you must ruin your lungs stick to smoking, it's more fun. Please use a dust mask while you sand.

Dowel Rod for plugs: A two foot piece of 1/4" soft pine dowel rod which will be used to fashion plugs for small holes.

90% Isopropyl Alcohol: This is essentially water-free alcohol and you will use it for drying as well as a degreasing solvent. Nearly water free isopropyl alcohol can be found in most large drug stores and should be at least 90% isopropyl. If you have access to the 99.999% water-free alcohol available commercially, usually called "electronics grade", the less water the better since you will use it for drying.

Pediatric Syringes: These look like a hypodermic syringes but with no needle. They are commonly used to medicate babies and reluctant pets. You will use them to pump epoxy resin into the foam core space. They are listed as materials instead of tools because you will throw them away as the epoxy in them starts to cure. Get at least 3-4 of them!

TOOLS:

Sanding Stuff: I use an electric drill with a soft rubber sanding disk and disk sandpaper. Used with care, it works for almost all sanding tasks. Go slowly. With this kind of sander it is possible to over-sand easily! Dry sanding is desired even though you will make a lot of dust. I strongly recommend that you wear a dust mask when sanding.

Unless you have access to tools specifically designed for working wet, Don't even think about wet-sanding! While it's true that wet sanding is the preferred way to sand plastics, tools not specifically designed for wet sanding are dangerous to use around water. Besides wet sanding on the scale necessary for hull work *transcends* messiness.

Clamping Stuff: You will need something to hold the patches in place while the adhesive cures. I use filament type packing tape and a couple of 25lb sacks of sand. Be sure to get sand bags that are made of fabric or plastic, not paper.

Heavy Shears: ABS has so little shear resistance and you can cut the 1/16" stuff with heavy shears. I have cut 1/8" using aircraft style metal snips. (I did it but it wasn't pretty.) Anything thicker is best cut on a bandsaw or a *sharp* squaring shear, if you have access to one.

Use a slow to moderate band speed on the bandsaw and be patient, you want to cut the plastic – not melt it.

A 1/8" Drill Bit: A cheap 1/8" drill bit or piece of 1/8" metal rod for capping and filling holes.

Vice Grip Pliers: To hold on to the 1/8" drill bit or rod when you heat it.

A Heating Pad: For drying.

A Roller: One of those one to two inch rollers used for wallpapering.

PLANNING YOUR WORK:

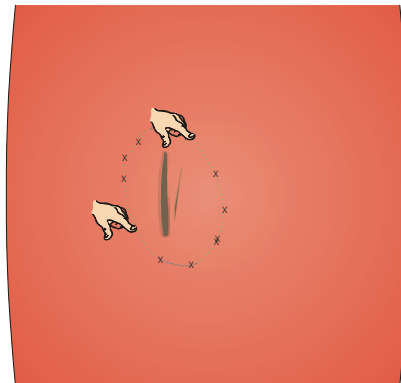
The first step is to plan your repair so that you will have an idea of where to sand and how much work it's going to be to make the repair. This involves determining the delaminated area.

Exposing the Area: If the inside of the hull at the damaged spot is covered with a saddle or flotation, remove it. If you glued your saddle in – tough! Take it out anyway! You have *got* to get to all the delamination and that means you have got to inspect and have access to the entire inside of the hull.

Checking for Delamination: Now press on the hull all around the damaged area, feeling for soft spots. Some people tap on the hull and listen for differences in the sound. Soft areas are where the Royalex has delaminated. Mark each soft place with a magic marker. Repeat with the opposite side of the hull even if the damage does not appear to go all the way through.

Probe Both Sides of the Hull for Soft Spots.

The hull will be noticeably soft where it is delaminated. The "X" marks give the outside boundary of the soft spot.



SANDING AND PREPERATION:

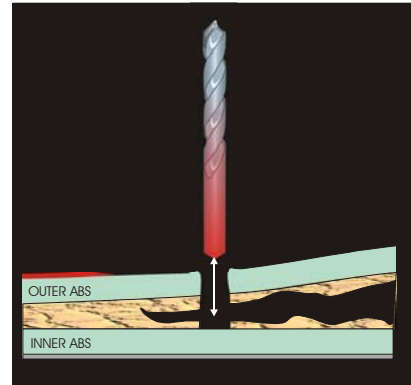
Sanding Off the Vinyl: It is necessary to sand off the vinyl outer layer around the damage. First, you must be able to see the extent of the damage to the ABS - much of which may be hidden by the vinyl. Second, the vinyl isn't bonded to the ABS very well so you will need to

bond your patch to the ABS itself for maximum strength.

Sand off the vinyl layer over the damaged area. Sand at least 1" beyond any cracked area even if it is not soft. Try to press pieces of severely damaged ABS back into place. If they will not go back they should be pulled or cut free.

Melting Cap Holes.

The 1/8" drill shank is not really heated red-hot. It is just shown that way to indicate that it is heated.



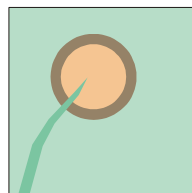
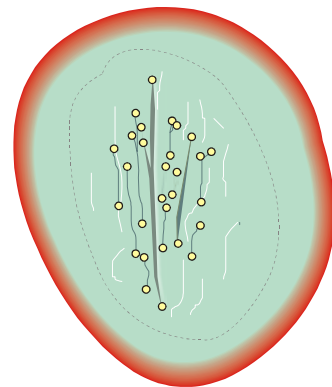
Stopping Cracking: This step will stop the progressive growth of cracks. Cracks are shearing situations and will continue to grow if not "capped". Melting makes a more stress-free cap than drilling so cap each crack in the hull

ABS by pushing a heated 1/8" drill, shank end first, through the ABS at the crack's end. Melt only to the foam core. It's really easy to melt all the way through the inner sheet of the ABS too so you must take care not to.

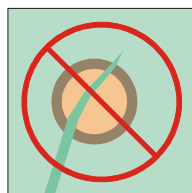
Capping Cracks in the ABS

Each crack should have a capping hole. The red vinyl outer layer has been sanded off to expose the ABS sheet. Each crack is capped by melting a 1/8" hole, (yellow circles) at its end.

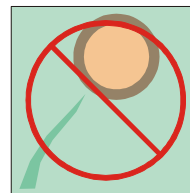
Be sure that each hole covers the end of the crack.



Good



Short of End



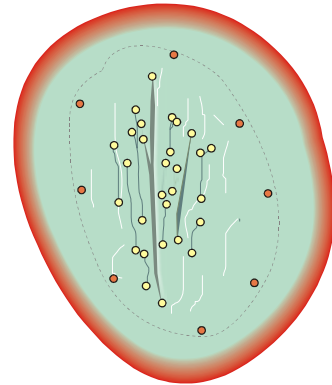
Past the End

Vent Holes: Melt additional 1/8" holes into the foam core at the extents of the delaminated area.

These are to aid even and complete distribution of the epoxy resin as it is pumped in.

Vent Holes

Holes, (orange circles), are melted at the edges of the delaminated area, as shown by the dashed line, to encourage complete distribution of the epoxy resin by providing both injection points and holes for the displaced air to escape through.



MAKE YOUR PATCHES:

Determine the Patch Sizes: Make a paper pattern for each patch. An oval shape is the best with a diamond shape with rounded points second best. A plain rectangular patch will work but should be avoided on the bottom of the hull as it creates drag and catches on rocks easily.

- If only an outside patch is to be used, make it at least 2" bigger than the damaged area in all directions.
- If an inside patch is to be also used, cut it to be at least 2" bigger than the damaged area in all directions. Cut the outside patch to be 2" bigger than the inside patch and the same shape. This creates staggered support for the hull material and tends to prevent it from flexing right at the hard area of the repaired delamination.

Bevel the Patches: Sand a bevel around the edges of each patch. This also aids in flexing of the hull and helps keep the outside patch from catching on rocks. This is one place where wet sanding will work.

Patches for Filling Voids: If you have a place where you have lost hull ABS, you need to fill the void before applying the a patch over it. If the void is less than roughly an inch, fill it with PC-7. If it is an inch or more in all dimensions, you can make a filler patch by layering 2 or 3 pieces of 1/16" patching ABS. Size and shape these filler patches to fit well into the space to be filled without jamming them.

DRY THE FOAM CORE COMPLETELY:

Next, *all* of the moisture must be removed from the foam core spaces. This is going to take time and patience.

Flush out the water: First, flush the area by running liberal quantities of 90% isopropyl alcohol through all the 1/8" holes. **DO THIS OUTDOORS!!**

Caution: Many drying solvents contain traces of oil or are petroleum based and will prevent the epoxy resin from holding and may attack the hull material. **DO NOT** use other drying solvents unless you are very sure that they will not affect the hull material or adhesive.

Dry the Foam Core: Apply gentle heat with a heating pad to the side of the hull opposite of the repair site for at least 24 hours to drive the moisture out. Flush the cavity with 90% isopropyl again and dry with heat for another 24 hours. Longer is better, perhaps even necessary, if the humidity is high. You can only guess when the core is dry so you must guess conservatively. If all the water is not eliminated, the epoxy will not hold, delamination will continue and all your work will be for nothing.

DE-DELAMINATION:

Inside Patch: If the hull is cracked all the way through to the inside, an inside patch is required to keep your epoxy from running out. It should be applied as the first step. Among other things, this will define the hull shape at the repair site so proceed carefully. See *Applying Patches* for details.

Prepare your epoxy resin. Follow the manufacturer's mixing instructions very carefully because it will be nearly impossible to re-do this step if the epoxy doesn't cure properly. Too much hardener will make the cured resin brittle and can actually encourage more cracking. Too little hardener and it turns into a kind of rubbery stuff that has little holding power. Commercial epoxies tend to be more demanding as to mix than the "over the counter" types. Be ready to work at once when the resin is mixed as curing time is limited.

Some epoxies have a *catalization time* where the mixed resin must set for a period of time, perhaps as long as an hour, before it is used. Follow these instructions carefully too.

Filler Patches: If you need a filler patch it should be put in next. The goal in this step is to stack up 2 or 3 layers of 1/16" ABS in the void left when you removed the hull ABS and perhaps the foam core. There should be a thin layer of epoxy between each piece. The only place that

the epoxy may be thicker is between the hull ABS and the first layer of the filler patch where there must be enough epoxy resin to ensure that the voids made by any irregularities in the hull ABS will be filled by it.

- Put down a slight excess of resin, place the first piece of the filler on it and roll or work the excess resin and, hopefully any bubbles, out from under it.
- Now add the second and third filler patches using as thin a layer of epoxy resin between the layers as you can get. Again roll each patch to eliminate bubbles and excess resin.
- Do not put any epoxy resin on the top of the topmost patch sheet.
- The level of this stack of sheets should be slightly above the level of the adjacent undamaged hull so that you can sand it down to hull level before applying the outer patch.
- Make sure that any voids around the edges of the filler patch are filled with resin.

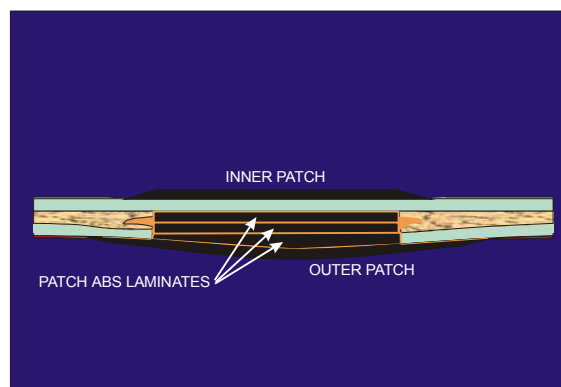
Clean up the excess resin and weight the stack with A 25 pound sack of sand until the epoxy resin hardens. Take care not to glue the sandbag to your hull! Allow the resin to harden enough that the filler will be secure as you work on the rest of the damage.

A Filler Patch

This patch is formed by layering 1/16" ABS patching material cut to fill the hole.

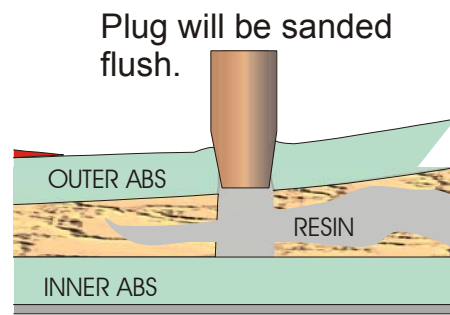
Make Some Plugs: You will need plugs for the filling and capping holes. Get a piece of 1/4" softwood dowel and cut it into pieces about 2" long. Taper one end of each, using a pencil

sharpener, not to a point but only until it will fit snugly into one of the 1/8" melted holes. You will use these as plugs in the capping and filler holes to keep the epoxy resin from coming out.



A Cap Or Injection Hole Plug

Note that the plug is not sharpened to a point but just tapered enough to plug the hole without going in too far.



Fill the Delamination: It is now time to fill the delaminated areas with epoxy resin. Your goal is to force as much air out of the foam core space as possible while working the resin as far into the core space as you possibly can.

- If there is no filler patching or large cracks, position the hull so that the space being filled is between a 45 degree angle and vertical. Filling from the low point up to the top one helps eliminate voids because any bubbles will tend rise as you fill and gravity will assist you.
- If there is a filler patch or large cracks it may be impossible to keep the resin from running out of a vertically oriented work area. In this case you should make the delaminated area as near to level as possible.
- Be patient. It may take more than one filling session, giving the resin time to harden between, to do a through job.
- Start by pumping resin into the lowest holes using a pediatric syringe. Keep filling until you see resin at the nearby holes. Temporarily Plug your filling hole and work the hull ABS a little to work the resin well into all the extents of the delaminated area. Remove the plug and pump in more resin until it again starts to come out of the nearest holes. Keep alternating pumping in resin and working the hull material until all the air bubbles are expelled.
- Permanently plug the hole you started with and move to the next lowest holes, filling, working the hull,

refilling and plugging until you have filled the delaminated area all the way to the top. Be sure that any cracks or voids around filler patch edges are filled with resin. Let the resin cure until it is hard enough to sand.

Sand: Cut off the dowel plugs close to the hull and leave the remaining ends in place. Then sand everything down to the level of the undamaged hull. Take it slow, if the damage has been severe you will actually be shaping your hull during this step. Also, if you sand fast you will melt the plastic and goo up your sandpaper. Soak a little epoxy resin into the sanded end of each wooden plug to seal it. Re-sand if necessary.

You are now ready to apply external patch.

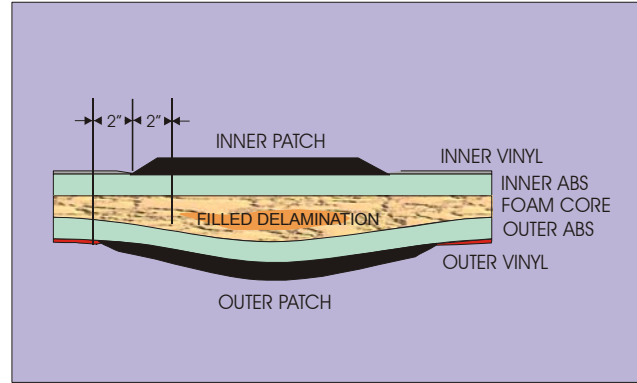
APPLYING PATCHES:

Staggered Sizing: Remember that careful sizing of your patches can go a long way to prevent the hull flexing right at the hard spot you have created with the epoxy resin. If you are using only an outside patch, making it a couple of inches larger than the hard spot will help graduate the transition stiffness of the hull near the hard spot.

If you are using an inside patch, it should be sized about two inches larger than the hard spot and the outside patch should be sized about two inches larger than that. Also the bevels sanded on the edges of your patches will help as well as resisting catching on rocks.

Staggering Patch Sizes

The filled delamination is stiff. Staggering patch sizes as shown will encourage the hull to flex into the fill gradually instead of all at once at its edge. Note the bevels on the edges of the patches.



Shaping the Patches: If the surface you are going to place the patch on is not reasonably flat, sharply curved, or curved in more than one axis, you must shape the ABS to the irregularities and curves by heating it until it softens. Do this by carefully placing the patch exactly where you want it and then heating the ABS until it is soft and working it while soft to match the surface.

An industrial heat gun or a couple of the heat lamps that auto body shops use for curing filler and paint, work well. Heat the patch gradually so that it heats evenly and don't let it get any softer than you need to work it into the shape of the hull surface. Around 300°F seems to be a good temperature.

A pair of heavy leather work gloves should serve well to protect your hands as you work with the hot patch. Press and rub it into the hull as it softens. Take care not to heat it so much that it "welds" to the hull under it. If this might be a problem, put a layer of aluminum foil between the patch and hull. If it does weld, you will have to sand it off and try again. Repeat for any inner patch you will be using.

Be sure to mark both patch and hull so that you can place the cooled-off patch exactly where it needs to go to fit perfectly.

Preparing the Patch Area:

- Lightly sand the hull where the adhesive will be applied with coarse sandpaper. Repeat with the side of the patch that will be bonded. The purpose is to provide rough scratches that the adhesive can cling to.
- Clean the hull where you will be gluing the patch with detergent and hot water followed by 90% isopropyl alcohol. Use a residue-free detergent and a good stiff brush, allow to dry thoroughly and then clean with the alcohol. Be sure to clean your patches too.

Gluing the Patch: Spread a layer of Goop on the hull. Start with a very thin layer and work the adhesive into the hull so that it "wets" the ABS thoroughly. If it "pulls up" without wetting

the hull you have not cleaned the surface adequately.

Follow up by building the layer of Goop up just thick enough to insure that any irregularities between the hull and patch will be filled. Spread a very thin layer of Goop on the patch and work it into the patch as described above. Curing will be delayed if any carrier solvent is left in the Goop. Allow everything to dry 10 to

15 minutes so that there are no blobs or puddles of Goop that are still soft with solvent anywhere. (Another good reason to keep it thin!)

Place the patch and work it with a roller if possible, to force all the air bubbles out from under it. On convex surfaces, tape it down using filament tape, as tightly as possible. Clean up any excess adhesive forced out from under the patch and weight it with your 25 pound sand bags. Again, take care not to glue the sand bags to the hull.

Curing and Cleanup: One of the arts of using Goop is knowing when to clean up. You must close a time when it has cured enough to hold the patch but is still soft enough to pare off the excess with a sharp knife.

Goop is an evaporation curing adhesive and it will take a long time for any remaining solvent to escape from the middle of the patch. Weeks, probably. (I have used a patch two weeks after putting it down without it coming loose even though I suspect that the Goop was still not cured all the way to the center.) One week, on the other hand, seems to be too soon.

If an inside patch is larger than about 6", drill small, (#30 or smaller), holes through the ABS on two to three inch centers to let the solvent escape the Goop there. A small enough hole will not compromise the strength of the patch much and you can fill it with a dollop of epoxy resin after the Goop has been given time to cure.

Once the Goop is thoroughly cured, all that remains is to clean up the repair and paint it. ABS, even the black stuff, does better if protected from the sun's UV. There are a couple of brands of "Royalex Paint" on the market. It's expensive but if applied carefully, it does a pretty good job.