

Repairing boats with Fibreglass Reinforced Plastics



a **Fibreglass
Limited** publication
in collaboration with
Tyler Boat Co. Ltd.

Five Shillings

Fibreglass Reinforced Plastics

Fibreglass Reinforced Plastics are now the most popular materials for building boats of almost every type. One of the main advantages of these materials is their high strength coupled with light weight, but it is, nevertheless, possible for an FRP boat hull to be damaged accidentally.

Even when damage does occur, FRP still has advantages over other boat building materials. Firstly, such damage will be localised around the point of impact, and secondly, in the majority of cases, it is possible for the average boat owner and handyman to carry out a speedy, safe and effective repair. The raw materials for an average repair are

relatively inexpensive and it is not necessary to own a specialised kit of tools. And boat builders are usually willing to sell the necessary small quantities of materials to owners of the boats they produce.

By repairing damage to his FRP boat the owner can also make considerable cash savings. To quote an actual example, a boat was returned to the builder for a relatively simple repair which cost £26. This cost had to take account of the disruption of production caused by the 'one-off' job, workshop overheads and the time taken by specialist, highly-trained staff. The materials to repair the boat would have cost the owner in the region of 50/-, or about 10% of the full cost of the professional job.

This manual will give the owner guidance on carrying out repair and maintenance work on his FRP boat. The basic skills required are simple and easily acquired, and boat builders or raw material suppliers are always willing to give advice on the best way to overcome any problems which may arise.



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Working Conditions

Boat repairs can be carried out both indoors and out under a variety of circumstances. It is advisable to work under cover whenever possible so that some control over working conditions can be exercised particularly protection from rain.

Ideally an FRP repair should be carried out indoors and the requirements which follow should be approached as closely as circumstances permit:

- a) Temperature** is probably the most important single factor influencing the success of a repair. Recommended minimum and maximum temperatures are 60-75°F (15-25°C).
- b) Humidity** can adversely effect the cure of the repair and when laminating is in progress it should not exceed 60-70% relative humidity.
- c) Direct sunlight** should be avoided as it can cause premature cure or excess evaporation of the styrene in the polyester resin. Both can result in permanent under-cure of the repair.

These ideal conditions will obviously be most important when larger repairs are being carried out using appreciable quantities of resin and taking time to complete. When a small repair is being made it is often possible to combat adverse conditions by adjusting the amount of chemical used.

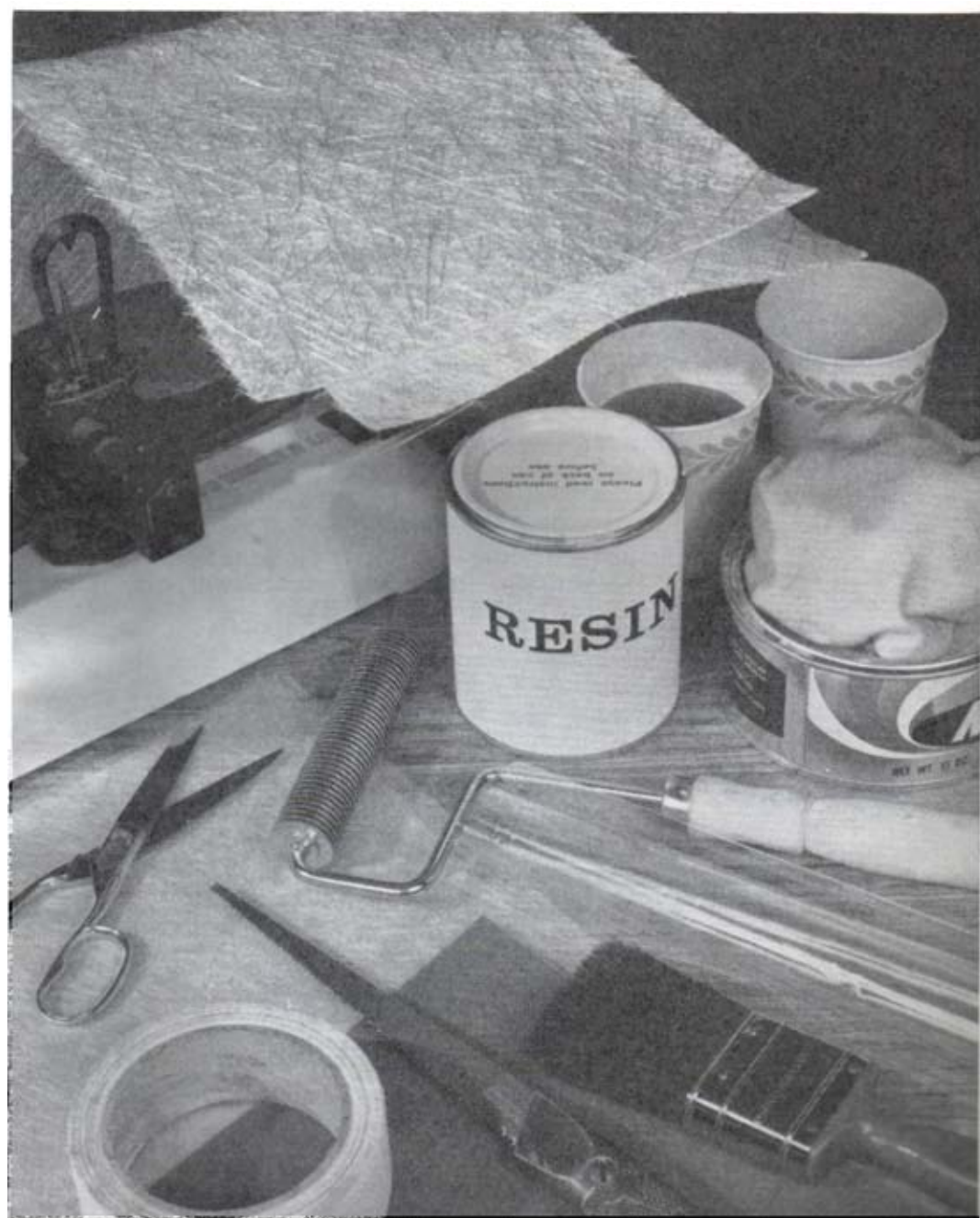
However, one rule must be observed with all repair work. The surface on which the repair is to be carried out **MUST** be dry. Failure to ensure this will result in the repair refusing to stick to the original laminate and the job will have to be repeated.

On an FRP hull, surface water raindrops or splashes can be removed with a rag soaked in acetone. Deep-seated moisture, in a timber hull for example, must be thoroughly dried out using infra-red lamps or some other form of radiant heat adjacent to the area to be repaired.

Tools ..

With few exceptions the tools required to carry out repairs to a Fibreglass Reinforced Plastics boat will already be in the possession of the boat owner or his wife. Those listed below will enable the owner to carry out the majority of repairs which he is likely to wish to attempt :

1. Hacksaw to cut away damaged laminate in the boat.
2. Chisel, file or Surform tool to trim back and feather the edge of the cut-out.
3. Wooden mallet to drive the chisel, position wooden bracing, etc.
4. Electric drill with disc sander and medium grit sanding discs to speed up edge trim of the cut-out and smooth off and fair-in the finished repair.
5. Rubbing block and sheets of 240-400 grade wet-and-dry abrasive to give the final smooth surface to the repair.
6. Tin of wax and sheets of cellophane or polythene to prevent the repair sticking to the backing plate or 'former'.
7. Set of household scales to weigh 5 to 10 lb for weighing Fibreglass reinforcement and correct proportion of resin.
8. Polythene bucket and several large and small waxed paper or plastic cartons for holding and mixing various quantities of resin to suit the repair being carried out. The top can be cut off washing-up liquid containers or a child's plastic potty can be pressed into service.
9. Laminating brush choose one of the less expensive paint brushes. A 1 1/2 inch size is a good general purpose tool, although larger and smaller can be used depending on the area of the repair.
10. Split washer roller this is one item unlikely to be readily to hand. It is a roller on which are several washers, with radial slots, spaced by smaller washers. One can be made using two sizes of washer, and is quite effective without the radial slots (see illustration), or the genuine article can be obtained from one of the suppliers listed.



11. Scissors or sharp knife for cutting chopped strand mat and woven reinforcement materials to shape to suit the repair.
12. Extending steel rule for general measurement and to check the size of reinforcement patches needed.
13. Broad knife to fill in blemishes in the cured repair before final sanding off.
14. Supply of acetone to clean resin from brushes, rollers or clothing before it cures and to remove surface moisture from areas to be repaired.
15. Measuring cylinder for catalyst and measuring cylinder for accelerator. Two cylinders are required, as catalyst and accelerator must not, under any circumstances, be mixed together. The cylinders will be used to measure chemicals when these are in liquid form. However, it is possible that the resin obtained will already contain accelerator (usually described as pre-accelerated resin) and will simply need the addition of the correct amount of catalyst. It is also possible that catalyst in paste form in a squeeze-tube will be used, in which case measurement will be of the length of catalyst paste exuded.

... and materials.

The basic materials used to carry out a repair are the same as those used in moulding an FRP boat hull and are as follows:

a) Glass fibre reinforcements

The most widely used reinforcement is supplied in the form of a chopped strand mat (CSM) in varying thickness identified for convenience by its weight per square foot. In many boat mouldings a small percentage of woven roving (WR) or cloth, once again in varying thickness, is used. Identification of these two materials is by their weight per square yard.

Many combinations of laminate construction are possible from the various weights of reinforcements available, but in general it will be found that 1, 1½ and 2 oz/ft² CSM and 10 and 16 oz/yd² WR will cover requirements.

b) Polyester resin

Boat hulls are moulded with an unsaturated polyester resin. The resin usually has a thixotropic agent added to achieve a measure for non-drip, non-drain control. Many resin manufacturers supply pre-accelerated resins and it is important to check whether or not the resin to be used is of this type.

A general purpose polyester resin will enable satisfactory repairs to be carried out, but an improvement can be achieved by using a special gel-coat resin for the outside surface of the repair. Filled resins are also available and these are useful for making pastes to knife into small blemishes which do not penetrate the hull skin, or before finally fairing-in the completed repair.

c) Catalysts and Accelerators

All polyester resins require the addition of catalyst and accelerator to complete polymerisation and cure. The catalyst is usually methyl ethyl ketone peroxide (MEKP) and it should only be mixed with the resin immediately before use. No more resin than can be used in half an hour should be catalysed at any one time.

The accelerator can be added by the resin manufacturer, as it has little effect without the presence of catalyst. It merely enables the process to continue at workshop temperature or increases the rate of cure.

If both catalyst and accelerator are to be added to the resin, they should be poured and mixed separately, stirring briskly after each has been added.

The proportion of catalyst and accelerator added to the resin

varies according to the resin, the required curing time and the ambient temperature. UNDER NO CIRCUMSTANCES should accelerator and catalyst come into direct contact with each other as spontaneous combustion will occur.

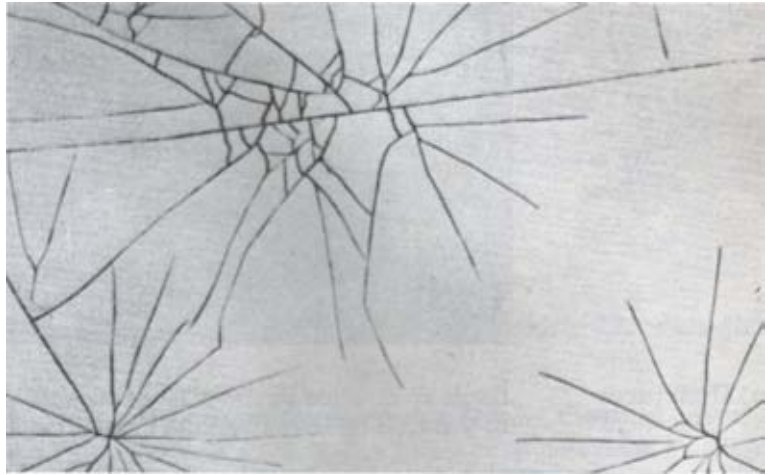
Resins, catalysts and accelerators are highly inflammable and should not be exposed to a naked flame. A 'no smoking' rule when mixing or laminating must therefore be observed. Materials should be stored at temperatures between about 60 and 70°F (15-20°C).

Hull damage

Depending on the severity of impact a reinforced plastics hull is likely to sustain damage of four distinct types. These are hairline fractures, grazes, impact fractures and punctures.

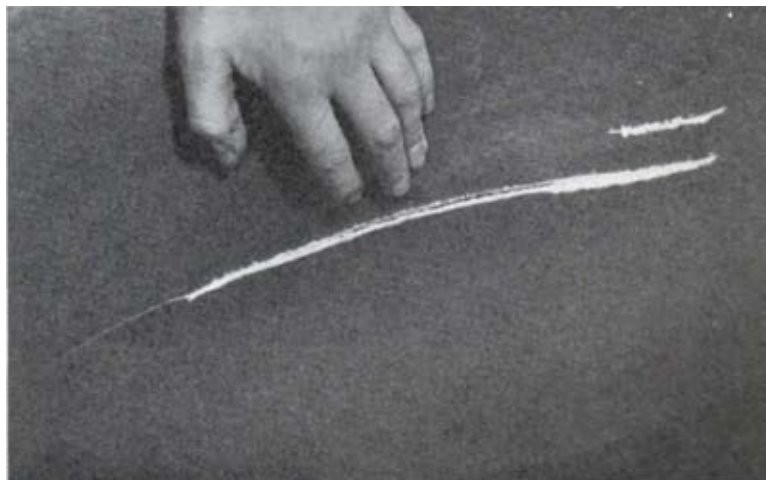
a) Hairline fractures

are cracks which are confined to the surface gel-coat and do not penetrate into the main laminate.



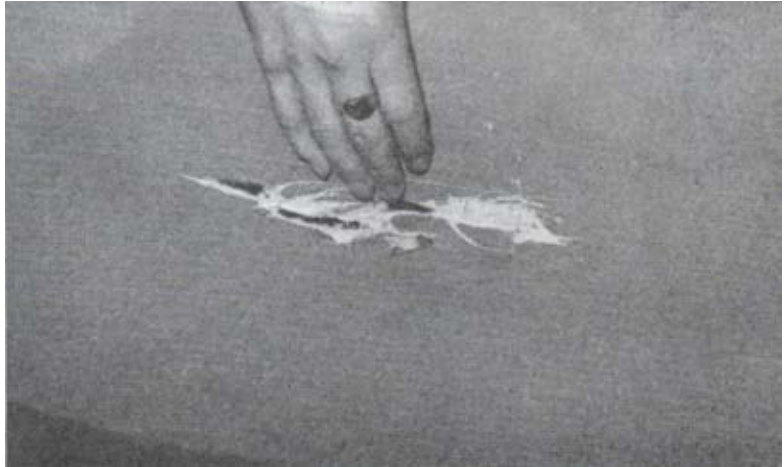
b) Grazes

are the result of abrasion rubbing off the gel-coat and exposing the Fibreglass reinforced laminate beneath.



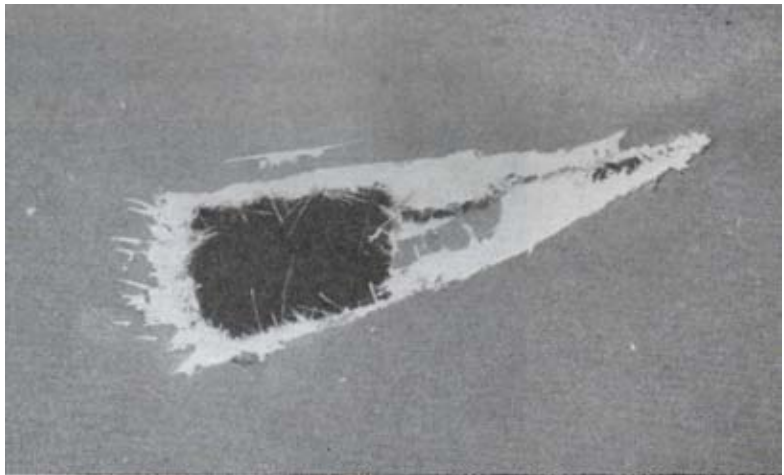
c) Impact fractures

are caused by a hard blow. In this case the laminate itself is crazed and damaged, although it is not completely penetrated.



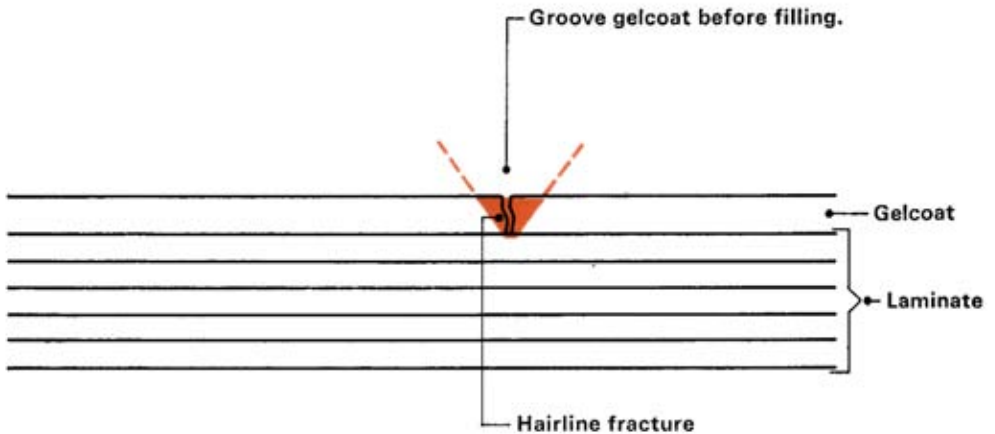
d) Punctures

result from a harder blow or impact with a pointed object and in this case there is a definite hole through the laminate.



Each type of damage requires a different repair procedure and these are detailed below with the aid of diagrams. In order to effect a complete and reliable repair it is essential that the purpose and application of the basic materials is fully understood.

Repairing a hairline fracture

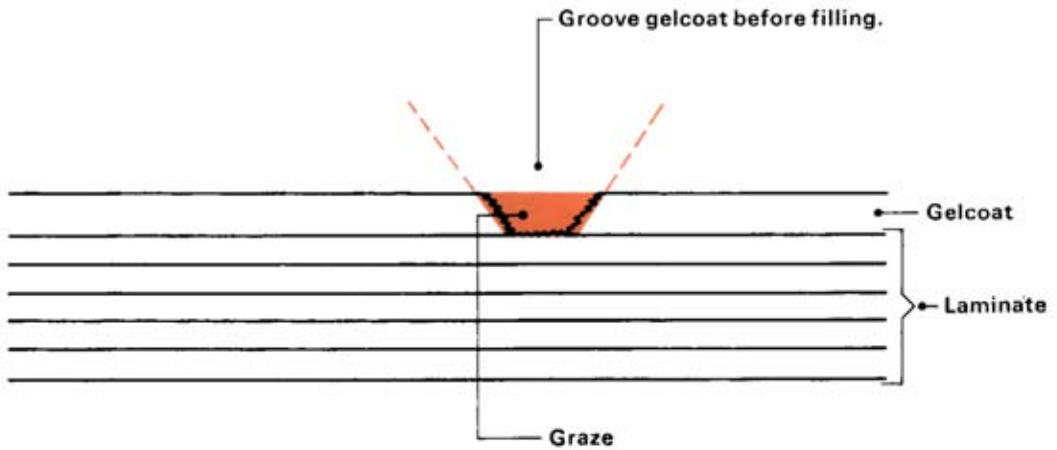


- (a) Remove any external obstruction covering the damaged surface.
- (b) Enlarge the hairline fracture into a definite V-shaped groove, using the corner of a chisel or a file. The groove must be deep enough to penetrate the gel-coat completely and expose the main Fibreglass Reinforced Plastics laminate beneath.
- (c) Prepare and activate a small quantity of resin. A filled resin is the best to use for this type of repair. Failing this, a general purpose resin can have filler-powder added. Work this into the groove, using a broad knife, until it is slightly proud of the external surface. Leave the repair to cure completely.
- (d) After the repair has cured, fair-in the surface with grade 320 wet-and-dry abrasive, used wet on a rubber block. Rub lightly in one direction only to prevent the area surrounding the repair becoming depressed. Too vigorous rubbing down can result in the original gel-coat surrounding the repair being depressed or even removed to expose the glass reinforced main laminate beneath.
- (e) If a sizeable area has been treated in this way it is sometimes noticed after rubbing down that a gap has appeared between the repair and the original laminate. This is not unusual and is caused by shrinkage. To remedy this fault stage 'c' should be repeated,

this time treating only the gap which has opened up. After curing, this secondary repair is again rubbed down.

(f) The 320 grade abrasive may have left scratches on the surface of the repair and its surrounds. Remove these by rubbing down with grade 400 abrasive, used wet, and finish off with a fine cutting compound. A final surface can be obtained with Simoniz wax polish, or the repair can be painted to match the finished colour of the hull.

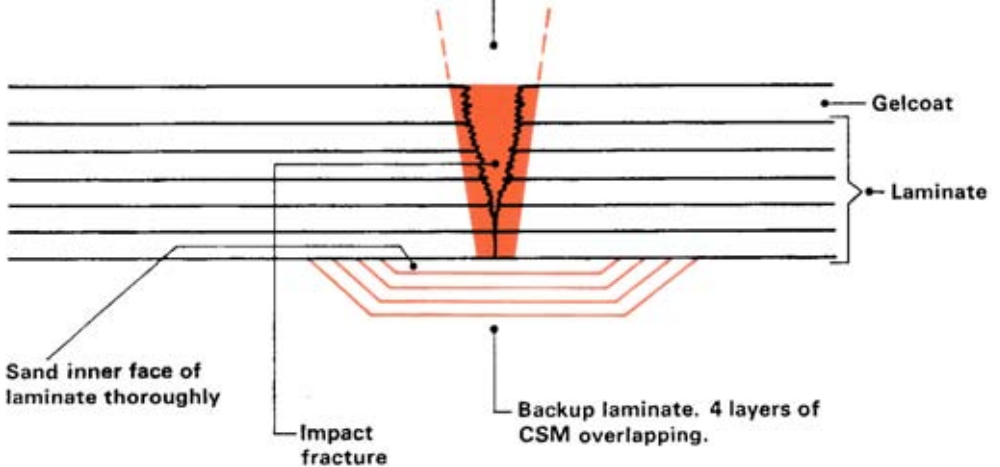
Repairing a graze



The repair procedure recommended for this type of damage is identical to that used for a hairline fracture. However, a graze is likely to be more extensive and, instead of a V-notch, a larger section of the surface will require cutting back to the main laminate. Note item 'e' above shrinkage of the repair is more likely to take place in the case of more extensive replacement of the gel-coat surface.

Repairing an impact fracture

Cut away all damaged laminate and fill with dough mixture or small pieces of pre-impregnated CSM to within $\frac{1}{10}$ in of surface.



- (a) Remove any external or internal obstruction in way of damaged area.
- (b) Enlarge the fracture into a V-shaped groove, taking care that all the damaged laminate is removed to the full depth of the fracture. To do this it may be necessary to continue the groove right through the laminate and form a slot in the internal face of the hull.
- (c) If a slot has been formed, sand the inside face of the old laminate thoroughly for at least 3 in all round the slot and brush off any loose powder.
- (d) Cut four strips of $1\frac{1}{2}$ oz/ft² CSM. The smallest should be 1 in larger all round than the slot. The other three should increase in size progressively by $\frac{1}{2}$ in all round.
- (e) Pour 1 lb of resin into a suitable container a 'potty' or a waxed paper carton and mix in the chemicals.

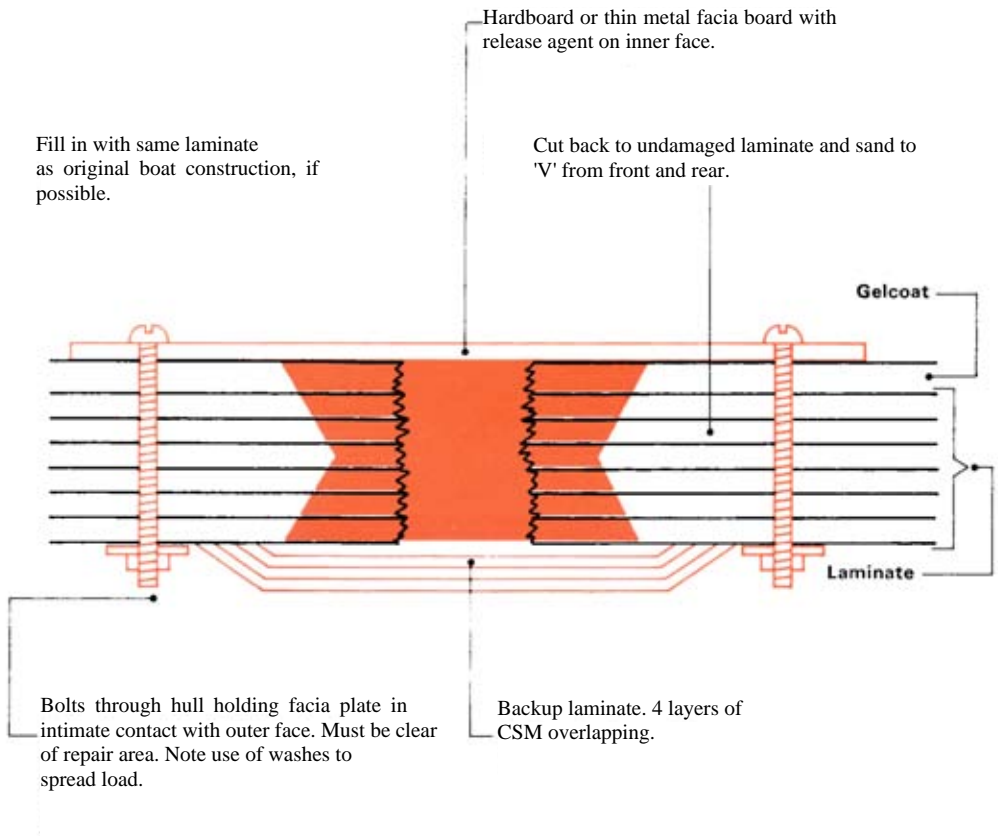
(f) Brush a liberal coat of activated resin over the whole of the sanded area, then lay the first and smallest strip of CSM in position covering the slot. Dip the brush into the activated resin and stipple the resin on to the CSM. Take care not to press the CSM into the slot concentrate on stippling the area of overlap on the old laminate. When the CSM is thoroughly impregnated it will have a clear, even, 'golden syrup' appearance. Roll carefully and gently to remove air stippled-in. Place the next larger piece of CSM in position on top of the first piece.

(g) The same procedure is carried out for all four layers of CSM and the laminate is then left to cure preferably overnight.

(h) When this new backing laminate has cured the laminate must be re-built working from the outside face of the hull. CSM dough or pieces of pre-impregnated CSM are applied to within $\frac{1}{10}$ in of the outer face of the surface.

(i) The repair is then completed using 'c' to 'f' of the procedure for repairing a hairline fracture.

Repairing a puncture



(a) Remove any external or internal obstruction in way of damaged area.

(b) All jagged edges and damaged laminate around the puncture must be cut back to a clean even line using a hacksaw.

(c) The old laminate on the internal face surrounding the hole must then be sanded-down. The amount to be sanded around the circumference of the puncture will depend on the size of the hole made and is mostly a matter of experience coupled with common sense. At least 3 in is a good starting point.

(d) Next, the edge of the puncture must be filed or sanded-down both from the inside and the outside to form a wedge-shaped edge all round.

(e) The whole area should be brushed free of loose glass, powder, etc., before the next step is started.

(f) Firstly, cut a quantity of CSM and woven rovings of identical weights to the original laminate, tailored to the total area of the hole. Details of the original laminate will generally be given by the boat builder on request. The backing laminate for the hole can also be tailored to suit the sanded area and layers should increase in size as in the repair of an impact fracture.

(g) Next a facia board is prepared and fixed to the external surface. This must be larger all round than the hole that has been cut and sufficiently flexible to pull to the exterior contour of the hull. This is bolted through the hull. The bolts must be as close as possible to the hole yet remain clear of the backing laminate repair area. Use enough bolts to pull the facia board into intimate contact with the exterior of the hull and to hold the edges of the hole in true alignment.

On smaller repairs a piece of hardboard, smooth face inwards, will form a suitable facia board. A sheet of aluminium is equally effective.

(h) Before the facia board is finally fixed into position the inner face must be given a generous coat of Simoniz or similar wax in the case of hardboard give several coats and then brushed over with PVA release agent.

(i) When the board has been fixed on to the outside of the hull and the release agent is quite dry, prepare a small quantity of pigmented gel-coat resin and apply a liberal quantity to the inner surface of the facia board through the cut-out. Leave this to cure until it will take a fingerprint without any gel-coat sticking to the finger.

(j) Now activate a mix of general purpose resin and apply a generous coat over the gel-coat. Place the first piece of reinforcement in position and stipple on more resin until thoroughly impregnated. Roll thoroughly. Add the remainder of the layers in their correct order, impregnating and rolling individually until

the laminate is complete and the hole filled flush.

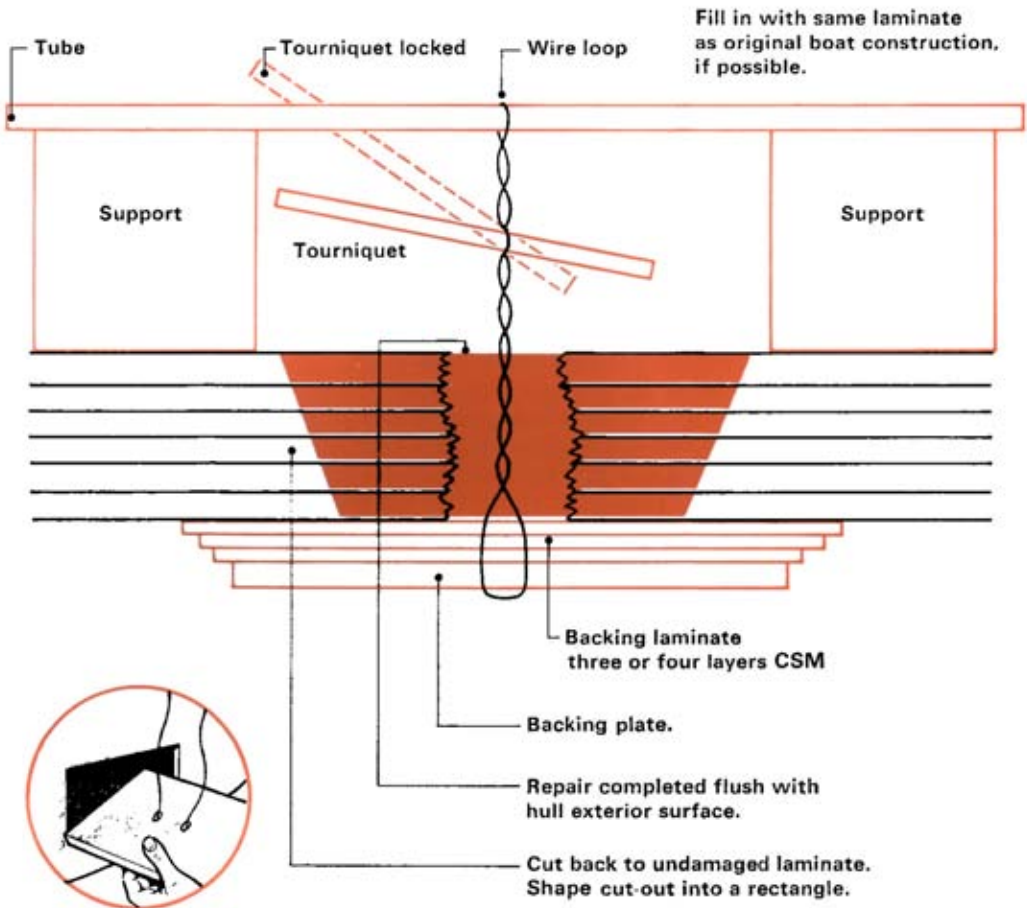
(k) The backing laminate can now be applied. This will usually consist of 4 to 6 layers of 1¹/₂ oz CSM but, where extra strength is required, a layer of 10 or 16 oz/yd² WR may be substituted for one or two layers of CSM. The size of the patches should be staggered as for the repair to an impact fracture.

(1) When all the new laminate has completely cured it will be best to leave it overnight the facia board can be removed.

(m) Any low spots on the exterior surface should be filled with pigmented resin, then sanded down and polished as previously indicated. The holes left by the bolts should also be filled at this stage. It must be appreciated that when large punctures are repaired the external finish is unlikely to be as good as the original. However, matching polyurethane paint can be obtained for most of the polyester colour pastes and, with careful application, a reasonably good overall finish can be achieved.

In some cases where the hole to be repaired is very large, a facia board of glass fibre can be taken from the female mould by the boat builder so that the repaired area will conform to the lines and shape of the original boat.

Repairing a blind panel



(a) In many boats it is impossible to reach the inner face of the hull in certain areas. When damage of the impact fracture or puncture type takes place in such a location a special repair technique has to be employed.

(b) The extent of the damage is first determined and a rectangular hole is then cut which removes any damaged laminate completely.

(c) A reverse facia plate is then produced. This can be plywood or hardboard, depending on the size of the cut-out. This plate is

also rectangular but is larger all round than the cut-out. It has to be passed through the cut-out and so the smaller dimension of this rectangle must be slightly smaller than the larger dimension of the cut-out. (See diagram.) Two small holes are drilled in the facia plate near to the centre.

(d) Three or four layers of $1\frac{1}{2}$ oz/ft² CSM are laid up on one face of the plate, stippling in activated resin then rolling to consolidate and remove air.

(e) A length of strong wire is passed through the two holes in the plate and through the laminate so that the ends project through the outer face of the laminate.

(f) The reverse facia plate and laminate are then passed through the cut-out and are pulled back into position so that the wet laminate is pressed hard into contact with the interior of the hull shell. Tension is applied to the wire to maintain this contact. An easy way to do this is to bridge the repair with a bar placed on stand-off blocks at each end. Fix the wire on a loop over this bar, then apply tension with a tourniquet.

(g) When the backing laminate has cured fully preferably overnight trim the wires back as close as possible to the laminate.

(h) Build up the repair with further layers as used in the hull construction until it is just below the hull exterior. Finish with a generous coat of resin.

(i) The repair can be left to cure as it is, but a better finish will be achieved if a piece of Cellophane is squeegeed down over the repair and left in position. This will simply peel off after cure.

(j) Use wet-and-dry paper on a rubber block and plenty of water to blend the repair in to the hull contours.

(k) Fill any blemishes with more resin, allow to cure, then rub down again. Repeat until the required surface is achieved.

Repair of timber boats

So far this manual has detailed repairs to the hulls of boats moulded in Fibreglass Reinforced Plastics. But FRP is also a very useful repair medium when damage occurs to hulls using other forms of construction.

Timber boats, for example, can often be repaired rapidly, effectively and at reduced cost if FRP is used. In general, the smaller plywood boat can be treated for repair purposes as similar to one of FRP construction. The plywood will, of course, be thicker than an equivalent FRP shell, but grazes, impact fractures and punctures can be repaired using the same technique.

A solid timber hull is usually so much thicker that, in the case of a puncture repair, the backing laminate can be dispensed with providing the 'V' sanding is carried far enough back to produce a really acute angle to lock the repair into place and give good area of contact with the wood.

Other repairs

When a boat hull is damaged it sometimes happens that the interior framing is also broken. This can be hollow 'top-hat' section FRP or solid timber. In both cases the repair is similar.

FRP Frames

- (a) If an FRP frame is damaged the broken section must be re-moved by cutting back to the hull using a Surform tool or file to cut away as much as possible of the part remaining bonded to the hull interior.
- (b) A former is next required over which the new section of frame will be moulded. This can be almost any material capable of being formed to the shape required. It will not become part of the load-bearing structure; this is the job of the FRP. Timber, plaster or even compressed newspaper, can all be pressed into service.
- (c) The ends of the original frame are sanded for several inches back from the break to give a clean surface for the repair to bond to.
- (d) CSM is cut into strips long enough to overlap the original frame by several inches and wide enough to give a generous flange in contact with the hull. The number of layers required will depend on the construction of the original frame. Be generous when building up the repair, but do not use too much FRP as a 'hard spot' could then be formed in the hull structure.

Timber Frames

- (a) Cut away and remove the damaged section.
- (b) Cut a replacement frame piece and glue and screw this into position with a good scarf joint to the existing frame ends.
- (c) Reinforce the joints by laminating FRP over the frame, carrying the laminate out as a flange on to the hull interior.

Additional uses of FRP

FRP can be used in many situations on a boat where it is required to fix something permanently into place or where an area must be strengthened.

Pipe runs for water, fuel and gas can be bonded into place between unions. The pipe is then reinforced and protected by a shake-proof mounting. This technique is, however, unsuitable for exhaust pipes.

FRP laid up behind a section of hull or deck which requires local reinforcement can be most effective. It is usually preferable to stagger the area of the layers of CSM to prevent a sudden change in stiffness forming a 'hard spot'.

Additional bulkheads or other similar timber constructions can be bonded into place with an FRP flange. This is easier than forming a timber fillet to shape and gluing and screwing into position. It can also save valuable space.

Once the simple technique of using Fibreglass Reinforced Plastics has been acquired, many more uses of the material will occur to the handyman boat owner. The main requirement is simply a firm surface either permanent or temporary against which to work the material.

Remember these points

The strength and ultimate surface finish of a repair will depend to a great extent on thorough preparation of the damaged area.

If either the damaged area or the repair materials are at all damp, the strength and life of the repair will be seriously affected.

The repair materials should overlap the damaged area by at least one inch all round.

Many repairs are ruined by attempting to smooth off or polish before the resin is thoroughly cured. Any repair should be allowed to cure at least overnight, or longer if the weather is particularly cold.

The Fibreglass reinforcement provides the strength of the repair and either chopped strand mat or tape must be used to achieve the required strength. It is not sufficient to embed layers of glass tissue in polyester resin.

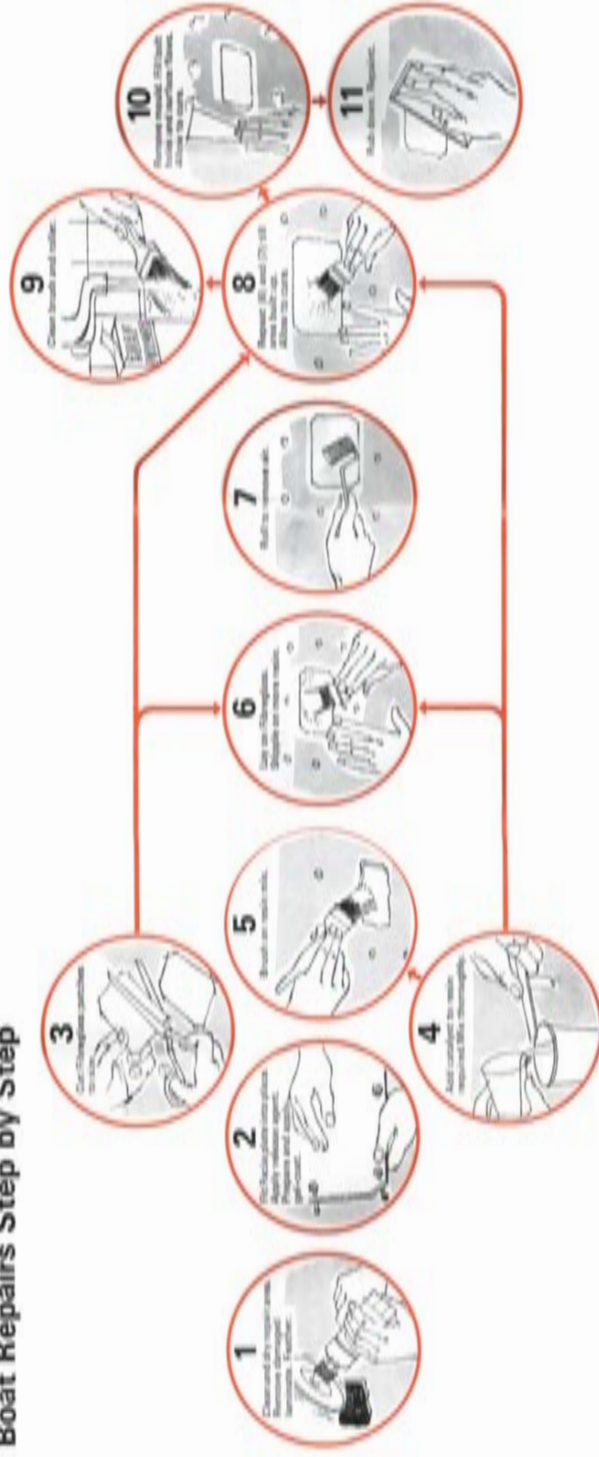
Always clean brush and roller immediately the laminating stage of the repair is completed.

Never mix more resin than is required for the immediate job.

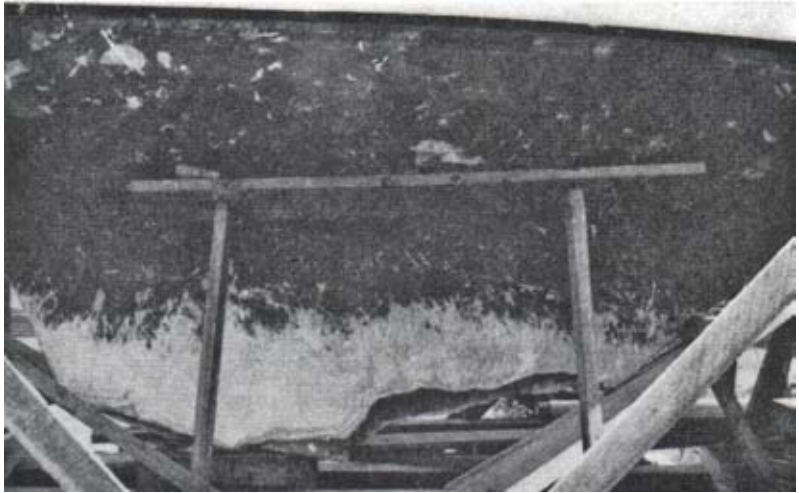
To prevent wastage of resin which starts to cure before it can be applied, limit each mix to a maximum of 1 lb.

Do not throw away offcuts of chopped strand mat. They are useful for small repairs and for adding local strength to larger repairs.

Boat Repairs Step by Step



A repair example

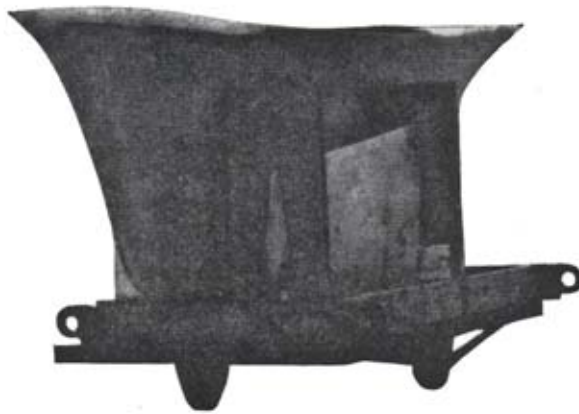


Perhaps the biggest single problem for the amateur contemplating a yacht repair in FRP is to judge whether a particular job is within his capabilities or if it should be carried out by specialists. Experience shows that frequently an amateur will be far too conservative in his estimates of what is possible. With this in mind it was felt that the story of the repair carried out to 'Merlin' an Excalibur class yacht would illustrate just what the possibilities are.

It is not intended to suggest that this repair is one which should have been carried out by the owner; it is used simply as an illustration of the results possible when working under the sort of conditions likely to be met by the average owner.

During a storm in the West Indies, 'Merlin' went aground on a reef and for 18 hours was pounded unmercifully. Once the storm had abated the yacht was refloated and sailed 3 miles to a safe anchorage. From there 'Merlin', with full rig, was towed 40 miles back to base in a fairly rough beam sea. When describing the incident the owner remarked on the surprising stability of the damaged boat when in tow.

Inspection revealed that damage was mainly confined to the keel, but through continuous pounding on the reef this was indeed extensive. A large section has been worn and gouged away and, in consequence, most of the bonded-in ballast had been lost; of the original total of 2 tons 15 cwts under 1 ton remained. The owner suggests that it was this loss of ballast which made the boat light enough to float off the reef as the gale died down and it was probably the bonded-in petrol and water tanks which gave



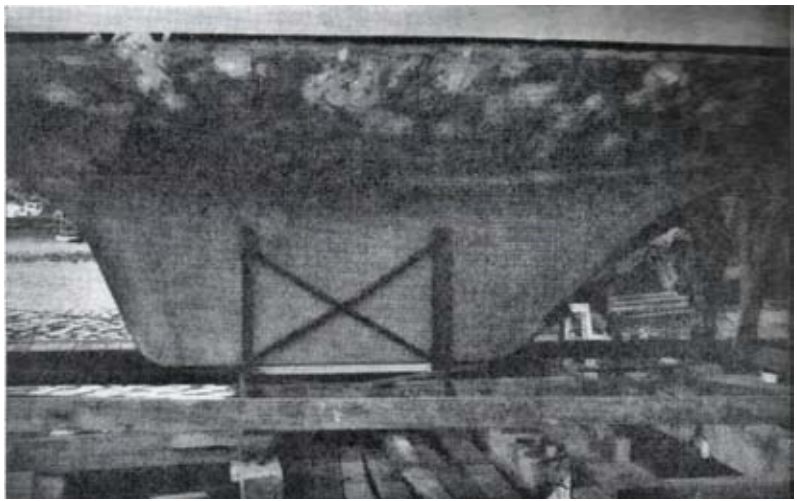
sufficient buoyancy for this to happen. The rudder plate was also damaged beyond repair, but had remained in place and was used for steering the boat home.

Once the Insurance Company had given the go-ahead the Tyler Boat Co. manufactured a completely new keel section in Fibreglass Reinforced Plastics, bonding-in the ballast and tacking into their correct positions a new set of tanks. A new rudder was also moulded and this, together with the keel and all the necessary materials and equipment for attachment and a kit of tools, was shipped out to the West Indies within a few days.

Once the keel had arrived one of Tyler's Technical Supervisors flew out to supervise the repair and work on the installation of the new keel. By the time he arrived most of the interior fittings in way of damaged keel area, including the engine installation, had been removed by a local yard.

The repair sequence was then as follows:

- i. The old keel section was measured carefully and cut off so that the hull of the boat would align with the newly moulded unit.
- ii. After removing the tanks tacked to it, the new keel section was offered up and aligned carefully with the cut-away hull. When a good joint had been achieved the section was clamped rigidly into position.
- iii. The new keel was bonded into the hull of 'Merlin' using a generous laminate of Fibreglass Reinforced Plastics.



- iv. The pre-fabricated tanks were next installed and tested, and these too were bonded into position with FRP.
- v. The exterior joint line between the old hull and the new keel was then filled and faired carefully into the contours of the boat.
- vi. Other minor damage to the hull was repaired and faired-in.
- vii. The final operation was repainting of the hull. The result 'Merlin' had an almost 'as new' appearance.

This repair took place on Granada and the facilities available were those of the average small British boatyard. This lack of modern facilities and the need to use local labour, untrained in the necessary FRP moulding techniques, tended to slow down the job. Even so, the Technical Supervisor from Tyler's completed the job within two weeks, which includes time spent in travelling to and fro. From receipt of official instructions to go ahead to completion the whole operation took only 7 weeks, including a shipping time of 2 weeks.

This example has not been quoted in the expectation that every amateur yachtsman is going to tackle a major re-build on a large boat. It does, however, indicate what can be achieved and shows how a boat, which in many cases would have been considered a total loss, can if moulded in FRP be repaired and put back into service in a sound and sea-worthy condition.