MODERN BOATBUILDING

A.Y.R.S. PUBLICATION No. 20

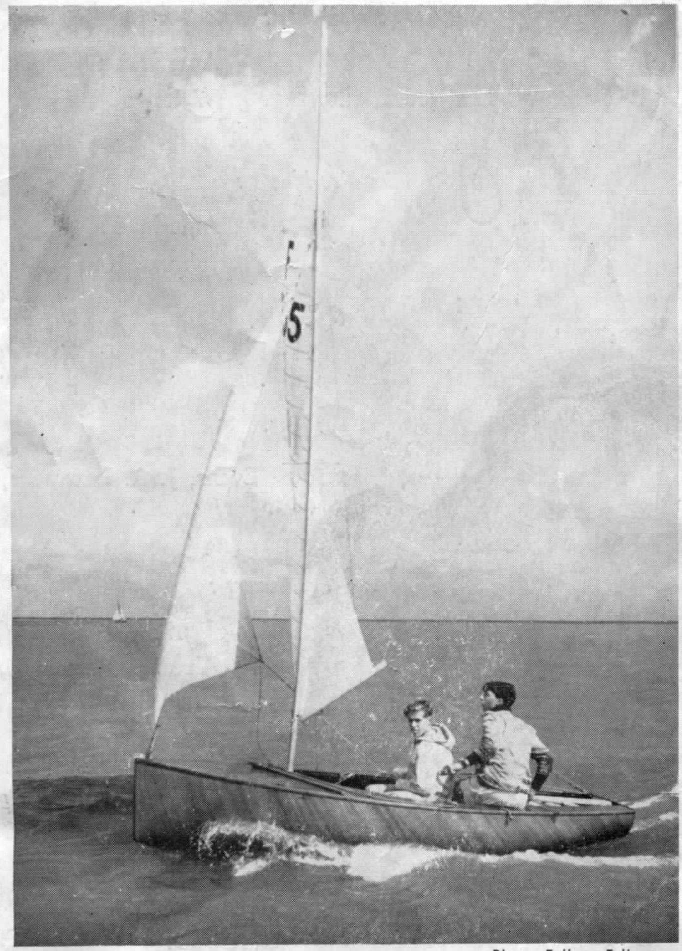


Photo: Fullers, Folkestone

The " hot moulded " FIREFLY dinghy

CONTENTS

PRICE 50 cents **PRI** 5/-

THE AMATEUR YACHT RESEARCH SOCIETY
(Founded June, 1955)

Presidents :

British :
Lord Brabazon of Tara, G.B.E., M.C., P.C.

American :
Walter Bloemhard.

Vice-Presidents :

British :
Uffa Fox, R.D.I.
Dr. C. N. Davies, D.SC.
Austin Farrar, M.I.N.A.
E. J. Manners.

American :
John L. Kerby.

Committee :

British : Owen Dumpleton, Mrs. Ruth Evans, J. A. Lawrence, Ken Pearce, Roland Prout, Henry Reid.

Secretary-Treasurers :

British :
Tom Herbert,
25, Oakwood Gardens,
Seven Kings,
Essex.

American :
Mrs. Yvonne Bloemhard,
143, Glen Street,
Glen Cove,
New York.

New Zealand :
Charles Satterthwaite,
Box 2491,
Christchurch,
New Zealand.

South Africa :
Brian Lello,
S.A. Yachting,
58 Burg Street,
Cape Town.

Editor and Publisher :

John Morwood,
Woodacres,
Hythe,
Kent.

Amateur Yacht Research Society
BCM AYRS
London
WC1N 3XX UK
www.ayrs.org office@ayrs .org
Contact details 2012

EDITORIAL

August, 1958.

The American A.Y.R.S. is getting on with the development of its research programme and has now worked out many practical details of what it can do. Mr. Mehaffey has made his recirculation test tank available for model testing. Blue prints for apparatus to test sails have been drawn up and these will be made soon. Mr. William Baur has offered his analogue computer for the mathematical side and several other tentative but very practical ideas are being developed. In all, the exciting prospect of gathering figures of sail and hull performance is at last taking shape. Members will realise that figures of this kind always result in new ideas and improved efficiency.

Walter Bloemhard, the President of the American A.Y.R.S. is starting a series of stencilled publications on a more technical level than the ordinary publications. They will cost 50 cent. or 2/6 each.

In England, Owen Dumpleton, 28, Grecian Crescent, London, S.E.19, owns a *Shearwater III* catamaran and several instruments for taking measurements. He is prepared to organise a small research group to study everything possible about this craft, such as resistance at various speeds, lateral resistance ratios, sail coefficients etc. This study, like that of the American A.Y.R.S. could give the most valuable information.

THE CROSS CHANNEL RACE, 1958

Sixty dinghies and forty catamarans were entered for this race of 26 miles across the English Channel. Of the 86 starters, 85 completed the course. The wind was force 1 for the first few hours which took the competitors to the Varne Light Vessel. Shortly afterwards, a strong wind came and the race was finished at maximum speeds. The wind was free at all times.

Of the first 25 boats to finish, 18 were catamarans, 5 were 505's and there was one *Jolly* and one *Osprey*. *Vae Victis*, a 505 was fifth boat over the line but the only dinghy in the first 11. The fact that the catamarans started 40 minutes behind the dinghies was of no significance as this 40 minutes was almost calm.

Endeavour, sailed by Ken Pearce was first over the line and made a magnificent spectacle as she did so with the weather hull just lapping the surface and going a good 18 knots.

Freedom, designed and built by Donald Robertson, an amateur, was sailing quite as fast and was second. *Freedom* has a lot of noteworthy points which gave this result such as a twistless jib with boom and luff spar and certain refinements of hull shape which will be described in a future publication. Donald Robertson was a test pilot and every detail seemed to be an improvement on the current practice. He is to be congratulated on a truly magnificent boat.

Francis Prout in *Fifi*, a *Shearwater*, was third. This was quite as fine a performance as the two leading boats as they are both 18 feet to her 16′ 6″.

Vae Victis, the first dinghy across, sailed by K. C. Trent, must have been superbly sailed to keep up with such speedy company and come in fifth.

The Food and Agriculture Organisation of the United Nations will be holding the Second World Fishing Boat Congress at F.A.O. Headquarters in Rome from 5th to 10th April, 1959. A.Y.R.S. members wishing to attend please contact Jan Olaf Traung, Chief Fishing Boat Section, Technology Branch, F.A.O., United Nations, Viale delle Terme di Caracalla, Rome, Italy.

There appears to be a need for a rating rule for catamarans and trimarans to allow them to race together and with conventional craft. Walter Bloemhard and Michael Henderson have already produced rules but we could well have other people's ideas on the subject.

A rule for catamarans and trimarans can produce a rating in feet so that they can race with the C.C.A. or R.O.R.C. Alternatively, the rating figure can be a provisional Portsmouth " Yardstick " number for comparison with the dinghies.

THE BOAT SHOW, 1959. We have again booked a stand for next year's London Boat Show. It is felt that small models of all the interesting craft produced by members will show off the A.Y.R.S. work to best advantage and we will have these on the walls as in 1957. Photographs and plans will again be displayed. Drawings of how to take readings of the resistance of hulls, sail force and similar should also be shown. Anyone willing to make models and do drawings, please get in touch with the Editor.

We still need a few more members to make us financially secure. The publications have been expanded in size to cover all the interesting material which is now beginning to come in faster but they also get more expensive. If members will only talk about the publications at their yacht clubs and try to interest people in our work, it will go ahead faster. Prejudice against multihulled craft is quickly dying and it has been noticed that the person who last year was most against them, often has bought one this year. American members have a great chance to get new members as the A.Y.R.S. is as yet little known there. Mrs. Bloemhard will send application forms for new members on request.

I would like to remind members who have designed multihulled craft of our two forthcoming publications *Multihulls in* 1958 and *Cruising Multihulls*. We would like these two issues to be as complete as possible and would welcome suitable articles or accounts from which articles can be written with lines, photographs etc. as early as we can have them.

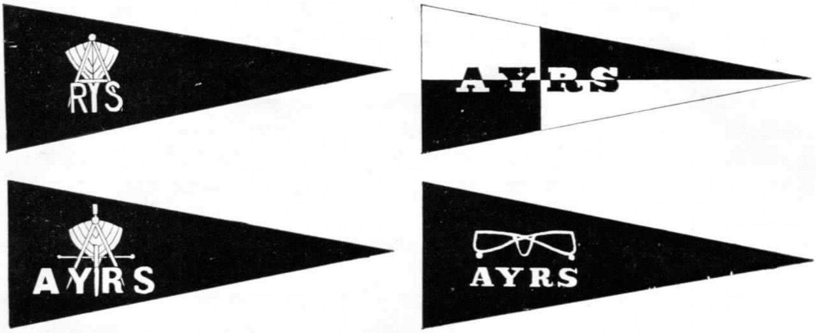
THE AUSTRALIAN CATAMARAN ASSOCIATION

Starting as the *Victorian Catamaran Association*, sailing *Yvonnes* and *Quickcats*, this organisation of Australian catamarans has produced branches in Queensland and West Australia and is now known as the Australian Catamaran Association. All three branches are extremely active with nowadays *Shearwaters* as well as the two Australian designed catamarans. Frank Strange, the secretary, says that the *Yvonnes* have proved themselves faster than the *Shearwaters* during the regular racing over last season, but of course, they are 4 feet longer. The *Yvonne* is described in publication No. 15.

The Australian Catamaran Association produces a 6-monthly publication called *Catamaran* giving news of the Australian and some other catamarans. Details and plans of the various types are given with some technical data.

THE A.Y.R.S. BURGEE

The drawings show four burgee designs. The top left one has been designed by Julian Godwin, of Auckland, New Zealand. It has the virtue of compactness but the A and Y of A.Y.R.S. are slightly obscure. The design below it uses the dividers and sections but the lettering has been made more prominent. The two right hand drawings are designs by N. G. A. Pearce. The top one uses a defaced L signal flag meaning " Stop, I have something important to communicate." The lower one shows a primitive Indonesian outrigger system.



Mr. Pearce points out that the function of a burgee is not merely to be pretty but also to be easily recognised when it is flapping about at the mast head. It should therefore be simple and presumably different to other burgees. The device might also be wanted for blazer badges, ties and shields or even for the cover of future A.Y.R.S. publications.

The cover photograph of this number is by Fullers, Commercial Photographers, 73, Tontine Street, Folkestone who have photographs of the craft which took part in the Cross Channel Race, 1958.

MODERN BOATBUILDING

INTRODUCTION

This publication is a summary of all the modern boatbuilding methods with the exception of those using steel and light alloy. Its purpose can be summed up in allowing a person to select the method which could suit his purpose to best advantage and also to stimulate thought on new methods and variations of the old ones.

Some accounts are very short as, for example, with the traditional methods which need not be fuller and fibreglass construction which would need a whole publication of itself to be of use. Simple methods which are not traditional have been given most space, such as strip planking.

As usual with such a review as this, new ideas appear. There are three such methods described here :

1. Fibreglass covered expanded polystyrene construction.

2. " Overdeveloped plywood " construction where plywood is marked out in the flat and pulled up into a boat shape.

3. " Mouldless fibreglass."

Finale. Perhaps the ultimate in wooden boatbuilding lies in " Overdeveloped plywood." Commercially made sheets of fibreglass may become available sometime with the possibility of "Overdeveloped Fibreglass Sheet." Perhaps the demand for mass produced yachts will be great enough for runs of moulded fibreglass little ships. These things lie in the future.

Our thanks are due to Reg. Briggs, A. Cooper of the EXPANDED RUBBER COMPANY, Dr. C. N. Davies, R. G. Hewitt of THAMES-PLY, C. G. James of FAIREY MARINE, J. S. Murphy of BRITISH CELLOPHANE, Norman Naish, Arthur Piver, Frank Priest of AERO RESEARCH, Francis Prout for articles and help in the preparation of this publication.

BOAT BUILDING GLUES

by

FRANK PRIEST

Aero Research Ltd.

One of the most important developments in modern boatbuilding is the extensive and rapidly increasing adoption of glued construction.

For those to whom the idea of this structure is still somewhat new, brief basic information about the glues used, and some knowledge of their record of service in boatbuilding should dispell any misgivings. In terms of performance the impressive fact is that boats of glued construction which have been in commission from 10-15 years are today structurally intact.

The glues most commonly employed are of three types of synthetic resins :

(1) urea formaldehyde glues ;

(2) resorcinol formaldehyde glues ; and

(3) phenol formaldehyde glues.

These possess ideal characteristics for boat construction including resistance to immersion in water, immunity to bacterial attack and extraordinary adhesion to wood. They each have a consistency similar to treacle syrup and are used with a liquid or powder hardener.

The resorcinol formaldehyde and phenol formaldehyde types are naturally gap filling and the special type of urea formaldehyde glue for assembly work also possesses this quality. The term gap filling means that a thick glue line will not craze and deteriorate on ageing and in fact all these glues are tested to a gap of .05″.

Most urea glues are colourless whereas phenol formaldehyde and resorcinold formaldehyde resins are brown, the latter in fact when fully cured turns nearly black.

Phenol Formaldehyde Glues

The use of phenol formaldehyde glues is mainly confined to making marine plywood in a hot press working at temperatures of anything between 115 - 140°C. This glue is extremely durable and will withstand total immersion in boiling water for long periods.

Resorcinol Formaldehyde Glues

The resorcinol formaldehyde glues have porperties which exceed perhaps those normally required in structural boatbuilding. For example they conform to Admiralty Specifications calling for extreme weathering conditions and also resistance to immersion in boiling water.

The application of these glues can be quite critical, particularly with reference to temperature during the curing periods. The Admiralty specification calls for a curing temperature of not less than 80°F. and unless some form of heating is applied to the glue line the use of the glue is therefore impracticable. However, it is fair to say that good results can be obtained at a glueing temperature of between 60 - 65°F., but the temperature should not drop below this figure.

Resorcinol glue does not readily wet the surface of the wood and spreading of the resin can become difficult. Sometimes it is necessary actually to rub the glue in to the wood surface to make a satisfactory joint. The use of a resorcinol formaldehyde glue is, therefore, justified only where a superlative standard of durability is subservient to other considerations.

Urea Formaldehyde Glues

It is the urea formaldehyde glues that are most widely used by the boatbuilder both professional and amateur. They have proved completely adequate, consistent and dependable in every type of boat construction and have the advantage of extreme simplicity in use combined with outstanding economy. From this it will be judged they are not critical to use and will harden at comparatively low temperatures. The wetting properties of these glues are very good and therefore they are easy to spread and consequently it is not difficult to make a good joint.

The hardener can be added to the resin itself just prior to application (mixed application) or it is applied to one surface and the resin to the other (separate application). For general purposes, therefore, it would seem that this latter type of glue is perhaps the most practicable as no careful weighing of proportion of hardener and glue is necessary.

Manufacturers give details of the correct method of using their produce. These are quite simple and if carefully followed, the glue will always do its job. Their instructions include information on mixing, application, grades of hardeners (fast, medium and slow), approximate clamping times at different temperatures and perhaps the most important of all, the closed assembly times. This is the time elapsing between the assembly of the joint and the final positioning and clamping which must be done before the glue begins to gell. The faster the glue sets the sooner the job is done. The speed of setting, however, is relevant to the assembly time. A fast curing glue mix allows a very short time only for positioning and clamping and it is not always convenient to make use of the fast setting properties in the mix because of the limited closed assembly time.

The manufacturer, therefore, provides a choice of hardeners controlling the curing time at given temperatures. As an example, the use of a medium setting hardener used say, at an air temperature of 60°F. will take approximately 4 - 5 hours to set. The closed assembly time at this temperature is in the order of 15 - 20 minutes. If the air temperature were 70°F. the glue used with this hardener would set in 3 hours but the closed assembly time would drop to probably below 10 minutes. Therefore, when glueing at comparatively high temperatures, the slow hardener should be used. The slow hardener is formulated to give a 4 - 5 hour setting time at say 70°F. with a closed assembly time of 15 - 20 minutes. At a temperature of 60°F. the slow hardener will need perhaps 8 - 10 hours to set, but it will give probably 30 - 40 minutes closed assembly time. Conversely if glueing is required to be done under cold conditions the fast hardener is required.

When maximum speed of production is required as in some shipyards, the setting time can be reduced to as little as one hour by strip heating and various other means of local heating. This means, of course, that at higher temperatures the glue sets much more quickly.

Perhaps the best known separately applied glue is Aerolite 300 and this type has been prominent in boatbuilding since the pioneer days of glued construction.

As soon as hardener comes in contact with the resin, setting commences by chemical interaction and when using the mixed glue this takes place as soon as the hardener is added to the resin. In the case of the separately applied glue the hardening of the resin does not take place until the surfaces are actually brought together in the joint. As these glues are gap filling it is necessary only to hold the surfaces firmly in contact and no special clamping is necessary. In addition this gap filling characteristic gives a perfect joint where roughness and irregularities are present in the timber.

The first rule in glueing is that the liquid glue must wet the surface to which it is applied. This wetting is sometimes difficult when glueing to greasy woods such as teak and to get a good joint the surface of the wood must be temporarily degreased. This is easily done by wiping down with any degreasing agent such as trichlorethylene, carbon tetrachloride or even Teepol.

Some plywoods are also difficult to wet due to what is known as "case hardening." The surface of the plywood appears to have a sheen which it is thought is caused by a blunt knife when cutting the veneers and is more apparent on very thin plywood. The remedy is to sand the surface lightly before glueing, taking care that it is well dusted as it is most important that the glue or hardener should not be spread on top of dust.

Failure of a joint can be caused by high moisture content of the timber which should not be more than 18% and preferably between 14 - 16%. If wet timber is glued it has the effect of diluting the glue causing it to penetrate into the wood and producing a starved glue line.

Failure of a bond due to high moisture content of the timber is recognised by the appearance of a white chalky substance in the glue line caused by the precipitation of the glue itself.

Although pressure is not necessary to make a strong joint using these glues it must of course be sufficient to bring the surfaces near enough in contact. In other words the joint must be completely filled by the glue and it must be certain that the glue remains in the joint. If on inspecting a failure the glue on one surface of the joint shows a glassy appearance it is certain that there has been no contact on the opposite surface.

Finally the urea formaldehyde glues can be obtained in either liquid or powder form, as an example Aerolite 306 is the powder form of Aerolite 300. The resin in powder form has the advantage of having a storage life of at least two years. The liquid resins like Aerolite 300 have a minimum storage life of from 3 - 6 months and in fact the containers themselves show clearly a specific expiry date. However, as long as the resin is liquid enough to be spread it will give good adhesion and if stored in a reasonably cool place this liquid state can last for many weeks after the actual date given on the container. There is no limit to the life of the hardeners.

CLINKER, CLENCH OR LAP STRAKE CONSTRUCTION

This is the traditional method of the Vikings, though it is also found in the Solomon Islands in the Pacific. It is characterised by the planks overlapping each other where the edges meet.

Clinker building was evolved from adding strakes to a dug out canoe. Indeed, a normal dugout from prehistoric times with the strakes in position has only recently been found. In the early Viking ships, each strake was made from a separate tree and lugs were left in place to which the frames were tied, the planks being sewn together at the seams.

Modern Clinker Construction. All around the coasts of Northern Europe are found little boatbuilding yards which have been making clinker built craft for generations. The method used is to align a series of " Moulds " or " Shadows " to give the hull shape and fit onto them the keel, stem and sternpost or transom. The planking is then laid on, strake by strake from the keel to the gunwale. The two garboard strakes are set into the keel or on the hog as well as the stem and transom. As each strake is laid, it is faired into the stem and sometimes the transom. Its outside edge is usually left square but it can be given a stroke or two with a plane to make the next plank sit better.

When the planking has all been laid and the gunwales fitted, the craft is taken off the moulds. Ribs, usually of ash, are then steamed and put in.

Fastenings are usually copper nails through the junction of the planks and to the ribs. They are clenched over rooves, or copper washers, on the inside. It is unusual to caulk a clinker built boat.

Clinker building has the reputation of producing a flexible though strong boat and it does not appear to have significantly more resistance than carvel construction.

Glued Clinker. The only improvement possible to modern clinker construction would be to use glue between the planks and fewer fastenings. It does not appear possible to avoid the fastenings altogether, but they could be withdrawn after the glue has set.

The " lands " or square edges of the planks could be planed off if glue were to be used, producing a hull which had the appearance of carvel construction. The outer skin of the moulded plywood hulls of the Prout *Shearwater III* are thus made and give a very pleasant and smooth outer surface.

Plywood Clinker. All clinker built craft need ribs or strength around the girth of the hull such as is given by the inner skin of the *Shearwater* hull. This can also be achieved by using plywood planks and this appears to be a very satisfactory way of making light craft of all types. Clinker building has the advantage of being suitable for *thin planking.* A carvel built boat with thin planking would be difficult to keep watertight.

CARVEL CONSTRUCTION

Carvel building is the traditional boat building method of Southern Europe and the Mediterranean, India and Pakistan. Its nature lies in the fact that each plank's edge only comes up to the next plank and does not overlap it, as with clinker building. As already mentioned, the planks must be fairly thick to allow the seams to be caulked and made watertight. Though the ships of Ancient Egypt, Chinese Junks and certain Pacific native craft are built with the planks coming together in this way, one cannot really consider them as carvel built. The ships of Ancient Egypt, for example were made of short planks which were edge nailed to each other so that Herodotus likened them to bricks building a wall. The large Micronesian Proas were similarly built. Chinese Junks mostly have flat floors and nearly all have chines.

Modern Carvel Construction. The first stage in carvel construction is to lay down the keel, stem and stern posts. Then the frames are made and attached to the keel, giving the skeleton framework of the hull. Lastly, the planking is laid on from the garboards to the gunwale. Except for a few planks at the turn of the bilge, each plank must be cut from a considerably wider one so that it is wider in the middle than the ends because of the extra girth. There will also be sideways curvature in many planks either upwards or downwards. When the hull has been completed, the seams between the planks are caulked with cotton.

It is an improvement on the normal carvel boat if the seams are glued together with a gap filling glue on construction, thus making the whole hull a single structure which is immune from leaks. Many racing craft are built thus nowadays, notably the Dragon.

STRIP PLANKING

Strip planking has been more used in America than Europe in recent years but it has a time honoured history dating back to the Roman galleys. It consists of making a carvel built hull using very narrow strips for the planking so that, instead of having to shape each plank from a much wider one, the planks can be given enough " edge set " to plank the hull without being shaped. It is very suitable for the amateur boat builder.

In the older form, paint was freely used between the strips to make the seams watertight and good durable hulls resulted which did not need caulking. Nowadays, we have the synthetic resin glues which make an even better job.

The Frames or Moulds. If it is intended to use frames or moulds and put the planking directly on them, it is recommended by some that their number be double that of the conventional carvel built boat. Otherwise, the edge setting of the strips can produce buckling. However, by using a strip aligner such as that described by Sam Rabl in in his book BOAT BUILDING IN YOUR OWN BACKYARD or by clamps, the strips can be held fair with each other till nailed and glued. The same number of frames as in orthodox carvel can then be used.

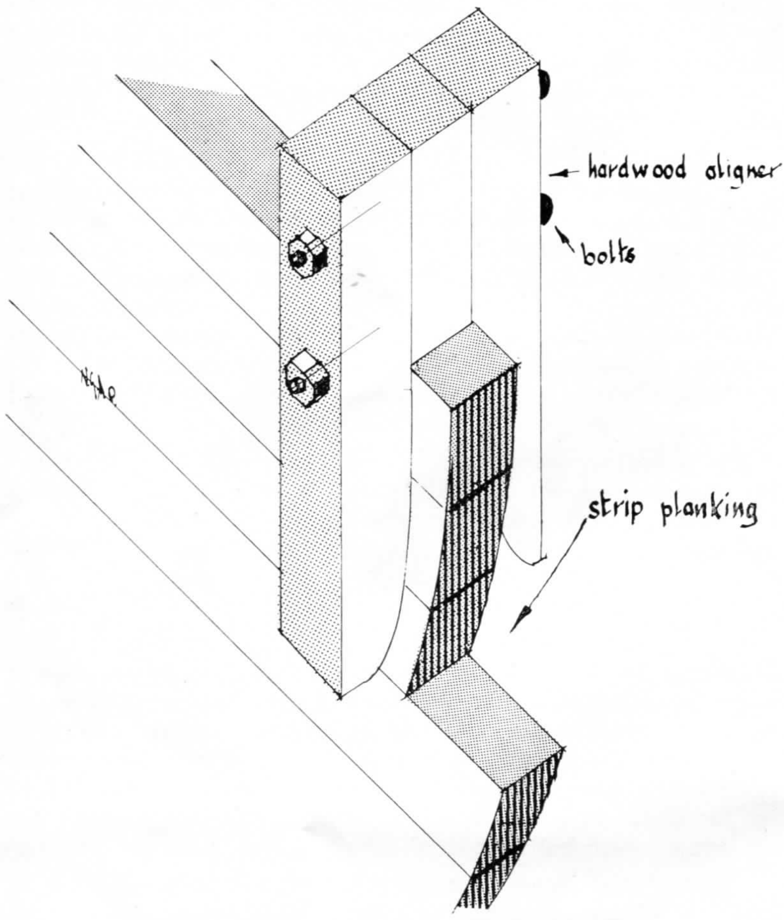


FIG. 1. *Sam Rabl's " Strip Aligner."*

Frames can be dispensed with if strip planking is used or steamed ribs can be put inside the formed skin. Alternatively, moulds can be used with ribbands from stem to stern laid on them and the ribs steamed and bent on these before planking begins. The planking can then be attached to these ribs as it is laid on.

Putting on the Strips. The main difficulty is to know where to begin. The girth of the hull is greater in the middle than at the ends so, if one starts at the keel, the strips become very U shaped along the sheer. This means that these strips are excessively edge set. If one starts at the gunwale, there is a large slice left in the middle of the boat when the planking reaches the base at the stem and transom. This slice then needs to be filled with shaped planks, or again, excessively edge set strips.

The logical way to avoid the above two difficulties is to start planking from a point half way along the girth of the largest frame and let the plank take its place along the other frames so that it has no edge set whatever. Indeed, this allows this plank and one or two on each side of it to be wider than the rest, thus saving work. From this middle plank, the strip planking can begin, working out to the gunwale and keel on each side. If this method is adopted, the boat will have to be turned over between laying the two sets of strips.

The Strips. These may either be rectangular in section or with a convex surface at one side and a concave surface at the other, the radius of these curves being the thickness of the planking. Making both these curves semi-circles would avoid the need for trimming the strips but the fine edges get broken easily and are difficult to work with. In practice, the rectangular strips have been most used in America but in England, the strips with curved edges seem to be preferred. There is little to choose between the two types for work because the moulded strips leave surface gaps which must be filled, unless the curve is a semi-circle. This about balances the work involved in touching the rectangular strips with a plane.

The strips are about 1/3rd greater in width than thickness, though they may be up to twice as wide as this in places where the edge set is least. They may stretch from stem to stern in one piece or be scarfed. For scarfing, it is worth while to make a mitre box and the scarf need not be longer than three times the strip width. The scarf edges should be left rough so that the glue will stick firmly to the wood. The scarfs should be well spaced along the boat so that no weakness appears.

Putting a strip on. From all the information available, rectangular strips seem to be as easy and cheap to deal with as the moulded shapes. However, if this shape is used, each strip must get a stroke with a

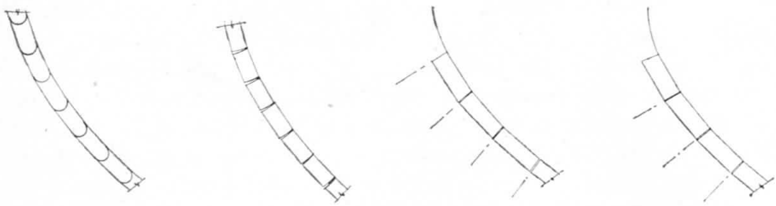


FIG. 2. (*a*) *Curved edges.* (*b*) *Lower edge planed.* (*c*) *Upper edge planed.*

plane to make it fit snugly against its neighbour. The glue will only fill a gap of 1/16th inch. The trimming can be done in either of two ways :

1. Each strip can be fitted to its neighbour and put on, leaving the free edge untouched.

2. Each strip, as it is put on, is trimmed so that its free edge will be square to the mould or frame and accept the next strip to come without planing. This system allows one to plane only the upper edge of the strip and it need not be either marked or taken off before doing so.

Nailing. Each strip is nailed to the next strip to it by square galvanised boat nails $1\frac{1}{2}$ times the width of the strip, spaced 12 to 15 inches apart though extra nails may be necessary in places to seat the strip firmly to its neighbour. Each nail may be put in obliquely to increase its holding power, first drilling the wood to prevent splitting. The glue should be quite strong enough to give a firm boat on its own, the nails being mainly used to hold the strips in position till the glue sets. The heads of the nails should be driven

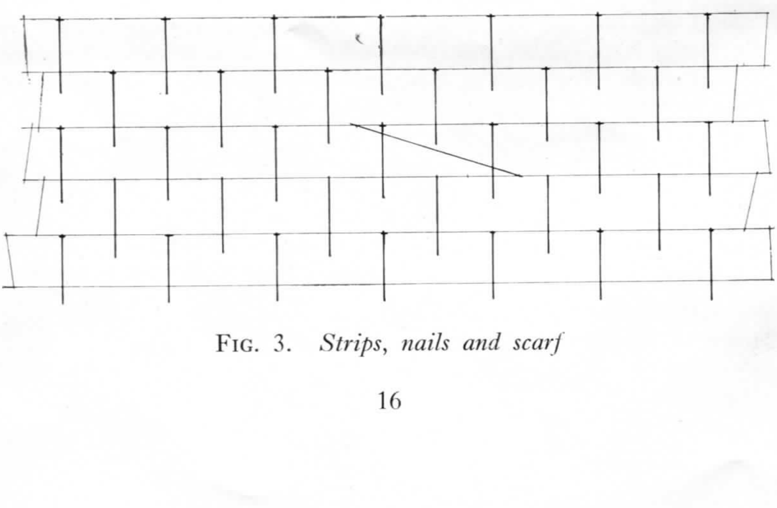


FIG. 3. *Strips, nails and scarf*

below the surface of the strip or countersunk, if necessary. Their position should be marked on the outside of the strip to prevent another nail from being driven on top of them.

The Glue. The glue used can be any of the good waterproof glues except for teak, when it must be a resorcinol glue such as Cascophen or Aerodux. It can be put on by brushes or a roller which must be carefully cleaned in special solvents before stopping work. Rubber brushes can also be used and, if not too much glue sets on them, it can be broken off before starting work on the next occasion. Alternatively, disposable brushes can be made from a length of rope whipped every four inches or so and the ends frayed out. Some fibres may be shed but these will not affect the work.

MARINE PLYWOOD

A tree can be thought of (most unromantically) as a cellulose structure designed by Nature to have a high strength to weight ratio. But trees grow in all kinds of soils in all kinds of climates and Nature has varied their structures accordingly. We can therefore have trees with great elasticity like the willow ; rigidity like the beech ; lightness like the balsa or resistance to wood borders like teak. We can correctly assume that every tree is the structure most suited to its natural place of origin, whether wet, windy, tropical or temperate.

Wood can therefore be thought of as Nature's plastic material and Man will have to be mighty clever to improve upon it. In fact, for strength to weight ratio and for general boat building purposes, wood is still the best material available. Not only is this so but we can still become personally attached to wood in a way which would be difficult with a material like fibre-glass-polyester resin. We have not yet reached a stage in our civilisation where a romantic poem is likely to be composed to a plastic utensil.

Wood is therefore fine material but its basic purpose was to hold up leaves and survive natural catastrophies like lightning, floods, gales, droughts and injuries from neighbouring trees. These things produce knots and shakes and variations in density. Also, all its strength is along the grain to withstand the compression and the shearing stresses of gales, while for boatbuilding, we need strength in many directions.

The few faults of wood as a material can be removed by first slicing it into thin veneers and removing the faulty parts and then glueing it together again to give the strength as and where we want it. If we want the strength to be greatest in one direction only as for frames, deck beams, keel and stem, we glue the strips of wood with the grain all running the same way. If we want strength in all directions we glue the wood so that the grain of each layer lies at right angles to that of the layers above and below it. The former process is called " Laminating " the wood and is most useful as an economy of wood and work and gives greater strength for the same weight than shapes sawn out of the solid oak crooks which were the mainstay of the traditional boat builder in wood. The construction of sheets of wood of layers with the grain running in different directions results in plywood.

Plywood and laminations are the perfection of wood for boat building. Plywood can either be made in flat sheets or it can be built up into the shape of the boat by either a hot or cold process of moulding. These last two will be the subjects of separate articles but for the present, the commercial manufacture of plywood sheets will be described.

THE MANUFACTURE OF PLYWOOD SHEETS

This article is taken from a publication of Messrs. Thames Plywood Manufacturers and describes their processes. We are grateful for their permission to use it.

Steaming. Logs from all over the world come by barge up the river Roding to the Thamesply works at Barking, Essex. As each log is brought ashore by the cranes, it is graded by experts for texture, grain and defects, thus ensuring that it is used to the best possible advantage. The logs are then steamed in great troughs up to 40 feet long for a number of days depending on their size and type of timber. This steaming removes any internal stresses caused by irregular drying and softens the tissues of the timber so that the peeling knife cuts a silky smooth veneer, instead of the rough surface caused by " tearing " veneer from a dry log.

Peeling. After steaming, the logs are stripped of their bark and sawn into lengths for the next process — peeling. This consists of rotating the log against the blade of a long knife so that the veneer comes off as a continuous sheet, like unrolling a roll of paper. This method of making the veneer uses all the wood of the log and there is no waste in sawdust. Gears from the main drive take the knife towards the long centre as the veneer comes off, the rate at which it travels varying the thickness of the veneer.

Slicing. For some purposes, the log is made rectangular in section and is held steady while a knife moves across it, shaving off rectangular veneers of automatically controlled thickness.

Cutting out defects. Being natural timber, the veneer all too often contains split, knots, wormholes, discolouration and other defects. These are all cut out by hand-operated clippers, only sound material being allowed to pass.

Drying. If plywood is not to warp, it must be built up of veneers all of which have the same moisture content and this content is governed by the glue used for bonding within rather critical limits. The veneer is therefore fed into an automatic drier some 50 feet long. The time of transit is varied to suit the individual species of wood and its thickness. When it comes out, the moisture content is checked by an electrical meter, whose readings are, in turn, checked by laboratory weighing.

Grading and sorting. The dried veneer is now carefully sorted into different qualities for use as face, back or core. Some of it pays another visit to the clippers, which remove any splits occurring in drying and any defects overlooked during the " wet clipping " stage.

Glueing and assembling. The sheets of veneer are now made to the size required and every alternate sheet in the " sandwich " is covered on both sides by a phenol-based glue for marine plywood by a glue spreading machine. The grain of the glued layers will ordinarily be at right angle to the dry layers.

Bonding. To cure the resin glue and bond the veneers into an inseparable entity, heat and pressure are needed. These are supplied by hydraulic presses, the largest of which can press at one go 12 boards up to 16 ft. long and 6½ ft. wide. Temperature, pressure and time under pressure are all set on the control panel of the press. A button is pressed and the curing process begins. When it is complete, the press opens and the plywood has been made.

Finishing. The plywood is now cut to size by double trimming saws. It may still have an uneven moisture content which is evened out by stacking for a while. Finally, the surfaces are sanded or scraped to produce a silky surface ; the sheet is inspected for quality and it is ready for despatch.

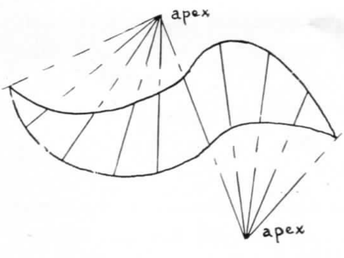
At every stage of the manufacture of Thamesply, there is an extensive inspection system so that the chance of a faulty sheet of plywood actually getting to the user is almost an impossibility. Moisture content and faults in the wood are the main things which are checked at every stage possible.

DEVELOPED SURFACES

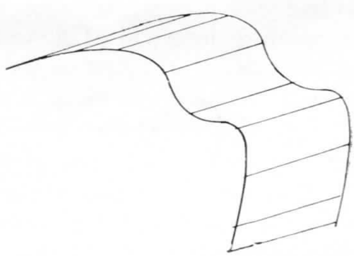
Flat sheets of commercially made plywood will not conform to the shape of the usual boat. If one tries to do this, it will split, tear or get waves in it. Nor can one twist plywood more than a certain amount without distorting it. However, it is possible to design a boat so that plywood sheeting can be used for the skin and it will sit easily and comfortably on the frames and need no forcing. The method used is known as the " Developed Surfaces " procedure because the surface of the hull is composed of parts of cones and cylinders which are the two shapes around which flat plywood can be wrapped. A boat designed with developed surfaces will ordinarily have a chine between the topside and bottom.

Boats designed with developed surfaces are only slightly inferior to freely designed craft in shape but they are both stronger and lighter than craft of conventional construction and they tend to be cheaper.

The principle of Developed Surfaces. The two figures show the two kinds of surfaces which can be covered with flat sheets of plywood without distorting it in any way. The figure on the left shows a surface which can twist and bend quite a lot but plywood will fit snugly to it AS LONG AS A LINE DRAWN ON ANY PART OF ITS SURFACE CAN POINT TO A SINGLE FOCUS. This system of design is called " Conical," though the shape is not a part



Conic development



Cylindrical development

of a single cone but rather of many cones. The focus is called the "Apex." The method of changing from one apex to another is also shown. The figure on the right shows the plywood bent back and forth in one plane only and is called "Cylindrical."

Design Procedure. The bow below the chine can be designed from part of one "Apex" as far back as the largest section. The position of the apex is slightly forward of and below the stem and to the opposite side from that being designed.

1. The keel line is first drawn and its shape is variable according to the nature of the design. It is not greatly affected by the design method.

2. The position of the apex is selected and from it, lines are drawn which cut the keel line and project beyond to give the shape of the bottom, below the chine. If the keel line just forward of the largest section is straight, the bottom of the largest section will also be a straight slope up from the keel. The bottom of the craft aft of this can then be simply designed by having it curve in one plane only to the transom. The topsides above the chine can be vertical or slightly sloped out and only curved in one plane. A boat designed in this way would make a good hydroplane type or sailing dinghy.

The above design procedure is quite easy and, given some practice, good boats can be designed with it. If, however, we want to be more elegant and carry a boat shape right to the stern, we are in difficulties because we have to marry up one conical projection with another. This can be done in three main ways :

1. One of the construction lines of the bow can be projected astern to make an "Apex" for the after body. This will then lie aft, above and to the same side as that being designed.

2. We can finish the fore body with a straight floor as in the hydroplane design described already and take an athwartships line on which to place the apex of the after cone. This apex can be placed on either side of the side being designed.

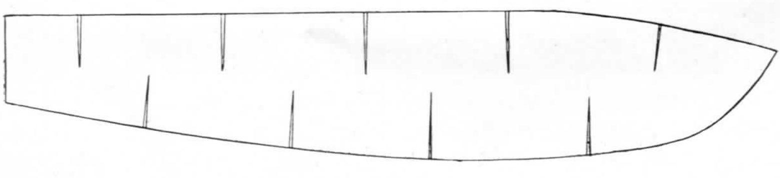
3. The midships section of a conically developed forebody is covered with plywood which is almost "Cylindrically" developed fore and aft because the apex is so far away from it. If the apex were at infinity, it would be developed thus. This is more true of the slim hulls of paddling canoes and multihulled craft than for wider craft. For this reason, it is often possible to marry a conical forebody onto a cylindrical piece in the middle of the boat, though slots may need to be cut to allow for some distortion. This cylindrical piece may then be married onto a conically developed afterbody.

Catamaran Hull Design. Developed plywood hull design seems ideal for the narrow hulls of catamarans and trimarans. Dr. C. N. Davies has shown how elegant a shape can be produced in the paddling canoe we had on our stand at the 1958 Boat Show and further improvement might just be possible. One of the advantages of the system lies in the fact that the plywood can be shaped in the flat and drawn up into the hull form afterwards.

OVERDEVELOPMENT — A SUGGESTION

Developed plywood can produce useful hulls but these must have a chine. This might be useful as with hydroplanes or unobjectionable as with Dr. Davies' canoe but we should at least try to produce even better hulls from flat plywood by a process of " overdevelopment."

" Overdevelopment " may be defined as the joining of many conically developed parts of a hull to give a good shape. To achieve it, one can start with a flat sheet of material and shape it as in the drawing. V's are then cut at both sides of it at spacings and of shapes which have not been fully worked out. If this flat sheet is then pulled up so as to close the V's, half a hull shape will appear. When the same process has been repeated and joined to the first part, a hull will appear. The hull between each V will assume a conically developed form and there will be a " Hump " at the apex of each V which will be greater or less according to the spacings of the V's. However, it is believed that the V's need not be spaced closer than every 2 feet for many shapes of hull, and still give a smooth surface without humps at all.



Flat sheet capable for forming half a hull

The V's may either but butt joined or scarfed and will be glued together when they are brought into contact. If butt joined, a strap would have to be glued inside the junction.

It is stated above that, when the sheet of plywood is drawn up to close the V's, half a hull shape appears. This is not strictly so, in practice, because the spring of the wood distorts it at this stage. However, when the two sides are joined, the true hull shape appears.

Designing for "Overdevelopment." This can be done in two ways :

1. The hull shape can be found by a process of trial and error, using at first light cardboard, "cellotape" and scissors. The size can then be stepped up by using heavier cardboard and finally plywood. In the plywood stage and presumably at full size, V's would not at first be cut out. A saw cut down the sheet could be overlapped and stapled in position till a satisfactory hull shape was achieved. Then, a further saw cut would give the V needed.

2. The hull can be freely designed and made from cold moulded plywood as described by Francis Prout in the following article. When the glue has hardened completely, the two halves of the hull are cut apart and saw cuts are made from the gunwale and centreline till the half hull can be flattened out completely. The saw cuts will then open out into V's of the appropriate shape.

Before the saw cuts are made, it might be of value to staple a thin plank along the turn of the bilge from stem to stern of the half hull with no edge set. It is thought that the saw cuts might only need to be made down to the edge of such a plank.

Summary. A method of boat construction is suggested which may produce round bilge hulls more cheaply and easily than any current constructional method. It is believed to be more suitable for catamaran hulls than for dinghies, though there should be no difficulty in using it for either.

COLD MOULDING

by

FRANCIS PROUT

One of the best types of moulding from wood veneers and resin glues is done by pressing the veneers together by a bag drawn over the mould and shell and creating a vacuum inside it. All this is then heated in an oven. We ourselves use this method to make the *Shearwater* moulded hulls. But the moulds have to be very strongly made to withstand the pressure and the equipment is expensive and elaborate. In this article, I propose to outline a very efficient and simple type of moulding very suitable for the amateur. It is a cold moulding process, using a staple gun for obtaining contact between the glued surfaces.

The Mould

The mould required for this type of moulding is fairly simple to make. Light frames should be used about one foot apart to give the desired shape and battens are put on these outside with gaps between them of no more than one inch. A key place should be left for the keel, stem and transom.

The mould should be varnished thoroughly and given a coat of a good wax polish as a separating agent. When this is done, the keel, stem and transom can be set in place and the transom and stem planed down to fair with the mould.

Veneers

A first quality veneer should be used, the thickness of which is determined by the number of laminations and the thickness of the skin. The grain of each layer of veneer should run across the grain of the other layers.

The Inner Skin

When making, for example, a two-ply dinghy with two 3 mm. veneers, the first step is to cut and shape all the planks of the inner skin so that they cover the mould transversely. Narrow strips 3 or 4 inches wide are used, except at the bow where a wider piece can often be fitted. The inner skin is first put on the mould without glueing.

Starting at the bow, temporarily staple the first piece to the stem, making sure that the veneer lies snugly on the mould. Fit the next piece alongside, planing off the edge where necessary to ensure an exact fit and so on till the last cross veneer is fitted and stapled temporarily to the transom. Repeat on the other side. The boat will be built upside down and the gunwale staples should be at least 2 inches below the gunwale line so that, when the shell is cut through at the gunwale, the staples are left on the mould.

When the inner skin has been completely made, all the staples in the stem, keel and transom are taken out. Glue is spread liberally on all parts where the veneers touch them and the strips are restapled back, making sure that the seating is good. When the glue has set, all the staples at those places are removed.

The Outer Skin

The laying of the top skin, the grain of which will run fore and aft, is a longer job than laying the inner skin and care will be needed in shaping the planks so that they lie flat onto the mould. There are two methods of laying the top skin, one with scarfed joins between adjoining planks which is the better and the other with butt joins between planks which gives a possibility of little holes where the planks cross each other which must be filled before varnishing or painting. Scarfing is the better job so let us consider this method. It forms a complete outer shell with no possible leaks except through the tiny staple holes which can very easily and effectively be filled.

The first plank is cut out the correct shape to fit along the keel and an exactly similar one is made for the other side. Mark a line $\frac{1}{2}''$ from the lower edge and plane down from this line to a feather edge. This plank is them temporarily stapled on at its top edge, leaving the scarfed lower edge a little free so that the second plank can be pushed a little way under it and it will be held so that its shape can be marked. It can then be cut to shape, its pair made for the other side and the edges scarfed. Repeat this, until all the planks are laid and stapled temporarily in position. There will then be the whole outer skin cut out and ready for glueing.

The Glueing

Before taking off the outer skin to apply the glue, it must be marked so that it can be put on again as accurately as before. This is done by making definite pencil lines right across all planks on either side at intervals of about 18 inches and labelling the planks A, B, C, D etc. The planks can then be removed.

When the planks have been taken off, that part of the surface of the inner skin over which the first planks will go is liberally spread with glue. The first plank is then put on and its mate at the other side is similarly dealt with, both being thoroughly stapled in place. Then the scarfed surface and enough of the inner skin to fix the second plank is spread with glue and the second plank is stapled on so that the pencil marks are aligned. This process is then continued till all the planks and scarf joins are stapled and glued in position on both sides.

Finishing the Shell

When the glue has set, all the staples are removed, the staple holes are filled and the hull is sand papered. The gunwale line is marked out and cut. The screws holding the stem and transom in position are taken out and the shell is taken from the mould. It is better to tie the hull across with pieces of wood to prevent spreading till the gunwale and thwarts are fitted, after which the dinghy will remain exactly the same shape always.

Tools needed

Normal woodworking tools, a " Staple Gun," a pair of pinchers, screwdriver and cutting knife.

Glues

Aerolite 306 or any gap filling synthetic resin glue.

HOT-MOULDING

This process is really only suitable for the professional boat builder. The details which follow are taken from an article by C. G. James in the SHIP & BOAT BUILDER, of March, 1955. They describe the process used by FAIREY Marine Ltd., in manufacturing their range of hulls such as the *Firefly*, *Jollyboat*, 505 etc.

All Fairey Marine hulls are hot moulded in autoclaves, using the rubber bag technique and synthetic waterproof adhesives. The method was originally developed during the war for making aircraft and consists of layering up veneers on a male mould, covering all with a rubber bag and producing a vacuum inside it so that the atmospheric pressure will hold the layers together and heating it in an autoclave.

The Mould. This is very strongly and accurately made to the internal shape of the hull. It sits on a base plate which is, in turn, mounted on a trolley on a track for easy handling.

The Skin. This is of two or more layers according to the boat being moulded. The veneers of selected mahogany, Agba or 5/64 plywood to British Standards Specification 1088 are layered up diagonally on the mould. Each layer is secured to the one below by synthetic waterproof adhesive applied by glue spreading machines and stapled in position by hand staples which are removed after curing. The stem, hog, keel and transom are integrally moulded in the boat.

The Bag. At Fairey Marine, the rubber bag does not completely surround the shell and mould but is clamped to the base plate on which the mould sits. This is done to allow the use of the trolley. A vacuum of approximately 27 inches of mercury is then created inside the bag and then, after checking that all skins are lying evenly, the complete assembly is wheeled into the autoclave where steam heat up to 100°C and an additional pressure of 45 lb. per sq. inch is applied, making a total pressure of about 60 lb. in all. Initial curing takes approximately $\frac{1}{2}$ hour but, after removal from the moulds, hulls are left for a week or more for final curing before being trimmed and worked upon.

The stiffness of the finished hulls is such that no frames are required in the racing dinghies, although the strength to weight ratio is better than with the older and conventional forms of construction by through-fastening to frames.

Adhesives. The modern synthetic resins are a great advance on the old pre-war adhesives. They are practically fungus and bacterial proof and inert against attacking elements such as oil or weak acid. When used properly, they not only make an extremely strong joint — the wood generally failing before the adhesive. When used by the heat and pressure method of moulding hulls, they are forced into the wood cells and fibres, thus making the hull extremely resistant to water soakage (of great advantage in racing dinghies) and also resistant to worm and termites which is a major factor when boats are used in tropical waters.

The adhesives used in Fairey Marine boats comply with British Standards Specification 1204 or B.S. 1203 and all plywood complies with B.S.S. 1088. It may be of interest to note that the firm have had an unvarnished *Firefly* hull on test for more than 6 years, lying in a creek embedded in mud. The boat is at times completely covered by tidal water and exposed to summer and winter climatic conditions. Last year, it was brought ashore, cleaned out, rigged and then sailed in a local race where it gained a second place.

Damage Repairing. A Fairey Marine hull is as easy to repair as a conventional type. The Company operates a repair scheme and supplies repair kits for home repairs.

Conclusion. For smaller craft, the hot moulding technique for hull manufacture has great advantages, especially when allied to modern production methods. There is no doubt that the method can be extended to larger craft and research is proceeding in this direction.

FIBREGLASS

by

NORMAN NAISH

This material which has come into prominence during the last five years has a great deal to recommend it as a boat building medium and at the same time has a number of drawbacks.

It consists basically of a laminate of glass fibres impregnated with synthetic resin and its properties are great impact and torsional strength in relation to its weight, a good surface finish and almost complete inertness when exposed to water and atmospheric conditions.

The usual method of construction when used for boats is to lay up the glass fibre and resin in a female mould which may be produced in aluminium or stainless steel or may itself have been made in fibreglass over a male former. Whatever material is used for the mould, the surface finish of the end product will never be better than that of the interior of the mould itself.

The lay up is completed in stages as follows : The interior of the mould is first brushed over with a releasing agent and, after this has dried, a thin coat of resin (the " Gell coat") is applied, the resin having been previously mixed with small quantities of accelerator and catalyst. When the gell coat has cured to the consistency of rubber, a further coat of resin is applied and then sheets of glass mat or woven glass fabric cut approximately to fit the mould. A liberal quantity of resin is now applied to this glass fabric and the whole is worked with metal rollers in order to drive out all air and to bed the fibres down in the resin. Further coats of glass fabric and resin may be applied according to the thickness required for the particular boat.

The time taken for the resin to cure is dependent upon the temperature and the amount of accelerator and catalyst added and it is therefore possible to control this time according to the complexity of the job in hand. The best results are obtained at a temperature around 65° Fahrenheit and with a curing time of about 30 minutes.

From the nature of the material, it is best suited to the manufacture of curved surfaces, which shape gives inherent strength and large flat surfaces should be avoided. It can be seen, therefore that a round bilged boat will be more satisfactory than a hard chine one when constructed of this material. Where more strength is required, it is a simple matter to produce ribs of a " Top Hat " section by moulding strips of fibreglass over formers of polythene tubing or even rolled up paper.

Deck sections, thwarts and buoyancy tanks may be moulded separately and then bonded to the hull with an application of resin. Where necessary, wood and metal sections may be bonded into the laminate and this should always be done where fixings are likely to be highly stressed, such as at chain plates etc.

To sum up, fibreglass will produce a watertight and extremely strong boat requiring the minimum of upkeep and may be readily worked by the amateur. On the debit side, the material is expensive and the cost of a mould reduces its attractiveness for a " one off " job. By the same token, a failure can be very costly and in this connection, a section of a hull which was cast for *Gemini* (described in A.Y.R.S. No. 15) had to be cut out and re-cast due to bubbles appearing between the hull and the mould. This break down of the surface which causes the well known " orange peel " effect is believed to be caused by thin spots in the gell coat or by local chilling due to draughts during the curing period.

" CELLOPHANE " FILM AS A RELEASE AGENT

by

A TECHNICAL EXPERT OF BRITISH CELLOPHANE

The technique of polyester/glass lamination has been simplified and improved by the use of " Cellophane " cellulose film as a release agent. A growing number of commercial firms are now using sheets of the film in the manufacture of flat panels and panels with one plane of curvature, in place of waxes and sprays. They have found that " Cellophane " film is cheaper and easier to use, gives a smooth glossy surface to the laminate and simplifies the all-important " wetting-out " process (removal of air bubbles). Also, it enables panels to be moved about before they have cured and the " Cellophane " film can be left on the surfaces of the laminates, protecting them from damage, until they are used.

The working method is as follows : a sheet of " Cellophane " film is laid on a working table, and coated with a thin layer of resin, which can be pigmented if required. The resin is then allowed to gel. The chopped strand mat, impregnated with resin, is laid on the sheet, and another sheet is laid on top, so that the strand mat is sandwiched between the two. Excess resin and air bubbles are then forced out of the lay-up with rollers or squeegees. The more care taken over this, the better will be the quality of the finished laminate. When this process is completed, the edges of the film are folded over and secured with cellulose adhesive tape. The lay-up is now effectively ' parcelled ' and is a moveable unit. It can be taken to another table or curved into a mould and left to cure.

It is not generally practicable to use a " Cellophane " film release agent for moulding sections curved in more than one plane. The film will wrinkle when placed in a multi-curved female mould, and the wrinkles will be transferred to the surface of the laminate. Even ' tailoring ' the film, using cellulose adhesive tape to join the patches, and to secure them to the mould, will result in impressions being transferred to the laminate. So, unless the finished moulding is to be rubbed down and painted afterwards, a wax or P.V.A. release agent should be used here.

If epoxide resins are used for laminating, another type of " Cellophane " film should be employed because of the exceptional adhesive properties of these resins.

Technical experts of British Cellophane Limited, 12-13 Conduit Street, London, W.1., will give help and advice on any problems which may confront a boat-builder who desires to try his hand at constructing his craft from a polyester/glass laminate.

MOULDLESS FIBREGLASS

The main drawback to making a single fibreglass hull is the expense of the mould. This may be avoided by the following method which is put forward here as a suggestion.

1. A hull shape is made up with cheap materials using moulds and stringers in the usual way. The stringers would be closely spaced where the curvature is greatest.

2. All outside surfaces are covered with cellophane sheeting.

3. Glass cloth is then used to cover the whole hull shape, being tailored to fit where necessary.

4. Polyester resin is then brushed onto the cloth and cured. This will then give the required hull shape which can be removed from the stringers and will maintain its shape within limits.

5. The glass-cloth polyester resin hull shape is then supported to its proper shape while glass mat and polyester resin are laid inside it in the appropriate number of layers. When this has been cured, the hull is complete.

Possible Faults. 1. The single layer of glass cloth and polyester resin may not give enough resistance to distortion. Multiplying the layers of cloth would correct this. It would also help if a wood gunwale strake were incorporated in the glass cloth. Distortion of the single layer of glass cloth could only occur with an unsupported gunwale and, if the gunwale were to be made rigid, no distortion could occur.

2. The outside surface might not be smooth. In the craft which I have seen using this system for part of the surface (the bottom of a chined hydroplane), the surface could have been better. This is not fundamental to the system, however.

PROTECTIVE SHEATHING FOR WOOD

It appears that polyester resin is not suitable on its own as a protective coating for wooden boats. Though capable of making a hull watertight and giving a hard surface immune to rot and marine borers, any movement of the planking below it will crack it or flake it off. Undoubtedly, a synthetic resin capable of being painted on a boat to give it protection will soon appear, but, in the meantime, we can only protect our hulls fully by a combination of resin and fabric. The purpose of the fabric is to bridge the seams of the boat and give cohesion to the resin.

Glass Fibre-Polyester Resin. A loose-woven cloth is used so that the resin can get into it and through it easily. If the hull has been previously painted or varnished, this is all scraped off, avoiding paint removers etc. The glass cloth is then stapled directly to the bare wood, being tailored where necessary. The resin-colouring-catalyst-accelerator mix is then brushed on and worked in with rollers to get rid of air bubbles beneath the cloth. When the resin mix is on, the staples are taken out.

A slightly better but much more messy way to do the job is to paint the bare wood with a coat of resin and allow it to become tacky before putting on the cloth. Staples are then not needed.

Glass Fibre-Epoxy Resin. This is in all ways similar to the above. Epoxy is a glue and sets up harder so the result is somewhat better but the resin is poisonous and it is useful to have an electric fan blowing the fumes away from the operator. It is more expensive than polyester resin.

NYLON-RESORCINOL SHEATHING

It is becoming customary to sheath all wooden boats in worm infested waters with polyester-glass fibre or glass fibre-epoxy coatings. Even in other waters, waterproof sheathing is used for racing boats to prevent rot and water absorption by the wood.

Glass fibre sheathing is usually satisfactory but it has the following faults :

1. It is not elastic so that blows can fracture the skin. Also for larger boats, the working of the hull may also cause tears.

2. Polyester resin is not a glue and does not *stick* to the wood though it adheres well if new and never been painted. Epoxy resin is better in this respect.

3. Working with either polyester resin or epoxy is messy and epoxy is poisonous.

To counteract these faults, Messrs. Leicester, Lovell & Co., Ltd. have developed a process using resorcinol glue to stick a nylon cloth to the bare wood of a boat and coating the outside with coloured vinyl resin giving a cleanly worked, firmly bonded and elastic coating. The process has been called " Cascover " or the "Aquasheath " process.

Materials : Glue : CASCOPHEN (RS.M-1124) Resorcinol resin. Catalyst FM.M. 1125. Cloth : CASCOFORM nylon cloth (4 oz. or 12½ oz. weight). Finish : CASCOTE resin finish (blue, green or red). CASCOTE thinners.

The Process

1. The area to be covered should be thoroughly cleaned down to the bare wood, removing all paint, varnish, oil, grease etc. Paint removing chemicals should not be used. It should then be sanded smooth. If it is an old boat, loose fastenings and faulty structures should be made good and rubbing strips removed. The part should be allowed to dry.

2. The CASCOFORM nylon cloth should next be roughly tailored to shape. Though elastic, the cloth is unlikely to be able to take a whole hull shape in one piece. To avoid excessive fraying, the cloth may be cut by a heat sealing gun.

3. The CASCOPHEN resorcinol glue and the catalyst are then mixed in the proportion of five parts of glue to one of catalyst. The catalyst is a powder and it should be slowly added to the liquid resin while stirring continuously till it is thoroughly dispersed. The working life will then be 9-10 hours at 60°F., 3¾ hours at 70°F., 1¾ hours at 80° and ¾ hour at 90°.

4. The glue mix is then applied to the timber at about 10 lb. per 100 sq. ft. The cloth is then put on and air bubbles beneath it are squeezed out with a squeegee. The glue should only go about half way through the cloth and not come out through it, giving clean working. In joining the cloth, either butt or lap joints can be used, care being taken that no glue gets onto the outer surface. The joints of the cloth can be heat-sealed with a " Sealing Gun."

5. *Curing.* 15 hours at 60°F. is necessary to cure the glue and local heat may be needed to achieve this. Higher temperatures will quicken the process.

6. *Finishing.* Three coats of CASCOTE vinyl resin finish can then be brushed on as with any paint, allowing 4 hours between each. The vinyl resin finish should be thoroughly stirred before use and the brushes and containers cleaned with the special CASCOTE thinners. Four to five days should be allowed before launching to allow thorough hardening.

7. *Repainting.* Repainting with CASCOTE vinyl resin may be done as wanted but the existing surface must be thoroughly cleaned first to free it from tar, grease etc.

8. *Dermatitis.* Synthetic glues will occasionally produce dermatitis in susceptible people. A wet swab should be frequently used to prevent glue from setting on the hands and barrier creams can also be used.

9. *Cost.* For 4 oz. cloth, which can be used on craft up to 25 ft. L.O.A. the cost is 5/6 to 6/9 per sq. ft. For craft above 25 ft. L.O.A. where $12\frac{1}{2}$ oz. cloth is used and for non-skid deck surfaces, the cost will be between 8/9 to 10/6 per sq. ft. (for materials only).

Summary. A sheathing method is described which gives a good surface of abrasion resistant and elastic waterproof material which may have several advantages over polyester-glass fibre sheathing. It is not anti-fouling. Further details can be got from Leicester, Lovell & Co., Ltd., North Baddesley, Southampton, or from Aqua-Craft, Ltd., Bridport, Dorset, who also sell the materials.

VERY LIGHT DENSITY MATERIALS IN BOAT BUILDING

This account is condensed from a longer article by Mr. A. Cooper of EXPANDED RUBBER COMPANY, which will be lent to members on request.

This article concerns two very low density materials namely :

1. Expanded ebonite, sold as ONAZOTE in Great Britain. It has been used for many years for a variety of purposes.

2. Expanded polystyrene, sold as POLYZOTE in Great Britain, a newer product.

The density varies from 4 to 10 lb. per cub. ft. compared with 25 lb. per cub. ft. for spruce. There is little to choose between either for a given purpose. Naturally, there has been more experience with the older product, ONAZOTE, but it can always be replaced by the expanded polystyrene, POLYZOTE which is cheaper.

There are three main boatbuilding uses :

1. Core materials in " sandwich " construction.
2. Buoyancy materials.
3. Thermal insulation.

We will mainly deal with sandwich construction here as both buoyancy and thermal insulation necessarily result and are desirable for boats.

Sandwich Construction. This consists of two thin outer skins of a material of relatively high density and strength but with low stiffness, stuck to a core of comparatively low density and strength but of high stiffness. The resulting laminate, provided the correct balance between skin and core thickness is achieved, will be many hundreds of times as stiff as a sheet of the same weight made of the skin material alone.

Wood, metal or polyester resin-fibreglass may be used for the skins. Expanded ebonite or polystyrene, honeycomb or even balsa wood may be used for cores. However, water absorption must be a minimum and the $1\frac{1}{2}\%$ water absorption of Onazote or 3.2% of Polyzote after six weeks immersion must make these the preferred boat building materials.

The function of the low-density core in sandwich construction is to provide a distance piece between the two outer skins so that, when subjected to bending moments, they are maintained at a predetermined distance from one another and are thus prevented from bending or buckling.

Applications. Sandwich construction was used for the two-man submarines made during the war. Panels of Onazote with plywood as the outer surface stood up to long periods of immersion without damage or loss of buoyancy. It has also been used in aircraft for flooring panels, undercarriage doors, bomb doors, flaps, hatches, etc.

Depending on the strength of the panel required, the density of Onazote can be varied. For parts needing strength, the highest density is used but for bulkheads and interior doors etc., the lowest density is enough.

Sandwich construction has now become standard for the roofs of motor buses. In many instances, Onazote sandwiches are being fitted because they are lighter, have a better appearance and are less subject to condensation than the previous type of roof. The panting of the roof, as the bus vibrates is eliminated and drumming cannot occur. It is also cooler in warm weather.

The Material. Onazote comes in boards of the following sizes :

4′ x 1′	2″ thick	4 lb. per cub. ft. density.
3′ x 1′	2″ ,,	4 lb. ,, ,, ,, ,,
4′ x 1′	2″ ,,	6 lb. ,, ,, ,, ,,
2′ x 1′	1″ ,,	6 lb. ,, ,, ,, ,,
3′ x 1′	1″ ,,	6 lb. ,, ,, ,, ,,

from EXPANDED RUBBER COMPANY LTD., Mitcham Road, Croydon, Surrey.

POLYZOTE comes in blocks or boards up to 8′ x 4′ x 20″ thick at a minimum density of 1 lb. per cub. ft.

Both expanded ebonite and polystyrene may be machined and cut with ordinary standard woodworking tools as with any soft wood.

Joints. Slabs or planks of these materials may be butt-jointed with glue, in which case, the join will be as strong as the material. Step jointing or tongue and groove may be used to increase thermal insulation.

Surfacing Media. About 11 or so surfacing media have been used but, for boatbuilding by the amateur only plywood and fibre-glass-polyester will ordinarily be used.

Adhesives. As a result of considerable research into all kinds of glues for all kinds of boards, the following has been proved under practical conditions to give the most satisfactory results in uniting wood or plywood to Onazote or Polyzote :

Cellobond 2664 on Bakerlite G 11116.

Polyester Resin-Glass Cloth Skin. Method 1.

Polyester resin dissolves Polyzote, if allowed to come directly in contact with it before it hardens. However a coat of Hycar latex or phenolic resin such as Celloband J 2664, on the Polyzote will act as an insulator between the two substances and this may be followed by a coat of polyester resin. Glass cloth can be put on and another coat of polyester resin will give a smooth finish. Further layers of glass cloth and resin may be needed to give the strength required.

Polyester Resin-glass Cloth Skin. Method 2.

If Onazote is used, it is necessary to remove any surface skin from it to make adhesion reliable. This can be done with a bandsaw, mechanical sander or thicknessing machine. This is not necessary with Polyzote. The adhesive used is Cellobond J 3752 with Hardener T 2854 or Cellobond J 2664 and Hardener T 100 applied according to the makers' instruction. The glass cloth is marked out on the dry surface with a pencil line and ¾″ Transotape (stationary quality) or Cellotape, obtainable from Messrs. John Gosheron & Co. Ltd., Shepherds Bush London, is applied to the line of cut. The fabric is then cut by scissors through the centre of the tape, thereby preventing the cut edges from fraying.

The resin is mixed with the Hardener and applied to the Onazote or Polyzote at a thickness corresponding to a coverage of 30 sq. ft. per lb. of adhesive. The clean, dry and shaped glass cloth is immediately put on the wet resin and smoothed out, taking care to eliminate all trapped air between the cloth and Onazote or Polyzote. The fabric is then trimmed so as to allow an overlap at all joints of approximately ½″. The laminate is then set aside for approximately 48 hours, when the rough edges of the glass cloth are trimmed off, the resin having set hard.

BUILDING WITH PLASTIC FOAM

by

ARTHUR PIVER.

A method of boatbuilding for the amateur which apparently will give the least possible weight is described below.

All the steps outlined have been proven in actual practice, although a complete boat using these methods exclusively is not yet built, as far as I know.

However, such a boat is now under construction. It is a yet-unnamed 16′ dinghy which I think of as *Planer* because it is expected to plane 100 per cent. of the time around a triangular course.

Briefly, the method consists of constructing a planked frameless boat of 1″ x 1′ x 9′ planks of an expanded polystyrene foam manufactured by the Dow Chemical Co. under the trade name of Styrofoam.

This material is commonly used as flotation material, with a weight per cubic foot of 2 pounds. However, in the new boat being built, high density foam weighing 4½ pounds cu. ft. is being used.

This weight material is not now generally available in small quantities, although this condition is of course subject to change.

The reason for the use of the high density foam is its greater compressive strength, which, when combined with a fibreglass skin on each side, makes a plastic sandwich of tremendous strength, rigidity, and extreme lightness with built-in buoyancy.

A former disadvantage of such construction has been that the polyester resin usually used with fibreglass dissolves the polystyrene foam, and the alternate Epoxy resin is both expensive as well as highly toxic.

However, experiments have proven that the foam can be insulated from the polyester resin by a suitable chemical barrier, and resorcinol glue makes an excellent adhesive with which to fasten together various pieces and members made of uncovered foam.

The barrier now being used is a very thin (sprayable) solution made from a plastic resin glue sold in the U.S. under the trade name Weldwood.

A chemist could doubtless find many other barriers, although the manufacturers of this foam apparently as yet are reluctant to name any.

The foam being used is quite flexible in long (9′) pieces, and can be used as is regular planking.

In the present boat, the round bottom of the dinghy is being made with 1″ square strips, with the topsides being made with the 1′ wide planks.

If the dinghy performs as expected, a V-bottom model will be made for comparison of performance.

The dinghy is now being planked, and will then be covered with fibreglass as would the usual wooden boat.

Bulkheads are glassed before being fitted in order to simplify construction. The centreboard case is also being glassed prior to installation.

All fittings must have backing blocks (in this case of ¼″ plywood) as ordinary fastenings will pull through the foam sandwich.

Several years ago the writer made a dinghy of somewhat similar construction, although the hull shell was made of the usual fibreglass laminate. This resulted in a 16′ boat which was considered too heavy (200 pounds) for the intended purpose.

All bulkheads and the centreboard case were of the foam planks, however, although at that time only the 2 pound material was available.

Because of the softer foam, several layers of glass cloth were necessary, in contrast to the single layer of medium weight cloth being used at present.

In the previous boat, buoyancy gunwales and seats were made of foam-in-place plastic.

With this material, two chemicals are mixed together, resulting in a foaming action with a tremendous increase in the volume of the chemicals.

In the present boat, just the foam planks will be used.

The Styrofoam can be fabricated with virtually all common power driven wood-working tools.

For smooth surfaces with the high density material, a blade with very little set, lubricated with soap solution, apparently gives the best results.

Printed by F. J. Parsons (Kent Newspapers) Ltd., The Bayle, Folkestone.