"SOME ASPECTS OF MOULDING THE LARGER TYPE OF REINFORCED PLASTIC HULLS."

By Mr. M. Campbell.
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In considering this material of ours, Fibreglass, G.R.P., F.R.P., Glassfibre, call it what you will, I prefer to call it G.R.P. - Glass Reinforced Plastic - we must be fully aware of its capabilities and its limitations. Simply, G.R.P. is the encapsulation or bonding of a strong compatible reinforcing material, in this case glass, with synthetic thermosetting resins; such as Polyesters and Epoxies. These resins cure or go hard by the addition of catalysts and hardeners, without evolving any water during the process. These types of resins only came into general use after the war so the G.R.P. industry is still a minor and will only reach its majority next year. These resins which are capable of being cured without the application of pressure or external heat, are called collectively contact resins, and the application of them became known as the Contact Moulding process, or the 'hand lay up'. It is this process which we shall discuss in the manufacture of the larger type of boat hull.

Of the two basic groups of resins Polyesters are in greater use due to the ease of handling, and are by far the cheaper of the two. They are, however, less strong than the Epoxies and exhibit greater shrinkage. For the reinforcement of contact resins, glassfibre has shown itself to be the best on almost all counts - very strong - tensile strength at least 100 tons per sq. in., it has a reasonably high stiffness and is readily available. Completely rot proof, it has an extremely high resistance to chemical attack, it is not excessively water absorbent, and does not effect the cure of the resins. In the early days the adhesion of the glass was suspect, but chemical sizes for the treatment of the glass have been evolved and the problem no longer exists.

Polyester resins are clear syrupy liquids to which catalysts are added immediately prior to use and after a time delay, the gel time, the resin sets hard. This time delay may be varied by the proportions of the catalyst and accelerator which are added. This then gives the working life of the material.

The Glass reinforcement is available in many forms. Rovings which are long continuous lengths of untwisted fibres form the basis of mats, and woven rovings. The rovings are chopped into 2" lengths deposited on a flat surface and bound into a mat form with an adhesive compatible with the resins. Woven rovings, as the name implies, are simply rovings woven on conventional looms. Glass is also available in fabric form, but, in this case, the long glass strands are sized and twisted into yarn and then woven to any desired fabric.

Let us now consider the moulding methods. The hand lay up process involves the laying of layer upon layer of reinforcement to a mould face, wetting with resin and finally excluding all the air entrapped as the laminate is consolidated.

Now in a little more detail. The mould surface must be cleaned and polished. The resultant moulding will only be as good as the surface from which it is taken. So this is critical. A release agent is applied, this may be wax or a synthetic preparation. Wax, however, is the best. It is not the wax but the degree of polish which acts as the release mechanism. Too much wax can cause the whole to stick. After this a surface coat of unreinforced resin is applied, known as the gel coat. It is this surface that imparts the decorative finish and the protection to the laminate. When this layer has gone hard the surface is coated with more resin and a layer of reinforcement applied. When this has gelled the sequence is repeated until the desired thickness has been achieved. It is inadvisable to ply many layers in the wet state, as resin drainage can occur and excessive heat may be built up due to the exothermic reaction of this resin curing.

Fundamentally it is simple, but to achieve good laminates, and these are required in structures such as boat hulls, aircraft parts and bulk storage vessels, to mention a few, a lot of expertise is required on behalf of the laminater. It is all too easy to entrap air, have resin-rich areas, resin-starved areas and uneven thicknesses. The process is relatively slow. This can be speeded up by the use of 'spray up' depositors which simultaneously chop the glass and spray the resin at the same time. This shows advantages in labour time and greater economy in material, as the glass used is cheaper than that for the hand lay up. Against this is the capital cost of the equipment, the inability to guarantee uniform thickness and uneven curing of the resin. Other production methods are available by using vacuum and pressure bags and matched die moulds.

<u>Moulding of Hulls.</u>

Some of the very early boat hulls were made by the 'Marco' Process. Where inner and outer moulds were jigged and the space filled with glass and resin introduced through stack pipes in the outer mould. It is of interest to note that the process slightly modified, the resin is drawn through under vacuum, is currently used for supersonic aircraft radomes. Also here in Sydney for producing the panels to make unitised freight containers.

This process has the advantage of good surfaces on both sides, the thickness is accurately controlled and, properly operated, gives good void-free laminates. Complications and uncertainty lead to this process being redundant.

Almost all large boat hulls, the notable exception being the Dutch Navy, are today made in female moulds using the hand lay up process.

The moulds are normally made of G.R.P. or combinations with concrete backing from a male plug. The male plug may be a hull of conventional material, or a special pattern made from any material which will give the required contours and degree of finish. The mould in its ready to go state can incorporate recesses to allow skin fitting to be flush, decorative markings such as cove lines, positions for other fittings as may be required. Post moulding operations are then minimised externally. Internally, bulkheads, stiffeners, tanks, shelves, engine beds and even engines may be fitted to predetermined reference points, thus facilitating subsequent fit out. It is essential, therefore, to have a good mould, and consequently mould costs are high and a long production run is required to ammortise these mould costs.

It is only natural because of these mould costs to look for methods where moulds are much cheaper, and from this arose the no mould technique, developed by Leo Taal in Holland in making 47' landing craft and 77' patrol boats.

Basically, what he does is this. He lofts a simple shape consisting of wooden formers and longitudinal stringers only and over this frame are fitted panels of P.V.C. (polyvinyl chloride) foam which have been softened by heat. When this has been completed he proceeds to lay up the G.R.P. on the outside of the hull. This is done very carefully to minimise irregularities. The whole surface is then sanded and dressed and finally coated with a layer of resin to give an acceptable finish. On completion of this the whole is inverted and the G.R.P. similarly applied to the inside of the hull. Separate mouldings are done of the decks in a similar manner and the hull and deck bonded together.

In Canada a 50' boat was made using only the bulkheads as mould formers. Corrugated G.R.P. planks were made and fitted to the bulkheads from the bottom up as in a conventional wooden build. The corrugation filled with sprayed urethane foam, sanded smooth and then over laminated with G.R.P. The surface sanded smooth and coated with an epoxide resin. The whole inverted and the process repeated on the inside.

This process, like the Dutch one, suffers, I feel, disadvantages over a single skin hull in a female mould. The degree of finish would be inferior; if not, then the labour costs involved producing such a finish, which must be done on each boat, would outweigh the initial cost of a female mould. There is also the danger of breaking through the structural layers of glass and the possibility of producing weakness. This is minimised by the use of diagonally laid directional tape. Problems also exist with the installation of through fittings and recesses in the hull and special consideration must be given.

The Dutch, however, seem to have acquired a particular skill in this type of work. This is demonstrated well in their welded steel yachts and the impressive service record of the G.R.P. boats.

Factors Governing the Strength of G.R.P. Hulls.

Considering the sizes of hulls at present made throughout the world, it is almost certain to be the strength of the hull to resist local sea impact rather than overall bending or torsional stiffness which will govern the design. The overall bending is normally taken care of by building up extra thicknesses in way of the shear strake, chine and keel and providing an adequate hull to deck join. There are many ways to stiffen hulls to resist the water impact, the three main ones are, a thick single skin, a thinner skin with stiffeners, or two thin skins with a sandwich core.

In the first case, a single skin would require to be very thick, if not its strength would be low and unable to contain the correct hydrodynamic form of the hull. G.R.P. hulls tend to be less stiff than their wooden counterparts for similar breaking strengths. In the second case we have the choice of longitudinal or horizontal stiffeners. Longitudinal stiffeners improve overall bending, but do very little for local strength. So if we must stiffen, and the economics dictate that we must, then it must be vertical or, to employ the third case, a sandwich structure.

Sandwich structures suffer several disadvantages over stiffened single skins. The surface finish and reliability of laminar integrity are not as positive or as good as for the single skin. At present it is virtually impossible to lay up a sandwich laminate in a female mould. The main difficulty is to guarantee the adhesion and exclusion of voids when laying the foam to a concave surface. The added problems associated with through hull fittings and the cost of the foam core. All these add up to increased costs making the whole far more expensive than that of a single skin.

In service a hull would be subject to two types of impact, a sharp one from solid objects and a soft one from the water. If a sharp impact is severe enough it would probably puncture the stiff sandwich skin but in the single skin, however, it would fracture the stiffener and the skin would then be free to deflect, and in deflecting, absorb the energy of impact. A broken stiffener is very easy to repair.

The Future.

At present in the U.S.A. the Coast Guard has standardised on all boats up to 40' in G.R.P. The U.S. Navy has replaced wood on all new construction up to 60'. We have mentioned the Dutch earlier with 47 and 77 footers. In the U.K. boats up to 56' are in service with Police, Navy and Customs, and a design study is current for a 120' fleet auxilliary. The Russians are reported to have a 120' trawler in service.

Size is a very limiting parameter from the points of handling, moulding and strengthening. At 60-70 feet most countries of the world have laws which prohibit the road transportations of such vessels. This would necessitate the re-siting of factories to sea or riverside locations. This in turn creates problems of high humidity, a bane in the life of a moulder, and necessitate air-conditioned factories. The South Africans have just produced an 83' fishing boat and slipped her direct from the factory into the water.

There are some doubts as to whether large and very large two piece moulds would be practical proposition. It will almost certainly be necessary to divide up into smaller manageable parts. Mould costs, regardless, would be very high.

Planks could be built up and covered with G.R.P. These would have to be built the right way up; it would be unthinkable to consider inverting boats of these sizes. This would involve large areas of the bottom of the boat being laminated upwards - messy, and extremely difficult. The process described earlier using 'no moulds' and requiring hand finishing would be very costly and the shells might locally be cut too thin.

The hulls could be divided into small sections and moulded with flanges which could be bolted or glassed over or both.

The latter method could pose problems of weakness at the joints. With the larger boats it is inevitable that the overall strength and stiffness will become more critical and it may be that the scantlings, to achieve this, will be uneconomical. It may be that we could learn from the "Cutty Sark" and use a steel member to stiffen the hulls as she was. The relative stiffness of glass is approximately 1/30 that of steel.

<u>Conclusion.</u>

I present this paper as a Chemist and one actively involved in producing the larger type of yacht and laminating in G.R.P. Our industry is not, as some will have it, a "bucket and brush brigade". Granted, we do use this equipment but, scientifically, G.R.P. is an exact science and a very complicated one, and we need the combined efforts of architects, engineers and chemists to manipulate this unique material. The information I have given in this paper is scant, but I hope it will serve as an introduction to the subject and the many gaps may be filled in during the discussion.

I would like to express my thanks to the Directors of Rudders Yachts Pty. Limited and Halmatic Limited in their assistance in publishing this Paper.

References: Scott Barder Ltd.,
Monsanto Chemicals Ltd.,
Leo Taal.

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Rudder Yachts Pty. Ltd.

D I S C U S S I O N, etc. 24th May, 1967.

Mr. M. Campbell:
It is rather difficult to illustrate this but I have one or two old photographs of relatively large structures that I have been associated with and I will pass these round for you to study.
G.R.P. ships of up to 1,000 tons can now be built - apparently a consortium has been set up between British Aeroplane Plastics and John Thornycroft who are backed by the Ministry of Defence, particularly the Navy, and they have built a full scale midship section of a 600 ton vessel. This is currently being tested at the Rosyth testing station. Initially they started off and did a feasibility study, then carried on with a design study and then built this full scale section.
I understand that the total cost was about $625,000. The strange part was that it was accepted from the onset that on efficient single skin for the laminate posed production problems and this erected an enormous cost barrier and so they decided that it would have to be of sandwich construction. The section itself weighed 30 tons and provided not only a full scale test vehicle, but also very good practical experience whereby they could try out production techniques under dockyard conditions.
The whole was laid up in a female mould and had a very specially modified gel coat. The layup was mechanised and this was carried out from bridges which travelled the full length of the inside of the hull. The sandwiched structure used woven fabrics on the skins and it used a reinforced plastic or G.R.P. honeycomb rather than the foam sandwich we know as the conventional honeycomb materials for boats. It is almost certain the cell sizes were infinitely larger than the sample shown here but I should imagine it would be very similar to that which they used.
They do claim that using this type of honeycomb material as a core that they do away with the very bad problem of non-adhesion between the core material and the skins. Now, it may be that they have developed a revolutionary technique but it also may be that this boat is so large that the areas of double curvature are so very small that you don't suffer the same sort of production problems.

Mr. L. Hedges:
That is because of the difficulty of bending that material in double curves.

Mr. Campbell:
No, not so much bending, that it is probably quite easy because the sides of the boat are so slab sided that they are almost doing flat panels all the way through, whereas, in a small boat you have wonderful curves. The weight of the midship section is about 30% to 50% lighter than the conventional steel counterpart and they anticipate that the costs will be increased by about 10%. They have stated that boats of this size must be made in sandwich because of economics but there is a firm in South Africa who are currently making a 30 footer, 74 footer and an 83 footer, all fishing trawlers, and they say that it is impossible to use a sandwich technique because it is so fantastically expensive they must make them of single skin out of solid glass.
I don't know if this is a fact that one consortium is working with Government contracts and Government money and the other is a commercial business.
I feel inclined to support the South Africans and consider that a single skin is a better economic proposition for a production vessel than is a sandwich laminate. The main consideration is someone has gone for a big boat and they expect that in the next year, 1968, plans will be underway for something like a 150 foot Fleet auxiliary which will be completely fibre glass throughout. This, particularly for our industry, is a tremendous step forward.
One of the questions that people raise is, with regard to reinforced plastics, is the durability of this material and what sort of life they can get out of it. I had an enquiry today by one who came to look at his new boat. We had just removed a 36 footer from the mould as he arrived, looked at it and

commented that it looked very nice and white. He asked how long it would stay white; when will it start to turn yellow. This is a very difficult thing to determine but I feel that if one takes notice of the detergent manufacturer's book and puts little specks of blue here and there and makes it a blue-white instead of an ordinary yellow-white then the anticipation of this remaining white would certainly be five years before it started to show any yellowing. If you took the trouble to scrub it with Ajax periodically and give it a good waxing I can see no reason why it would not stay reasonably white for a period of ten to eleven years; you would probably have to think aboutpainting it then.

One of the biggest problems that seems to be arising from reinforced plastic laminates in service is that the gel coat tends to be very highly filled when obtsined from certain sources and this filling makes the gel coat into a semi-permeable membrane. The sea water diffuses through the gel coat and goes into little micro-voids behind the laminate and gradually builds up until you start getting hydraulic pressure in these voids with the changes in temperature and an increase in water migration and de-lamination occurs. There is a theory that it is best to throw away gel coat and not bother with it and to mould your boat with straight laminating resins with no fillers in at all and then paint it afterwards. I know of two companies in the U.K. who are seriously going over to this technique, i.e. forgetting about gel coats altogether. We, as a policy in our company, on the larger boats, do not pigment below the water line fortwo reasons. One is to keep this filler content down to refute the possibility of this osmosis taking place and the other is that we can drop a high powered light source into the bilge and we can look through the laminate and inspect if for voids, defects, etc. If you see any defects at this stage it is very simple to fix them. If you have a void it is no problem to put a small drill hole in there, inject resin in with a hypodermic, this completes it satisfactorily.

With regard to reinforced plastic boats, it is well to bear in mind the maintenance side. It is completely maintenance free and will last forever. I do think you have to keep it clean and wax it and once you have waxed it this reduces the wetted area and also reduces the general errosion that takes place on the surface. Liken this to two people with new cars. The one who waxes his and looks after it regularly retains a nice looking car whilst the one who doesn't worry at all has a shabby car in 6 months. The finishes they are putting on cars now-a-days are akin to polyester resins so you might say are the same type of material. I feel that this policy of waxing the boat hulls, quite regularly, is a very good one. We recommend this to our customers and they seem to have followed our advice with the net result that the boats look to be in a good condition over a period of years. The boats that have been in the water for a long time are relatively few and far between and there does not seem to be too many records of what has happened to these boats. My old company in England and the resin manufacturers, have done a survey and tried to trace some of these boats that were built about 1954 to build a history and see what had happened to them. I have a record of one which was called "Perpetuo", built in 1954 and designed by Peter Thornycroft. She was 48'8", and incidently the first boat built in the world with a resin which is available in Australia, called Crystic 189, and this is still one of the best resins to be used for boats or large structural applications at the moment. The problem was that the Admiralty said at that time, that it was impossible to fit diesel engines into a reinforced plastic hull because the vibrations from the diesel engine would shake it to pieces. Peter De Laslow, who was a director of Halmatic in those days, decided to design it around an Admiral's barge and fit two great big Perkins diesel engines in it to see what happened. He put in twin Gardiner L.W.6 and this boat was re-surveyed in 1965 by Lloyd's and was fully approved A1 again. There was no record of any collisions, damage or problems with that boat. "Shearwater" was built in 1956 with twin Ruston engines designed for 14.5 knots at 11 ton load. She was 53'8" and used on gerry work between the shore and ships in Aden. She was slipped in September, 1966 and found to be perfectly satisfactory and this contrasts rather well with a timber Police launch which had evidence of toredo worm within 12 months of being built. The Americans are very proud of their efforts in the G.P.P. boat field. About 15 years ago they built three 40 foot patrol boats which were used extensively on the Great Lakes and I am told that this is one of the most corrosive waters in the world. After ten years they analysed the maintenance costs and found that there was an 80% saving over the conventional craft. One boat they pulled up onto the hard, cut foot sections out of the deck, the topside and the bottom; physically tested these and found that the physical properties were identical to those recorded for the resins used when she was made. It is fair to say that one can certainly expect 15 to 20 years life out of a boat like this without any evidence of deterioration. This is proven by boats that have been in service this length of time. One could guess and say they will go on for another 10 years without too much trouble but of course this is unknown. Another problem that people raise, particularly Boards of Trade and other official bodies, is the flamability of G.R.P. laminates. Polyesters and Epoxies are organic materials and like all organic materials they will burn. There is no doubt about this and G.R.P. laminates are no exception. There are certain additives you can put to these resins to make them self-extinguishing and I make a point of saying self-extinguishing. Self extinguishing is defined as the time for the flame to go out when the source of ignition is removed. They are certainly not fire proof, far from it. If you put these additives into a reinforced plastics laminate to make it self-extinguishing you do so and effect the weathering properties of the laminate. In fact, the durability of the laminate falls off at an alarming rate and as the durability falls off so does the fire retarding properties. By the time you get 2 or 3 years in service, it is a shabby old moulding that is starting to fall to pieces because the surface is decaying and the fire retardant properties virtually no longer exist so that there was no real point in doing it in the first place because it was only of short duration. I feel that there is very little to be gained in making laminate for marine applications fire retardant. If there is, or if someone insists that you must do this, then I feel that the outer surface layer of resin, the gel coat, should be made of a conventional material which has very good weathering properties and then the main bulk of the laminate behind it be made fire retardant or flame retardant such, that if the outer layer is burnt, then you will have a certain protective barrier from the laminate behind it. One of the more popular processes that seems to be coming out from reinforced plastic to-day is sheathing of boats. This is a very good system but there are a lot of pitfalls in it and unless people are aware of these pitfalls then it is certainly going to have a very bad name because it won't withstand the service conditions. Even with new timber there are problems which you have to face before you start. The timber must be absolutely dry; if the moisture content of the timber is in excess of 10% then you are certainly going to have troubles with adhesion. Also, most timbers contain a material called phenol which inhibits the cure of polyesters, it just stops them curing completely. This phenol is present in the soft woods but it is far more pronounced and in greater quantities in the hard woods. It is necessary to neutralise this before going on with sheathing, otherwise you will suffer from bad adhesion. The best way to do this is, apply a sealer coat which is normally made up of a straight polyester resin which is wax free and is diluted with a reactive dilutant and a solvent. Once this primer coat is applied and the whole of the timber is sealed then there are no problems and the process is relatively straightforward. The reinforcement which you have decided on, whether it be a glass fabric or one of these new synthetic materials, cut to shape and laid over the area to be treated. A layer of resin applied to the boat, the material is placed on, a further layer is brushed over the top, making sure all the reinforcement is fully impregnated, allowed to cure and sanded back. The surface is then built up with a further layer of resin and repeat this until quite satisfied that the finish wanted is achieved. Old timber boats have to be cut back to bare wood from the very start. Most of the old paint primers, undercoats, which have been used, are oil based. This gives very bad adhesion and unless taken back to bare wood there is no chance of getting any reasonable service out of your sheathing. This is with polyesters. There are two or three other systems available. The two of the wet lay up methods are based on epoxy resins or polyurethane resins and these, to me, are an infinitely better method because polyurethane and epoxies have far better adhesive qualities and you would expect them to stick better to the timber than polyester. The phenol that remains in the timber does not affect the cure of the epoxies, in fact, most epoxy manufacturers put a little phenol into their resin to make sure it cures quicker so you have the advantage of having this phenol in the timber which acts as a catylist and tends to increase the cure of your epoxy. There are other methods based on laminates which are not fully cured, they are arrested in a part-cured stage, known as the B stage. These are in laminates and are normally kept refrigerated; these are brought out of the refrigerator and literally bonded on to the sides of the boat as and when required. We still have to use anti-foulling as no one has managed to incorporate any copper oxide into the laminate. This inhibits the cure so cannot be used. Arsenic and pyrritherum have been tried but these don't seem to be effective at all and it is not surprising when you consider that there are 1,927 varieties of borers, worms and algaes, so can control only very few. It can be foulled but it cannot be attacked, I think that is the operative phrase to use. The big problem is getting rid of any residual wax which you have on to get your boat out of the mould in first place. You take all this trouble to wax and polish and even put a synthetic preparation onto your mould to make sure that when you have made your boat you can get it out. Once you have it out you have a very nice surface but it is so impregnated with wax that you can make very little stick to it. There is only one way, that I know of, to make sure your anti-foulling will stick and that is to de-grease it, scurf it with a very coarse abrasive system, re-degrease it and then go on with your undercoat. I feel you have to use an epoxy undercoat to get maximum adhesion and then what you do after that is virtually to your own liking, whether you use a vynal anti-foulling or one of these copper oxide leaching systems is immaterial, the main thing is to remove your wax and get a very good undercoat from which you can build on.

The fibre glass laminator is at last being accepted as a tradesman. He certainly has a skill at his fingertips. It is not anybody who can weild a brush, roller and dip into a bucket of resin and produce a laminate. In fact it is extremely difficult and we are, at the moment, trying to legalise the laminator and bring him up to an official trade; the Plastics Institute of Australia have just initiated a one years Course at Sydney Technical College. We have 60 people enrolled in the three nights the course operates and we still have a waiting list of about another 15. It is intended next year to extend this one year course to a three year course. After the end of 3 years the students will have a Diploma.

In reinforced plastic, the raw materials are good, the techniques are good, but the problem is putting them together. It is the one structural material that the operator is fabricating on the spot. It is not like building a boat with steel or timber. These are already specific materials of known physical properties and it is known exactly what their performance will be. The reinforced plastic laminator makes this on the job, in his mould, so all the controls are up to him and it is quality control and process control that is going to make or break the industry over the next few years. It is very easy to make a mistake, in fact, one $6.00 bucket of resin could quite easily ruin a $10,000.00 project.

G.R.P. has a tremendous future, its potential has only been tapped. It protects the astronaut when he comes down from outer atmosphere, beers and wines are carried in it, certainly not yet in Australia, but they are in Europe and the U.K. Sculptors use it, houses can be built with it. It is a material that is here to stay.

I will close with these comments.

<u>Mr. Trivett:</u>

We have had a very interesting extension to the Paper.

I now declare the meeting open to questions.

<u>Mr. I. Charles:</u>

I am the leading hand of the Fibre Glass Section at Garden Island. The U.S. Navy used fibre glass small craft for their larger ships but suddenly they are starting to change. Could you give a reason for this, as you commented that in America they are building large ships in the single lay up method.

<u>Mr. M. Campbell:</u>

South Africa, the American Press reporting the S.P.I. Conference in the Edgewater Beach Hotel in Chicago last year, stated quite specifically that all new boats upto 40 feet would be made in reinforced plastics for the Coastguard.

All boats up to 60 feet will be made in reinforced plastics for the Navy. I am not aware that they have stopped using some G.R.P. boats and I would be very surprised if this is true. One thing that would lead me to believe that certain official bodies within the U.S. could oppose using these boats would be the fact that their methods of producing these boats are so streamlined. For example: A 36 foot yacht is started in the mould at 10 o'clock in the morning and at 10 o'clock the following morning the mould is empty again and they have started the next. The mixes are so fast, they are putting down so many layers together, that you cannot bear to put your hand on the mould. This boat is moulded at 10 o'clock, nineteen days later it will be out and sailing. As it moves down the production line you can see the shrinkage taking place as it cures out. You can see the ribs starting to show through, you can see the bulkheads showing through and then later on down the line you can see the roving pattern coming through. The purchaser this year has finished with the boat next year and like everything else, he trades it in and gets a new one. Unless the particular boats for the Navy are built by a responsible organisation such as a ministry body or d efence body where they pay attention to the small details and make sure that they get a good finish. They are not getting laminates where the resin has been so hot that it has microcrazed all the way through and it is useless. This can happen.

Lieut. B. Swan: H.M.A.S. Penguin.
You mentioned one inspection without any filling or pigment was with lights. Can we not also use ultrasonics for G.R.P?

Mr. Campbell:
This can be done. I do not know of any instrument that is commercially available at the moment that will do this readily and is foolproof. As far as I would be concerned with inspecting G.R.P. laminate, if it is non pigmented, use a light source to inspect the integrity of the laminate. Failing that, if it is pigmented and is consequently opaque, the best test is a fifty cent piece and tap it. A tap test is still the best test you can find for a laminate and if you get a nice sonorous ring from it, you have a good laminate. If you get a dull response then use a knife to dig in and look for what is underneath. There is nothing better than this at the moment, even the magic Barkall hardness machine which everyone says is the only non destructive machine for inspecting laminates. Granted, this tells you what the hardness of the surface is. The machine itself is inaccurate within +5 so you can ignore 10° of readings. It will tell you if the laminate is cured but it will not differentiate between whether it is cured marginally or if it is cured very well so I still think a good inspector with a 50cent piece can tell you more than the instruments that are commercially available.

F/M.Shipwright J. Wilson: Garden Island.
We have been talking about G.R.P. but only concerned with polyesters. At present, apparently, they are bad in laminating onto laminating with the exception of the 189 MB. Are there any investigations with a view to changing to the epoxies as a laminating resin in lieu of polyesters? We have had a great deal of success in laminating onto oil and water contaminated timbers with epoxy resins.

Mr. Campbell:
This happens in organisations which can afford to use epoxy resins. I think it is purely a matter of economics and reconciling whether your end product that you produce in a polyester is satisfactory; if it is not satisfactory then you have to go to the more expensive medias and use those. Epoxy resins would be approximately three times the price of polyesters. I can give you an example of this. When I was with De Havilland Propellors in 1954, we used to make fibre glass spinners for Blackburn Bevelies and Britannia aircraft with a polyester resin called Nuron 15. This was made by Shell Chemicals who decided they were not going to make it anymore. We did not seem to be able to get the physical properties from the polyester resins so tried epoxies and we made all our spinners out of epoxy resins after that. They were paid for mainly by Ministry Organisations so they could afford to use

these resins. They are certainly designed sufficiently well to be used as laminating resins, they have all the attributes of good adhesion, good chemical resistance, some of their cure characteristics are a little bit nebulous at times but there is no technical reason why you can't use them, if you can reconcile the fact that they cost you more.

Mr. J. Wilson:
The gel coat situation seems to be dubious.

Mr. Campbell:
There are some very good epoxy gel coats. There is nothing to stop you if you wanted to just laminate it and when it is finished apply an external gel coat with something like a polyurethane.

Mr. J. Wilson:
Now and again we find incompatibility between the clothes or matts and the epoxies.

Mr. Campbell:
I think this is a matter of ordering the right binder and right size on your reinforcing material from your manufacturers. Most of the manufacturers of woven fabrics here in Australia use T5 or voland treatment which is certainly compatible with epoxies even more so than the silenes or garans that you get for your polyesters. We use one particular fabric and we have a hard job to get it in silenes. It always seems to be treated in valand, probably it is because they are selling it to you.

Mr. J. Coleman: Cockatoo Docks.
I had an occasion to buy a rather common pressure pack fire extinguisher just recently and it said on the label "This is not to be used on fibre glass boats". Could you explain why this is stated?

Mr. Campbell:
I would have thought it was a dry chemical type, it is not a wet type of chemical extinguisher and I see no reason for it. At one stage they were using a certain acidic type of fire extinguisher which was not recommended for reinforced plastic boats, but I believe that they are now off the market.

Mr. J. Coleman:
These are readily available. It is the one with the red fireman's helmet as the stopper.

Mr. Campbell:
I certainly do not know what could be in there to warrant this. Most of these are atomised powders are they not?

Mr. Coleman:
I thought these fibre glass boats were imperious to most things and I would have used it in a boat without reading the small print and it was rather small but it was underlined.

Mr. Campbell:
The only thing I can think of is, it is one of those old caustic soda fire extinguishers which would certainly have a marginal effect on the surface of the laminate. I would not think there would be sufficient in it or the duration of time that it would be in the boat would impair the structure at all. I am at a loss as to the reason for that.

Mr. A. Hunter: Dept. of Navy.
I am mainly concerned with the repair of fibre glass hulls. Could you give me any idea as to the facilities which have become available for emergency repairs of hulls. How effective would they be in comparison with wood and steel hulls.

Mr. Campbell:
The repair of a G.R.P. hull is a very small problem indeed. Your material is versatile and it lends itself to be repaired readily, dependant on the type of damage. Assuming you punch a hole in it then the way to repair it is to cut away all the extraneous and powdered matter, because polyester resin laminate is relatively brittle, if you do fracture it all the edges will be frayed and all the glass will be shattered, cut this back to parent material. You can soon tell

when the material is solid by a tap test. Champher the edges inside and outside, scurf and de-grease the inside of the boat with about 6" or 7" of the sides of the hole. Dependant on the area this will be varied, then take a piece of cardboard or masonite or arborite or something similar, fair it over the hole in the vessel, screw it down with self tapping screws having waxed it previously, then apply a gel coat through from the inside of the boat onto this patch you have put on. Then build up sufficient laminate until it is flush with the inside of the hull, let this cure and then put a further patch over the infilling onto the parent piece of hull, let this cure, take off your arborite, stop up the holes and just dress back the gel coat.

Lieut. V. Fazio: H.M.A.S. Nirimba.
What about the weather conditions. Has this to be done under ideal weather conditions?

Mr. Campbell:
Polyester resins can be cured under pretty adverse conditions. You would not get the optimum properties from the laminate but this would not matter. What you could do, if this was a temporary measure, is put sufficient resin and glass on there, sufficient layers to make sure you have two or three times more than you needed so if the physical properties were 50% lower, what would it matter, you have plenty on there to withstand the trip back to base where you could do something about it.

Lieut. Fazio:
You would have to be skilled to judge the conditions.

Mr. Campbell:
No, not necessarily. You could write out a set of instructions for an operator which would be virtually foolproof, to put a temporary patch on.

Lieut. B. Swan:
Would the ingredients have to kept under refrigeration to retain effectiveness?

Mr. Campbell:
No, provided they were kept away from direct sunlight and their temperature was kept around 70 to 75 degrees. A dark corner would be perfectly all right.

Mr. J. Wilson:
There are repair kits available from Naval Stores for this purpose.

Mr. Campbell:
Presumably with a pre-set screed on how to use it.

Mr. Wilson:
Yes, with the procedures, they are an epoxy kit.

Mr. Campbell:
That is better still. Epoxy is not as susceptible to moisture and humidity as are polyesters, in fact, there are certain epoxies that they say can be cured under water. All they do is uprate the active ingredients in the epoxy so they cure so fast that the temperature does not matter.

Mr. L. Hedges:
There is a problem with repair kits of polyester. Of course, if they are pre-accelerated they have a limited shelf life.

Mr. Campbell:
Pre-accelerated polyester resin provided it was kept at around 70° without being in direct sunlight could be expected to have a shelf life of about 12 months, but I would say if one was making up a repair kit to be kept in stores you would certainly not pre-accelerate it. You would just use neat resin.

Lieut. V. Fazio:
I had an occasion to test a fibre glass repair kit on H.M.A.S. Sydney and we found it a little bit cumbersome. It came in a large black box and we found it absolutely useless. In fact, we carry Nock & Kirby proprietary repair kits on board and we found these were admirable and did the job quite well.

Mr. L. Hedges:
They would not last very long.

Lieut. V. Fazio:
Probably not, but we found they did not last that long as everyone wanted them.

Mr. Carran: G.I.D.
You have shown us a very nice sample of a sandwich construction honeycomb. Is this available in Australia and where can it be obtained?

Mr. Campbell:
I obtained that from Quantas and have been trying to get hold of some myself. I am doing a project at the moment which is an aerofoil sail. It is a solid fibre glass sail over a fibre glass honeycomb structure which is going to be put on a dinghy. As soon as I find where it can be obtained I will advise you.

Lieut. B. Swan:
In answer to the question on the honeycomb construction.
British Aeroplane Plastics also make this for Thornycrofts for the new minehunter they are building. The cells are about 1" hexagon. I understand the difference between polyesters and epoxies but isn't design the controlling factor on this problem of fire retardancy of G.R.P.

Mr. Campbell:
In certain respects you mean, by whether you use a woven fabric etc.

Lieut. B. Swan:
In streamlining design internally, for after all, we are interested in fire protection internally as the main aspect. By streamlining your reinforcing and ribs, stringers etc., surely this is the controlling factor in fire retardancy.

Mr. Campbell:
I think the main problem with fire retardancy is the fact that life boats on passenger vessels are in G.R.P. If your boat goes up in flames and you happen to drop a lifeboat over the side onto an oil slick that is burning, what happens to your reinforced plastic boat. Will it burn?

Lieut. B. Swan:
I was looking at it from a larger aspect - a vessel over 150 tons.

Mr. Campbell:
I would think that this Bristol Aeroplane Thornycroft project used woven fabric in the skins because they consider it improves the fire resistance. The only reason I can think of for this is in using a woven fabric your resin to glass ratio is reduced. Instead of 2½ to 1 it is about 1 to 1 so that the available material to burn is minimised. I can think of no other reason why a cloth over a matt should improve the fire resistance.

Lieut. B. Swan:
By using a woven matt you improve the directional strength of the vessel.

Mr. Campbell:
Yes, but this does not effect the fire rating of the boat. The polyester is still going to burn, you have to put it there in any case. It will burn if you have it there whether it is bound in matt or it is bound in a woven fabric.

Mr. L. Hedges:
The problem is akin to the fire risk in a ship that is struck by an explosive shell where all the paint inside a bulkhead will flash off immediately.

Mr. Campbell:
If you are so worried about a fire rating then the thing to do is to have your gel coat a conventional gel coat which will weather well but will burn when it comes its time to burn. The main structural laminate to be of a self extinguishing type of polyester and the inside of your boat to be painted out with one of those new intumescent paints whose function is such that as soon as flame comes to it, it bubbles and puts down an inert barrier over the surface which

stops the flame getting to the surface. The photo of silo that was handed round was the first one we did and we painted that with an intumescent paint because the customer was worried about the fire rating and we were worried about the weatherability of a fire retardant polyester. We tried this intumesing paint. We found that after about 9 months in the open it was completely useless and we might as well not have bothered and as the project was kept in service, after about 2 years they did not bother painting it any more. If flour ignites, it just explodes, so there would not be any reason to worry about marginal protection from fire because flour is quite explosive.

Mr. Callingham: G.I.D.
You stated that the 30 foot boats in America are curing too fast and consequently the ribs etc., are showing through. What is your recommendation for a cure time for a 30 foot yacht so that your resin is completely cured, lay ups are dried and there is no stress retained?

Mr. Campbell:
Dependent on certain factors, mainly economic, which govern this, you presuppose that the end product you are producing has a perfect external finish. If you are laying large areas it is uneconomical to put down one layer at a time. We have found that the optimum number of layers that you can put down at one time is 3 of 2 oz. matt with a gel time, assuming an ambient temperature of around 70, of about 50 to 60 minutes. This will give you a laminate which will cure effectively without drawing the surface too much and your exotherm build up from the resin curing is not sufficient to turn the laminate pink or white.

Mr. Callingham:
If a laminate took more than 2 hours to gel on the job, could you say the properties would be destroyed by styrene evaporation?

Mr. Campbell:
You would stand a chance of undercure from the fact that it did not cure out within two hours.

Mr. Carran: G.I.D.
What size area per man?

Mr. Campbell:
It is as much as you can put down. He is controlled by how long it is going to take for his bucket to set.

Mr. Carran:
How many men for a lay up like you have just stipulated?

Mr. Campbell:
I am talking about a 3 to 4 man team working an area. If we were working a 30, 32 or 36 foot boat, we would probably put down 3 - 2oz. layers and probably tear them between 15 and 20 foot long so we did not have a square edge. These 3 to 4 men could quitereadily put down 3 - 2oz. layers over that area within that time. If you get your resin in 10 lb. buckets or 15 lb. buckets or 20 lb. buckets, as we do, then if you have 3 men working they have only 5 lb. each to put down. A man can put down 5 lb. of resin in no time on flat surfaces or simple curvatures so he can overtake his gel time. He can certainly put down the 20 lb. in his bucket well within the 60 minutes that he is allowed so he can progress and gradually go round the boat. You start at the transom, work right up to the bow and down the other side. The time it is going to take that 3 man team is probably 4 or 5 hours and by the time they come to the end of the series, the part that was on originally, that had a 60 minute gel time, has probably been cured for about another 2 or 3 hours so that all its heat was dissipated and it was cool again. They can go round in a big ring.

Mr. Carran:
In other words, 4 men could lay up a 30 foot yacht in a day.

Mr. Campbell:
No. The point you are trying to make is that you want to uprate the time taken to get that boat out of the mould by putting down sufficient glass and getting it all glassed up within a certain period of time.

Mr. Carran:
No, not getting it out of the mould, just laminating it. I have done this but we are having trouble getting others to do it. Evidently a 14 footer would be simple for your set up.

Mr. Campbell:
Relatively speaking yes.

Mr. Carran:
By hand lay up 3 - 2oz. layers.

Mr. Campbell:
In a 14 footer you probably would not put 3 - 2oz. layers. These are the bosun dinghy. It is very difficult as I don't know the total weight of glass that goes into the boat, the total weight of resin, so I cannot say definitely what weight layers to use.
The limiting factor in a big boat which is more pronounced than a small boat is you have a great volume of material to deposit in the quickest time that you can to make it a commercial proposition. It is no good putting a 2 oz. all the way round and then following that with the same and then another one; you just would not make any money. The most you want when laying large boats is 3 - 2oz. matts. Never lay more than that. If you lay 3 - 2oz. matts you must be sure that your gel time is around 60 minutes because if it is less than that you are going to be in trouble from exotherm and you are going to have substandard laminates. I have a chart which I have built up over the years since 1953 which has time in minutes to lay certain areas whether it be gel coat followed by tissue, 1 oz., 2 oz., 5 - 2oz., 10 - 2oz., or whatever it might be to complete a 10 oz. laminate or to complete a 20 oz. laminate and this will give you, within minutes, the time it should take to lay that area. It is also graduated between flat sheets, simple curvatures, double curvatures or very small or complex moulding.

Mr. Carran:
When the sample of honeycomb reached me it cracked. I tested it by flexing it one way reasonably lightly and then the other way and it cracked. I did not apply much pressure. With half of what was left I bent it one way again and I noticed that it wanted to go completely the opposite way to that which you would want it to go for a concave surface.

Mr. Campbell:
This is a problem. This is why I was very surprised when they said this had completely obviated all the problems of adhesion between the core and the skins. I am sure that Mr. T. Williams has used this when he was in England. The little reinforced plastic building that we made was for the B.B.C. and we put it on top of a mountain. We used 1" celled paper honeycomb for that and it was awful to use, you just could not control it. You can get around a single curve but the ends curl up in the middle where you get the curvature. It forms this hyperbolic curve.

Mr. Wilson: G.I.D.
There must be some answer to it because the Radome on the "Ikara" is made of this particular honeycomb.

Mr. Campbell:
Infra-red heat is used to form it but also there is a G.R.P. or a glass honeycomb which you buy and it is just a woven glass. It has been glued at the points where the intersection takes place between the cells. It is like a concetina and you just pull it out. You drape it over your radome and then you dab resin on and impregnate it on the spot.

Mr. Wilson:
This ... dome is about 3 or 4 foot in diameter and it is not impregnated just stuck between the inner and outer layer.

Mr. Campbell:
It is probably impregnated when it is bought.

Mr. L. Hedges:
Some of these Radomes do use a honeycomb but they are pre-machined out of thick honeycomb; you collapse them, machine them to the curvature then open them out again. That is one of the methods used.

Mr. Campbell:
This is right. The older aircraft companies used this but it is terribly expensive. I am almost certain that if they have gone round the curvature where they get down into the bilge, they have collapsed cells there or highly distorted cells.

Mr. Carran:
What in your opinion is a good honeycomb to use as a core?

Mr. Campbell:
I would say that honeycomb is perfectly alright for flat panels. I prefer for double curvatures, a rigid P.V.C. foam. This is about the best that is on the market at the moment - trade name Daycell, clagacell.

Mr. Carran:
For compound curves do you use Daycell? We use infra-red lamps on Unifoam (P.V.C. polyurethane) but under laboratory tests this is no good. I was told you can bend this under extreme heat but it has to be so extreme you will burn it. What we are doing is fitting it.

Mr. Campbell:
We fit ours as we use the same foam.

Mr. Wilson:
You use the Daycell?

Mr. Campbell:
We did use it. It is now out of production. Daycell first originated with B.T.R. in England and they made one called Pastiside. This was very good P.V.C. foam but the only problem was that as soon as you raised its temperature to above 60°C. its physical properties were non existant, it softened and distorted but was possible to use infra-red lamps. You warmed it gently and you could curve this very nicely.

Mr. Wilson:
We did some marvellous curves with the Unifoam which is the same as P.V.C. foam.

Mr. Campbell:
This is uncrossed, linked P.V.C. foam. The Daycell is slightly crossed, linked and it is not a true thermoplastic. It is almost a thermoset and it has a softening point of about 212°F. You have to get it hot to start to deform it and once you are deforming it at these temperatures it is very close to the degradation point. It is marginal but the best way certainly is to fit it or tailor it. You can get it round simple curves.

Mr. Carran:
Do you know the reason why Daycell has gone out of production? It is the best we have found.

Mr. Campbell:
I agree.
They started to sell it at a price which we will call 30 cents (this is not relative). Six months later stated they had made a mistake and increased the price to 42 cents, being the order of cost. It was still cheaper than balsa

and it did not cultivate marine growth like balsa. Another six months later they dropped the price to 32 cents. I think the basic problem is economics. Their costing cannot be correct and the reason they have given us is because it is uneconomic to produce and there is not the demand for the end product so that they cannot justify large production rates.

Mr. Carran:
What are you going to use in its place?

Mr. Campbell:
We are going to import it from France, not England, because the Daycell type from England will be the low softening temperature but the one from France will be of the high softening temperature you want.

Mr. Carran:
In your opinion this is the best on the Australian market?

Mr. Campbell;
Definitely.
There is a firm in Brookvale, called J.W.W., who were experimenting with a semi-rigid P.V.C. and I don't know how far they have progressed as yet. They are the Unifoam manufacturers.

Mr. Callingham: G.I.D.
What about the P.V.C. foam used to make the new cored car bodies?

Mr. Campbell:
I thought that was A.B.S.

Mr. Callingham:
Haven't they a new P.V.C. one as well? I think it is a combination of P.V.C. and A.B.S. A.B.S. sub straits and P.V.C. foam which is actually foamed in situ while being moulded. They heat the sheet on both sides, prop it till it starts to sag in the middle and then put it on the mould with a combination of heat and applied pressure. It expands there and then and gives you about 1" increase in thickness. Some of this is P.V.C. core with something like six skins altogether, it is not two skins and a core, it is quite a complex thing and is weather resistant.

Mr. Campbell:
You would have problems of adhesion with polyester. It sounds impossible to me.

Mr. Callingham:
Do you know of any P.V.C. suppliers of sheet, etc., who stock this?

Mr. Campbell:
There are not many P.V.C. people in Australia in a big way. There is Storey & Davis and the people who have just bought an interest in the I.CI. P.V.C. organisation, a Melbourne company, Moulded Products, but they don't do anything in that field that I know of.
Balsa in my opinion, forms a good structural material. The problem is getting it in the right form. You can buy it in 2" blocks with the nylon net on the back, the only trouble is the little blocks fall off the net and time is spent putting them back on the net to put in the job. It is more like building a mosaic. It is very expensive, 59 cents per square foot. The danger is if it is damaged, it will support marine and biological growth so there is a rotting action from the inside. You can get dry rot in your reinforced plastic deck and it gets heavy.

Mr. H. Owen: G.I.D.
What properties do you want then in a material for this work.

Mr. Campbell:
Essentially, you want a material that you are able to shape to the curvatures, one which can be readily bonded to, one which is not going to be friable, it does not break up readily like the old polyurethanes and finish as a mass of powder, one which has a good shear factor in the foam itself and cheap, also a better recovery rate helps.

Mr. J. Wilson:
It must be compatible with the resin you are using too.

Mr. Campbell:
Yes, that is why I said it is one you can readily adhere to. Polystyrene is the old favourite highly dissolvable with polyester. The polyurethanes are too soft and friable and if you try to go up in density from 2 lbs. per square inch to something like 4 lbs. per square inch, which you would have to, to be compatible with the 2 lbs. per square inch Daycell, would cost an exorbitent amount. The Daycell is a little bit more expensive than the polyurethane and you are quite prepared to pay that for the increased physical properties you get compared to what you would get if you asked to ballast the polyurethane out to do the same thing. I doubt if they would make it unless you could guarantee a tremendous production from them and even then it would be a prohibitive price.

Mr. Callingham:
Would the material cost offset the labour cost?

Mr. Campbell:
Not necessarily. If you are going to shape the polyurethane you still have to cut it and chisel it.

Mr. Callingham:
Could you chip and apply it with a gun?

Mr. Campbell:
Now you are getting into a different field. You are talking about putting your core material in by cutting it, tailoring it, heat deforming it and sticking it on, this is all well and good, but as soon as you start talking about foaming polyurethane in situ you are talking about enormous jigs. When you bear in mind that the blowing pressure of a polyurethane foam is 5 lbs. per square inch in all directions you don't need a very large area before you are getting pressures up in the ton range and this is the big problem.

Mr. Callingham:
Do you think that a firm who say they can do this without a jig cannot do this?

Mr. Campbell:
No. They are probably using a frothing gun which pre-froths the polyurethane foam in the head and then jets one of these inert gases, freon or argon, into the foam. They pre-froth it in the head and it comes down the tube into your job. It will still rise and blow but the pressure, instead of being 5 lbs. per square inch is more like ½ lb. per square inch and you still have problems from secondary blow. As soon as your exotherm temperature builds up you have this secondary growth from the foam and can rupture any skins you have. Some sort of jigging is needed no matter what you use.

Mr. L. Hedges:
There has been a successful boat built in the U.K. recently, where a timber jig was formed, a male mould and the inner skin was laid up with G.R.P. and then foam about 2" thick, followed by an outer skin laminated onto that. I do not know what kind of jig stresses they hoped to achieve with this.

Mr. Campbell:
I saw a demonstration of that gun being used by Shell Chemicals at their Ultimo Plant and it did not impress me at all. It was a nice foam but depended upon the density at any one place, solely on luck, there was no control over density by the operator.

Mr. L. Hedges:
It is very variable due to the laying process.

Mr. Campbell:
By the time you had your area covered you could not guarantee how much foam you had in there and it was completely unbalanced. You imagine doing that in a little skiff where you wanted to use two thin skins and a foam core. You could quite easily be 10 lbs. heavier on one side than the other. We foam in situ our rudder on a number of the boats and we use the best bucket and brush technique. We use two paper cartons with 75 grammes in each, we mix it up with an old air drill, pour it down the hole. We have about 6" webs glassed onto the side of the rudder mould and this contains the pressure quite well and is satisfactory in operation. If you increase the area you have to then worry about your pressures. This will be the problem in manufacturing containerised freight units that are currently proposed. In the specification it states that the urethane insulation should be frothed or foamed in place. The panel in question is 20' long x 8' x 4" thick. The volume and pressure comes to approximately 47 tons on the side of the panel.

Mr. Callingham:
Dairy Products have done something along these lines with their refrigerated vans and have spent a fortune on this.
That would be done in sectional pours not in one pour?

Mr. Campbell:
Yes, but you still have the same pressure build up even if you do it in small sections, because of skin formation over the foam. It is like a hydraulic pressure, it is in all directions. It is not directional and you cannot say because there is a little hole on top that it will all squirt up, you still get your sideways pressure.

Mr. Callingham:
Yes, the higher your lift, the greater your pressure on the side but you are only pouring a small lift and you would not get the same amount of pressure on the side.

Mr. Campbell:
With the polyurethane foam most of the pressure comes in the second stage of the blow. The initial blow takes place then it stops and does not rise much further initially. As the temperature builds up exothermic reaction in the polyurethane starts and the little gas in the cells expand then this pressure comes in all directions, you cannot help it. The skin that you get on the top of the foam to a certain extent, acts as a local mould so you still have sideways pressure then it shrinks and you are in trouble if you have no adhesion.

Mr. Carran:
This all gets back to Daycell doesn't it? What is it going to cost to bring it from France compared to what you and the Navy have been paying for the local product.

Mr. Campbell:
I do not know.

Mr. T. Williams: De Havilland.
There is a possibility it will be less, if someone is prepared to import it.

Mr. Campbell:
There is a firm interested if they can obtain a Tariff Board inquiry. There might be a tariff put onto it but I would say at the moment they could not supply the needs of Garden Island, De Havilland and Rudder's Yachts, with their present production set up so they would be in no position to object against the importation of this material into Australia.

Mr. Wilson:
What was the name of the firm in France?

Mr. Campbell:
Do not know.

Mr. Wilson:
We have found it is the best type of stiffening so far, unless someone comes up with something else.

Mr. Campbell:
No doubt about this.

Mr. Wilson:
As the Navy we can import the material and it comes to us duty free. If you could find out the name of the firm and advise us we would appreciate it.

Mr. Campbell:
I would like to be fair to Storey & Davis. They are going to import it. They contacted me and asked what quantity of foam I needed over the selected period of time. I have placed an order and they are making this for our company, to be held in store and drawn off as we want it. I presume they have done this with other companies. I have given them a 12 months forward order.

Mr. Carran:
How are they going out of business?

Mr. Campbell:
The plant is extremely expensive and it is very complicated, also, to a certain extent, it is hit and miss. I would imagine that their scrap rate would certainly be of the order of 15 to 20% with this type of process. They must have a high overhead content and unless they can obtain a relatively high production rate per month it is not a viable proposition.

Mr. L. Hedges:
You mentioned using a seal coat to start with. Did you intend that seal coat to be fully cured before you proceeded with the rest of the laminate?

Mr. Campbell:
I think it can be fully cured providing you use a non wax resin system.

Mr. Hedges:
This does not cure very well.

Mr. Campbell:
Which?
The top 2 to 5 thousanths of an inch is completelyundercured because it is fully inhibited. Used with something like 10% styrene dilution and possibly 10% acetone you put it on as a very thin film, obtain a good flashing time from it so that you do not have solvent entrapment and obtain a very good seal on your timber.

Mr. Hedges:
You trust that fairly well?

Mr. Campbell:
Yes.

Mr. Hedges:
I have had trouble with sheathing. Occasionally it can be a problem.

Mr. Campbell:
We are doing a 37 foot boat next week this way.

Mr. Callingham:
With the polyester?

Mr. Campbell:
Yes.

Mr. J. Wilson:
Do you prefer polyesters or epoxies?

Mr. Campbell:
I prefer epoxies unreservedly. I initially trained on epoxies, polyester was unheard of to me for 10 years and chopped strand matt was not used in the factory. I think it is a matter of common sense and economics. Certainly polyesters can give you 95% of the requirements that you want and if you design accordingly you can certainly get full use out of them and you can do it as an economic proposition.

Mr. Wilson:
It depends on the type of craft. We are just about to find out how good our greatest experiment has been when the H.M.A.S. "Curlew" comes into the Dock.

Mr. Campbell:
What was done to the "Curlew"?

Lieut. F.A. Bush: R.A.N.
Our reports show that the sheathing on this has been successful.

Mr. J. Wilson:
The ton class minesweepers were sheathed with the "Cascover" sheathing process with a resin glue. This is so unsatisfactory in service that we are continually patching them and we decided to do the H.M.A.S. "Curlew" completely with an epoxy and chopped strandmatt. This is a system that Mr. R. Callingham and myself experimented with and proved to be satisfactory. She has been in service now for 18 months, mostly in the tropics, and she is due to come into Dock which will be the proving point. She was originally waterlogged and soaked with oil.

Mr. Hedges:
What condition did you get the planking into when you sheathed her?

Mr. Wilson:
The moisture content was between 30 and 40% and in way of the engine room, a similar content in oil and water. We went over the whole area with methylene chloride, applied a seal coat immediately, which we feel now is not necessary. We can laminate straight on provided we use the methylene chloride first.

Mr. Campbell:
The biggest problem is to get it off.

Mr. Wilson:
The methylene Chloride?

Mr. Campbell:
Yes.

Mr. Wilson:
No, the methylene chloride we find dries the area out and evaporates the whole surface down about 1/16 inch. We start laminating straight on there. We have 3 or 4 small craft operating from Garden Island now that have been done this way, up to 4 or 5 years for the oldest.

Mr. Campbell:
You found no problem from any residual methylene chloride?

Mr. Wilson:
Methylene chloride we find very compatable with the epoxy resin.

Mr. Campbell:
I use it for dissolving epoxy resin.

Mr. Wilson:
We have found it very compatable with the methylene chloride.

Mr. Campbell:
This is the basis of 95% of these ardrox strippers.

Mr. Hedges:
It is quite likely you will have H.M.A.S. "Curlew" floating in a fibre bath.

Mr. Campbell:
The use of methylene chloride amazes me because I have always used it as a medium for stripping off part cured or fully cured polyesters and epoxies. It is the only material I know that will show any surface attack to these materials and the big problem is to get it off. The only way to do this is maximum irrigation with water so it is defeating its object.

Mr. Wilson:
We had a dhory that a sub-contractor was going to sheath for us and when we turned it upside down, the timber content would have been about 80% oil in the way of the engine room without a doubt. When the contractor saw it he refused to do it. We were given the task and contrary to the resin manufacturers who advise to use epoxy and cloth, we used epoxy and chopped strand matt. We used the methylene chloride and it has been in service now for 3 years with no sign of de-lamination in the hull whatsoever.

Lieut. Bush:
You said to get an anti-foulling paint to band to fibre glass or G.R.P. that you would need, more or less, an epoxy undercoat. This is not true as we have used an aluminium bitumenous undercoat with a oleoresin anti-foulling and we found that this worked quite well. It was the same ship - H.M.A.S. "Curlew". I have seen her docking reports from Singapore and the Naval Architects reports which indicate she is in very good condition.

Mr. Campbell:
But you do not have the same problem because when you mould a boat you put 4 or 5 coats of wax on to make sure you can free the boat from the mould. Then when you have the boat out you have all this wax to remove. When you sheath something you do not use any wax.

Mr. Callingham:
Yes, but under adverse climatic conditions you have your hardener coming out of your resin.

Mr. Campbell:
You should not.

Mr. Wilson:
In the winter time you definitely do, particularly with the epoxy that we are talking about. With epoxy you use a hardener and this was done in the floating dock, sitting above water. The worst thing with epoxies is to operate close to any atmospheric conditions where water is present. All these boats were done within about 6 feet of the salt water. We have not had a failure yet.

Mr. Campbell:
One counter question to you Mr. Wilson.
Why chopped strand matt as opposed to woven fabric?

Mr. Wilson:
We conducted tests and we found it more flexible.

Mr. Campbell:
Was this boat planked?

Mr. Wilson:
Yes. We have a 22 foot motor boat, 206, built in 1939. There was not a nail holding it together as when it was running the water was squirting

Mr. Wilson:
We have found it very compatable with the methylene chloride.

Mr. Campbell:
This is the basis of 95% of these ardrox strippers.

Mr. Hedges:
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around the nails. She was done 3 years ago.

Mr. Callingham:
This is a perfect example. One side of it was done with chopped matt strand and the other with cloth. The cloth has let go while the chopped strand matt is still holding.

Mr. Wilson:
This is contrary to all the resin manufacturers recommendations. This is mainly because the resin manufacturer market the cloth.

Mr. Campbell:
Yes and they get more for the cloth than they do for the chopped strand matt.

Lieut. V. Fazio: Nirimba.
We do not do vary much, the longest we have done is an 8 foot dinghy. Most of the other work is mainly small repair jobs and the manufacture of crests. We use a water soluble releasing agent and we find no trouble at all with these.

Mr. Campbell:
P.V.A. is all right. You have a problem of drying times with P.V.A. You also have problems that it does form a film and you don't get as good a finish off a P.V.A. mould as you do off a waxed mould. Also it costs too much to clean down between processes. We have a system whereby in our big moulds we stop for one week either before or after Christmas. We scrub it 3 or 4 times with Ajax, wash it thoroughly with plenty of water. When we have finished we go over it and look for any defects, patch all these up and then we wax. We probably wax 4 or 5 times and when I say wax, we wax and polish it all off again and there is virtually no wax left on, there is just a very slight bloom of wax on the surface, then we mould the boat. You start pulling a boat about 7.30 in the morning (for a 32 or 36 foot) and by about 9.00 the boat is out of the mould and well out of the way. You have the mould bolted back up again, and have it waxed one more time only, then you put the gel coat on. Now the down time on themould is very negligible but with a P.V.A. film you have to water wash it off and re-apply it. Where you are using a reasonably large production programme is where you want minimum time on your mould and you can't afford to use P.V.A.

Mr. Wilson:
How many releases would you get from each waxing or do you wax every time?

Mr. Campbell:
One.

Lieut. Fazio:
What about international Plastics?

Mr. Campbell:
They use Kelos and they obtain fifty pulls out of one application.

Mr. Carran:
The one only release from waxing.

Mr. Campbell:
This is all I want.

Mr. Carran:
You must also have some very competent, well-paid staff.

Mr. Campbell:
They are reasonably highly paid and they are worth paying good money to. I have 8 laminators that I would take anywhere in the world and put up against anyone because they are first class laminators. They are thinking men, they are paid a good wage and we have given them shares in the company. They are now part shareholders in the company and they have a vested interest in it.

Mr. Callingham:
Do you personally supervise the waxing and make sure it is to your satisfaction?

Mr. Campbell:
I supervise everything where I can. When we changed this new Company over, two of the laminators became directors. When we were setting up the structure and working out the overheads, they saw what my salary was and asked why I was getting that much. All he does is walk around the shop and watch us. I make sure that they do what they do at the critical stages. All the critical stages, the waxing, the gel coating and the first 1 oz. I believe stongly in putting a 1 oz. behind a gel coat no matter what it is. Behind the 1 oz. in the big boats we put a scrim cloth just to improve the surface impact, but if you put the scrim cloth in straight behind the gel coat you invariably get a fabric pattern showing through. Another good technique on the larger boat is to have it gelled about lunch time then leave it till about 7.30 next morning, i.e. leave your gel coat overnight.

Mr. Wilson:
You use 189 exclusively don't you?

Mr. Campbell:
We use the unwaxed polyester 189.

Mr. R. Callingham:
Do you have any snags?

Mr. Campbell:
You do.

Mr. Wilson:
Is that a fully fixatropic resin?

Mr. Campbell:
There is no fixatropic additive in it. We use a very mild form of fixatropic additive, the recommended proportions are up to 10% and we use 1%. Hallmatic in England do not use gel coats on their hulls and they use a high viscosity version of 189. They can paint this resin on vertical surfaces without any sag.

Mr. Williams:
How long have they been operating this process?

Mr. Campbell:
They started in 1952 and are still using it. I don't know how they do it.

Lieut. Bush:
A 16 foot runabout was used in H.M.S. "Cumberland" which was a diesel engined craft. This is probably the basis for your statement that the Royal Navy was not using fibre glass.

Mr. Campbell:
The American Navy.

Lieut. Bush:
No, the Royal Navy. They had this 16 foot runabout and they found after a certain period, which I think was 9 months, that the gel coat actually crazed. They painted it, applied many coats of grey paint and after about 18 months they decided to take it off with caustic soda and consequently finished the craft. This could be where the R.N. got their animosity against G.R.P.

Lieut. Fazio:
I think you have already covered this by saying the Admiralty did not think that a diesel engined G.R.P. craft would be feasible.

Mr. Wilson:
Do you spray your gel coat or apply by hand?

Mr. Campbell:
I spray gel coats.

Mr. Wilson:
Again in this instance it could have been a hand gel coat. Now we found out when we first started that we could not put enough gel coat on. We thought we just kept going with brush after brush and we got crazing but once we started the spraying of gel coats and put down about 10 mil., we have not had any problems.

Mr. Campbell:
This is a fact.

Mr. Wilson:
It eliminated the surfacing tissue which we consider only builds up the thickness of gel coat.

Mr. Campbell:
I saw a 50 foot yacht, called "Van Dieman", made in Holland by Le Cont; Swanson's fitted her out and she is owned by Stan Halwitts and he sails her. She is at Palm Beach at the moment. We had a look at her on behalf of Swanson's and the gel coating in parts was 0.1" thick. We used to get 60 thousanths on at Hallmatic. We only get 15 thousanths on in Australia.

Mr. Wilson:
What is the hull thickness?

Mr. Campbell:
5/16", it is very thin. Around the shear it varies from four - 2oz. or six - 2oz. to four - 2 oz. There is not any one particular area that is a constant thickness. We draw our men pictures and colour it all in, in various coloured crayons - this is the sequence. You start off with your gel, scrim cloth and then you put down 2 - 2oz in coloured resin. Then you come in with clear resin and at this stage you stop. Where it is shaded green you put an extra 2-2 oz.and where it is shaded purple you put an extra 3-2 oz. You have to make it fool proof.

Lieut. Bush:
This is the sort of thing you need for fibre glass if you canmake it sailor proof.

Mr. Campbell:
I think the fundamental problem with reinforced plastics to-day is good process and quality control in your product and unless this comes through the industry will not progress too much further.

Mr. Williams:
A question on flexure or bending. In the days when De Havilland's were

building aluminium only, they did some testing on the quadralight boats and decided that they were very inferiour because of crystalisation due to flexure damage. The figure I heard was 50,000 flexures at 15% proof stress to produce crystalisation. Would this be right?

Mr. Campbell:
I cannot remember figures but in the U.K. at De Havilland Propellors we made prime structures which were not static, they were moving structures. These were the spinners and these were revving at something like 1100 RPM. These spinners were lasting for 3 and 4 thousand hours whereas an aluminium one would fatigue out or it would be dropped and broken. These were worth about £1500 and a fibre glass one would bounce. We then took this a stage further because we wanted to make wings, control fins, nose cones and such for missiles. We took a whole series of polyester, epoxy, glass, chopped strand matt and sent them down to the vibration department to put on test at high and low frequency vibrations. We found nothing in these tests to say that the reinforced plastic was inferior to aluminium. In fact, the wing of the Firestreak missiles were glass, the control fins were phenolic asbestos and a lot of the cones were glass. All the Bristol and English Electric nose cones were glass on their missiles and I think this speaks for itself. The material is perfectly satisfactory under vibrational fatigue. I think it is a bad laminate that breaks down.

Mr. G. McGoogan: Cockatoo Docks.
What requests do you get to build these boats to suit Lloyd's requirements?

Mr. Campbell:
At the moment we build a 32 foot boat, the design of which is fully approved by Lloyd's. Number 14 of these went in the water a week ago. I think six have been fully approved to class, that included moulding and full class to Lloyd's. The new Swanson 36 is another of which the design is being submitted to Lloyd's and the first off moulding which came out of the mould to-day was surveyed this morning. I expect overall we would be around 40%. In England the figure at Hallmatic was of the order of 65% to 70% - it was higher.

Mr. Hedges:
Would the bigger the boat mean more were to Lloyd's?

Mr. Campbell:
Not necessarily, it depends on the type of person who is buying it and what he is buying it for, what he wants it for, and if he is fully aware of the value of his boat. It is a difficult thing to say why people want Lloyd's and why people don't want Lloyd's. The mere fact that the boat at the onset is approved as a design by Lloyd's is sufficient fact in itself. You know that you have a boat which is perfectly alright and will suit all conditions and when you ask for a certificate you are only asking Lloyd's to confirm that the design has been faithfully executed. I think the fact that Lloyd's have brought out all these scantlings for reinforced plastic boats is good. I could argue with some points, anyone could. You can argue with any specification or schedule that is laid down. It has set a yardstick and al the end products which have been produced to this yardstick stood up in service so it is good. It might be very good, it might be that you could make the boat lighter and say it is as good as that one but it is not to Lloyd's. Once you have this yardstick and the more people you can get who produce this yardstick the better. The fact that Lloyd's fully approve one's factory and confirm that you carry out reasonably rigid process and quality control, that you have a decent mixing bay, that it is not by guess that you put the catalyst and accellerator in the mix, it is done in a logical form, that you attempt to keep your temperature constant, you are aware of the fact that the humidity fluctuated. This all helps in making a better end product. I am for standards and specifications in an industry which is

so fraught with variables and you just have to iron these variables out and that is one of the few ways you can do it.

Mr. Wilson:
Apart from the little book t that has been put out by Scott-Barder, do you know of any really reliable book that you can use as a yardstick that you can guarantee.

Mr. Campbell:
I would say the Scott-Barder book is one of the best I have seen. Grant you it sells their product but if their product is as good as its technical write up, it is worthwhile buying. There is one published by Ileffe and it was called "Reinforced Plastics", very old now, and it was a collection of papers given by leading men in their own particular industry. One from a glass manufacturer, one from resin, someone using contact moulding, someone using pressure moulding, vacuum moulding, tube manufacture. If you want a book to refer to for reinforced plastics when we are talking about design quality control, analysis of laminates, you should buy the Gibson-Cox "Fibreglass Marine Design Manual". It is a very good book and has a statistical analysis of all the physical properties of laminates. It is highly technical in its approach.

Lieut. Fazio:
Where can we obtain this?

Mr. Campbell:
Magraw-Hill I think are the publishers.

Mr. Trivett:
I now call on Mr. J. Wilson to move a vote of thanks.

Mr. J. Wilson: G.I.D.
I have seen the premises where Mr. Campbell operates at Brookvale and I can assure you it is quite an efficient establishment. I would like to move a vote of thanks to Mr. Campbell for presenting this Paper and affording us such an interesting and informative evening.

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