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REINFORCED PLASTIC SMALL CRAFT. W.R. MORGAN

Reinforced plastics are creating a vast interest today in many fields in this country. There are many intricacies involved in this process, which, due to the novelty and the apparent limitless number of components to which it might be applied, it is very easy to get a wrong perspective. The future possibilities of this process appear to be very great and it is important that it should be approached from a sober and realistic angle and development be consistent with a good theoretical and practical knowledge.

Reinforced plastic consists of a suitable reinforcement and a synthetic resin. For marine purposes the reinforcement is to a great extent, glass fibre, although other types of fillers are used in special applications. The synthetic resin may be of several groups such as phenolic, epoxy, and polyester, the latter being the most commonly used. A combination of glass fibre and resin results in a very strong material; while resin has considerable compressive strength its tensile strength is low, just as steel is used to reinforce concrete, so the exceptionally strong glass fibres are used to reinforce the resin, resulting in a material which has high tensile, compressive, and impact strength.

Although today, glass fibres are looked upon as a recent development, they were invented by the ancient Egyptians and represent the earliest use of glass in any form. Glass fibres were not commercially produced until 30 years ago, when it was used chiefly for insulation purposes. The first successful attempt with reinforced plastics was made in 1907, when Leo. H. Backeland produced a canvas/phenolic laminate; it was seen that there were certain disadvantages, viz. high moulding pressures were necessary and the organic reinforcement readily absorbed water, resulting in the swelling and bursting of the plastic bond.

Reinforced plastic underwent a period of development and, it was not until 1940 that the happy combination of glass fibre reinforcement and low pressure synthetic resin was achieved which forms the basic material in plastic boats of today.

The advantages of glass reinforced plastics as compared to orthodox materials are many. In brief these are:-

1- Favourable strength/weight ratio. To obtain similar tensile strength of mild steel, the reinforced plastic is required to be three times the cross section area and will be approximately half the weight.

2- It can be moulded into large shapes without the use of heat and pressure.

3- Good chemical resistance and remarkable freedom from normal corrosion.

4- Very high impact strength with the additional advantage of nom-denting.

5- Exceptionally good temperature range up to 400°F.

6- With boats the low maintenance and ease of repair in the event of damage is an attractive feature.

The disadvantages of glass reinforced plastics are few and can be placed into the following categories:-

1- The cost of the raw materials, viz. fibreglass and resin, are very high as compared with timber, aluminium, steel etc. This is largely offset by the saving in labour costs in the construction of large mouldings, such as boats.

2- The moulding cycle may be from a few minutes to several hours duration and, where repitition of a large number of parts is contemplated, considerable thought must be given to matched moulds and heating.

3- The rigidity of glass reinforced plastic mouldings is generally less than other constructional materials of the same shape, and it is as well to bear in mind when contemplating a design that full advantage should be taken of double curvature.

4- Fire risk is present, although this can be greatly reduced by the addition of fire retardent fillers, dependent upon the physical properties required in the finished moulding. At no time does the inflammability of fibreglass exceed that of hardwood.

The appazent ease of the fabrication of glass reinforced plastic has encouraged many to enter this field and, although many servicable small craft have been made, it will be noted that good mouldings of glass reinforced plastic require skill in design and production technique. This is important owing to the absence of definite standards and specifications, otherwise it can lead to a good deal of unprofitable trial and error by many establishments.

There is now a regular production of small craft up to 25ft. over-all and special hulls are being made 50ft. and up. Many have been built for service use in the U.S.A. and U.K. and, at present, are undergoing extensive tests.

The moulding of small craft in glass reinforced plastics is usually carried out by one or more of the following methods:-

1- <u>Contact Moulding</u>.

This is probably the cheapest way in which satisfactory boat mouldings are manufactured and, in some cases, the only practicable method when the number of mouldings is small and of varying designs. No large capital outlay is necessary - moulds are constructed of almost any material which can be worked into the proper shape and sealed, such as wood, plaster, concrete, metal etc. However, where long runs are anticipated, reinforced plastic can be used as a mould material - this has been used in this country and upwards of 250 mouldings have been taken with little deterioration of the mould. Phenolic casting resin has been used successfully overseas for mould material, Diagram 1 shows a typical female mould.

No provision is made for applying pressure to the laminate as all air is removed either by brushing or rolling the resin into the glass cloth or mat. In contact moulding it is essential that a readily soluble binder should be specified in the glass mat so that this should readily break down and allow the mat to conform closely to the contours of the mould without pulling away.

The quality of the moulding by contact methods depends largely on the skill of the operator. In many cases mouldings of poor quality result but, on the other hand, moulding of good quality are by no means uncommon.

In contact moulding the finish of the outer surface is good but the inside surface has always been a problem and, it must be pointed out, that the quality of the finish measured in terms of smoothness and uniformity of thickness, is definitely limited. This is not a great disadvantage in many applications, such as small craft, which do not require both sides of the moulding to be smooth or the thickness of the moulding to be within fine tolerances. Whether the finish obtained by contact moulding is acceptable depends on whether the fin ish detracts from the physical requirements or its saleablity.

In contact moulding, the resultant moulding is of lower strength than mouldings obtained by other methods; this strength depends upon the glass content and it is rarely by this method that a ratio of more than 25% to 30% of glass fibre to resin is obtained. It will benoted that the strength of the laminate will be well below laboratory samples.

In general, contact moulding can be achieved without high capital outlay but the following disadvantages appear to be apparent:-

i- It does not lend itself to mouldings of uniform thickness

ii- A moulding made by this method is usually heavier than one made under pressure, as normally extra resin is used for wetting, which adds to the cost of the moulding.

iii-Since there is no way of containing the moulding, or, in other words, retaining the thickness within close tolerances, the glass content is naturally low.

iv- Although moulding costs are generally lower, labour costs are relatively high and, in some cases where large numbers of mouldings are contemplated, pressure methods should be considered.

v- The moulding cycle by contact method is rarely less than 8 hours for small craft of up to 15ft. overall and, therefore, if greater production is required, it will be necessary to duplicate the mould.

2- Bag Moulding.

Bag moulding is a method of producing reinforced plastic mouldings faster than contact moulding; as in contact moulding the mould can be quickly made from wood, plaster, phenolics, reinforced plastic, or aluminium. Generally speaking the cost of a mould for bag-moulding is higher than for contact moulding. It may be described as a process in which a flexible bag or blanket is used to apply pressure against a lay up while it cures. Pressure may be applied through the bag in various ways, such as by placing the assembly in an autoclave to which positive pressure is applied; or by positive pressure within the bag or against the blanket - this being resisted by a mould of sufficient strength to withstand the pressure; or by exhausting the air from between the bag and the mould, creating atmospheric pressure. Combinations of these methods may be used and it is found that a pressure of between 30 to 40 pounds per square inch gives a very satisfactory moulding.

The above methods, in short, can be classified as under:-

i- Vacuum moulding,
ii- Pressure bag moulding, and
iii- Autoclave moulding.

Bag moulding can be used, either with heat or room temperature curing resin. When heat is used, a higher production can be expected but, in this case, the mould cost becomes more expensive as heating facilities have to be built in - normally steam or electricity.

Diagram No. 2 shows a typical vacuum set up. First the part to be moulded is laid up in the mould, similarly to contact moulding, eliminating the finishing, the bleeder material, which can be of a suitable porous material, suchas hessian, is placed round the lay up, leaving a small gap between the lay up and the bleeder material, the bag is laid over the mould and clamped down into position, the vacuum is drawn, exhausting the air from between the air and the bag, bringing the atmospheric pressure to bear on the laminate. The hessian bleeder provides a porous and absorbent path through which the air passes to the vacuum outlet in the bag, and absorbs any excess resin which flows from the laminate. It is found that complete exhaustion of the air by this method is not usually possible and that vacuum-process mouldings contain more air and a higher resin content than positive pressure mouldings.

Diagram No. 3 shows the set up for positive pressure. When the pressure plate is clamped into position, the rubber bag can be inflated to the required pressure, usually about 30 to 40lbs. per square inch, causing the resin to flow. An escape channel is necessary for the air between the bag and the mould. If a vacuum is used in conjunction with this method, highly satisfactory mouldings will result, giving higher glass/resin ratios.

Diagram No. 4 gives an illustration of the autoclave method, this is an alternate means of applying additional pressure to the lay up and differs only slightly from the pressure bag method. Great care should be exercised to ensure that there are no leaks inthe bag or around the seal between the bag and mould, especially when steam is used as a source of pressure, otherwise a faulty moulding will result

Generally speaking, these methods produce a moulding of more uniform thickness, more favourable glass/resin ratios and smoother surfaces, while on the other hand, sharp radii should be avoided as bag moulding tends to decrease the thickness over convex radii and thicken up over concave radii.

3- Vacuum Injection Moulding.

This is a comparatively new method and has only become possible since room temperature-curing resins and fibrous filler materials in sheet form were introduced. The method involves the use of matched moulds, the male mould being mounted in a trough and the female having one or more vacuum outlets at the top. (vide Diagram No. 5) The male mould is laid-up with tailored fibreglass cloth or mat, the female mould is then lowered over it and clamped into position to prevent movement. Resin is then prepared and poured into the trough, a vacuum is drawn and the air is exhausted between the two moulds. As the air is exhausted the resin rises to take its place, until it becomes visible in the sight glass in the vacuum line. When this takes place the vacuum lines are cut off at the valves and the resin is allowed to cure at room temperature. A high vacuum should not be used, as it will cause bubbling and excessive evaporarion of the styrene in the resin. Great care must be taken in the manufacture of the moulds and the laying up of the dry fibreglass material, for should there be a discrepancy in the moulds or excessive thickness of the fibreglass material, causing packing, this will prevent the even impregnation of the resin, resulting in dry spots. The moulds can be made of metal, reinforced plastics etc., the main requirement being that it is not porous and also smooth internal surfaces are important.

Although the vacuum injection method has the advantage of producing a smooth surface on both sides of the moulding, it has not, as yet, found favour with commercial producers, as the time factor is high.

4- Preform and matched die moulding.

This method has only recently been used for the construction of small craft, as it entails heavy expenditure for equipment and matched die moulds, of a size not contemplated before. Recent developments in the U.S. have shown that a boat of 15ft. overall will be produced by these methods. Tooling costs and equipment will will be in the region of £75,000 and it will be seen that unless an extensive market can be assured, it will not find favour amongst builders in smaller communities. Preform moulding involves the use of preform reinforcement in matched metal moulds, accurately machined to the dimensions of the finished hull. The preform is made by collecting chopped glass strnds on a perforated screen, the precise size and shape of the moulded part. This preform is placed into the mould, a predetermined amount of resin is added and the mould is closed under pressure, usually 90 to 100lbs per square inch, for the duration of the cure; the moulding is withdrawn and usually only then requires a brief finishing operation. Although this appears to be a simple operation, it should be pointed out that more problems arise before a successful moulding is obtained than in any of the foregoing methods. The chief advantage of preform is large economical production of high glass content mouldings, giving good strength, finish, and consistent accuracy.

In all of the foregoing methods of moulding, reference has been made in each case to the fibreglass/resin ratios, this must be taken into consideration when calculations are being made for design, as this affects (i) the strength of the moulding, (ii) the specific gravity.

To give comparable figures, 20% glass content will give a tensile strength of approximately 19,000 p.s.i., with a specific gravity of 1·35, whereas 33.1/3% glass content gives approximately 24,000 p.s.i. tensile strength with a specific gravity of 1·42.

It is necessary that the methods of moulding should be taken into consideration before any design calculations are made.

The lack of design information has been a serious limitation and a good deal of experimental work will be necessary before any definite standards can be achieved. Steps in this direction are being taken overseas. Until the results of this are known, progress will depend on the moulder to produce satisfactory samples from which the strength may be assessed.

Moulded hulls of a size which require transverse and longitudinal stiffening have been reinforced by the inclusion of box sections and where through fastenings are necessary, cored with a suitable material.

Although in many cases, pigment of a desired colour is incorporated in the moulding, final finishing is necessary and can be of any suitable marine paint. The moulding should be carefully cleaned to remove all traces of the mould releasinf agent which tends to adhere to the moulding.

In this paper I have only briefly touched on the general principals of fibreglass reinforced plastic moulding of small craft and, to a great extent, this has been of a non-technical nature. I believe, as many others, that fibreglass reinforced plastics will eventually become a specialised field, which will progressively develop in years to come.

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NOTES ON DISCUSSION FOLLOWING THIS PAPER.

The President, Mr. Boden.

Is the material used in any way injurious to the health of the workers

Answer.

Generally no, under normal methods of handling. About one person per hundred have an alergy resulting in dermatitis, and these must be taken off this type of work. No special protective clothing or equipment is necessary unless doing very heavy continuous dressing of mouldings when it may become desirable.

Mr. K. Murray.

Is any special paint necessary, or is the procedure as for steel or wood, i.e. flat paint first then gloss coats?

Answer.

That is so. On work having a very smooth finish it is necessary to provide a key for the adhesion of the paint. This may be obtained by the normal use of wet and dry paper.

Mr. L. Hedges.

In using a male and female mould do you use a filler with the resin or a straight resin? Does the use of a filler extend the resin? Will the resin still flow through the mould without a filler? Does use of a flourlike filler prevent resin flow.

Answer.

A straight resin may be used, fillers do not extend the resin, and they do not melt into it. The resin will flow more readily without a filler, in fact the use of a filler may prevent flow on vertical surfaces.

Mr. W. Nicol.

In the event of similar collisions what damage could be expected to be sustained by a plastic hull as compared, say, with a wooden hull of normal scantlings?

Answer.

This is a most interesting question. There is a considerable difference not only in the nature and extent of the damage, but also in the method of repair.
Recent experiments in the U.S. illustrate this point. Two workboats of the same limes, one built of wood in the normal manner, the other of reinforced plastic, were subjected to test. The hulls were subjected to a drop tes% from a height of fourty feet. The plastic hull suffered only superficial damage, while the timber hull was extensively damaged. In a further test the boats were driven at a speed of four knots into a sea wall. The plastic hull split the seam joint between the deck and the side at the forward end only. The timber hull smashed in the bow particularly at the forefoot.
In order to repair damage to a plastic hull it is necessary to cut out the damaged area and then to lay in new material, as for original construction, which is then allowed to cure at room temperature, or a flat iron may be used if heat is required.

Mr. Boden.

Does the repair then become integral with the hull?

Answer.

Yes completely.

Mr. C. Sparrow.

What is the fire risk with this type of hull?

Answer.

There is the normal fire risk when in contact with flame which could be expected with a vessel constructed of, say, hardwood. At no time is the fire risk greater than that of hardwood.

Mr. W. Lines.

The cost of raw material has been quoted as one of the disadvantages of this method of construction. What comparisons may be drawn with normal timber construction?

Answer.

In the U.K. plastic hulls appear to work out about 10% cheaper than wooden hulls of a similar size. In Australia both types of construction are about equal in cost at present.

Mr. Boden.

How is the material sold? Could an indication of cost be given?

Answer.

The materils are sold by weight. The fibre glass mat costs about 10/- per pound, while the resin works out about 6/- per pound.

Mr. R. Bryant.

It is established that vessels up to 16'-0" may be readily produced here. What is the size of the largest craft built in this country to date?

Answer.

An 18'-0" power boat hull has been produced.

Mr. R. Bryant.

We have seen tonight photographs of vessels of up to 50'-0" in length What would be the largest hull so constructed? What type of framing would be adopted, box moulding, or keel and normal stringers? What would be the thickness of the hull?

Answer.

In the U.S. hulls of up to 57'-0" (interjection 87'-0") have been constructed. The construction is of a cellular plastic form reinforced in the form of preformed sections moulded into the plastic. Either a wooden or aluminium keel has been moulded in in some cases. Stern tubes and similar fittings are of gunmetal and anre also moulded into the plastic.
The hull thickness would be about $\frac{7}{8}$" fairing off to about $\frac{5}{8}$" on the topsides.
The present limit of length appears to be about 85'-0"

Mr. Boden.

What is the adhesion between the plastic and wood, or gunmetal?

Answer.

There is some penetration of the wood by the resin, resulting in mechanical adhesion. There is no adhesion between gunmetal and plastic, this must be moulded in to the construction.

Mr. L. Hedges.

Will preformed honeycomb construction plastic bend into two way curvature?

Answer.

No. Such bends must be moulded into the original honeycomb.

Mr. A. Colquhoun.

Referring to the tests made on the 40'-0" hulls. How were the engine bearers formed in this case?

Answer.

The bearers were of timber, and were moulded in during construction, being completely encased in the plastic.
There have been cases when items such as fenders and gunwales have been worked on at a later stage in construction. Buoyancy tanks have been lined with onozote.

Mr. F. Westhorp.

what chemical reactions take place with plastic in contact with timber, gunmetal, aluminium, fuel and lubricating oils?

Answer.

There is no chemical reaction in any of these cases.

Mr. J. Follan.

An interesting point which arises with these craft is that they are transparent to radar waves.

Mr. F. Westhorp.

What, if any, are the magnetic effects upon compasses and the like?

Answer.

There are no magnetic effects whatever from the plastic hull.

Mr. Boden.

Is it possible to prefabricate the hull in parts, and subsequently to join them together?

Answer.

Yes, this can be done. The joint efficiency using polyester is about 50% and about 80% of the basic structure when using epoxy resin.

Mr. Bergman.

In a further reply to the question regarding magnetic effects, it is of interest to note that there are no electrolysis effects with reinforced fibre glass. In fact exposed shafting and propellers may be protected from electrolysis by coating these items with plastic.

Mr. H. Walsh.

Are any other methods other than laying up practicable, as for example a spray technique?

Answer.

The resin can be sprayed, using a double tube blower, similar to the method used for asbestos insulation. Double curvatures, however, must be laid up.

Mr. Boden.

What would be the effect of spraying on a wooden hull?

Answer.

This has not been done. The cloth mat brushed on gives a very smooth finish, which, however, will show up any imperfections in the wooden structure underneath, as, for example, improperly filled seams. The adhesion to wood is perfect being stronger than the wood, always provided that the wood must be very clean and freshly sanded. The resin may be pigmented, thus doing away with the necessity for painting, but, due to the fact that normal fouling of the hull takes place, the underwater structure must be treated with anti-fouling paint.

Mr. K. Murray.

Could fibre glass be used to coat the inside of a Kort nozzle, thus doing away with the troubles consequent upon electrolysis?

Answer.

We have no knowledge of this having been done.

Mr. W. Hood.

Regarding painting. Could a toxic filler be used to avoid the necessity for anti-fouling treatment?

Answer.

This does not seem to be practicable, since the action of these paints involves some leaching of the toxic substance.

Mr. H. Walsh.

What of the adhesion to steel? This in view of Mr. Murray's question.

Answer.

This is very poor. See earlier answer to Mr. Bryant.

Mr. F. Westhorp.

What splitting or shattering effects may be expected consequent upon a collision causing rupture of the hull?

Answer.

Rather like the rupture of a steel hull. Local damage with shattered edges. The glass mat prevents spreading of the damage.

Mr. A. Colquhoun.

The plastic appears to be effective against electrolysis, would it also be effective against cavitation?

Answer.

It would appear to be doubtful. It would be effective against any oxidation resulting from gasification of the water, but it is not known how it would withstand erosion. In this connection it may be noted that fresh sandblasting will improve adhesion to steel, and that epoxy will adhere better than polyester.

Mr. L. Hedges.

The plastic has an exothermic reaction. In view of this what is the maximum quantity which may be prepared at one time?

Answer.

This depends upon the curing time required. The material cannot be worked after the curing time has elapsed. We find that about one half to one gallon of mix is satisfactory.

Mr. Boden.

What type of labour is required for this work, and are there any demarcation issues involved?

Answer.

This is work for unskilled labour. It is monotonous in the extreme, and it has been found that female labour reacts more favourably than male to this type of work. At present there are no demarcation issues involved.

Mr. C. Hutchins.

At the Royal Easter Show there was a Chevrolet Corvette motor car in which reinforced plastics had been used. How was this done?

Answer.

By contact moulding as described in the paper, not by pressure.

Mr. Boden.

What weight comparisons may be made between fibreglass construction and timber construction?

Answer.

A 26'-0" Utility boat of reinforced plastic proved to be 1600 pounds lighter than a wooden version to the same lines. Its payload capacity was 25% greater than that of the wooden hull.

Mr. W. Anderson.

How are fittings secured to the hull during outfit?

Heel fittings for attachments may be moulded into the hull during construction, these being either in the form of inserts or of the fibre glass itself. The material may be drilled quite readily, and door and window fitments made as in, say, an aluminium hull.

Mr. L. Middleton.

Is there any ageing effect such as embrittlement?

Answer.

Some plastics do age, some craze and crack, but no such effects have so far been observed in reinforced plastic small craft.

Mr. A. Hedger.

Is heat normally used in setting and curing of contact mouldings, as for example, by the use of infra-red lamps?

Answer.

Yes, if quick production is required. However, if the moulding may be left overnight full curing at room temperature is achieved.

Mr. L. Hedges.

What is the result of contact with fire, melting, warping or burning?

Answer.

Above a temperature of 400°F. the material is affected. Globules are formed which ultimately charr, but they do not burn. (Mr. Bryant) The M.O.T. has approved the use of fibreglass as a fire protective over onozote.

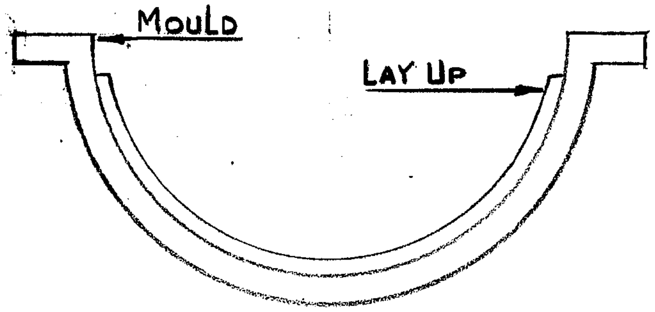
Mr. L. Middleton.

The paper states that the plastic required about three times the section area of steel, with about half the weight, for the same strength. How would this compare with hardwood?

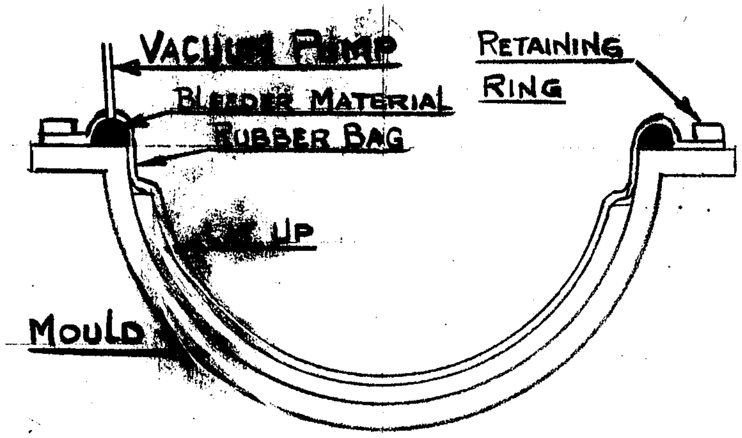
Answer.

There are terrific variations in the tensile strengths of this material. It is dependent upon a multiplicity of factors, the skill of the operator, climatic conditions, and type of resin used vary the strength greatly. Variations of up to 30% may reasonably be expected from the one sample. This makes any figures quantitative rather than qualitative, the following figures, however, may be of interest:-

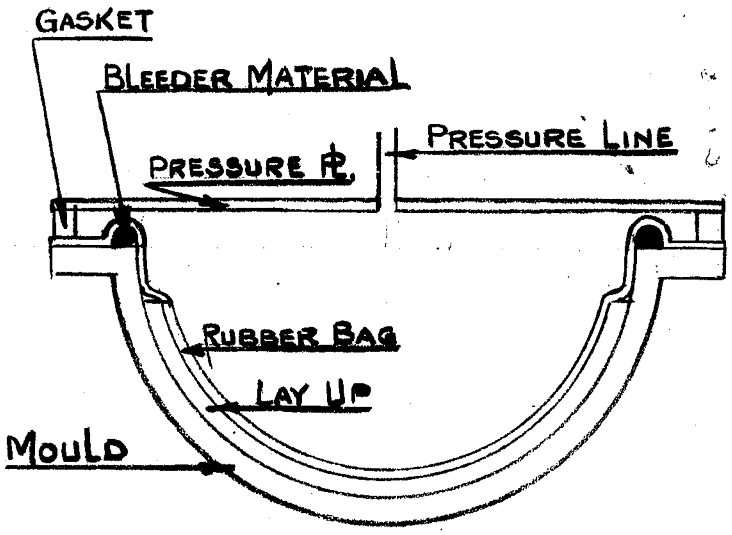
MATERIAL	Specific Gravity.	Yeild strength (lb/in^2 x 10^3)	
		Tensile	Compressive.
Aluminium alloy 24S.T.	2.77	42.5	42.5
181 Glass cloth plus Polyester resin	1.87	41.0	34.0
Parallel glass fibre plus Polyster resin	1.9	100.0	80.0
Random glass mat plus Polyester resin	1.55	24.0	25.0
High grade Spruce	0.4	10.0	5.0



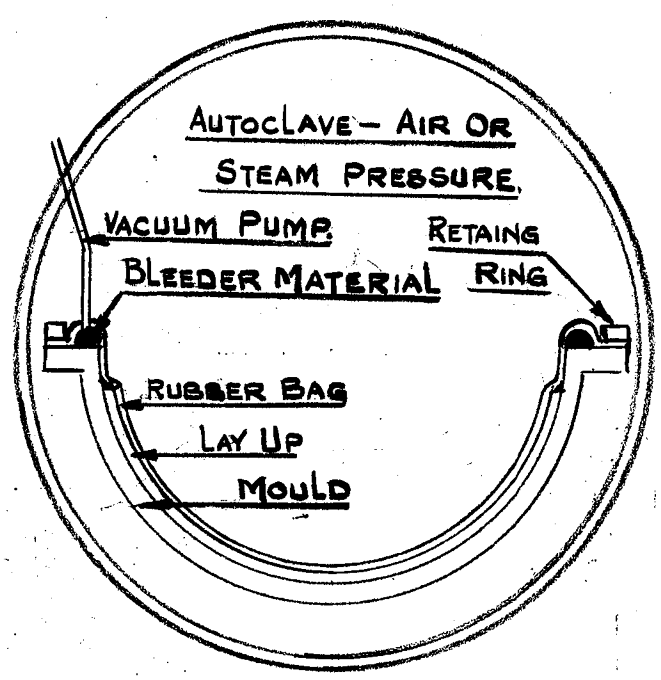
CONTACT MOULDING Nº 1



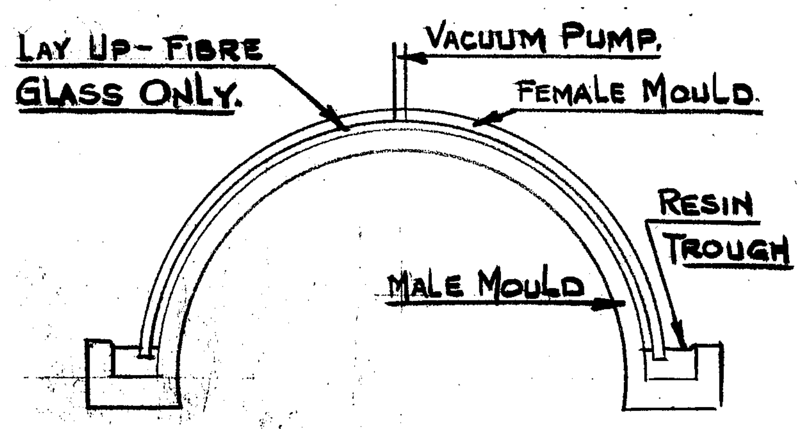
VACUUM BAG MOULDING Nº 2



PRESSURE BAG MOULDING Nº 3



AUTOCLAVE METHOD Nº 4



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