Nov. 26, 1946. J. S. BARNES 2,411,497

MAKING LAMINATED ARTICLES

Filed Oct. 3, 1940 2 Sheets-Sheet 1

FIG. 1.

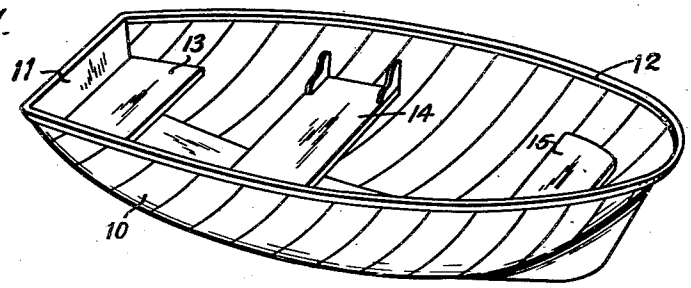


FIG. 2.

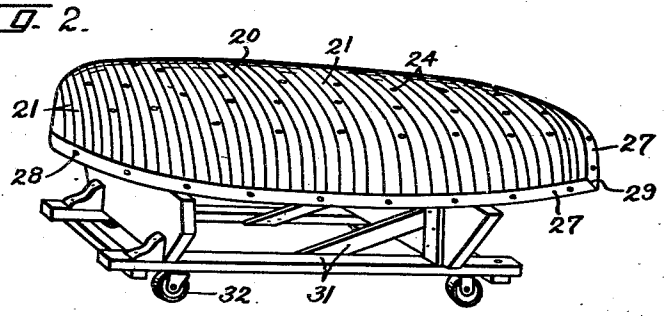
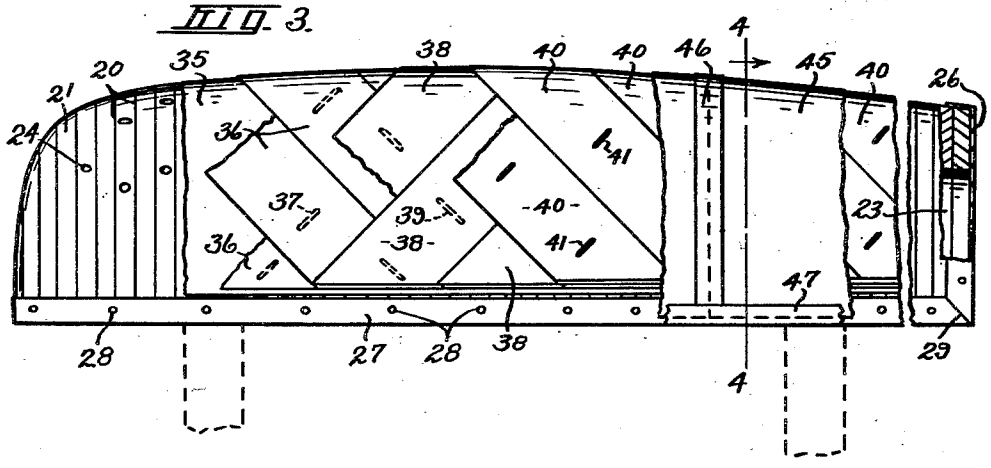


FIG. 3.



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FIG. 4.

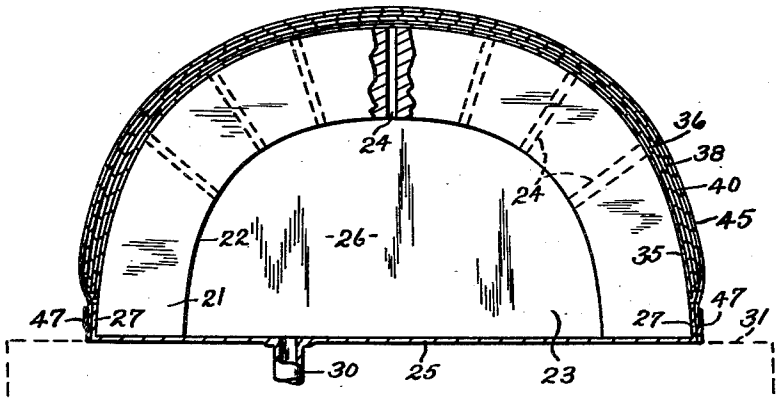
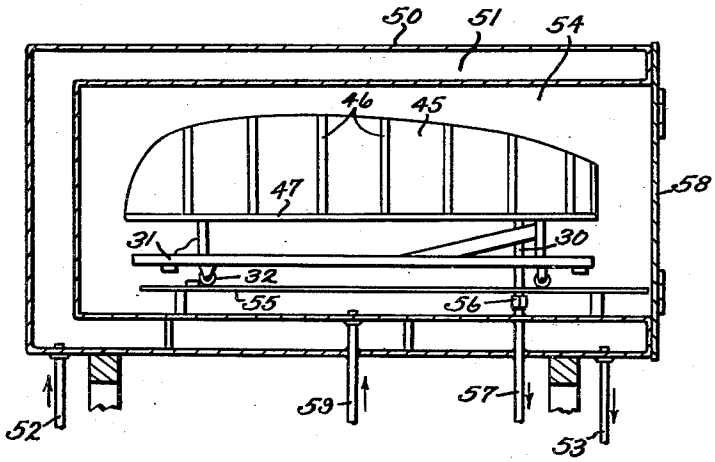


FIG. 5.



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MAKING LAMINATED ARTICLES

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Application October 3, 1940, Serial No. 359,559

3 Claims. (Cl. 18—56)

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This invention relates to making laminated articles, and relates more particularly to the construction of articles composed of a plurality of laminations of sheet material, for instance, wood veneer, joined together by a suitable binder, for example synthetic resin. My invention is particularly applicable to the manufacture of hollow articles of this character having compound curved surfaces. While I herein describe my invention in connection with the manufacture of boat hulls, it will be understood that it is equally applicable to the making of numerous articles of this general character.

Among the objects of my invention are to provide a simple, convenient and economical process for the manufacture of articles of the type described above, in such manner as to insure a workmanlike product with a minimum of rejects, strong yet light in weight, and without requiring the use of expensive equipment.

Another object of my invention resides in the production of curved laminated articles of sheet material joined together under pressure by the use of a form or die, which may be either male or female, without requiring any cooperating form or die, substituting for the latter a novel covering layer of flexible sheet material through which the pressure is applied.

Other objects and advantages of my invention will become apparent from the following description taken in conjunction with the accompanying drawings in which:

Figure 1 is a perspective view of a boat of the dinghy or yacht tender type constructed in accordance with my invention.

Figure 2 is a perspective view of the form used in the manufacture of the boat hull of Figure 1, mounted on a carriage.

Figure 3 is an enlarged view of the form of Figure 2 showing materials used in constructing the hull applied thereto, parts being broken away and in section.

Figure 4 is a section taken on the line 4—4 of Figure 3 but on a larger scale.

Figure 5 is a central vertical section through an autoclave for carrying out my process, and showing the form and carriage of Figure 2 located therein.

Referring more particularly to the drawings, Figure 1 shows a boat comprising a hull 10, stern or transom 11, gunwale 12 and thwarts 13, 14 and 15, which serve also as seats. The boat is shown in Figure 1 in a semi-completed stage, the oarlocks and certain other trim being omitted. The following description is concerned principally with the manufacture of the hull 10, the other parts mentioned above being added after the hull has been constructed in accordance with the present invention. It will be understood, however, that it would be quite possible to incorporate the transom and gunwale into the structure at the time of molding the hull as hereinafter described.

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The hull 10 is initially shaped upon a form 20, which is carefully made to the exact shape desired for the finished hull. The form 20 may be built up of a number of wood planks 21 securely joined together by nailing and gluing. Each of the planks 21 has an outer shape corresponding to the inner shape of the hull section at the point at which it is located. The inner portions of the planks 21 may, if desired, be cut away, as shown at 22, Figure 4, to provide a hollow space 23 within the form 20. A plurality of holes 24 may be drilled through the planks 21 to provide communication between the space 23 and the upper surface of the form 20. The bottom of the form is provided with a closure or sealing plate 25 having an extension 26 covering the open end of the form at the stern of the boat and having a flange 27 extending around the edge of the form 20. The sealing plate 25 may be fastened to the wooden portion of the form 20 by means of nails 28. The parts 25, 26 and 27 are preferably made of a single sheet of steel and the joint 29 shown in Figures 2 and 3 and is welded, in order to make the sealing plate 25 air-tight. A pipe 30, illustrated in Figures 4 and 5, permits communication with the space 23 for a purpose to be presently described.

The form 20 may for convenience be mounted on a carriage 31 provided with casters 32. The carriage 31 may be of any convenient type, and a suitable construction which it is not believed necessary to describe in detail is illustrated in Figure 2.

The first step in building the hull is to place a layer 35 of Cellophane or like material over the upper surface of the form 20. As shown in Figure 3, this layer may terminate just short of the metal flange 27. The layer 35 serves simply as a parting sheet so that the hull may be easily stripped from the form 20 when completed without adhering thereto. It is not desired that the parting sheet 35 be air-tight. It may conveniently be made of fairly wide strips of Cellophane, the edges of which are joined together by narrow strips of cellulose tape, such as the tape widely sold under the trade name "Scotch tape."

The laminated hull 10 is then built up on the

form 20 over the parting sheet 35. As shown in Figures 3 and 4, the hull 10 comprises three layers of wood veneer, but this is merely for convenience of illustration. As will be appreciated by practical boat builders, it is desirable to provide additional strength in certain areas of the hull, such as at the stem, the keel and the bilge keel. I accomplish this in practice both by using additional layers of wood veneer and by using shaped pieces of lumber which are joined to the layers of veneer. These details, however, need not be here described further, inasmuch as they form no part of the present invention.

The first layer of wood veneer comprising the hull may be made of a plurality of strips 36 of wood veneer, preferably cut to predetermined shapes before application so as to ensure smooth joints between them and to avoid wrinkling or creasing of the veneer, and laid spirally around the top of the form 20, but these features are by no means essential to my invention. The strips 36 may conveniently be temporarily secured to the form 20 by means of ordinary wire staples 37, which may be driven by a conventional staple driver through the strips of veneer 36 and the parting sheet 35 into the wood planks 21. The second layer of wood veneer comprising the hull is then applied on top of the first layer. This second layer may be made up of a plurality of strips 38 which may likewise be spirally arranged about the top of the form 20 but at an angle, preferably a right angle, to the strips 36. As each strip 38 is laid in place, the staples 37 which would otherwise underlie it are withdrawn, and the strip 38 is temporarily fastened in place by staples 39. A third layer of wood veneer comprising the strips 40 may be similarly laid on top of the strips 38 by means of staples 41, the staples 39 being withdrawn in their turn, although some of these staples may advantageously be permitted to remain in place. It will be noted that the strips 36, 38 and 40 terminate a slight distance from the flange 27 so that the parting sheet 35 entirely underlies these layers and separates them from the form 20. The ends of the wood veneer strips are preferably also staggered upward as best shown in Figure 4 so as to provide a less abrupt edge or shoulder than would be the case if they all terminated in the same plane.

Each of the veneer strips is impregnated or coated before application to the form 20 with a suitable binder which is preferably a synthetic resin lacquer capable of taking a permanent set under the application of heat and pressure. I have found it convenient to use a clear, reddish lacquer which is a solution of a phenolic condensation product and is available on the open market, being sold by the Bakelite Corporation. I have successfully applied this solution by merely brushing it on to the strip of wood veneer and permitting it to air dry before the strips are applied to the form 20. It will be apparent to those skilled in this art, however, that a wide variety of binders could be successfully employed. Indeed, practically the only limitations are that the binder must be one which is capable of being applied to the wood veneer strips without rendering them too tacky for easy subsequent handling, which is capable of setting to bind the layers of veneer together under a subsequent application of pressure or of heat and pressure, and for which the pressure and temperature required are not excessive. There are on the market a number of solutions of natural and artificial resins, commonly called "lacquers," and also various glues and other adhesives, among which may be mentioned the recently developed "cold press glues," which would meet these specifications.

While I prefer, in the case of boat hulls, to make the various laminations of fine quality, clear wood veneer of appropriate thickness, it is to be understood that this invention is not limited to the employment of such material. Layers of cloth, paper and other moldable sheet materials coated or impregnated with suitable binders could be used in making laminated articles by the practice of my invention.

After the hull has thus been built up on the form 20, the outside of the hull is covered with a pressure membrane or covering layer 45 of Cellophane or the like which overlaps the edges of the wood veneer layers and extends over the flange 27, as shown most clearly in Figures 3 and 4. This covering layer 45 is preferably substantially air-tight and should be joined in an air-tight manner to the sealing plate 25. For this purpose, all joints between the strips of Cellophane making up the layer 45 may be sealed with strips 46 of cellulose tape ("Scotch tape"), and a strip 47 of similar tape serves to seal the joint between the edge of the layer 45 and the flange 27. Instead of using ordinary Cellophane and sealing the joints between pieces of the same with Scotch tape, I may employ so-called "heat-sealing" Cellophane, which is capable of being sealed to itself by running a hot iron along the joints. Also, if in the later stages of the process direct steam or water is to be used as hereinafter described, I find it desirable to employ the so-called "moisture-proof" Cellophane, either of the conventional or heat-sealing varieties. As a practical matter the covering layer 45 may be made of several Cellophane films one on top of the other, thus providing additional strength and reducing the likelihood of serious leakage.

It is now necessary to subject the entire assembly of the form 20 and hull 10 just described to the action of pressure or of heat and pressure to set the binding agent. For this purpose, I preferably employ a large autoclave 50 as illustrated diagrammatically in Figure 5. The autoclave 50 is illustrated as being of the double wall type having a chamber 51 between the walls to which steam may be supplied through the pipe 52 and exhausted through the pipe 53 for the purpose of heating the central chamber 54 of the autoclave by indirect steam. It will be understood, however, that indirect steam coils or direct steam could be used as a heating medium, if desired. The central chamber 54 of the autoclave may also, if desired, be provided with electric heating elements not shown. The chamber 54 is preferably provided with tracks 55 on which the casters 32 of the carriage 31 are adapted to run. The carriage 31 bearing the form 20 and the hull assembly described above is wheeled into the autoclave chamber 54 on the tracks 55 and the pipe 30 is joined by means of a union 56 to the pipe 57 leading through the double wall of the autoclave and venting to the atmosphere or to a vacuum pump as described hereinafter. After this has been done, the door 58 of the autoclave may be closed and sealed in the usual manner. The autoclave is also provided pith a pipe 59 extending through the chamber 51 and communicating with the central chamber 54. The pipe 59 is connected to a source of air pressure not shown.

Before the carriage 31 is wheeled into the autoclave, it is advisable to test for air leaks in the

layer 45 by connecting the pipe 30 to a vacuum pump. The vacuum thus produced in the space 23 will suck air through the apertures 24 and draw the covering layer 45 snugly against the hull and the latter against the form. If a satisfactory vacuum can be maintained, it indicates that the layer 45 is sufficiently tight, and if not, any leaks may readily be located by the hissing noise which they cause, and repaired with the cellulose tape. During this test, an inspection may also be made through the transparent Cellophane layer 45 to determine if the layers of wood veneer are drawn snugly into proper position against the form 20.

After the carriage 31 with its burden in satisfactory condition has been placed in the autoclave chamber 54, the pipe 30 has been connected up as described and the autoclave sealed by means of its door 58, the autoclave chamber 54 may be brought to the desired temperature in the manner described above. The raising of the temperature in the chamber 54 will of itself increase the pressure therein, but the maintenance of the proper temperature for setting of the binder will not ordinarily provide sufficient pressure in the chamber 54. Accordingly, I admit air or steam under pressure through the pipe 59 to such an extent as to raise the pressure to the desired value. With the specific binder agent described above, I have found a pressure of sixty pounds gauge and a temperature of 245° F. in the autoclave chamber 54 to be satisfactory. This temperature and pressure are maintained for a suitable period, which will usually not exceed one hour. The autoclave is then preferably allowed to cool down, which step may be accelerated by using a water spray in the autoclave, and after it has cooled somewhat and the pressure has been released, the door 56 is opened and the carriage 31 withdrawn from the chamber.

During the heat and pressure treatment in the autoclave, the space enclosed by the covering layer 45 is vented to atmosphere through the pipes 30 and 57 as described. There is thus exerted on the outside of the covering layer 45, the gauge pressure existing within the autoclave chamber, whereas the inside of the form and hence the inside of the hull is subjected to a pressure of only atmosphere. A net effective pressure equal to the gauge pressure is thus secured over the entire surface of the hull, while at the same time the wood veneer composing the hull is raised to the temperature specified. Under these conditions, the phenolic lacquer sets and firmly binds the strips of wood veneer to one another. If desired, the pressure differential may readily be increased without utilizing a higher gauge pressure in the autoclave chamber 54 by connecting the pipe 57 to a vacuum pump instead of to atmosphere.

I have found it to be desirable to close the pipe 57 by a suitable valve during the period while the autoclave is coming up to temperature and before a curing temperature is reached. A back pressure is thus built up inside the covering layer 45, resulting in a lower differential pressure during that period. When the curing temperature is approached, the pipe 57 is opened, releasing the back pressure rapidly and causing a sudden application of the full differential pressure at the same time curing is taking place.

In the specific construction described above, the venting takes place from the underside of the parting sheet 35 through the holes 24, into the chamber 23 and thence into the pipe 30. As

stated above, the parting sheet 35 is intentionally not made air-tight, and the space between the covering layer 45 and the parting sheet 35 is therefore vented through the joints between the pieces of the latter and the holes made therein by the staples 37. Where the form 20 is made of comparatively porous wood, it will be evident that the holes 24 may be omitted. Furthermore, the form 20 may be made solid, eliminating the chamber 23. In such case, venting occurs around the surface of the form 20 both above and beneath the parting sheet 35 and thence between the form 20 and the sealing plate 25 (the latter being not too tightly fastened to the former) into the pipe 30.

Were the parting sheet 35 to be made air-tight, venting could still take place around the edges of the sheet 35. I consider it preferable, however, not to have the parting sheet 35 air-tight and to have the form 20 so constructed as to permit venting through it to the pipe 30, as by so doing, it is easier for the outside pressure to force the layers of wood veneer snugly against the form 20 and pocketing of air under those layers is rendered less likely.

It will be evident that it is desirable, for reasons of economy, to have the sealing plate 25 cover as much as possible of the surface of the form 20 that is not covered by the hull, that is to say, whatever is not working surface of the form, thus reducing the consumption of Cellophane. The principal function of the sealing plate 25, however, is to permit the vent pipe 30 to communicate with the space enclosed by the covering layer 45, and this function could be discharged were the sealing plate to be made much smaller, although the layer 45 would have to be made correspondingly larger.

It will be evident also that economy and efficiency are best served by having both the sealing plate 25 and the covering layer 45 air-tight, and by having an air-tight seal between them. Minor leaks, however, do not destroy the efficacy of my process, simply requiring more work to be done to obtain the desired differential pressure.

I am aware that it has previously been proposed to mold articles made of wood veneer and synthetic resin in an autoclave under heat and pressure by enclosing the article in a rubber or neoprene bag the inside of which is vented to atmosphere through the wall of the autoclave. For large articles, however, it becomes extremely unwieldy to use such bags; they are quite subject to accidental rupture, are difficult to repair, short-lived and expensive to replace.

My Cellophane covering layer 45, on the other hand, is cheaply and easily constructed in situ on the form, need not be fitted accurately as it can wrinkle and crease under the applied pressure without causing leakage, can conveniently be reenforced by using additional thicknesses at points of maximum strain, can be easily patched if a serious leak develops on test, and may be discarded after a single use, although it is capable of reuse if removed with care. The transparency of the Cellophane has the advantage of permitting inspection of the work, particularly during the preliminary vacuum pump test described above. Moreover, large articles can be covered by piecing together Cellophane sheets or strips of sizes regularly available commercially. A further very important advantage of the Cellophane layer 45 is that it need not completely surround the form, but need cover only the material to be molded, since Cellophane may be

efficiently sealed to a metal or like smooth surface as described above.

While I have described and prefer the use of Cellophane in making the parting sheet **35** and the layer **45**, it will be understood that other like regenerated cellulose films marketed under different trade names may be employed. Indeed, so far as certain advantages of the present invention are concerned, any flexible air-tight sheet material capable of withstanding the temperatures and pressures required without adhering objectionably to the material to be molded, and capable of being readily pieced together in a substantially leak-proof manner and sealed to a smooth surface of metal or the like, would suffice for the covering layer **45**, although economy and convenience under present conditions dictate the use of regenerated cellulose sheet material.

After the carriage has been removed from the autoclave, the layer **45** is stripped from the hull, whereupon the hull may be lifted off the form **20** as a complete unit. Either before or after this is done, the staples **41** may be removed. The edges of the hull are then trimmed, and the boat completed by the addition of the transom **11**, gunwale **12** and the seats **13**, **14** and **15** as described above, as well as by the usual finishing. If a proper lacquer and a good quality of veneer have been employed, the hull will be found to have a pleasing color when it is removed from the form **20**, and the finishing operation may be easily and simply performed.

It will be evident to those skilled in this art that various changes and modifications might be made in the process specifically described above without departing from the spirit of my invention. Thus, the form **20** is in effect a male die, but my invention could equally well be applied were the form **20** to be made as a female die. Similarly, instead of using strips of wood veneer or the like with close fitting butt joints between their edges, overlapping strips could be employed, and this would be especially desirable were sheets of treated cloth or paper to be substtiuted for the wood veneer. Other modificatons will readily suggest themselves, and I desire to be limited, therefore, only by the scope of the appended claims.

I claim:

1. The method of making articles by molding moldable material on a removable form by differential fluid pressure, which comprises providing a rigid form having a working surface of the desired shape of the article, applying moldable material to said working surface, covering said moldable material with a substantially air-tight pressure membrane of transparent, flexible sheet material in such manner as to form an entirely enclosed space, said pressure membrane being constructed by joining together pieces of said sheet material in situ on the form, connecting said space to a source of suction to draw said transparent membrane against said moldable material to permit inspection thereof, and thereafter subjecting said moldable material to a molding operation in which fluid pressure is applied to the outside of said membrane while said space is connected to a zone of lower pressure, and separating the molded article.

2. The method of making articles by molding moldable material on a removable form by differential fluid pressure, which comprises providing a rigid form having a working surface of the desired shape of the article and having a sealing surface adjacent to and extending completely around said working surface, applying moldable material to said working surface, applying a substantially air-tight pressure membrane of flexible sheet material over said moldable material, said pressure membrane being constructed by joining together pieces of said sheet material in situ on the form, whereby said membrane may be tailored to the desired shape, and sealing said membrane to said sealing surface in such manner that said membrane is supported throughout substantially its entire area, whereby rupture of said sheet material due to its inherent structural weakness is avoided and whereby said form, said moldable material and said membrane constitute a unitary assembly, and thereafter subjecting said assembly as a unit to a molding operation in which fluid pressure is applied to the outside of said assembly while the space between said membrane and said working surface is connected to a zone of lower pressure, and separating the molded article.

3. A unitary molding assembly for making articles by molding moldable material under differential fluid pressure on a removable form, comprising a rigid form, a working surface on said form of the desired shape of the article, a sealing surface on said form adjacent to and extending completely around said working surface, a substantially air-tight pressure membrane of flexible sheet material adapted to cover moldable material applied to said working surface, said pressure membrane being made of pieces of said sheet material joined together and tailored to substantially the shape of said working surface, and said pressure membrane being sealed to said sealing surface in such manner that said membrane is supported throughout substantially its entire area and rupture of said sheet material due to its inherent structural weakness is avoided, and means for withdrawing air from the space between said membrane and said working surface, whereby said form, said moldable material, said membrane and said means constitute a unitary assembly capable of being handled as a unit for differential fluid pressure molding.

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