

March 10, 1964

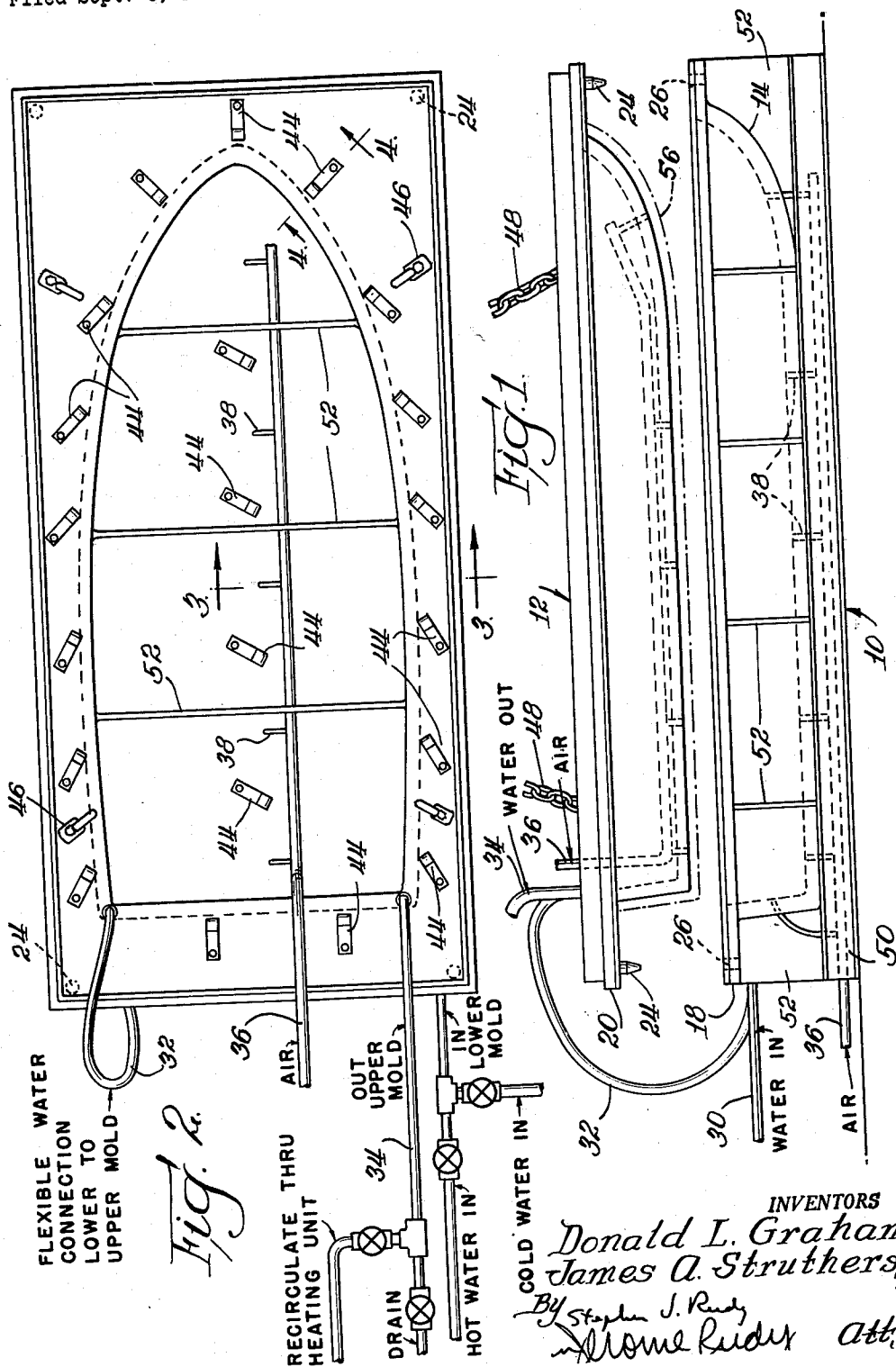
D. L. GRAHAM ETAL

3,124,626

PROCESS FOR PRODUCING BOAT HULLS OF SANDWICH CONSTRUCTION

Filed Sept. 6, 1960

4 Sheets-Sheet 1



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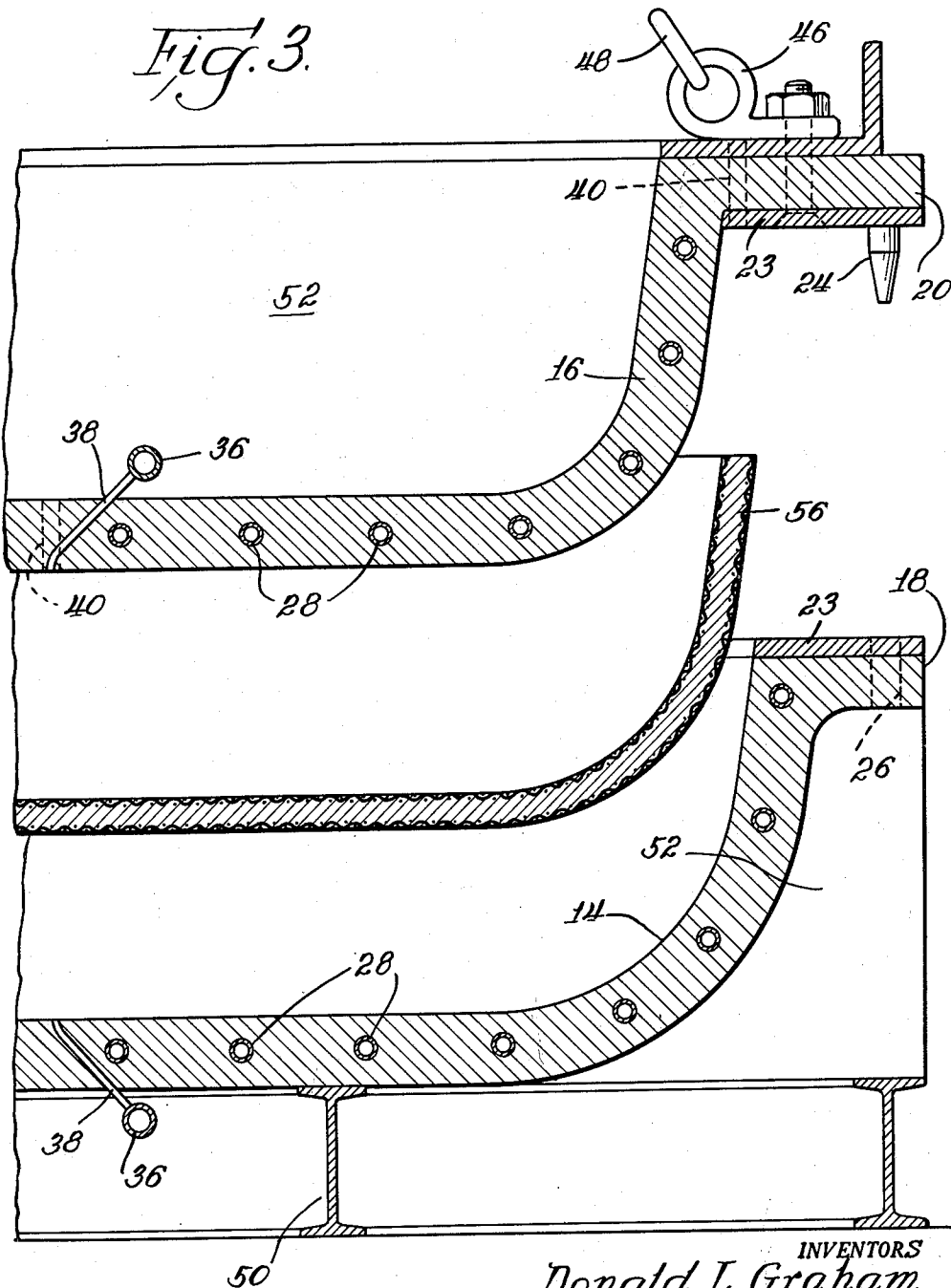
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Fig. 3.



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Fig. 5

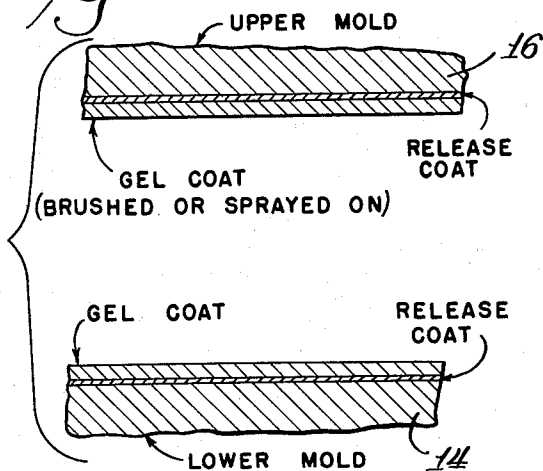


Fig. 6

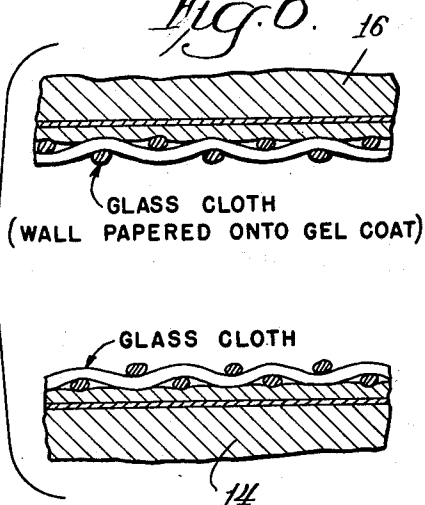


Fig. 7

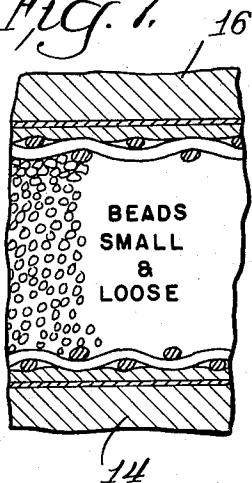


Fig. 8

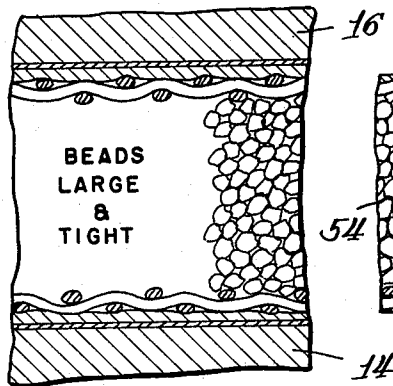


Fig. 9

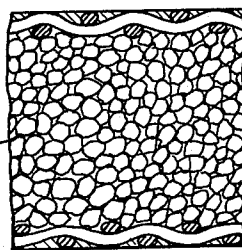
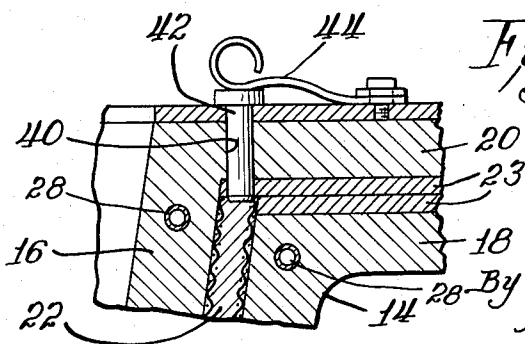


Fig. 4



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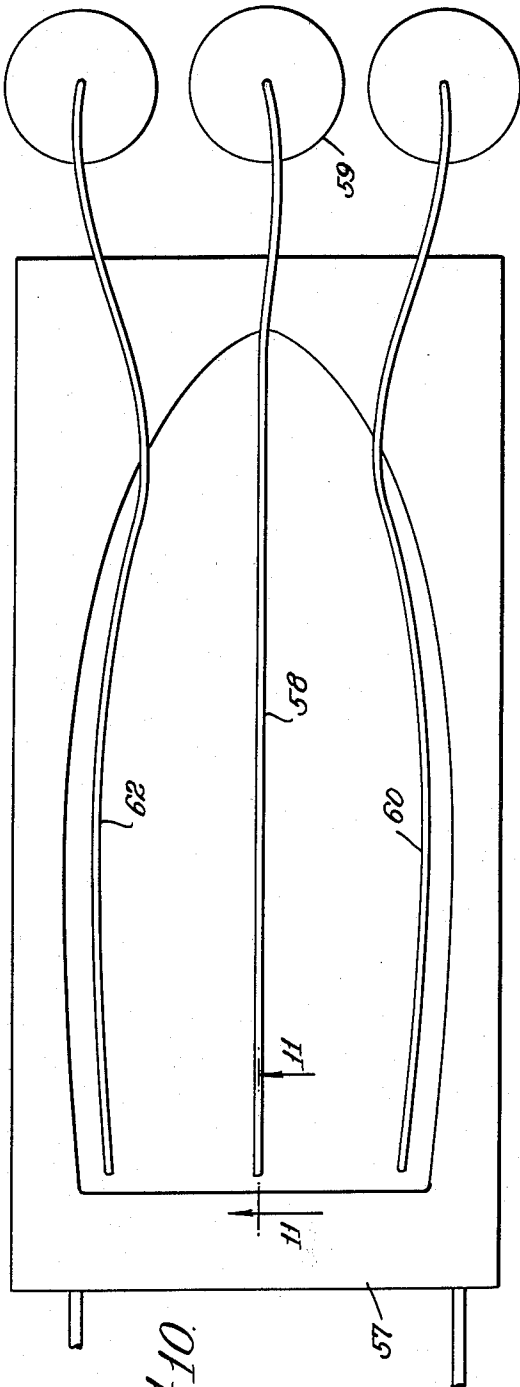


Fig. 10.

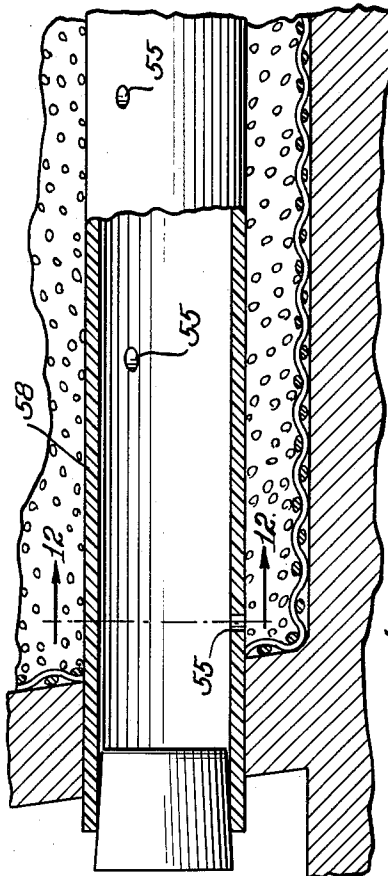


Fig. 11.

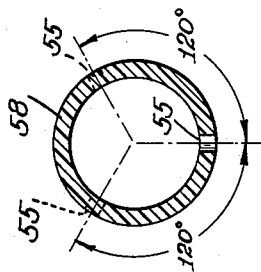


Fig. 12.

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3,124,626

PROCESS FOR PRODUCING BOAT HULLS OF SANDWICH CONSTRUCTION

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8 Claims. (Cl. 264—45)

This invention relates to a molding process and more particularly to a molding process by which boat hulls of "sandwich construction" may be produced economically.

Boats formed of sandwich construction have many desirable features such as, high strength to weight ratio, stiffness, and built-in buoyancy. However, such type boats made according to the methods of the prior art generally require numerous fabrication steps employing a great amount of hand labor. Consequently, the quality and uniformity of the finished molded boat product depends largely upon the skill of the individual workman.

The process of the present invention utilizes the basic technique and compositions of the copending patent applications of: Robert F. Newberg and Ritchey O. Newman, Jr., Serial No. 791,301, filed February 5, 1959, which issued on November 8, 1960, as Patent No. 2,958,905; and Donald L. Graham, Robert N. Kennedy, and Earle L. Kropscott, Serial No. 562,122, filed January 30, 1956, which issued on November 8, 1960, as Patent No. 2,959,508. However, the present disclosure sets forth in detail, and with certain additional steps, how such basic process may be used in making boat hulls in an effective and economical manner.

The boat hull molding process of the present invention reduces the number of fabrication steps as compared with methods of the prior art for producing molded boat hulls. Furthermore, it provides high quality and uniformity of finished boat hulls which do not depend primarily upon the skill of the workman.

Briefly, the process of the invention involves the following steps: (a) providing a male mold and a female mold having contoured surfaces of desired finished boat hull shape; (b) applying mold release to the surfaces of both molds; (c) applying "gel coat" to both surfaces of the mold; (d) allowing the gel coat surface to cure to a tacky state; (e) applying a reinforcing material, such as glass cloth, to the tacky gel coated surfaces; (f) closing the molds to form a mold cavity; (g) introducing prefoamed thermoplastic expandable beads into the mold cavity; (h) injecting a mixture of epoxy resin curing agent and modifier into the bead-filled cavity; (i) allowing time for a chemical reaction which develops exothermic heat to cause expansion and setting of the thermoplastic beads and, advantageously, impregnation of the reinforcing material with reacted epoxy resin forced therein by the expanding action of the beads, and (j) separating the mold halves to remove the resulting molded boat hull. In some cases, it may be advantageous for step (g) to partially or completely precede step (f), depending on the particular sequence of operations and bead charging procedure desired to be followed.

The main object of this invention is to provide a molding process for producing boat hulls of sandwich construction in an economical manner.

Another object of this invention is to provide a molding process for production of boat hulls which reduces the number of fabrication steps.

Still another object of this invention is to provide a molding process for the production of boat hulls of sandwich construction of high quality and uniformity.

A further object is to produce a boat hull of sand-

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wich construction having a light weight rigid core, and a plastic skin covering on the exterior surfaces of the core, wherein the plastic network extending through and reinforcing the core is also saturated into and impregnates the weave or interstitial texture of the reinforcing material constituting the cover for the core.

Still another object of the invention is to provide a molding process for producing boat hulls of sandwich construction which process does not primarily depend upon manual skills.

These and further objects and features of the invention will become more apparent from the following description and accompanying drawings wherein:

FIG. 1 is a side elevation view illustrating in separated position two molds used for practicing one embodiment of the process of the invention;

FIG. 2 is a plan view of the molds shown in FIG. 1;

FIG. 3 is an enlarged section view generally as seen along line 3—3 in FIG. 2;

FIG. 4 is an enlarged fragmentary section view generally as seen along line 4—4 in FIG. 2;

FIGS. 5 to 9, inclusive, are illustrations depicting various stages in the process of the depicted embodiment of the invention for the molding of a boat hull;

FIG. 10 is a plan view showing a lower mold arranged according to a modified embodiment of the invention;

FIG. 11 is an enlarged section view generally as seen along line 11—11 in FIG. 10; and

FIG. 12 is a section view as seen along line 12—12 in FIG. 11.

Referring now to the drawings, and more particularly to FIG. 1, the numeral 10 identifies a lower mold section, while numeral 12 identifies an upper mold section. The lower mold section includes a wall portion 14, the inner surface of which is curved, to provide a molding form for the exterior surface of a boat hull to be molded thereby, while the upper mold section includes a wall portion 16, the outer surface of which is curved to provide a molding form for the interior surface of a boat hull to be molded thereby. As best seen in FIG. 3, the wall 14 of the lower mold includes a horizontal flange 18 arranged about the entire upper periphery, while the wall 16 of the upper mold has a horizontal flange 20 which extends around the entire upper periphery of the curved wall.

When the upper mold section 12 is lowered into the lower mold section 10 so that the horizontal flange 20 seats upon the horizontal flange 18 of the lower mold section, a space, or cavity 22 (FIG. 4) will be provided between the walls 14 and 16. Such cavity 22 is designed to provide the desired thickness and configuration of a boat hull to be molded therein. Plate, or shim means 23 placed upon the flanges 18 and 20, may be used for regulation of hull thickness.

For the purpose of maintaining predetermined cavity dimensions, indexing, or locating pins 24 are secured to the upper mold flange 20 and project downwardly for entry within holes 26 formed in the lower mold flange 18.

While the lower and upper mold sections 10 and 12 respectively may be made of various materials, the sections are preferably formed of aluminum. Such material has the necessary strength, is readily cast and machined, has good thermo-conductance, and is of light weight which makes for easy handling of the mold sections. In forming the mold sections, a continuous tubing, or pipe means 28 is arranged in the walls of each section which pipe means is used for circulating heating and cooling medium, such as water, through the mold sections as required. A mold preheating temperature of approximately 115° F. generally produces good results. Water cooling is advantageously used after molding operations

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are completed and in preparation for mold opening and finished hull removal.

Water enters the pipe means 28 in the lower mold section via a pipe, or hose 30. After circulating through the pipe means in the lower mold, the water flows through a pipe, or hose 32 to the upper mold section where it passes through the pipe means 28 thereof and exits through a pipe, or hose 34 back to the source, or a drain, as required. A pipe 36 is arranged on each mold section for feeding compressed air through the mold walls 14 and 16 via a plurality of short pipes 38, so as to ease the parting force developed by the sticking of the finished hull and the vacuum build up during separation.

In one embodiment of the invention, as illustrated, a plurality of openings, or holes 40 are provided in the upper mold section wall 16 and in the keel line for charging all materials to the mold cavity 22. These holes are each closed with a removable plug 42 maintained in position by a leaf spring clamp 44. Eyelets 46 are secured to the upper surface of the flange 20, for attachment of chains 48, whereby the upper mold section 12 may be moved as required. Frame means 50, as well as support ribs, or plates 52, are arranged for maintaining the lower mold wall portion 14 in position. Bolt means (not shown) may be used to secure the mold sections together during molding operation.

The apparatus as above described may be used to practice the process of the invention, the steps of one embodiment of which are as follows:

(1) A mold release material is applied to the surface of the mold cavity walls 14 and 16 of the mold sections, such material being of the type commonly used for this purpose, as for example, wax, or polyvinyl alcohol, or a combination of both.

(2) A "gel coat" is next applied over the mold surfaces which have been treated with the release material which may be applied by brush, or spray (FIG. 5). The gel coat, which may be a polyester, or epoxy resin, is then allowed to cure to a tacky state. With air inhibiting polyester resins, the surface will remain tacky for a considerable period of time (if not indefinitely) until air is excluded from it, or until subsequent foaming resins, or laminating resins are applied to it.

Suitable gel coats are of the variety known to the art for such purposes. For example, a good polyester gel coat for use in practice of the present invention is comprised of the reaction product of about 1.2 moles of propylene glycol with a mixture of 0.5 mole of maleic anhydride and 0.5 mole phthalic anhydride dissolved in 20 to 40 weight percent, based on composition weight, of styrene monomer (preferably about 35 weight percent styrene) and containing about 50 weight percent of combined conventional extender, filler and pigment including about 3 weight percent of an expanded silica (such as "Cab-O-Sil") as a thixotropic agent. The polyester composition is cured with about 1 weight percent of a peroxide, such as methyl ethyl ketone peroxide, in the gel coat formulation.

A satisfactory epoxy gel coat is made from the reaction product of Bisphenol A and epichlorohydrin having an epoxy equivalent weight of about 190. To this is added about 10 weight percent, based on gel coat composition weight, of butyl glycidyl ether as a reactive diluent. The same extender, filler, pigment systems (including the expanded silica) as above described is utilized in about the same proportion as indicated. The epoxy gel coat is cured with about 11 parts by weight 100 parts of the resin/diluent combination of a conventional epoxy curing agent, such as diethylene triamine.

(3) A reinforcing material is then placed uniformly over the tacky gel coat surface (FIG. 6). The reinforcing material may be glass cloth, woven rovings, glass mat, sisal mat, needled mat, synthetic fibers, or other materials as employed in reinforced plastic work. A double thickness of reinforcing material may be placed

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in high stress areas of the hull, such as in the corners and on the transom and bow.

The gel coated surface presents an ideal base for "wall papering" on reinforcing materials, since it provides necessary support to make the material conform and adhere to the mold contours, yet does not saturate the weave, texture or openings in the material.

In placing the reinforcing material it will be necessary to form openings therein which coincide with all of the charging openings 40 when such method of operation is employed. Such openings may be patched later when the molded boat hull is removed from the molds, if necessary or desirable. To minimize such patching, the charging ports may be kept to a minimum, employing only enough to readily charge the mold cavity with expandable bead filler.

(4) The upper mold section 12 is then placed into the lower mold section 10 so that the flange 20 seats upon the flange 18, thus providing the enclosed cavity 22; expandable thermoplastic prefoamed beads, and/or granules, of a density, say of 4#/ft.³, are put into the cavity. These beads are capable of further expansion. The cavity charging may be done for example, by the use of pneumatic blowing equipment (FIG. 7). Or, if preferred, the beads (as has been indicated) may be completely charged to the mold before its closing or the bulk of the total charge added at said point with the remainder introduced through charge ports. Such beads are preferably polystyrene or modified styrene polymer granules of the type known under the trademark "Pelaspan" as are obtainable from the Dow Chemical Company, Midland, Michigan.

(5) A mixture of epoxy resin, polyamine curing agent, and modifier is next pumped, or forced into the bead filled cavity via some of the openings 40. The exothermic heat which is developed from the chemical interaction of the epoxy resin and polyamine curing agent causes expansion of the expandable thermoplastic beads. The expansion of the beads and the accompanying pressure development from such expansion, forces the reaction components throughout the beads in the mold cavity. Such distribution pressure force progressively brings the reaction components in contact with more expandable beads, which are thus expanded and force the reaction components onward in the cavity. Finally, as the expandable beads are fully enlarged and knit together forming a solid light weight core, the epoxy resin is forced to the outside where it saturates the reinforcing material with resin. Each resulting reinforced laminate thus produced is bonded on one side to the gel coat, and to the foamed core on the other side (FIG. 8). As indicated, the so-called exothermus epoxy resin agent which foams the beads to their finally expanded form provides an interlacing network throughout the expanded plastic granules which extend to and through, in saturating interstice impregnating contact with, the reinforcing layer of glass cloth or the like.

The composition thus produced 54 (FIG. 9) is strong, of light weight, and excellently suitable for boat hull construction.

If desired, particularly when a minimum of cavity openings are to be employed, the entire cavity may be filled with both beads and self-reacting epoxy resin exothermus agent through one or more (usually three or four) charge ports disposed (generally about equispaced but however may be preferred) in and through the lower mold section 10 along the keel line. Actually, excellent results can be achieved with only a single charge port in the mold (either upper or lower), especially when pneumatic bead injection and probes (as hereinafter described) for epoxy resin distribution are employed. In this way all or any desired portion of the illustrated openings 40 can be dispensed with.

Alternatively, the epoxy resin agent can be added to the bead filled mold cavity (charged with beads full before closing or in any efficient way through one or more charge openings) through tubes or probes (either perfo-

rated or merely open ended, or both) disposed in the cavity prior to closing. One or more such probes may be employed, with two or three being frequently suitable, so long as they are disposed to efficiently interject and disperse the epoxy resin agent in the mold cavity. Such probes for pressuring the exothermus agent to the beads may advantageously be left within the core after the foaming operation, since they generally do not materially degrade or weaken the resulting structure. Advantageously, in such instances, the probes are made of a plastic material, such as polyethylene tubing, which is flexible and actually is compressed to be all or nearly flat or interiorly closed upon expansion of the beads. Of course, pressure probes of rigid materials, including metals, may also be employed.

Good results with probes are obtained in a boat hull construction using $\frac{1}{2}$ " I.D.- $\frac{5}{8}$ " O.D. polyethylene tubing as probes having spiral perforations 55 on 1" centers using 120° rotation per hole. Three such tubes may be used as seen in FIG. 10. One tube 58 is layed along the keel of a lower hull mold 57 and extends for about the entire length thereof, being fed from the fore or after section of the hull mold 57 but advantageously through an aperture in the bow from a charging pot 59. Two other tubes 60 and 62 are layed lengthwise of the hull mold about along the gunwales (in smaller units) or, at any rate, about equidistant between the heel and upper edge of the mold cavity. Prior to laying the tubes 58, 60 and 62, the upper and lower molds are prepared by covering with a release coat, and a gel coat, following which a reinforcing material, preferably glass cloth, is placed thereupon. Expandable thermoplastic preformed beads are placed in the lower mold 57 so that the tubes are completely covered. The upper half of the hull mold (not shown) is then placed in position upon the lower mold thus forming a cavity having the shape of a boat hull. If necessary, additional preformed beads may be fed into the cavity by pressurized probes (not shown). The assemblage is now ready for charging with an epoxy resin agent. With such a set-up, it is beneficial to add the first portion of epoxy resin mixture through the keel tube 58 (using enough to foam the beads in the bottom part of the mold) then, sequentially, to add the rest through the outer tubes 60 and 62. This ensures excellent foaming and expanding action in the upper side portions of the hull and achievement of uniform, premium quality construction.

A hull made according to the invention, which may be damaged in use, can be quickly repaired by use, for example, of high density foamed material cemented in place with a quick drying (or other) cement, following which a layer of fiberglass cloth or other reinforcement impregnated with a fast hardening epoxy resin is placed over the foamed material and allowed to cure.

(6) The upper mold section 12 is then lifted out of the lower mold section 10. Compressed air is advantageously directed at this time through the pipes 36 to cause separation of a formed boat hull 56 from the molding surfaces of the upper and lower molds.

It will be apparent from the foregoing that the process of the invention provides fabrication of boat hulls of sandwich construction in a very economical manner, and which process satisfies all the objectives as hereinbefore set forth. It may be added that by the process of the invention, various kinds of surfaces and inserts may be easily bonded to the hull during the molding thereof.

The foregoing description has been given in detail without thought of limitation since the involved inventive principles, as is apparent from a reading of the specification, are capable of assuming other forms without departing from the spirit of the invention or accompanying claims.

What is claimed is:

1. A process for producing a boat hull of sandwich construction with an outer plastic skin covering and a

lightweight rigid core of beaded expanded thermoplastic material, comprising the steps of forming a lower mold section with an inner curved surface to provide a mold form for the exterior surface of a boat hull and an upper mold section with an outer curved surface to provide a mold form for the interior surface of said boat hull, each of said sections having means therein for releasing the boat hull from said sections after molding, and inlet means for charging the mold cavity formed when the mold sections are placed together, applying mold release material to said inner and said outer curved surfaces respectively, followed by application of a gel coat, allowing the gel coat to become tacky, applying a reinforcing material over the tacky gel coat, placing the mold sections together to form a mold cavity, charging prefoamed expandable thermoplastic beads into said mold cavity via said inlet means, then injecting an exothermous epoxy resin mixture via said inlet means into the bead charged cavity, said exothermous resin mixture chemically interacting with evolution of heat which causes further expansion and final setting of the prefoamed beads to produce a boat hull having a solid lightweight core with epoxy impregnated reinforcing material embedded on the exterior surfaces as a plastic skin covering, and removing the boat hull from the mold cavity utilizing the release means in said lower and upper mold sections.

2. The process of claim 1, wherein the mold release material comprises a combination of wax and polyvinyl alcohol.

3. The process of claim 1 wherein the gel coat comprises a reaction product of propylene glycol, maleic anhydride, phthalic anhydride and styrene monomer.

4. The process of claim 1 wherein the gel coat comprises a reaction product of biphenol and epichlorohydrin.

5. The process of claim 1 wherein the reinforcing material comprises glass cloth.

6. The process of claim 1 wherein the expandable thermoplastic beads comprise polystyrene.

7. A process for producing a boat hull of sandwich construction with an outer plastic skin covering and a lightweight rigid core of beaded expanded polystyrene, comprising the steps of forming a lower mold section with an inner curved surface to provide a mold form for the exterior surface of said boat hull and an upper mold section with an outer curved surface to provide a mold form for the interior surface of said boat hull, each of said sections having means therein for releasing the boat hull from said sections after molding, and inlet means for charging the mold cavity formed when the mold sections are placed together and a perforated charging tube communicating with said inlet means, applying a mold release to said inner and outer curved surfaces respectively, followed by application of a gel coat, allowing the gel coat to become tacky, applying a reinforcing material over the tacky gel coat, placing expandable polystyrene beads in the lower mold section to enclose said perforated charging tube, placing the mold sections together to form a mold cavity, introducing prefoamed expandable polystyrene beads into the mold cavity via said inlet means and said charging tube, then injecting epoxy resin, polyamine curing agent, and modifier via said inlet means and said charging tube into the bead charged cavity, said resin, curing agent and modifier chemically interacting with the evolution of heat to cause further expansion of the prefoamed beads thereby forcing at least a portion of the epoxy resin into and through the interstices of the reinforcing material to produce a boat hull having a solid lightweight core with epoxy impregnated reinforcing material as a plastic skin covering, and removing the boat hull from the mold cavity utilizing the release means in said lower and upper mold sections.

8. The process of claim 7 wherein the charging tube

has a plurality of perforations which are spirally arranged in repetitive pattern along its length.

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