

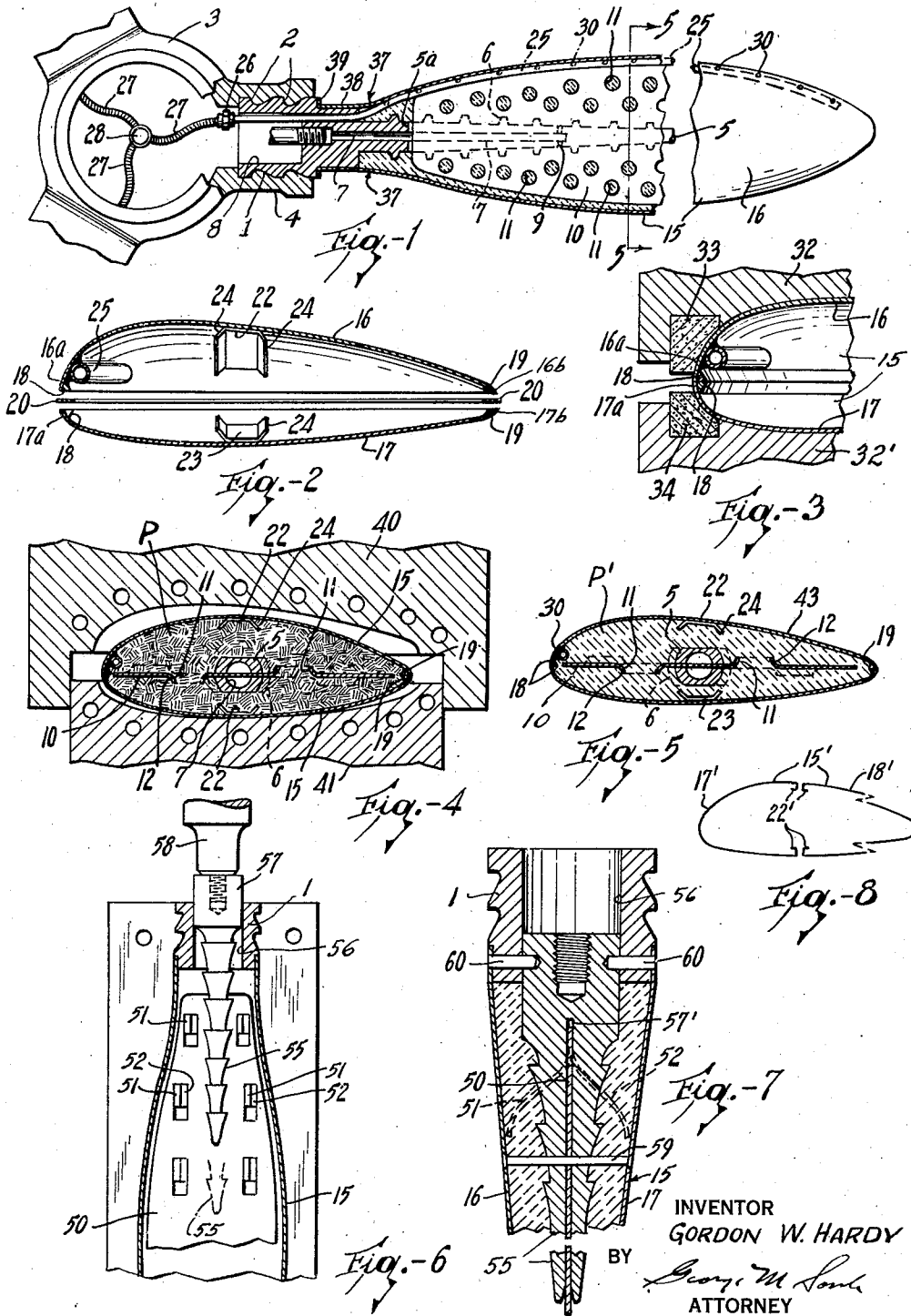
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PROPELLER BLADE

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PROPELLER BLADE

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3 Claims. (Cl. 170—159)

1

This invention relates to a propeller blade particularly for aircraft and a new method of making such blade.

One object of the invention is to provide a propeller blade which can be made without any great amount of hand work and have strength, flexibility and other desirable characteristics comparable to, if not excelling, the higher grades of laminated wooden propellers and all-metal propellers while at the same time being moisture and impact resistant and of light weight.

A further object is to provide an improved method of making metallically armored propeller blades.

A specific object is to provide a propeller blade having an adequately reinforced core including high strength plastic material and an armor sheath partially or wholly covering the same of sufficient tensile strength and impact resistance to prevent chipping and abrading of the propeller surface as by projectiles, particularly at low temperatures.

A further object is to provide a composite propeller blade with imperforate metallic armor, wherein the armor is of pre-formed sheet metal and core portions of the blade comprise plastic material of tough and strong character so associated with the armor that all parts of the armor are firmly and solidly buttressed or backed by the core material notwithstanding any inherent tendency that may exist for the metal to become loosened locally or otherwise from said core material.

Another object is to provide an improved manner of making, from sheet metal parts, an armoring shell for a propeller blade having an internal reinforcing and shape-sustaining structure, which armoring shell is capable of being made accurately to size and shape and as strong as though made from one piece of sheet metal.

A further object is to provide a novel and effective manner of incorporating plastic material with a sheet metal shell such, for example, as referred to in the next preceding object so as to produce a propeller blade having marked strength, distortion and bending resistance and other desirable characteristics.

Another object is to provide an improved propeller blade made partially from plastic material with an improved reinforcing core formed substantially as an integral part of a shank piece or butt of the blade suitable for mounting in a metal hub provided with means for turning the blade about its longitudinal axis for pitch adjustment, feathering and the like.

2

Another object is to provide a de-icing means for propeller blades which means is operative efficiently to de-ice all the blade surfaces on which ice is likely to accumulate.

Further objects include the provision of a propeller blade having adequate tensile, compressive, twist resisting and impact resisting strength, notwithstanding relatively light weight and resistance to the effects of temperature change and relative humidity or even immersion in water for long periods.

Further objects and features of the invention will become apparent from the following description and by reference to the accompanying drawings, in which

Fig. 1 is a front view of one blade of a propeller, partly in central section, and a more or less diagrammatic representation of a hub on which the blade may be mounted;

Fig. 2 is an exploded typical cross-sectional view showing two sheet metal parts or assemblies preparatory to assembling them in accordance herewith to produce a pre-formed hollow shell approximately of propeller blade form;

Fig. 3 is a typical cross sectional detail view showing one manner of effecting a strong joint between sheet metal parts in forming a shell of propeller blade shape;

Fig. 4 is a typical cross sectional view showing two forming dies by which the final blade shape may be determined and effected and molding pressure applied to an organic plastic component of the blade;

Fig. 5 is a typical transverse cross sectional view of the completed blade;

Fig. 6 is an assembly view of a propeller blade shell and an associated supporting die, said view showing a variation of the preferred method of forming the blade and also variations in the blade construction;

Fig. 7 is a relatively enlarged longitudinal sectional view of shank portions of a blade made according to Fig. 6 after a plastic component therefor has been cured or solidified, and

Fig. 8 is a diagram (exploded view) showing a further variation of the essential method and blade construction produced hereby.

This application and my application Serial No. 491,037 filed concurrently herewith are companion cases both showing methods of utilizing effectively, in propeller blade construction, cores or core portions of tough, hardenable organic plastic material of high resistance to the various destructive forces likely to be imposed on propellers, particularly those designed for use on aircraft. The

3

plastic in each case is preferably non-resinous material such as cellulose acetate or cellulose acetate butyrate, but other non-brittle materials, both thermoplastic and thermosetting, having similar properties and strength characteristics may be considered equivalents within the intended scope of this invention.

Prior hereto it has been proposed to use synthetic resins and more or less brittle plastic materials (e. g. "hard" rubber) as propeller blade components and to reinforce said materials in various ways, usually by fabric strips and other embedded members, e. g. paper, wires, etc., so that the synthetic resins and allied materials could serve notwithstanding their inherent brittleness and low tensile strength at normal temperatures; and also it has been proposed to armor such synthetic resins and allied materials with "doped" tape and with partial or complete envelopes of metal to resist the tendency for the inherently brittle materials to be chipped or shattered upon impact with sand, stones, flak and missiles generally. The great difference in thermal expansion and contraction between such previously proposed plastic materials as mentioned and metals as well as the inherent brittleness and lack of tensile strength of the plastics has, I believe, prevented the general adoption of composite plastic and metal propeller blades by the airplane industry to date hereof. As indicated by the foregoing "objects" of the present invention the latter offers a better solution to the various problems encountered in composite airplane propeller construction as will become apparent from the following description of the preferred forms and process or method steps, and produces propeller blades superior in many respects to all metal and laminated wooden propellers, with and without protective metallic armor, and at relatively low cost.

Referring further to the drawing, Fig. 1 shows a left hand portion of a blade in central section and a right hand portion in elevation. The blade has a shank or butt portion 1 suitably formed, for example, generally cylindrically, and with flange projections as at 2 which, in the form shown, are buttress "thread" effects for mounting the propeller in a suitable hub. A hub is diagrammatically indicated at 3 with a tubular extension 4 adapted to receive the projections 2 and which may include provision for turning the entire blade about its longitudinal axis into high and low pitch, feathering and/or reverse positions. Reference is directed to my copending application, Serial No. 498,492, filed August 13, 1943, for a suitable hub construction providing for variable pitch as to the blades of which there may be any suitable number and arrangement and for one manner of supplying de-icing fluid to the blades. The ribs 2 on the butt portion 1 are, in actual practice, supported in split mounting sleeve members such as shown for example in my copending application Serial No. 476,398, filed February 19, 1943. For simplicity, the butt portion 1, as herein shown, is embraced by metal of the associated hub extension 4 as though turnable for pitch adjustment therein.

The principal portion of the body of the propeller blade is plastic material on the order of that mentioned above, namely cellulose acetate or cellulose acetate butyrate or materials of equivalent desired properties (see Plastics Catalogue 1942 for example). The plastic is preferably molded about an extension of the butt or shank piece 1 constituting a blade reinforce bar indi-

4

cated at 5 and which is generally tapered toward the tip portion of the blade partly to reduce the tendency for the metal of the bar to crystallize during flexure of the blade in use, or in other words, in order to lend greater rigidity to portions of the blade nearer the hub than to portions toward the tip. Also, preferably, the plastic is molded about a metal reinforcing sheet or plate 10, which is rigidly attached to the reinforce bar 5 at a central longitudinal slot of the bar 5, e. g. in the manner explained more fully in said companion case.

The sheet or plate 10 has projections at each side formed as by the provision of a fairly large number of openings as at 11 and flanges around the openings projecting outwardly at respective sides of the principal plane of the sheet or plate 10 as suggested for example in Fig. 5 at 12. The exterior surfaces of the completed blade are formed by a metal shell 15 comprising for example two peripherally matching sheet metal sections 16 and 17, typical section portions of which are as shown in Fig. 2. The section 16 forms the camber side of the blade and 17 the thrust side.

The preferred manner of forming the shell 15 so that the shell, together with the shank or butt piece 1 and reinforce bar 5, if used, may constitute a mold for the plastic material in forming the same to propeller blade shape is as shown by Figs. 2 and 3. Each shell preferably has adjacent the leading edge portions 16a and 17a, respectively, a generally triangular strip of material 18 brazed or otherwise secured thereto on the inside of the shell so that, in effect, the edges of the metal of the respective shells are amplified—made wider—for facilitating the formation of permanent strong joints between the aligned edge portions of the shells. The particular form of the strips 18, which may be modified, is mainly in order that the plastic body (to be described later) will more effectively interlock the shells together at the brazed or welded joints. The trailing edge portions 16b and 17b of the two shells are similarly supplied with joint-surface-enlarging and plastic-interlocking strips 19 also shown as generally triangular in section.

It will be observed that the strips 18 and 19 when of triangular section or other shape providing opposite relatively diverging and inwardly extending surfaces are finely held together or interlocked with the solidified plastic (see P', Fig. 5) so that the plastic effects an auxiliary or insuring bond between the shell edges in cases where the brazing or welding may be carelessly done. Instead of using separate strips such as 18, the matching edges of the two shell sections 16 and 17 may be flanged inwardly in the manner suggested, for example, by Fig. 8 hereof to be described later, in which event the inwardly directed flanges are locked together by the plastic body adjacent the joint between the shell sections, regardless of the shapes of such flanges and further interlocked if the flanges are of appropriate shape.

While the two shell sections equipped with the strips 18 and 19 (or flanged for similar edge-surface-amplifying effect) can be secured together by any known welding method, I preferably braze the shell sections together by interpositioning between the registering edge surfaces fairly thin and preferably peripherally continuous welding stock as suggested at 20, for example brass or other readily fused metal. The welding stock as well as the strips 18 and 19 run continuously around the blade shell sections from

a point adjacent the open end of the completed shell around the tip and back to a similar point adjacent the open end but on the opposite side from the first mentioned point.

Prior to assembling the two shell sections 16 and 17 together, flanged strips such as 22 and 23 are secured as by welding to the inside surfaces of the shells and running substantially for their entire length so that the portions of the shells intermediate the brazed or welded edges above described will be solidly interlocked with and backed or buttressed by the plastic material to be later contained in the completed shell 15. As shown each of the strips 22 and 23 has two flanges, the flanges all being indicated at 24. The flanges of each strip diverge in the particular form illustrated for dovetail interlock effect with the plastic. Buttons with T-heads can be used instead of strips.

There may, of course, be provided a greater number of strips such as 22 and 23 on each side wall depending upon the tendency for the metal of the side walls to draw away from the solidified plastic. The variation would result from the use of different metals to form the shell sections.

The shell section 16 which constitutes the camber-surface-forming element of the blade has secured thereto inside near the leading edge a metal tube 25 for containing and conveying de-icing fluid to the blade surfaces which are likely to accumulate ice. The tube 25 may extend through the butt piece 1 at a suitable eccentric bore therein for connection as at 26 with a respective flexible conduit 27 leading to a source of supply of de-icing fluid such as alcohol. The arrangement, shown in my copending application, Serial No. 498,492, filed August 13, 1943, enables all of the blades to be supplied simultaneously with fluid from a single source such as a central tube 28 (diagrammatic); and the flexible connections permit the shank or butt pieces 1 of the blades to turn in their mountings as would be necessary in the event the blades are used for variable pitch during flight. The blade has a plurality of small openings as at 30 which are drilled through from the outside of the blade into the tube 25 to carry the de-icer fluid to the blade surfaces. The preferred arrangement would be such a series of openings 30 as indicated on Fig. 1 for the camber side of the blade and a lesser number, for example, one third as many, leading to the thrust side of the blade as more fully illustrated and described in my said companion case. The arrangement is unique in that all surfaces along the blade from shank to tip and which are likely to accumulate ice are served with de-icer fluid. The de-icer tube hereof is essentially the same as that shown by my said companion case and somewhat more fully explained in that case.

An efficient manner of welding the two shell sections 16 and 17 together is illustrated by Fig. 3 wherein suitable dies 32 and 32' lightly support the shells over substantial surfaces thereof and electrical contactor elements are arranged in the dies as at 33 and 34 for carrying welding current to the shells closely adjacent the joints to be formed therebetween. The elements 33 and 34 preferably comprise strips of carbon or other non-arcing conductor material which extend entirely about the peripheral portions of the blade shells to be joined and make firm intimate uniform contact therewith to carry the welding current. When current of opposite polarity is applied to the respective strips of each pair, the

edges of the shells and strips 18 and 19 are integrally joined together through the intermediary of the fused welding stock 20. The welding stock can, of course, take other forms. In cases where the shell stock is fairly thick, it is not necessary to extend the surface as by application of the strips 18 and 19.

After the tubular shell 15 has been fully formed as described above the open end portion of the shell adjacent the hub may be extended as from the point indicated at 37 on Fig. 1 toward the hub 3 by a continuous or seamless tube 38 of metal butt-brazed or welded to the open end of said shell or otherwise firmly secured thereto, entirely around the open end of the shell 15. As shown in Fig. 1, the tube 38 has a flange 39 which is fixed to the shank or butt piece 1 in any suitable manner, as by welding, adjacent a suitable shouldered portion of the butt piece.

The reinforce bar 5 has a plurality of parallel circumferential extending ribs 6 thereon, for firm interlocking with the plastic, along as much of the length of the bar as desired or found necessary. The reinforce bar furthermore has a central bore as at 7 which bore extends through the butt piece into a socket 8 of the latter. Such bore 7 may be used as an injector passage for introducing the plastic material into the metal assembly as through lateral passages in the reinforce bar as illustrated and described in my said companion case.

In the present form of blade and method of making it I supply the raw plastic material, for instance cellulose acetate, as in the usual granular form (P in Fig. 4) to the inside of the shell 15 before the reinforce bar and butt piece are attached thereto. In order to compensate for the difference in volume between the plastic in such granular form and the solidified plastic (P', Fig. 5), I may temporarily expand the shell as by introducing compressed air through the bore 7 and communicating small lateral passages 9 so that the shell 15 is "blown up" and bears to the finally formed shell somewhat the relationship exhibited by comparison of Figs. 4 and 5. The shell could, instead be pressed originally into the "blown up" shape shown by Fig. 4 and later contracted between suitable dies.

Fig. 4 shows the shell 15 between two heated dies 40 and 41 which are complementary in that one die, namely 40 is configured to form the shell section 16 into proper propeller camber surface shape and the other die, 41, to form the shell 17 into proper thrust surface shape. As the two dies 40 and 41 are brought together sufficient heat is transferred to the thermoplastic stock through the shell walls to melt the stock and thereupon final pressure is brought against the opposite sides of the shell so as to form the final propeller blade shape, a typical section of which is indicated at 43 in Fig. 5. The blade, of course, has the usual or suitable twist or air-screw shape not brought out by the drawing. An important function of the flanges 24 of the strips 22 and 23 in the procedure particularly brought out by Figs. 4 and 5 is that any tendency for the relatively expanded camber and thrust side walls of the shells 16 and 17 to separate from the plastic as by reason of pre-expansion for charging purposes and inherent elasticity tending to retain the shell sections in expanded condition is fully overcome by the interlocking of the flanges with the solidified plastic.

In the case of using the preferred plastic and method of introducing it into the shell 15, as

above described, said shell, preferably, is charged with the proper amount of granular plastic material before the butt piece 1 is fastened to the shell as by brazing the flange 39 of the tube 38 (Fig. 1) into place against the butt piece.

The joints between the shell sections could be at other regions than as shown in Figs. 2 to 5. The illustrated forms of shells 16 and 17 according to those figures are preferred because the shell sections have less "drawing" depth and are therefore less likely to wrinkle during the forming operation than if made to constitute fore and aft shell sections of the blade armor (cf. Fig. 8, described below). However, in many cases, the deep drawing such as would seem to be necessary by an arrangement according to Fig. 8 is actually a folding operation on the sheet stock over the principal areas of the sheet.

The manner of making the shells 17' and 18' according to Fig. 8 so as to constitute a complete blade armor or shell 15' has a special advantage which compensates in part for the deep drawing or relatively difficult forming operations in that the leading and trailing edge portions of the blade are jointless and in that the special side wall anchor strips such as 22 and 23 are rendered unnecessary because strips such as 18, used to increase the metal stock thickness for welding purposes (or interturned flanges such as illustrated at 22', Fig. 8, can function fully not only to reinforce the welded or brazed joints through interlocking with the plastic but also in effecting a solid structure by holding the two main side walls of the armor shell in fixed relationship to each other through the intermediary of the solidified plastic P' when included as herein described.

A variation in essentially the method of incorporating the metal and plastic parts with each other according to Figs. 4 and 5, is illustrated by Figs. 6 and 7 wherein, instead of expanding the volumetric capacity of the pre-formed metal shell as by relative expansion of main side wall portions of the shell prior to filling the shell with raw plastic, e. g. in granular form, a different (effective) wall of the shell is initially placed in relatively expanded position with respect to the remainder of the shell, which wall is later moved to a different and final position reducing the volumetric capacity of the hollow wall or shell structure as a whole to correspond with the volume of the charge of plastic when solidified or cured. Thus in lieu of so making the shell 15 that the sheet metal portions may be contracted in volume as necessary to enable the plastic to fill the effective mold cavity supplied by the shell, I may make the two shell sections 16 and 17 in final propeller blade shape and size and secured together and to the butt piece prior to introducing the reinforce bar into final position, and the reinforce bar becomes the effective wall of the shell which is moved to reduce the volume.

In Figs. 6 and 7 the sheet or plate 50, which is of the same general character as the plate 10, is provided with oppositely extending lugs or tongues 51 and 52 in pairs such that terminal portions of the tongues can make contact with respective opposite walls of the shell 15 (see Fig. 7) and hold the plate 50 substantially in the desired position, for example, midway between the shell sections 16 and 17 by yielding contact of the tongues therewith until the plastic is cured or solidified. The reinforce bar 55, shown as separate from the butt piece 1 and insertable thereinto through a close fitting bore 56, can

be placed into position with a central slot 57' of the reinforce bar closely embracing the opposite sides of the sheet or plate 50. When the reinforce bar 55 is finally moved inwardly through the bore 56 to fixed position as shown in Fig. 7 the entire space within the shell not otherwise occupied is filled with the plastic.

The arrangement just described contemplates filling the completed shell with raw plastic stock as in granular form through the bore 56 of the butt piece 1, then treating the plastic until, as by application of heat to the shell walls by "hot die" surfaces in face to face contact with the shell, the plastic is capable of molding flow and finally inserting the reinforce bar 55 into final position by sliding engagement of a head portion 57 of the reinforce bar with the bore 56 of the butt piece. Said operation of inserting the reinforce 55 may be done in a press as by a plunger 58, Fig. 6, while the shell is supported between suitable dies or shape-maintaining means.

In the finished blade the plate 50 and reinforce bar 55 may be locked together as by a pin or plurality of pins 59 passed through at least one wall of the shell 15 through aligned openings in the reinforce bar and plate 50 as shown in Fig. 7. Spring pawl forming tongues on the plate 50 (not shown) arranged to abut ratchet shoulders on the reinforce bar 55 could be used instead to lock the bar and plate 50 together. Also the butt piece and reinforce bar may be finally pinned or otherwise secured together as at 60.

For illustrative emphasis the raw plastic material has been omitted from Fig. 6; but it is assumed that the proper amount of plastic has been introduced at the stage illustrated to cause complete filling of the shell upon movement of the bar 5 to final position and curing or solidification of the plastic and interlocking of all parts of the blade through the medium of the solidified plastic as previously described.

It will be apparent from the disclosure hereof that the present invention overcomes a problem which is generally accepted as an unavoidable disadvantage in the process of injection molding of plastic materials. A limitation in the use of the cellulose acetates and other thermoplastic materials has been the inability to form large pieces particularly if long and irregular recesses must be filled. The disadvantage comes about because it is frequently impossible to control the direction of flow of the plastic, and two or several streams of the plastic come together and form what is known as "weld joint" effects inherently weakening the molding when the joints are imperfect. In the present procedure perfect integral plastic blade bodies are formed regardless of size since the raw plastic stock (e. g. loose granules) can easily reach all outlying parts of the mold (shell) before any heat or pressure is applied. A further advantage is that with the present procedure there is no tendency for the finally applied pressure to displace any of the core parts, for instance, the sheet 10 (or 50) or central reinforce 5 (or 55) out of position due to unequal flow of different stream portions of the plastic material and partial solidification in transit. The plastic portion of the blade, in other words, is certain to be integral without "weld joint" effects and such inherent weaknesses as discussed above. A general distinction apart from inherent organic plastic properties from certain previously proposed methods of making

composite metallic and organic plastic propeller blades is that in the case of the present procedure the plastic material shrinks slightly as it solidifies from molten or plastic state and shrinks in volume considerably from the state in which it exists as raw plastic stock if granular. Therefore, no expansion joints or their equivalent are necessary such as are required if condensation products (e. g. phenol resin and allied plastics) are cured in a pre-formed metal shell.

I claim:

1. A propeller blade comprising in combination, cooperating separate shell sections having abutting edges joined together to unite said sections to form blade surfaces, inner reinforcing flanges along the edges of each shell section, and a filler formed by an organic plastic material constituting the body portion of the propeller, filling the shell and enclosing said reinforcing flanges so as to lock said abutting edges together.

2. A propeller blade comprising in combination, cooperating separate shell sections having abutting edges joined together to unite said sections to form blade surfaces, tapered reinforcing flanges along the edges of each shell section extending inwardly therefrom to provide a re-entrant angle extending along the inner faces of said sections adjacent said edges, and a plastic filler constituting the body portion of the propeller filling the shell and the area of said re-entrant angles and enclosing said reinforcing flanges to lock said edges together.

3. A propeller blade comprising in combination, cooperating separate sheet metal shell sections having abutting edges joined together to unite said sections to form blade surfaces, inwardly directed portions of said sections forming inwardly directed flanges along the edges of each shell

section to provide re-entrant angles along the inner faces of said sections, and a plastic filler constituting the body portion of the propeller filling the shell and said re-entrant angles and enclosing said inwardly directed flanges to lock said shell sections together.

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