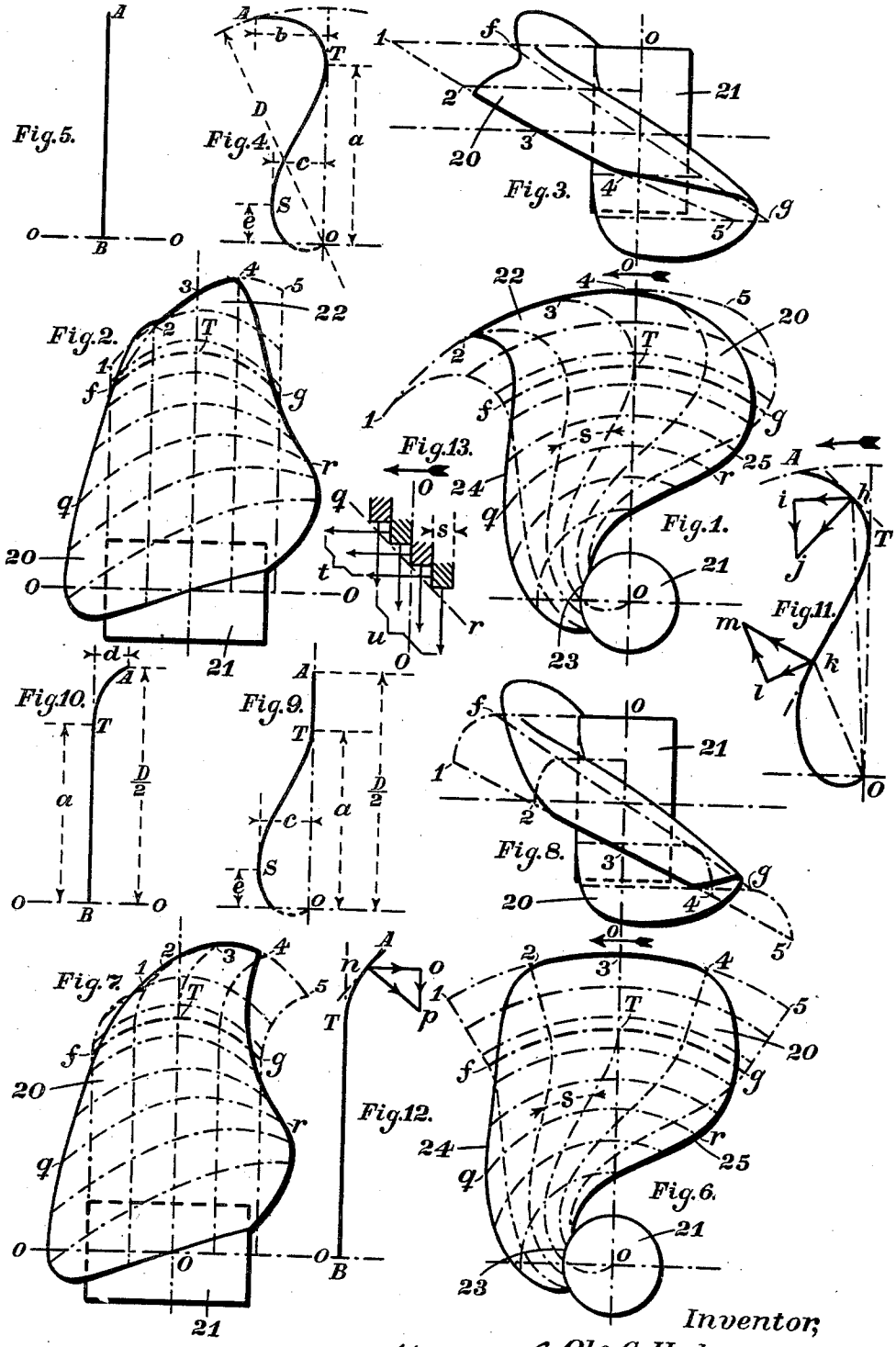
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SCREW PROPELLER

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SCREW PROPELLER

Application filed March 19, 1929. Serial No. 348,253.

The invention relates to screw propellers which may be used in any fluid.

The principal object of the invention is to shape and form the blades of the propeller in such a manner that a greater efficiency in operation of the propeller may be attained than is possible with many other forms of propellers.

In the specification of my United States Letters Patent Number 1,031,545, issued July 2, 1912, there has been described the movement of fluid particles relative to the face of a propeller during its rotation, the propeller there considered being one formed by a straight line generatrix, perpendicular to the axis of rotation of the propeller. The fluid particles lying outside of a certain distance from the axis of rotation were shown to have an outwardly directed radial force component, and those fluid particles lying inside of the said distance were shown to have an inwardly directed force component. These radial forces acting upon the fluid next to the propeller are created by a wave motion caused by the slip of the propeller. This radial movement of the fluid next to the propeller-face causes loss of fluid, to a certain extent, which loss will reduce the mass of fluid, to a certain extent, against which the propeller acts while it rotates. This results in a reduction of propeller-thrust. On the other hand, the wave motion mentioned causes a loss of a certain amount of power from the source of same, which power will be lost.

In the above mentioned Letters Patent a means was described by which the power loss caused by the radial movement of the fluid next to the propeller could be eliminated. This was accomplished by increasing the mass of the fluid upon which the propeller face acted during its rotation. More specifically the screw surface upon which the propeller blades were designed, was curved in such a way that it created radially directed forces equal in quantity but opposite in direction to those caused by the above mentioned wave motion. The generatrix of the screw surface was suitably curved in a plane through the axis of rotation of the propeller and was given such curvature as to oppose the radial forces found by the experiments described in the above mentioned Letters Patent.

The present invention is an improvement over that shown and described in the above mentioned Letters Patent and shows a different means for counteracting the radially directed forces. In the propeller described in Letters Patent Number 1,031,545, use was made of the propeller-thrust as a source of the counteracting force, but in the present invention these counteracting forces are taken from the propeller shaft torque. These last mentioned forces act in a plane perpendicular to the axis of rotation of the propeller and act circumferentially, consequently the direction of these forces will be perpendicular to the radius at any point of the blade surface.

A further object of the invention is to form a propeller having blades which are so shaped that it may be readily and efficiently installed and rotated in the ordinary propeller-well in the stern of the ship, and yet be given a high pitch ratio and produce the counteracting forces above described. In my Patent Number 1,031,545, it was impossible to use a propeller of my design having a high pitch ratio because of the interference with the hull of the ship. With the new design for propeller herein described, however, it is possible to employ a propeller of high pitch ratio with any ordinary ship.

It will be understood that the invention is applicable to propellers and impellers having any number of blades and that the pitch of the propeller or impeller may be constant or variable.

Although the propeller of the invention may be used in any fluid it will be hereinafter considered in connection with its use in liquids.

The invention will be explained and more readily understood when read in conjunction with the accompanying drawings, which illustrate embodiments of which the invention is susceptible, it being understood that various changes and modifications in the structure may be made without departing from the spirit of the invention, as expressed

in the appended claims, forming a part hereof.

In the drawings:

Figure 1 is a front elevational view of a propeller blade, employing a generatrix, curved in a plane perpendicular to the axis of rotation, the blade being attached to a hub.

Figure 2 is a side elevational view of the propeller blade and hub shown in Figure 1, and shows the curved generatrix as projected in different positions upon a plane through the axis of rotation, the projections of which on this plane being straight lines.

Figure 3 is a top or plan view of the propeller blade and hub in Figures 1 and 2, and shows the pitch of the propeller blade illustrated.

Figure 4 shows the generatrix as projected upon a plane perpendicular to the axis of rotation, viewing the face of the propeller blade from the front.

Figure 5 shows the projection of the generatrix shown in Figure 4 upon a plane through the axis of rotation, the projection being a straight line, viewing the propeller blade from the side.

Figure 6 is a front elevational view of a modified form of propeller blade, constructed partly in accordance with the principle which utilizes the propeller shaft torque and partly in accordance with the principle which utilizes the propeller thrust, the blade being attached to a hub.

Figure 7 is a side elevational view of the propeller blade and hub shown in Figure 6 and shows particularly projections of its generatrix upon a plane through the axis of rotation.

Figure 8 is a top or plan view of the propeller blade and hub shown in Figures 6 and 7.

Figure 9 shows a projection of the generatrix of the propeller blade shown in Figures 6, 7 and 8 upon a plane perpendicular to the axis of rotation, viewing the face of the propeller from the front.

Figure 10 shows a projection of the generatrix illustrated in Figure 9 upon a plane through the axis of rotation and illustrates the manner in which the two principles are combined in the one propeller, viewing the propeller blade from the side.

Figure 11 shows the curvature of the generatrix of the propeller illustrated in Figures 1, 2 and 3 in conjunction with force-component diagrams, the forces acting in a plane perpendicular to the axis of rotation of the propeller and created by the propeller shaft torque.

Figure 12 shows a projection of the generatrix of the propeller blade shown in Figures 6, 7 and 8 in conjunction with a force-component diagram, the generatrix being projected upon a plane through the axis of rotation of the propeller, and illustrates the reactions existing because of the curvature of the generatrix in this plane, in other words, the forces of which are created by the thrust reaction of the propeller blade, and

Figure 13 is a fragmentary sectional view taken on the curved line q—r of the propeller shown in Figures 1, 2 and 3, and shows the force reactions upon small imaginary sectors of the curved propeller surface.

For convenience in illustration the propeller as shown in Figures 1, 2 and 3 is provided with only one blade 20, which is mounted on the hub 21. It will be understood that the propeller will be equipped with the usual number of blades, as desired, each of the same construction. The blade 20 has the tip portion 22, and is joined to the hub at 23. The curved edges 24 and 25 may be of any suitable contour symmetrically arranged with respect to the center line of the propeller blade.

The propeller has a horizontal axis or axis of rotation O—O, and a vertical axis O—T. The curve f—g indicates the neutral line, that is, the line which represents the demarcation or division of the outwardly directed radial forces from the inwardly directed radial forces.

In order to simplify the explanation of the construction of the screw surface, the face of the propeller blade is cut by a series of imaginary parallel planes perpendicular to the axis of rotation O—O, the sectors 1—0—2, 2—0—3, 3—0—4, etc., thus being formed as shown most clearly in Figure 1. The intersection lines of the imaginary parallel planes with the propeller blade face are curved dot and dash lines 1—0, 2—0, 3—0, etc., in vertical projection, as shown most clearly in Figure 1, and are straight dot and dash lines 1—0, 2—0, 3—0, etc., when projected upon a plane through the axis of rotation as shown most clearly in Figure 2.

The curve q—r represents a portion of a helix lying upon the propeller face at any given distance from its center O. In Figure 13 the line q—r represents in horizontal projection any of the curves q—r in Figures 1 and 2, which consequently follows the face of the blade at a given distance from the axis of rotation O—O. The line q—r in Figure 13 will thus act as a limitation line for the step shaped line formed by the above mentioned curved sectors 2—0—3, 3—0—4, etc., the annular thickness of each sector being denoted by s, as shown most clearly in Figures 1 and 13.

The entire face of the blade can thus be considered as made up of numerous radially curved steps following the curved lines 0—1, 0—2, 0—3, etc., as shown in Figure 1; the height of these radially curved steps being equal to the distance between the imaginary parallel planes, represented in Figure 2 by the straight lines 0—1, 0—2, 0—3, etc.

During the rotation of the propeller in the direction of the arrows in Figures 1 and 13, the side of each one of the imaginary steps being normal to the direction of rotation of the propeller, will exert a pressure *t*, (Figure 13) upon the liquid next to the blade-face, and create a reaction from same acting in a plane perpendicular to the axis of rotation of the propeller and always be circumferentially directed. The reaction *t* is always circumferentially directed because of the fact that the torque from the propeller shaft is the source of the reaction.

Figure 11 shows one of the above mentioned imaginary radially curved steps of the propeller blade in end projection, consequently their shape conforms with the curves 0—1, 0—2, 0—3, etc., in Figure 1. The vectors *h*—*i* and *k*—*l*, respectively placed outside and inside of the neutral line *f*—*g* in Figure 1, will be equal in quantity to the forces *t* shown in Figure 13, and always acting at right angles to the radius at the particular point in consideration of the above mentioned curved steps.

In order to create the desired counteracting force, it is necessary to radially curve the above mentioned imaginary steps in such a way that the forces *h*—*i* and *k*—*l* (Figure 11) will create a reaction against the steps at the given point in such direction and quantity, that the inwardly and outwardly directed components *i*—*j* and *l*—*m*, respectively, will just balance the respective outwardly and inwardly directed radial forces arising from the magnitude of the wave motion (which is to be subdued) of the liquid next to the blade-face when the propeller is revolving.

These components being found, the resultants *h*—*j* and *k*—*m* (Figure 11) will now act normally to the tangent to the curve at the points *h* and *k*, respectively, and no radial movement of the liquid next to the propeller-face will take place. This geometric device being represented at a sufficient number of distances from the axis of rotation of the propeller, the correct shape of the curve A—T—O (Figure 11) will be obtained.

By making the angular thickness *s* of the imaginary curved sectors 1—0—2, 2—0—3, 3—0—4, etc., (Figures 1 and 13) infinitesimally small and the number of same infinitely large, the step-shaped line in Figure 13 which has been described above will coincide with the curves *q*—*r* in Figures 1, 2 and 13, and the entire surface of the blade will become smooth, thus having the forces evenly distributed along any of the curves *q*—*r* in Figures 1 and 2 from the root of the blade to the tip of the same.

It is to be remembered that the curves *q*—*r* represent intersection lines, at any distance from the axis of rotation, of concentric cylinders with the face of the propeller blade. Having found the shape of the curve A—T—O, it becomes possible to generate a screw surface using the curve A—T—O, as a generatrix and then form the propeller blade shown in Figures 1, 2 and 3.

In Figures 6, 7 and 8, a modified form of propeller is shown which combines the torque from the propeller-shaft in connection with the axial thrust from the propeller as sources of counteracting forces.

To facilitate the explanation of the propeller face, the face of the propeller blade is cut by a series of imaginary rotation surfaces, the rotation planes of which are perpendicular to the axis of rotation O—O, and represented by the lines 1—0, 2—0, 3—0, etc., as shown in Figure 7. The intersections of these surfaces with the face of the propeller form the lines 1—0, 2—0, 3—0, etc., as shown in Figure 6.

It will be noticed that each portion of the intersection lines 2—0, 3—0, 4—0, etc., which lies outside of the neutral line *f*—*g* of Figure 6, and which extends to the tip of the blade and projected on a plane perpendicular to the axis of rotation, is a straight line, while the portion which lies inside of the neutral line *f*—*g* is curved.

In Figure 7, which shows a side elevation of the modified form of construction, the intersection lines 0—2, 0—3 and 0—4, etc., are straight lines inside of the neutral line *f*—*g* and are curved sternwardly outside of the neutral line *f*—*g*.

This change of the intersection line or curve from a straight line to a curve and vice-versa, is because of the fact that the part of the propeller blade which lies outside of the neutral line *f*—*g* is constructed upon the principle disclosed in my patent, hereinbefore mentioned, while that portion which lies between the neutral line and the hub of the propeller utilizes the principle illustrated in the propeller of Figures 1, 2 and 3.

Referring to Figures 7 and 13, that portion of the propeller blade which lies between the neutral line *f*—*g* and the hub, creates a reaction against the liquid upon which it acts, this reaction being represented by *t*. This reaction, it will be noted, is precisely the same as that found in the propeller of Figures 1, 2 and 3, because the same curve is under consideration. That portion of the propeller blade, which lies between the neutral line *f*—*g* and the tip of the propeller, reacts against the liquid in a plane perpendicular to that in which the forces *t* act and these forces are represented by the vectors *u*.

Figure 12 shows in side projection the end of any one of the curved sectors, 1—0—2, 2—0—3, 3—0—4, etc., (Figure 6), formed by the above mentioned imaginary rotation surfaces intersecting with the propeller face, corresponding to any one of the steps as shown in Figure 13. The force component

n—O in Figure 12, which is parallel to the axis of rotation O—O, is the same as u in Figure 13 and is of such quantity that it creates an inwardly directed component o—p which will just balance the outwardly directed radial force arising from the magnitude of the wave motion (which is to be subdued) of the liquid next to the propeller face when the propeller revolves.

As soon as this equality between these two latter mentioned forces acting against each other at any distance from the neutral line f—g to the tip of the blade has been obtained there will be no radial movement of the liquid next to the propeller face and consequently no liquid will slip over the tip of the blade.

In order to obtain this, the resultant n—p, (Figure 12), will have to be perpendicular to the tangent to the curve A—T at the point n, and by considering in a similar manner, as described above, several points between A and T, (which latter point T represents the neutral line f—g) several tangents under increasing angles with the radius from the latter mentioned line will be obtained.

By drawing a curve touching these tangents, the curve A—T will be obtained, and any liquid particle next to the propeller face from T to A will thus be kept at a constant distance from the center of the propeller during the rotation of the same.

Having obtained the curvature of the blade of the portion lying outside of the neutral line, necessary to counteract the outwardly directed radial force above mentioned, there will be no radial movement of the liquid next to the propeller face and consequently the volume of liquid upon which the propeller acts will be at its maximum.

By making the angular thickness s of the imaginary curved sectors 1—0—2, 2—0—3, 3—0—4, etc., (Figures 6 and 13) infinitesimally small and the number of sectors infinitely large, the step shaped line in Figure 13 will coincide with the curve q—r in Figures 6, 7 and 13. This results in making the face of the propeller blade smooth and in having the forces regularly and uniformly distributed along the curves q—r. (Figures 6 and 7) from the root of the blade to its tip.

The reason why the blade is bent in a plane perpendicularly to the axis of rotation of the propeller from the neutral line f—g to the tip of the blade as shown in Figures 1, 2 and 3, and the same part of the blade being bent sternwardly from the neutral line f—g to the tip of the blade, as shown in Figures 6, 7 and 8, is due to the fact, that, in some cases the propeller-well, that is, the opening for the propeller in the stern frame of the ship, has been given such a shape, that does not permit a propeller, the blades of which being bent sternwardly, as per Figure 7, to be placed in same.

In the latter mentioned case, the blades being bent sternwardly, as shown in Figures 6, 7 and 8, from the neutral line f—g to the tip of the blade, is preferable, as it gives more room between the propeller tip and the hull of the ship.

It will thus be seen that the propeller above described eliminates the two principal kinds of loss in the ordinary propeller. In the first place, in the ordinary propeller, a quantity of liquid outside of the neutral line will be pushed from the propeller blade at its tip and another quantity inside of the neutral line will be forced toward the center of the propeller and will rotate with it.

This reduction of the mass of the fluid against which the propeller blades act, decreases the reaction against the propeller blades and results in a loss of power.

In the second place the above mentioned wave motion causes a loss of mechanical work as no movement of a body can take place without expenditure of work. Inasmuch as mechanical work is a product of force and distance, the mechanical work caused by the wave motion (radial movement of the liquid relative to the propeller blade) will be reduced to zero when the radial movement of the liquid while passing over the blade is eliminated. This means that all liquid particles must remain at a constant distance from the axis of rotation when passing over the face of the propeller blades.

By constructing a propeller in accordance with this invention all of the above objectionable work may be obviated, thereby greatly increasing the efficiency of the propeller.

As has been described, the lines 0—1, 0—2, 0—3, etc., in Figures 1, 2, 3, 6, 7, and 8 are to be considered as intersection lines of planes or rotation surfaces, the rotation planes of which being perpendicular to the axis of rotation of the propeller, with the face or pressure side of the propeller blade.

The shapes of these intersection lines have been found by experiments and calculations and their shapes are illustrated in Figures 4, 5, 9 and 10. The dimensions of these intersection lines may be found and ascertained by means of the table hereinafter set forth, for different diameter ratios (diameter divided by pitch) of the propellers in question, as the shape of the intersection line curves vary with the said ratio.

For diameter ratios falling between those appearing in the table below, the figures may be found by interpolation. The dimensions "a," "b," "c," and "e" refer to the curve A—T—S—O, as shown in Figure 4, and the dimensions "a," "c," "d," and "e" refer to the curve A—T—S—O, as shown in Figure 9,

and the curve A—T—B as shown in Figure 10.

The following is the table referred to:

$$a=v\cdot\frac{D}{2};\ b=w\cdot\frac{D}{2};\ c=x\cdot\frac{D}{2};\ d=y\cdot\frac{D}{2};\ e=z\cdot\frac{D}{2}$$

D=diameter of propeller.

Diameter-ratio	v	w	x	y	z
0.5	0.807	0.231	0.282	0.146	0.200
0.7	0.758	0.325	0.220	0.151	0.150
0.9	0.590	0.589	0.133	0.220	0.178
1.1	0.440	0.842	0.074	0.286	0.150
1.3	0.369	0.785	0.064	0.216	0.121

Having thus described the invention what I claim and desire to secure by Letters Patent is:

1. In a screw propeller the combination of a propeller blade and a hub, a neutral line on said blade, the portion of the surface of said propeller blade lying inside of said neutral line being curved in a plane perpendicular to the axis of rotation, and the portion of the surface of said propeller blade lying outside of said neutral line being curved in a plane through the axis of rotation.

2. In a screw propeller, the combination of a propeller blade and a hub, said blade having a screw face curved in a plane perpendicular to the axis of rotation, a neutral line thereon, the curvature of the blade surface progressing in a constant angular direction from the neutral line toward the axis of rotation, and progressing in the opposite angular direction from said neutral line to the tip of the propeller blade.

3. In a screw propeller, the combination of a propeller blade, and a hub, said blade having a screw face curved in a plane perpendicular to the axis of rotation, said curve being of such shape that a force component normal to the curve at any given point thereon and representing in direction and quantity the reaction of the screw face of the propeller blade upon the fluid upon which it acts will create a radial force component at the said point equal in quantity but opposite in direction from that force component which tends to move the fluid particles radially along the propeller face at the said given point, said forces acting in a plane perpendicular to the axis of rotation.

4. In a screw propeller, the combination of a propeller blade and a hub, said blade having a screw face curved in a plane perpendicular to the axis of rotation, a neutral line thereon, said curve being of such shape that all points on the curve which lie outside of the neutral line from the axis of rotation will create an inwardly directed force component and all points on the curve which lie inside of the neutral line will create outwardly directed force components, said force components each being equal in quantity but opposite in direction to the relative magnitude of radially directed forces acting on the particles of the medium in which the blade acts at the respective points.

5. In a screw propeller blade, a neutral line thereon, that portion of the blade inside the neutral line being curved in a plane perpendicular to the axis of rotation, and that portion of said blade outside said neutral line being curved in a plane through the axis of rotation, said curvatures being such as to neutralize any tendency of the fluid next to the propeller face to move radially relative thereto.

6. In a screw propeller the combination of a propeller blade and a hub, a portion of the propeller blade being curved in a plane perpendicular to the axis of rotation, and a portion of said blade being curved in a plane through the axis of rotation, said first mentioned portion being of such shape that a force component, normal to the curve at any given point thereon and representing in direction and quantity the reaction of the screw face of the propeller blade upon the fluid upon which it acts will create a radial force component at the said point equal in quantity but opposite in direction from that force component which tends to move the fluid particles radially along the propeller face at the said given point, said forces acting in a plane perpendicular to the axis of rotation, said second mentioned portion extending from the neutral line to the tip of the propeller and being of such shape that it will create force components in the plane of the said second mentioned portion of the curve, equal in quantity but opposite in direction from the respective force components of the radially directed movement of the fluid next to the propeller face.

7. A screw propeller, having any number of blades, the faces of which are formed by curved, imaginary intersection lines, in successive axial and angular positions of planes perpendicular to the axis of rotation of the propeller, with the faces of the propeller blades at any axial position of said planes, and said intersection lines having points of tangency with the radius of the propeller, the distance of which from the center of rotation of the propeller varies with the pitch ratio and number of blades of the propeller, an angle situated in a plane perpendicular to the axis of rotation of the propeller, between the tangent to said intersection lines, at any point of the latter, and a straight line intersecting the axis of rotation of the propeller at a right angle and passing through said point of said intersection lines, said angle between said tangent and said straight line successively increasing from point to point on either side of the geometrical locus of said point of tangency in a general direction from the latter, where it is zero, to

the tip of the blade and to the root of the blade, respectively, and at any point of the blade face, having such a size that the reaction from the propeller-shaft-torque will create an inwardly directed component at any point of the part of the blade outside of the geometrical locus of said point of tangency and an outwardly directed component at any point of the part of the blade inside of the geometrical locus of said point of tangency, which components being equal in quantity but opposite in direction to those at the same points, respectively outwardly and inwardly directed forces created by the motion of the liquid arising from the propeller's work in said liquid, at any distance from the root of the blades to the tip of same, substantially as described.

8. A screw propeller, having any number of blades, the faces of which are formed by curved, imaginary intersection lines, in successive axial and angular positions, of rotation surfaces, the rotation plane of which is perpendicular to the axis of rotation of the propeller, with the face of the propeller blades at any axial position of said surfaces, and said intersection lines having points of tangency with the radius of the propeller, the distance of which from the center of rotation of the propeller varies with the pitch ratio and number of blades of the propeller, said rotation surfaces being planes perpendicular to the axis of rotation of the propeller inside of the geometrical locus of said point of tangency and curved sternwardly outside of said geometrical locus, an angle situated in a plane perpendicular to the axis of rotation of the propeller and located inside of the geometrical locus of said point of tangency, between the tangent to said intersection lines at any point of the latter inside of said geometrical locus, and a straight line intersecting the axis of rotation of the propeller at a right angle and passing through said point of said intersection lines inside of said geometrical locus, said angle located inside of said geometrical locus between said tangent and said straight line successively increasing from point to point in a general direction from said geometrical locus, where it is zero, to the center of rotation of the propeller and at any point within said part of the blade having such a size, that the reaction from the propeller-shaft-torque will create an outwardly directed component equal in quantity but opposite in direction to that at the same point inwardly directed force created by the motion of the liquid arising from the propeller's work in said liquid, and another angle situated in a plane through the axis of rotation of the propeller, and located outside of the geometrical locus of said point of tangency, between the tangent to said intersection lines at any point of the latter outside of said geometrical locus and the radius of the propeller, said latter angle, located outside of said geometrical locus between said tangent and said radius successively increasing from point to point in direction from said geometrical locus, where it is zero, to the tip of the blade, and at any point within said part of the blade having such a size that the reaction from the axial propeller thrust will create an inwardly directed component equal in quantity but opposite in direction to that at the same point outwardly directed force created by the wave motion arising from the work resulting from the thrust of the propeller against the liquid, substantially as described.

In witness whereof, I hereunto subscribe my name this 15th day of March, A. D. 1929.

OLE G. HALVORSEN.