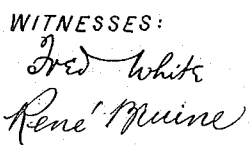


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SCREW-PROPELLER.

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Specification of Letters Patent.

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To all whom it may concern:

Be it known that I, ALBERT MÜHLBERG, a citizen of the Swiss Republic, and resident of Basel, Switzerland, engineer, have invented new and useful Improvements in and Relating to Screw-Propellers, of which the following is a full, clear, and exact specification.

The object of this invention is a screw propeller, the blades of which are so constructed that it considerably raises the degree of efficiency, by reducing the waste in the impact and current which attends the screws now in use. At the same time, the form of the pressure surface (thrust-side) of the blades is such that it is primarily capable of being automatically worked or shaped, whereby a perfectly smooth surface is obtained with a view to reducing loss by friction.

Figure 1 is a developed cylindrical section, concentric with the axis of rotation, of a screw blade of known type; Fig. 2 is a projection thereof upon the plane of rotation; Fig. 3 shows a projection of one form of the improved screw blade in the plane of rotation; Figs. 4 and 5 are sections across the blade respectively along the straight line I—III and the arc I—II of Fig. 3; Figs. 6, 8 and 10 illustrate three other forms of the improved screw blade in projection upon the plane of rotation; and Figs. 7, 9 and 11 show the respective cross sections of said blades along the arc I—II of Figs. 6, 8 and 10. Fig. 12 is an elevation of the nave or hub of the propeller with the propeller shaft shown in section and the propeller blade broken away. Fig. 13 is a plan of the nave shown in Fig. 12, with the propeller blade in section and the shaft broken away.

Before describing the construction of the new shape of the blades, I deem it advisable, in order to clearly define the invention and its particular effect, to give some preliminary particulars about the behavior of screws generally as hitherto used in ships, and in doing so I shall, for shortness sake,

consider a screw with uniform radial and axial pitch only.

A developed cylindrical section concentric with the axis of rotation of such a screw across a blade at any radius has, for the pressure surface (thrust-side), a straight line of intersection which, as shown in Fig. 1, embraces the angle of pitch β with the plane of rotation. Now when the ship is in motion, the speed, viz. the actual axial speed s , is less than the theoretical axial speed, by which is understood the product of the pitch and of the number of revolutions. The difference between the actual and theoretical axial speed is called the "Slip."

Under the influence of the speed s of the ship, and of the velocity of rotation v , the blade moves, as illustrated in the concentric section shown by Fig. 1 of the drawing, in the direction of the resultant o through the water and, therefore, the direction of the latter, owing to the slip, does not coincide with the direction of the section line of the pressure surface, but forms therewith an angle which is less than 180° .

The velocity o , with which the blade moves through the water and the relative velocity u (by which latter I understand the velocity with which the water elements would move along the pressure surface of the blade if this latter be supposed stationary and the surrounding water entering the screw with the velocity o) produce now, as resultant, the absolute velocity c . Now the latter is the velocity which produces the axial thrust of the propeller to overcome the resistance of the ship, and the axial motion of the ship can only be brought about by means of the production of axial absolute velocities through the propeller-blades. If the direction of the velocity o coincided with the section line of the pressure surface and thereby with the direction of the relative velocity, the absolute speed c and the slip would be *nil*, and the axial thrust would be *nil* also. In screws with uniform axial pitch, there must thus be a slip for the purpose of producing the axial thrust of the

propeller. It should be borne in mind, however, that in any case a portion of the axial thrust force of the propeller, used to overcome the resistance of the ship, is produced not only by the effect of the pressure surface (side thrust), but also by the suction of the front side (front surface) of the blades, if the latter cut through the water in the direction of the velocity o obliquely to the pressure surface, whereby a certain vacuum upon the front surface and an additional pressure upon the side of the pressure surface, take place. This suction of the front surface, however, naturally occurs only when the angle of pitch β_v of the front surface is at least equal to, or larger than the angle of pitch β_o of the velocity o . Hence the slip, in screws with uniform axial pitch, is also necessary for this reason. The parallelogram of velocities o , u and c , now shows that on account of the sudden deflection of the water, entering the propeller, a considerable portion of the absolute velocity c , owing to the slip, manifests itself as impact and is, therefore, attended with a large loss of energy. Furthermore the water which is once deflected, when entering in the direction of the section line I—II of the pressure surface, while continuing to move along the pressure surface, is no longer capable of producing any further effective work, because no further deflection of the water, and therefore no absolute acceleration, can now be produced. The water which enters the screw now assumes a motion of rotation about the axis of the propeller, and it may also be seen from the direction of the absolute velocity c that besides the effective axial component c_z it also possesses a component in the tangential direction c_n , which represents the rotary motion. Owing to the rotary motion of the water a radial acceleration is now set up under the influence of the centrifugal force which then imparts an outward motion to the water, particularly in the extreme parts of the blades. If we now consider a blade in the projection upon the plane of rotation according to Fig. 2, the centrifugal force arising has the effect of causing a water element introduced at point I in radius r_o to no longer move along the concentric arc I—II, but rather outwardly in a curve I—III and to emerge finally at a larger radius r_a at the point III. If we now imagine a section perpendicular to the plane of rotation through the relative path I—III of the water element, the latter will no longer produce a straight section line, but the convex form shown by dotted lines in Fig. 1. If β be the angle of pitch of the driving face at the ingress, then the same, at the issue, designated in Fig. 1 by β_a is smaller, *i. e.* is smaller, the larger r_a is. If

the water element were now to retain its original direction with the angle of pitch β , in its relative path, then it would shortly separate itself from the blade surface, behind the ingress point, so that a free space would then be formed between the water element and the blade surface, which, however, owing to the influence of the water pressure, from the sea would be again filled with water.

The usual screw blades with the uniform pitch of the pressure surface therefore possess the following disadvantages which considerably influence the degree of efficiency: 1. The impact loss at the ingress owing to the slip. 2. The loss arising from the after-current produced by the centrifugal force. 3. The portion of the pressure surface against the egress point is no longer capable of producing absolute speed for the generation of the axial impact. Now these disadvantages have not only been removed, for the most part, owing to the form of blade of this screw propeller by means of this invention, but the effect of the centrifugal force is also partly utilized to improve the motion of the water. The new shape of these blades is shown by Figs. 3, 4 and 5. Fig. 3 shows a projection of the blade in the plane of rotation and Figs. 4 and 5 are sections across the blade, Fig. 4 being a section along the relative path I—III of the water element and Fig. 5 a section in an arc concentric with the axis of rotation. The tangent of the angle of pitch β is here at the ingress point equal to the ratio of the speed s of the ship to the peripheral velocity v , whereby is meant that this new screw works generally without slip at the ingress for the purpose of avoiding losses of impact at the ingress. In conformity with the laws of hydro-mechanics and the application thereof to ship propellers, the relative paths which arise under the influence of the centrifugal force, may now be determined for all ingress radii and said paths form then all together the pressure surface of the blade.

In order to avoid loss of energy, it is certainly of the greatest advantage if any deflection of the water element is avoided in a section perpendicular to the plane of rotation through the relative path according to Fig. 4, provided that it is possible, notwithstanding the straight relative path, to produce the absolute forces and velocities necessary for the production of the axial thrusts. If the relative path forms, in the aforesaid section, a straight line which includes from the ingress to the issue, with the plane of rotation the same angle of pitch β , then the water will enter without any loss of impact and will move along, and leave the rear surface without any such loss. The

following elucidations will show that, notwithstanding the straight relative path in the new screw, absolute forces and velocities are obtained. Owing to the effect of the centrifugal force, the relative paths in a projection upon the plane of rotation, as shown by Fig. 3, run now, not concentrically with the axis of rotation, but along stream lines rising transversely, and therefore the angle of pitch β , at the radius r_e of the ingress point along the whole relative path up to the egress point in the radius r_a must always be of equal magnitude, whereby it is naturally not to be measured in a cylindrical surface concentric with the axis of rotation, but in the section plane, as shown by Fig. 4, normal to the plane of rotation and passing through the relative path. In a section across the blade in a cylindrical plane concentric with the axis of rotation, as shown by Fig. 5, however, the angle of pitch β can naturally no longer be the same everywhere, but it must become greater toward the egress point, so that the section line of the pressure surface with the concentric cylindrical surface forms a concave curve; that is to say, it results in a pressure surface of peripherally increasing pitch. These two different section forms of the screw-blade constitute the distinguishing feature of the invention.

If we show in the section along the concentric cylindrical surface, in Fig. 5, in which all forces act and in which the momentum of rotation is given, the relative and absolute velocities, it will be seen that, owing to the absence of slip, there is no absolute velocity at the ingress point, but that on the contrary the absolute velocity is only produced in the further course by the increasing of the angle of pitch and reaches its maximum at the point of egress. The new screw blade has also the property that, although there is no appreciable slip at the point of ingress, and the relative path of the water seen in a plane section across the blade perpendicular to the plane of rotation is a straight line, it produces an absolute velocity which is necessary for the generation of the axial thrust. The new screw is, therefore, of a pitch which increases along a coaxial cylindrical section from the ingress to the issue and its novelty consists in the dependency of the ratio of pitch on the relative path of the water owing to the action of centrifugal force, whereby it becomes possible to avoid slip at the ingress and axially curved relative paths, and the new screw is distinctly differentiated from all hitherto known constructions by the peculiar form arising therefrom. It is also necessary to determine exactly the form of the relative paths in a projection upon the plane of rotation. From the theory of the

motion of water in centrifugal pumps and turbines, it follows that with the maximum effect of the centrifugal force, the relative paths seen in a projection upon the plane of rotation are straight lines, which are perpendicular to the radius vector of the ingress point.

The following statements concern screw blades with radially constant pitch and are to be modified for variable pitch in accordance with the law of variability. If r_e be the radius at which a water element reaches the blade at the ingress point and γ the central angle which the radius r_a of any other point of the relative path forms with the ingress edge or with r_e , then its radius is as follows:

$$r_a = r_e \sqrt{1 + \tan^2 \gamma} = \frac{r_e}{\cos. \gamma}.$$

As, however, the relative path in a plane section, which according to Fig. 4, is perpendicular to the plane of rotation, is straight also, the same is also a straight line in space. The relative paths can, therefore, be at once drawn, without further calculation, after noting the ingress point, and they constitute a correct characteristic of the new screw. It is also a matter of interest to know the relation between the ingress and egress angles of pitch of the same concentric blade section. If tangent β be the tangents of the angle of pitch at the point of ingress, then the tangents of the angles of pitch β_a on the egress side are in the same concentric section, as follows:

$$\tan. \beta_a = \tan. \beta (1 + \tan^2 \gamma_2)$$

where γ_2 is the central angle which the radius vectors of the ingress and egress points form with one another.

It is the general practice, in illustrating screw blades to represent the same in concentric blade sections. For the purposes of illustration, we therefore require the magnitude of the degree of pitch Z , according to Fig. 5, for various points of the section curve. If β be the angle of pitch at the ingress, then the degree of pitch Z at the egress point III or at any other point of the concentric section at the radius r_e , provided that the pressure surface shall have a radially constant pitch, is as follows:

$$Z = r_e \tan. \beta \cdot \tan. \gamma_2$$

wherein γ_2 is the central angle which the radius vector of the particular point forms with that of the ingress point I. (By a pressure surface of radially constant pitch I mean such a surface that at every point of a radius vector the pitch is constant.)

If the ingress edge is a radially straight line, as shown by Fig. 3, the pressure surface of the new screw is represented by straight lines lying all in parallel planes perpendicular

lar to the radial ingress edge and forming an angle with the plane of rotation which accordingly varies with its distance from the axis of rotation.

5 If we now consider the concentric section (Fig. 5) across a blade, we find a marked sharpening toward the ingress edge, if it is desired, for the purpose of obtaining a powerful suction, to have an angle of pitch
10 β_v on the front side at the ingress at least equal to or even larger than β . As, in order to possess strength, the blade must have a certain thickness and therefore be more or less obtuse at the ingress edge, a small slip
15 angle always results at the latter for practical reasons. Now with the new screw it becomes possible, for the purpose of more rationally constructing the front surface, to so provide for the pitch ratio of the pressure
20 surface that such slip angle occurs on the ingress side, according to definite rules, and to nevertheless preserve the properties of the above described pressure surface.

25 Figs. 6, 8 and 10 in the drawing, illustrate three different constructions of blades in projection upon the plane of rotation and Figs. 7, 9 and 11, the concentric sections of the blade along the arc I—II respectively belonging thereto. Let R—M be the radius
30 vector to which the straight or relative paths forming the pressure surface are perpendicular. Upon rotating this radius R—M with the straight lines forming the pressure surface around the axis of rotation M, relatively to the blade edge curve, the
35 most various relations of pitch will be obtained. Figs. 6 and 7 represent, for instance, a blade in which the radius R—M has been shifted relatively to the ingress edge by a certain angle γ_e toward the egress
40 edge. A pressure surface is thereby produced of the description shown in Fig. 7, the pitch of angle whereof, β_e , is larger at the ingress than β and gradually diminishes until at the point *a. i. e.* at the section point
45 with the radius R—M it becomes equal β . From here toward the egress edge the angle of pitch increases in that ratio, above stated and described. Figs. 8 and 9 show a blade
50 in which the radius R—M coincides with the central line of the blade. This produces a pressure surface with a pitch which diminishes from the ingress point toward the center and again increases from there to the
55 egress point. The angles of ingress and egress pitches β_e and β_a are for instance of the same magnitude, when the central angles γ_e and γ_a are equal to each other, that is to say, when the blade is symmetrical with the
60 central line. Finally Figs. 10 and 11 represent a blade in which the radius R—M is entirely outside the edge curve of the blade so that too sharp a reduction of the blade is avoided.

In all three forms of blade the material 65 requisite for the solidity of the blade can be very easily provided without the ingress angle of pitch β_v of the front surface having to be made smaller than β .

In constructing the new screw according 70 to Figs. 3, 4 and 5, it is advantageous to so construct the body of the nave that the water entering next to the nave should actually pass through the screw in the direction of the above mentioned relative paths, whereby
75 the cross section of the incoming water is increased, as compared with that issuing from the screw and the conditions of continuity of the effective water current are best satisfied. 80

It is obvious that it is only necessary that the line of intersection of the blade pressure surface with the nave body itself should exhibit the form of a relative path. Figs. 12 and 13 show such a nave body and the mag- 85 nitudes r_n , r_k and l_n of the nave therein given, are no longer capable of being chosen at will. The best plan is to proceed from the smallest front nave-radius r_k necessitated by strength and by the diameter of the axle or
90 shaft, as well as from the central angle γ_n of the root of the blade. The largest nave radius r_n gives then the following equation:

$$r_n = r_k \sqrt{1 + \tan^2 \gamma_n} \quad 95$$

and the length l_n

$$l_n = r_n \tan. \beta \cdot \tan. \gamma_n.$$

Now in order that the line of intersection between the body of the nave and the pres- 100 sure surface should be straight, and in direction and magnitude, a relative path, that portion of the nave body which is traversed by the root of the blade, must be a hyperbolic body, the envelop whereof is formed
105 by straight lines which, in direction and magnitude, form relative paths with the radius of ingress r_k and with the central angle γ_n . From the egress point III of the root of the blade, the nave body may extend cylindrically backward, and in order to avoid
110 perturbations in the water current, it is advisable to elongate this cylindric part as much as possible and to make it pointed at the end. As the pressure surface of the new
115 screw is composed of straight surface elements, its production and construction is a particularly simple one.

What I claim is:

1. In blade screw propellers, a blade hav- 120 ing a pressure surface of such concave shape that the angle of pitch which it forms with the plane of revolution, changes peripherally from point to point in a concentric blade section, but is nevertheless everywhere equally
125 large, from entrance to exit, in a plane of intersection perpendicular to the radius vector of the entering point and to the plane

of revolution, substantially as and for the purpose described.

2. In blade screw propellers of the kind described, blades, and a hub, from which
5 the blades arise, the front part of which hub is formed in such a manner that the line of penetration of the hub and of the pressure surface of the blade forms a straight ascending line of the size and direction of a relative
10 path issuing from the innermost point of

entry, substantially as and for the purpose described.

In witness whereof, I have hereunto signed my name in the presence of two subscribing witnesses.

ALBERT MÜHLBERG.

Witnesses:

GEO. GIFFORD,
AMAND BRAUN.

Copies of this patent may be obtained for five cents each, by addressing the "Commissioner of Patents,
Washington, D. C."