Dec. 9, 1924.

1,518,501

J. H. W. GILL

SCREW PROPELLER OR THE LIKE

Filed July 24, 1923

3 Sheets-Sheet 1

FIG. 1.

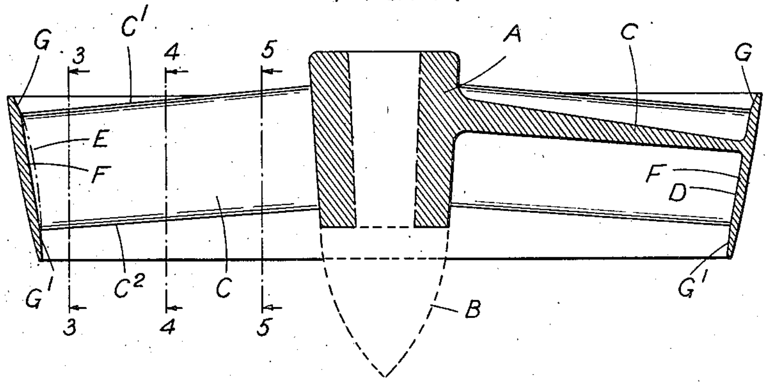


FIG. 2.

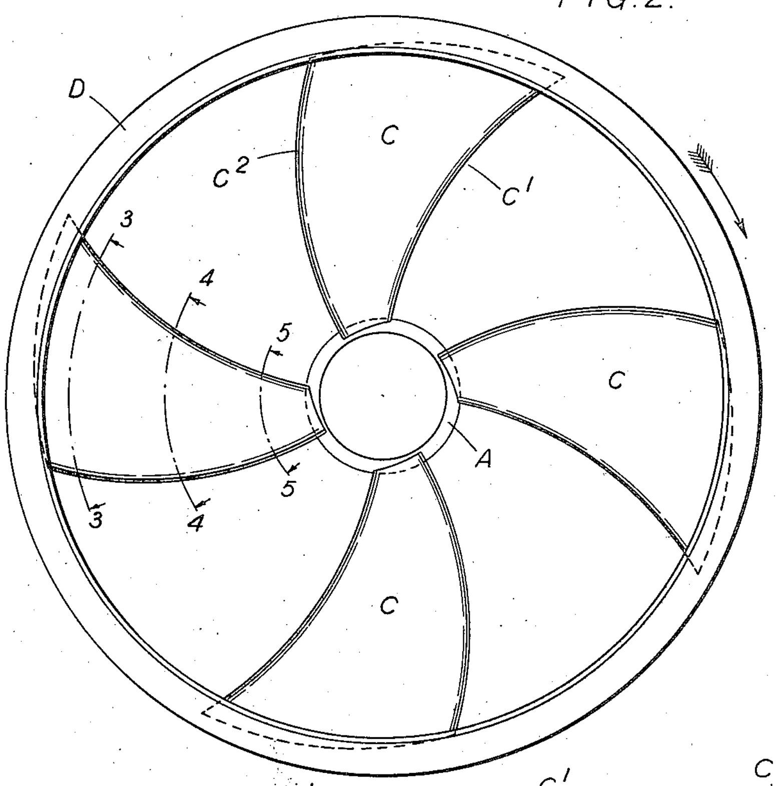


FIG. 3.

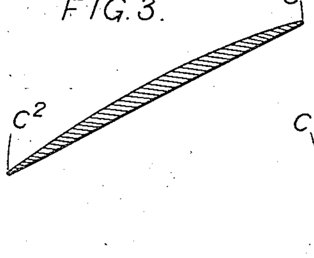


FIG. 4.

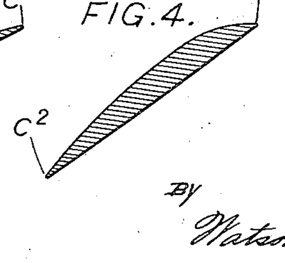
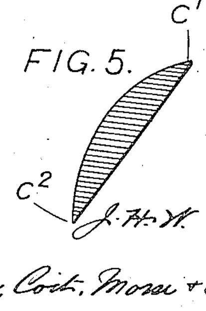


FIG. 5.



INVENTOR

J. H. W. Gill

BY

Watson, Coit, Morse & Grindle

ATTY'S

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1,518,501

J. H. W. GILL

SCREW PROPELLER OR THE LIKE

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FIG. 6.

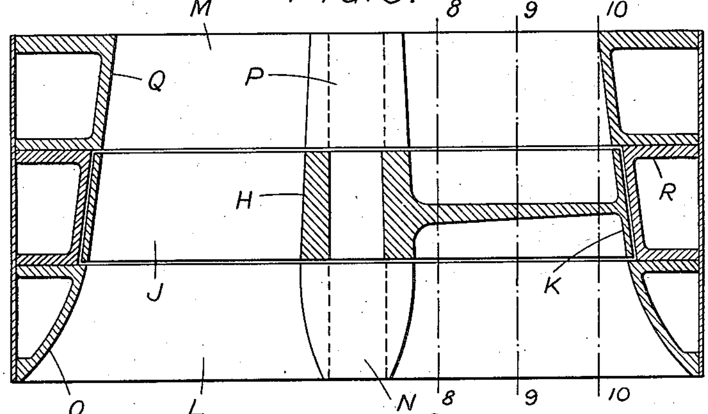


FIG. 7.

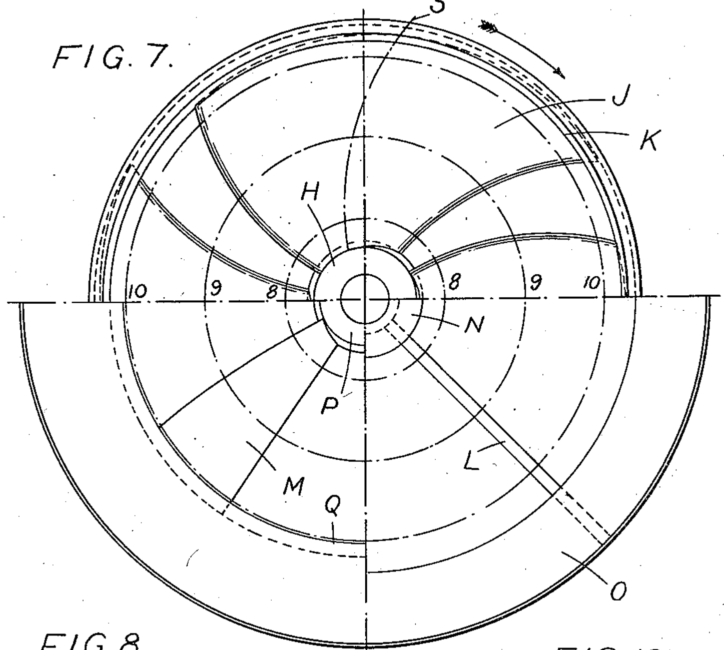
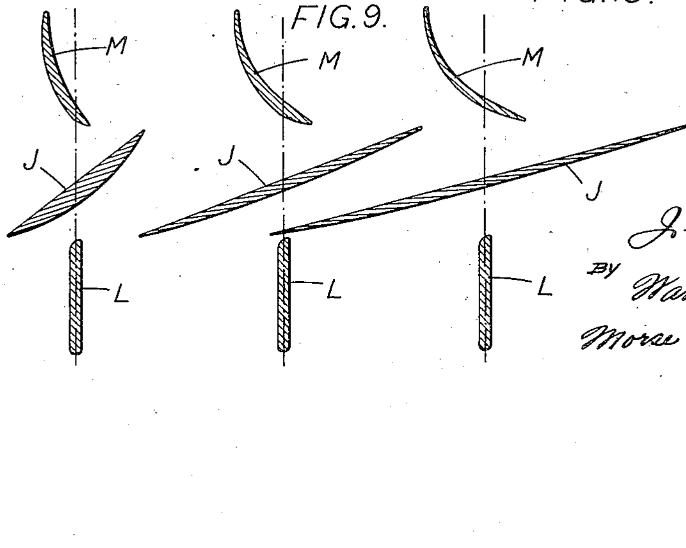


FIG. 8.

FIG. 9.

FIG. 10.



INVENTOR

J. H. W. Gill,

By Watson, Coit, Morse & Grindle.

Attys.

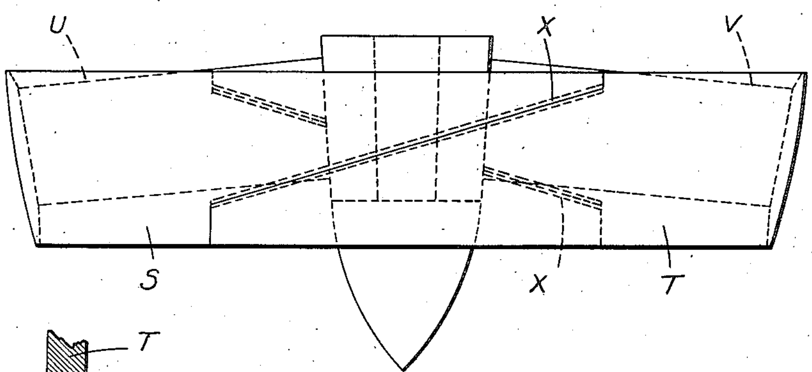
Dec. 9, 1924. 1,518,501

J. H. W. GILL

SCREW PROPELLER OR THE LIKE

Filed July 24, 1923 3 Sheets-Sheet 3

FIG. 12.



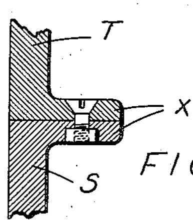
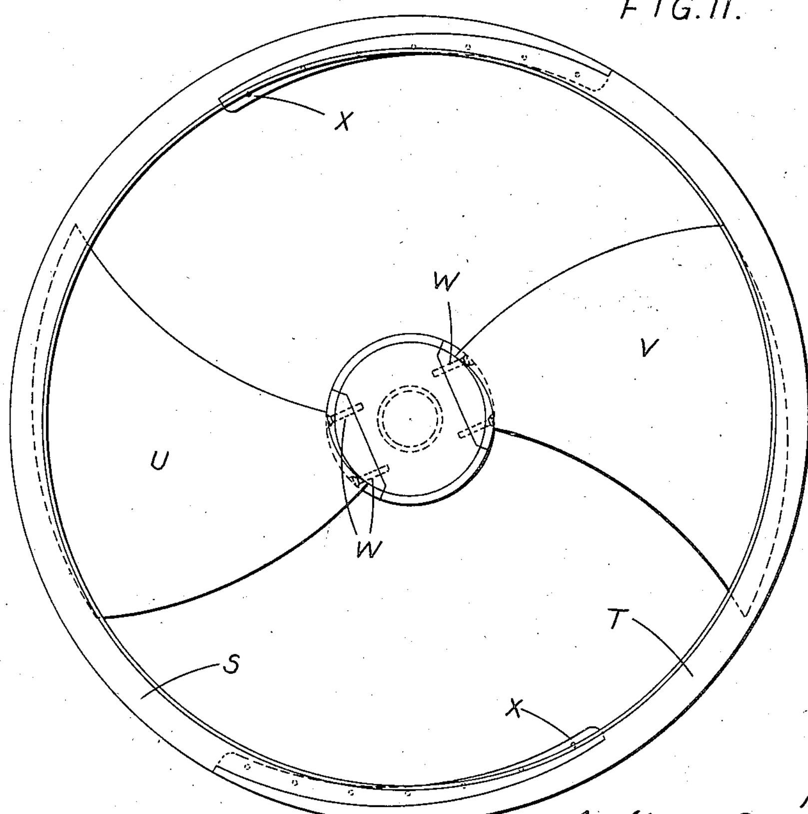


FIG. 13.

FIG. 11.



INVENTOR

J. H. W. Gill,

BY

Watson, Coit, Morse & Grindle

ATTYS

Patented Dec. 9, 1924. **1,518,501**

UNITED STATES PATENT OFFICE.

JAMES HERBERT WAINWRIGHT GILL, OF HEACHAM, ENGLAND, ASSIGNOR TO GILL PROPELLER COMPANY LIMITED, OF NORFOLK, ENGLAND, A COMPANY OF GREAT BRITAIN.

SCREW PROPELLER OR THE LIKE.

Application filed July 24, 1923. Serial No. 653,561.

To all whom it may concern:

Be it known that I, James Herbert Wainwright Gill, a subject of the King of England, and residing at Heacham, Norfolk, in England, have invented certain new and useful Improvements in Screw Propellers or the like, of which the following is a specification.

This invention relates to screw propellers or the like and has for its object to effect improvements in the propeller described in the present applicant's prior United States of America Letters Patent No. 1,454,967, dated 15th May, 1923, and presents features that are restricted on the applicant's concurrent application, No. 653,758, for improvements in screw propeller or the like to the use in axial flow pumps. In the screw propeller or the like described in the specification to that patent a shroud is mounted on or integral with the tips of the propeller blades, the contour of the inner surface of the shroud being substantially that of a nozzle designel so as to give to the fluid stream on which the propeller acts such rate of increase in the velocity of flow as corresponds to a uniform progressive increase in the dynamical equivalent of head (herein referred to by the word "head") per unit axial distance through the shroud i. e. so that there is a constant rate of increase in the square of the velocity of the fluid stream per unit axial distance through the shroud. It has been found desirable, however, in many cases to employ blades of varying thickness. This varying thickness of the blades modifies the nett cross-sectional area of the fluid stream, with the result that the propeller designed without allowances for blade interference area does not as a whole fulfill the desired condition of giving to the fluid stream a substantially uniform progressive increase in head.

In the screw propeller or the like according to the present invention allowance is made for the thickness of the blades when determining the shape of the shroud and the propeller boss, so that the nett cross-sectional area available for the fluid stream flowing through the propeller varies substantially according to the theoretical law hereinafter stated. The cross-sectional area of the fluid stream is measured on a series of surfaces which are at all points normal to the direction of "effective fluid flow." Actually the individual fluid particles will move along spiral paths (i. e. will have a whirling motion imparted to them) and each particle will therefore have a velocity component in a circumferential direction as well as two components—axial and radial—in the plane containing the particle and the axis of the propeller. When considering the flow of the whole body of fluid, however, this circumferential component is equivalent to the individual particles changing places with one another, and the phrase "effective fluid flow" is to be taken to refer to the flow of the whole body of fluid, taking into account only the axial and radial velocity components of the individual particles.

The law governing the variation of cross-sectional area may be theoretically stated in a number of forms all of which can be shown to be equivalent to one another. The necessary condition is that the product of the cross-sectional area at any section and the square root of the axial distance to the section is constant, this distance being measured along the axis from a selected origin thereon. The actual position of the selected origin relative to the inlet section of the propeller in any particular case is dependent on the dimensions desired for the inlet and outlet areas and the axial length of the shroud, these dimensions being determined in accordance with practical considerations, such for example as the shaft horse-power and revolution speed of the installation and the shape of the hull of the vessel. The governing condition for the variation of cross-sectional area may also be expressed in an equivalent form, which is independent of an origin of reference, in the following manner—that the difference between the reciprocals of the squares of the cross-sectional areas at any two sections is proportional to the axial distance between the sections.

The screw propeller or the like is primarily intended for application to sea-going vessels and is therefore more particularly designed to operate on liquids. Owing to the fact that liquids may be considered for practical purposes to be incompressible, the quantity of liquid crossing each transaxial section within the shroud per unit time must be constant. In other words, the product of the cross-sectional area and the mean velocity of effective fluid flow over the section is constant. In this case the above condition of constant product of cross-sectional area and square root of axial distance is equivalent to the square of the velocity of effective fluid flow at any section being proportional to the axial distance from the selected origin to that section.

These conditions may be expressed mathematically in the following manner, the various equations being given only for the case when the propeller is operating on a liquid.

Let

h=dynamic equivalent of head,
v=velocity of effective flow,
g=acceleration due to gravity,
x=axial distance from origin,
a=cross-sectional area,

Then $2gh=v^2$ or $h \propto v^2$.

The form of nozzle which gives the maximum coefficient of flow is that in which the rate of change of dynamic head per unit axial length is constant, i. e. in which

$$\frac{dh}{dx}=\text{constant}$$

or

$$\frac{dv^2}{dx}=\text{constant}$$

Hence $v^2 \propto x$

Since the volume of liquid passing each section per unit time is constant, it follows that

$$av=\text{constant},$$

and therefore also that

$$a^2 \propto \frac{1}{x}$$

or

$$a^2x=\text{constant}.$$

To locate the origin, from which the distance x is to be measured, for any particular case, it is necessary to decide on the inlet area (a_1), the axial length (s) from inlet to outlet, and the acceleration to be imparted to the liquid within this length of shroud. Since av= constant, this acceleration determines the outlet area (a_2).

Then, if x_1 is the axial distance from the origin to the inlet section,

$$x_1a_1^2=(x_1+s)a_2^2$$

Hence $$x_1=\frac{sa_2^2}{a_1^2-a_2^2}$$

The blades preferably have an axial increase in effective pitch in the direction of flow, the rate of increase being inversely proportional to the rate of variation of the square root of the cross-sectional area of the fluid stream. The blades may be of lenticular section and in this case the effective pitch line lies somewhere between the face and the back of the blades.

The form of screw propeller which will give the best results is that which is designed to give a substantially uniform distribution of thrust over the projected surface of the blades. The rate of change of momentum of the fluid stream acted on, which results in the axial reaction or thrust, is represented by the mass of fluid projected axially per unit time multiplied by the absolute velocity imparted thereto. This may be expressed mathematically as follows.

At any transaxial section of the propeller, let

T=theoretical thrust due to change of momentum of the fluid stream,
m=mass of fluid per unit volume,
a=cross-sectional area of fluid stream,
u=theoretical absolute velocity imparted to the fluid stream by a non-advancing propeller,
P=mean effective pitch of the blade section,
x=axial distance to the section from the selected origin,
n=number of revolutions per unit time (assumed constant).

Then the expression for the thrust is

$$T=mau^2$$

If the thrust is to be uniform at each section and the fluid dealt with arrives at each section under the same conditions, then T is constant, and since m is also constant, it follows that—

$$au^2=\text{constant}$$

or

$$u^2 \propto \frac{1}{a}.$$

Since the revolution speed is assumed constant, and also $u=Pn$, it follows that the pitch P is proportional to u.

Hence

$$p^2 \propto \frac{1}{a}$$

or

$$P\sqrt{a}=\text{constant}.$$

This gives a theoretical definition of the variation of pitch with respect to area of cross-section for approximately uniform loading of the propeller blades. The foregoing explanation does not take account of acceleration and true direction of flow, which would vary in accordance with frictional resistance, etc., or of slip at the blades of the propeller, or of other factors which vary with individual cases, but allowances and corrections should be made for these factors to obtain an accurately uniform distribution of thrust.

It will be understood that, when pitch, velocity, thrust, etc., are mentioned in the preceding paragraphs, the main pitch, mean velocity, means thrust, etc., over the section are meant.

The invention may be carried into practice in various ways, amongst which the following may be instanced as a preferred arrangement, some examples of this arrangement being illustrated in the accompanying drawings, in which—

Figure 1 is a central section through a construction of screw propeller.

Figure 2 is an end elevation of the propeller viewed from the outlet end.

Figures 3, 4 and 5 are sections through a blade on the lines 3—3, 4—4 and 5—5 respectively of Figures 1 and 2.

Figure 6 shows in central section an application of the invention to an axial flow impeller, guide vanes being employed at inlet and outlet.

Figure 7 shows end elevations in its upper half of the impeller and in its lower half on the left-hand side of the outlet guide vanes and on the right-hand side of the inlet guide vanes.

Figures 8, 9 and 10 are sections through the blades and the guide vanes on the lines 8—8, 9—9 and 10—10 respectively of Figures 7 and 8.

Figures 11 and 12 illustrate in end and side elevations respectively a modified arrangement for a screw propeller in which the shroud is built up in sections, and

Figure 13 shows a section through one of the joints in the construction shown in Figures 11 and 12.

In Figures 1 to 5 of these drawings the propeller comprises a boss A mounted on the propeller shaft so as to rotate therewith, blades C mounted on the boss A, and a shroud D carried on the tips of the blades, the boss, the blades and the shroud being formed integral with one another.

The boss A, which has an after end fairwater B, the blades C and the shroud D are so shaped that the nett available cross-sectional area for the fluid stream is within practical limits inversely porportional to the square root of the axial distance measured from an origin on the axis, giving the desired inlet cross-sectional area and proportions depending thereon. The required variation in cross-sectional area may be obtained solely by shaping the inner surface of the shroud after suitable boss and blades have been chosen, allowance being made for the shape and thickness of the blades and the shape of the boss.

It will generally be found more economical, however, to make the internal surface of the shroud conform to that of a conical frustrum throughout that portion of its axial length which is intercepted by the blades, as shown at F in the drawings, the edges being bevelled off as at G G′ at suitable angles. The blades and boss sections are then so proportioned that the nett resulting cross-sectional areas conform as nearly as possible to those of a nozzle designed to give the maximum coefficient of discharge within the limits determined by the diameters of the ends of the shroud. The incidence of the maximum thickness of blade section, the effective interference areas of this section and of other sections parallel thereto, and the corresponding interference areas of the boss are taken into account in determining the exact shape of the shroud and of the boss, so that the nett available area of cross-section for the fluid stream varies according to the law above described.

The chain line E on the left of Figure 1 shows what the contour of the inner surface of the shroud would be to give the desired variation in cross-sectional area if the blades were assumed to have negligible thickness. The total interference volume of the blades is thus approximately equal to the volume enclosed between the surface F and the surface generated by the chain line E. It will be seen that in this drawing the bevelled surfaces G G′ continue the slopes of the ends of the chain line E.

Theoretically the cross-sectional areas should be measured, as has been stated, on a series of surfaces at all points normal to the flow lines, but in practice a very close approximation can be made by measuring the cross-sectional area on a series of surfaces parallel to that traced out by the leading edges of the blades as they rotate. In the example illustrated the blades have straight leading edges and are raked back, and in this case the surfaces, on which the cross-sectional areas are measured, will be a series of cones.

The blades are of lenticular section, since it is necessary that they should be thin at their edges and yet must be thick enough towards the middle to give the necessary strength. The thickest portion of each blade need not be at the centre of its width but may sometimes be as near the leading edge as one third of the blade width. A satisfactory shape for the blades is shown in Figures 3, 4 and 5 for the example illustrated, in which the maximum blade thickness is nearer the leading edge C′ than the following edge C^2, the distances from these edges being about .37 and .63 of the blades width respectively.

The effect pitch of the blades increases in an axial direction from their leading edges to their following edges (taking the normal direction of rotation). The rate of axial increase in pitch of the blades is inversely proportional to the rate of decrease of the square root of the cross-sectional area of the fluid stream, i. e. the product of the square root of the cross-sectional area by the mean pitch over the section is constant. In calculating the shape of the propeller, it must be remembered that with lenticular blades the effective pitch line, which is to conform to the selected law, lies between the face and the back of the blades, its actual position depending on the curvature of the two surfaces.

In addition to an axial increase in pitch, the blades may be in some cases also be given a radial variation in pitch. In this case the effective pitch of the blades is made to decrease radially outwards. This arrangement has the effect of giving the quickest rate of flow near the axis, with the result that dispersion of the thrust column is prevented. The rate of radial variation in pitch is preferably such that the curve of the velocity of effective flow plotted against the radial distance from the axis varies smoothly from a maximum value near the boss to a minimum value at the shroud. With blades as usually constructed, the roots are thicker than the tips, and this in itself provides a small radial decrease in effective pitch, but it may be advantageous in certain cases greatly to accentuate this decrease.

It will usually be desirable, when applying the invention to screw propellers, to allow the shroud to "overhang", that is to project beyond the blades, more on the outlet than on the inlet side. This is shown in the example illustrated wherein the bevelled surface G′ has a greater axial length than the bevelled surface G. When, however, the invention is applied to an axial flow impeller, such an overhang is a disadvantage since the guide vanes, which must be used at inlet and outlet, have to lie fairly close to the blade edges. In this case it is preferable to arrange that the shroud projects little or not at all beyond the blade edges. This arrangement is shown in Figures 6–10, herenafter described in detail. Such an arrangement may also be useful in certain cases with screw propellers.

The edges of the blades may have any desired contour. Thus the "circumferential" projection of the edges on an axial plane (i. e. the line of intersection between an axial plane and a surface of revolution through the blade edges) may be straight and either radial or inclined, or may be curved. In the latter case the curvature is preferably such that the blade edges are convex towards the inlet side. In the example illustrated in Figures 1 to 5 the blades are raked, that is the edges are such that a circumferential projection on an axial plane is straight and inclined back from the inlet side towards the tips at a small angle to a normal transaxial plane, the edges thus lying on the surface of a cone. Figure 1 shows a circumferential projection of the blade edges on an axial plane rather than a correct view of the edges as seen in a true central section, in order to make the construction more clear. This figure also shows on the right-hand side a section along the line of maximum thickness of the blades, in order to illustrate clearly the change in thickness of the blade from the root to the tips.

The projection of the blade edges on a transaxial plane may also be straight and either radial or offset, but is preferably curved, so that the blade edges are "sickle" shaped, i.e. concave towards the normal direction of rotation, as shown in Figure 2, in which the arrow shows the normal direction of rotation.

Thus when the particular form of blade to be used has been chosen, the exact contours of the blades, boss and shroud are calculated so that the nett available area of cross-section for the fluid stream varies inversely with the square root of the axial distance from the origin. This is the condition necessary to obtain the maximum coefficient of discharge. A propeller constructed according to the present invention gives a very considerable increase in efficiency over open propellers and also over shrouded propellers in which the shapes of the blades, boss and shroud are not so proportioned as to conform to the laws above mentioned.

To obtain the best results it is found that the ratio of the axial length of the shroud to the inlet diameter should lie between about 0.20 and 0.25. Greater axial lengths merely serve to increase the frictional resistance to the passage of the fluid and thus reduce the efficiency of the propeller, whilst shorter lengths result in insufficient guidance of the fluid stream. Again the angle between the main portion F of the shroud and the axis should lie between 9° and 13°, the most satisfactory angle being 11¼° giving a slope of about 1 in 5. Similarly the angle between the axis and the bevelled portion G of the shroud at the inlet end should be about 22°, and for the bevelled portion G′ at the outlet end about 4°.

The actual angles of these bevelled surfaces G G′ depend on the variation of nett cross-sectional area within the portion of the shroud intercepted by the blades, and the slopes are such as to continue this variation so that the surfaces continue the curve of the chain line E shown in Figure 1. Theoretically these surfaces should be curved to conform to the law governing the variation of cross-sectional area, but in actual practice they are made conical, the error thus introduced being extremely small.

It has also been found that there is a limit to the increase in velocity of effective flow, which may be imparted to the fluid stream through the shroud. Thus with a propeller in which the axial lengths of the shroud and blades bear suitable ratios to the leading edge diameter, it is found that under normal seagoing conditions the increase in effective flow velocity from inlet to outlet should not exceed about one-sixth. In the example illustrated the percentage increase is about 16.18. The percentage increase through the length of the blades is about 11.64.

A propeller constructed according to the proportions specified in the following table has been found to give very good results. In this table the diameter of the blades at the leading edge has been taken as the unit of length and all other lengths are given in terms of this unit.

Blades:	
Diameter at leading edge	1.000
Diameter at following edge	.940
Axial length	.150
Radius of edges (transaxial)	.500
Maximum thickness projected to axis	.044
Maximum thickness projected to leading edge tip line	.010
Distance of maximum thickness section from leading edge (axially)	.054
Shroud:	
Internal diameter at inlet	1.018
Internal diameter at outlet	.932
Thickness at edges	.004
Thickness at maximum section line	.012
Axial length	.220
Inlet overlap (axial)	.022
Outlet overlap (axial)	.050
Boss:	
Diameter at forward end	.200
Diameter at after end	.172
Axial length between faces	.210
Radius of tail end fairwater	.344
Axial distance of forward face from leading edge projected to axis	.020

These dimensions must be considered as applying to a propeller having straight blade edges, the blades being raked, as in the example illustrated, at a slope of 1 in 10. For other slopes allowance must be made in calculating the blade thickness and the blade pitch. For practical purposes the effect of a change of blade rake may be taken as equivalent to a parallel motion effect from the original to the new inclined position. The blade section thickness projected to axis and to an axial line through the leading edge tip will vary with the width of the blade face, which in turn varies with the pitch ratio, so that the interference areas of the blades within the shroud remain constant for any pitch ratio. With unit leading edge diameter the mean pitches for the blade faces are represented by the pitch ratios, and these can be so selected as to give a constant value (.150) to the ratio of axial blade length to leading edge diameter. This necessitates a variation in the angle subtended by the transaxially projected face of each blade with each variation in pitch ratio. Thus the angle subtended by each blade has the same ratio to 360° as the axial length of the blade has to the pitch due to mean diameter of blade. For instance in the example illustrated the angle subtended by each blade is 40° i. e. $^1/_9$ of 360°, and the mean pitch ratio is therefore (9×.150) i. e. 1.35 of the leading edge diameter.

The dimensions given in the above table should also be modified in accordance with the material used in order to obtain the best results. Thus for example when phosphor bronze is employed instead of cast iron (for which the proportions are intended) the blades should be somewhat thinner, the maximum thickness projected to axis being about .035 instead of .044. The screw propeller illustrated in Figures 1–5 is constructed according to the dimensions given in the above table.

Figures 6 to 10 show the application of the invention to an axial flow impeller. In these figures the impeller comprises a boss H mounted on the driving shaft, blades J and a shroud K, and is mounted to rotate between two sets of fixed guide vanes L and M. The guide vanes L on the inlet side are fixed to or formed integral with a boss N and a shrouding ring O, the outlet vanes M being similarly mounted between a boss P and a shrouding ring Q. The two shrouding rings O and Q are separated by a distance piece R surrounding the impeller. The whole assembly constitutes an axial flow pump designed to impart a uniformly progressive head of flow to the fluid on which it operates.

The construction of the impeller is generally similar to that of the screw propeller illustrated in Figures 1–5. Thus the nett available area of cross-section for the fluid stream varies inversely as the square root of the axial distance measured from a suitable origin. The mean pitch of the blades increases in an axial direction and is inversely proportional to the square root of the cross-sectional area. The effective pitch also preferably decreases in a radial direction from the boss to the tips of the blades. A detailed description of these features has already been given with reference to the screw propeller illustrated in Figures 1–5. The following description refers in detail only to those features in which the construction of Figures 6–10 differs from that of Figures 1–5.

Although curved or raked blade edges

may be employed, it is generally more convenient for the blades to have straight radial edges as shown in Figure 6. The blade edges projected on to a transaxial plane are preferably "sickle" shaped, that is concave towards the normal direction of rotation, but they may be straight and either radial or offset, if desired. Since it is important that the edges of the guide vanes L and M should lie close to the edges of the impeller blades J, the shroud K does not "overhang" the blades, i. e. project axially beyond the blade edges. Thus the blades extend axially over the full length of the shroud. The number of blades may vary, but in the construction illustrated three blades are employed and the angle subtended by each blade at the axis is much wider than in the case of the screw propeller. It is found to be preferable that the blade edges should not overlap each other. The blades are again preferably of lenticular section and the line of maximum thickness (shown at S in Figure 7) is more nearly at the centre of the width of the blades than in the construction of Figures 1–5.

Figure 6 shows on the right-hand side a section through one of the blades, the section being taken along the curved line S of maximum thickness. This section shows clearly the decrease in thickness of the blades from the roots to the tips. The variation in thickness across the width of the blades is also shown clearly in Figures 8, 9 and 10, the chain line in each of these figures being drawn through the point of maximum thickness.

The surfaces of the bosses N and P of the inlet and outlet guide vanes are so shaped as to continue the surface of the boss H of the impeller, and in a similar manner the internal surfaces of the shrouding rings O and Q continue that of the shroud K. These bosses and shrouding rings, together with the guide vanes L and M, are so shaped that the nett available area of cross-section for the fluid stream varies through the guide vanes as well as through the impeller in such a manner as to be substantially inversely proportional to the square root of the axial distance measured from a suitable origin.

The inlet guide vanes L in the construction illustrated are shown as straight radial vanes having parallel plane surfaces. Other shapes of vanes may be employed, however, if desired. These vanes serve to guide the fluid in an axial direction to the inlet side of the impeller. Any number of vanes may be employed, but the number is preferably not the same as that of the blades of the impeller and is in the case illustrated five. The vanes L extend over the full axial length of the shrouding ring C.

The outlet guide vanes M have curved surfaces, the slope of the surfaces near the leading edges (i. e. the edges nearest the impeller) being approximately parallel to the direction of flow of the fluid particles as they leave the impeller blades, whilst the surfaces at the outlet end are parallel to the axis. Other slopes may be employed as may be desirable to suit particular requirements. In the case illustrated the leading edge pitch of these vanes is approximately twice that of the impeller blades. These vanes M thus serve to deflect the fluid stream discharged from the impeller into a direction parallel to the axis. The guide vanes M are preferably of lenticular section and have their line of maximum thickness nearer the leading edge than the following edge. This can be clearly seen from Figures 8, 9, and 10 in which the chain lines pass through the point of maximum thickness. The number of outlet vanes M employed is preferably not the same as the number of impeller blades, four being employed in the case illustrated. The vanes M extend over the full axial length of the shroud.

The shroud either for a screw propeller or for an axial flow impeller may be made continuous and mounted on or integral with the blades or may be made up in sections, each section being formed by a curved plate mounted on or integral with the tip of one of the blades. Figures 11–13 show an arrangement in which the shroud of a two-bladed propeller is divided into two sections.

In these figures the two sections S and T of the shroud are formed integral respectively with the two blades U V, these blades being fixed to the boss W by means of bolts. The shroud sections are bolted together at their ends through inwardly projecting flanges X. Figure 13, which is a section across one of the joints, shows clearly the arrangement of the flanges and the manner of fastening them together. In order to reduce interference with the fluid flow by the projecting flanges X, the ends of the sections are cut diagonally in such a manner that the flanges X occupy the positions which would be occupied by the tips of two additional blades. These flanges thus act as portions of blades and serve rather to assist than to obstruct the flow. Moreover the flanges X do not extend from edge to edge of the shroud but only as far as the planes containing the tips of the leading and following edges of the blades, the ends of the shroud sections being cut straight across from these planes to the edges of the shroud.

The shroud sections are thus so arranged as to form a practically continuous surface. This arrangement is especially useful for large propellers particularly for those having separate blades bolted to the boss. Instead of providing a separate section for each blade tip, the sections may be made large enough to extend over and and be carried on the ends of two or more blades. Thus in the case of a four-bladed propeller, it would be possible to employ two shroud sections, each section being carried on the ends of two blades.

The propeller or axial flow impeller constructed according to the present invention may be employed, as described, in single form either with or without guide blades, or two separate sets of blades on the same boss and within the same shroud may also be employed if desired. The invention is also applicable to the known arrangement, in which two separate shrouded propellers are arranged coaxially but rotating in opposite directions, the inner contours of the two shrouds being practically continuous.

It will be understood that the descriptions are given by way of example only, and that modifications may be made in the details of the arrangement without departing from the scope of the invention.

What I claim as my invention and desire to secure by Letters Patent is:—

1. A screw propeller or the like comprising a boss, blades carried thereby, and a shroud mounted on the tips of the blades, the shroud, the boss and the blades being so shaped that the nett cross-sectional area available for the fluid stream flowing through the propeller varies substantially in such a manner that the difference between the reciprocals of the squares of the cross-sectional areas at any two sections is proportional to the axial distance between the sections as set forth.

2. A screw propeller or the like comprising a boss, blades of lenticular section carried by the boss, and a shroud mounted on the tips of the blades and having a substantially conical inner surface, the blades and the boss being so proportioned that the product of the nett available cross-sectional area between the boss and the shroud at any section and the square root of the axial distance to the section measured from a suitable origin is constant as set forth.

3. A screw propeller or the like comprising a boss, blades carried thereby, and a shroud mounted on the tips of the blades, the shroud, the boss and the blades being so shaped that the nett cross-sectional area available for the fluid stream flowing through the propeller varies substantially in such a manner that the difference between the reciprocals of the squares of the cross-sectional areas at any two sections is proportional to the axial distance between the sections, whilst the effective pitch of the blades increases in an axial direction at a rate inversely proportional to the rate of variation of the square root of the cross-sectional area as set forth.

4. A screw propeller or the like comprising a boss, blades of lenticular section carried by the boss, and a shroud mounted on the tips of the blades and having a substantially conical inner surface, the blades and the boss being so proportioned that the product of the nett available cross-sectional area between the boss and the shroud at any section and the square root of the axial distance to the section measured from a suitable origin is constant, whilst the effective pitch of the blades increases in an axial direction at a rate inversely proportional to the rate of variation of the square root of the cross-sectional area as set forth.

5. A screw propeller or the like comprising a boss, blades carried thereby, and a shroud mounted on the tips of the blades, the shroud, the boss and the blades being so shaped that the nett cross-sectional area available for the fluid stream flowing through the propeller varies substantially in such a manner that the difference between the reciprocals of the squares of the cross-sectional areas at any two sections is proportional to the axial distance between the sections, whilst the effective pitch decreases radially outwards from the boss to the shroud as set forth.

6. A screw propeller or the like comprising a boss, blades of lenticular section carried by the boss, and a shroud mounted on the tips of the blades and having a substantially conical inner surface, the blades and the boss being so proportioned that the product of the nett available cross-sectional area between the boss and the shroud at any section and the square root of the axial distance to the section measured from a suitable origin is constant, whilst the effective pitch of the blades increases in an axial direction at a rate inversely proportional to the rate of variation of the square root of the cross-sectional area, the effective pitch of the blades also decreasing radially outwards from the boss to the shroud as set forth.

7. A screw propeller comprising a boss, blades carried thereby, and a shroud mounted on the tips of the blades, the propeller being constructed substantially according to the following table of proportional dimensions, the diameter of the blades at the leading edge being taken as unit of length:—

Blades:	
Diameter at leading edge	1.000
Diameter at following edge	.940
Axial length	.150
Radius of edges (transaxial)	.500
Maximum thickness projected to axis	.044
Maximum thickness projected to leading edge tip line	.010
Distance of maximum thickness section from leading edge (axially)	.054

Shroud:	
Internal diameter at inlet	1.018
Internal diameter at outlet	.932
Thickness at edges	.004
Thickness at maximum section line	.012
Axial length	.220
Inlet overlap (axial)	.022
Outlet overlap (axial)	.050
Boss:	
Diameter at forward end	.200
Diameter at after end	.172
Axial length between faces	.210
Radius of tail end fairwater	.344
Axial distance of forward face from leading edge projected to axis	.020

8. A screw propeller or the like comprising a boss, blades carried thereby, and a shroud which is composed of a number of separate curved plates mounted on the tips of the blades in such a manner as to form a practically continuous surface, the shroud, the boss and the blades being so shaped that the nett cross-sectional area available for the fluid stream flowing through the propeller varies substantially in such a manner that the difference between the reciprocals of the squares of the cross-sectional areas at any two sections is proportional to the axial distance between the sections as set forth.

9. A screw propeller or the like comprising a boss, blades of lenticular section carried thereby, and a shroud which is composed of a number of separate curved plates mounted on the tips of the blades in such a manner as to present a practically continuous and substantially conical inner surface, the blades and the boss being so proportioned that the product of the nett available cross-sectional area between the boss and the shroud at any section and the square root of the axial distance to the section measured from a suitable origin is constant, whilst the effective pitch of the blades increases in an axial direction at a rate inversely proportional to the rate of variation of the square root of the cross-sectional area as set forth.

10. A screw propeller or the like comprising a propeller boss, blades carried thereby, means for securing the blades to the boss, and a shroud which is composed of a number of separate curved plates respectively formed integral with the tips of the blades and so disposed as to form a practically continuous surface, these curved plates having flanges projecting inwardly from their edges in such positions as would be occupied by the tips of further propeller blades if such were provided, the shroud, the boss and the blades being so shaped that the nett cross-sectional area available for the fluid stream flowing through the propeller varies substantially in such a manner that the difference between the reciprocals of the squares of the cross-sectional areas at any two sections is proportional to the axial distance between the sections as set forth.

In testimony whereof I have signed my name to this specification.

JAMES HERBERT WAINWRIGHT GILL.