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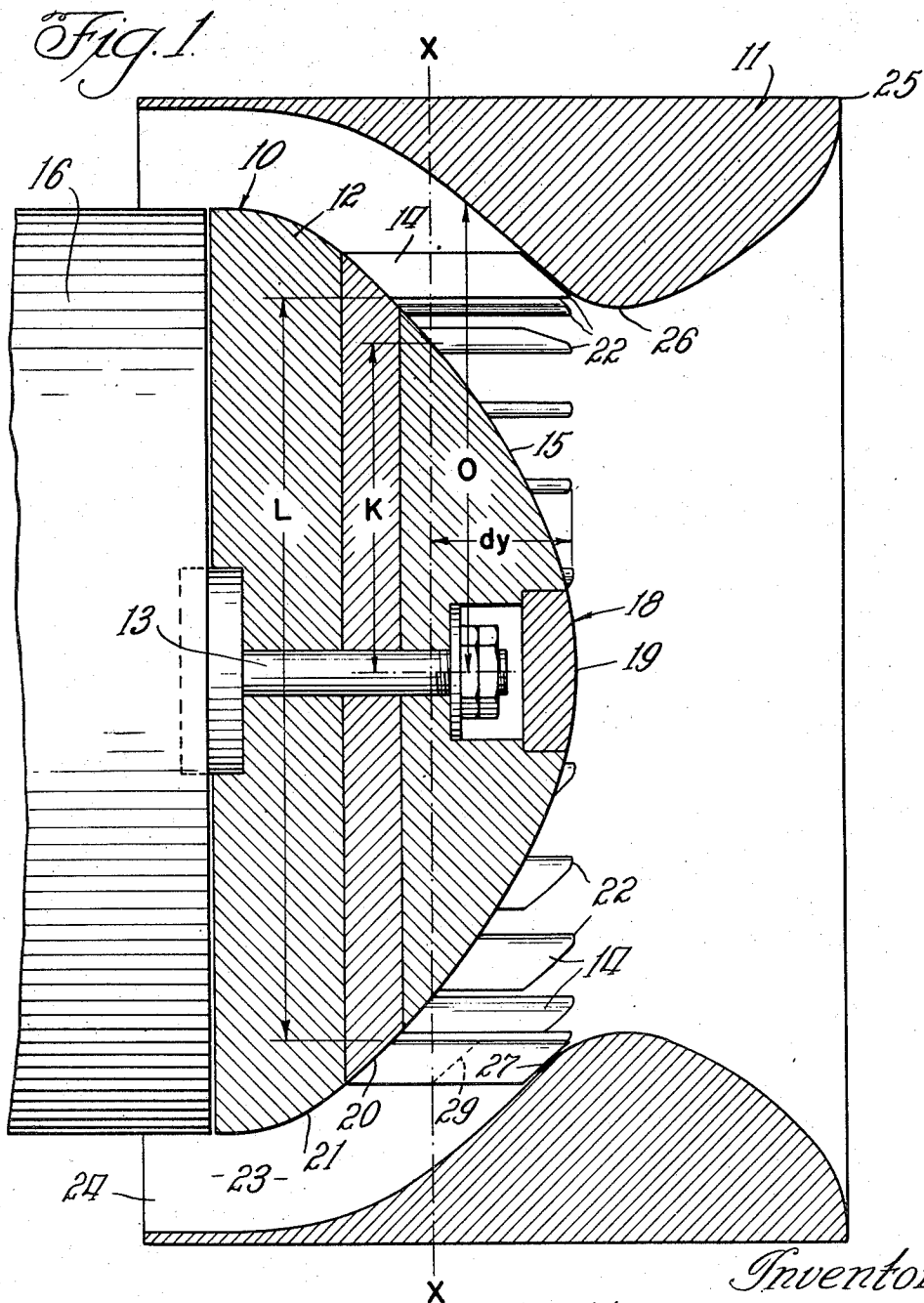
W. AYERS

2,434,896

CENTRIFUGAL IMPELLER

Filed Aug. 8, 1942

3 Sheets-Sheet 1



Inventor:
William Ayers
By: Mann, Brown & Co.
Attys

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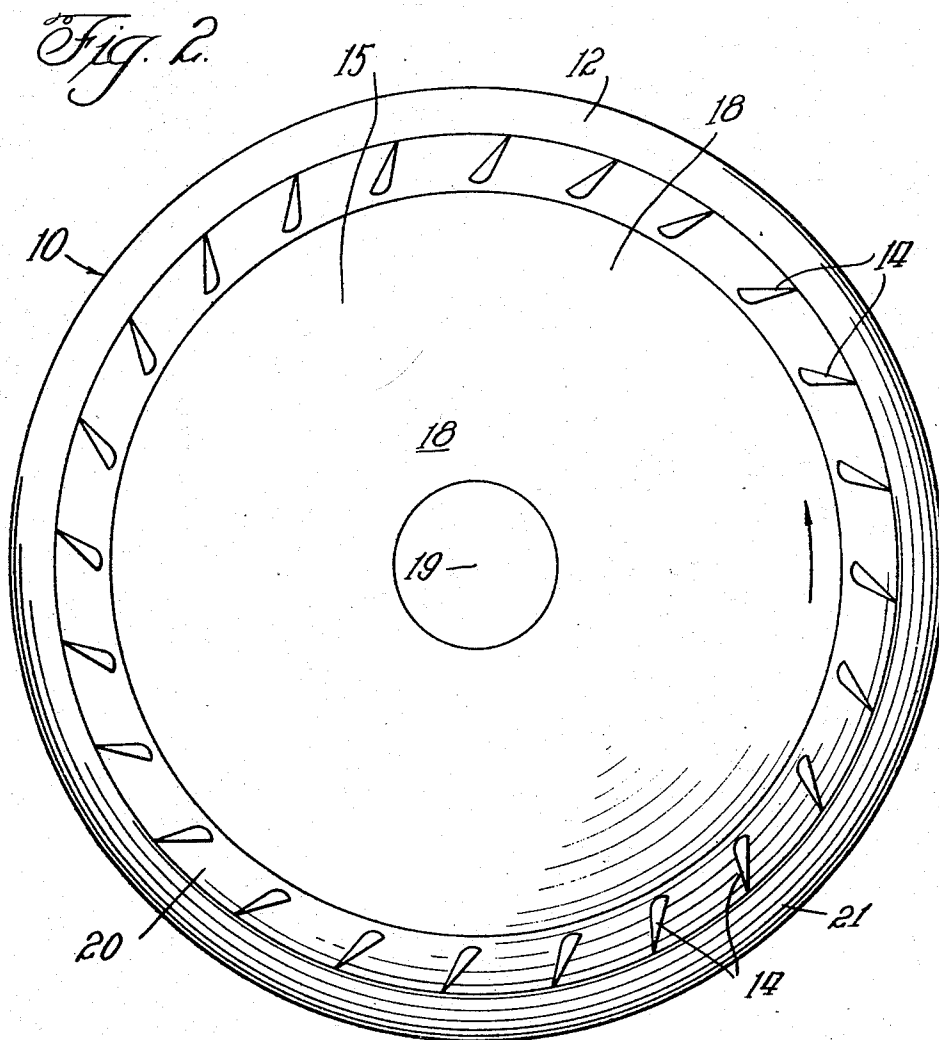
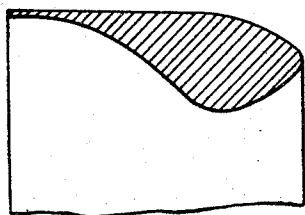


Fig. 4.



Inventor:
William Ayers
By Mann, Brown & Co.
Attys.

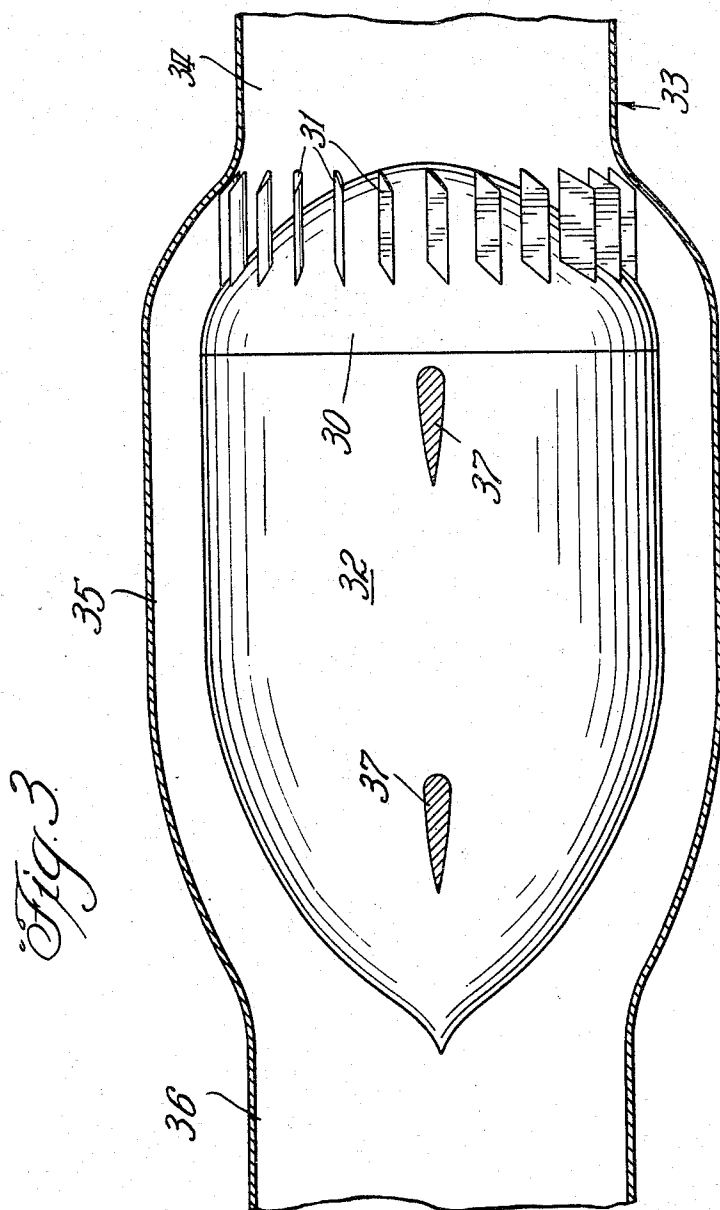
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Inventor:
William Ayers
By: Mann, Brown & Co.
Att'ys.

UNITED STATES PATENT OFFICE

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CENTRIFUGAL IMPELLER

William Ayers, Evanston, Ill., assignor to Ayr Corp., Evanston, Ill., a corporation of Illinois

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4 Claims. (Cl. 103-103)

1 The principal object of the present invention is to provide a low resistance, highly efficient axial flow, centrifugal fluid wheel. It is adapted for use as a blower, for moving air and other gases, as a propeller for air, water, and land vehicles, and as a pump for moving liquids.

Other objects and advantages will become apparent from the following description and the drawings, in which

Fig. 1 is a sectional view of a single entry centrifugal fluid wheel and housing taken along the diameter of the wheel, the wheel being illustrated as a propeller;

Fig. 2 is a front view of the wheel reduced in size with the housing removed;

Fig. 3 is a plan view of the fluid wheel shown as a blower, the blower housing and the air ducts being indicated in section; and

Fig. 4 is a fragmentary sectional view of a modified form of housing or cowl for use with the impeller shown in Fig. 1, the view being reduced in size.

This application is a continuation in part of applicant's abandoned copending application Ser. No. 438,791, filed April 13, 1942.

For the purpose of disclosure, two embodiments of the present invention have been selected, one showing the wheel as an airplane propeller, and the other illustrating the wheel as a blower. Modifications, of course, can be made without departing from the scope and spirit of the invention. As previously mentioned, the invention has uses in other types of wheels than those specifically illustrated.

Throughout the following description, one embodiment of the invention at a time will be discussed. The propeller shown in Fig. 1 will be described first, but in principle the remarks made with respect to this specific embodiment will apply to other embodiments as well. The function of the propeller is to draw air toward the propeller blades, and then to push it away from the propeller axially; i. e., in a direction substantially corresponding to the direction of flow of the incoming air. Ideally, during the passage of air through the propeller there should be neither expansion nor compression of the air. In the event the air is allowed to expand, it should not be compressed because considerable energy is thereby lost. Any variation from this ideal condition will result in decreased efficiency of the propeller.

One of the most important features of the present propeller is the fact that a constant volume

2 and velocity of the air is maintained from the time it enters the propeller until it is discharged, and during the passage of the air through the propeller turbulence is reduced to a minimum.

Referring to Fig. 1, a propeller is generally indicated at 10, and is surrounded by a housing or cowl 11. The propeller 10 comprises a wheel or rotor 12 mounted on a shaft 13 and having a plurality of propeller blades 14 extending away from the outer surface 15 of the rotor 12 in a direction parallel to the shaft 13. For the purpose of illustration, the propeller is shown as applied to an airplane, the aeroplane having a fuselage or housing indicated at 16.

15 The leading face of the rotor 12 is indicated at 18 and is convex in shape having a constantly varying radius of curvature from the rotor apex 19 to the base 20 of the blades at the inner edge thereof. Behind the blades at 21 the rotor curves gradually into the plane of the fuselage 16 to provide a streamlined surface over which the air passes.

The curve of the leading face of the rotor is extremely important as this portion of the rotor serves to maintain a constant volume of air throughout the propeller interior, and at the same time to direct the air through the blades along the path of least resistance. This curve is calculated in such a manner that for any distance back from the leading tips 22 of the blades a plane perpendicular to the shaft 13 and passing through the blades at said distance from the leading tips will cut a section through the rotor 12 having an area equal to the product of the circumference of the wheel at the inner edges of the blades times the distance from the leading tips 22 of the blades to the position where the section is taken. This is illustrated in Fig. 1 by plane X-X passing at right angles to the shaft 13 and at a distance dy from the leading tips 22 of the blades. The letter K represents the distance from the shaft 13 (which corresponds to the center of the circle cut through the rotor 12 by plane X-X) to the outer surface of the leading face 18 of the rotor. The diameter of the wheel or rotor 12 taken at the inner edges of the blades is designated by the letter L. dy represents the distance from the tips 22 of the blades 14 to the plane X-X. The formula for K, then, is as follows:

$$K = \sqrt{Ldy}$$

Since L is a constant for a given propeller wheel, the various values of K from the apex 19 of the leading face 18 to the base 20 of the

blades at their inner edges can readily be calculated by varying the value for dy in the foregoing formula. In this manner, the curve of the leading face 18 can be accurately plotted.

As previously mentioned, the foregoing formula applies only to the leading face 18 and has no bearing on the contour of the rotor behind the blades. The curve of the surface 21 behind the blades is intended to be sufficient for streamlining purposes to minimize turbulence and other resistance so as to allow the air to flow unobstructedly through the passage 23 to be exhausted at 24.

The leading face of the housing 11 is curved from the forwardmost edge 25 on its inner surface to its throat 26 to produce a Venturi effect. The radius of curvature of this leading face should be at least one-quarter of the diameter of throat 26. The diameter of the throat 26 is substantially equal to or slightly less than the diameter L of the wheel at the inner edges of the blades. In Fig. 1, the diameter of the throat 26 is shown as being slightly less than the diameter L . If the diameter of the throat 26 were made to correspond exactly with the diameter L , there would be an absence of air adjacent to the sides of the throat, because the normal flow of air would follow more or less the throat contour shown in Fig. 1. The throat in Fig. 1 has been rounded to conform to this natural flow of air.

Inwardly of the throat 26 and commencing approximately at the leading edges of the blades 14, the curve of the inner face of the housing 11 is such that a constant volume of air is maintained as it flows from the throat 26 through the blades 14 and passage 23 until it is exhausted from the propeller housing at 24.

The distance from the shaft 13 to the inner face of the housing 11 is represented by the letter O shown in Fig. 1. This letter O represents this distance only in the region throughout the depth of the blades 14 from their forwardmost tips 22 to their bases 20 at their innermost edges. The formula for determining the value of O for any distance back from the forwardmost tips 22 of the blades to their bases at their innermost edges 20 is as follows:

$$O = \sqrt{Ldy + \frac{L^2}{4}}$$

Thus, since the value for L remains constant, by varying the value of dy by small increments from the forwardmost tips of the blades toward their bases, numerous values for O can be calculated and the proper curve plotted. The remainder of the inner surface of the housing 11 from the region opposite to the innermost point 20 at the base of the blades to the exhaust opening 24 is curved in accordance with the curvature of the rotor 12 so that a constant volume of air is maintained as it passes through the channel 23.

It is apparent from the description to this point that the rotor 10 and the cowling 11 provide two coaxially related parabolic surfaces forming an annular fluid flow passage in which the rotor blades 14 function.

The blades 14 are parallel to the shaft 13. Each blade has a surface of a suitable airfoil as shown in Fig. 2. The blades may be arranged with their width disposed radially of the wheel, or they may be pitched backwardly with respect to the rotation of the wheel to an angle of 60 degrees from the radius of the wheel. An angle of 45 degrees is a satisfactory pitch because it represents the resultant of the equal component wind velocities produced by the rotation of the wheel,

and the blades pitched as shown in Fig. 2 with their flat faces disposed at an angle of 45 degrees with respect to the radii of the wheel, substantially corresponding to the relative wind so that the angle of attack is approximately zero degrees to eight degrees, is a satisfactory arrangement.

It is apparent that the series of blades 14 being substantially parallel with the axis of rotation define what may be termed a cylindrical fluid-propelling zone across the annular passage 23, and, that, since the blades throughout their lengths move at substantially the same velocity, the blades exert substantially uniform fluid pressure throughout the length of the fluid-propelling zone. Such uniform propelling effect across the annular passage favors minimum turbulence and, of course, the constant cross-sectional area of the passage is a further factor tending to eliminate turbulence.

As a further important factor bearing on turbulence, it is to be noted that the cylindrical fluid-propelling zone extends rearward from a forward plane of rotation substantially at the tip or apex 19 of the nose or leading face 18, and, that, by virtue of the mathematical relationships heretofore set forth, the cross-sectional area of said nose or leading face at any given plane of rotation within said cylindrical fluid-propelling zone is substantially equal to the circumferential area of said cylindrical zone between the given plane and said forward plane. The practical effect of this relationship is that as the fluid moves relatively rearward around the curved nose, the fluid is displaced by the nose through the cylindrical zone substantially uniformly along the axial dimension of the zone. In other words, if we consider a plane perpendicular to the axis of rotation as moving rearward from the tip 19 of the nose 18, it will be found that the instant cross-sectional area of the nose in the traveling plane will equal the circumferential area of the cylindrical fluid-propelling zone traversed by the traveling plane, the two increasing at equal rates.

From the foregoing then, it is evident that there are three factors contributing to uniform flow of the fluid with minimum turbulence through the device shown in Figure 1, the three factors being; first, the uniform displacement of the incoming fluid stream into the zone of action of the blades 14; second, the uniform velocity of the blades throughout their lengths; and, third, the constant cross-sectional area of the passage 23.

It may be noted that the outer wall of the annular passage 23 in the immediate region of the cylindrical series of blades is, in profile, not inclined at substantially less than 45° from the axis of rotation. If the inclination were substantially less than 45°, the effect of air deflection by the outer wall would be undesirable, especially in tending to create turbulence. This angular relationship is especially important when, as in the present arrangement, the blades are substantially parallel with the axis of rotation.

The width of each blade should not be so great that the efficiency is impaired. The distance between blades preferably should be approximately 1½ times the true chord of the blade. The true chord is indicated in broken lines 29 in Fig. 1 and corresponds in length to a line extending from the inner to the outer edge of the blade at an angle corresponding to the bisector of the angle between the leading edge 27 and the base 20 of the blade.

As shown in Fig. 2, the distance between the blades at their outer edges is greater than at their

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inner edges. To compensate for this in maintaining a constant area between the blades during the travel of the air from the inner to the outer edges, the leading edge 27 of each blade is sloped so that the length of the outer edge is less than the length of the inner edge.

The entire rotor 12 is shown as being rotatable. It may be more convenient and desirable to rotate just the blade portion, allowing the remainder of the wheel to be fixed.

The exhaust of the air from the propeller is effected through opening 24. As shown, this opening has the same width as passage 23. It may be found desirable, however, to exhaust this air over a greater area so as to decrease its velocity by allowing it to gradually expand through a duct having gradually increasing dimensions.

In the form of the invention shown in Fig. 1, the engine for driving the propeller would be in the housing indicated at 16. Engine exhaust may be bled into the stream of air entering the propeller blades to impart heat to the blades. An effective means for preventing ice formation on the blades is thereby provided.

The theory upon which the design of conventional blowers has been based is that the length of the blades should correspond to the radius of the wheel. This gave the maximum capacity for the wheel of the given radius. Any reduction from this length in the blade resulted in a reduction in the capacity of the wheel. Because of the use of these long blades, the destructive forces created by rapid rotation of the wheel required relatively strong construction and limited the materials suitable in the propeller construction. The present invention makes it possible to reduce greatly the lengths of the blades for equivalent capacities, thereby reducing the destructive forces. One result of this is to open the door to materials not heretofore thought suitable for conventional propellers.

In Fig. 3, the invention is shown in the form of a blower. The rotor is indicated at 30 and the blades at 31. Behind the rotor, 30 is a stationary housing 32 in which may be mounted the motor for driving the wheel or rotor 30. The blower operates in a duct generally indicated at 33, which is made up of an inlet duct 34, an intermediate duct 35, and an exhaust duct 36. Air entering the blades 31 from inlet duct 34 is passed through the blades in the manner previously described and is discharged into the intermediate duct 35, where it follows its natural course around the casing 32 and is finally discharged into the duct 36. The contour of the rotor or wheel 30 is determined as described with reference to the propeller, and the diameter of the inlet duct 34 corresponds with the diameter of the wheel taken at the inner edges of the blades 31. Throughout the intermediate duct 35, a constant volume is maintained which corresponds to the volume of the air discharged from the blower fan blades. The inner contour of the intermediate duct 35 as it tapers and merges into the discharge duct 36 is intended to be a streamlined curve producing as little resistance as possible to the normal flow of air. The casing 32 is tapered so as to maintain a constant volume for the air as it passes through the narrowed portion of the intermediate duct 35 into the discharge duct 36. Preferably, as shown in Fig. 3, the rotor 30 and the stationary housing combine to form an inner means or body of streamlined configuration. In this instance, the streamlined configuration may be aptly described as that of an elongated teardrop. Brackets or

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struts 37 of some suitable type support the casing 32 and wheel 30 in the ducts, and maintain their proper space relationship.

The spacing of the blades on the rotor is in accordance with the gap-chord ratio applied in aeronautics. The chord used in this ratio is the true chord, as was previously explained.

As a pump for moving liquids, the form of the invention can be similar to the arrangement shown in Fig. 3. The pump motor can be mounted in casing 32, which, in this event, will be a water-tight compartment. The electrical connections may be passed through one of the brackets 37, which would be water-tight and hollow.

Though specific embodiments of the invention are shown and described, it is to be understood that the possibility of making many modifications is recognized. In some instances, for example, as a propeller, it may be preferred to dispense with the housing 11 and employ the propeller without a housing. Obviously, there are many different forms which the various embodiments may take without departing from the intended scope and spirit of the invention. In any event, the principles concerning the fluid flow and the design necessary to maintain certain constant conditions will apply irrespective of the exact form or arrangement of the structure used.

The leading edge of the casing 11 shown in Fig. 1 may be further streamlined so as to reduce resistance by curving the outer surface back, as shown in Fig. 4.

The stall position of the blades for purposes herein shall be that corresponding to the peak position on the lift-to-drag ratio curve; i.e., where turbulence at the blade occurs and the efficiency commences to drop off rapidly.

I claim:

1. In an aeroplane-propelling means, a driven rotary inner member of circular cross section formed with a forward unobstructed nose curved in profile, wall means concentrically surrounding said inner member and defining therewith an annular fluid passage of progressively increasing diameter, said wall means extending forwardly from said nose to form an intake opening forward of said annular passage, the forward portion of said wall means being in longitudinal cross section convex radially inward to form a throat in said opening and being tapered in profile to form a leading edge of less diameter than the maximum outside diameter of the wall means but of greater diameter than the inside diameter of said throat, and fluid-propelling blades on said inner member extending across said passage parallel with the axis of said nose.

2. In a fluid-propelling means, an inner member of circular cross section formed with a forward, substantially unobstructed nose bluntly curved in profile and shaped throughout as a paraboloid of revolution, wall means concentrically surrounding said inner member and defining therewith an annular fluid passage of progressively increasing diameter, said wall means extending forwardly from said nose to form an intake opening forward of said annular passage, and a rotary series of blades spanning said passage, said blades being parallel with the axis of said inner member and terminating in a forward plane perpendicular to said axis at the inlet end of said blunt nose and being located to form a cylindrical fluid-propelling zone extending rearward from said forward plane, the cross-sectional area of said nose at any given plane perpendicular to said axis within said cylindrical zone being

substantially equal to the circumferential area of said cylindrical zone between said given plane and said forward plane, and all cross-sectional areas of the annular space between said nose and said wall means being equal, whereby as the fluid moves relatively rearward around said nose the fluid is displaced by said nose through said cylindrical zone substantially uniformly along the length of the zone.

3. A fluid-propelling means as set forth in claim 2, wherein said blades are spaced circumferentially in the cylindrical fluid-propelling zone so that the distance between successive blades is approximately one and one-half times the true chord of each blade.

4. A fluid-propelling means as set forth in claim 2, wherein each of said blades has an air foil configuration with a camber on the side of the blade nearest the axis of rotation and a leading edge disposed toward said axis.

WILLIAM AYERS.

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