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H. F. HAGEN

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METHOD AND APPARATUS FOR PROPELLING FLUIDS

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2 Sheets-Sheet 1

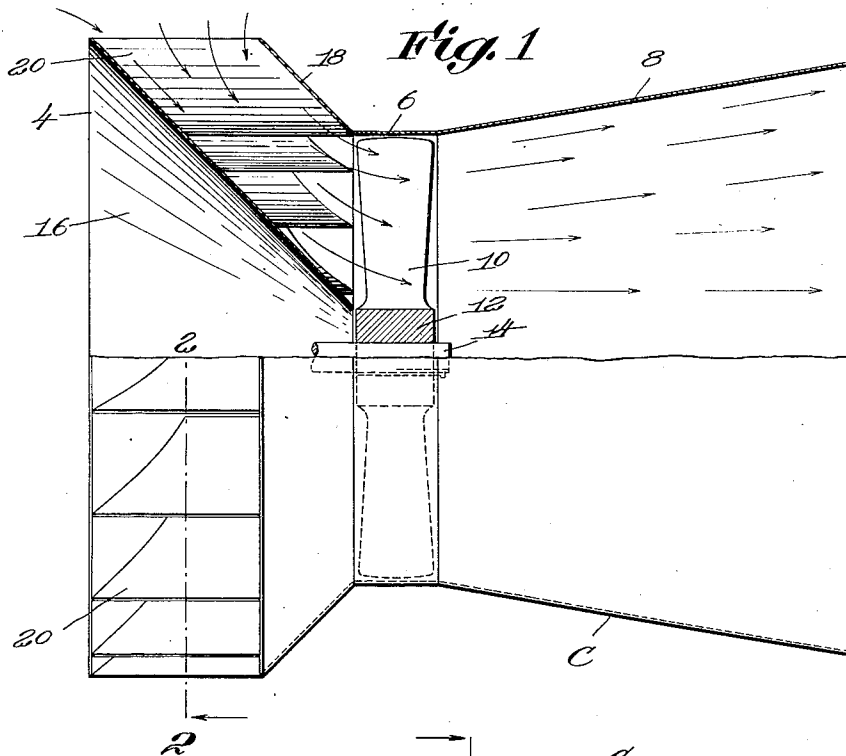
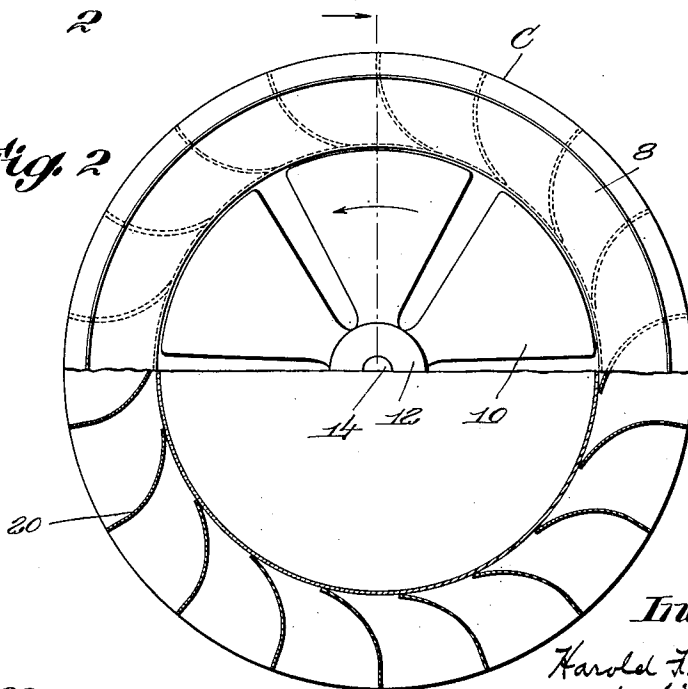


Fig. 2



Witness:

Alfred H. McGlinchey

Inventor:

Harold F. Hagen
by his attorneys

Van Eenun, Fish, Hildreth, Cary

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Fig. 5

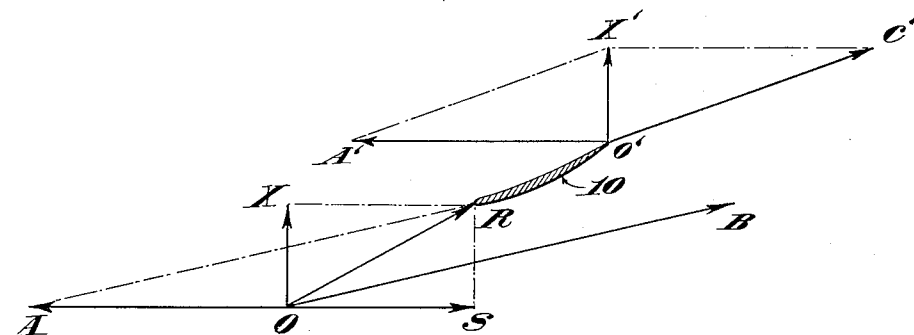
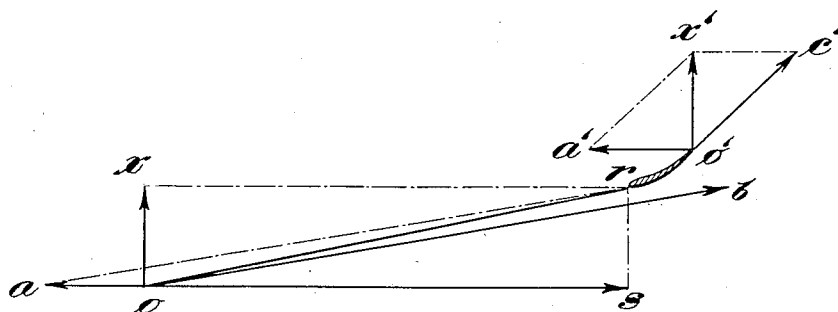


Fig. 4



Inventor

Harold F. Hagen
by Van Eeman Bush
Hildreth Healy *Attys.*

UNITED STATES PATENT OFFICE

HAROLD F. HAGEN, OF DEDHAM, MASSACHUSETTS, ASSIGNOR TO B. F. STURTEVANT COMPANY, OF HYDE PARK, MASSACHUSETTS, A CORPORATION OF MASSACHUSETTS

METHOD AND APPARATUS FOR PROPELLING FLUIDS

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The present invention relates to methods and apparatus for propelling fluids.

The usual apparatus for propelling fluids operates by acting on the fluid by a plurality of curved blades which impart to the fluid an increased pressure and a longitudinal component of velocity as well as a velocity of spin or velocity of rotation. The well known propeller fan which is a typical example of apparatus of this type, while useful for handling large volumes of air, is known to be extremely inefficient in operation. The low efficiency of the usual propeller follows from the fact that it is not capable of doing equal amounts of work on all particles of fluid. The result of the action of unequal work on different fluid particles is that eddies and turbulent cross currents are set up in the fluid stream, giving rise to excessive losses. While the criterion of equal work may in some instances be theoretically satisfied by a proper design of fan blades, this can be done only when the hub diameter forms an extremely large proportion of the fan diameter; thus the increased efficiency is obtained only at the expense of the capacity of the fan. Moreover, the enlarged hub diameter requires heavy parts and bearings for its support. Accordingly it is the practice to sacrifice efficiency for volume by making the blades of considerable length as compared to the diameter of the hub.

Even though the requirement of equal work should be satisfied, the usual propeller fan possesses another disadvantage, namely, the presence of an undesirable spin velocity in the fluid stream. The ideal condition of operation is one in which the fluid is directed in a straight longitudinal direction without velocity of rotation. It can be demonstrated, however, that the spin velocity is a necessary consequence of the action of the propeller blades in increasing the energy content of the fluid and that no effective work can be done on the fluid without a corresponding velocity of spin. In fact the theoretical work upon a particle of air is directly proportional to the product of the linear velocity of the blade and the velocity of spin imparted by the blade to the fluid.

The object of the present invention is to provide an efficient method and apparatus for propelling fluids by which the separate particles of fluid are caused to receive equal increases of energy content and by which the resulting fluid flow is rendered wholly axial and substantially free of turbulence and eddy currents.

With this object in view, the present invention contemplates as its principal feature a method and apparatus by which the fluid is acted upon, prior to its entrance into the propeller, to impart to each particle a spin velocity which is opposite to the direction of rotation of the propeller and varies in magnitude substantially in inverse proportion to the radial distance from the axis of rotation of the propeller. Since the work done by the propeller on any particle is proportional to the product of the spin velocity or change of spin velocity and the linear velocity of the propeller, the requirement of equal work on all particles is satisfied. This insures that the possibility of violent turbulence which, in the usual propeller, follows from unequal work on the particles of fluid, is eliminated. Moreover, the introduction of the air with a reverse or negative spin velocity permits a material increase in the effective area of the propeller, thus permitting a high capacity without sacrifice of efficiency.

Inasmuch as the fluid is admitted to the propeller with a spin velocity opposite to the direction of rotation of the blades, the spin velocity is at least partially neutralized by the positive spin which the blades tend to impart to the fluid. In order that the efficiency may be further improved, a further feature of the invention consists in the provision of a method and apparatus by which the spin velocity of the fluid is completely neutralized by the action of the propeller so that the resultant spin velocity at the discharge side of the propeller is reduced to zero. This desirable result is accomplished by a construction of the propeller in such a manner that the positive spin velocity which it tends to impart to the fluid is not only opposite in direction to the spin velocity of the admitted fluid, but is also equal in magnitude thereto.

Accordingly, by the introduction of the fluid to the blades with a predetermined negative spin velocity which the blades are shaped to neutralize, the two desirable conditions of an equal work and nonrotative discharge are at once satisfied.

The method and means by which the fluid is caused to assume at each point the proper velocity of spin prior to its entrance into the propeller constitutes in itself an additional feature of the invention. According to this method, the fluid is admitted at a uniform radial distance from the axis of rotation of the propeller blades with a uniform component of spin velocity, and is then permitted to pass freely in a general radial direction to enter the propeller blades at a number of points. If a body of fluid is so admitted to the propeller, the separate particles in passing to points at different radial distances from the axis will assume under the action of natural laws the requisite negative spin velocity to insure that the energy content imparted to the various particles of fluid will be uniform at all radii; that is to say, the fluid will automatically assume at each point a velocity of spin which is inversely proportional to the radius. In passing through the propeller, the spin velocity is wholly or partially neutralized, as discussed above.

In the accompanying drawings, Fig. 1 is a side elevation partly in section of the preferred form of the apparatus of the present invention; Fig. 2 is an end view looking from the right hand end of Fig. 1, and taken partly in section on line 2—2 of Fig. 1; Fig. 3 is a vector diagram illustrating the manner of determining the curvature of the blade at the tip; and Fig. 4 is a similar diagram showing the curvature of the blade at the hub end.

The illustrated embodiment of the invention comprises an air propeller fan having a casing indicated generally at 2. The casing is provided with an intake portion 4, an intermediate blade chamber 6, and a flared outlet portion 8. Supported in the chamber 6 is a series of fan blades 10, the construction of which will hereinafter be described in detail. The blades are mounted on a central hub 12, supported on a shaft 14 which is journaled in suitable bearings (not shown). As in usual constructions, the fan blades are supported so as to give a minimum of clearance with the casing in order that there may be no excessive leakage of air. The inlet portion of the casing comprises two cooperating substantially conical members 16 and 18 between which are supported a series of curved vanes 20 dividing the inlet chamber into a series of curved air inlet passages to direct the air to the propeller fan blades. The conical member 16 tapers inwardly from the left hand end of the casing as viewed in Fig. 1 to a diameter approximately equal to that of the hub 12 so as effectively to pre-

vent any appreciable entrance of air in a direct axial line. The conical member 18 is formed as a continuation of the main part of the casing 2, its internal diameter being equal to that of the fan chamber 6, and together with the member 16 encloses a sloping inlet chamber.

The vanes 20 are cylindrical in shape, that is to say, they are surfaces whose linear elements are parallel to each other and to the axis of the fan. As shown in Fig. 1, the inner end of each vane terminates at approximately the outer extremity of the fan blade. The curvature of each vane is such that air drawn in through the intake passages between the vanes has imparted to it a spin velocity opposite in direction to that which is imparted to the air by the fan blades.

In operation the rotation of the blades 10 in the direction of the arrow of Fig. 2 acts to drive the air longitudinally through the outlet portion 8 of the casing. The exhaustion of air in the vicinity of the blades serves to draw air through the inlet passages enclosed between the vanes 20 and the conical portions 16 and 18 of the casing. While the air is entering through these inlet passages it has three components of velocity—first, an axial component due to the conical slope of the members toward the fan blades; second, a radial component due to the passage of the air from the exterior of the fan inwardly toward the fan axis; and third, a spin component due to the curvature of the vanes. The sloping inlet chamber, by which the air is given an axial component of velocity in its passage between the vanes, serves to direct the air against the fan blades without abrupt changes of direction. The radial component of velocity serves to bring the air into position to be acted upon by the fan blades at all parts thereof, while the rotative component supplies the proper spin velocity so that upon emergence from the fan the air will have no remaining rotative velocity but will be directed in a purely axial or longitudinal direction.

The spin component of velocity is of the greatest importance in satisfying the conditions of equal work and non-turbulent flow. The manner in which the spin velocity is caused to vary in inverse proportion to the radius in the inlet chamber is explained as follows:—Owing to the symmetry of the structure, the spin component is uniform for all points at a given radial distance from the axis. For example, at the outer extremities of the fan blades, corresponding to the inner terminus of the vanes, all particles of air will have a definite spin velocity which is determined by the speed of the fan and the curvature of the vanes. The vanes are so constructed that this spin velocity at the largest radius of the fan is such as to be equal and opposite to that which the fan blades tend

to impart to the fluid at their outer extremities. Some of the air will enter directly into the fan at the outer extremities of the blades and other portions of the air will move progressively toward the center to be acted upon by the blades at other positions nearer the axis. As a particle of air moves inwardly its spin velocity increases, and at any given radius the increased velocity is at all points equal and opposite to the increased spin velocity which the blades tend to impart at the same radius. This fact follows from a consideration of the laws of fluid motion, particularly Bernouilli's theorem and the laws of centrifugal motion. The incoming air at the inner extremities of the vanes is at a certain definite pressure and spin velocity and as a particle moves inwardly, it enters a zone of decreasing pressure and must consequently increase in spin velocity to maintain an equilibrium of pressures. The spin velocity at any point will assume a value which is inversely proportional to the radius. The energy imparted to the fluid by the rotating impeller is proportional to the product of the rotative speed of the working portion of the impeller blade and the change in fluid spin velocity produced. With the spin velocity as described varying inversely as the radius and the rotative speed of the blades necessarily varying directly as the radius, the product of the change in spin velocity and the rotative blade speed is constant at all radii, thus giving uniform energy throughout the fluid and a fluid discharge of longitudinal motion without any wasteful spin component. It will be understood that the spin velocity referred to above is the linear velocity of spin, that is, the actual linear velocity of the fluid in a circular path, as distinguished from its angular velocity.

The vector diagrams of Figs. 3 and 4 not only illustrate the manner of determining the shape of the blade, but also give a graphical explanation of the compensation for spin velocity which takes place in the passage of the air through the fan. The diagram for the tip of the blade is shown in Fig. 3. The blade is indicated in cross section at 10. The linear velocity of the blade is indicated by the vector OA, and the velocity of the admitted air by OR. The vector OR is divided into two components, namely OX and OS, the former representing the axial intake velocity and the latter the negative velocity of spin. The inlet side of the blade 10 is parallel to the vector OB which is the vector difference of OA and OR and which represents the relative velocity of the air with respect to the blade. This condition of parallelism is imposed so that the air may enter into contact with the blade without a sudden change of direction. The work done upon the fluid by the fan is proportional to the product of OA and OS. At

the exit side of the blade the diagram is formed on the new origin O', and the blade velocity is represented by O'A' and the axial air velocity by O'X', where O'A'=OA and O'X'=OX. The air leaves the blade with a velocity having magnitude and direction represented by the vector O'C', which is tangent to the curvature of the blade at its exit side. Since O'C' is air velocity relative to the blade, the vectorial sum of O'A' and O'C' is the resultant absolute velocity of the air. The angle of inclination of the exit side of the blade with respect to the plane of the fan is such that this vectorial sum is coincident with O'X', which is in a straight axial direction. The spin velocity is therefore completely neutralized.

Turning now to Fig. 4, which is similar to Fig. 3, except that it is taken at the hub end of the blade, and assuming that the hub diameter is four-tenths of the fan diameter, the vector *oa* representing the linear velocity of the blade is reduced to four-tenths of that at the tip, while the vector *os* representing the spin velocity is increased in inverse proportion, namely, to ten-fourths of its tip value. The axial velocity component *ox* is unchanged, being equal to *ox*. The work done on a particle of air will be *oaxos*, which is the same as before, thus satisfying the requirement for equal work at all radii. The vectors *or* and *ob* are determined as before and the entrance side of the blade is arranged parallel to *ob*. At the exit side of the blade the vectors *o'c'* and *o'a'* add to *o'x'* which is the absolute velocity of the fluid without spin or turbulence. For this case also, the exit curvature of the blade is such that the length and direction of *o'c'* compound with *o'a'* to give *o'x'*, the vector *o'c'* being tangent to the exit surface of the blade. The blade is smoothly curved from its entrance angle to its exit angle. The curvature of the blade section may be determined in like manner for radii intermediate to the hub and tip ends, and thus the shape of the entire blade may be completely determined.

It will be seen that in each case the entrance angle of the blade from the plane of rotation of the fan is the angle whose tangent is the ratio OX to AO+OS; and the exit angle of the blade is the angle whose tangent is the ratio of OX to OA. Stated mathematically

$$\text{Entrance angle} = \tan^{-1} \frac{V_o}{V_a + V_s}$$

$$\text{Exit angle} = \tan^{-1} \frac{V_c}{V_a}$$

where

V_o = axial velocity of fluid

V_a = linear velocity of the blade

V_s = linear velocity of spin of the admitted fluid

The present invention is not limited to a construction in which the hub diameter is 40% of the fan diameter, but this ratio affords a convenient and strong mechanical assembly without excessive weight. At a 40% ratio, the effective area acted upon by the fan blades is high, being 84% of the total area of the air passage. By a similar vector analysis for the ordinary propeller fan in which the spin velocity appears as a vector only at the discharge side of the blades, it may be shown that the requirement of equal work can be satisfied only when the hub diameter forms a much larger percentage of the total fan diameter, usually around 70%. Even under these conditions it is necessary that the hub end of the blade be warped to a limit of ninety degrees from the plane of the fan, a construction which while theoretically possible, cannot be practically realized. Inasmuch as the hub takes up 70% of the fan diameter there is, therefore available only about one-half of the total area for useful work by the fan, thus preventing the handling of any considerable volume of air. Moreover, even if this limiting condition could be realized, the fan would have the disadvantage of permitting a velocity of rotation in the discharge. By the elimination of losses due to eddying and turbulence, the efficiency of the fan of the present invention is increased by a very considerable amount. While prior forms of propeller fans were unable to attain static efficiencies of more than 30 to 40%, the fan of the present invention obtains a static efficiency approximating 50 to 60%. Moreover, with the usual types of propeller fans the speed limitation imposed by the strength of materials gives a pressure below commercial requirements. The fan of the present invention, however, at that same speed limit develops 50% higher pressures than the ordinary propeller fan.

Having thus described the invention, what is claimed is:

1. The method of controlling the inflow of fluid to a rotary propeller having inclined blades which consists in inducing in the body of the fluid at a fixed radial distance from the axis of the blades a uniform linear velocity of spin opposite to the direction of rotation of the blades and opposite to the spin velocity tended to be imparted by the blades at such radial distance from the axis, and permitting free radial and rotary movement of the fluid to allow the fluid to assume a spin velocity at each point which is substantially in inverse proportion to the radial distance from the axis.

2. The method of propelling fluids which consists in imparting to the fluid a rotary motion about an axis and of predetermined velocity at a definite radial distance from such axis, permitting the fluid freely to move radially, and simultaneously neutralizing the

rotary motion of the fluid and propelling it axially.

3. The method of controlling the inflow of fluid to rotary propellers having inclined blades which consists in inducing in a body of the fluid at a fixed radial distance from the axis of motion of the blades a uniform velocity of rotation opposite to the direction of such motion and equal to the spin velocity tended to be imparted by the blades at such radial distance from the axis, and permitting free radial and rotary movement of the fluid to allow the fluid to assume a progressively increasing spin velocity toward the center of rotation of the blades to compensate at each point for the spin velocity tended to be imparted by the blades at such points.

4. The method of controlling the inflow of fluid to rotary propellers having inclined blades which consists in inducing a rotary motion in the fluid about the axis of motion of the propeller blades and opposite in direction to such motion, the velocity of the fluid at a distance from said axis equal to the radial length of the propeller blades being equal to the spin velocity tended to be imparted to the fluid at the outer extremity of the blades, and permitting free radial and rotary movement of the fluid before being acted upon by the blades to allow the fluid to assume a progressively increasing spin velocity toward the center of rotation of the blades to compensate at each point for the spin velocity tended to be imparted by the blades at such points.

5. A propeller having, in combination, rotary inclined propeller blades acting to impart an axial component of velocity and a velocity of spin to a fluid, means for directing fluid to the blades comprising fluid admission passages curved in a direction opposite to the direction of rotation of the blades and constructed and arranged to deliver fluid at a fixed radial distance from the axis of rotation of the blades with a uniform velocity of spin and spaced from the blades to permit the fluid to assume at each point prior to its engagement with the blades a spin velocity opposite to that tended to be imparted by the blades and inversely proportional to the radial distance from the axis.

6. A propeller having, in combination, rotary inclined propeller blades acting to impart an axial component of velocity and a velocity of spin to a fluid, means for directing fluid to the blades comprising fluid admission passages annularly arranged beyond the outer extremities of the blades and curved in a direction to admit fluid at the outer extremities of the blades with a uniform velocity of spin opposite in direction to the spin velocity tended to be imparted by the blades, and a chamber into which the fluid is free to pass radially and rotationally prior to its engagement by the blades to permit it to assume at each point a spin velocity which varies sub-

stantially in inverse proportion to the radial distance from the axis.

7. A propeller having, in combination, a fluid admission chamber, curved vanes for admitting fluid to the chamber with a uniform velocity of spin at a fixed distance from the axis of the propeller, a chamber in which the fluid is free to move radially to permit it to assume at each point a velocity of spin which varies substantially in inverse proportion to the radial distance from the axis, and propeller blades rotatable in a direction opposite to the spin velocity of the fluid and acting to impart an axial component and a spin component of velocity.

8. A propeller having, in combination, rotating inclined propeller blades acting to impart an axial component of velocity and a velocity of spin to the fluid, means for directing fluid to the blades comprising fluid admission passages curved in a direction, and constructed and arranged to deliver fluid at the outer extremities of the blades with a uniform velocity of spin, to permit the fluid to assume at each point prior to its engagement with the blades a spin velocity equal and opposite to that tended to be imparted by the blades at such point.

9. A propeller comprising rotating inclined propeller blades, a fluid admission chamber through which fluid passes to the blades, the chamber being annularly extended beyond the outer extremities of the blades to admit fluid to the blades, a plurality of vanes in the annularly extended portion of such chamber curved in a direction to admit the fluid with a spin velocity opposite to that imparted by the blades, the vanes being in the form of curves whose elements are parallel to the axis of rotation of the blades.

10. A propeller having, in combination, rotating inclined propeller blades to impart an axial component and a rotative component of velocity to a fluid, and means acting on all portions of the entering fluid for admitting fluid to the blades with a rotative component of velocity equal and opposite to that tended to be imparted by the blades at the point of admission to neutralize the spin velocity imparted by the blades.

11. A propeller comprising rotating inclined blades, a fluid admission chamber through which air passes to the blades, consisting of an inner unobstructed portion adjacent the blades at the intake side thereof, and of an outer portion through which all of the fluid passes to the inner portion, and a plurality of vanes in the outer portion for imparting a spin to the fluid opposite to that tended to be imparted by the rotating blades.

12. A propeller comprising rotating inclined blades, an annular frusto-conical fluid admission chamber having a free, unobstructed portion to admit the fluid to the blades and an outer portion of greater exter-

nal diameter than the diameter of the propeller, and vanes in the outer portion constructed and arranged to impart a reverse spin to the fluid.

13. A propeller comprising rotary propeller blades to impart an axial component and tending to impart a rotative component of velocity to a fluid, means for admitting fluid with a uniform component of spin velocity at a fixed radial distance from the axis of the propeller, which spin velocity is opposite to the direction of motion of the blades, a fluid admission chamber through which the fluid is free to move prior to its engagement by the blades to permit it to assume at each point a spin velocity which varies substantially in inverse proportion from the radial distance to the axis, the exit angle of the blades at each point being such as to discharge the air with a velocity relative to the blade which when compounded with the velocity of the blade, produces a substantially axial absolute velocity without appreciable velocity of spin.

14. A propeller having, in combination, rotating propeller blades, and means for admitting fluid to the blades with a spin component opposite to the direction of rotation of the blades and varying in magnitude substantially inversely as the radial distance from the axis of the blades, the blades having at each radius an exit angle from the plane of rotation which is the angle whose tangent is the ratio of the axial velocity of the fluid to the linear velocity of the blade at such point.

15. A propeller having, in combination, rotating propeller blades, and means for admitting fluid to the blades with a spin component opposite to the direction of rotation of the blades and varying in magnitude substantially inversely as the radial distance from the axis of the blades, the blades having at each radius an entrance angle from the plane of rotation which is the angle whose tangent is the ratio of the axial velocity of the fluid to the numerical sum of the linear velocity of the blade and the spin velocity of the fluid at such point, and an exit angle whose tangent is the ratio of the axial velocity of the fluid to the linear velocity of the blade at such point.

16. A propeller having, in combination, rotary inclined propeller blades acting to impart an axial component of velocity and a velocity of spin to a fluid, means for directing fluid to the blades comprising fluid admission passages curved in a direction opposite to the direction of rotation of the blades and constructed and arranged to deliver fluid at a fixed radial distance from the axis of rotation of the blades with a uniform velocity of spin and spaced from the blades to permit the fluid to assume at each point prior to its engagement with the blades a spin velocity opposite to that tended to be imparted by

the blades and inversely proportional to the radial distance from the axis, the blades having at each radius an exit angle from the plane of rotation which is the angle whose tangent is the ratio of the axial velocity of the fluid to the linear velocity of the blade at such point.

17. A propeller having, in combination, rotating inclined propeller blades to impart an axial component and a rotative component of velocity to a fluid, means for admitting fluid to the blades at a fixed radial distance from the axis with a rotative component of velocity opposite to that tended to be imparted by the blades at the point of admission, and a chamber in which the fluid is free to move radially to permit it to assume at each point a velocity of spin which varies in inverse proportion to the radial distance from the axis.

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

HAROLD F. HAGEN.

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