April 25, 1933. E. S. G. REES 1,906,180

PROPELLER, PUMP, OR FAN

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FIG. 1.

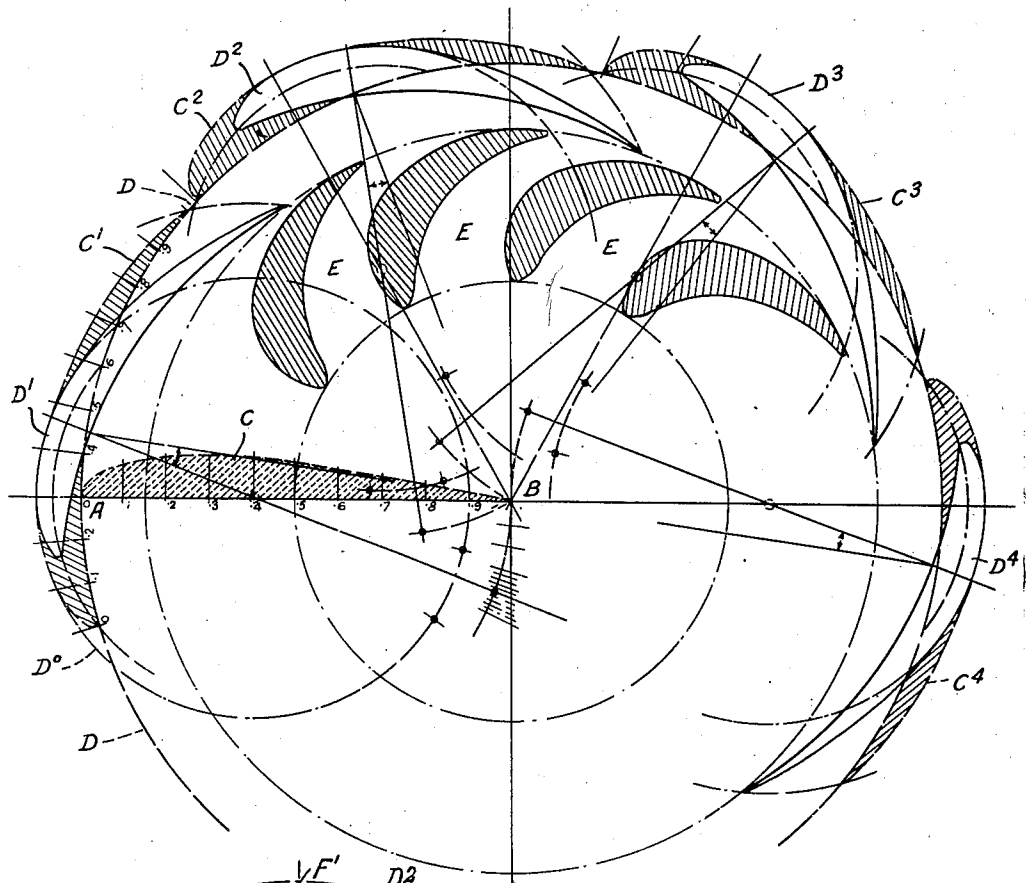
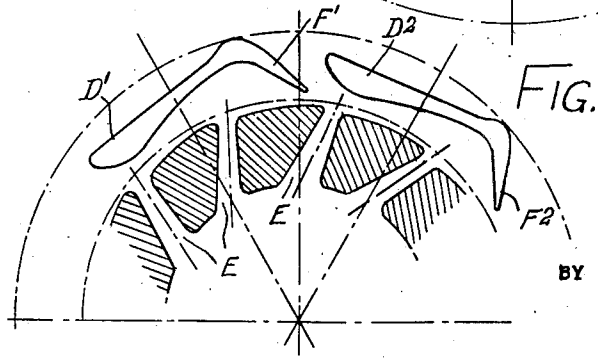


FIG. 2.



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FIG. 2.

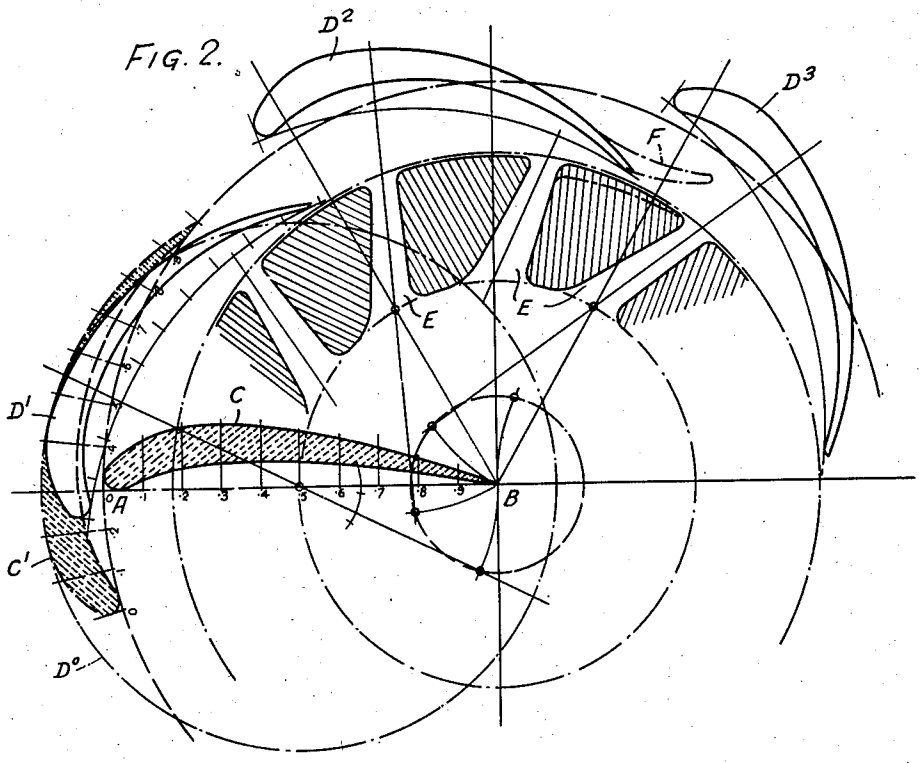
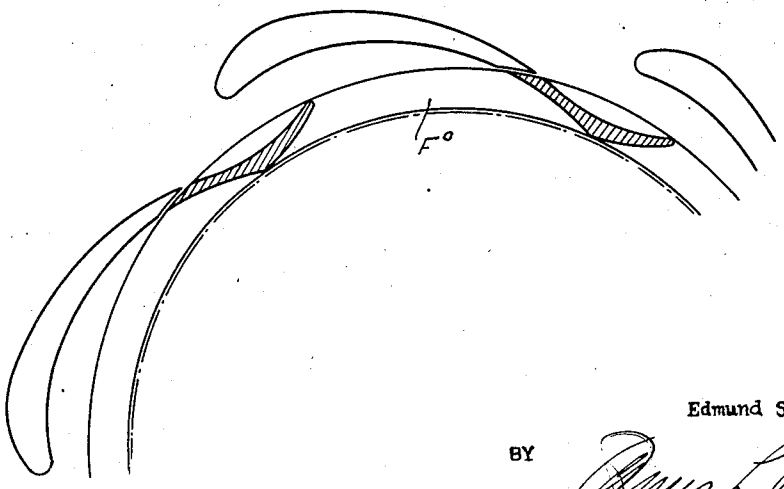


FIG. 3



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PROPELLER, PUMP, OR FAN

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FIG. 4.

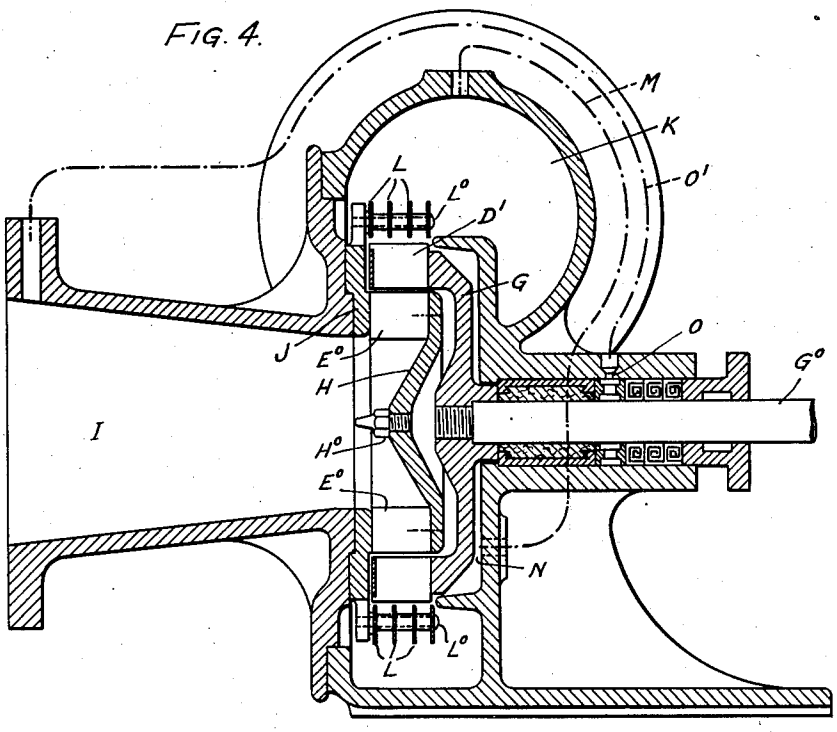
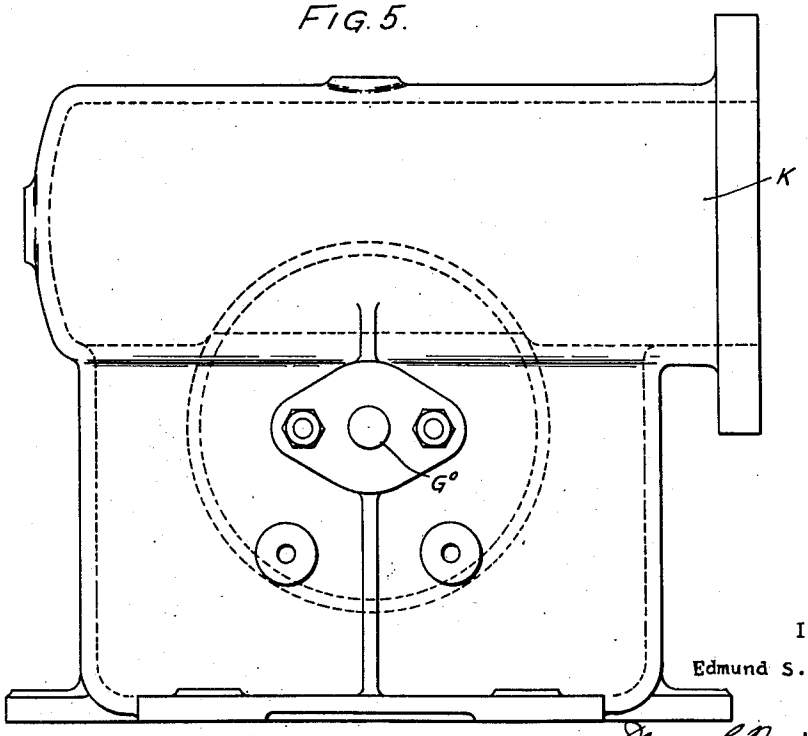


FIG. 5.



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PROPELLER, PUMP, OR FAN

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FIG. 6.

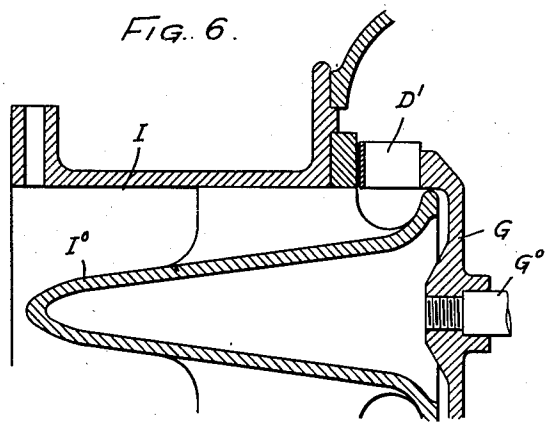


FIG. 7.

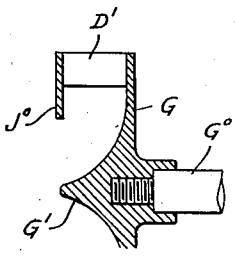
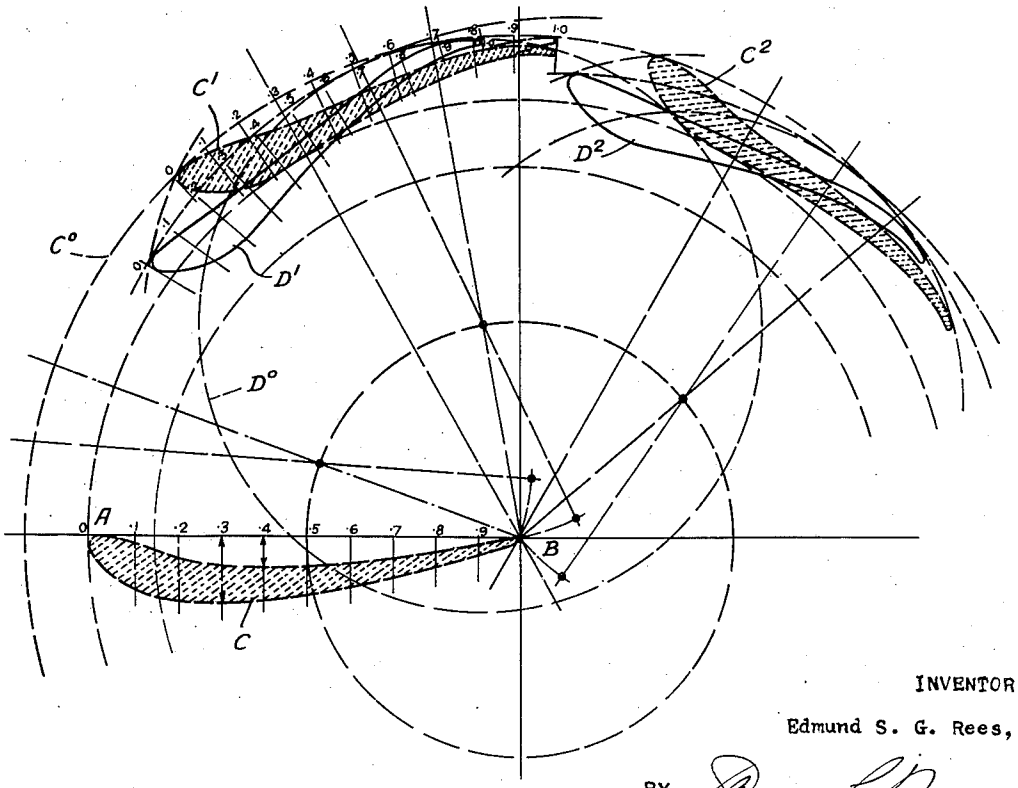


FIG. 8.



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UNITED STATES PATENT OFFICE

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PROPELLER, PUMP, OR FAN

Application filed October 2, 1929, Serial No. 396,844, and in Great Britain October 5, 1928.

This invention relates to propellers and impellers operating in a liquid or gaseous medium, and although it will be hereinafter described mainly as applied to a rotary hydraulic pump, it must be understood that the invention is also applicable to blowers or air fans, or jet propellers.

A principal object of the invention is to overcome certain inherent defects in all centrifugal pumps, as for example those due to a suction inlet or eye of a necessarily seriously restricted cross sectional area, and the tendency of a liquid with a gas in suspension, as air and water, to separate under the action of centrifugal force within the rotary member of the pump, the air tending towards the inlet or centre of the pump impeller, and the water towards the periphery. In a pump according to the present invention the impeller is designed to induce or constrain the water to flow within the impeller in the direction which air or gas tends to take in centrifugal pumps, i. e. from the periphery towards the center of rotation.

With this object the impeller blades, instead of being substantially radial as in the ordinary centrifugal pump and designed to promote an increasing velocity of the fluid from the eye towards the rim, are essentially circumferential blades or foils, and are of such a character that when the impeller is rotated in undisturbed water a portion is trapped under each advancing foil, and provision is made to ensure that the fluid so trapped will not escape outwardly, but will be discharged in an inward or an axial direction, as for example along expanding channels formed between circularly arranged stationary guides or cutwaters to a discharge pipe or an expansion duct or diffuser in which any remaining velocity of flow is converted into the desired pressure of discharge. The stationary expanding channels may lead inwardly or laterally or in any other desired direction.

The rotating circumferential blades or foils may conveniently be designated "rotafoils", and a rotafoil is defined as a blade of the character of an aerofoil bent into an arc of a circle or other curve, giving the characteristics of an aerofoil upon being moved along a circular path in a fluid medium, and experiencing a reaction at right angles to the direction of movement in the manner of an aerofoil. The simplest way of arriving at the required shape is to select a standard aerofoil, preferably a high lift aerofoil, and plot its section, not along a straight chord as in the case of an aerofoil but along such a chord bent into an arc of a circle or other curve.

One of the surfaces of these rotafoils being formed with a pronounced fore and aft camber, their progress through the fluid produces a reduced pressure or suction on that surface and consequently the surrounding fluid will flow inwardly and rearwardly along the cambered surface of each rotafoil towards the succeeding one. The rotary part of the apparatus in its usual form may be regarded as a series of inverted troughs circumferentially arranged with a slight tilt inwardly or outwardly from front to rear, the outer or circumferential walls of these troughs being formed by the rotafoils. There is thus a body of fluid within each trough under pressure due, not to centrifugal action, but to impact and by providing an appropriate means for sealing the rear ends of these troughs, that is preventing the escape of the fluid from the troughs in an undesired direction, its discharge in a controlled direction can be effected by utilizing the static pressure of the fluid.

The invention is illustrated more or less diagrammatically in several forms in the accompanying drawings, wherein Fig. 1 is a section in a plane at right angles to the axis of rotation of an impeller having six troughs or rotafoils, the shape and disposition of which are arrived at as follows:—

Along a radius AB as base or chord is plotted in section an aerofoil C of an efficient type, that selected being the standard R.A.F. 6, the length of the chord being taken as unity and all other linear measurements given in terms of it. The aerofoil section, which is divided into ten equal parts by ordinates at right angles to the chord, is shown in hatched lines and approximates in

section to a standard aerofoil or wing of an aeroplane having its maximum ordinate equal to .1 at a point .3 measured from its leading edge or origin. With the point B as center and AB as radius a circle D, shown in broken lines, is described. This circle may conveniently be referred to as the "pitch" circle or circle of chords and around this circle six of these aerofoils C are plotted with equal spacings, as shown in dotted lines at C', C^2, C^3, C^4, the ordinates in this case being radiating lines with the maximum ordinate in line with the base or chord of the "standard" section. This position of foils may be considered as equivalent to zero angle of incidence of the wings of an aeroplane in flight, and if the foils are tilted inwardly towards the tail from this zero position up to a maximum angle of incidence of approximately 15°, the openings to the troughs formed between the tail of one foil and the nose of the following foil may be adjusted so as to deal with any desired lift or flow of the fluid, up to the maximum, per unit of length, for each diameter of impeller or "pitch" circle. The maximum angle of incidence and lift possible without sacrifice of efficiency, based on aeroplane data, for the simple forms of wings would be about 15°. The tilted foils shown in full lines D', D^2, D^3, D^4 have an angle of incidence of 12½°, and therefore approach the maximum angle and depth of nozzle desirable. The foils D', D^2, D^3, D^4, when rotated about an axis perpendicular to the plane of the paper through the point B, become rotafoils.

When the "standard" foils are plotted by means of the radiating ordinates on the chords bent round the circumference of the circle of chords or pitch circle, it will be seen that the outer or convex surfaces can be drawn as parts of circles, and the "bounding" circle D° for the camber in the region of the maximum ordinate is struck with a radius of .5 of the standard chord from a point .4 from the origin of the chord. By rotating or tilting the foils round this point within the limits allowed without sacrifice of efficiency, the extreme diameter of the revolving rotafoils is not varied for different angles of incidence. There are certain practical advantages in this feature, and therefore it is desirable in settling the contour of the outer or convex surfaces of the circumferential foils to make these portions circular, more especially as this can be done without departing materially from the proportions of the best practice in aerofoil construction.

The inner or concave surfaces of the rotafoils may be made with a positive camber, as well as the outer surfaces, thereby increasing the capacity of the troughs, and this may be carried to the extreme in which the foils consist of bent plates having an appropriate fore and aft camber and an appropriate tilt.

Fig. 2 is a view similar to Fig. 1 of an impeller the foils of which have a positive camber on their concave, as well as on their convex surfaces. The "standard" foil section C in this case is that of aerofoil R.A.F. 19, which has a maximum under camber of .075 at a distance of .4 along the chord from the origin and a maximum camber on its upper surface of .152 at .3 along the chord. The same reference characters as are used in Fig. 1 are applied to corresponding parts in this figure and the description of Fig. 1 generally applies. In this case, however, the foils are tilted about the center point (.5) of the chord AB and the radius of the "bounding" circle D° is .652 of the length of the chord.

In both these figures the tails of the rotafoils may, as shown, approximate very closely to the periphery of the stationary drum or ring of blocks in or between which the expanding channels E are formed, the negligible clearance between rotating and stationary parts forming a mechanical seal adapted to prevent the escape of fluid from the pressure or concave side of the foil around its trailing edge and ensuring its discharge through the channels E to the delivery outlet. The number of channels E may vary. In the drawings there are twice as many channels as there are rotafoils or rotary troughs, but whatever their number the sum of the cross sectional areas of their inlet ends should be approximately equal to the sum of the cross sectional areas of the inlets of the rotafoil passages or troughs if it is desired to secure the maximum pressure of discharge.

The sealing of the rear ends of the rotating troughs may be accomplished by other means than above described, and one method of effecting it is by adding a straight or a curved extension to the rear part or tail of the rotafoil flexed towards the concave or inner surface of the succeeding rotafoil as indicated at F in Fig. 2, which shows one of the rotafoils D^2 provided with a re-flexed extension of its trailing edge which is overlapped by the leading edge of the succeeding rotafoil, thus forming a restriction or nozzle in the inlet of the trough which operates as a seal, preventing any tendency of the fluid passing under the tail of the rotafoil and over the leading edge of the succeeding rotafoil. This arrangement is adapted for large angles of incidence giving high suction lift with smaller nozzles and volume than is possible with the previously described tail seal.

The tail extensions F may be integral with the rotafoils or separate therefrom. It may, for example, be convenient to cast the tail extensions on a separate ring F^0 attached to the side disc or ring carrying the rotafoils themselves. This construction is illustrated in the

modification of Fig. 2 which is shown in Fig. 3.

The ring of re-flexed tail extensions thus co-operates with the noses of the succeeding rotafoils so as to control and direct the flow of the fluid along the pressure or concave side of the rotafoils in the same manner as the flow of air is directed over the upper or suction side of the wings of an aeroplane in flight by means of the well known slotted wings or auxiliary aerofoils which, in conjunction with the leading upper surface of the main wings, form nozzles to control the direction of the stream, enabling larger angles of incidence to be used and greater maximum lifts obtained without stalling.

As with the construction shown in Figs. 2 and 3, the sealing of the rear ends of the rotary trough is no longer dependent upon the close approximation of the tails of the rotafoils with the periphery of the structure containing the expanding passages E, greater clearance can be allowed between these two structures, and preferably this greater clearance is accompanied by an increasing cross sectional area, as indicated in dotted lines in Fig. 2. In some cases, as for example in air fans, the structure containing the inwardly directed expanding channels E may be dispensed with entirely.

Fig. 4 of the drawings shows in longitudinal section one construction of a complete pump embodying the invention, and Fig. 5 is an end elevation of the same.

The rotafoils D′ etc. are cast with or secured to a disc G fast on the shaft G^0 which is driven by an electric motor or other suitable means, not shown in the drawings. Similarly the stationary blocks E^0, between which the inwardly directed expanding channels E are situated, are cast or secured to a stationary ring or disc J bolted to the fixed casing, the outer portion of the disc closing the open sides of the rotafoils to prevent leakage around the sides. The rotafoil troughs may also be sealed by a disc fixed over the open sides. Similarly the inwardly directed expanding channels E are closed by a disc H, the center part H^0 of which is cone-shaped and projects axially towards an expanding pipe I in which the velocity of the fluid is converted into pressure, the delivery pipe of the pump being connected with this expanding pipe.

The suction inlet K of the pump may be provided with a screen or sieve in the usual manner to prevent access to the pump of large particles of solid matter or, as shown in Fig. 4, this sieve may surround the ring of rotafoils and may consist, as shown, of a number of flat rings L secured on studs L^0 projecting from the fixed ring J.

To prevent accumulation of air on the suction side of the pump, a pipe M is connected with the top of the suction inlet K and is led to a space N which, by the action of the pump, is subject to a strong sucking action and is carried therefrom, together with the water, through the rotary member of the pump to the discharge outlet. Further, a water seal, indicated at O, may be provided in the bearing, which may be connected by means of a pipe O′ with the pressure or delivery pipe I in the usual manner.

A modification of the construction shown in Fig. 4 is illustrated in Fig. 6. In this case the delivery pipe I, instead of being formed with increasing external diameter, is of uniform diameter externally, and a tapered core I^0 is provided which forms an annular discharge outlet of suitably increasing cross section, wherein the velocity of the fluid is converted into the required pressure.

Fig. 7 shows a part longitudinal section illustrating the essential features, according to the present invention, of a blower or fan in which the rotafoils D′ etc. are inverted and given a slight tilt inwardly from tail to nose and are secured on a disc G which is fast on the shaft G^0 and has an axially projecting coned boss G′ adapted to direct the streams of air delivered by the rotafoil troughs in an axial direction through a central aperture of appropriate size left in the side ring J^0 which closes the sides of the rotafoil troughs.

Fig. 8 shows an arrangement of rotafoils suitable for the blower or fan of Fig. 7. Similar parts are designated by the same reference characters as are used in Figs. 1 and 2.

The rotafoils D′, and D^2 . . . are derived from a standard aerofoil R. A. F. 19 inverted. This is shown at C plotted in the inverted position along a straight chord or base AB, B being the center of rotation of the impeller. With B as center a circle C^0 is described having a radius equal to AB plus the maximum ordinate of the convex surface of the standard foil C. Equally spaced arcs on this circle each of the length of chord AB are taken as the bases or curved chords on which are plotted the inverted foils C^1, C^2 . . . shown in dotted lines. It will be seen that the result is a foil which is doubly flexed, that is, both its outer and inner surfaces have concave and convex portions, the tail portion being slightly flexed towards the center.

By tilting these foils nose inwardly from zero angle to incidence through some 7° about a suitable point along their length they assume the positions shown at D^1, D^2 . . . , the point chosen being in this case .7 from the nose or zero of the chord. It will be seen that in this case the main cambered surfaces with the greatest vacuum are on the inside of the foil or trough and the pressure region is on the outer surface. The result is an inward flow of air from the surrounding space towards the center of rotation and along the

inner surface of each rotafoil from the nose towards the tail, and as previously described this air stream can be deflected or directed axially or otherwise by suitable devices either stationary or rotating.

Also the tails of the rotafoils may be flexed inwardly or have inwardly flexed extensions F^1, F^2 . . . as shown in Fig. 9, these extensions co-operating with the nose of the succeeding rotafoil (in a manner similar to the auxiliary plane of a slotted plane aerofoil) to accelerate and direct the flow of the surrounding fluid along the cambered face of that rotafoil.

As shown in Fig. 9 the outer surface of the flexed portion or extension of the rotafoil may have a pronounced camber from its leading point towards the tail, so that in effect the rotafoil is composed of two foil elements continuous with each other but oppositely tilted and cambered on opposite surfaces, the leading foil element being tilted nose inwards and having its cambered surface facing inwards while the trailing foil element is tilted inwardly at the tail and has its cambered surface outwards.

When such an impeller as is shown in Figs. 8 and 9 is applied to a hydraulic pump the impeller has within it, as shown in Fig. 9, a stationary structure of the same character as the corresponding structure of Fig. 2 having expanding channels E along which the water trapped under each advancing rotafoil D^1, D^2 . . . is discharged into a delivery pipe or an expansion duct or diffuser as described with reference to Fig. 2, and these stationary expanding channels may lead inwardly or laterally or in any other desired direction. In a fan or blower the fixed cut-waters are replaced by deflectors on the inside of the rotafoils.

It will be understood from the foregoing description that the essential feature of the invention is an impeller having circumferentially disposed rotafoils, that is to say circumferential blades constructed in the manner described which, upon the impeller being rotated in air or open water or other incompressible fluid, produce a reduction of pressure on one of their surfaces, viz: their trailing surface, with a consequential inflow of the fluid from the surrounding space towards the centre of rotation, and in conjunction with this suitable means for entrapping the fluid within the pressure region and discharging it back into the surrounding medium from the centre of the impeller with the full velocity due to the internal pressure, or to expanding channels leading to a delivery pipe at a suitably reduced velocity and increased pressure.

Having thus described the nature of the said invention and the best means I know of carrying the same into practical effect, I claim:—

1. In rotary pumps, jet propellers and the like, an impeller having circumferential blades rotating without overlap in undisturbed water each blade having the character of an aerofoil bent into a curve as by plotting the cross section of an aerofoil, not along a straight chord, but along a curve.

2. In rotary pumps, jet propellers and the like, an impeller having circumferential blades in the form of rotafoils rotating without overlap in undisturbed water, said blades being tilted to an angle not exceeding approximately 15° with respect to the periphery of the impeller.

3. In rotary pumps, jet propellers and the like, an impeller having circumferential blades in the form of rotafoils rotating without overlap in undisturbed water, said blades being tilted to an angle not exceeding approximately 15° with respect to the periphery of the impeller, and a stationary structure within the impeller provided with expanding channels.

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

EDMUND SCOTT GUSTAVE REES.