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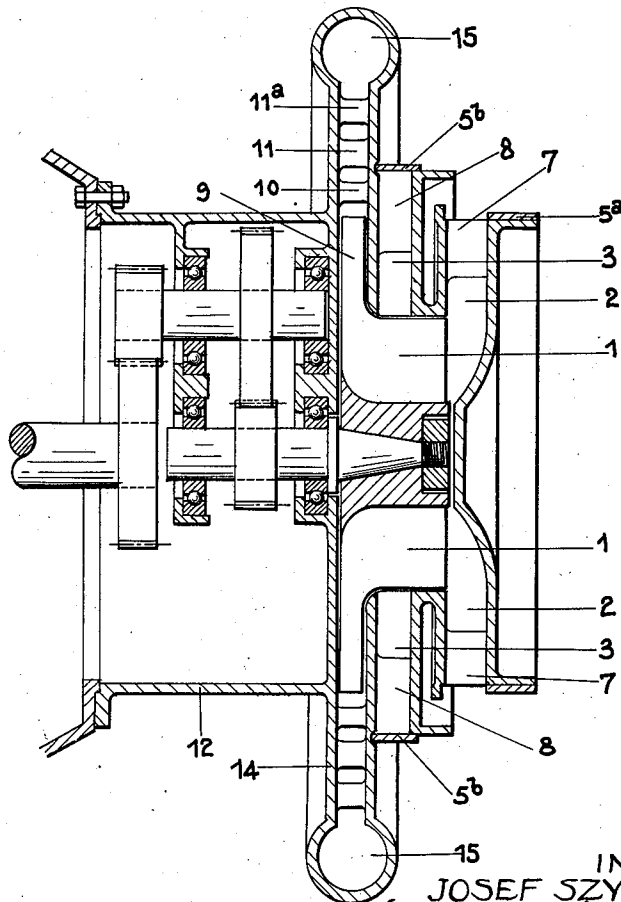
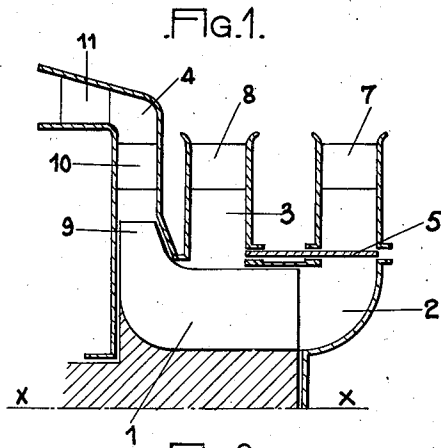
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2,210,155

MACHINE FOR THE DISPLACEMENT AND COMPRESSION OF FLUIDS

Filed July 12, 1937

2 Sheets-Sheet 1



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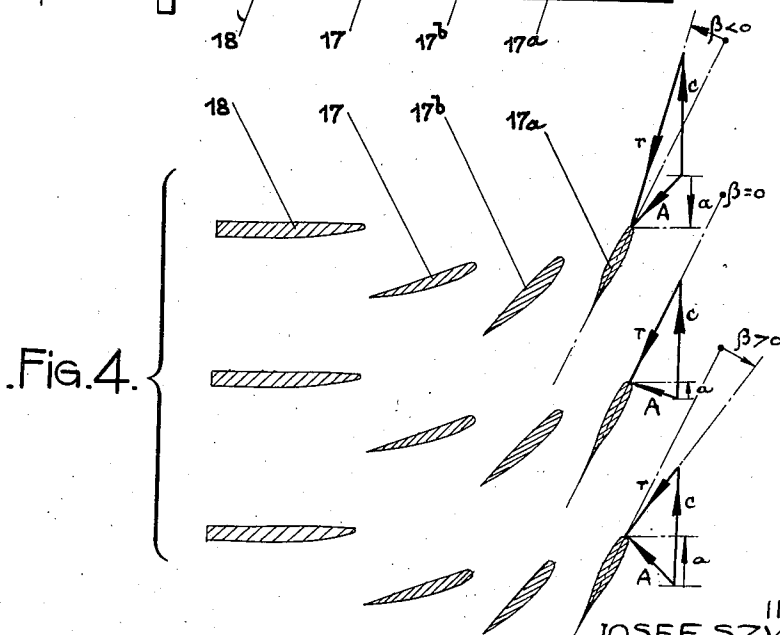
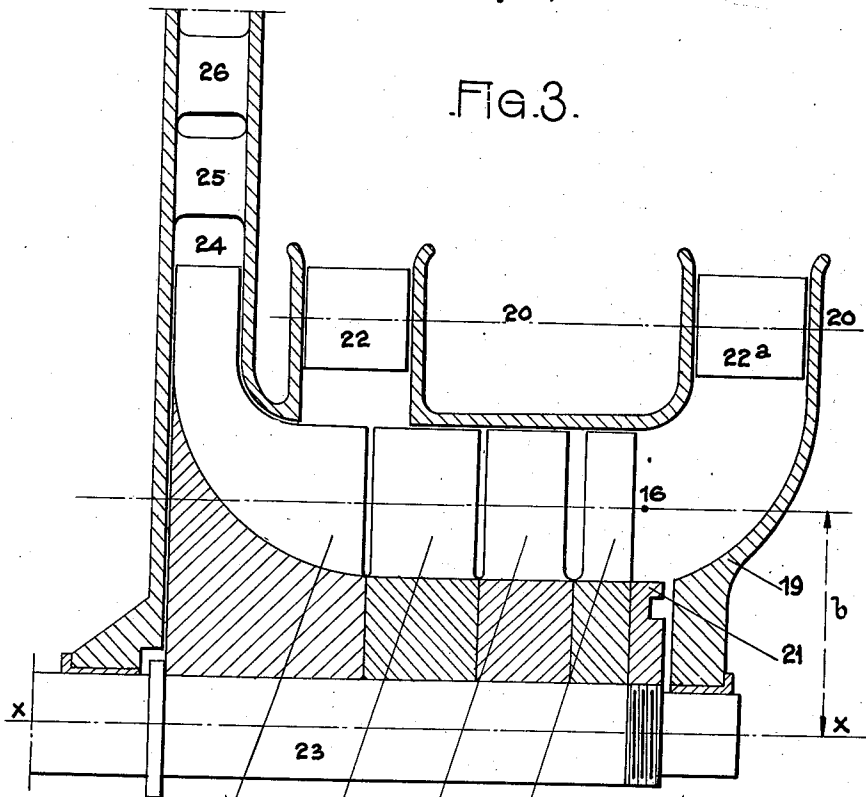
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MACHINE FOR THE DISPLACEMENT AND COMPRESSION OF FLUIDS

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MACHINE FOR THE DISPLACEMENT AND COMPRESSION OF FLUIDS

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The present invention relates to machines for the displacement and compression of fluids, such as turbo-pumps, turbo-blowers, turbo-compressors and the like. It has for its purpose or for industrial result to obtain with these machines and for a constant angular speed of the rotor, speeds or pressures of the fluid which are different at the outlet, and this always with a high efficiency.

The invention mainly consists in providing, for the turbo-machine, at least two distinct fluid inlets which, used at will, each determine, with an entrance theoretically without shock and all things being equal, a different increase of pressure at the outlet, or a different ratio between the pressures at the outlet and at the inlet.

Another object of the invention is to obtain, for the pressure generated by the machine, any desired value comprised between the extreme values which, for one and the same angular speed of the rotor, can correspond to two of the above mentioned inlets provided for the fluid.

The variation of pressure obtained proceeds from the known formula

$$H = \frac{C_2 a_2 - C_1 a_1}{g}$$

into which:

H is the theoretical height of fluid column which balances the pressure produced by the machine.

C_2 and C_1 the speed of the rotor at the outlet and the inlet respectively, a_2 and a_1 the projections upon C_2 and C_1 of the absolute speeds of the fluid at the same places.

These results are obtained by arranging in the fluid inlets guide means, such as fixed or movable sets of blades arranged for imparting to the fluid, before its entrance into the rotor, a speed of rotation about the axis of the machine variable at will, and for so giving to a the necessary value.

The values of the increase of pressure generated which are intermediate between the theoretical values corresponding, for two different inlets, to an entrance without shock into the rotor, can be obtained only by a distortion of the velocity triangle at the leading edge of the rotor. However, this distortion can produce, if it is not prevented, the shock phenomenon at the inlet, which is prejudicial to a satisfactory efficiency.

In order to avoid the shock at the inlet when the normal known structure is absent, usually involving curved surfaces forming the axial portion of the blades of the rotor, the invention consists in replacing these curved extensions of the blades

of the rotor by independent sets of blades, formed wheels on the upstream side of the rotor and rigidly secured on the shaft of the rotor, and therefore rotating at the same angular speed as the latter.

The number of these wheels, the number of blades constituting each of them, the dimensions and profile of said blades, the relative angular fixing of these profiles can then be chosen in order to obtain the best results with a great freedom owing to the increased number of the available variables.

Other advantageous features of the invention are indicated in the description given hereinafter, with reference to the accompanying diagrammatic drawings which illustrate, by way of example only, forms of carrying the invention into practice.

Fig. 1 is a partial axial diagrammatic section showing a turbo-machine having two fluid inlets and utilising, in its most simple embodiment, the principle of the invention.

Fig. 2 is an axial section showing an improved air turbo-compressor constructed according to the principle of Fig. 1.

Fig. 3 is a partial axial section showing an air compressor provided with two inlets and with a rotor having distinct series of blades.

Fig. 4 is a developed view on the plane of figure, of a cylindrical section having b for radius and made through the compressor of Fig. 3.

In the diagrammatic view of Fig. 1 a rotor 1, having $x-x$ for axis, is provided with two air inlets 2 and 3 and an outlet 4. An obturator 5, illustrated as being constituted by a sliding shutter, allows of obturating at will one of the inlets 2 and 3, the other being left open. Sets of guide blades, as indicated above, are provided at 7 and 8 for each of the inlets 2 and 3. If one of the speeds or components of rotation to be imparted to the air entering the rotor 1, is null, the corresponding set of guide blades can be constituted by radial planes, or it can be dispensed with.

Recent researches in hydrodynamics and aerodynamics show that it is impossible to obtain, a suitable recovery of the kinetic energy of the fluid when the air issues from the rotor at 9 and is received by a diffuser of known type.

The invention allows this recovery by arranging, on the downstream sides of the usual set of blades 10, one or more additional sets of blades 11 through which successively passes the fluid issuing from the rotor. Each of these additional sets of blades serves to reduce the residual speed

of the fluid and, consequently, its kinetic energy, by increasing the difference of pressure produced by the machine and, consequently, by increasing its efficiency.

5 The location and arrangement of these sets of blades are variable according to the conditions of adaptation imposed to the machine and the various constraints (axial or diametral cumbersome-ness, weight). In the diagrammatic view of Fig. 1, the blades 10, are, as usual, contained between two planes normal to the axis $x-x$. The blades 11 are contained between two surfaces of revolution having a common axis $x-x$, and any generatrices whatever.

15 By way of example only, the application of the invention for providing a supercharging compressor for an aircraft engine will be described hereinafter. This embodiment is illustrated hereinafter in Fig. 2. The rotor 1 is driven, from the shaft of the engine, by a train of gearing up gears arranged in a casing which can, for instance, be made in one piece with the casing 14 of the compressor. Two air inlets are provided at 2 and 3, each of them having blades 7 and 8, as explained with reference to Fig. 1. Two obturators 5^a and 5^b, in the shape of rings, are axially moved by any suitable driving means, so that one of them obturates the inlet to which it corresponds, whilst the other uncovers its own inlet, and reversely. The issue of the air takes place at 9 towards a header 15. Between the outlet 9 and the header 15 are arranged the sets of blades 10, 11 and 11^a, the function of which has been described with reference to the sets of blades 10 and 11 of Fig. 1.

25 The smallest pressure ratio is obtained when the inlet 8-3 is open, it is used either for the taking off of the airplane, in order to avoid an excessive pressure in the inlet connecting branches at this moment, or during flight under reduced power (cruising flying speed for instance).

The highest pressure ratio, used for full power in altitude, is obtained when the inlet 7-2 is open.

35 The same notation as that employed in the preamble to the present specification will be adopted concerning the theoretical considerations which justify the advantages of the invention.

In the formulas thereafter:

50 C_0 is the tangential speed of the rotor at the radius r_0 of the inlet 3 (Figs. 1 and 2).

ω is the angular speed of the rotor.

55 a_0 is the projection of the absolute speed of the fluid at the same point as above upon the tangential speed C_0 .

C_1 is the tangential speed of the rotor at the mean radius r_1 of the inlet 7-2 of Figures 1 and 2.

60 a_1 is the projection of the absolute speed of the fluid at the inlet 3 (radius r_0) of Figures 1 and 2 upon the tangential speed C_1 .

65 C_2 is the tangential speed of the rotor at the maximum radius r_2 corresponding to the exit of the fluid out of the rotor and before it enters into the diffuser 10 of Figures 1 and 2.

a_2 is the projection of the absolute speed of the fluid at the inlet 3 (radius r_0) of Figures 1 and 2 upon the tangential speed C_2 .

70 $\alpha_0, \alpha_1, \alpha_2$, are three constants which correspond respectively to the above points of the rotor and the values of which depend upon the shape of the said rotor.

75 p_0 and p_1 are the pressures of the fluid at the inlet and the exit of the machine respectively.

The peripheral speed C_2 is, in aircraft compressors, necessarily very high, owing to the high pressure ratios which must be obtained. It is therefore necessary to constitute the rotor solely of radial blades in order to resist to the centrifugal stresses involved.

In these conditions a stream line leaves the rotor with a relative radial movement, whereby:

$$\alpha_2 = C_2 = r_2 \omega$$

$$\alpha_2 = 1$$

Likewise, the terminal portion of the rotor, facing the entrance 3, is composed of radial elements. By adding the index 0 to this portion, one has:

$$a_0 = C_0 = r_0 \omega$$

$$\alpha_0 = 1$$

The pressure obtained with the inlet 8-3 is then proportional to:

$$C_2 a_2 - C_0 a_0 = \omega^2 (r_2^2 - r_0^2)$$

When the inlet 7-2 is open, the surface constituting the leading edge whilst remaining radial, can have such a shape that the admission or entrance without shock is obtained for any value of α_1 : i. e. for instance $\alpha_1 < 0$, that is to say for α_1 of a direction opposed to C_1 . One then has:

$$C_2 a_2 - C_1 a_1 = \alpha_2 (\omega r_2)^2 - \alpha_1 (\omega r_1)^2 > \alpha_2 (\omega r_2)^2$$

since $\alpha_1 (\omega r_1)^2 < 0$.

The ratio of the two pressures obtained will be:

$$\frac{p_1}{p_0} = \frac{C_2 a_2 - C_1 a_1}{C_2 a_2 - C_0 a_0} = \frac{r_2^2 + |\alpha_1| r_1^2}{r_2^2 - r_0^2}$$

by remembering that $-\alpha_1$ is positive.

It is therefore possible by suitably choosing the three mean radii r_0, r_1 and r_2 as well α_1 (that is to say by choosing the shape of the speed triangle at the inlet 2) to give to the ratio

$$\frac{p_1}{p_0}$$

a value satisfying to the necessities of practice.

In the embodiment of Figs. 3 and 4, the rotor has axial-radial surfaces 18 having a purely centrifugal action and it is provided with distinct sets of blades 17, 17^a and 17^b fast, as the surfaces 18, on the same shaft 23 and, consequently, all rotating at the same angular speed.

The change of setting of the sets of guide blades 22^a and 22^b from the position corresponding to the entrance without shock of the fluid into the rotor, necessarily gives rise to a distortion of the velocity triangle at the inlet. This distortion is without inconvenience if it does not exceed the limits between which a correct flow of the fluid is still possible in the inlet of the rotor. The velocity triangle, corresponding to the admission or entrance without shock of the fluid into the front sets of blades of the rotor, illustrated at 17, 17^a, 17^b in the accompanying drawings, can be so much the more departed from as the profiles constituting these sets of blades can admit a more important variation of the angle of incidence of the fluid without causing swerving of the latter and, consequently, will allow, without reducing the efficiency, a more important variation of the pressure generated by utilising the inlet 16 of the machine.

It is at the entrance or inlet of the set of blades 17, encountered by the fluid reaching the rotor that the angle of incidence of the fluid varies the most, when the velocity triangle is distorted by changing the setting of the sets of

guide blades such as 22, movable about the axis 20—20 for modifying the pressure generated by the machine.

An important feature of the invention consists in the use for the sets of inlet blades of the rotor, such as 17, 17^a, 17^b, and more particularly for that which is at the front, of biconvex profiles, having a rounded leading edge and a sharp trailing edge, of the type of those used in aviation.

The most advantageous of these profiles are symmetrical bi-convex profiles, the advantage of which, for this new application consists in the possibility of causing them to operate with an equal efficiency by attacking them on either of their faces with an equal inclination β relatively to their axis of symmetry.

The arrangements of the velocity triangle corresponding to the various values of β are visible in the lower portion of the figure, which illustrates a cylindrical section having b for radius and assumed to be developed on the plane of figure.

The driving speed $c = \omega b$ is assumed to be upwardly directed and is the same in the three cases shown in the figure. In the first case shown at the upper part, the absolute speed of the fluid A is so arranged that its projection a on c is of a direction reverse to the driving speed. The relative speed r is located at the front, in the direction of the movement, relatively to the axis of symmetry and forms the angle β with it. The profile then operates as pressure generator by borrowing energy from the driving shaft and by reducing the relative speed of the fluid.

In the second case, the angle of incidence β is null as well as the action of the profile on the fluid, with the exception of friction, and neither the pressure nor the speed of the fluid vary from the up side to the down side of the profile. In the third case, the absolute speed is projected at a , in the same direction as c ; the relative speed r forms with the axis of symmetry of the profile the angle β and is located rearward of this axis: the profile is therefore attacked from behind.

The action to which it is subjected by the fluid has for effect to increase the relative speed of said fluid and to impart an impulse towards the front of the profile 17 which then operates as a turbine blading profile by transforming the energy of the fluid into a driving power exerted on the shaft of the rotor. This utilisation for two distinct and, so to speak, opposed purposes of one and the same set of movable blades used sometimes for supplying to and sometimes for borrowing energy from the fluid which passes through it and which it subsequently delivers to the down side sets of blades, constitutes an essential feature of the present invention.

The changes of setting of the relative speed of the fluid when it reaches the next sets of blades, are less important at 17^a than at 17 and still less important at 17^b than at 17^a.

It may happen that these changes in the angle of incidence are still sufficient for causing one or more of these sets of blades to operate alternately through one and the other face: the invention extends of course to the use for these sets of blades of any shape suited to these conditions, a biconvex symmetrical or asymmetrical shape for instance.

In the figure, they have been shown by way of indication only without prejudicing the most suitable shape to give them.

It is to be understood that, when the setting

of the sets of guide blades 22 is caused to vary between relatively wide limits in order that the value of the angle of incidence β should become excessive, a shock is produced at the inlet of the profile 17 and a swerving of the jet is also produced along said profile, which shock and swerving have for unavoidable effect to reduce the efficiency of the machine.

But experience shows that the variation of setting gives rise to losses in efficiency which are smaller when it is caused to act for reducing the pressure, than when it is attempted to increase this pressure. In the first case, in fact, the shock at the inlet, which dissipates a part of the energy of the incident fluid, takes place on the rear face of the blades of the rotor and thereby imparts to the latter a forward impulse. This can also be explained if it is considered that a reduction of the pressure generated corresponds to an algebraic increase of the tangential component of the fluid admitted into the rotor, the components directed in the direction of the speed of rotation being positively counted.

Therefore:

On the one hand, a reduction of the useful effect is produced owing to the loss of energy;

On the other hand, a reduction of the power absorbed by the machine is produced, since the latter receives a forward impulse.

The loss in efficiency results only from the difference between these two effects.

The loss in efficiency, if the shock at the inlet takes place on the front face of the blades of the rotor; results, on the contrary, from the sum of the loss of useful effect and of the increase of the resistant torque. This loss is much more important than in the first case. It can be reduced in both cases by the new application, for the construction of the blades of the rotor of the machine, of the wing profiles indicated above.

By successively acting on the sets of guide blades of a plurality of fluid inlets, such as 22, 22^a, movable about the axis 20—20, wide and nearly continuous variations of the pressure generated by the machine can be produced, with a reduction in efficiency as small as possible, since the distortion of the velocity triangle is thus reduced in each of the inlets successively employed relatively to what it would be in a machine having a single inlet.

Fig. 4 allows of ascertaining that, for one and the same variation of the component of rotation a , corresponding to a displacement on its axis of the vector c , the angle under which the displacement of its end is seen from the point where the profile is attacked, is more or less small.

Now, this angle represents the variation of the angle according to which the profile is attacked by the fluid.

For obtaining an important variation of a without any swerving of the jet, it is therefore advantageous that the angle of the directions of the vectors c and r (or angle external to the velocity triangle) should approximate as much as possible 180 degrees, the angle according to which the displacement of the end of c is seen being then minimum.

Such an arrangement of the triangle A, c, r , obviously corresponds to the case in which the component a is negative and very high in absolute value. This result can be obtained without swerving of the jet only with multiple sets of up side blades owing to the very great deflection

to which the fluid jet is to be subjected for entering the axial-radial portion 18 of the rotor.

The total obturation of the fluid inlets of the rotor, by a suitable setting of the movable blades provided in the various inlets, substantially avoids the necessity of using obturators, such as 5, 5^a and 5^b of Figs. 1 and 2. The figure has been drawn by assuming, by way of example, that the machine was not provided with such obturators. However, said obturators can be maintained for ensuring a perfect fluid-tightness.

What we claim as our invention and desire to secure by Letters Patent is:

1. In a machine for the displacement and compression of fluids, a rotor adapted to rotate coaxially in a casing and having blades for displacing the fluid, an annular peripheral inlet for the fluid at an end of the casing, an annular peripheral outlet at the other end, successive sets of distinct blades in the said outlet on the down side of the rotor for transforming kinetic energy of the fluid into potential energy, an intermediary annular peripheral inlet for the fluid upon the said casing, sets of guide blades in each of the said inlets for imparting to the fluid before its admission into the rotor, a rotating motion about the axis of the rotor, and means for closing at will one of the said inlets.

2. In a machine for the displacement and compression of fluids, a rotor adapted to rotate coaxially in a casing, and having blades for displacing the fluid, an annular peripheral inlet for the fluid at an end of the casing, an annular peripheral outlet at the other end, successive sets of distinct blades in the said outlet for transforming kinetic energy of the fluid into potential energy, the said sets of blades being arranged between surfaces of revolution about the axis of the rotor, an intermediary annular peripheral inlet for the fluid upon the said casing, and means for closing at will one of the said inlets.

3. In a machine for the displacement and compression of fluids, a rotor adapted to rotate coaxially in a casing and having blades for displacing the fluid, an annular peripheral inlet for the fluid at an end of the casing, an annular peripheral outlet at the other end, successive sets of distinct blades in the said outlet for transforming kinetic energy of the fluid into potential energy, the said sets of blades being arranged between surfaces of revolution about the axis of the rotor, an intermediary annular peripheral inlet for the fluid upon the said casing, sets of guide blades in each of the said inlet for imparting to the fluid before its admission into the rotor, a rotating motion about the axis of the rotor, and means for closing at will one of the said inlets.

4. In a machine for the displacement and compression of fluids, a rotor with a portion having solely centrifugal action and adapted to rotate coaxially in a casing and having successive sets of blades on the up side of the portion of the said rotor having a solely centrifugal action, an annular peripheral inlet for the fluid at an end of the casing, an annular peripheral outlet at the other end, an intermediary annular peripheral inlet for the fluid upon the said casing, sets of guide blades in each of the said inlets for imparting to the fluid before its admission into the rotor, a rotating motion about the axis of the rotor, and means for closing at will one of the said inlets.

5. In a machine for the displacement and compression of fluids, a rotor with a portion having solely centrifugal action and adapted to rotate coaxially in a casing and having successive sets of blades on the up side of the portion of the said rotor having a solely centrifugal action, an annular peripheral inlet for the fluid at an end of the casing, an annular peripheral outlet at the other end, successive sets of distinct blades in the said outlet for transforming kinetic energy of the fluid into potential energy, an intermediary annular peripheral inlet for the fluid upon the said casing, and means for closing at will one of the said inlets.

6. In a machine for the displacement and compression of fluids, a rotor with a portion having solely centrifugal action and adapted to rotate coaxially in a casing and having successive sets of blades on the up side of the portion of the said rotor having a solely centrifugal action, an annular peripheral inlet for the fluid at an end of the casing, an annular peripheral outlet at the other end, successive sets of distinct blades in the said outlet for transforming kinetic energy of the fluid into potential energy, the said sets being arranged between surfaces of revolution about the axis of the rotor, an intermediary annular peripheral inlet for the fluid upon the said casing, sets of guide blades in each of the said inlets for imparting to the fluid before its admission into the rotor, a rotating motion about the axis of the rotor, and means for closing at will one of the said inlets.

7. In a machine for the displacement and compression of fluids, a rotor with a portion having solely centrifugal action and adapted to rotate coaxially in a casing and having successive sets of blades on the up side of the portion of the rotor having a solely centrifugal action and rigidly secured on the same axis as the said rotor for deflecting the fluid by avoiding shocks and swerving movements, an inlet for the fluid in the casing, means arranged in the said inlet for imparting a rotation to the fluid before it enters the rotor, and successive sets of distinct blades in the outlet, for transforming kinetic energy of the fluid into potential energy, the said sets being arranged between surfaces of revolution about the axis of the said rotor.

8. In a machine according to claim 6, successive sets of blades on the up side of the portion of the rotor having a solely centrifugal action and at least the first of the said sets having blades with a symmetrical bi-convex profile.

9. In a machine according to claim 7, provided with successive sets of blades on the up side of the portion of the rotor having a solely centrifugal action and wherein, at least, the first of the said sets having blades with a symmetrical bi-convex profile.

10. In a machine according to claim 7, wherein at least the first of the sets of blades has blades with a symmetrical bi-convex profile, and the component of rotation of the fluid at an inlet has a direction reverse to the rotation of the rotor.

11. A machine according to claim 7, wherein the component of rotation of the fluid at an inlet has a direction reverse to the rotation of the rotor.

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