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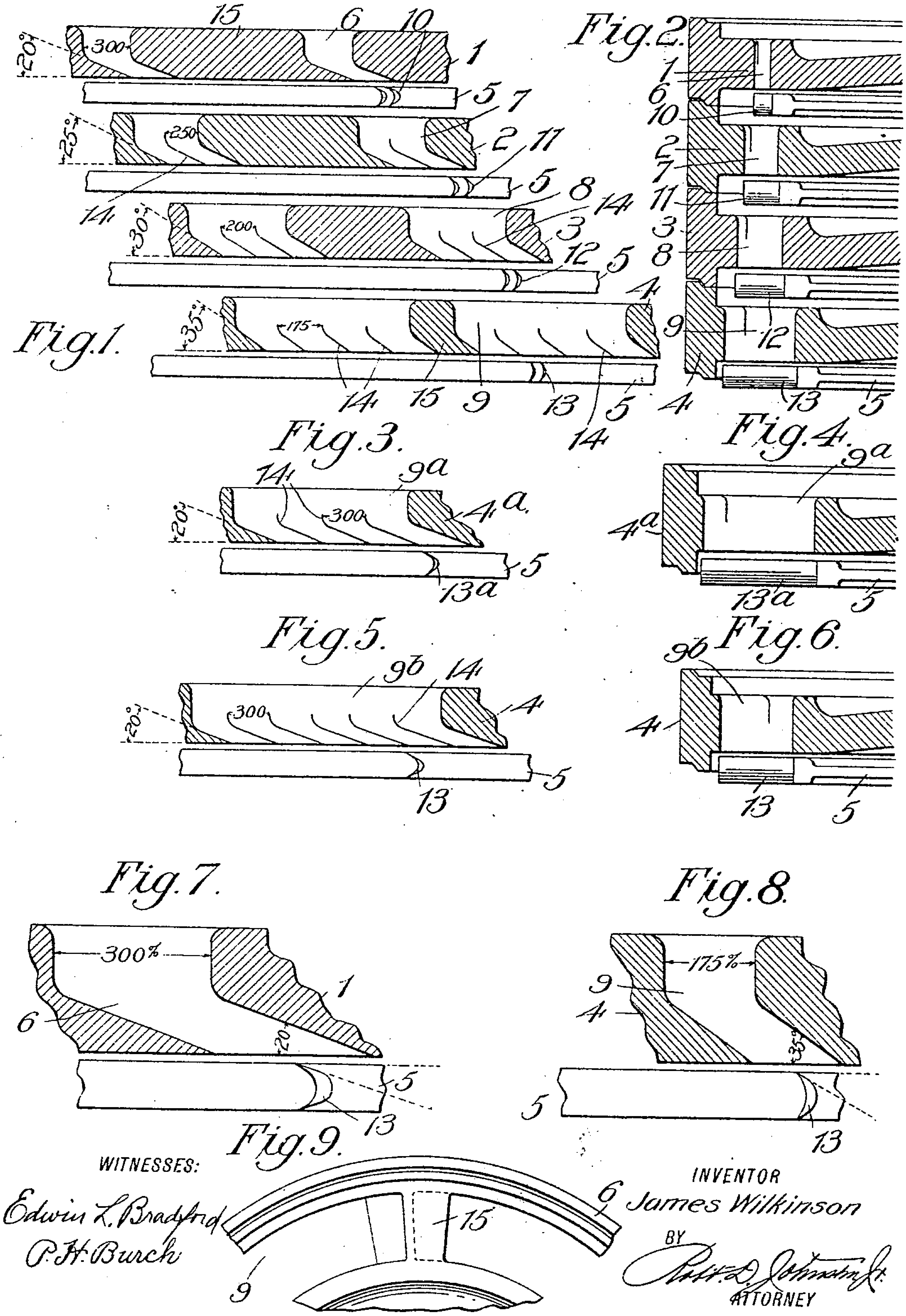
J. WILKINSON.

ELASTIC FLUID TURBINE.

APPLICATION FILED JUNE 23, 1905.



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ELASTIC-FLUID TURBINE.

No. 822,799. Specification of Letters Patent. Patented June 5, 1906.

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To all whom it may concern:

Be it known that I, JAMES WILKINSON, a citizen of the United States, residing at Providence, in the county of Providence and State of Rhode Island, have invented new and useful Improvements in an Elastic-Fluid Turbine, of which the following is a specification.

My invention relates to elastic-fluid turbines operating by stage expansion of the motor fluid to convert it fractionally into *vis viva*, which is abstracted by sets of rotatable buckets disposed within the stage-compartments.

In turbines of this general type as the fluid flows from stage to stage and acts successively against the rotatable buckets therein it increases in volume as it drops in pressure. This necessitates the provision of a working passage for the fluid which increases in cross-sectional area across stages in accordance with the fluid's increase in volume. This working passage comprises nozzle-passages for the fluid between stages, which successively increase in cross-sectional area, these nozzle-passages being formed in or leading through the division wall or walls between stages which may be considered here as diaphragms. One of the most important points to be considered in designing a turbine of this type is the cross-sectional area of the last row or rows of nozzle-passages relative to the available cross-sectional area of the passage at the admission side of the diaphragm, since they will fix the cross-sectional area of the first and other rows of nozzles, which are of a definite proportion to the last row and determine the total capacity or power of the turbine. For this reason it is important that the capacity of the last row of nozzles should be as large as is consistent with maintaining the proper strength in the diaphragm through which they lead, as this diaphragm must be designed to preserve the strength and stiffness requisite to withstand the pressure to which it is or may be subjected.

The object of my present invention is to design a turbine which will possess the greatest possible nozzle capacity consistent with proper strength in the diaphragm.

It will be evident that the area of the nozzle-supply openings in the last diaphragm should be as large as its strength will permit to produce the maximum nozzle capacity for the last stage. In practice the diaphragms are provided with webs or arms between the several nozzles, which must possess sufficient strength to withstand the pressure-load on the diaphragm. Where the diaphragm must be provided with nozzles calculated to pass the fluid in an expanded condition, the problem of preserving the stiffness of the diaphragm and at the same time discharging the fluid with the highest efficiency against the succeeding buckets becomes of vital importance. The nozzle-supply openings being larger in cross-sectional area than the nozzles become the determining factor in design.

It will be evident that the diaphragm-passages must be enlarged either circumferentially or radially to increase their capacity. When elongated circumferentially, the increase in their proportions is limited by the necessity of preserving the necessary width of supporting-webs. Their radial enlargement is also limited by the practicable bucket length and the disadvantages attendant upon the use of long buckets. These two methods of enlarging the working passage are now commonly practiced and carried to the maximum extent consistent with safety and efficiency According to my invention, taking this maximum nozzle-supply area or capacity as a fixed quantity, the available cross-sectional area and the capacity of the nozzles proper may be further increased relatively thereto without affecting the strength of the diaphragm by increasing the angle of inclination of the nozzles. It must be readily evident that the cross-sectional area of two parallel nozzles leading at different angles from the same supply-opening will be different, the area increasing as the nozzle-angle approaches ninety degrees to the plane of the buckets' rotation. Here, then, we find a purely mechanical condition by which without sacrifice of diaphragm strength or large increase of bucket length and wheel diameter the nozzle capacity may be materially increased relatively to a fixed maximum supply area or capacity. It is therefore an important object of my invention to provide a turbine having pressure-loaded diaphragms or equivalents with nozzle-passages of relatively increasing angular inclination toward its discharge end, whereby I am enabled to pass a maximum volume of fluid with a minimum bowl or supply-opening in the diaphragms.

The inclination of the nozzles and the curvature of the buckets have a fixed relationship which must be provided for in designing a turbine where the angles of nozzle inclination vary, and it may be roughly stated that the angle of the buckets' receiving edges to their plane of rotation should increase in proportion with the nozzle angle, while the curvature or depth of the buckets should decrease. I therefore propose to provide the turbine above described with rows of buckets having increasing angles and decreasing concavity toward the low-pressure end of the turbine, it being assumed that the lower efficiency at which the fluid will act upon buckets of less depth and curvature will be compensated by reducing the fan action of the long buckets, which would otherwise be necessary in the low-presssure stage or stages.

Briefly stated, it is my object to increase the angle of both nozzles and buckets proportionately to enable a maximum amount of fluid to pass with as small loss as possible through a minimum opening or working passage in a diaphragm or division wall or walls between stage-compartments.

As illustrative of the principles governing turbine construction and pertinent to the conditions which control the designing of a machine in accordance with my present invention, I make reference to the accompanying drawings, in which—

Figure 1 is a vertical sectional view through the working passage of a multistage turbine in which there is a successive increase in the degree of nozzle inclination and bucket angle, while there is a successive decrease in the bucket concavity or curvature and depth. Fig. 2 is a partial vertical section through one of the working passages, Fig. 1. Fig. 3 illustrates the construction of a nozzle-passage in the last diaphragm, Fig. 1, when the nozzle has an inclination of twenty degrees. Fig. 4 is a section through Fig. 3, which by comparison with Fig. 2 illustrates the increased radial dimensions of both nozzle and bucket requisite to pass the same amount of fluid as flows through the last nozzle in Fig. 2. Fig. 5 illustrates the circumferential elongation of the nozzle-passage in Fig. 3 requisite to pass the same volume of fluid when the nozzle and bucket correspond in radial dimensions with the last nozzle and bucket illustrated in Fig. 2. Fig. 6 is a sectional view through Fig. 5. Figs. 7 and 8 are enlarged views of nozzle-passages, illustrating more clearly the relation between the cross-sectional areas of the nozzles proper and their supply-openings for different angles of nozzle inclination. This view also illustrates the variation in bucket angles and concavity. Fig. 9 is a partial plan view of a diaphragm, illustrating one of the webs or arms which support the pressure-load on the diaphragm and determine its strength.

Similar reference-numerals refer to similar parts throughout the drawings.

I have illustrated my invention embodied in a multistage turbine comprising a plurality of diaphragm-partitions 1, 2, 3, and 4, which subdivide the turbine into wheel-compartments within which the wheels 5 rotate. These wheels are keyed to a shaft (not shown) and carry concavo-convex buckets, which coöperate with nozzle-passages leading at an incline through the diaphragms.

The diaphragms may form the exterior casing or may be connected to an outer shell or retained in relative position in any desired manner. Also fluid-pressure may be supplied to the initial set of nozzles in any desired manner, none being here shown, as the same forms no part of my present invention. The nozzles 6, 7, 8, and 9, which respectively lead through the successive diaphragms 1, 2, 3, and 4, respectively coöperate with sets of buckets 10, 11, 12, and 13, carried by the wheels 5. For the purpose of illustrating the principles governing the improved design of this turbine I illustrate these nozzles as of the parallel type and disposed at successively-increasing angles to the plane of rotation of their respective buckets. Thus the nozzles 6, of which there may be several successive rows of the same size and inclination, are inclined at an angle of twenty degrees, the nozzles 7 at an angle of twenty-five degrees, the nozzles 8 at an angle of thirty degrees, and the nozzles 9 at an angle of thirty-five degrees. As the nozzles increase in circumferential proportions they are provided with guides 14, secured therein in any desired manner and subdividing the nozzle into parallel passages for the motor fluid. Using the term "bowl" to designate generally the enlarged supply end from which the nozzles proper lead, it will be noted readily that the cross-sectional areas of the bowls or supply-openings differ from that of the nozzles. Thus taking the areas of the nozzles proper as a base and giving it a rating of one hun dred per cent. opening, the relative rating of the supply-opening for the nozzle when at an angle of twenty degrees will be substantially three hundred per cent., when at an incline of twenty-five degrees substantially two hundred and fifty per cent., when at an incline of thirty degrees substantially two hundred per cent., and when at an incline of thirty-five degrees substantially one hundred and seventy-five per cent. Figs. 7 and 8 more clearly illustrate these extremes, the nozzles there shown being of equal cross-sectional area and capacity, whereas the relative area of the supply-opening for the nozzle having an inclination of twenty degrees is nearly twice as large as that of the nozzle having an inclination of thirty-five degrees. From this it follows that the greater the angle of nozzle inclination the less amount of metal it is necessary to cut out of the diaphragm to pass equal volumes of fluid therethrough. The value of the application of this principle of design to a turbine is evident when we consider the importance of providing the last diaphragms with a maximum nozzle-opening consistent with preserving their strength, for by increasing the angle of nozzle inclination, as shown in Fig. 1, the undesirable results which would follow from the use of nozzles of the same inclination, as illustrated in Figs. 3 and 6, are largely avoided. Referring to the nozzle-passage 9 in the last diaphragm, by increasing its angle of inclination from twenty to thirty-five degrees I am enabled to reduce the cross-sectional area of the supply-opening approximately forty per cent. and at the same time to shorten the radial length of the buckets approximately fifty per cent. I thus avoid not only weakening the diaphragm, but also increasing the diameter of the bucket-wheels due to the elongation of the buckets, which would require a corresponding increase in the dimensions of the diaphragm and outer casing of the turbine. This latter point is illustrated by the comparison of Fig. 4 with Fig. 2, the nozzle 9^a, diaphragm 4^a, and buckets 13^a being designed for dimensions which would be requisite if substituted for the last diaphragm 4 and buckets 13 in Fig. 2. If this change in wheel diameter is to be avoided, it can only be done without my invention, as shown in Figs. 5 and 6, where the circumferential elongation of the nozzle 9^b will reduce the number of webs or arms 15, and as a certain number of these are requisite to insure the stiffness of the diaphragm the nozzle capacity must be sacrificed to provide for them.

Without further elaborating the advantages attendant upon the use of the nozzles of varying inclination I pass on to a consideration of the design of the buckets calculated to coöperate at highest efficiency with the several sets of nozzles. The angle of inclination of the nozzle is the determining factor controlling the angle of the bucket's receiving edges to the jet of fluid and also the maximum concavity which the bucket's impact-surface may have. The increase in the angles of the nozzles in the last diaphragm or diaphragms will necessitate an increase in the angles of the bucket's receiving edges and a decrease of its concavity. In Figs. 7 and 8 I have illustrated the changes in bucket conformation attendant upon a change of fifteen degrees in nozzle inclination. It will be understood that the angles and conformation of the buckets may be varied from the disclosure, that shown being approximately estimated as the most efficient design for coöperating with the nozzles at the indicated angles.

In the drawings and preceding specification I have illustrated and described one form of turbine embodying my invention. This is done in compliance with the requirements of the patent law and not with a view to limiting myself either to the angles given or the construction shown, the invention being of such a character that it may be varied with the design of each turbine and may be applied to any of the forms of turbine now in use, whether the stage-comparments be formed in the same or separate shells or whether substantially the equivalent of diaphragms be used.

Having thus described my invention, what I claim as new, and desire to secure by Letters Patent, is—

1. An elastic-fluid turbine operating by stage expansion and having a working passage which enlarges across stages, the provision therein of successive nozzles formed in stationary elements and disposed at increasing angles across stages to the plane of bucket rotation, and buckets of decreasing concavity coöperating with said nozzles.

2. In a multiple-stage turbine, buckets rotatable within the several stages, and nozzle-passages discharging fluid-pressure against said buckets, the nozzle-passages for supplying motor fluid to the low-pressure stage or stages having a greater angle of inclination than the nozzles for the other stage or stages, substantially as and for the purposes described.

3. In a multiple-stage turbine, buckets rotatable within the several stages, nozzle-passages discharging fluid-pressure against said buckets, the nozzle-passages for the low-pressure stage or stages having a greater angle of inclination than the nozzles for the other stages, and the buckets coöperating with said nozzle-passages having different angles of inclination, substantially as described.

4. In a multiple-stage turbine, stationary elements between the stage-compartments, nozzle-passages leading through said elements and forming conduits for the fluid between stages, said nozzles having relatively smaller induction ends, as proportioned to the cross-sectional area of the nozzles, and relatively larger angles of inclination, for the low-pressure stages than for the high-pressure stages.

5. In a multiple-stage turbine, partitions between stages and nozzle-passages leading through said partitions and having enlarged admission-openings and angularly-disposed discharge-passages leading therefrom and constituting the nozzles proper, the cross-sectional area of the nozzles proper for the last stages being increased relatively to the cross-sectional area of their admission-openings.

6. In a turbine operating by stage expansion, nozzle-passages formed in stationary elements through which the motor fluid flows

in succession to act against rotatable buckets, and supply-openings for the nozzles, the cross-sectional area of said openings representing a decreasing percentage of the cross-sectional area of their respective nozzles for the last stage as compared with the preceding stages.

7. In a multiple-stage turbine, fluid-supply nozzle-passages comprising enlarged admission ends and nozzles proper leading therefrom, the cross-sectional area of the nozzles proper for the last stage or stages being increased relatively to the cross-sectional area of their admission ends by increasing their angle of inclination to the rotating buckets against which they discharge fluid.

8. In an elastic-fluid turbine subdivided into stages by diaphragms, nozzle-supply openings formed in said diaphragms and nozzles leading therefrom at a determined angle, the angle of the nozzles in the last diaphram being greater than that of the nozzles in preceding diaphragms, and buckets in the several compartments which coöperate with said nozzles, the buckets for the nozzles having the greater inclination being less concave than the other buckets but having their admission edges disposed at a relatively greater angle to their plane of rotation than said other buckets.

In testimony whereof I have hereunto set my hand in the presence of two subscribing witnesses.

JAMES WILKINSON.

Witnesses:
M. Freeman Cocroft,
A. Brintnall Tingley.