No. 874,965.

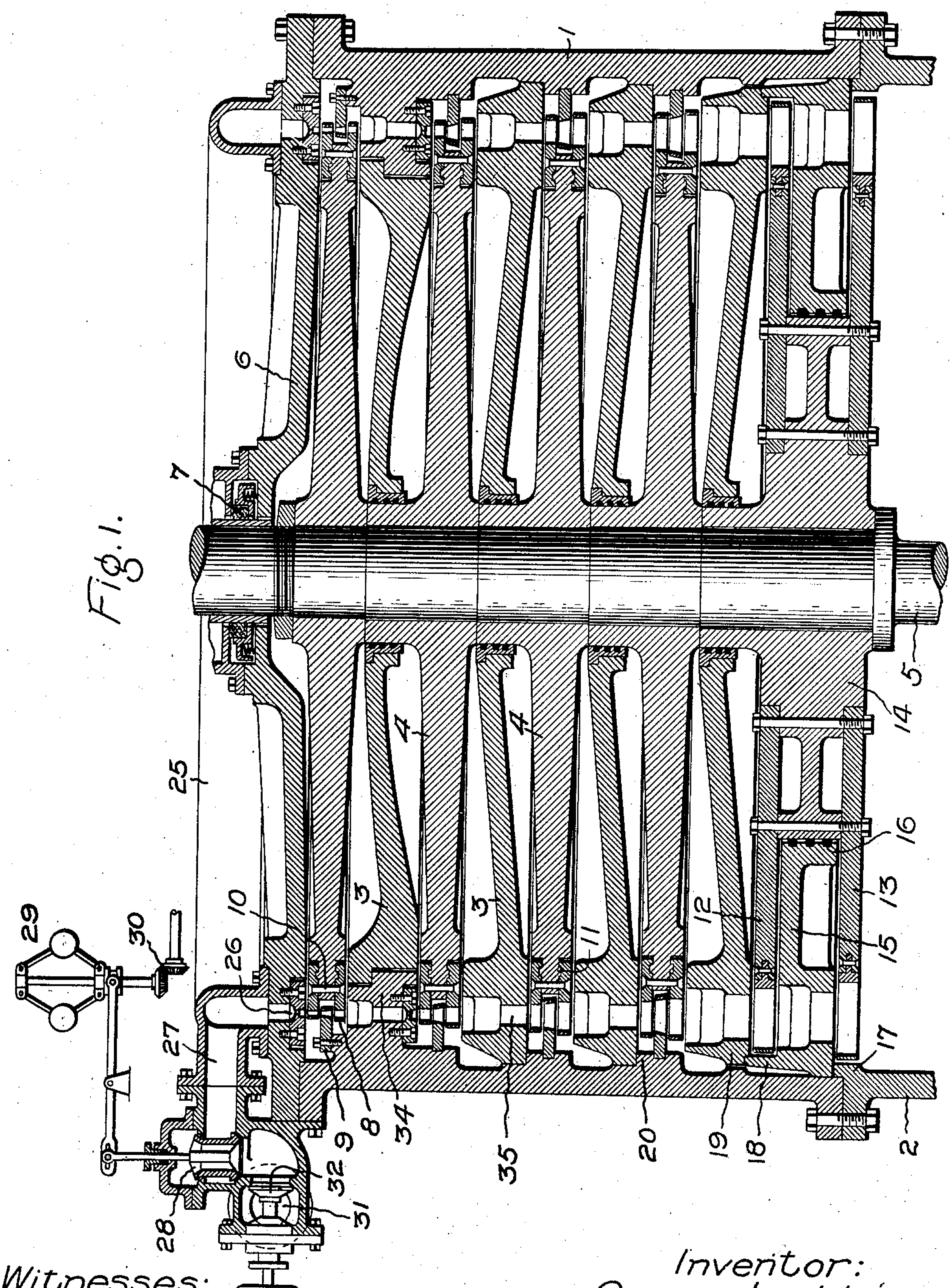
PATENTED DEC. 31, 1907.

O. JUNGGREN.

MULTIPLE STAGE IMPACT TURBINE.

APPLICATION FILED AUG. 9, 1905.

2 SHEETS—SHEET 1.



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2 SHEETS—SHEET 2.

Fig. 3.

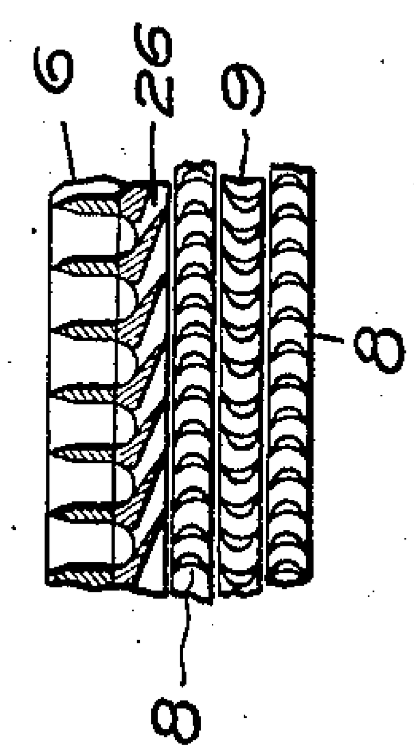


Fig. 4.

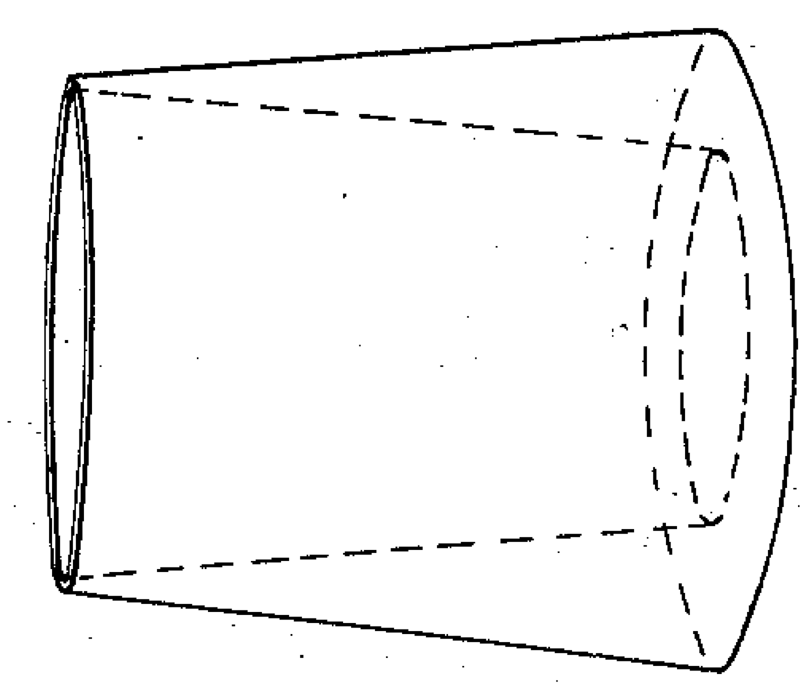
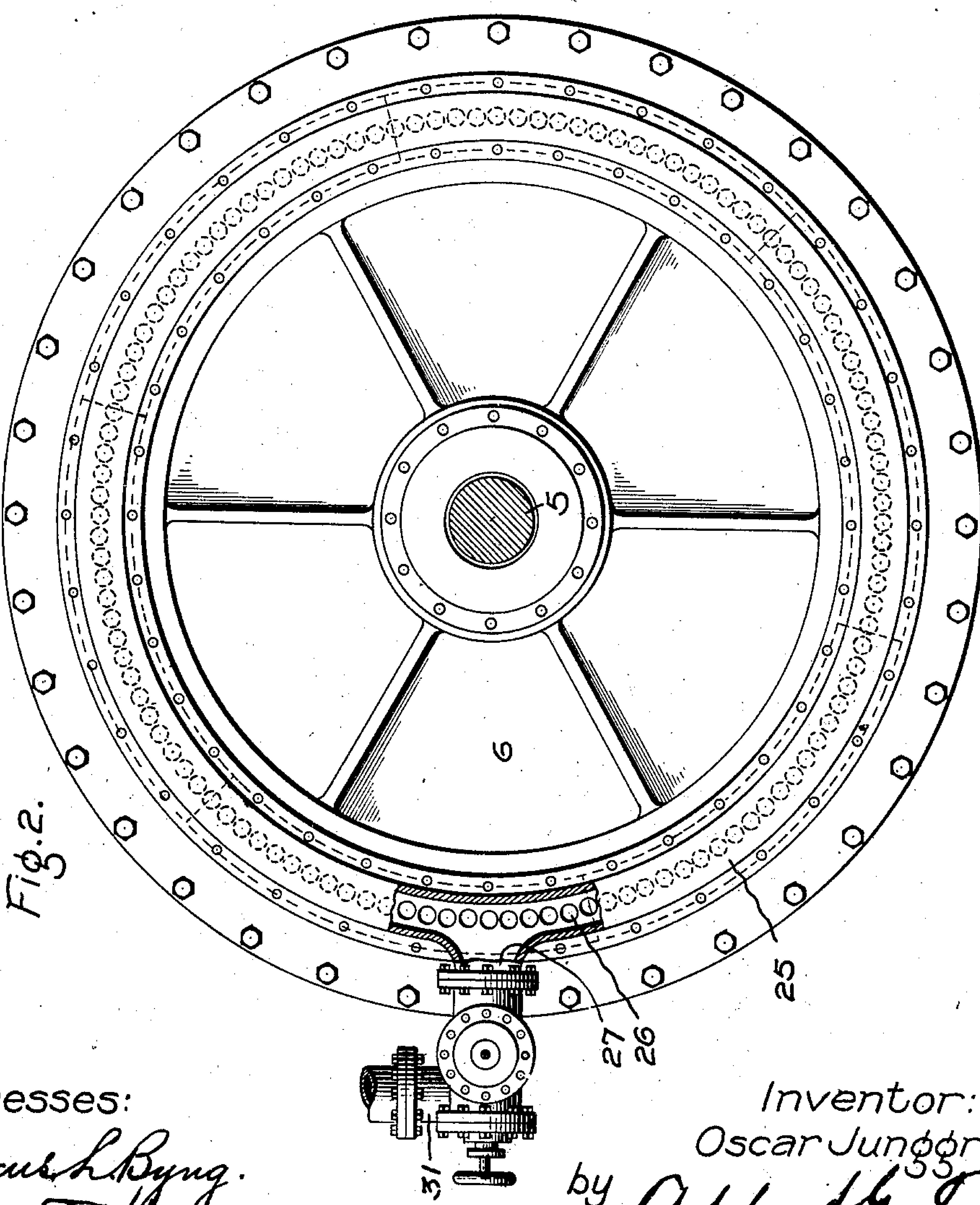


Fig. 2.



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UNITED STATES PATENT OFFICE.

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MULTIPLE-STAGE IMPACT-TURBINE.

No. 874,965. Specification of Letters Patent. Patented Dec. 31, 1907.

Application filed August 9, 1905. Serial No. 273,361.

To all whom it may concern:

Be it known that I, OSCAR JUNGGREN, a citizen of the United States, residing at Schenectady, county of Schenectady, and State of New York, have invented certain new and useful Improvements in Multistage Impact-Turbines, of which the following is a specification.

Elastic-fluid turbines of the multi-stage type operating on the jet or impact principle are capable of efficiently abstracting the energy from the motive fluid delivered thereto, but as now constructed they are subject to certain losses which it is the purpose of this invention to prevent or overcome.

As now constructed the motive fluid, which may be of any suitable character but for the purposes of this description will be referred to as steam, is admitted to the turbine through suitably formed nozzles of comparatively large cross-section of discharge, covering only a very limited arc of the first stage bucket wheel or wheels. The buckets themselves are relatively deep in order that the necessary amount of steam can impinge thereon and pass through the bucket spaces to develop the required power. This means that the majority of the buckets, at least in the early stages, are not only idle during a large portion of each rotation of the wheel but are actually opposing a certain resistance to rotation due to their fan-like action. In addition to this there is a certain resistance to rotation due to the friction between the body of the wheel and bucket supports and the surrounding medium; this resistance or loss is greatly increased if there are any ribs or projections on the wheel or supports extending at right angles to the direction of motion.

In addition to the foregoing there is a loss due to the energy required to start the dead steam in the spaces between the idle buckets into motion as the latter pass in front of the nozzles. The buckets pass the nozzles under high velocity, 350 to 450 feet per second not being unusual. The spaces between the buckets are filled with dead steam at the pressure and density of the stage in which they are located, and before the steam jet can perform any useful work it has to start this dead steam into motion and get it out of the way. This obviously requires a certain amount of energy. The amount required for each bucket space is small, but the aggregate is considerable. Calculation shows that in a certain machine of 2000-kilo-watts rated capacity the energy required to start the dead steam into motion may consume as much as $2\frac{1}{2}$ per cent. of the total energy required under full-load conditions. These losses are greatest in the high-pressure stage, and decrease by stages as the density of the steam decreases. These figures differ of course with different machines and are given merely as an illustration. When two or more separated nozzles or groups of nozzles are employed the losses are correspondingly increased because the dead steam in the bucket spaces in front of each nozzle has to be discharged before the buckets become fully effective. The amount of moisture in the dead steam also has to be taken into account in this connection.

There is also an additional loss as the buckets leave the active stream or jet because the bucket spaces are filled with a body of steam moving at a given velocity, which, as soon as the supply is shut off by reason of the bucket spaces moving beyond a nozzle, or as soon as these spaces are adjacent to a blank section of an intermediate, immediately loses its velocity wholly or in large part, and therefore is incapable of performing its proper share of the work. To state the matter in a different way, the rapidly moving buckets drag the steam with them to a certain extent out from under the supply nozzle thereby permitting the steam to leave the wheel without doing its full share of the work. Besides failing to perform its share of the work, this steam may be a source of further loss by interfering with the proper functioning of some of the other nozzles or buckets in the stage. Anything which tends to divert the fluid stream from its prescribed path is objectionable as it results in losses of one character or another.

Another loss is occasioned by the currents of steam circulating within the stage or wheel compartment. These currents of steam may flow in various directions in the stage, as for example, from one side to another and parallel or substantially parallel to the wheel-body or web, where the nozzles are angularly displaced about the wheel. These currents of steam tend to disturb the flow through the nozzles and create objectionable eddies and losses.

My invention therefore has for its object to provide a multi-stage elastic-fluid turbine, operating on the jet or impact principle, of improved construction, which is free from the objections above referred to and which efficiently abstracts the energy of the motive fluid by successive stages.

In carrying out my invention the turbine is divided into as many stages of expansion as are desirable or necessary to effectively abstract the energy from the motive fluid. In each of these stages are as many wheel buckets as are necessary arranged in one or more rows to abstract the velocity of the steam wholly or in large part. When two or more rows of wheel buckets per stage are employed to fractionally abstract the energy of the steam in said stage, intermediate buckets are located between each two rows. Ordinarily the intermediate buckets will be stationary, but they may revolve in a direction opposite to the wheel if desired. Instead of making the buckets in the earlier stages relatively deep and wide, as in the previous constructions, I make them relatively shallow and narrow, since they are all in action when the machine is in operation. Owing to the fact that all of the wheel buckets are active, I may make the diameter of the wheels in one or more of the high-pressure stages of less diameter than those in the low-pressure stage or stages. This construction obviates the use of especially small nozzles and buckets in the earlier stage or stages, which may be objectionable in some cases owing to the difficulty of manufacture and also on account of the leakages.

Steam is admitted to the turbine through a number of nozzle orifices of small cross-sectional area which convert a portion of the steam pressure into velocity, the sum total of said areas being sufficient to supply the necessary amount. These nozzles or nozzle sections may be expanding or non-expanding in character in some or all of the different stages. The nozzle orifices or passages should be so closely associated and arranged that the steam issues therefrom in the form of a solid unbroken column or belt which is cylindrical in cross-section. These nozzles instead of acting on a limited arc of the wheel circumference in the different stages as in the former construction, are so arranged that they act on the entire circumference of the wheel.

In addition to the admission nozzles, nozzles are provided for each stage which are similar in their arrangement and mode of operation. These nozzles have a somewhat greater cross-sectional area, due to the increased volume of the steam caused by the reduced pressure, but in each stage the fluid discharged therefrom should act on all of the buckets. These nozzles may also be expanding or non-expanding in character, and the discharge orifices or passages should be so closely associated that the steam issues therefrom in an unbroken cylindrical column. Since the pressure of the steam is reduced and its volume augmented in passing from the stage of highest to lowest pressure it follows that the areas of the nozzle passages and bucket spaces throughout the turbine must increase as the pressure decreases and in proportion thereto.

From the foregoing it is evident, disregarding for a moment the physical structure of the turbine, that the steam flows axially through the machine in the form of a substantially cylindrical and hollow body, the contour of which is at no point broken. This arrangement of steam flow obviates the losses due to the fan-like action of the buckets, the losses caused by starting dead steam in the bucket spaces into motion, the dragging of the column of steam out of its proper plane or path by reason of the high rotative bucket speed, and finally it holds the steam particles at the periphery of the wheels and in line with the nozzles and buckets and thus prevents any cross-currents. This also prevents the steam from striking the adjacent walls of the casing or the diaphragms between stages and rebounding against the buckets and thus opposing rotation.

The buckets in the stages should be so constructed and arranged with respect to the wheels or supports that there are no projections whatsoever acting to retard the rotation of the wheels. This is particularly important in the high-pressure stages where the density of the steam is high. As an example of what is meant, the parts of the wheel should be perfectly smooth with no projecting bolt-heads, nuts, ribs, projections, etc. The wheel parts should be made as smooth as possible, and preferably also the interior of the wheel casing and the supports for the intermediate buckets and nozzles. By making the buckets smaller in the first stage than is possible with partial injection machines of the same power there is a material gain due to the fact that the buckets do not offer so much opposition to rotation.

Located within one or more of the stages, and preferably in all of them, is a ring presenting a smooth unbroken surface to the wheel and in close proximity thereto. This ring should be separated from the wheel by a clearance which is less than that between the wheel and intermediate buckets so as to prevent them from contacting and causing damage. This is an important feature since the buckets are relatively small and constitute the more delicate part of the organization.

The ring may be made in one piece or in segments, and it may form an integral part of a casing wall or diaphragm or partition between stages, or it may be separable therefrom. It is preferable to provide one or more for each stage and to form it or them as integral parts of the diaphragm. This adds greatly to the simplicity of the construction, decreases the amount of machine work, labor in handling, and tendency of the parts to distort due to heat changes.

With a turbine constructed as above I may and prefer to use a throttling type of governing mechanism and throttle the admission of steam to the first stage, since it is desirable not to interrupt the continuity of the fluid column. The overload condition can be taken care of by admitting live steam to the subsequent stages of lower pressure after the first, through nozzles having the proper ratio of expansion. The throttle valve or valves may be operated by the shaft governor directly or through suitable relay mechanism of an electrical, mechanical or fluid-pressure nature. I may also govern the turbine by admitting steam in periods and governing the length of the periods. I may also govern the turbine by cutting the admission nozzle sections into and out of service in response to load changes. The valves controlling the passage of fluid to the nozzles or nozzle sections may be and preferably are separately actuated. The valves may be controlled electrically, hydraulically, mechanically or otherwise as desired to best meet the requirements of service.

In the accompanying drawings which illustrate one embodiment of my invention, Figure 1 is an axial section of a vertical shaft multi-stage turbine; Fig. 2 is a plan view of the same showing certain parts broken away for the purpose of illustration; Fig. 3 is a detail view showing the relation of the nozzles to the wheel and intermediate buckets; Fig. 4 is a diagrammatic illustration of the unbroken cylindrical column of motive fluid flowing through the turbine.

1 represents the casing of the turbine which is supported by a suitable base 2, the latter being provided with a chamber that is connected to a condenser or to atmospheric exhaust. The casing is divided by diaphragms 3 into stages, and each stage is provided with a wheel 4. The wheels are mounted one above the other on the vertical shaft 5 which is supported in suitable bearings. At the point where the shaft passes through the head 6 a suitable packing 7 is provided. Each of the wheels in the earlier stages is provided with two rows of wheel buckets 8 between which is an annular row of intermediate buckets 9 that serve to direct the passage of steam from one row of wheel buckets to the next. The wheel buckets are provided with ring-like supports which are secured to the wheel by rivets 10 and which are flush so as not to offer resistance to rotation. In order to take the centrifugal strains off of the rivets a tongue and groove 11 is provided between each bucket support and the wheel. The wheel is provided with a shoulder near the periphery, the side surfaces of which are flush with the sides of the bucket supports. The surfaces of the wheel are finished so as to offer a minimum resistance to rotation. The construction of the last two stages is somewhat different, inasmuch as a single row of wheel buckets is provided for each stage instead of two. The wheels 12 and 13 are mounted upon a common support or hub 14 which is mounted on the main shaft 5. Located between the wheels is a ring or half-diaphragm 15. The inner surface of the half-diaphragm is finished, as is also the periphery of the support 14, and between these two finished surfaces is a suitable packing 16 to prevent leakage. The half-diaphragm is supported by an internal shoulder 17 formed on the base 2 of the machine and is provided with a peripheral flange 18 upon which rests the diaphragm 19. The other diaphragms are supported by internal shoulders 20 formed on the inner walls of the wheel casing, the latter being divided into suitable segments, the planes of division being parallel with the shaft. The diaphragms 3 and the half-diaphragm 15 are provided with suitable strengthening ribs adjacent to the nozzles. The surfaces of the diaphragms adjacent to the wheels are finished and are separated from the wheels by a clearance, measured in an axial plane, which is preferably somewhat less than the clearances between the wheel and intermediate buckets and between the wheel buckets and the nozzles, so that any rubbing between the wheel and the stationary parts will take place, not on the sharpened edges of the buckets, but on the large flat surfaces formed on parts of substantial size.

Mounted on top of the head is a steam chest 25 which supplies steam or other elastic fluid to all of the admission nozzles 26. Steam is admitted to the chest by the conduit 27. The passage of fluid therethrough is controlled by the throttle valve 28. This throttle valve is under the control of a speed-responsive device 29 that is either mounted on the main shaft or driven therefrom by suitable gearing 30. As the speed of the turbine changes due to variations in load, the throttle valve 28 opens or closes by an amount sufficient to satisfy the demand for steam. The throttle valve and governor are shown in a more or less diagrammatic manner for the purpose of simplicity in illustration. 31 represents the supply pipe leading from the boiler and 32 a shut-off valve whereby the turbine can be stopped.

The admission nozzle 26 is of the expanding sectionalized type, best shown in Fig. 3. It is bolted to the underside of the head 6.

This nozzle, as well as those in the subsequent stages, simultaneously supplies steam to all of the wheel buckets located adjacent thereto and the steam issues therefrom in the form of an unbroken cylindrical column. The second stage nozzle 33 is of the same construction as nozzle 26, except that the passages are somewhat greater in cross-sectional area, owing to the increased volume of the steam to be handled, due to the decreased pressure. This nozzle is detachably secured to an overhanging shoulder 34 on the interior of thewhe el casing. The nozzle 35 for the third stage, is formed directly in the diaphragm. In the present instance, the nozzle is formed by casting thin, metal plates into the diaphragm, these thin plates serving as partitions for directing and expanding the steam as it flows through them. The construction of the subsequent nozzles being the same, further description is unnecessary.

Owing to the enormous expansion of the steam between the initial and final stages, the passages of the admission nozzles are made small and the first stage buckets are made short in the radial dimension and relatively narrow in the direction of flow. The remaining buckets throughout the turbine increase in radial depth, and also in width from the high to the low pressure stages.

In Fig. 4 is shown diagrammatically the column of steam as it flows through the turbine. This figure is not made to scale, but is intended merely as an illustration of the fact that the steam preserves an unbroken cylindrical column throughout its passage through the turbine.

In accordance with the provisions of the patent statutes, I have described the principle of operation of my invention, together with the apparatus which I now consider to represent the best embodiment thereof; but I desire to have it understood that the apparatus shown is only illustrative, and that the invention can be carried out by other means.

What I claim as new, and desire to secure by Letters Patent of the United States, is,—

1. In an elastic-fluid turbine, the combination of a casing, diaphragms dividing the casing into a plurality of stages, a nozzle for each stage that converts a certain portion of the pressure of the motive fluid into velocity and simultaneously discharges it in the form of an unbroken cylindrical column to all of the wheel buckets, wheel buckets in the high-pressure stage that are short and narrow, and wheel buckets in the low-pressure stage that are relatively long and wide, all of said buckets abstracting wholly or in large part the velocity of the motive fluid due to the preceding nozzle and at the same time preserving the continuity of the fluid column, substantially as set forth.

2. In an elastic-fluid turbine wherein portions of the pressure of the motive fluid are successively converted into velocity and the velocity abstracted by stages, the combination of a sectionalized nozzle in each stage for discharging motive fluid in an unbroken cylindrical column against all of the buckets adjacent thereto to produce rotation and also to prevent bucket losses, and rows of wheel and intermediate buckets for abstracting the energy of the motive fluid by stages and for fractionally abstracting the energy of the fluid in each stage, the diameter of the wheel in the high-pressure stage being less than that of the wheel in the low-pressure stage.

3. In an elastic-fluid turbine wherein portions of the pressure of the motive fluid are successively converted into velocity and the velocity abstracted by stages, the combination of a plurality of stages, rows of wheel and intermediate buckets for abstracting the energy of the motive fluid in said stages, single rows of wheel buckets for the low pressure stages and one or more nozzles for each stage which convert the pressure of the motive fluid into velocity and simultaneously discharge it against all of the buckets in an unbroken column to produce rotation and at the same time reduce bucket losses, the said nozzles and buckets being arranged in axial alinement so that the motive fluid enters the first wheel and leaves the last in the form of a hollow cylinder.

4. In an elastic-fluid turbine wherein portions of the pressure of the motive fluid are successively converted into velocity and the velocity abstracted by stages, the combination of a casing, diaphragms for dividing it into stages, one or more sectionalized nozzles for each stage which convert the pressure of the motive fluid into velocity and simultaneously discharge it with its velocity unimpaired against all of the wheel buckets to produce rotation and prevent bucket losses, buckets in the stages, and wheels and bases for the buckets presenting smooth unbroken surfaces to the nozzles and diaphragms of the stages to decrease rotation losses.

5. In an elastic-fluid turbine wherein portions of the pressure of motive fluid are successively converted into velocity and the velocity abstracted by stages, the combination of one or more nozzles for each of the stages, which convert the pressure of the fluid into velocity and simultaneously discharge it against all of the wheel buckets to produce rotation, and in an unbroken cylindrical column to prevent bucket losses, wheel buckets in the stages revolving in front of the nozzles all of which are active at all times, the buckets increasing in width and depth from the high- to the low-pressure stage, supports for the buckets presenting smooth unbroken surfaces to the fluid in the stages, and surfaces adjacent the wheel periphery, to prevent rotation losses.

6. In an elastic-fluid turbine wherein portions of the pressure of the motive fluid are successively converted into velocity and the velocity abstracted by stages, the combination of a casing, diaphragms which divide the casing into compartments, a bucket wheel for each compartment, a sectionalized nozzle for each stage which simultaneously discharges motive fluid in an unbroken cylindrical column against all of the wheel buckets, an annular steam chest mounted on the head of the casing and a separate annular set of intermediate buckets for each stage that is situated between the diaphragms, the arrangement of nozzles and wheel buckets being such that they are active at all times and preserve the continuity of the fluid column, the buckets in the high pressure stage being relatively short and narrow, and those in the subsequent stages increasing in width and length, substantially as and for the purpose described.

In witness whereof, I have hereunto set my hand this 7th day of August, 1905.

OSCAR JUNGGREN.

Witnesses:

BENJAMIN B. HULL,

HELEN ORFORD.