C. G. CURTIS.

ELASTIC FLUID TURBINE.

APPLICATION FILED MAY 28, 1909.

945,919. **Patented Jan. 11, 1910.**

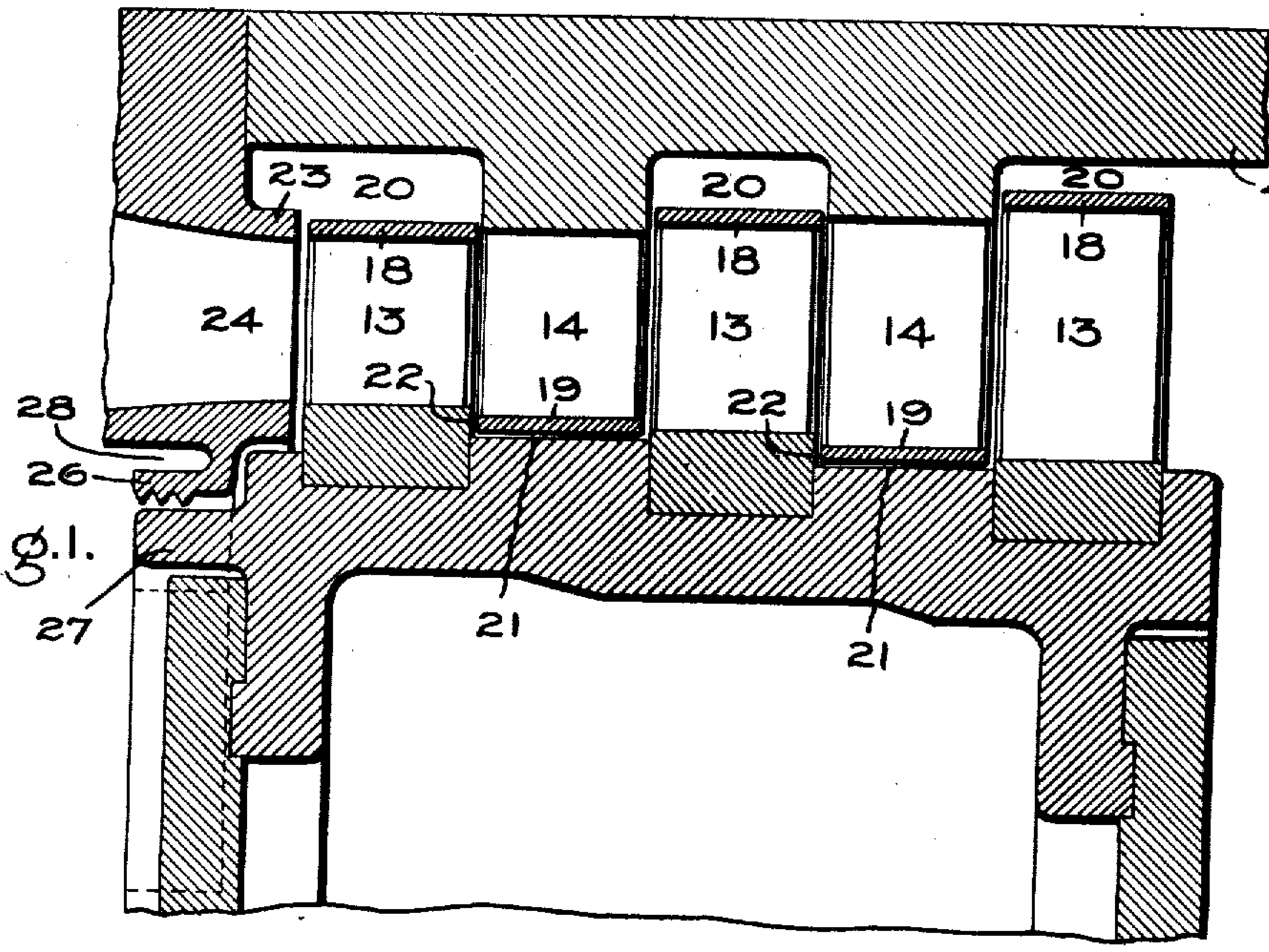


Fig.1.

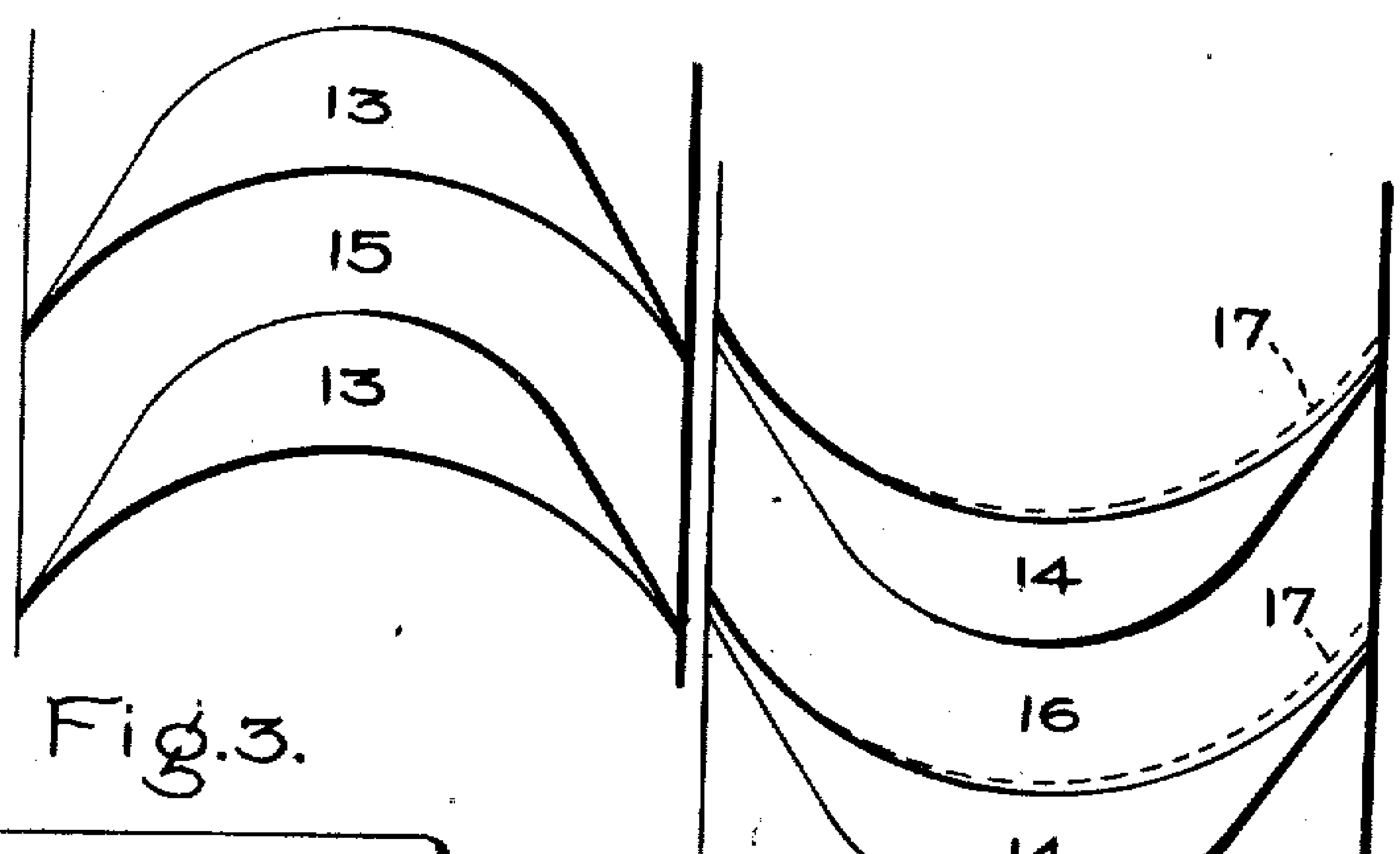


Fig.2.

Fig.3.

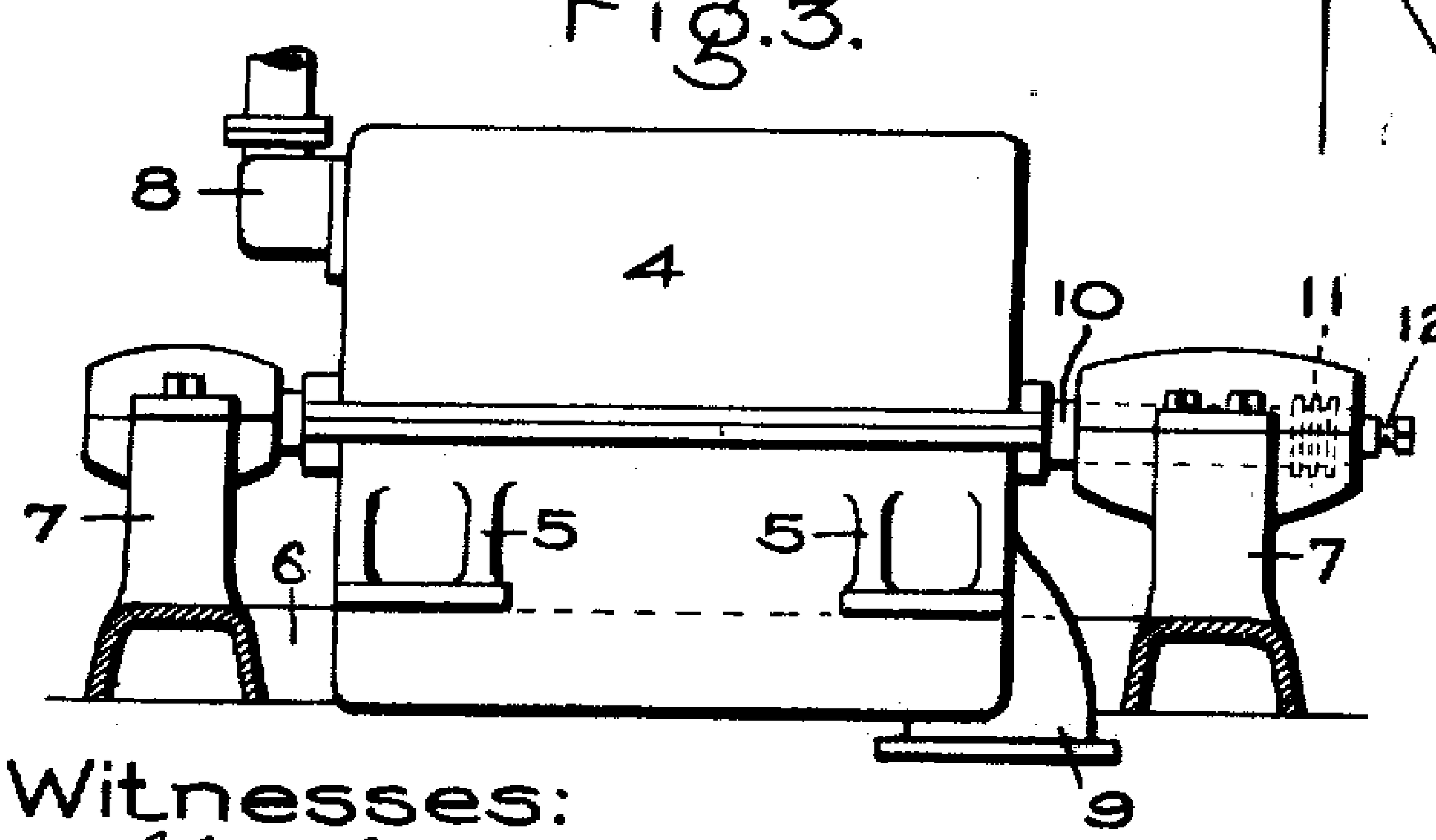
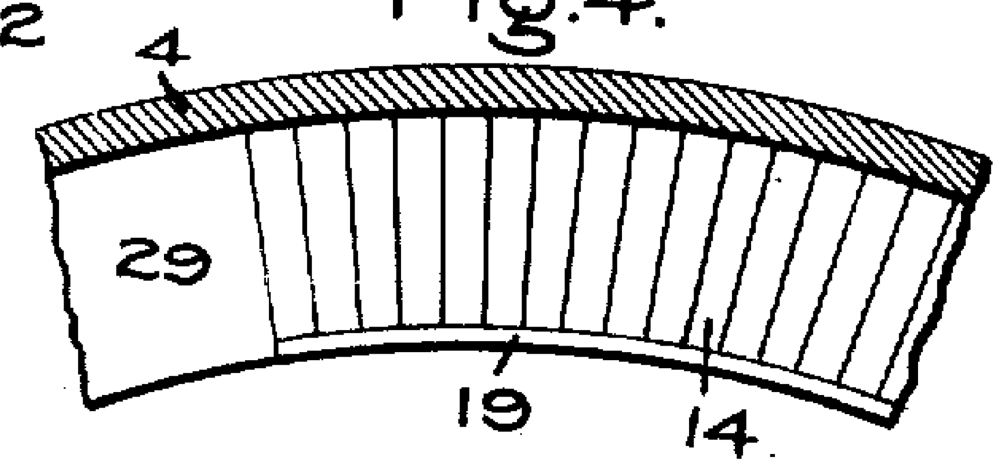


Fig.4.



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UNITED STATES PATENT OFFICE.

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ELASTIC-FLUID TURBINE.

945,919. Specification of Letters Patent. **Patented Jan. 11, 1910.**

Application filed May 28, 1909. Serial No. 499,030.

To all whom it may concern:

Be it known that I, CHARLES G. CURTIS, a citizen of the United States, residing in New York, in the county of New York and State of New York, have invented certain new and useful Improvements in Elastic-Fluid Turbines, of which the following is a specification.

My invention relates to elastic-fluid turbines operating on the jet or impact principle, and has for its object to improve their economy by decreasing the leakage, eddy and friction losses.

I have discovered that where elastic-fluid issues from a nozzle with a very high velocity and is discharged against a sufficient number of rows of buckets carried by a rotor to properly extract said velocity, certain losses take place. These are largely due to eddying of the fluid from various causes in the bucket spaces. Also to the friction between the fluid column and the walls of the bucket spaces or working passage. In certain turbines having theoretically the proper number of rows of buckets to effectively extract said velocity, each row doing its proper percentage of work, I have found that as a matter of practice the last row of rotating buckets was doing very little work and in some cases absorbing work. In a turbine of the character referred to the work done by the fluid varies as the square of its velocity while the losses vary as the cube of said velocity, hence it is extremely important to keep said losses at as low a value as possible. To this end, instead of using a very high fluid velocity I so shape the nozzle and proportion the area thereof that the velocity of the issuing jet is moderate. The working passage in the row of moving buckets receiving fluid from the nozzle is designed to receive and convey it to the adjacent stationary or intermediate buckets without converting any of its pressure into velocity or at least without any substantial conversion. I aim to prevent such conversion as fully as possible. The working passage in the stationary buckets is on the other hand designed not only to convey the volume of fluid received from the first row of buckets but also to decrease its pressure in passing, and gives it the desired moderate velocity. The fluid, however, issuing from said stationary buckets acts on the adjacent row of wheel buckets without substantial change in pressure. This action is repeated throughout the turbine, or a portion of the turbine, until the fluid exhausts either to the atmosphere or condenser. To state the matter briefly and in another way, there is no substantial conversion of pressure of the fluid into velocity in the wheel or rotor buckets but there is in the stationary or intermediate buckets. The extent of such pressure conversion will depend chiefly upon the total difference in pressure to be considered, the number of rows of wheel buckets, and their speed with respect to fixed parts. These conditions naturally change with different sizes of machines and with the purpose for which the latter are intended. A turbine designed along these lines means that the pressure at the end of the nozzle is considerably higher than the pressure of the exhaust and hence there will be a large leakage unless means are employed to prevent it. To reduce the nozzle leakage, an annular leakage reducing device is provided that is carried by the nozzle or some adjacent stationary part, which device presents a cylindrical surface to the rotor and is separated therefrom by a small clearance. The clearance is preferably parallel to the axis of the rotor so that the latter can be adjusted endwise, if desired. To guard against injury in the event of the rotor running out of true caused by distortion due to heat or otherwise, the said annular leakage device is provided with a yielding portion sawed or cut into a segmental piece that can expand and move away from the rotor in the event of rubbing and the heating incident thereto. The clearance mentioned should be as small as possible consistent with free movement of the rotor.

Owing to the desirability of reducing the size of the machine as a whole as much as possible, and in some cases to the absolute necessity for such reduction, decreasing the cost and simplifying the construction where a large number of rows of buckets is provided, the particular leakage reducing device above referred to cannot be effectively utilized between the rotor and stationary buckets.

As before stated there is no pressure conversion in the wheel buckets hence there is no appreciable tendency for the steam to leak past the ends of the buckets which are provided with the usual cover forming one wall of the working passage. By reason of this I can make the radial distance between the cover and the casing as large as I choose. Since there is pressure conversion in the intermediate buckets the situation is altogether different because there will be a decided leakage over or past the covered ends of the buckets unless a suitable means is employed to prevent it. In the first place I so arrange the rows of wheel and intermediate buckets that they increase in depth step-by-step instead of gradually. As a result the fluid jet tends to shoot past or through the clearances without being deflected or permitted to deflect into them. There will be considerable velocity in the steam as it leaves each row of wheel buckets which will be largely sufficient for the purpose. As a further means for reducing the leakage from one side of a row of stator or intermediate buckets to the other and over the cover, (the only place where it can leak because the bases of the buckets are solid and surround the rotor) I arrange the covers thereof as close to the rotor as can safely be done. By reason of this arrangement it is necessary to consider the radial clearance at this point as well as that of the leakage reducing device of the nozzle. Usually the clearance of the latter device will be slightly less than the one between the stationary covers and the rotor, and hence will be the controlling factor in alining and operating the turbine. The clearance at the covers of the intermediate buckets also extends axially so as not to interfere with endwise adjustment of the rotor. As a further precaution against leakage I adjust the rotor by means of thrust collars, step bearing or the equivalent so that the clearance on the inlet side of each row of its buckets is slightly less than on the discharge side. As an example the clearance between the bucket covers and the adjacent stationary part at the inlet side of the rotor may be made from one thirty second to one sixteenth of an inch.

My invention is applicable to that portion of the turbine where the nozzle and intermediates extend only partially around the wheel, and also to that portion where they extend entirely around. In the former case the nozzle leakage reducing device will of course extend entirely around the rotor and the segmental space in each row not occupied by the intermediate buckets will be filled with a blank wall to prevent the free passage of motive fluid. This wall will also have the advantage of reducing the rotation losses of the idle buckets if properly arranged so as not to be too near the edges of the buckets.

I may utilize my invention in connection with the high pressure portion of the turbine or the low pressure portion or both.

In the accompanying drawing which illustrates one of the embodiments of my invention, Figure 1 is an enlarged axial section of a part of a turbine; Fig. 2 is a detail view showing rotor and stator buckets; Fig. 3 is a view in side elevation of a turbine, and Fig. 4 is a detail view showing blank walls between the groups of stator buckets.

4 indicates the casing of the turbine which carries the stator buckets. The casing is supported by feet 5 resting on a suitable foundation 6, the latter supporting the shaft bearings 7 of the rotor. Steam is admitted to the turbines by the valve chest 8 under the control of any suitable governing mechanism and is exhausted by the conduit 9. The rotor is carried by the shaft 10 and its longitudinal position is adjusted and maintained by the thrust collars 11, shown in dotted lines, and the adjusting screw 12. The rotor is provided with rows of buckets 13 between which are rows of stator or intermediate buckets 14. The depth of these buckets increases step-by-step as shown to reduce leakage. The working passage or spaces 15 between the wheel buckets is of the same width throughout as shown in Fig. 2, so that there will be no conversion of pressure into velocity of the motive fluid which may be steam, air or other elastic fluid, or at least such conversion will be reduced to the minimum value. On the other hand the working passage or spaces 16 between the stator buckets enlarges between the entrance and exhaust sides to produce the desired drop in pressure and hence produce the desired conversion of pressure into velocity. For example there may be a pressure drop from 90 to 80 pounds in the first row of stator buckets. As the pressure is reduced toward the exhaust of the turbine, this pressure difference may and preferably does decrease in amount in order that the rows of wheel buckets may perform equal amounts of work. I have shown the buckets on a somewhat enlarged scale. The dotted line 17 is concentric with the convex wall of the adjacent bucket, and the space between said line and the concave face of the bucket indicates the enlargement. This enlargement has been somewhat exaggerated for the purpose of illustration. The various working passages should have a cross-sectional area sufficient to convey the motive fluid without choking, and the working passage in the stator buckets in addition should enlarge sufficiently to produce the necessary pressure drop.

The rotor buckets are provided with covers 18 and those of the stator with covers 19. The covers 18 are separated from the casing 4 by an unrestricted clearance 20 while those of the stator are separated by a restricted clearance 21. It is to be noted that the covers 19 are below the adjacent bottom wall on the left of the rotor buckets and the side clearance at 22 is made as small as possible consistent with free operation. This latter clearance can be adjusted by the adjusting screw 12 and thrust collars 11.

Motive fluid is admitted to the rotor by a nozzle 23 preferably comprising a plurality of passages separated by thin partitions 24, the latter all having the same inclination or angle of delivery. This nozzle converts the desired amount of pressure into velocity. To reduce the leakage around the nozzle a leakage reducing device is provided comprising an annulus 26 having teeth or projections that run in as close proximity to the annular part 27 of the rotor as is possible consistent with good operation. The metal back of the teeth is cut-away at 28 so that said annulus can expand outward in case the parts rub and heat. To assist in this the annulus is slotted at a number of points as indicated by the dotted lines so that in effect the annulus is made up of a number of closely associated segmental pieces.

In most cases the stator buckets will entirely surround the rotor but where they do not for any reason the space between them will be filled by a blank wall 29. This wall in cross-section closely conforms to that of the space occupied by the stator buckets when viewed in axial section. The wall when separated from the moving buckets by an amount about equal to the clearance between relatively moving buckets will reduce the rotation losses due to windage. If placed too close water due to expansion of the steam will act to retard rotation, and if too great the effects on the windage will be largely lost although in any case the wall will serve to prevent the free passage of steam. Such an arrangement is shown in cross-section in Fig. 4 where 14 indicates the intermediates and 29 the blank wall.

I have shown my invention in connection with an axial flow machine but it can be used in radial flow machines if desired.

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 rotor having rows of buckets between which the motive fluid passes without substantial conversion of pressure into velocity, rows of intermediate buckets between which the motive fluid passes and has a portion of its pressure converted into velocity, the depth of the rows of buckets increasing step-by step, a device for discharging motive fluid with a moderate velocity against the first row of moving buckets, a casing for the buckets, and an exhaust conduit.

2. In an elastic-fluid turbine, the combination of a rotor having rows of buckets against which the motive fluid acts without substantial conversion of pressure into velocity, rows of intermediate buckets between each two rows of rotor buckets through the working passage of which the fluid received from the rotor buckets passes, the said intermediate buckets in addition to directing the fluid acting to convert a certain amount of its pressure into velocity, a device for discharging motive fluid against the first row of rotor buckets with a moderate velocity, a device which presents an annular surface in close proximity to the rotor to reduce leakage from said device, a casing for the parts, and an exhaust conduit.

3. In an elastic-fluid turbine, the combination of a rotor having rows of buckets, a stator also having rows of buckets located between those of the rotor, the rotor buckets acting to extract velocity from the motive fluid without substantial conversion of pressure into velocity while the stator buckets direct the fluid and act to convert pressure into velocity, covers for the buckets, those of the stator being located in close proximity to the rotor and beyond the path of the fluid jet to provide a restricted clearance to reduce leakage while those of the rotor are widely separated from the casing and have an unrestricted clearance, a nozzle for discharging fluid against the first row of buckets, a casing for the turbine, and an exhaust conduit.

4. In an elastic-fluid turbine, the combination of a rotor having rows of buckets, a stator also having rows of buckets located between those of the rotor, the rotor buckets acting to extract velocity from the motive fluid without substantial conversion of pressure into velocity while the stator buckets direct the fluid and act to convert pressure into velocity, the alternate rows of buckets increasing in depth step-by-step, covers for the buckets, those of the stator having a restricted clearance with the rotor, and those of the rotor an unrestricted clearance with respect to the casing, a nozzle which converts a portion only of the pressure of the fluid into velocity and discharges it against the first row of buckets, a casing, and an exhaust conduit therefor.

5. In an elastic-fluid turbine, the combination of a rotor and a stator both having rows of buckets, those of the rotor extracting velocity of the motive fluid without substantial pressure conversion while those of the stator act to convert a portion of the pressure into velocity and direct the fluid against the rotor buckets, the depth of the buckets increasing by rows step-by-step, a device for discharging fluid with a moderate velocity against

the first row of buckets, means for reducing leakage from the said device, other means for reducing leakage around the ends of the stator buckets, a casing, and an exhaust conduit.

6. In an elastic-fluid turbine, the combination of a rotor and a stator both having rows of buckets, those of the stator alternating with those of the rotor, the said buckets increasing in depth step-by-step, the conversion of pressure into velocity taking place solely in the buckets of the stator, a device discharging fluid at a moderate velocity and substantial pressure against the first row of buckets, a casing and an exhaust conduit therefor.

In witness whereof, I have hereunto set my hand this 26th day of May, 1909.

CHARLES G. CURTIS.

Witnesses:

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E. DAILEY.