D. KEMBLE.

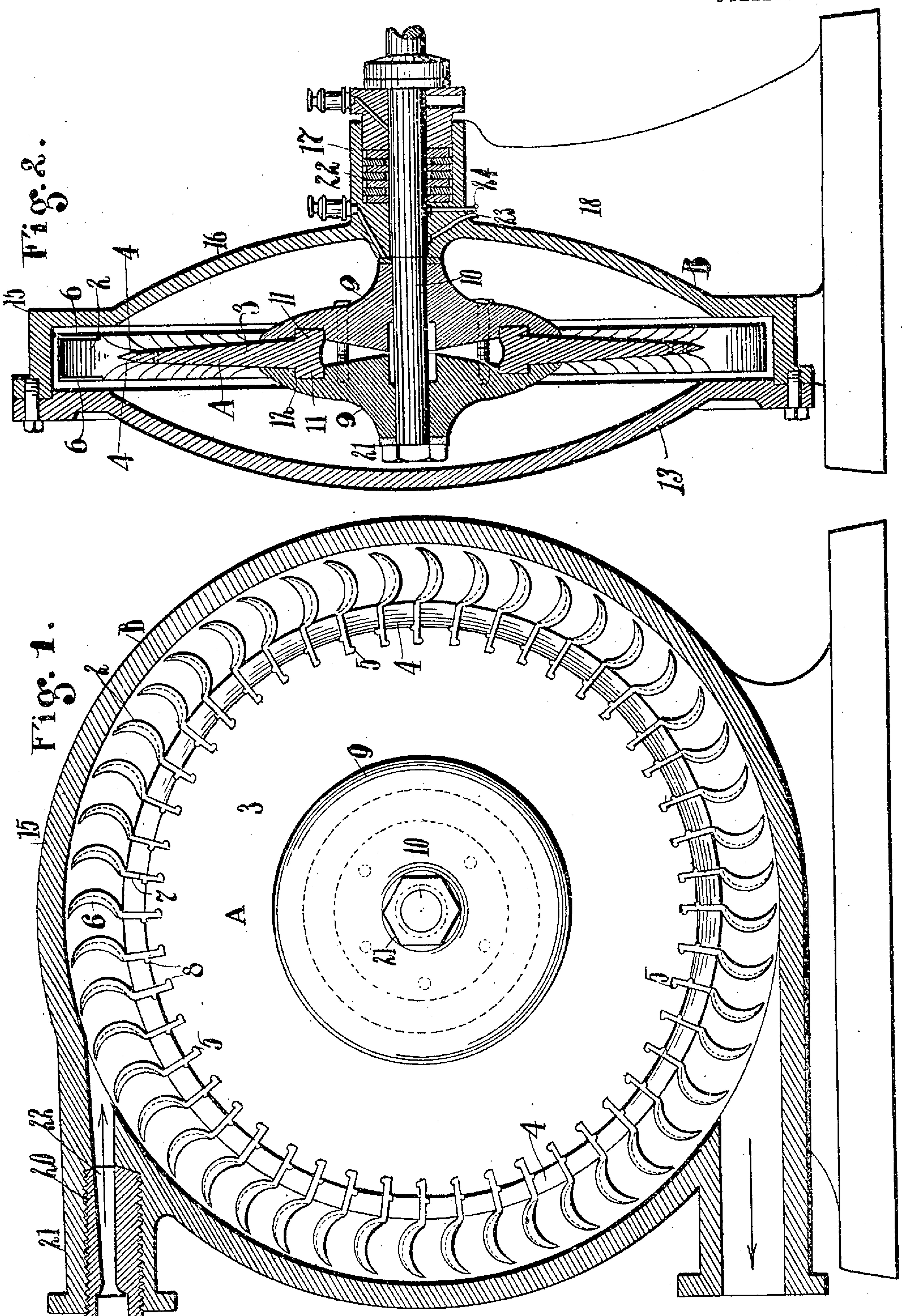
STEAM TURBINE.

APPLICATION FILED AUG. 17, 1908.

927,657.

Patented July 13, 1909.

3 SHEETS—SHEET 1.



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3 SHEETS—SHEET 2.

Fig. 3.

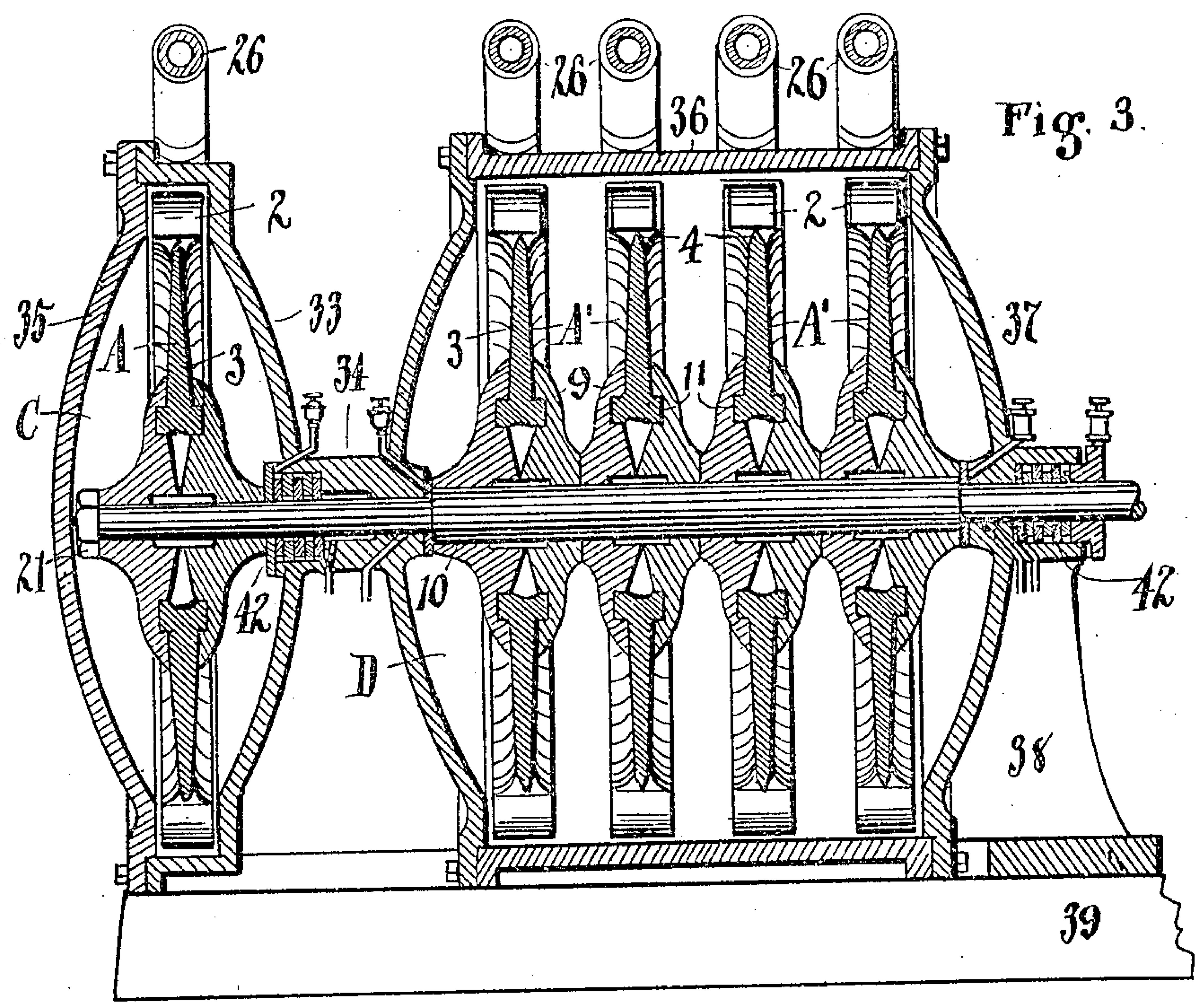
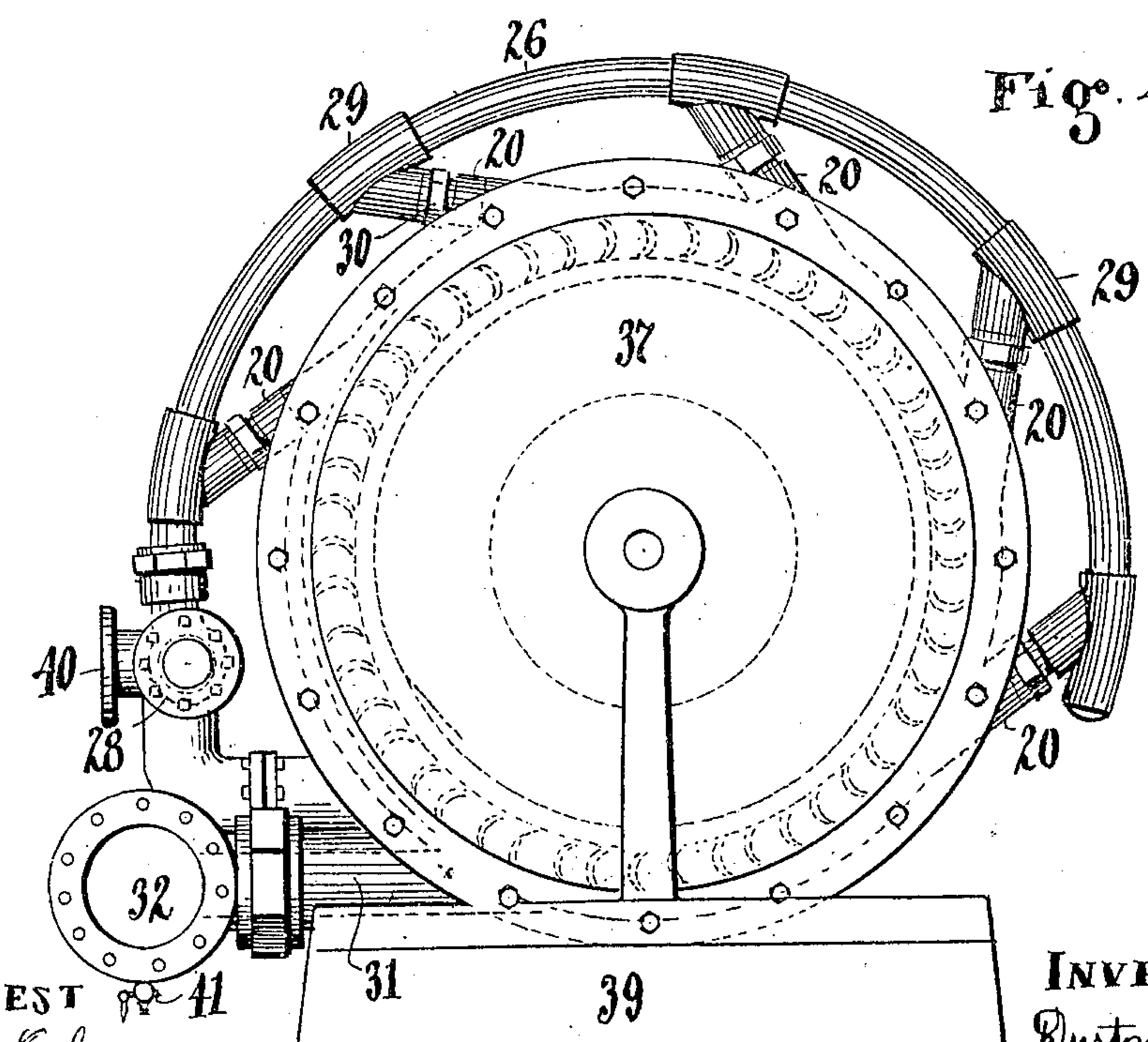


Fig. 4.



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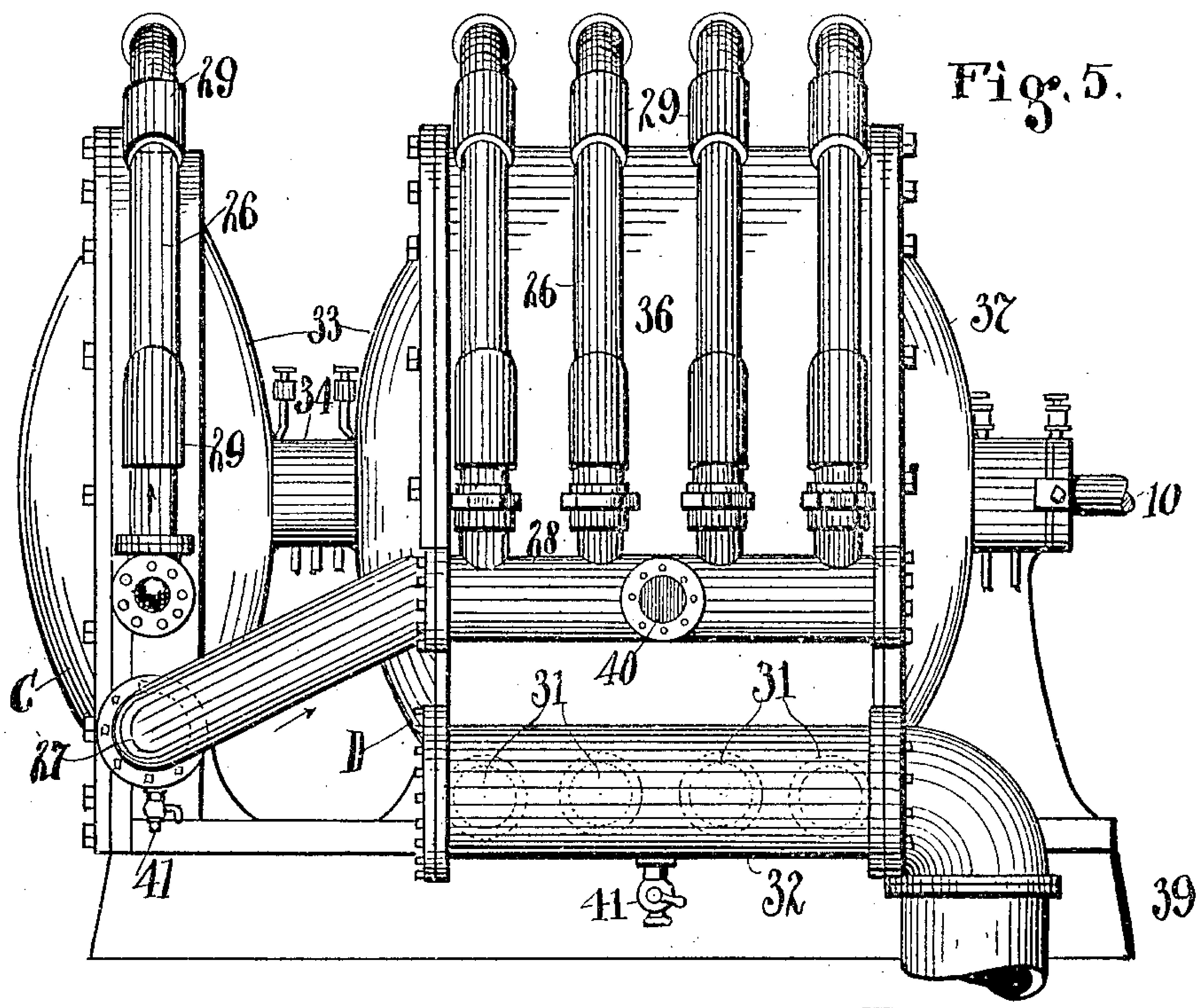

Fig. 5.

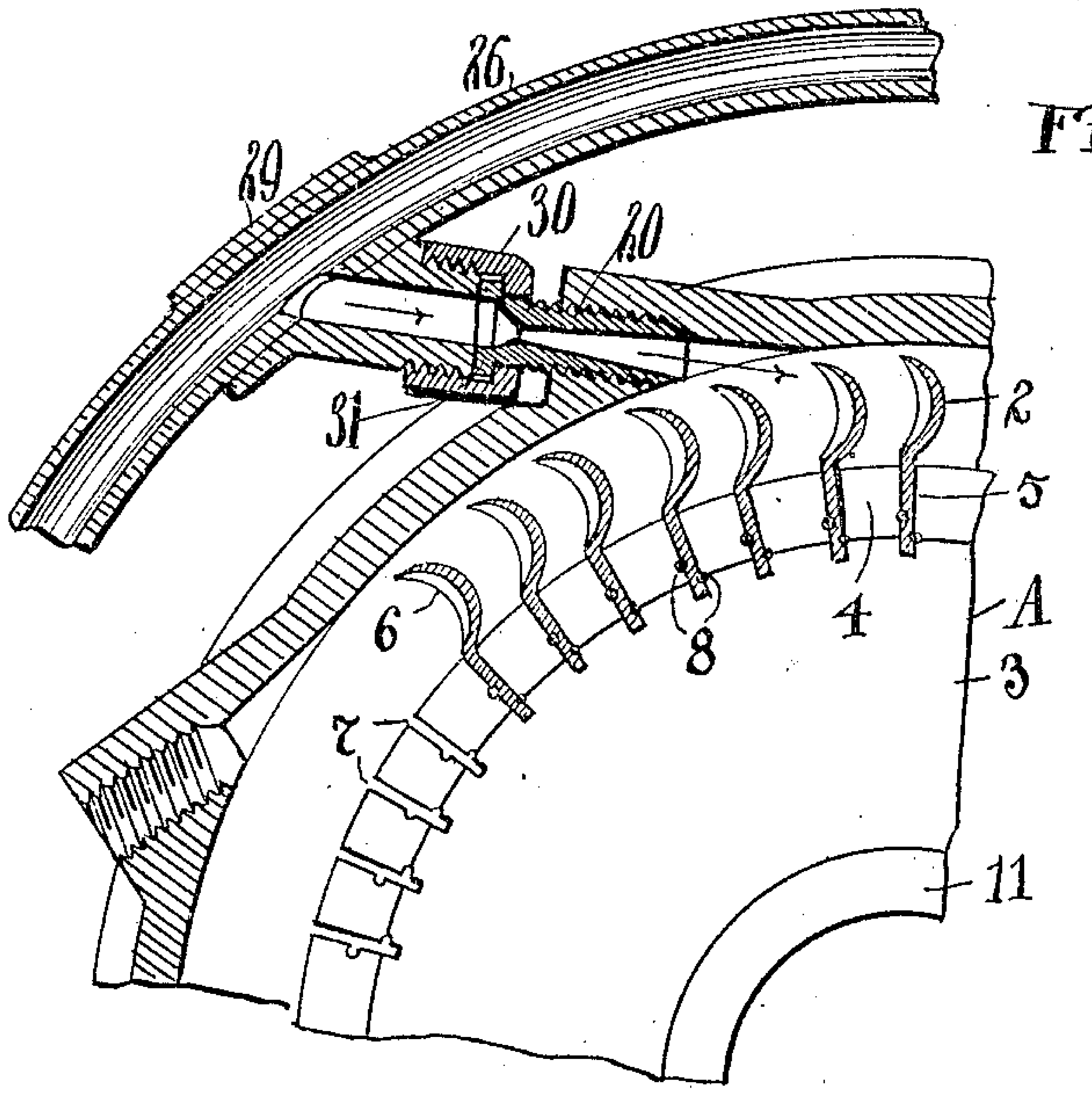

Fig. 6.

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UNITED STATES PATENT OFFICE.

DUSTON KEMBLE, OF MILLERSBURG, OHIO.

STEAM-TURBINE.

No. 927,657. Specification of Letters Patent. Patented July 13, 1909.

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To all whom it may concern:

Be it known that I, DUSTON KEMBLE, a citizen of the United States, residing at Millersburg, in the county of Holmes and State of Ohio, have invented certain new and useful Improvements in Steam-Turbines, and do declare that the following is a full, clear, and exact description of the invention, which will enable others skilled in the art to which it appertains to make and use the same.

My invention relates to steam turbines, both simple and compound, and is an improvement in the peripheral feed type of machine having one or more circles of moving vanes, all substantially as hereinafter shown and described and more particularly pointed out in the claims.

In the accompanying drawings, Figure 1 is a sectional view and elevation of a simple form of my improved steam turbine, and Fig. 2 is a vertical section thereof on the line of the shaft. Fig. 3 is a central sectional view of my improved compound steam turbine, and Fig. 4 is an end elevation thereof looking in from the right. Fig. 5 is a side elevation of the turbine shown in Fig. 3, and Fig. 6 is a cross sectional view of a portion of my improved turbine on the line of the feed pipe and showing one of the steam nozzles connected therewith.

Now referring to Figs. 1 and 2, wherein the invention is shown in its simplest form, it will be noted as a peculiarity of this design that the rotor element A consists of a series of concave vanes —2— set radially in the edge of a vane disk 3 which is tapering in cross section to provide a thinner body at the edge than near the center to avoid centrifugal strain. Said disk 3 is also beveled at 4 on both sides to throw off the escaping particles of steam in both directions as they flow off from the inner side of the concave part of the vanes thereby preventing back pressure. Vanes 2 are flat across their face but curved otherwise in the form of a segment of a circle from their straight shank 5 outward and whereby a curved steam impacting surface is presented beyond the peripheral edge of disk 3. Each vane is also provided with a flange or wall 6 at each side edge to pocket the steam and direct its flow inward toward the center of the steam chamber and against the beveled edge of the disk. The straight shank 5 of each vane is set in the beveled edge of the vane-disk with the curved portion of each vane projecting or turned so as to deflect toward or from a radial plane instead of along axial lines as is the usual method and practice. The shanks 5 are inserted in radial slots 7 milled through the disk at its edge from side to side and being of a suitable depth more or less as shown, and are fastened in place by lateral ribs or shoulders 8 on opposite sides of the said shanks and which fit tightly in drill holes or cross grooves located in the edge face of slots 7. These drill holes or grooves for locking ribs 8 are preferably placed at unequal distances from the edge of the vane-disk so as not to weaken the metal, and if desired, separate keys or pins may be used instead of integral ribs or shoulders 8 to effect locking of the vane in place. The vane-wheel in its entirety is a built up structure comprising disk 3 with its series of vanes as described, combined with a divided metal hub made in two similar parts or halves 9 adapted to withstand a very high centrifugal strain. Said hub parts 9 are sleeved upon shaft 10 and keyed or otherwise fastened thereto, and are bolted together so as to clamp the inner edge portion of disk 3 between them. To this end, the vane-disk is made of finely tempered steel or of bronze and is formed with an annular shoulder 11 around each side at its inner edge, said disk being of ring shape with an opening centrally therethrough. Shoulders 11 fit snugly within correspondingly located grooves —12— in the meeting faces of the hub pieces 9, and are thereby firmly secured in place. The opposed faces of hub parts —9— are also inclined from the grooves 12 toward the shaft and are preferably spaced apart as shown to permit the shaft to have a slight spring at the middle of the vane wheel and which would not occur with a solid wheel. One advantage of this form of vane-wheel is its convenience of manufacture and in making repairs, especially in the larger sizes of such wheels for high speeds.

Now still referring to Figs. 1 and 2, the wheel chamber of this simple turbine is made of two principal pieces or castings of iron or other metal, and the larger of these consists of a circular casing B with a right angled portion 15 and a dished or rounded portion 16 having an integral boss or projection 17 through which shaft 10 extends and within which it has its bearing. Casing B is integral with or secured to a pedestal part 18 which may be bolted to a suitable base of cast iron or other material to support the whole. The open side of casing B is covered by a circular dished casting or plate 13 of equal diameter but not so deeply hollow and is bolted fast to the flanged edge of casing B. This provides a closed vane-wheel chamber within which the vane-wheel may rotate freely without touching the walls at any point of its circle as it will be seen that there is considerable clearance or space allowed on both sides of the vanes and opposite the periphery of the wheel. However, the precise form of this wheel chamber is not essential, and the side walls to the left and right might be made straight or flat instead of dished. A boss and shaft bearing might also be made in the central portion of the cap casting as well as in the larger piece on which is the pedestal, but where the exhaust pressure is not far from the atmospheric tension, the end pressure on the shaft caused by the slight excess of pressure surface on the left side of the wheel will be so small as to be of no material importance, and thus the simple cap may be adopted as the cheapest and most convenient construction. The vane wheel is here shown in a section of the proportions most approved by experience as best adapted to withstand the centrifugal strain of very high velocities, but it may also be made of other proportions, according to the material used and the requirements of the case. It is set upon a shaft, preferably of fine steel, resting against a shoulder upon the shaft at one end, and held firmly in place by a larger nut and washer 21 at the opposite end of the hub, but any other means, as a pair of feathers in channels on both sides of the shaft may be used for the purpose, if found more convenient. To provide for a steam tight bearing and also a means of obviating the results of vibration at very high velocities of the vane-wheel, I have adopted the plan of a series of washers 22 around the shaft, and made to fit alternately the shaft and the bearing walls in boss 7 and lubricated by graphite, or by any other means which is found suitable. A bushing may be used or not with these washers, as it seems to be hardly essential, if the washers are of brass or other soft metal. For the more perfect lubrication of the central portion of the shaft bearing, I have adopted the plan of forced oil circulation by a force-pump. Under the shaft and bushing at the intersection of the boss with the main part of the casing wall, I make an opening into the interior of the bearing into which a small but strong pipe 23 is inserted and connected with the oil pump (not shown). When this is set in operation, oil is forced in beneath the shaft, which is thus partially lifted from the lower side of the bearing, and the oil gradually works over on either side to the ducts from whence it is led back by pipe 24 to the oil reservoir to be pumped again and again. If sufficient oil is used, it may have the effect of aiding to keep the bearing normally cool. Any suitable oiling arrangement may be used instead of the foregoing, and the bearings may also be other than shown.

To operate the vane-wheel, I arrange one or more expanding feed nozzles 20 for projecting the steam at high velocity against the vanes, and locate this nozzle or series of nozzles in the casing wall in the plane of rotation. If a series of nozzles are used, they are preferably mounted at definite distances apart around larger casting B carried by pedestal 8. Nozzles 20 may be made of brass or other suitable metal, and firmly screwed into a boss or projection 21 on the outer casing wall. If desired, the flaring opening 22 through the nozzle and the casing may be more or less flattened in the direction of a rotary plane at their inner extremities, thus reducing the channel nearest the vanes to a cross section of an oblong or ellipsoidal shape. The line of projection of the nozzle is tangential to the vanes but relatively with no great radial depth at the point of impact against the same. Thus it may be seen that this design contemplates the use of a relatively small number but large vanes in proportion to the size of the vane-circle and also to the cross section of the steam jet or jets for actuating the same, and as compared with other steam turbines. The advantages to be derived by the use of vanes of the size, shape and arrangement of the construction described and shown are as follows: first, the use of fewer vanes will materially reduce the expense and difficulty of construction; 2nd, the caliber of these larger and heavier vanes than ordinary will enable them to last longer under the wearing impact of the steam jet; 3rd, the turning outward during rotation of the inner edge of the curved portions of each vane with respect to the tangent line of impact will enable me to obtain a more complete reversal of the direction of the steam jet than is the case in most other steam turbines; 4th, the wider space between each successive pair of these vanes in comparison with the relatively thin portion of the steam jet that is admitted across the outer edges of the vanes gives less friction and more room for taking up the velocity of the steam particles between the vanes than is the case in ordinary vane construction; 5th, this plan of peripheral feed with the shape of vanes and nozzles as already shown, is well adapted to my plan for a compound turbine in which losses by steam friction and compression shock are comparatively small. The simple form of any steam turbine, as shown in Figs. 1 and 2, may indeed, be used with a plain nozzle for operation by a jet of water, like a Pelton wheel, where this is desired. But it is more especially intended for use with steam-power, and an expanding nozzle in which the steam-particles may attain a maximum velocity of at least 3600 feet per second and when the vanes are permitted to run at a velocity of from 420 to 840 feet per second, more or less. This will enable us to utilize as much of the kinetic energy of the expanding steam-jet as may be found practically possible with a single impact steam turbine. However, as it may be desired to obtain more power from a single wheel of a given radius than can be obtained with a single steam-nozzle, I have also provided several similar nozzles, to operate on successive portions of the vane-circle simultaneously, and connect them all with a single curved feed-pipe 26 with brazed T joints, and when actuated by steam or any other elastic medium of gas or vapor under pressure and issuing from the expanding nozzles at high velocity, my steam turbine may be constructed in two or three members, adapted to successive stages of diminished pressure and increased expansion of the steam, as shown in Figs. 3 to 6.

It will be seen more particularly in Figs. 3, 4, and 5 that my compound turbine consists of two wheel-chambers C and D respectively, the first containing one vane-wheel A arranged with five expanding steam nozzles 20 about it, and a suitable exit 27 for the exhaust steam as it comes away from the vanes, and the second wheel-chamber containing four vane wheels A′ similar to the one in the first chamber, but with wider vanes and arranged with five larger steam nozzles about each wheel, with the exhaust steam from the first chamber turned into a supply pipe 28 which is connected with all the four feed pipes 26 and their respective steam nozzles as arranged about the four wheels in the second chamber. These curved feed-pipes are connected with each of their steam nozzles by brazed T joints 29 and screw clips 30 over the heads 31 of the nozzles. Thus the four vane wheels of the second stage are designed to be operated in parallel and on a common shaft and a steam exit 31 from each opens through the wall of the wheel chamber and is then connected with a common exhaust pipe 32. The body of the two wheel-chambers of this two-stage turbine is preferably made up of four principal parts or castings of iron or other metal, all suitably fitted and bolted together, and including parts for support on a common base, (which may also be of iron or other metal) and bosses for shaft-bearings as well as for mutual bracing, and suitable projections with openings for inserting the steam nozzles, and also with suitable ports or exits for the exhaust steam. The first of these four castings is a double-dished piece 33 having one side much deeper than the other, the two sides connected by a thick rounded portion 34 bored and fitted for a shaft bearing, and the entire casting suitably mounted upon a common base, so as to stand between the first and second wheel chambers, and so as to form a principal means of support for that part of the turbine. Under this part, on the base there may also be a groove or grooves to facilitate the sliding of its foot endwise for taking the turbine apart or putting it together, but this is not shown nor regarded as important in this case. The second of these four castings is a shallow dished cap 35 of suitable form and dimensions to cover the deeper open side of the first casting above mentioned, and thus to inclose the first and single vane-wheel in its own chamber, the one used for the highest stage of steam pressure. The nozzle insertions through the chamber wall, and the port for steam exit from this first wheel-chamber are to be made preferably in the deeper side of the double-dished first casting and not in the second piece which forms the cap. The third of these four castings is made in the form of a wide ring or tube 36 with suitable projections properly arranged about its outer surface for the insertion of the four series of five steam nozzles, each corresponding to the four vane-wheels in this chamber, and also with suitable openings or ports for the exit of the exhaust steam at proper places opposite the lower part of each of the four vane-wheels as already described and preferably on the same side of the turbine as that where the steam-supply pipe is placed. The inner surface of this third or tubular piece is like the deeper side of the first piece to be of somewhat greater diameter than its inclosed vane-wheels, so as to fit quite loosely about them, and permit them to revolve freely therein, without any guide-vanes or other obstacles to their entrance or removal. One end of this third piece is to be fitted and bolted fast, as shown, to the double-dished casting 33 on its left, forming a steam-tight connection; and its opposite end at the right is likewise to be fitted and bolted fast to the fourth and last principal casting composed of a single round dished part 37 forming a cap to cover one end of the annular piece and having a large boss in the center bored for the shaft-bearing; and finally, a strong pedestal part 38 for support on the base. To the right of this last principal part of the turbine may be a place on the common base 39 for an electric generator, with a shaft coupling to be put in direct connection with the turbine. For an absolute steam pressure of 150 pounds or more, and with a good condenser on the exhaust pipe, the throats of the expanding nozzles used on the first and second wheel-chambers of this 2-stage compound turbine should have their diameters in about the ratio of 1 to $1\frac{1}{2}$; and this will give a steam expansion of about 9 (10) volumes (adiabatic) in each of the two chambers. A 3-stage compound turbine of this type may be arranged similarly to the 2-stage one just described by interposing a chamber with only two vane-wheels between the two already provided for; and making the throat diameters of the respective sets of nozzles in the proportion of 1 to $1\frac{1}{2}$ to $2\frac{1}{4}$ which will give about $4\frac{1}{2}$ to 5 volumes of expansion (adiabatic) in each stage. This turbine may be regulated by either a centrifugal or an electric steam governor, but I do not deem it necessary to present any special form. A cold water chamber may be arranged about the bearing between the first and second wheel chambers, and water run through for cooling same. I also show a port or opening 40 midway of the supply pipe 28 of the lower stage part of the machine and with which connection may be made for a valved by-pass, and this by-pass valve may be controlled by the same governor as the valve for the main inlet and arranged so that it will open upon an overload. A drain cock 41 is also provided for the exhaust pipes of both the low and high pressure chambers.

Either the nozzles or the vanes may be enlarged or the number and capacity of the vane-circles may be increased with each successive pressure-stage in the compound machine, and a convenient series of expansion ratios would be somewhat as follows: for a 2-stage compound turbine 10 vols. $\times$ 10 vols. = 100 volumes; for a 3-stage, $5 \times 5 \times 4$ or $5 = 100$ to 125 volumes; for a 4-stage, $3 \times 3 \times 3 \times 3$ or $4 = 81$ to 108 volumes, and this may be carried on to a still higher number of stages. The vane-wheel shaft should preferably be of a slightly larger diameter in each stage from the highest initial pressure to the lowest, chiefly for convenience in adjusting the packing rings when putting the shaft into its bearings or removing it when necessary.

The packing rings 42 about the shaft should be placed only in that end of each bearing which is nearest the higher pressure, unless it may be in the chamber or chambers where the steam is below atmospheric pressure, as this is the most practical form of construction and also facilitates the use of a forced oil circulation for the bearings.

It will be noted that the feed nozzles are made so that they can be turned around without changing the impact of the jet or itself touching the vanes, as the widest flaring portion of the jet opening is in the casing wall and may therefore be shaped variously to provide for the featherless part of the jet. Attention is also directed to the arrangement of the vanes in respect to the peripheral feed nozzle or nozzles, and which vanes are of such relative size, number, and spaced apart at predetermined distances, and the tangential angle of presentation of the steam to the vanes is such that the impinging steam jet or jets do not cover more than one-third the cross*section of space between successive blades, and this at the outer end thereof and which may be reduced by a different angle of impact if desired. The vanes are made sharp on their outer edges to receive the steam jet peripherally, and gradually increase in thickness or caliber of their curved portion from said outer edges to their junction with the shank.

What I regard as more or less fundamentally new is embodied in the form of peripheral feed vanes shown and also the beveled edge of the vane disk and the compounding plan with multiple wheels in parallel and as to the advantages of this plan, since it contemplates the adoption of pretty high vane-velocities, even in compounding, it will give very large power in comparatively small sizes, and in multiple expansion stages, with a steam economy that will compare with any other turbine generally in use for electrical generators.

What I claim is:—

1. In a turbine, a vane disk having radial slots at its edge, in combination with vanes removably mounted in said slots, and means to fasten the vanes upon said disk, said means being on different radial lines thereof and at unequal distances from the axis of said disk.

2. In a turbine, a vane disk having radial cross slots at its edge, in combination with vanes removably mounted in said slots and comprising a flat cross face portion curved in the form of a segment of a circle with a straight shank adapted to be secured in said slots and provided with side flanges of greatest depth centrally between the ends of said vanes.

3. In a turbine, a vane disk having a series of slots in its edge portion, in combination with curved vanes having shank portions adapted to fit said slots, and locking means to secure said shanks on different radii and at different distances from the edge of said disk.

4. In a turbine, a vane disk having a radially slotted edge and vanes having shanks adapted to be secured therein and fastening devices on each side of said shanks at unequal distances from the edge of the disk.

5. In a turbine, a vane-wheel having a sharp peripheral edge and beveled faces extending therefrom to either side to permit escape of steam with a minimum of back pressure, and vanes of tapering thickness centrally mounted at said edge.

6. In a turbine, a vane-wheel having a sharp peripheral edge and beveled on opposite sides to permit escape of steam and to eliminate back pressure, and radially curved tapering vanes having shanks removably set within said edge and overlapping said edge at either side.

7. In a turbine, a vane-wheel having a beveled periphery and vanes extending therefrom constructed with impact faces curved in a continuous line from said peripheral edge to their extremities and having flanges at each side to pocket the steam and combining therewith to utilize the steam with a maximum impact and minimum back pressure.

8. In a turbine, a vane-wheel comprising a ring disk having radially mounted vanes at its periphery and shoulders at its inner circumference and a two-part hub adapted to clamp said shoulders between them, and said hubs being separated from each other and apart from the shaft at the middle of said vane-wheel.

9. In a turbine, a vane-wheel consisting of a disk having radial slots, vanes held in said slots, a shaft and a two-part hub thereon between which said disk is supported out of contact with said shaft and said hub parts spaced apart at said shaft.

10. In a turbine, a vane-wheel comprising a disk tapering from its center outward and vanes removably mounted at the peripheral edge of said disks, a shaft and a two-part hub thereon to support said disk and spaced apart from each other and the said shaft to permit the shaft to spring.

11. In a turbine, a vane-wheel comprising a disk having a doubly beveled edge and radial slots across the same and vanes having a flattened and curved impact face and a shank to secure the same in said slots, and a hub and a shaft to support said disk.

12. In a turbine, the combination with a feed pipe and a replaceable expanding nozzle for peripheral feed detachably connected therewith, with a vane wheel having a series of radially curved vanes.

13. In a turbine, a feed pipe having a series of individually removable and replaceable expanding feed nozzles and means to secure the same thereto, combined with a vane-wheel having a series of peripheral vanes curved on continuous radial lines from their inner and outer edges and radially arranged thereon at predetermined distances apart, and said nozzle being tangentially disposed to said wheel.

14. In a turbine, a vane-wheel having vanes curved radially of the wheel and sharp on their outer edges to receive the steam jet peripherally and having gradually increasing thickness or caliber throughout their curved portions from their outer portion to the edge of said wheel.

15. In a turbine, a plurality of vane-wheels having vanes openly exposed to each other side by side within a common steam chamber and having a common steam supply pipe, a plurality of feed pipes connected with said supply pipe and individual nozzles connected with said feed pipes and tangentially arranged to operate said vane-wheels in parallel.

16. In a turbine, a plurality of separate vane-wheels spaced apart in open relation to each other and mounted to rotate together within a common steam chamber, a plurality of feed pipes one for each vane-wheel and a series of independently removable nozzles leading therefrom to the periphery of each vane-wheel, an exhaust port opposite each vane-wheel and a common exhaust pipe for said ports.

17. In a turbine, a series of vane-wheels and a plurality of separate steam chambers therefor, a series of steam nozzles increasing both in number and caliber from each successive vane wheel and pressure stage to the next, thereby providing graduated expansion steps for the steam from its inlet to its final outlet, and separate exhaust ports directly opposite each and every vane-wheel in all of said steam chambers.

18. In a turbine, a high pressure chamber and a vane-wheel therein, combined with a low pressure chamber having a series of vane-wheels therein, a feed pipe and nozzles for each vane-wheel, and the low pressure stage vane-wheels and feed nozzles arranged in parallel and adapted to receive in common the exhaust from the high pressure chamber, and separate exhaust ports for said lower pressure stage vane-wheels arranged directly opposite each and all thereof.

19. In a turbine, a casing providing double chambers consisting of four principal castings comprising a double dished member having a pedestal support and a shaft bearing intermediate thereof, a cap member for one side of said dished member, and a cylindrical member for the other dished side thereof, and a single dished cap part having a central hub and bearing for the shaft adapted to fit upon and cover the open end of said cylindrical member, in combination with separate vane-wheels rotatably mounted within said chambers, and separate feed nozzles leading to said vane-wheels.

In testimony whereof I sign this specification in the presence of two witnesses.

DUSTON KEMBLE.

Witnesses:
Carl Schuler,
Wayne L. Stilwell.