No. 795,516. PATENTED JULY 25, 1905.

C. M. JONES.

STEAM TURBINE.

APPLICATION FILED MAR. 28, 1902.

3 SHEETS—SHEET 1.

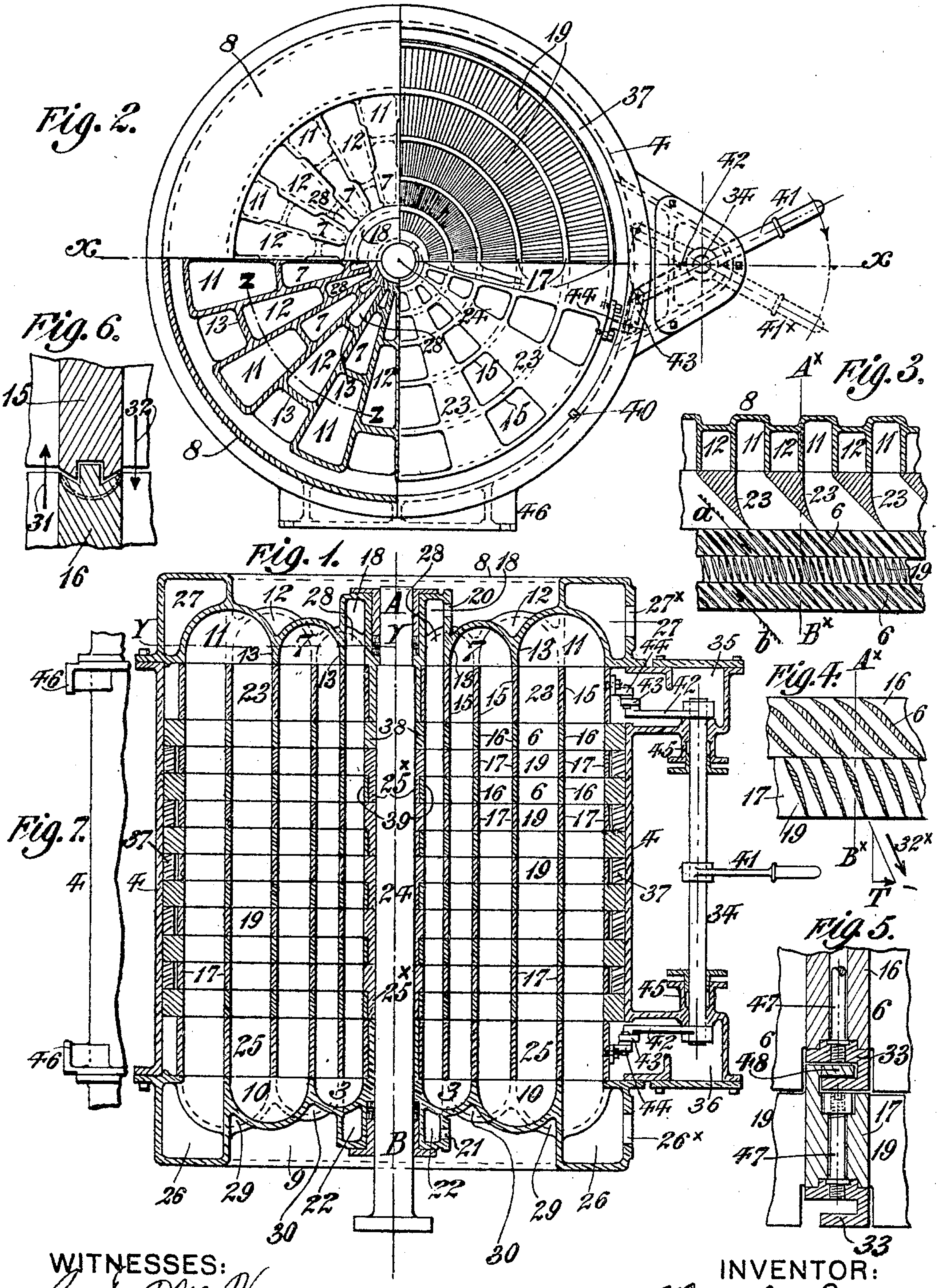

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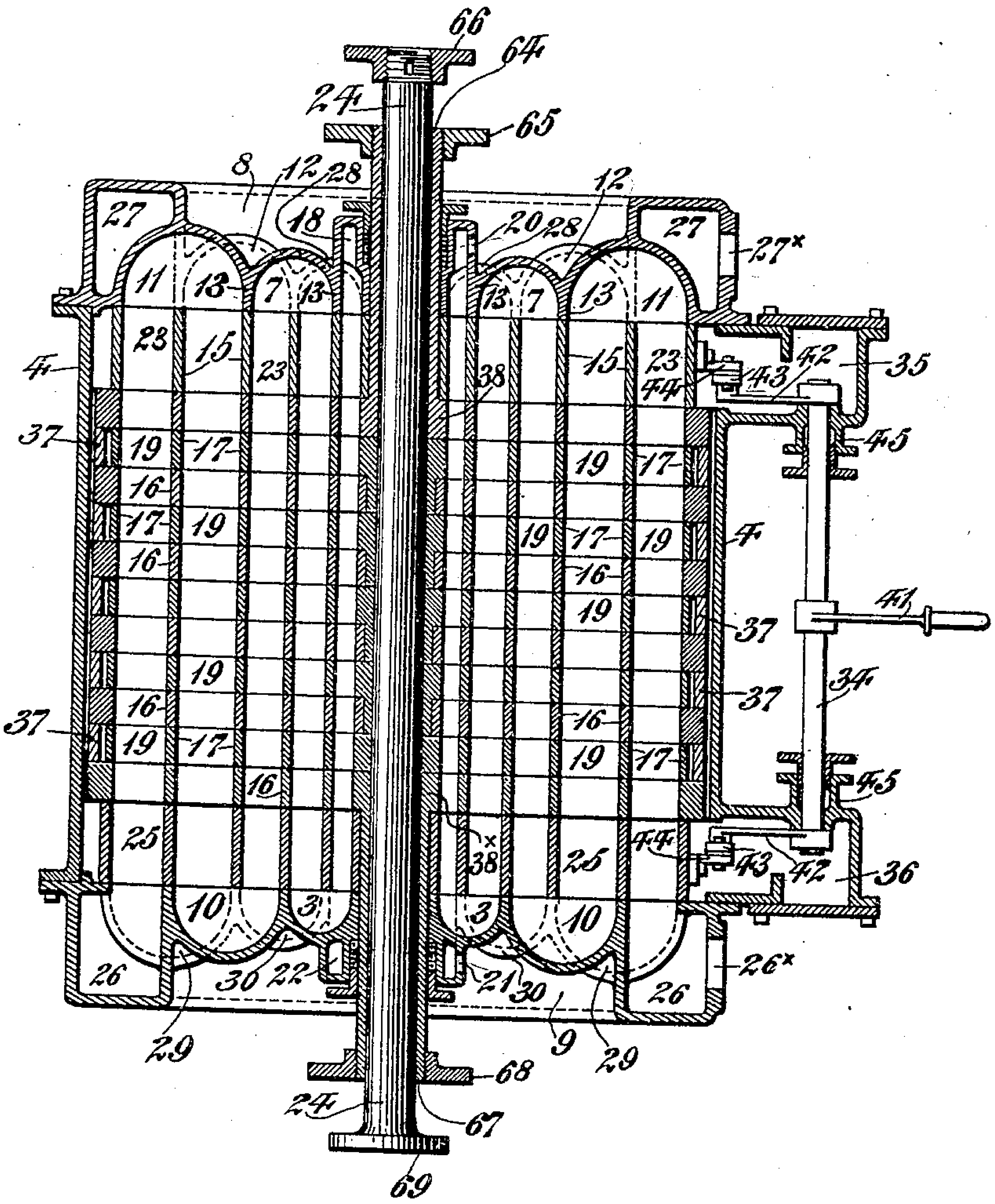
Fig. 8.



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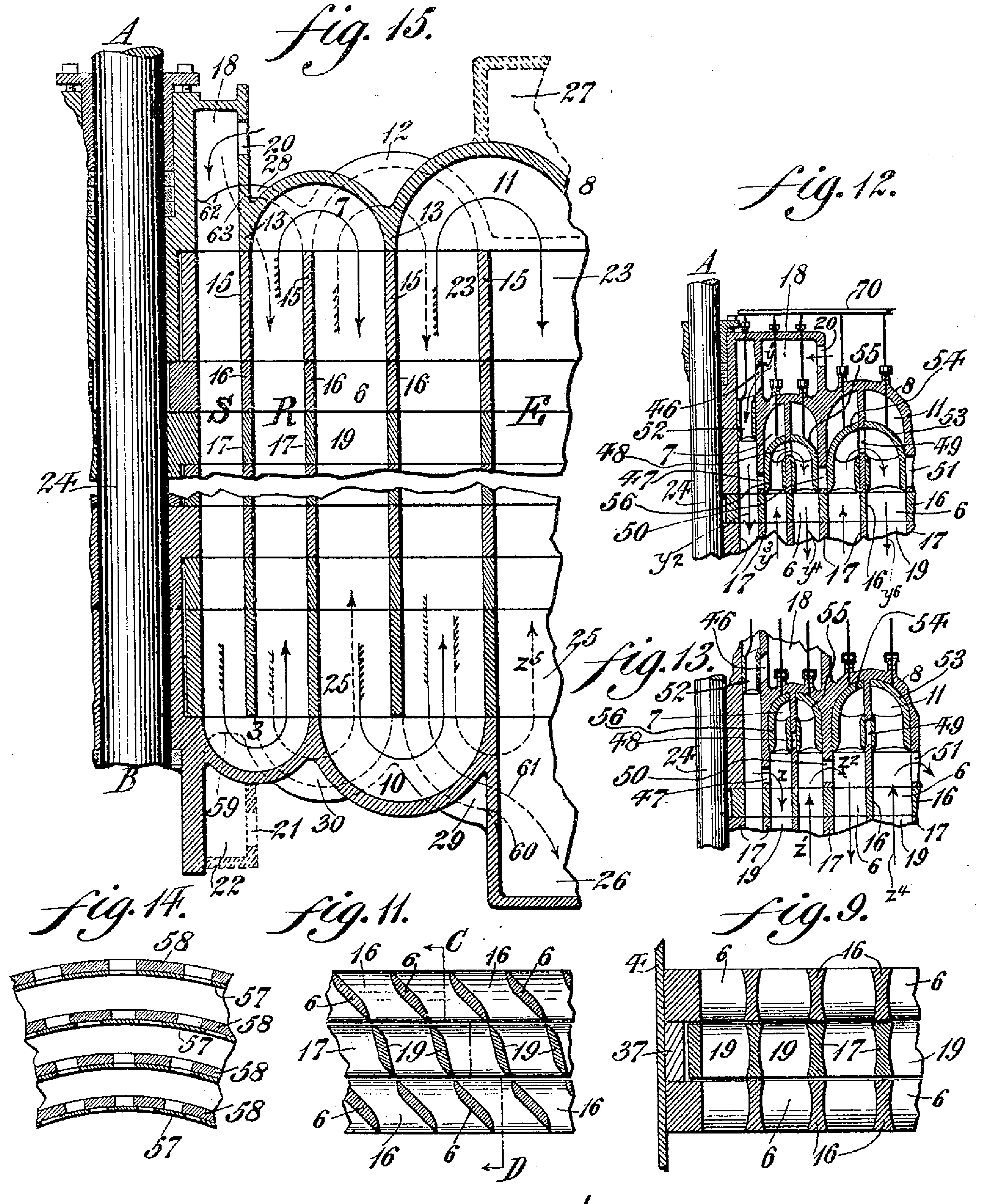

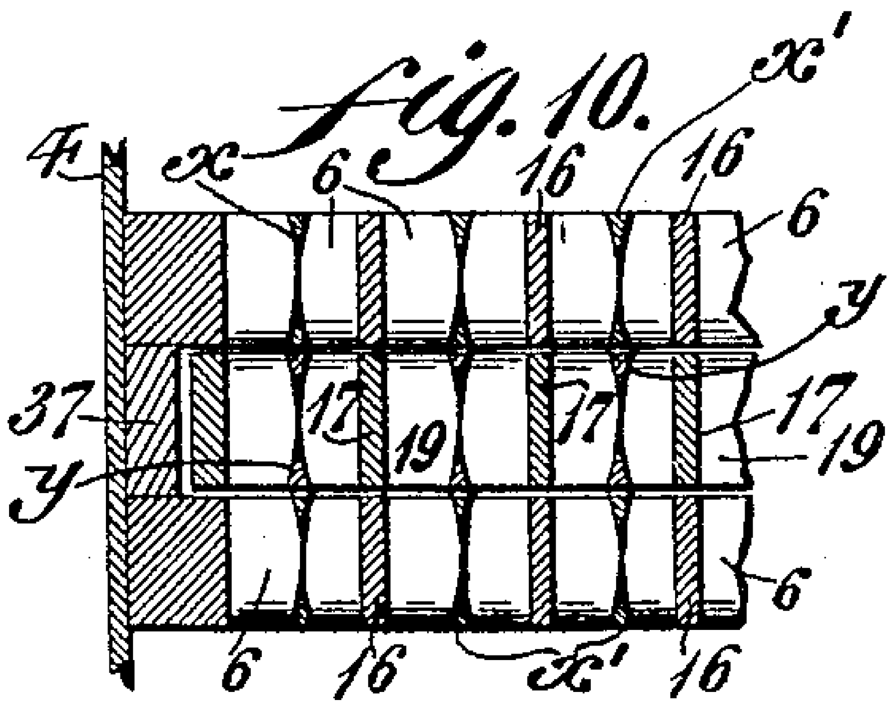

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STEAM-TURBINE.

No. 795,516 Specification of Letters Patent. Patented July 25, 1905.

Application filed March 28, 1902. Serial No. 100,361.

To all whom it may concern:

Be it known that I, CHARLES M. JONES, a citizen of the United States, residing in the city and county of Philadelphia, State of Pennsylvania, have invented a new and useful Improvement in Steam-Turbines or Rotary Engines, of which the following is a specification.

My invention relates to an improved construction of a steam-turbine or rotary engine which renders such motors highly efficient and economical at the slowest desired rates of speed, whereby they are fitted for general power purposes.

My invention also consists of novel means for enabling the direction of rotation of the turbine-shaft to be as readily reversed as in the shaft of an ordinary reciprocating engine, the turbine power and efficiency not being materially lessened after such reversal.

It also consists of novel improvements of various details whereby the economical and efficient motor is produced.

It further consists of novel details of construction, all as will be hereinafter fully set forth, and particularly pointed out in the claims.

Referring to the drawings, Figure 1 represents a longitudinal section on line *x x*, Fig. 2, of a turbine embodying my invention. Fig. 2 represents an end view of Fig. 1, partly in section, with portions of the device removed. Fig. 3 represents a sectional view of a portion of the mechanism in detached position. Fig. 4 represents a sectional view, on a somewhat larger scale, of a portion of the device. Fig. 5 represents a sectional view, on an enlarged scale, showing the steam-tight joint between certain fixed and moving parts. Fig. 6 represents a sectional view of the steam-tight joint as modified for certain purposes. Fig. 7 represents an elevation of a portion of the device, showing the base or brackets by means of which the motor may be bolted down or secured. Fig. 8 represents a longitudinal section showing a modification in the connection of certain elements of the device. Figs. 9, 10, and 11 represent sectional parts, showing my means for securing proper cross area of the steam-passages where the fining down of the guide and drive blade edges tends to increase such passage areas, Fig. 9 being a section taken on line C D in Fig. 11. Figs. 12 and 13 represent partial sectional views showing modifications of the reversing-valve. Fig. 14 represents a partial section showing modifications of the reversing-valves somewhat different from that seen in Figs. 12 and 13. Fig. 15 represents a sectional view of a portion of a turbine of a modified form.

Similar numbers and letters of reference indicate corresponding parts in the figures.

My turbine consists in its preferred form of a casing or cylinder 4, to which are bolted or otherwise secured steam-tight covers or bonnets 8 and 9, that carry bearings A and B, in which the turbine-shaft 24 revolves, the inner portions of the bearings being fitted as stuffing-boxes to prevent leakage from around the shaft.

Each of the covers or bonnets has centrally located an annular steam-chest 18 and 22, that may be supplied with steam from the boilers or other sources through the inlets 20 and 21, respectively, and each cover has also an exhaust-chamber 27 and 26 and the exhaust-outlets therefor $27^{\times}$ and $26^{\times}$, respectively, through which the exhaust-steam may be led to a condenser or elsewhere.

Secured to the turbine-shaft 24, which in the ordinary construction extends beyond the casing are drive-disks composed of drive-rings 17 and drive-blades 19 therebetween, while fixed against rotation by a key 40 or otherwise are guide-disks composed of guide-rings 16 and guide-blades 6, it being seen that the said guide-disks and drive-disks alternate with each other and that the rings form the walls of annular passages in which are situated the guide-blades and drive-blades. Between the bonnets and the first or outer guide-disks are movably secured the reversing-valves, which are ported disks composed of radiating bars 23 and port-rings 15, the central ring forming a hub that pivots around an extension of the bonnet, preferably substantially as shown, or around the turbine-shaft itself or otherwise, as desired, while the outer rings form continuations of the walls of the annular passages through the guide and drive disks above referred to.

Bolted or otherwise fastened to the periphery of the valve-disks are standards or brackets 44, which, through the medium of links 43, fitted with suitable pins or studs, engage with the reversing-arms 42, that are keyed to the reversing-shaft 34, which by means of the reversing-lever 41 may be rotated in bearings which may, if desired, be formed in the walls of the pockets 35 and 36 and provided with stuffing-boxes 45 to prevent leakage of steam therefrom.

Between the guide-disks and formed to clear the peripheries of the drive-disks are distance-rings 37, which prevent the guide-disks bearing against the drive-disks and which instead of being distinct members, as shown, may be portions of the guide-disks or may be simply stepped rings or projections formed on the inner surface of the casing 4 itself.

The cylinder head or bonnet 8 has pockets 7 and 11, each of which communicates with a distinct pair of the radially-adjacent passages formed by the blade-disk and valve-port rings, and alternate pockets 28 and 12, each of which likewise communicates with a distinct pair of radially-adjacent passages, but with passages that would otherwise be separated by the partition-rings 13 of the first set of pockets. The second or opposite cylinder-head 9 has like alternating pockets, and both sets of pockets form return-bends that direct the flow of the steam or other motive fluid through particular pairs of passages. The radiating side walls of both sets of pockets or return-bends in each bonnet are so located and formed that either set may be closed completely by the proper movement of the valve-disk, the radiating bars of which mask or cover one system of return-bends, while the ports open the alternate bends for the free flow of steam through them.

The radially adjacent guide-blades of each guide-disk are inclined in opposite directions as regards an axial plane of reference, the blades between corresponding rings of all the guide-disks inclining in the same general direction, and the same is true of the drive-blades, (except in certain cases to be hereinafter explained,) which being set at a different angle from that of the guide-blades deflect the streams of motive fluid flowing from the latter, and so receive the impulsive pressure tending to rotate the turbine-shaft.

The operation of the turbine is as follows: Steam being admitted to the centrally-located steam-chests 18 and 22 and the reversing-valves 23 and 25 being placed in their proper positions, the working fluid enters the first or central passage and sweeps through to the return-bends 3, which deflect it and cause it to flow from said bends 3 to the bends 7. From the bends 7 the steam passes to the bends 10, from 10 to 11, and from 11 it escapes through the extreme outer or exhaust passage into the exhaust-chamber 26, from which it flows through the outlet 26$^\times$ to the condenser or elsewhere. The reversed inclination of the disk-blades in radially-adjacent passages, before referred to, causes the opposite lines of flow in such adjacent passages to combine in forcing the turbine-shaft to revolve in some one particular direction, such direction being determined by the actual inclination in any specific case and by the lines of flow of the motive fluid as well. To reverse the turbine, the reversing-lever 41 (supposed to be in position seen in Fig. 2) is thrown over to the dotted position 41$^\times$, (seen in Fig. 2,) which movement rotates the valves 23 and 25, causing their faces to cover the set of return-bends in each bonnet that were formerly open, while their ports open each set of alternate pockets or bends formerly closed, the central portions of the valves also closing the openings from the previously-open steam-chest and opening the opposite chest and the peripheral portions of the valves, closing one exhaust and opening the opposite exhaust. The motive fluid now enters the first or central passage from the steam-chest 22, flows to the alternate return-bends 28, from 28 to 30, from 30 to 12, thence to 29, and from 29 through the last or exhaust passage to the exhaust-chamber 27, and through 27$^\times$ to the condenser or elsewhere, the reversed direction of flow in each passage acting on the reverse side of the drive-disk blades, and so forcing the turbine-shaft to revolve in the opposite direction to the previous motion, as shown by the arrows *a* and *b* in Fig. 3. In whichever direction the turbine is rotating the motive fluid enters the central passage first and thence travels gradually toward the periphery of the disks by way of the various passages and return-bends, as is evident.

In turbines heretofore in use direct reversal has been accomplished by admitting the live steam to the exhaust end of the motor and exhausting it from what is properly the live-steam end. Since in any case the live or high-pressure steam is of much less volume weight for weight than at exhaust, the proper or "go-ahead" live-steam passages must be of less cross area than the exhaust channels or passages in order that the motive fluid may pass through with sufficient velocity to develop the necessary impact-pressures, and the turning of the boiler-steam in at the greater cross-sectioned passages for reversal forces it to pass through them at slow speed, developing no proper impact reaction against the drive-blades, while at the same time the contracted area through which it must crowd its way toward the changed exhaust prevents a proper weight of flow and causes a heavy loss of total power and efficiency, and so great are these losses that in practice separate turbines used only for the reverse motion are considered by many as essential adjuncts in spite of the extra cost, complication, and weight entailed. In my turbine the steam in all cases enters the central passages first, as explained, and exhausts from the peripheral spaces, the only contraction during the flow being that due to difference of areas of ends of the individual channels and not, as with the ordinary system, to difference of the areas of the ends of extreme channels, so that the weight of steam passed, its velocity, and available energy are in my turbine closely equal for both go-ahead and reversed motion, which valuable features I claim as being new.

In order that the radiating blanks of the reversing-valves 23 and 25 may not obstruct the proper flow of the motive fluid to or from the turbine-blades, I make the cross-sections of said blanks, taken on such a line as Z Z, Fig. 2, something as shown in Fig. 3, the passage being formed to guide the steam or other fluid without unduly-abrupt changes of direction. In some cases I may curve the blades of the extreme or outer guide-disks themselves to give easy lead for the steam flowing between the disks and the return-bends, the valve-sections being modified to suit.

To enable the turbine to operate efficiently at slow speeds of revolution, it is necessary not only that the resistance due impact and friction of the working fluid passing through should prevent too great velocity of flow, but that the retarding effect upon the drive-disks of said friction should, where possible, be eliminated and turned to the useful purpose of adding to the motor effort. Up to the present time turbines have been designed with the general inclination of the revolving or drive blades taken as regards an axial plane of reference the reverse of that of the guide-blades, so that the working fluid in escaping from the drive-blades has a tangential velocity component in opposition to the tangential component of the drive-blade's circular motion. As the force of fluid friction acts on the blade and passage surfaces in the same direction as the stream's line of flow, such a method of construction gives rise to the retarding component before mentioned and absorbs a large percentage of the available energy of the working fluid. To overcome such loss of efficiency, I incline the drive-blades of my turbine (which blades I prefer to make as plain as possible and of the general cross-section shown in Fig. 4) in the same direction as the guide-blades, but at a less angle than the latter, so that the stream of working fluid passing between the blades, as shown by the arrow $32^{\times}$, Fig. 4, has a tangential component of motion T in the direction of rotation of the drive-disk and exerts a corresponding effort due to friction alone to assist the impact-pressure in turning the turbine-shaft. The limit to which this principle of construction applies is that at which the drive-disks are neutral in so far as being directly affected by the fluid friction, and in this case the drive-blades stand practically parallel to an axial plane of reference, and it is evident that the drive-blades may be set at such an angle, within the implied limits, that the axial component of the force of fluid friction acting tangentially on the surfaces of the passages and blades of said disks, as well as the axial forces on the disks due to direct variations of the pressures in the streams of motive fluid, may be locally neutralized or balanced by the axial component of the motive fluid's impact-pressure acting normally or at right angles to said surfaces, thus rendering it unnecessary to fit special thrust-bearings for taking up the axial thrust of the drive-disks and shaft. This method of eliminating the retarding effects on the drive-disks of the fluid friction and of causing such friction to assist the turbine's motion, as well as of locally balancing the axial forces of the friction, impact, and static pressure of the motive fluid, is new. It is applicable to turbines of radial-flow type, as well as to the parallel-flow construction here shown and described, and I claim it as patentable. In practice I do not entirely confine myself to this manner of inclining the drive-blades, which is of the greatest value when the turbine-passages are contracted and the flow of working fluid rapid. Where the passages are large and the fluid friction of less moment than the direct impulsive effect, I incline the blades after the ordinary method in general use.

Except in Figs. 5 and 6 the blade-disks are shown with plane faces, the adjacent rings merely touching; but in actual practice where the turbine is of reasonable size leakage between the passages must be prevented, and steam-tight packing is necessary. To avoid the friction and inconvenience of using the ordinary packing composed of metallic rings held in grooves or recesses and pressed against the adjacent surfaces to be rendered tight by means of springs or otherwise, I preferably construct the turbines with the joint substantially as shown in section in Fig. 5. In this figure, which is merely an enlargement of a portion of the longitudinal section shown in Fig. 1, 16 and 17 designate blade-ring sections; but instead of having plane faces the part 16 is fitted with a hooked ring 33, that is held securely by bolts, such as 47, while 17 has a lip or hook 48, that engages with said ring, both lip and ring being practically continuous (except for necessary divison to allow of their being hooked together) or forming complete circles around the turbine-shaft axis. Except at the hub and periphery each face of each blade-ring is preferably fitted with this joint, which while allowing free and unrestricted play for vibration and unequal expansion, such as must occur in motors of any size, is practically steam-tight as long as the turbine-disks revolve, and in some cases I may cut spiral or other scores or grooves in the faces and edges of the interlocking members to assist the friction and rotational effect of the mere surfaces in retarding the flow of steam through the joint.

The lip 48 is shown as being formed of the solid metal of the blade-ring; but in some cases I prefer making it of a distinct piece, as is 33, in which case I consider it advisable to use a separate system of bolts for securing it to the blade-rings. In some turbines I may make the hooks or lips solid on both sets of disks, making the latter disks in sections, which may be bolted or otherwise fastened together after the joint-rings are interlocked.

Instead of bolting the hooked rings to the blade-rings any other suitable means for fastening them may be employed. At the hub and periphery of the disks I usually employ no packing between the blade-rings, as the leakage at those points is but trifling in amount and of no particular moment.

To pack the joints between the valve-port rings and the rings of the adjacent guide-disks without the use of separate packing-rings, I employ the tongue and groove shown in section in Fig. 6, which is an enlarged portion of the section shown in Fig. 1, the latter for clearness showing simply plain joints between the various rings.

The joint shown in Fig. 6 is an improvement over the ordinary tongue and groove for the reason that the surfaces between which the fluid must enter and pass out are inclined in such directions that when the turbine is in go-ahead gear the higher-pressure steam flows past the joint relatively as shown by the arrow 31, while the lower-pressure steam flows past as shown by the arrow 32. The flow in the direction (relatively to the inclined or beveled surface) of the arrow 31 tends both by velocity and friction or attraction to prevent the particles of the working fluid from entering the joint, while the flow shown by the arrow 32 tends by impact against them to keep particles in the joint from issuing therefrom. In some cases I may employ this type of joint for the drive and guide disk rings instead of the interlocking rings shown in Fig. 5, and where it is expedient I make the surfaces of the latter species of packing with the above-stated inclination, and in some turbines I may use both constructions and may also employ plain packing-rings set out by springs or otherwise, as circumstances may dictate.

In Fig. 5 the rings are shown as having a single lip or hook; but two or more such interlocking members may be fitted, and instead of the single tongue and groove of Fig. 6 a number of such may be employed.

The joint shown in Fig. 6 may be modified by cupping one ring and forming the other ring to fit as per the dotted lines in the figure. This construction preserves the principle before specified of the inclined surfaces and may be supplemented with a tongue and groove, or the surfaces of the tongue and groove may be inclined and extended to the cylindrical surfaces of the blade-rings, forming a simple V-joint, while preserving the feature of inclining in relation to the directions of the flow of the working fluid for the purpose before explained.

When necessary, the joints between the blade-rings may be of the ordinary beveled variety, one ring formed to slightly overlap another, or, if the turbine is small and the parts can be accurately fitted, reliance may be had on the closeness of plain-faced rings supplemented, if desired or necessary, with spiral grooves, as described in Fig. 5.

To make the joint between the walls and partition-rings of the bonnets and the faces of the reversing-valves, I prefer to rely on plain scraped surfaces, the valve-disk being held up to the bonnet by springs or other devices suitable for such purpose, which as they form *per se* no part of my invention are not shown in the drawings.

Where unequal expansion or the warping of the valves and bonnets require it, packing strips or rings, or both, held in suitable scores or grooves in the valve or bonnet faces or otherwise fitted, may be used, and such packing may also be fitted to pack the joints between the valves and the outer or extreme guide-disks.

In Figs. 1, 2, 5, and 6 the inner and outer boundaries of the blade-rings are shown for simplicity as straight lines; but since the drive and guide blade edges must be much thinner than their main section to avoid obstructing the flow of the steam or other working fluid, parallel or straight-lined ring-sections would, in effect, cause the cross-area of the passages between the blades to alternately contract and expand in relation to the steam passing through and the expansion of area, which would cause decreased velocity in the flowing fluid, would be at the points where the full maximum velocity is required to generate the proper impulsive pressure. To prevent such fluctuations of stream velocity, I secure uniform area of passage cross-section by hollowing the mid-portions of the blade-rings, as shown in Figs. 9 and 11, or by introducing false rings x' and y of proper section, as shown in Fig. 10, and in some turbines I use both means of accomplishing the desired object. The hollowed form of the blade-rings proper may be obtained by building up or inserting pieces between the blades, and the false rings between the true blade-rings may also be separate pieces inserted and secured in position between the blades. The gain in efficiency due to so maintaining the proper area of passage at the blade edges is so great and is so radical a departure from the ordinary practice that I claim it is a distinct advance in the general construction of impact motors of this type. In addition to their value in compensating for changes of cross-area of the passages false rings are in many cases necessary to stiffen the radially long blades in the passages at and near the exhaust portion of the disks by limiting their flexural continuity.

In Fig. 8, which is on substantially the same section-line as Fig. 1, the guide-disks 16 and 6 and distance-pieces 37 instead of being prevented from revolving are fastened together and may revolve in the opposite direction to the drive-disks secured to the turbine-shaft, becoming themselves a second set of drive-disks, both such sets when in operation reversing their direction of motion on the reversing-valves being properly moved. In this construction the disks 16 and 6 are carried, preferably, by the central bosses or hubs 38 38$^{\times}$ of the outer disks pivoting about the shaft, one or both hubs extending through the casing-bonnet stuffing-boxes and having an outside flange-coupling 68 and 65 or other attachment for transmitting power. In Fig. 8 no fixed guide-disks are shown; but in practice I prefer fitting between the valves and the first revolving disks proper guide-disks to increase the efficiency of the first series of revolving blades. This modified form of turbine is valuable in situations where the double direction of rotation can be made use of, as a given relative speed of the two sets of disks (to which the power is mainly due) requires but half the actual rotative speed of shaft that would exist with one set of blades fixed or standing. With this arrangement leakage of the working fluid from between the shaft and sleeves or boss extensions may be prevented by suitable stuffing-boxes at 64 and 67, or dependence may be placed in the fit of the sleeves themselves. It is readily seen that, if desired, such sleeves or extension-pieces may be distinct members bolted or otherwise fastened to the disks instead of being parts thereof and that instead of the main shaft 24 extending through with a coupling 66 it may be shorter than the sleeve of the second set of disks and its end be covered in by a plate at 64 or by that end of the sleeve being made solid. It is also plain that either set of disks may be used as guide-disks by preventing the rotation of the shaft or sleeves, as the case may be, and that the main shaft-coupling 69 may be secured to the shaft, as is 66, and that both sleeve and shaft may be stopped short in the bearing and the ends covered by a plate or flange or other suitable device to prevent leakage. It is evident that this modified turbine may be used as a reversing-motor without the use of any reversing-valves whatever, since a system of clutches or their equivalent may be fitted that will prevent either set of blade-disks from revolving while the opposite set of disks is connected to a line of shifting, the clutches engaging either set of disks at the will of the operator. Where this method of reversal of motion is applied, I preferably make the blades of each set of disks of the "reaction" or "half-moon" pattern, the general angle of each system of blades as regards an axial plane being symmetrically opposite in each passage to that of its fellow system.

Fig. 15 shows a modification of the return-bends or alternating pockets by means of which one of the steam-chests 22 and one of the exhaust-chambers 27 may be dispensed with, the turbine still being reversible and of but slightly-reduced power when in backing motion. In this form instead of the alternate return-bends 28 being as in Fig. 1 the curved back walls at 62 do not exist, and when the reversing-valves are in proper backing-gear the working fluid, which is shut out of the first or central passage, passes from the steam-chest 18 through the opened pocket or bend 28 (the back wall of which rounds into the chest at 63) and the valve-ports being open to these bends enters the second passage R and sweeping through, as shown by the dotted arrows, reverses the turbine, the first passage S being cut out or idle. In the same way the outer or back wall of 29 being stopped off and rounded into the exhaust-chamber metal at 60 instead of the working fluid taking the path shown by the dotted arrow Z^5 it sweeps at once into the exhaust-chamber 26, as shown by the arrow 61, leaving the passage E idle, the exhaust-chamber 27 not existing.

As in any case the turbine can be constructed with an even or an odd number of passes between the inlet and exhaust, both steam-chest and exhaust-chamber may be at the same end of the motor.

In Figs. 12 and 13 I have shown reversing-valves of a different form than those already described. Instead of rotating, these valves 52, 53, 54, 55, and 56 slide parallel to the turbine-shaft and uncover and cover the ports 46 47 48 49 50 51, &c., for passing the working fluid into and out of the various passages. Fig. 12 shows the valves of one end in go-ahead gear, while in 13 they are in backing or reversing position and, as clearly shown, do not give as clear and easy a lead for the steam as does the arrangement before described. These valves may form complete rings around the shaft, or each may be in two or more distinct pieces and instead of having stems passing out through stuffing-boxes and secured to a yoke 70 for connection to suitable reversing-gear may be actuated by any other suitable means. The opening and closing of the ports, and the directions of flow through them as per the arrows Z Z' Z^2, &c., in both go-ahead and backing position, is clearly shown and requires no particular explanation.

Fig. 14 is a partial cross-section showing valves that open and close the proper ports by rotation. These ports are similarly situated to those shown in Figs. 12 and 13; but instead of sliding longitudinally the valves 57 cut out or close and open the proper ports in the passage-walls 58, which are practically identical with those in Figs. 12 and 13, by turning through a small angle around the shaft-axis as center, and it is readily seen that both a sliding longitudinal motion and a turning about the shaft-axis may be combined to produce the same desired result. With the types of valve seen in Figs. 12, 13, and 14 both ends of the turbine are fitted substantially alike.

In some cases instead of having steam-chests in the bonnet I may connect the steam-pipe to one end of the turbine-shaft, which I then make hollow and by proper ports or openings in the bonnet-center extensions or hubs covered by the valves or otherwise admit steam to or shut it from the passages, and in particular instances I lead the steam or other working fluid to the middle of the first or central pass, whence it flows in both directions toward the return-bends in the bonnets, which being modified in relation to the valve-ports and radiating bars return it from each end again toward the center of the next passage, which by means of an opening at its middle causes it to again flow outwardly toward the bonnets through the radially adjacent passages between the blades, or the steam or other working fluid may enter the ends of the first passes, and flow reversely to the manner just described, or combination of such lines of flow through the turbine may be used, the guide and drive blade inclinations being made to properly conform to such arrangements.

Instead of the reversing mechanism shown in Figs. 1 and 2 any other suitable device for actuating the valves may be employed, and such devices may engage with the valves at any proper point instead of at the periphery, as shown, and the steam-tight chambers 35 and 36 (which in any case may be separate from the casing or cylinder and bolted or otherwise fastened to it) may be dispensed with and the reversing members be located elsewhere.

The main-shaft stuffing-boxes, shown as within the shaft-bearings, may be exterior to them, or the bearings may be separate from and fastened to the bonnets or may be separate and secured to entirely exterior foundations, and such bearings may, where found desirable, be supplemental by fitting the central bosses of one or more guide-disks to act as supports to take up the spring of the shaft, and as many of the blades of such supporting-disks as may be necessary or desirable may be omitted and the central supporting-sleeve be held by single struts, the rings being retained to preserve the passages.

The steam-chests 18 and 22, shown as cast with the bonnets, may be separate pieces and bolted or otherwise properly fastened on, as may be the exhaust-chambers, or these latter may be part of the cylinder or shell or be separate and bolted or otherwise secured thereto, the exhaust from the passages between the disk blades being led to such changed position by suitable formation of the bonnets near the valve-peripheries or by means of openings at or near the edges of the valve's outer rim or otherwise.

In the drawings the bonnets and shell or cylinder are shown without jackets; but such jackets for either steam or other hot gases may be supplied, and even the disk rings and the valve-bars and port-rings may be made hollow and supplied with jacketing-steam through suitable channels or piping, if desired or expedient.

The return-bends or alternating pockets, Figs. 1, 2, 3, 8, and 15, shown and described as part of the bonnets proper, may be in disks or portions thereof separate from the bonnets between such covers and the valves and may be the members to rotate instead of the valves, which may then remain fixed, or both valves and such return-bend disks may move when the direction of motion of the turbine is being changed. Also instead of the alternating pockets being entirely separated, as shown, any or all of the members of a distinct set may be in free communication by means of suitable connections, such connections, properly proportioned, forming receivers or reservoirs into which the rapidly-advancing column of motive fluid may store a portion of its kinetic energy during the period of relatively lessening velocity at reversal of motion, the reabsorption of which energy by the column of fluid after said reversal of motion adding materially to the turbine's operative economy. When the turbine is of moderate dimensions, I preferably secure the proper receiver action by enlarging the volume of the return-bends proper over that necessary to merely pass the motive fluid. In either case the motive fluid enters the receiver-spaces through gradually-increasing areas of passage and leaves such reservoirs at gradually-increasing speeds through decrease of passage areas. When water is the motive fluid, the return-bends or alternating pockets may in addition be connected to proper air-chambers to absorb the surplus shock of the steam's reversal.

In the drawings the return-bends are shown as without interior ribs or braces; but in practice stays or partitions of any sort consistent with the flow of the motive fluid may be introduced for strength, subdivision, or other purpose.

Instead of the bonnets being made separate from the cylinder one may be cast with it or both may be cast with portions of the casing, which may be bolted or otherwise secured together, either directly or with an intermediate piece between, and one or more such pieces or members may be built up of two or more sections, as may be deemed desirable or necessary, and the guide-disks or the drive-disks, or both, as well as the other details, may be built up instead of being formed of one piece.

Where the turbine is to run in one direction, I prefer discarding the reversing-valves and fitting the outer or extreme end guide-disks close against the bonnets, in which case I modify the return-bends by substituting for the alternating pockets continuous scores or grooves, circumscribing the axis of the turbine-shaft, that connect the proper pairs of passages, and in such instances but one steam-chest and one exhaust-chamber are needed.

In the drawings the disk-passages are shown as parallel from end to end; but in practice where an expansive fluid is used the exhaust ends of at least the passages at and near the periphery of the turbine are best made with some flare to give area sufficient to keep down to reasonable limits the velocity of flow of the expanding working fluid.

In my motor the inlet at the central passage allows the passage-ring boundaries to be reasonably separated radially, while restricting the passage cross-area to the proper value for forcing the small volume of high-pressure steam to sweep through at sufficient velocity to generate the necessary impact against the blades. The increased area required of each passage by the steam expanding as it sweeps through is had with a fairly-uniform ring separation by reason of the greater area due a set radial distance apart as the mean or central radius of the passages increase. With inlets at the periphery in turbines of this general type already in use the proper initial passage areas would require so close a radial distance between the rings that the loss of energy in forcing the steam to pass between the close surfaces against the capillary attraction, viscosity, &c., would reduce the motor efficiency to a very low figure. Again, with the central inlets, as here proposed, the exterior loss of heat mainly takes place from the steam that has done most of the work required of it and is about to be exhausted from the motor, while with the live steam at the periphery exterior radiation reduces the initial energy before the fluid has done any appreciable work whatsoever, and so requires an increased weight of steam for a given output. In my turbine by reason of the small losses through exterior radiation, leakage between passages, and retarding components of friction on the revolving disks, as hereinbefore explained, I am able to reduce the velocity of flow through the passages and so confine the steam in the motor for a much longer period than would be economical with other constructions.

To confine the steam and prevent its too quickly escaping, I multiply the number of disks and passages until the sum of the resistances of the blades in deflecting the working fluid and of the friction of the blade and passage-surfaces equals (slightly modified for the leakage and radiation at the desired velocities of flow) the total difference of pressure between entrance and exhaust, and as this adjustment can be made for any rotative speed of disks it follows that the turbine can be run at the slowest, as well as the highest, rotative velocities.

The speed of flow of the working fluid being properly selected to furnish with the given number of sets of revolving blades the necessary rotating effort, the slowest disk velocities can be had with the fullest economy, the more so as the losses by fluid friction are much less with slow flow than with the high speeds.

My motor, which is essentially a "pressure-turbine," as the variations of pressure of the steam (or other working fluid) flowing through it are due to the internal resistances and not to free expansion, is preferably governed where the load fluctuates by a simple throttling device, such as is used on many engines of the ordinary reciprocating type. Cut-off governors admitting the steam in "gusts" may be employed; but the sudden changes of internal pressure and temperature are not conducive to economy. Partial closing of the exhaust-outlet may also be resorted to as a means of changing the power and speed, or combinations of such appliances may be employed as with other motors.

It will be apparent that changes may be made in the details of construction without departing from the spirit of my invention, and I do not, therefore, desire to be limited in each case to the same.

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

1. In a parallel-flow multipassage turbine, a series of concentric rings, blades or impact members therebetween, and means for regulating local variations of velocity of flow of the motive fluid passing between said rings.

2. In a parallel-flow multipassage turbine, a series of concentric rings, blades or impact members therebetween, and means for eliminating the retarding effects on the rotating elements of the force of fluid friction acting on the revolving blade and passage-surfaces.

3. In a parallel-flow multipassage turbine, a series of concentric rings, blades or impact members therebetween, means for regulating local variations of velocity of flow of the motive fluid passing between said rings, and means for eliminating the retarding effects on the rotating elements of the force of fluid friction acting on the revolving blade and passage-surfaces.

4. In a parallel-flow multipassage turbine, a series of concentric rings, blades or impact members therebetween, and means for limiting in the individual passages the flexural continuity of said blades.

5. In a parallel-flow multipassage turbine, a series of concentric rings, blades or impact members therebetween, means for regulating local variations of velocity of flow of the motive fluid passing between said rings, and means for stiffening said blades.

6. In a parallel-flow multipassage turbine, a series of concentric rings, blades or impact members therebetween, means for eliminating the retarding effects of the force of fluid friction acting on the revolving members and

means for limiting in the individual passages the flexural continuity of said blades.

7. In a parallel-flow multipassage turbine, a parallel-flow multipassage series of concentric rings, blades or impact members therebetween, means for regulating local variations of velocity of flow of the motive fluid passing between said rings, means for securing a useful effort from the force of fluid friction acting on the blade and passage-surfaces and means for stiffening said blades.

8. In a parallel-flow multipassage turbine, a series of concentric rings, blades or impact members therebetween, means for forming between abutting ring-faces flexible joints, and means for rendering said joints impervious through the impact and attractive actions on the idle fluid between said faces of the motive fluid radially adjacent the main streams of flow.

9. In a parallel-flow multipassage turbine, a series of concentric rings, blades or impact members therebetween, means for forming frictionless joints between abutting ring-faces, and means for rendering said joints impervious through the impact and attractive action on the idle fluid between said ring-faces of the motive fluids radially adjacent the main streams of flow.

10. In a parallel-flow multipassage turbine, a series of concentric rings, blades or impact members therebetween, means for forming flexible frictionless joints between abutting ring-faces, and means for rendering said joints impervious through the action on the idle fluid between said abutting ring-faces of the motive fluids radially adjacent main streams of flow.

11. In a parallel-flow multipassage turbine, a series of concentric rings, blades or impact members therebetween, means for forming frictionless joints between abutting ring-faces, and means for rendering said joints impervious through the centrifugal action of the rotating rings on the idle fluid between said abutting ring-faces.

12. In a parallel-flow multipassage turbine, a series of concentric rings, blades or impact members therebetween, means for forming flexible joints between abutting ring-faces, and means for rendering said joints impervious through the centrifugal action of the rotating rings on the idle fluid between said abutting ring-faces.

13. In a parallel-flow multipassage turbine, a series of concentric rings, blades or impact members therebetween, means for forming frictionless flexible joints between abutting ring-faces, and means for rendering said joints impervious through the centrifugal action of the rotating rings on the idle fluid between the faces of said abutting rings.

14. In a parallel-flow multipassage turbine, a series of concentric rings, blades or impact members therebetween, means for forming frictionless joints between abutting ring-faces, and means for rendering said joints impervious through the action on the idle fluid between said abutting ring-faces of the flowing motive fluids radially adjacent the main streams and of said abutting rings relative rotative velocity.

15. In a parallel-flow multipassage turbine, a series of concentric rings, blades or impact members therebetween, means for forming flexible joints between abutting ring-faces, and means for rendering said joints impervious through the action on the idle fluid between said abutting ring-faces of the flowing motive fluids radially adjacent main streams and the relative rotative velocity of said abutting rings.

16. In a parallel-flow multipassage turbine, a series of concentric rings, blades or impact members therebetween, means for forming flexible frictionless joints between abutting ring-faces, and means for rendering said joints impervious through the action on the idle fluid between said abutting ring-faces of the rotative velocity of the revolving rings and the motive fluids radially adjacent main streams of flow.

17. In a turbine, a plurality of rotative elements, series of blades or impact members fixed thereon, means for directing the flow of the motive fluid between alternate series of blades, and means for changing at will the connected alternation of the blade series.

18. In a parallel-flow multipassage turbine, a plurality of distinct passages, the areas of said passages increasing from the axis to the periphery of said turbine, means for admitting the motive fluid to the central or axial passage, means for conducting the motive fluid from each inner passage to the next outer passage, means for exhausting said fluid from the outer or peripheral passage, and means for reversing at will the axial directions of the flow of said motive fluid while preserving the general lines of flow between the axial and peripheral passages.

19. In a turbine, a plurality of rotatable members, series of blades or impact members fixed thereon, means for directing the flow of the motive fluid against said blades, means for directing the flow of the motive fluid between alternate series of blades, and means for changing at will, the direct alternation of connected series for the purpose of reversing the turbine's direction of rotation.

20. In a parallel-flow multipassage turbine, a series of concentric rings forming passages therebetween, blades or impact members between said rings, means for directing the flow of the motive fluid through said passages, means for regulating local variations of velocity of flow of the motive fluid passing through said passage and means for reversing at will the direction of flow of the motive fluid through individual passages while preserving the gen-

eral line of flow between inlet and exhaust, whereby the turbine's motion is reversed.

21. In a parallel-flow multipassage turbine, a series of concentric rings forming passages therebetween, blades or impact members between said rings, means for directing the flow of the motive fluid through said passages, means for reversing at will the direction of flow of the motive fluid through individual passages while preserving the general lines of flow between inlet and exhaust whereby the turbine motion is reversed, and means for securing a useful effort from the force of fluid friction acting on the blade and passage-surfaces.

22. In a turbine, a plurality of passages, blades or impact members in said passages, means for directing the flow of the motive fluid through said passages, means for reversing the direction of flow of said fluid through individual passages, whereby the turbine motion is reversed, means for regulating local variations of velocity of flow of said motive fluid passing through said passages, and means for securing a useful effort from the force of fluid friction acting on the blade and passage-surfaces.

23. In a parallel-flow multipassage turbine comprising a cylinder or casing, bonnets or covers for the ends of such casing, disks composed of a series of concentric rings with blades or impact members therebetween, shafting supported by bearings and carrying within said casing a set of said disks alternating in position with disks otherwise supported, inlets to admit the motive fluid to the central or axial passages between the concentric disk rings, grooves, scores or return-bends, for directing the flow of the motive fluid from each inner passage between concentric disk rings to the next outer passage between such rings, outlets for the exhaust of the motive fluid from the peripheral or exhaust passages, reversing at will valves for reversing the axial direction of flow of the motive fluid in the individual passages between concentric disk rings, while preserving the general lines of flow between the turbine's inlets and exhausts reversing-gearing for operating said reversing-valves and packing members for abutting surfaces.

24. In a turbine, a plurality of passages, return-bends or alternating pockets for directing the flow of the motive fluid through said passages, means for transforming the kinetic energy of the streams of motive fluid entering said bends or pockets into actual head or increased pressure within said bends or pockets, and means for transferring from said increased head or pressure the equivalent kinetic energy to the outward-flowing motive-fluid streams.

25. In a parallel-flow multipassage turbine, a plurality of rotative elements, blades or impact members carried thereon, means for directing the flow of the motive fluid against said blades or members, and means for locally balancing axial forces due to the action on the rotative members of the friction and pressure of the motive-fluid streams.

26. A rotary engine comprising a rotary disk having a series of inclined transverse passages at different distances from the center, means for admitting a steady flow of motive fluid at one side of said disk for rotating it in one direction, means for admitting a steady flow of motive fluid at the opposite side of said disk for rotating it in the reverse direction, and means for directing a steady flow of the motive fluid from each series of passages to the next series.

27. A rotary engine comprising a rotary disk having a plurality of series of inclined transverse passages at different distances from the center, means for admitting steam at one side of said disk for rotating it in one direction, means for admitting steam at the other side of said disk for rotating it in the opposite direction, and means for directing the steam from each series of passages to the next.

28. In a turbine, a rotary member having a plurality of series of blades or impact elements at different distances from its axis of rotation, means for directing a steady flow of the motive fluid against said impact elements, means for directing a steady flow of the motive fluid between alternate series of blades, and means for changing at will the directing fluid connections between said blade series.

29. In a turbine, a rotary member having a plurality of series of blades or impact elements at different distances from its axis of rotation, means for directing a steady flow of the motive fluid successively against said impact elements, means for directing a steady flow of the motive fluid between alternate series of impact elements and means for changing at will the fluid-directing connections between said series of elements or blades.

30. In a turbine, a rotary member, a plurality of series of blades or impact elements at various distances from the axis of rotation carried thereby, means for directing a steady flow of the motive fluid against said blades, means for directing a steady flow of the motive fluid between successive series of blades, and means for changing at will the fluid-directing connections between successive series.

31. In a turbine, a rotary member, a plurality of series of blades or impact elements at various distances from the axis of rotation carried thereby, means for directing a steady flow of the motive fluid against said blades, means for directing a steady flow of the motive fluid between successive series of blades, and means for changing at will the fluid-directing connections between successive series of impact elements.

32. In a turbine, a rotary member having a plurality of impact members at different distances from its axis of rotation, means for directing the motive fluid against said impact

members, and means for reversing the action of the motive fluid on individual impact members.

33. In a turbine, a rotary member having a plurality of impact members at different distances from its axis of rotation, means for directing the motive fluid successively against said impact members, and means for reversing the action of the motive fluid on individual impact members.

34. In a turbine, a rotary member having a plurality of impact members at different distances from its axis of rotation, means for directing the motive fluid against said impact members and successively from inner to outer impact members, and means for reversing the action of the motive fluid on individual impact members while preserving the general outward movement of the motive fluid.

35. In a turbine, a rotary member having a plurality of series of blades or impact members at different distances from its axis of rotation, means for directing the motive fluid from one series of blades to another, and means for changing the order in which the different blades of each series are acted on by the motive fluid, substantially as described.

36. In a turbine, a rotary member having a plurality of series of blades or impact members at different distances from its axis of rotation, means for directing the motive fluid successively from one series of blades to the next, and means for changing the order in which the different blades of each series are acted on by the motive fluid, substantially as described.

37. In a turbine, a rotary member having a plurality of series of blades or impact members at different distances from its axis of rotation, means for directing the motive fluid from one series of blades to another, and means for changing at will the fluid-directing connections by which the fluid is directed from one series of blades to another, substantially as described.

38. In a turbine, a rotary member having a plurality of series of blades or impact members at different distances from its axis of rotation, means for directing the motive fluid successively from one series of blades to the next, and means for changing at will the fluid-directing connections by which the fluid is directed from one series of blades to the next, substantially as described.

39. In a fluid-impact machine, the combination of rotatable ported members or valves, and pocketed covering plates or bonnets, as specified and described.

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Witnesses:

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