R. CRAMP.

REVERSIBLE TURBINE.

APPLICATION FILED AUG. 4, 1910.

971,730. Patented Oct. 4, 1910.

5 SHEETS—SHEET 1.

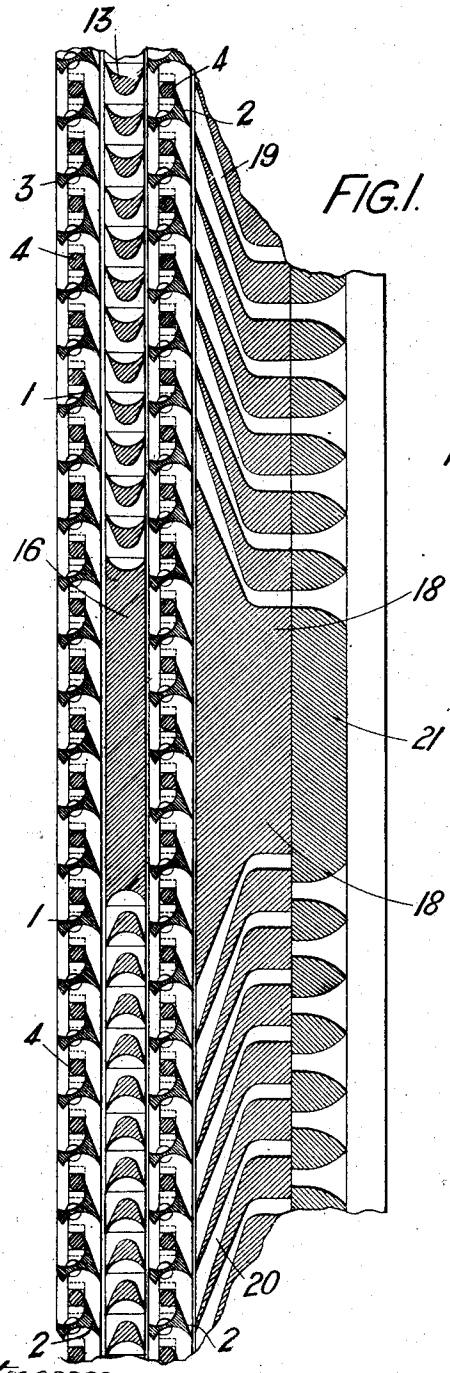


FIG. 1.

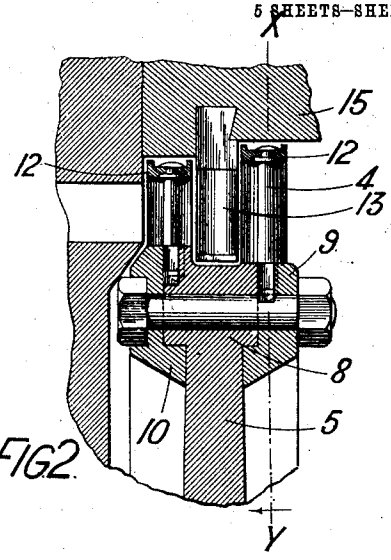


FIG. 2.

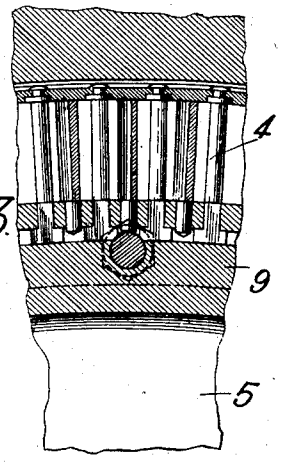
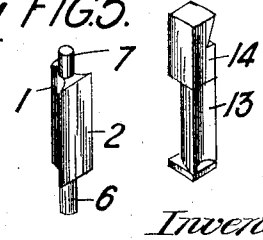


FIG. 3.

FIG. 6.

FIG. 4.

FIG. 5.



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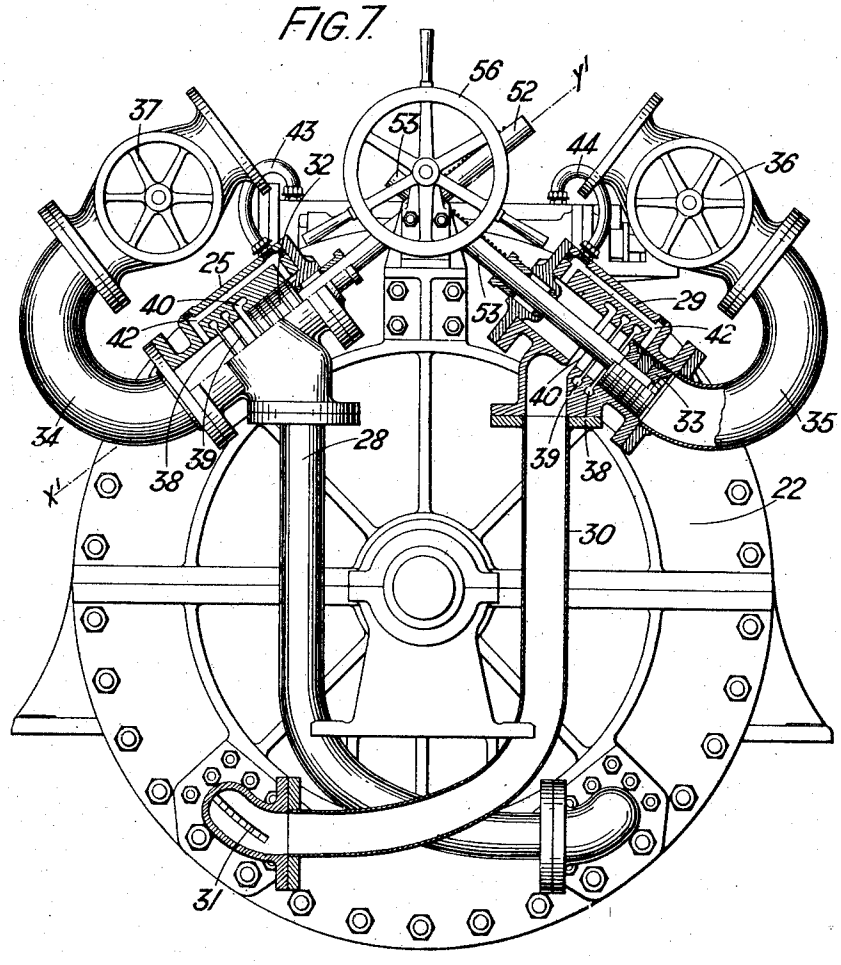
5 SHEETS—SHEET 2.

FIG. 7.



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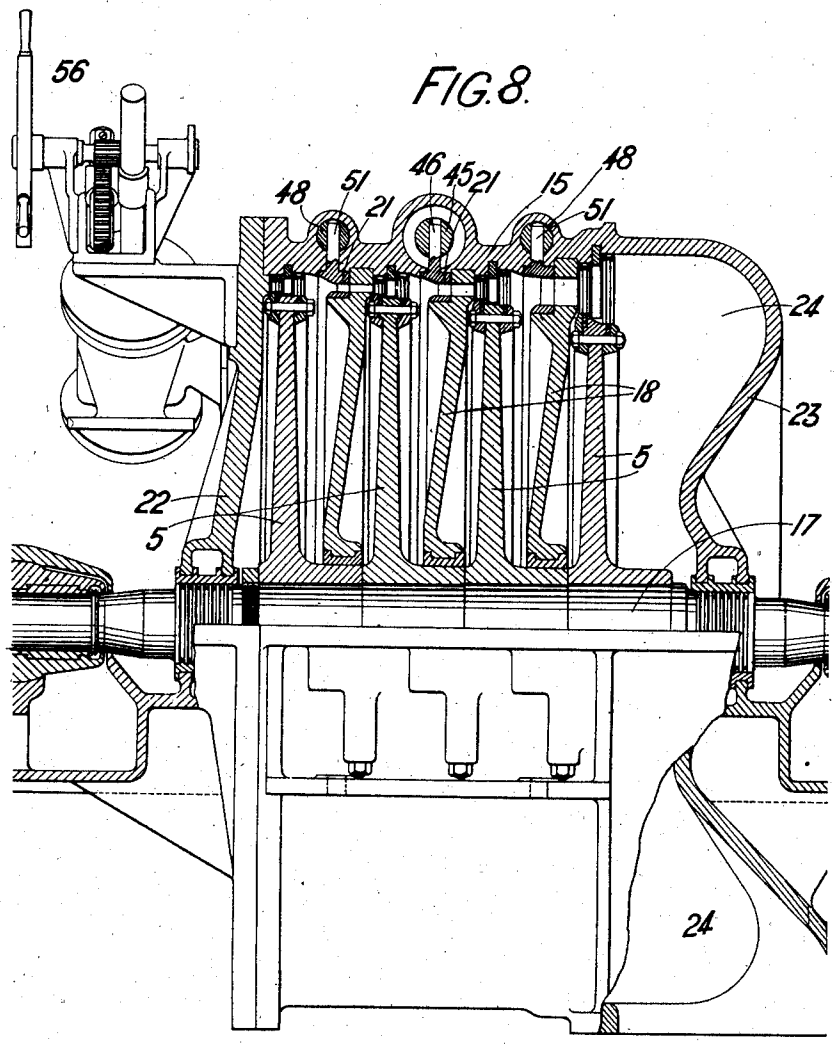
5 SHEETS—SHEET 3.

FIG. 8.



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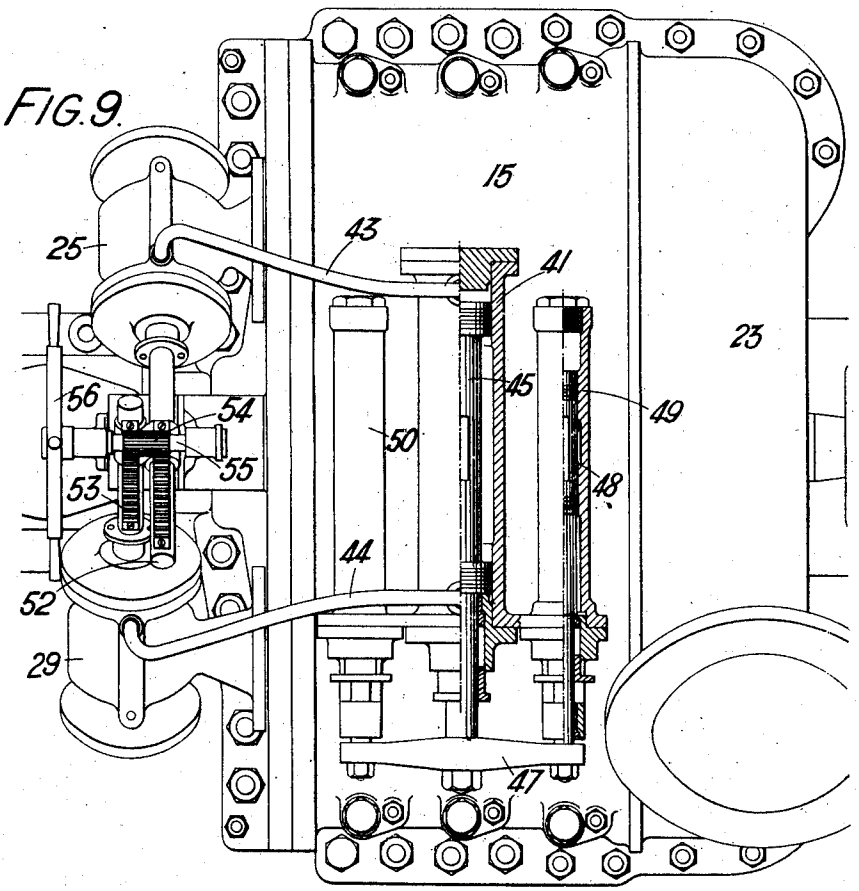
5 SHEETS—SHEET 4.

FIG. 9.



Witnesses

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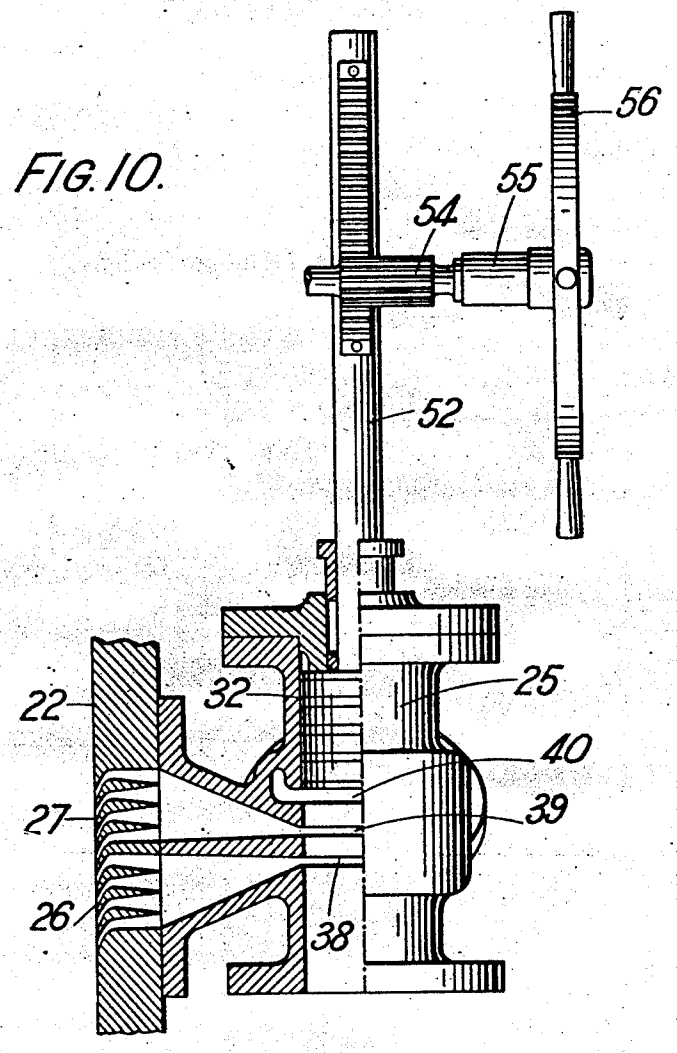
5 SHEETS—SHEET 5.

FIG. 10.



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UNITED STATES PATENT OFFICE.

RICHARD CRAMP, OF EAST HAM, ENGLAND, ASSIGNOR TO CRAMP'S PATENT REVERSIBLE TURBINE, LIMITED, OF LONDON, ENGLAND.

REVERSIBLE TURBINE.

971,730. Specification of Letters Patent. Patented Oct. 4, 1910.

Application filed August 4, 1910. Serial No. 575,526.

To all whom it may concern:

Be it known that I, RICHARD CRAMP, a subject of the King of Great Britain, residing at East Ham, in the county of Essex, England, have invented certain new and useful Improvements in or Relating to Reversible Turbines, and of which the following is a specification.

It has before been proposed to construct a reversible turbine in which the pressure fluid is caused to pass through sets of steam admission ports arranged in segmental series, one segment of ports directed in one angular direction and the other set in an opposite angular direction, while a segmental valve mechanism is located on the admission side of such a disk and ring so as to admit steam either to one segmental series of ports for driving in a counter-clockwise direction, or to another segmental series of ports for driving in a clockwise direction, and the pressure fluid passing through one or other segmental series of directing ports operates upon an adjacently located ring or disk carrying pivoted vanes which are capable of limited angular movement in either direction about axes extending approximately radial to the said disk or ring, so that the said pivoted vanes of such a rotor assume automatically one or other of their angular positions according as the fluid pressure is admitted by one or other segmental series of angularly directed ports through the stationary disk or ring. In a construction of such a turbine it has been proposed, after the pressure fluid has passed through the first rotor having the reversible blades, that it shall enter an expansion or distributing space, and then again pass through another similar series of members, that is by way of the segmental valve mechanism through the series of segmental directing ports in the stationary disk or ring, and then through the next adjacent rotor carrying the reversible blades, the dimensions of the ports in the next directing ring or vane and the dimensions of the reversible vanes in the rotor of that set, being of increased dimensions so as to permit of the steam acting expansively, and so on. It has also been proposed to pivot each reversible blade of a rotor between two radial abutments fixed on the said rotor, and to fork the free ends of the pivoted blades so that upon change of direction, the pressure fluid should act upon one or other member of the fork to move the vanes about their pivots.

Now the present invention refers to improvements upon the known construction of turbine engines such as have been hereinbefore stated, and the said improvements have special reference to the means by which the inlet of steam for driving counter-clockwise or clockwise is governed, and to the means by which the several series of segmental valves (which govern the directing admission ports in the stationary disks or rings) are governed.

It has previously been proposed to employ two or more sets of blades secured to the rotary portion of a turbine having intermediate blades fixed to stationary portions of the said turbine, and the present invention does not therefore include such an arrangement *per se*, but it further refers to the construction and combination of a group of elements—and a turbine engine according to the present invention may contain a number of such groups—each group consisting of a movable valve governing admission ports formed in an adjacent stationary disk forming a diaphragm to the cylinder, an annulus of reversible vanes carried by the rotor adjacent thereto, an annulus of stationary directing vanes carries (adjacent to said annulus of reversible vanes) from the stationary cylinder and an annulus of reversible vanes also carried by the rotor adjacent to said annulus of stationary directing veins; beyond this the present invention refers to an improved construction of reversible blades, and further provides that two or more series of reversible blades can be carried and mounted on each disk of the rotor.

The invention will be readily understood by further describing the same with reference to the example of construction shown in the accompanying drawings, whereon—

Figure 1 shows a partial development of one group consisting of the movable valve, the stationary disk having the admission ports, the double annulus of reversible vanes carried by the rotor, and the annulus of stationary directing vanes located between the double annulus of reversible vanes. Fig. 2 shows, on a larger scale, a vertical section illustrating one of the groups of elements

before mentioned but omitting the valve governing the steam admission, the group illustrated being at the entrance end of the cylinder. Fig. 3 is a vertical cross section of some of the parts shown at Fig. 2 taken about the line X, Y of Fig. 2 looking in the direction of the arrow. Fig. 4 is a perspective view showing one of the radial abutments for the reversible vanes detached. Fig. 5 is a perspective view showing one of the reversible vanes detached, and Fig. 6 shows one of the segments a number of which, annularly arranged, form the intermediate stationary directing vanes which are located between the double annulus of reversible vanes. Fig. 7 is a sectional end elevation showing that end of the turbine at which the steam enters. Fig. 8 is a longitudinal elevation partly in section of the turbine shown at Fig. 7. Fig. 9 is a sectional plan view of the turbine and Fig. 10 is a section drawn to a larger scale and taken upon a plane indicated by the line X^1 Y^1 of Fig. 7 and is intended to illustrate the admission ports and the means for governing same located at the entrance of the turbine.

Referring more particularly to Figs. 1 to 6 of the accompanying drawings, each reversible vane 1 is formed with a curved concave forward face and a similarly curved concave rearward face, while the forward end—that end toward the incoming steam—of each reversible vane 1 has an extended face 2 at right angles to the width of the vane, and the rear end 3 (Fig. 1) of the vane is of less width and is somewhat curved in the construction shown, although if desired this rear end may have a face which is parallel to the extended face 2 of the vane. Between each pair of such vanes 1 there is located a radial abutment 4, carried preferably by means hereafter described from the periphery of the rotor disk 5 (Figs. 2 and 3). The distances between the centers of the abutments 4 and of the reversible vanes 1 are so proportioned, that one end of the flat forward face 2 of a vane contacts, when thrown over, with one of the abutments 4, (which may be circular in cross section as shown) and the edge of this flat face 2 of the vane so contacts with the abutment in a line thereon coincident with a vertical plane passing through the center of that abutment 4 and including the axis of the rotor 5; by this arrangement it will be understood that supposing two adjacent vanes 1 were caused to contact with the same abutment 4, those edges of the flat faces 2 of the vanes 1 would still be clear of each other. Each vane 1 is fitted or formed with pivots 6, 7 mounted in the rotor as hereafter described, so that the said vanes 1 will automatically change their angular positions by rocking about the said pivots upon and by the change of direction of the steam admission jets caused by the mechanism hereafter described.

In order to fix the radial abutments 4 against which the rocking vanes 1 contact, and in order to conveniently locate the pivots 6, 7 of the vanes themselves, the rotor disk 5 is provided with a slightly flanged rim 8 as will be observed at Fig. 2, and two rings or segments are also provided, which compose two rings, shown at 9 and 10, Fig. 2. Each abutment 4, as shown at Fig. 4, is made with a squared butt-end and a cross head 11, and there is cut out of the flange of the disk 5 (Fig. 2) an annular groove to receive the cross heads 11 of the abutments and radial recesses to receive the squared portions of the shanks, so that the butt-ends of the said abutments 4 can be fitted into such recesses and all secured by the bolting on of the ring 9 to the rotor disk 5. On the opposite side as shown at Fig. 2, similar recesses and the annular groove are formed in the flange of the ring 10 to receive the butt-ends of the other of the double annulus of abutments. Grooves are also formed in the rotor disk and its rings, to receive the pivots 6 of the reversible vanes 1.

The outer ends of the abutments 4 and outer pivots 7 of the vanes 1 are received and supported by rings 12 (Fig. 2) which rings of course may be constructed in halves or segments, and in assembling the parts the outer ends of the abutments and the pivots 7 of the vanes may be first placed in the said rings 12 and then the butt-ends of the abutments and the pivots 6 of the vanes can be located in their respective grooves and the rings 9, 10 of the rotor bolted in position; by this means it has been found that the parts can be easily assembled, that when bolted together a rigid structure is formed, that the said parts can be easily manufactured and can be with great readiness dismantled for the removal and insertion of other blades or abutments, and furthermore, as has been previously stated, the two series or double annulus of reversible blades and abutments can be thus carried upon a single rotor disk 5 without involving an undesirable complex construction.

The intermediate stationary directing vanes 13—which are located between the double annulus of reversible vanes as is shown at Fig. 1—are conveniently constructed of a number of segments such as is shown at Fig. 6, each segment being formed with a head 14 of somewhat dove-tail character, which is slid into a groove formed in the internal periphery of the stationary cylinder 15 (see Fig. 2) before the two halves of the cylinder are bolted together. The intermediate vanes 13 are arranged in segments, the effective curved surfaces of the vanes 13 of one segment facing in one direction, and the

effective curved surfaces of the next segment of vanes facing in the opposite direction, each two segments of intermediate vanes being divided by a solid portion as at 16, Fig. 1.

The turbine according to this invention when assembled, comprises several rotor disks 5, concentrically mounted one behind the other upon the same shaft 17 (Fig. 8) which is carried in bearings in the stationary cylinder 15, and each rotor disk may carry, as before described, several annularly arranged series of reversible vanes, there being two or a double series of such shown in the drawings, and between each series of said reversible vanes 3 there extends the series of intermediate stationary directing vanes 13 before described. At the rear of each rotor disk 5 there is an adjacent stationary disk 18 (Fig. 8) forming a diaphragm or partition in the cylinder, and each partition disk 18 is formed with segmental groups of nozzles as shown at Fig. 1, one group 19 being inclined in a clockwise direction for rearward driving and the next group 20 in a counter-clockwise direction for forward driving, and each group of inlet nozzles 19, 20 through the partition disks is governed by a segmental or annular valve 21 (Fig. 1). In the drawing, Fig. 8, each valve is annular and is carried in face contact with that partition disk 18 which is adjacent to it, being supported, in the construction shown, by a rib or flange on its partition disk. The steam ports in each annular valve 21 are so arranged, that at the moment the closure of the angularly directed nozzles 19 (Fig. 1) is effected, the oppositely directed nozzles 20 will still be closed; and then the continued motion of the valve will open the nozzles 20 gradually, while the other series of nozzles 19 still remain closed even when the nozzles 20 have become fully opened. Thus during the reversal of this engine at a time when it is running for instance in a clockwise direction and the annular valve 21 is moved, the steam admission in both the counter-clockwise and clockwise directions will be wholly cut off momentarily; before the commencement of the steam admission by the other series of admission ports for counter-clockwise direction driving, but as will be hereafter observed these annular valves are only operated, and that automatically, when no steam is in the cylinder as hereafter described.

Steam is admitted to the first series of reversible vanes carried by the first rotor 5 through groups of directing passages or nozzles in the end wall 22 of the cylinder, and these inlet nozzles are governed by means as hereafter described. The rear end 23 of the cylinder (the latter being horizontal as shown) is formed with a suitable steam exhaust passage 24. The arrangement of the groups of oppositely directed inlet nozzles through the end cover 22 will be understood by reference to Figs. 7 and 10 of the accompanying drawings.

Located immediately behind the valve cylinder 25 (Fig. 7) there are two groups of inlet nozzles 26 and 27 (see Fig. 10) extending through the end cover 22 of the main cylinder, with which nozzles the interior of the cylinder 25 is in communication, it being also in communication by a steam pipe 28 (Fig. 7) with a single series of steam inlet nozzles having the same inclination, diametrically on the opposite side of the end cover 22, this diametrically opposite series of nozzles being equal in number to those shown at Fig. 10 but undivided.

Located immediately behind a valve cylinder 29 on the end cover 22 is a similar divided series of inlet nozzles as shown at Fig. 10 but oppositely directed or inclined, and the interior of this cylinder is in communication by a pipe 30 with an undivided series of nozzles 31 diametrically opposite to the nozzles with which the cylinder 29 communicates.

The valve cylinder 25 contains a valve piston 32 while the valve cylinder 29 contains a valve piston 33, and the outer end of each cylinder 25 and 29 is respectively connected to steam supply pipes 34 and 35, each of which is fitted with any suitable form of controlling or throttle valve 37, 36, and each of the valve cylinders is formed with steam ports communicating with the inlet nozzles.

Referring now to the valve cylinder 25, it will be observed that this is formed with three ports, see Fig. 7, the first of which 38 communicates with the nozzles 26 (Fig. 10), the second 39 communicates with the nozzles 27 (Fig. 10), and the third 40 communicates with the pipe 28 and the diametrically opposite series of inlet nozzles. The other valve cylinder 29 is similarly fitted and constructed so that its ports 38 and 39 communicate with the divided series of nozzles in the end cover 22 of the main cylinder, while its third port 40 communicates, by the pipe 30, with the undivided diametrically opposite series of nozzles 31.

Formed in or mounted upon the main cylinder 15 is a plunger cylinder 41, see also Fig. 9, and there is a steam passage 42 in the wall of each of the valve cylinders 25, 29 which communicate with pipes 43, 44 (Fig. 7) with opposite ends of the cylinders 41 (Fig. 9); and also the passages 42 of the cylinders 25, 29 communicate interiorly with the opposite ends thereof, so that after either of the valve pistons has opened the passages 42, they are balanced by the steam pressure. The cylinder 41 (Fig. 9) contains a piston plunger 45 which is formed with a slot between its piston heads, and through the wall

of the said cylinder 41 there extends a tongue 46 from one of the annular valves 21 (Fig. 8). The rod of the plunger piston 45 extends through a gland of the end cover and carries a cross head 47 (Fig. 9), to the arms of which cross head the piston rods of plunger pistons 48 are connected (see Fig. 9). The plunger pistons 48 are located in cylinders 49, 50 (Fig. 9) mounted upon or formed with the main cylinder 15, and tongues 51 from the annular valves (Fig. 8) extend into slots in the said plunger pistons 48. The piston rods 52, 53 of the valve pistons 32, 33 are formed or fitted with rack teeth, both of which gear with the teeth of a pinion 54 (Fig. 9) carried upon a shaft 55 capable of being rotated by a hand-wheel or the like 56. By rotating the shaft 55 by means of the hand-wheel 56, it will be observed that the piston valves 32, 33 can be moved in opposite directions to each other.

In describing the operation of the engine, the position of the parts shown at Fig. 7 will be thus considered, it being supposed that the steam admission valves 36, 37 are open, so admitting steam to the ends of the cylinders 25 and 29. In this position the entry of steam into the valve cylinder 29 is prevented by the position of the valve piston 33, but steam is entering through all the ports 38, 39 and 40 of the valve cylinder 25, and consequently is passing through, not only the divided series of steam inlet nozzles 26, 27 (Fig. 10) but also by the pipe 28 through the diametrically opposite undivided series of nozzles to drive the turbine counter-clockwise with a full head of steam. At the same time steam has entry by the passage 42 of the valve cylinder 25 and the pipe 43, to one end of the plunger 41 (Fig. 9) holding over the plunger piston 45 in the position shown, while the opposite end of the cylinder 41 is in communication by the pipe 44 with the interior of the cylinder 29, and thus the plunger pistons 48 in the cylinders 49 and 50 are similarly held over and consequently all the annular valves 21 (Figs. 1 and 8) are in position to admit steam through their fully opened ports to those segments of steam directing nozzles in the partitions for counter-clockwise motion of the turbine. If now by rotating the hand-wheel 56 the valve piston 32 in the cylinder 25 is moved to close the port 40, steam will then only be admitted by the divided series of nozzles 26 and 27, but at the same time it will be observed the annular valves 21 are not altered in position, and therefore the turbine will be running under a half head of steam. If the valve piston 32 is further adjusted by the hand-wheel 56 to close the port 39, steam will only be admitted through those inlet ports 26 (Fig. 10) while again the annular valves 21 will not receive motion and the turbine will be running under a quarter head of steam. During these motions of the valve piston 32, the piston valve 33 in the cylinder 29 will not yet have admitted steam to any of the passages within the cylinder. If now the valve piston 32 is moved to cover steam entrance to the passage 42, the valve piston 33 of the cylinder 29 will uncover the entrance to the steam passage 42 of the cylinder 29, and immediately steam pressure will pass by the pipe 44 and reverse the position of the plunger piston 45 (Fig. 9), and at the time of this admittance of steam to the latter passage 42, it will be observed that steam pressure is not being admitted to the steam inlet passages in the end cover 22 of the main cylinder, and therefore the movement of the annular valves 21 will take place at a time when steam pressure is not admitted to the turbine. A further forward movement of the valve piston 33 will uncover the port 38 of the cylinder 29, and steam will be admitted through a quarter of the whole of the available nozzles through the end cover 22 and act to drive the turbine in the reverse direction to that at which it was previously running, *i. e.* in a clockwise direction, and the reversible vanes 1 will be turned about their pivots automatically through the medium of the change of direction in the steam inlets. A further forward movement of the valve piston 33 of the cylinder 29 will uncover the port 39, and the engine will then be driven with half a head of steam, while a still further movement of the valve piston 33 uncovering the port 40 will place the engine under a full head of steam, which will be free to pass by the pipe 30 to the undivided nozzles 31. Change of direction of the motion of the turbine can therefore be effected with ease and facility by the operation of the hand-wheel 56, without reversal of the direction of the passage of steam through the turbine, and in fact if the throttle valve 37 is closed while the throttle valve 36 remains open, the steam will then act upon the piston 33, force it up in the cylinder 29, while the piston 32 of the cylinder 25 will move downward and reversal can be effected in this manner if so desired or required.

What I claim as my invention and desire to secure by Letters Patent, is:—

1. In a reversible turbine of the type specified; the combination with a stationary cylinder, a cover at the entrance end and a cover at the exhaust end of said cylinder, said exhaust end cover having an exhaust aperture, a rotor disk within said cylinder adjacent to the interior face of the said entrance end cover, pivoted reversible vanes carried by said rotor disk, said entrance end cover on said cylinder having two adjacent segmental groups of steam inlet nozzles diametrically opposite to a single segmental group of nozzles equal in number to the two

said groups and all inclined in clockwise direction, and having also two adjacent groups of nozzles diametrically opposite to a single group of nozzles equal in number to the said two groups and all inclined in a counter-clockwise direction; of two valve cylinders located on said entrance end cover of said cylinder, the first of said valve cylinders having one port communicating with one and another port communicating with the other of the two adjacent groups of said steam inlet nozzles and having a third port communicating with the diametrically opposite single group of said inlet nozzles all inclined in a clockwise direction, the second of said valve cylinders having one port communicating with one and another port communicating with the other of the two adjacent groups of said steam inlet nozzles and having a third port communicating with the diametrically opposite single group of said inlet nozzles all inclined in a counter-clockwise direction, means for supplying pressure steam to both of said valve cylinders, a sliding valve in each of said valve cylinders, and means for operating said valves in said cylinders in reverse directions to admit pressure fluid to one or both groups of inlet nozzles or to the whole of the said inlet nozzles for driving the engine in a clockwise direction while the other valve maintains the closure of all the admission nozzles for driving in a counter-clockwise direction and vice versa, substantially as set forth.

2. In a reversible turbine of the type specified; the combination with a stationary cylinder, a cover at the entrance end and a cover at the exhaust end of said cylinder, said exhaust end cover having an exhaust aperture, a rotor disk within said cylinder adjacent to the interior face of the said entrance end cover, pivoted reversible vanes carried by said rotor disk, said entrance end cover on said cylinder having two adjacent segmental groups of steam inlet nozzles diametrically opposite to a single segmental group of nozzles equal in number to the two said groups and all inclined in a clockwise direction, and having also two adjacent groups of nozzles diametrically opposite to a single group of nozzles equal in number to the said two groups and all inclined in a counter-clockwise direction; of two valve cylinders located on said entrance end cover of said stationary cylinder, the first of said valve cylinders having one port communicating with one and another port communicating with the other of the two adjacent groups of steam inlet nozzles inclined in a clockwise direction, a pipe extending from said cylinder to the diametrically opposite single group of said inlet nozzles inclined in a clockwise direction, said cylinder having a third port communicating with said pipe, the second of said valve cylinders having one port communicating with one and another port with the other of the two adjacent groups of said inlet nozzles inclined in a counter-clockwise direction, a pipe extending from said cylinder to the diametrically opposite single group of said inlet nozzles inclined in a counter-clockwise direction, said cylinder having a third port communicating with said pipe, pipes for supplying steam to the ends of both of said valve cylinders, a valve in each of said steam supply pipes to control said supply, a sliding valve in each of said valve cylinders, a rod extending from said valves through the ends of said cylinders, means for operating said valve rods to move said valves in reverse directions to admit fluid pressure to one or both groups of inlet nozzles or to the whole of the inlet nozzles for driving the engine in a clockwise direction, while the other valve maintains the closure of all the admission nozzles for driving in a counter-clockwise direction and vice versa, substantially as set forth.

3. In a reversible turbine of the type specified; the combination with a stationary cylinder, a cover at the entrance end and a cover at the exhaust end of said cylinder, said exhaust end cover having an exhaust aperture, a rotor disk within said cylinder adjacent to the interior face of the said entrance end cover, two circular series of pivoted reversible vanes carried by said rotor disk and located at a distance apart, an annulus of stationary directing vanes fixed to the interior periphery of said cylinder and located between the double series of said reversible vanes carried by said rotor disk, said entrance end cover on said cylinder having two adjacent segmental groups of steam inlet nozzles diametrically opposite to a single segmental group of nozzles equal in number to the two said groups and all inclined in clockwise direction, and having also two adjacent groups of nozzles diametrically opposite to a single group of nozzles equal in number to the said two groups and all inclined in a counter-clockwise direction; of two valve cylinders located on said entrance end cover of said cylinder, the first of said valve cylinders having one port communicating with one and another port communicating with the other of the two adjacent groups of said steam inlet nozzles and having a third port communicating with the diametrically opposite single group of said inlet nozzles all inclined in a clockwise direction, the second of said valve cylinders having one port communicating with one and another port communicating with the other of the two adjacent groups of said steam inlet nozzles and having a third port communicating with the diametrically opposite single group of said inlet nozzles all inclined in a

counter-clockwise direction, means for supplying pressure steam to both of said valve cylinders, a sliding valve in each of said valve cylinders, and means for operating said valves in said cylinders in reverse directions to admit pressure fluid to one or both groups of inlet nozzles or to the whole of the said inlet nozzles for driving the engine in a clockwise direction while the other valve maintains the closure of all the admission nozzles for driving in a counter-clockwise direction and vice versa, substantially as set forth.

4. In a reversible turbine of the type specified; the combination with a stationary cylinder, a cover at the entrance end and a cover at the exhaust end of said cylinder, said exhaust end cover having an exhaust aperture, and rotor disks in said cylinder; of pivoted reversible vanes carried by each of said rotor disks, each of said vanes having curved concave forward and rearward faces, the forward end of said blades having extending faces at right angles to the widths of said vanes, and radial abutments on said rotor disks so located that each edge of the flat forward face of a vane when turned about its pivot contacts with the adjacent abutment and is clear of the next adjacent vane, substantially as set forth.

5. In a reversible turbine of the type specified; the combination with a stationary cylinder, a cover at the entrance end and a cover at the exhaust end of said cylinder, said exhaust end cover having an exhaust aperture, a rotor disk within said cylinder adjacent to the interior face of the said entrance end cover, pivoted reversible vanes carried by said rotor disk, said entrance end cover on said cylinder having two adjacent segmental groups of steam inlet nozzles diametrically opposite to a single segmental group of nozzles equal in number to the two said groups and all inclined in a clockwise direction, and having also two adjacent groups of nozzles diametrically opposite to a single group of nozzles equal in number to the said two groups and all inclined in a counter-clockwise direction, of two valve cylinders located on said entrance end cover of said stationary cylinder, the first of said valve cylinders having one port communicating with one and another port communicating with the other of the two adjacent groups of steam inlet nozzles inclined in a clockwise direction, a pipe extending from said cylinder to the diametrically opposite single group of said inlet nozzles inclined in a clockwise direction, said cylinder having a third port communicating with said pipe, the second of said valve cylinders having one port communicating with one and another port with the other of the two adjacent groups of said inlet nozzles inclined in a counter-clockwise direction, a pipe extending from said cylinder to the diametrically opposite single group of said nozzles inclined in a counter-clockwise direction said cylinder having a third port communicating with said pipe, pipes for supplying steam to the ends of both of said valve cylinders, a valve in each of said steam supply pipes to control said supply, a sliding valve in each of said valve cylinders, a rod extending from said valves through the ends of said cylinders, rack teeth on each of said valve rods, a rotative shaft, bearings to carry said shaft, a toothed pinion fixed on said shaft with which the rack teeth of both of said valve rods engage, and means for effecting rotative adjustment of said shaft to traverse said valve rods and valves in reverse directions to admit fluid pressure to one or both groups of inlet nozzles or to the whole of the inlet nozzles for driving the engine in a clockwise direction while the other valve maintains the closure of the admission nozzles for driving in a counter-clockwise direction and vice versa, substantially as set forth.

6. In reversible turbines of the type specified; the combination with a stationary cylinder, a cover at the entrance end and a cover at the exhaust end of said cylinder, said exhaust end cover having an exhaust aperture, a revoluble shaft passing concentrically through said cylinder, a plurality of rotor disks fixed on said shaft the first of said rotor disks being located adjacent to the entrance end cover, pivoted reversible vanes carried by each of said rotor disks, said entrance end cover having two adjacent segmental groups of steam inlet nozzles diametrically opposite to a single segmental group of nozzles equal in number to the said two groups and all inclined in a clockwise direction, and having also two adjacent groups of nozzles dimetrically opposite to a single group of nozzles equal in number to the two said groups and all inclined in a counter-clockwise direction, a stationary partition disk in said cylinder located before the second and a similar disk before each subsequent rotor disk, said partition disks each having one segmental group of through steam nozzles inclined in a clockwise direction and another group in a counter-clockwise direction and so on, and an annular valve on each partition disk to control said nozzles; of two valve cylinders located on said entrance end cover of said stationary cylinder, the first of said valve cylinders having one port communicating with one and another port communicating with the other of the two adjacent groups of said steam inlet nozzles through said end cover and having a third port communicating with the diametrically opposite single group of said inlet nozzles all inclined in a clockwise direction, the second of said valve cylinders

having one port communicating with one and another port communicating with the other of the two adjacent groups of said steam inlet nozzles and having a third port communicating with the diametrically opposite single group of said inlet nozzles all inclined in a counter-clockwise direction, plunger cylinders one for each of said annular valves, plungers in said cylinders having central slots therein, a radial tongue extending from each annular valve and entering said slot in its respective plunger, and means for operating said plungers to adjust said annular valves prior to the admission of steam to said turbine, means for supplying steam to both the said valve cylinders, a sliding valve in each of said valve cylinders, means for operating said valves in said cylinders in reverse directions to cause one of said valves to admit steam to one or both groups of inlet nozzles or to the whole of said inlet nozzles for driving the engine in a clockwise direction while the other valve maintains the closure of the ports to the admission nozzles for driving in a counter-clockwise direction, and vice versa, substantially as set forth.

7. In reversible turbines of the type specified; the combination with a stationary cylinder, a cover at the entrance end and a cover at the exhaust end of said cylinder, said exhaust end cover having an exhaust aperture, a revoluble shaft passing concentrically through said cylinder, a plurality of rotor disks fixed on said shaft the first of said rotor disks being located adjacent to the entrance end cover, pivoted reversible vanes carried by each of said rotor disks, said entrance end cover having two adjacent segmental groups of steam inlet nozzles diametrically opposite to a single segmental group of nozzles equal in number to the said two groups and all inclined in a clockwise direction, and having also two adjacent groups of nozzles diametrically opposite to a single group of nozzles equal in number to the two said groups and all inclined in a counter-clockwise direction, a stationary partition disk in said cylinder located before the second and a similar disk before each subsequent rotor disk, said partition disks each having one segmental group of through steam nozzles inclined in a clockwise direction and another group in a counter-clockwise direction and so on, and an annular valve on each partition disk to control said nozzles; of two valve cylinders located on said entrance end cover of said stationary cylinder, the first of said valve cylinders having one port communicating with one and another port communicating with the other of the two adjacent groups of said steam inlet nozzles through said end cover and having a third port communicating with the diametrically opposite single group of said inlet nozzles all inclined in a clockwise direction, the second of said valve cylinders having one port communicating with one and another port communicating with the other of the two adjacent groups of said steam inlet nozzles and having a third port communicating with the diametrically opposite single group of said inlet nozzles all inclined in a counter-clockwise direction, plunger cylinders one for each of said annular valves, a principal plunger in one of said cylinders, plungers in the other said cylinders said plungers having central slots therein, a radial tongue extending from each annular valve and entering said slot in its respective plunger, a connection from the principal of said plungers to the other said plungers to cause same to move in unison, each of said valve cylinders having a fourth port, means for conveying pressure fluid from the fourth ports of said cylinders to opposite ends of the principal plunger, means for supplying pressure steam to both of said valve cylinders, a sliding valve in each of said valve cylinders, means for operating said valves in said cylinders in reverse directions to cause one of said valves to admit steam to one end of said principal plunger cylinder to adjust all said annular valves prior to said cylinder valve admitting steam to said turbine, and to subsequently admit pressure fluid to one or both groups of inlet nozzles or to the whole of said inlet nozzles for driving the engine in a clockwise direction, while the other valve maintains the closure of the fourth port and of the ports to the admission nozzles for driving in a counter-clockwise direction and vice versa, substantially as set forth.

8. In reversible turbines of the type specified; the combination with a stationary cylinder, a cover at the entrance end and a cover at the exhaust end of said cylinder, said exhaust end cover having an exhaust aperture, a revoluble shaft passing concentrically through said cylinder, a plurality of rotor disks fixed on said shaft the first of said rotor disks being located adjacent to the entrance end cover, pivoted reversible vanes carried by each of said rotor disks, said entrance end cover having two adjacent segmental groups of steam inlet nozzles diametrically opposite to a single segmental group of nozzles equal in number to the said two groups and all inclined in clockwise direction, and having also two adjacent groups of nozzles diametrically opposite to a single group of nozzles equal in number to the two said groups and all inclined in a counter-clockwise direction, a stationary partition disk in said cylinder located before the second and a similar disk before each subsequent rotor disk, said partition disks each having a segmental group of steam nozzles inclined in a clockwise direc-

tion and another group in a counter-clockwise direction and so on, and an annular valve on each partition disk to control said nozzles; of two valve cylinders located on said entrance end cover of said stationary cylinder, the first of said valve cylinders having one port communicating with one and another port communicating with the other of the two adjacent groups of said steam inlet nozzles through said end cover and having a third port communicating with the diametrically opposite single group of said inlet nozzles all inclined in a clockwise direction, the second of said valve cylinders having one port communicating with one and another port communicating with the other of the two adjacent groups of said steam inlet nozzles and having a third port communicating with the diametrically opposite single group of said inlet nozzles all inclined in a counter-clockwise direction, plunger cylinders one for each of said annular valves, plungers in said cylinders having central slots therein, a radial tongue extending from each annular valve and entering said slot in its respective plunger, a connection from the principal of said plungers to the other said plungers to cause them to move in unison, each of said valve cylinders having a fourth port, means for conveying pressure fluid from the fourth ports of said cylinders to opposite ends of the principal plunger, each of said valve cylinders having a steam passage from said fourth port to the opposite ends of said valve cylinders, means for supplying pressure steam to said valve cylinders, a piston valve in each of said valve cylinders, means for operating said valves in said cylinders in reverse directions to cause one of said piston valves to admit steam to one end of said principal plunger cylinder to adjust all said annular valves prior to said cylinder valve admitting steam to said turbine and to balance said piston valve, to admit pressure fluid to one or both groups of inlet nozzles or to the whole of said inlet nozzles for driving the engine in a clockwise direction while the other valve maintains the closure of the fourth port and of the ports to the admission nozzles for driving in a counter-clockwise direction and vice versa, substantially as set forth.

9. In a reversible turbine of the type specified; the combination with a stationary cylinder, and rotor disks in said cylinder; of vanes to be carried by said disks, pivots on said vanes, an outer segmental ring having through perforations to receive the outer pivot of each vane, each of said rotor disks having lateral recesses in its peripheral flange to receive the inner pivot of each vane, radial abutments for said pivoted vanes, a cross-head formed on the inner end of each abutment, said outer ring having through perforations to receive the outer ends of said abutments, said rotor disk having lateral recesses in its flanged periphery to receive the cross-head of each abutment, and a locking ring located against the peripheral flange of said rotor disk to retain the cross-heads of the abutments and the inner pivots of the vanes in position, and means for securing said ring to the flange of said rotor disk, substantially as set forth.

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

RICHARD CRAMP.

Witnesses:
THOMAS WILLIAM ROGERS,
ALFRED P. DEARLE.