

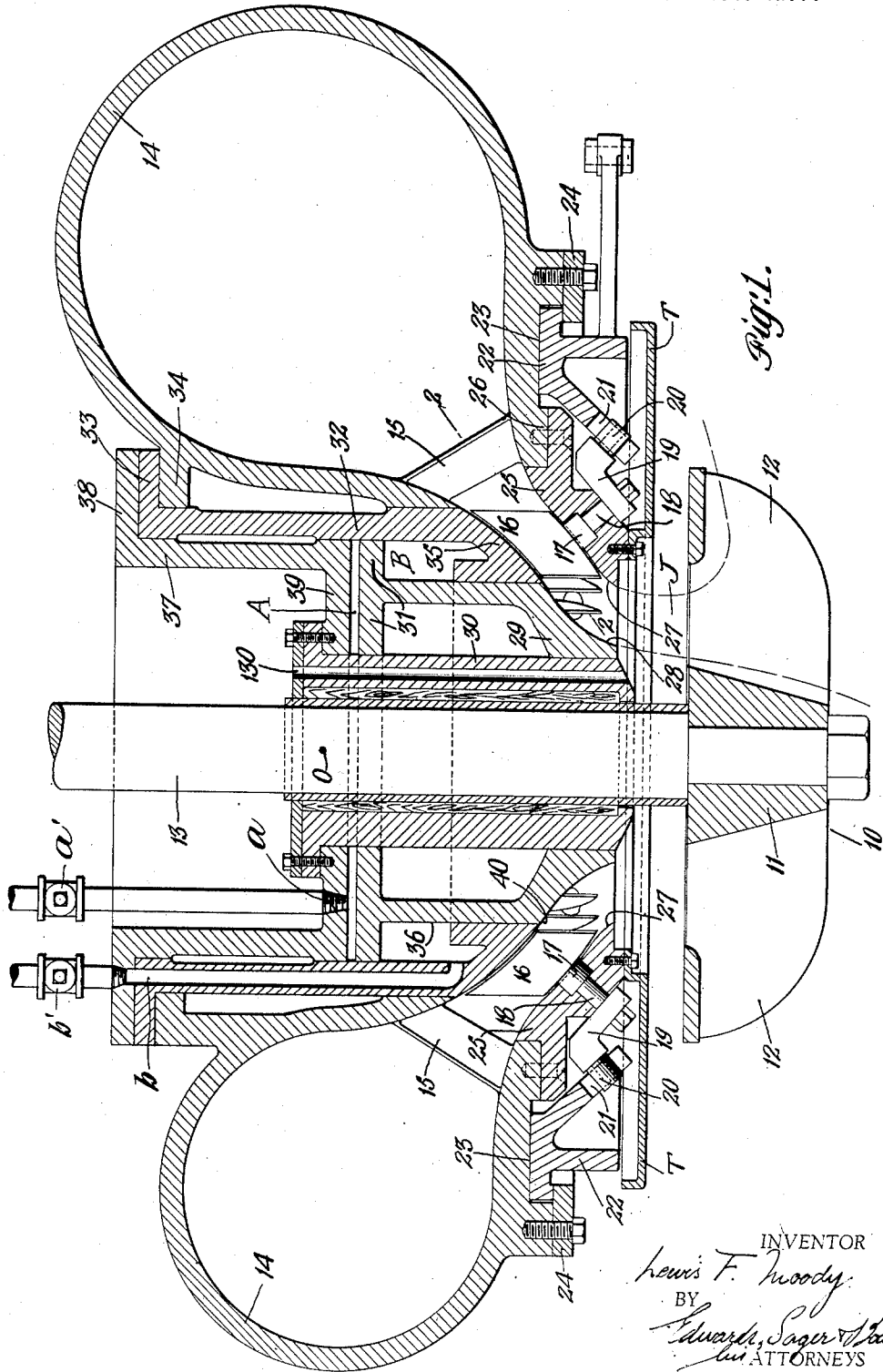
Oct. 19, 1926.

1,603,973

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HYDRAULIC TURBINE

Filed June 22, 1923 . 5 Sheets-Sheet 1



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5 Sheets-Sheet 2

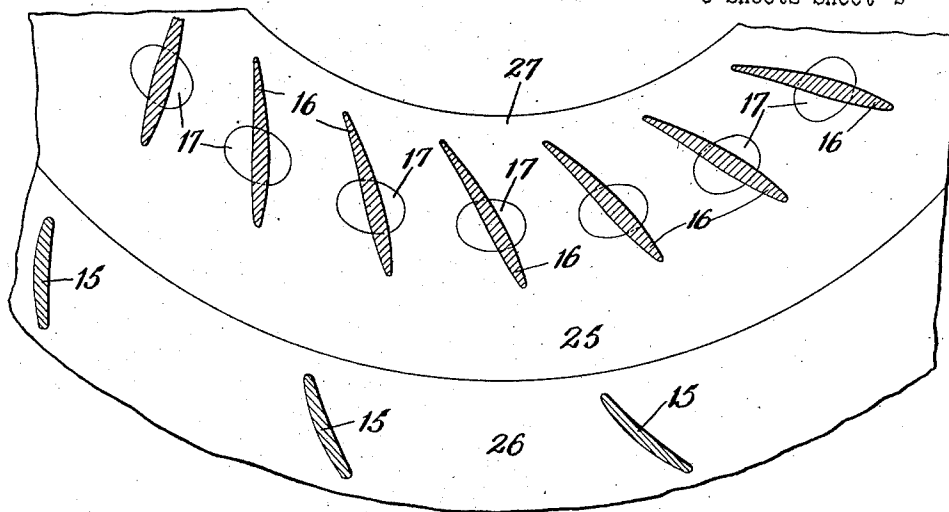


Fig. 2.

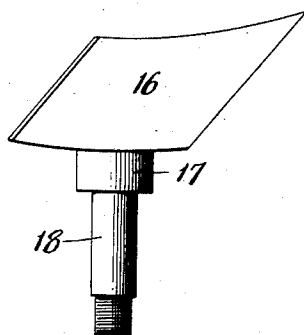


Fig. 3.

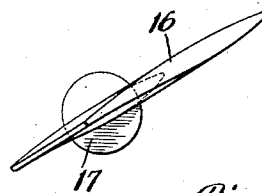


Fig. 4.

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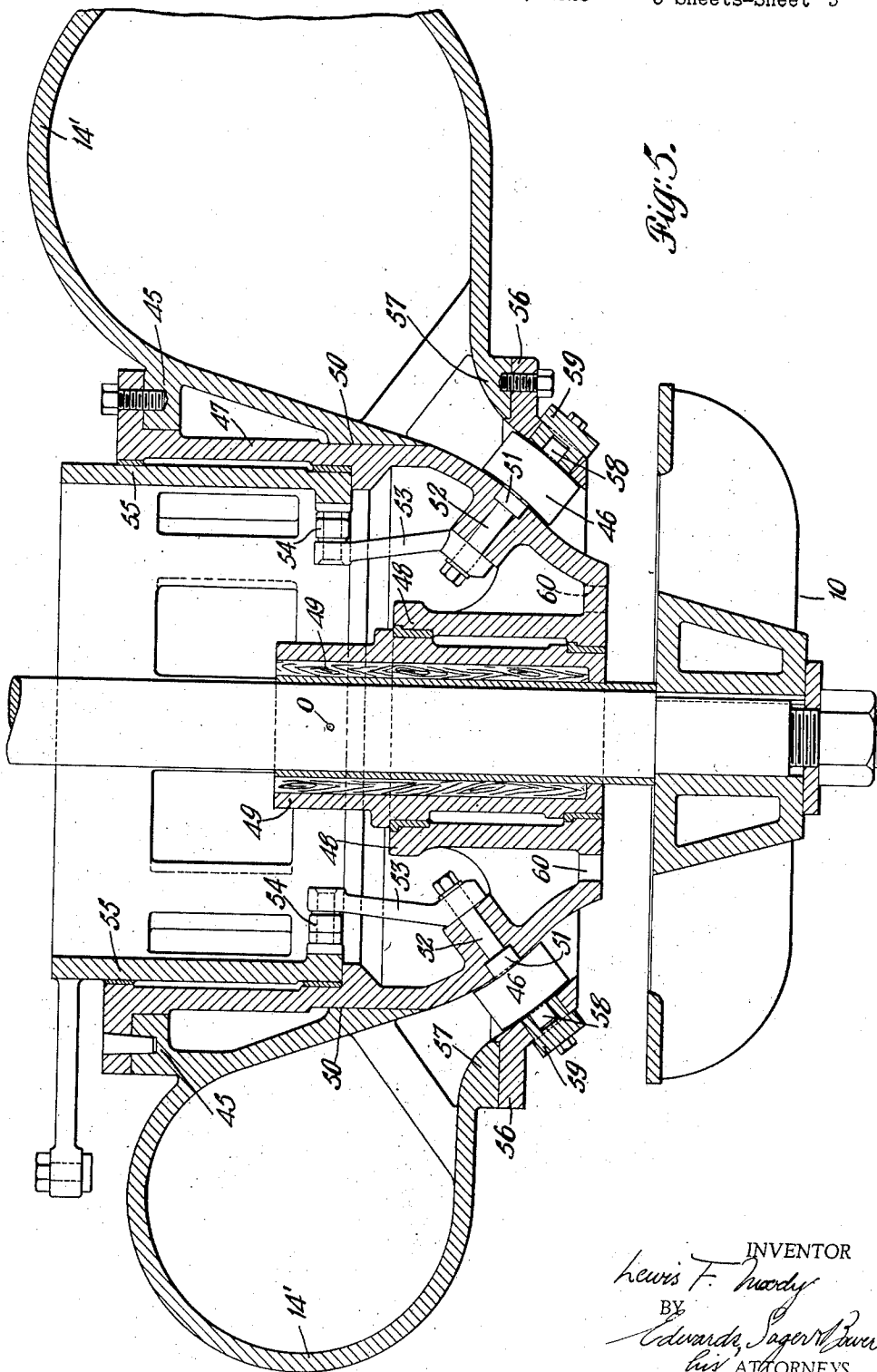
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5 Sheets-Sheet 3



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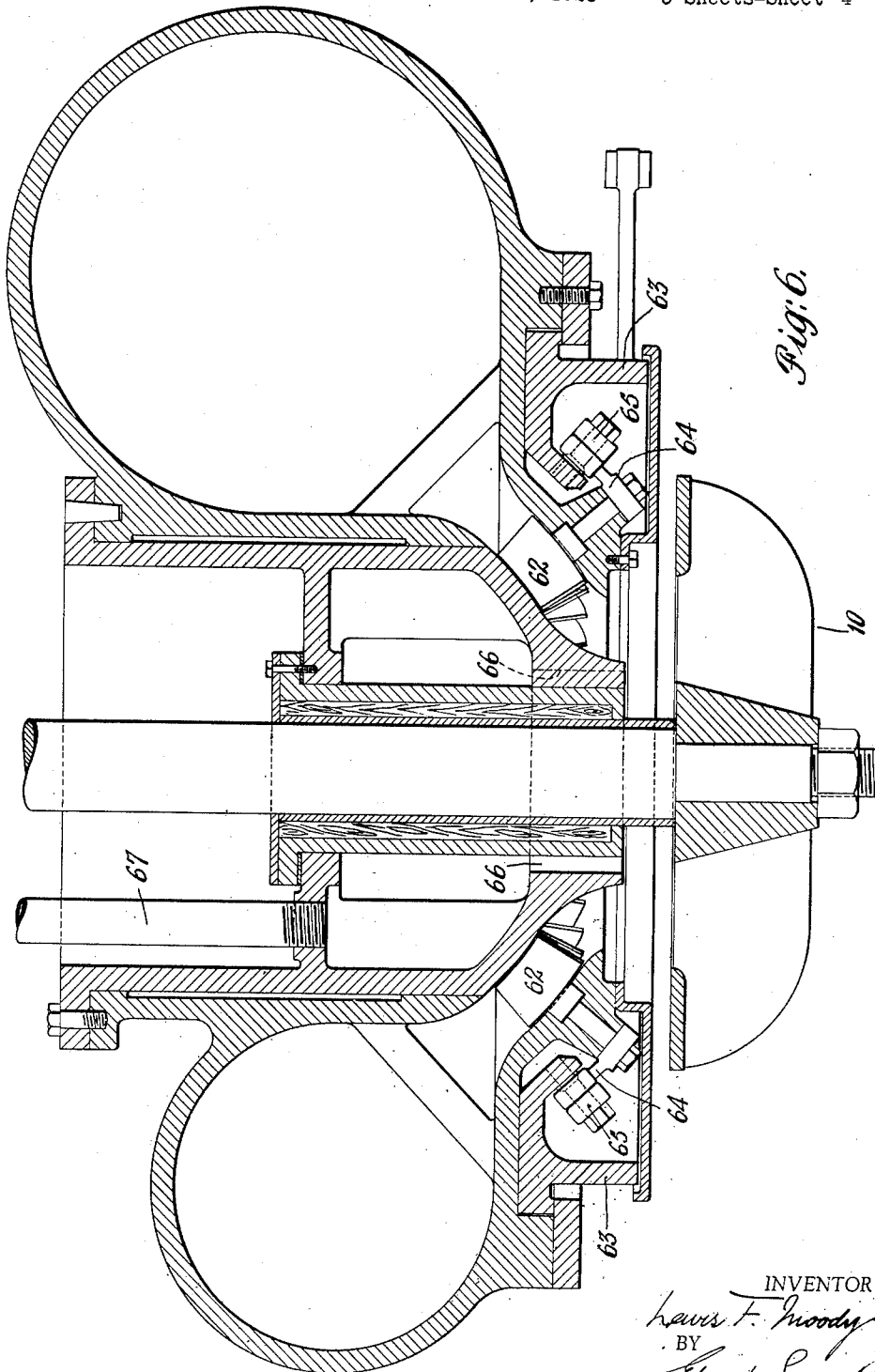
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5 Sheets-Sheet 5

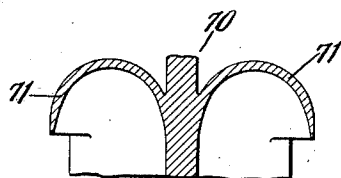
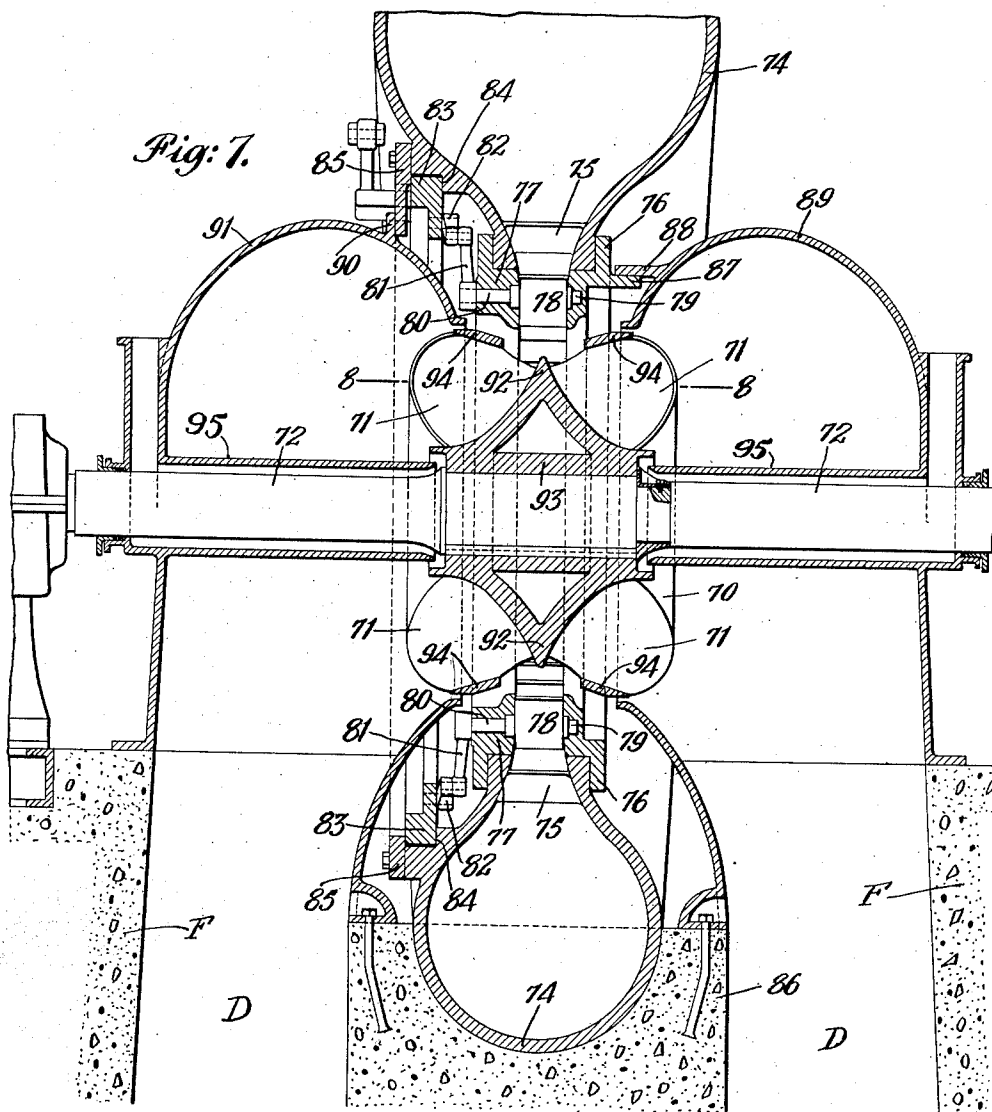


Fig. 8.

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HYDRAULIC TURBINE.

Application filed June 22, 1923. Serial No. 647,048.

This invention relates to hydraulic turbines and particularly to turbines of the impulse type in which a jet having a free surface is directed against the blades or buckets of a runner. The chief object of the invention is to provide a turbine in which the flow lines of the jet may be varied or adjusted so as to adapt the turbine to different conditions of head and also to serve to regulate the speed of the runner and the power developed.

A further object of the invention particularly in adapting the adjustable guiding means to an impulse turbine delivering a jet continuous around the runner will appear from the following description taken in connection with the accompanying drawings, in which—

Fig. 1 is a vertical sectional view through a turbine illustrating one embodiment of the invention.

Fig. 2 is a sectional view of a portion of the turbine taken along a conical surface indicated by line 2—2 of Fig. 1.

Fig. 3 is an elevational view of one of the adjustable guide vanes.

Fig. 4 is a plan view of one of the adjustable guide vanes.

Figs. 5 and 6 are vertical sectional views similar to Fig. 1 but illustrating modified forms of turbines.

Fig. 7 is a vertical sectional view of a further modification illustrating a horizontal shaft turbine and

Fig. 8 is a sectional view of a portion of the turbine shown in Fig. 7 taken on the line 8—8.

In the specific embodiment of the invention shown in Fig. 1 a runner 10 having a hub 11 and buckets 12 and vertical shaft 13 receives an annular jet J from above and discharges it downwardly and outwardly. The intake casing 14 surrounds the shaft above the runner and is provided at its inner portion with the stay vanes 15 near the annular outlet where the flow passes from the intake casing to the adjustable guide vanes 16. Each guide vane 16 is provided with a collar 17 and stem 18 extending outward and provided at its outer end with an arm 19 carrying a pin and slide block or roller 20 moving in the groove 21 of the operating ring 22 which is concentric with the shaft 13 and is turned by any desired means to adjust the guide vanes 16 through the interconnect-

ing mechanism described. The operating ring 22 turns in the bearing recess 23 of the lower surface of the intake casing 14 and is held therein by the annular retaining ring 24. An annular plate T connected to the lower surface of the ring 25 protects the operating mechanism from the spray and runner.

The guide vanes 16 have their collars 17 and stems 18 mounted in and extending through the vane ring 25 fitted and fastened to the lower lip 26 of the intake casing 14 and having its inner edge 27 forming the outer surface of the nozzle orifice forming the jet J. The inner portion of the annular nozzle is provided by the curved end surface 28 of the annular plunger 29 fitted around the cylindrical shell 30 of the shaft bearing and carrying at its upper end the annular piston member 31 fitted between this bearing shell 30 and an outer annular casting 32. The upper end 33 of the casting 32 is flanged over to rest on an annular shoulder 34 of the intake casing 14, and the lower end 35 of the casting 32 is extended inward and fitted to the cylindrical surface 36 of the plunger 29. A cover casting 37 is fitted at its upper end 38 to rest on the flange 33 so as to be supported from the shoulder 34 and the lower end 39 of this cover casting 37 fits tightly between the bearing shell 30 and the casting 32. In this way a fluid pressure chamber A is provided above the annular piston 31 and another fluid pressure chamber B below said piston so that the plunger 29 may be moved vertically by the control of fluid pressures in said chambers A and B through proper connections and control valves, the pipe *a* controlled by valve *a'* leading to the chamber A while the passage *b* controlled by valve *b'* leads to the lower portion of the chamber B. The outer edge 40 of the plunger 29 will thus be moved downward just within the edges of the guide vanes 16 so as to restrict the nozzle opening and decrease the size of the jet J. In its lowermost position the edge 40 of the plunger will seat against the edge 27 of the vane ring 25 to completely close off the flow. An air passage 130 is provided through a portion of the bearing 30 to supply air to the interior of the jet. A separate air supply to the outer portion of the jet may also be used and both the air supplies provided with control means if desired.

The water passage through the guide vanes 16 is inclined inward and downward and in order to permit adjustment of these guide vanes to different positions while still maintaining their fit within the water passage, the end surfaces of the guide vanes and the adjacent surfaces of the casting 35 and ring 25 forming the water passage are finished as spherical surfaces around a center coinciding with the point of intersection of the axes of rotation of the guide vanes with the turbine axis, this point being designated O. The axes of the pins 20 of the arms 19 also pass through this same point O.

The guide vanes 16 may therefore be adjusted to any desired angle and this adjustment may be varied during the operation of the turbine to control the latter according to the load. Or a joint control by plunger 29 and the vane 16 may be used. Or the gate 16 may be set for a given head and desired speed and a control of the jet size for regulation of the turbine effected by movement of the plunger 29.

When stationary guide vanes are used with plunger control of the jet, the part-gate efficiencies of the runner are in some cases impaired due to the fact that when the plunger is partially closed the velocities through the guide vane passages become low owing to the reduced amount of water flowing, and, on account of this reduced velocity through the vanes, the guide vanes do not direct the water so effectively and the tendency is for the discharge from the nozzle to take up a direction differing from that of the vanes and more nearly in meridian planes, that is, planes containing the turbine axis. The desired amount of tangential component is therefore secured only under normal gate position of the plunger or approximately normal gate position. When, on the other hand, the regulation is accomplished entirely by the angular adjustment of the guide vanes without the use of a movable plunger, the velocity corresponding to the head is turned more and more into the tangential direction as the guide vanes are closed resulting in unduly large tangential components of the entering velocity under part-gate conditions.

Therefore, in cases where a very flat efficiency curve is desired, that is, when it is important to maintain a nearly uniform efficiency over a wide range of loads, this may be accomplished by the double means of regulation shown in Fig. 1. By suitably co-ordinating the motions of the plunger and guide vanes, the tangential velocity component of the water entering the runner can be maintained at approximately the proper value and the direction of entrance of the water into the runner may be controlled so as to give high efficiency over a wide range of gate openings. The motion of the guide

vanes and the motion of the plunger may be made simultaneous by interconnecting the mechanisms, or the quick regulation of the turbine speed may be secured by the use of only one of the two means of control, the motion of the other means being produced automatically but taking place at a slower rate. In small installations, the plunger could be under governor control, and the guide vane mechanism under hand control, or vice versa.

In many turbines it may be unnecessary to provide for the control of the jet by the movable plunger, and the adjustable guide vanes or gates alone may be relied upon for regulation. It may also be desirable in other cases to provide the adjustable guide vanes without any regulating mechanism and to govern the unit entirely by use of the plunger, simply providing means whereby the guide vanes may be set at exactly the point giving the maximum efficiency of the runner, and this angle can then be changed to suit any change in the turbine operation, such as a change in the head on the plant.

The jet being projected against all of the runner buckets simultaneously keeps all these buckets in continuous operation giving high power within a relatively small space. The general inclination of the flow lines of the jet as directed by the adjustable guide vanes will be forward in the direction of rotation of the runner and this forward or tangential component of the jet as it strikes the buckets will vary with the adjustment of the guide vanes. The angle which the jet lines make with the direction of motion of the runner buckets will increase as the load increases and the gates open, or, vice versa, will decrease as the load is lowered and the gates turned to restrict the flow. The flow entering through the intake casing 14 will preferably be given an initial spiral direction by the volute form of the casing and will then pass through the stay vanes 15 inclined in the general direction of inclination of the guide vanes 16 through which the flow passes downward and inward and with tangential components around the runner axis so that the flow lines of the jet instead of passing down parallel to the runner axis have variable tangential components in the direction of rotation of the runner. By varying the setting of the guide vanes 16 the size of the jet may be varied and the tangential components of the jet flow lines will also be varied. The adjustable guide vanes 16 at their upper ends have no stems and no bearing in the end 35 of casting 32. These guide vanes are supported and rotated through the stems 18 and collars 17. The end 35 of the casting 32 with its associated parts including the shaft bearing and the cover casting 39 and

the plunger 29 may, therefore, be removed upward without disturbing the guide vanes 16 and similarly the guide vane ring 25 with the guide vanes 16 may be removed downward without disturbing the parts above it.

In the turbine shown in Fig. 5 the general arrangement of the runner 10 and intake casing 14' and the nozzle means is similar to the arrangement in Fig. 1. The adjustable plunger control of the nozzle orifice is, however, omitted and the adjustable guide vanes 46 are differently formed, and controlled from the inside instead of from the out. The annular shoulder 45 projecting inward from the casing 14' has bolted to it the annular casting 47 which at its inner portion 48 supports the shaft bearing 49. The outer surface of this casting 47 is finished to fit snugly within the cylindrical surface 50 of the casing 14' and the casting 47 is then carried down along smoothly curving lines as the inner surface of the annular nozzle. The collars 51 and stems 52 of the adjustable guide vanes 46 are rotatably mounted in this lower portion of the casting 47 and the stems 52 extend therethrough and carry at their inner ends the arms 53 connected by links 54 to the operating ring 55 rotatably supported in the casting 47 and moved in any desired manner to adjust the movable guide vanes 46 to desired position. The axes of the guide vanes 46 and of the bearings at each end of the links 54 all meet at a central point O on the axis of the runner shaft and the end surfaces of the guide vanes 46 and the adjacent surfaces of the water passage are formed as spherical surfaces around this point O as a center so that the adjustment of the guide vanes will take place without binding or substantial variation in the clearance between the guide vanes and the adjacent walls. The detachable vane ring 56 is fitted and fastened to the lower lip 57 of the intake casing 14'. Each adjustable guide vane 46 has a pintle 58 seating in a removable bushing member 59 fitted into a corresponding recess in the ring 56 and having an outer portion bolted against a face on this ring. By removing these bushings the vane or nozzle ring 56 can be dropped down or if desired, the guide vanes and head cover casting 47 can be lifted out, the guide vanes 46 being moved into their closed position to clear the inner edge of the casing.

The entrance and discharge edges of the guide vanes 46, it will be noted are substantially parallel to the axis of the guide vanes and are not generally vertical in direction as are the edges of the guide vanes 16 of the Fig. 1 turbine. Any desired direction to these edges may be adopted best suited for cooperation with each particular turbine structure. Air vents 60 are provided within the jet and when desired these vents will be

furnished with control valves in order to regulate the amount of air admitted so as to preserve a desired degree of vacuum within the space in which the runner is located. Similar vents and similar control of the vacuum in which the runner operates may, of course, be used in connection with the turbine shown in Fig. 1.

In the modification shown in Fig. 6 there is no adjustable plunger and the operating mechanism for the adjustable guide vanes 62 is outside of the annular nozzle forming the jet. In this operating mechanism the operating ring 63 is connected to the arms 64 of the guide vanes 62 by links 65. Air is admitted to the interior of the jet by openings 66 supplied by pipe 67 and the supply may be regulated by any suitable control means to maintain the desired vacuum in the jet chamber.

In Figs. 7 and 8 a horizontal shaft turbine is shown having a rotor 70 with buckets 71 on a shaft 72. A volute inlet casing 74 surrounds the runner and has stay vanes 75 across its inner neck portion. Vane rings 76 and 77 are fastened to the inner portion of the volute casing 74 and have inner surfaces in parallel planes forming a nozzle projecting an annular jet against the runner buckets. Between the rings 76, 77 are mounted adjustable guide vanes or wicket gates 78 turning around axes parallel to the shaft 72. Each guide vane has a collar and pintle 79 joined in a recess in the ring casting 76 and at their opposite ends the guide vanes have collars and stems 80 carrying arms 81 connected by links 82 to the operating ring 83 rotatably mounted in bearing surfaces 84 of the intake casing 74 and held therein by the annular casting 85. The volute casing 74 is set in the concrete of the foundation F of the central pier or bridge 86 on each side of which is the draft tube passage D. The upper portion of the ring 76 is also provided with a flange 87 connected to the flange 88 of a casing 89 supported from the foundation F. On the other side the volute casing 74 is connected by the ring casting 85 to the flange 90 of casing 91 also supported from the foundation F. The casings 89 and 91 enclose discharge spaces surrounding the runner 70 and receiving the discharge therefrom and collecting it and directing it downward to the draft tube D.

The flow entering through the intake casing 74 passes through the stay vanes 75 which are inclined in the same direction as the whirl imparted to the flow by the volute form of the casing. This whirling flow then passes on through the adjustable guide vanes 78 which are moved to the desired position according to the head and load on the turbine. The flow thus leaves the nozzle as a whirling jet and enters the bucket 71 on each side of the central wedge or splitter 92. The

buckets 71 are cup shaped as indicated in Figs. 7 and 8 and they turn and spread and decelerate the flow and finally discharge it outward on each side into the casings 89 and 91. The annular jet is thus split in a central vertical plane and turned and discharged outward so that there is little or no axial thrust on the shaft 72.

In the turbine shown in Fig. 7 the runner 10 is of extremely small diameter having a hub 93 of only sufficient diameter to support the runner from the shaft 72; and this small diameter gives a correspondingly high speed of rotation to the runner. Shroud rings 94 15 may also be provided around the runner edges for additional strength.

In all of the figures the transverse width of the annular jet forming passages is narrow measured transversely to the lines of flow. At any point, for instance, this transverse width is less than the diameter of the inner wall of the passage at the point measured.

Air may be supplied to the inside of the jets through the sleeves 95, and any desired means may be used to supply air to the outside of the jets such as the clearance space between the runner and the casings 89, 91. These casings are formed in parts separable 30 along a horizontal plane containing the shaft axis.

While the turbines shown and described are impulse turbines many of the specific features such as the particular formation of the inlet passages and guide vanes are also 35 applicable to reaction turbines; and the invention is not confined to the specific embodiments shown but is intended to cover such modifications thereof as fall within the scope of the appended claims.

I claim:—

1. In an impulse turbine the combination with a rotor having buckets, of a nozzle for directing a free jet against said buckets 45 and means for adjusting the lines of flow within said jet to various angles with relation to the buckets to control the turbine characteristics without changing the axis of the jet.

2. In an impulse turbine the combination with a rotor having buckets, of a nozzle directing a free jet against said buckets from one side of said rotor, and means for adjusting the jet flow to various angles with relation to the plane of rotation of the runner so 55 as to control the turbine characteristics.

3. In a hydraulic turbine means for forming a free annular jet and discharging it against the buckets of a runner, means for imparting tangential velocity components to said jet, and means for varying said tangential components.

4. In a hydraulic turbine means for forming a free annular jet, means for imparting 65 tangential velocity components to said jet,

means for varying said tangential components, and means for varying the thickness of said jet.

5. In an impulse turbine the combination with a rotor having buckets, of a nozzle directing a free jet against said buckets from one side of said rotor, and means for varying the size of the jet and the angle of the jet flow with relation to the plane of rotation of the runner so as to control the turbine characteristics. 70 75

6. In an impulse turbine the combination with a rotor having buckets, of a nozzle directing a free jet against said buckets from one side of said rotor, and means for independently varying the size of the jet and the angle of the jet flow with relation to the plane of rotation of the runner so as to control the turbine characteristics. 80

7. In an impulse turbine the combination with a rotor having buckets, of a nozzle directing a free jet against said buckets from one side of said rotor, and means for simultaneously varying the size of the jet and the angle of the jet flow with relation to the plane of rotation of the runner so as to control the turbine characteristics. 85 90

8. An impulse turbine having a runner provided with a circular series of buckets, means forming an inlet passage having an annular orifice for directing an axially progressing continuous circular free jet against all of said buckets simultaneously and means within said orifice for varying the direction of the flow lines of said jet with relation to the direction of movement of said buckets. 95 100

9. An impulse turbine provided with a runner and an inlet casing having an annular jet forming orifice around the runner shaft adapted to direct a free jet axially against said runner and means within said orifice for varying the direction of the flow lines of said jet with relation to the direction of movement of said buckets. 105

10. An impulse turbine provided with a runner and an inlet casing having an annular jet forming orifice around the runner shaft adapted to direct a free jet against the runner and means cooperating with said orifice for controlling the flow of liquid there-through comprising adjustable guide vanes adapted to impart variable tangential components to the flow lines of the jet. 110 115

11. In an impulse turbine the combination with a runner of the free jet or impulse type, of an inlet passage having an annular orifice directing a continuous circular free jet against said runner and adjustable means in said passage for imparting to said jet variable tangential components of flow with respect to the axis of said runner. 120 125

12. In an impulse turbine the combination with means for forming an axially progressing circular free jet containing tangential components of motion, of means for varying 130

said tangential components of said jet, a runner having a circular series of buckets continuously acted upon by said jet, and means for varying the thickness of said jet to control the speed of said runner.

13. In a hydraulic turbine the combination with a runner of the impulse type, of a nozzle forming an annular free jet contained between inner and outer surfaces of revolution and means in said nozzle for imparting variable tangential components to the flow lines of said jet.

14. In a hydraulic turbine the combination with a runner of the impulse type, of a nozzle forming a free jet contained between inner and outer surfaces of revolution and control means in said nozzle for simultaneously varying the thickness of said jet and the angle of the jet flow so as to give a variable tangential component to the jet flow lines as they enter the runner buckets.

15. In a hydraulic turbine the combination with a runner of the impulse type, of a nozzle forming a free jet contained between inner and outer surfaces of revolution and control means in said nozzle for varying the thickness of said jet and means for simultaneously varying the direction of the jet flow.

16. In a hydraulic turbine the combination with an inlet water passage having adjustable guide vanes therein and forming a free jet contained between inner and outer surfaces of revolution, of a movable plunger for regulating the flow through said passage and a runner of the impulse type receiving the flow from said passage.

17. In a hydraulic turbine the combination with an inwardly directed inlet water passage having adjustable guide vanes therein and forming a free jet contained between inner and outer surfaces of revolution, of a movable plunger for regulating the flow through said passage and a runner of the impulse type receiving the flow from said passage.

18. In a hydraulic turbine the combination with an inwardly directed inlet water passage having adjustable guide vanes therein and forming a free jet contained between inner and outer surfaces of revolution, of a movable plunger sliding within the inner edges of said guide vanes for regulating the flow through said passage and a runner of the impulse type receiving the flow from said passage.

19. In a hydraulic turbine the combination of a runner and means for directing water to said runner with both meridian and tangential components of velocity, said means comprising a passage bounded by surfaces forming portions of two concentric spheres, and adjustable guide vanes between said surfaces.

20. In a hydraulic turbine the combination of a runner and means for directing

water to said runner with both meridian and tangential components of velocity, said means comprising a passage bounded by surfaces forming portions of two concentric spheres, and adjustable guide vanes between said surfaces, said surfaces being of substantial extent in the direction of flow.

21. In a hydraulic turbine the combination of a runner and means for directing water to said runner with both meridian and tangential components of velocity, said means comprising a passage bounded by surfaces forming portions of two concentric spheres and adjustable guide vanes between said surfaces, said surfaces extending in the direction of flow a distance at least equal to their distance apart.

22. In a hydraulic turbine the combination of a runner and means for directing water to said runner with both meridian and tangential components of velocity, said means comprising a passage bounded by surfaces forming portions of two concentric spheres and adjustable guide vanes between said surfaces, said guide vanes being adjustable by rotation about axes forming radii of said spheres.

23. In a hydraulic turbine the combination of a runner of the impulse type, and means for directing water to said runner to form a free jet contained between inner and outer surfaces of revolution and for controlling the flow of the water comprising rotatably adjustable guide vanes and a member adjustable by motion parallel to the axis of the runner.

24. In a hydraulic turbine the combination of a runner and means for directing water to said runner comprising guide vanes rotatably adjustable and operating between concentric spherical rings, each of said guide vanes being supported by a stem extending from one side thereof.

25. In a hydraulic turbine the combination of a runner and means for directing water to said runner comprising guide vanes rotatably adjustable and formed with two edges engaging concentric spherical stationary rings, each of said vanes being supported by an extension from one of said edges.

26. In a hydraulic turbine the combination of a runner and means for directing water to said runner comprising guide vanes rotatably adjustable about axes diagonal to the runner axis, each of said guide vanes being supported by a single stem extending from only one side thereof.

27. In a hydraulic turbine the combination of a runner, an annular passage leading the flow to said runner the transverse width of said passage normal to the lines of flow being less than its smallest diameter, and guide vanes in said passage supported by a single stem extending from only one

side thereof, said guide vanes being rotatably adjustable about axes diagonal to the turbine axis.

28. In a hydraulic turbine the combination of a runner, an annular passage leading the flow to said runner in a substantially diagonal direction while permitting the flow also to have tangential velocity components about the turbine axis, the radial width of said passage measured between its inner and outer walls transversely to the flow lines being less than the diameter of its inner wall at the point measured, and guide vanes in said passage supported by a single stem extending from only one side thereof and adapted to impart said tangential components to said flow.

29. In a hydraulic turbine the combination of an axial flow runner, an annular passage leading the flow to said runner in a substantially diagonal direction while permitting the flow also to have tangential velocity components about the turbine axis, the radial width of said passage measured between its inner and outer walls transversely to the flow lines being less than the diameter of its inner wall at the point measured, and guide vanes in said passage supported by a single stem extending from only one side thereof, said guide vanes being adjustable to vary said tangential components of said flow.

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