Dec. 22, 1931. L. F. MOODY 1,837,569

HYDRAULIC TURBINE

Original Filed April 14, 1923 4 Sheets-Sheet 1

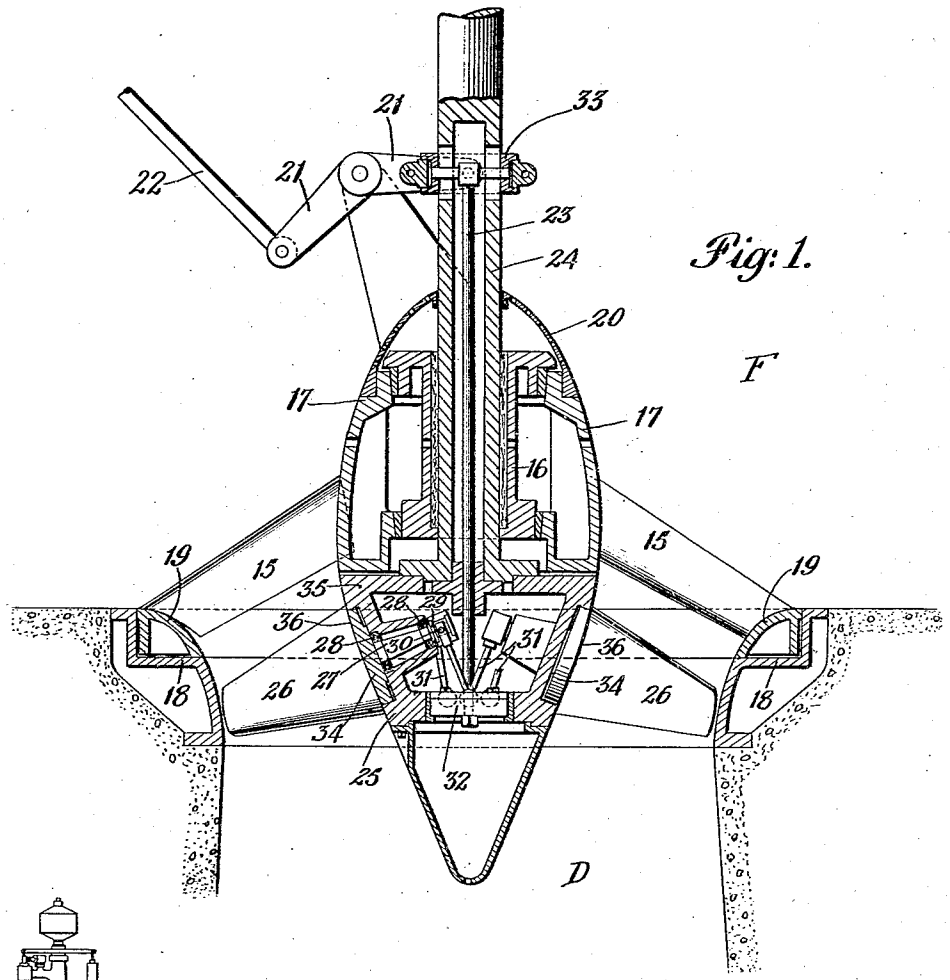


Fig: 1.

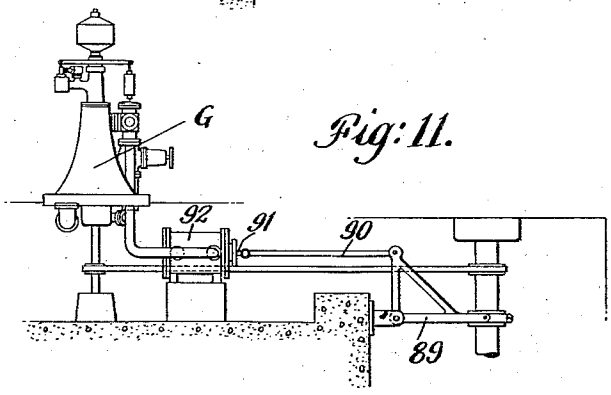


Fig: 11.

INVENTOR
Lewis F. Moody
BY
Edwards, Sager & Bower
ATTORNEYS

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Fig: 2.

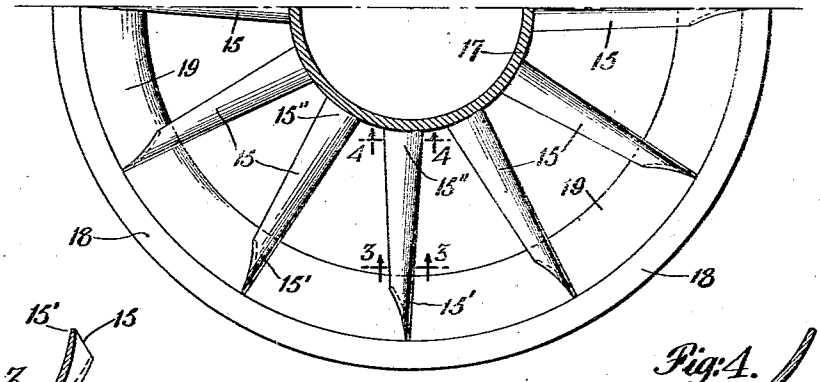


Fig: 3.

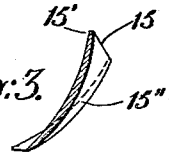


Fig: 4.

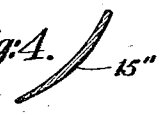


Fig: 5.

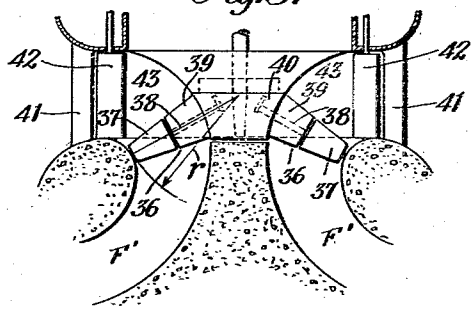


Fig: 6.

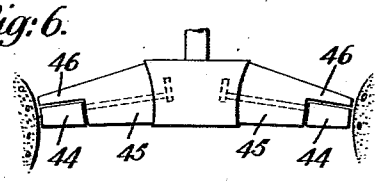
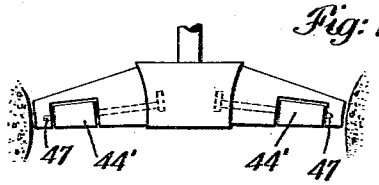


Fig: 7.



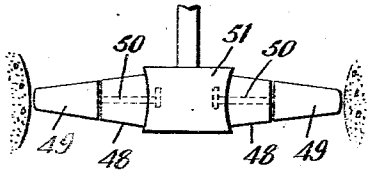


Fig: 8.

INVENTOR
Lewis F. Moody
BY
Edwards, Sager & Bowers
His ATTORNEYS

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Fig: 9.

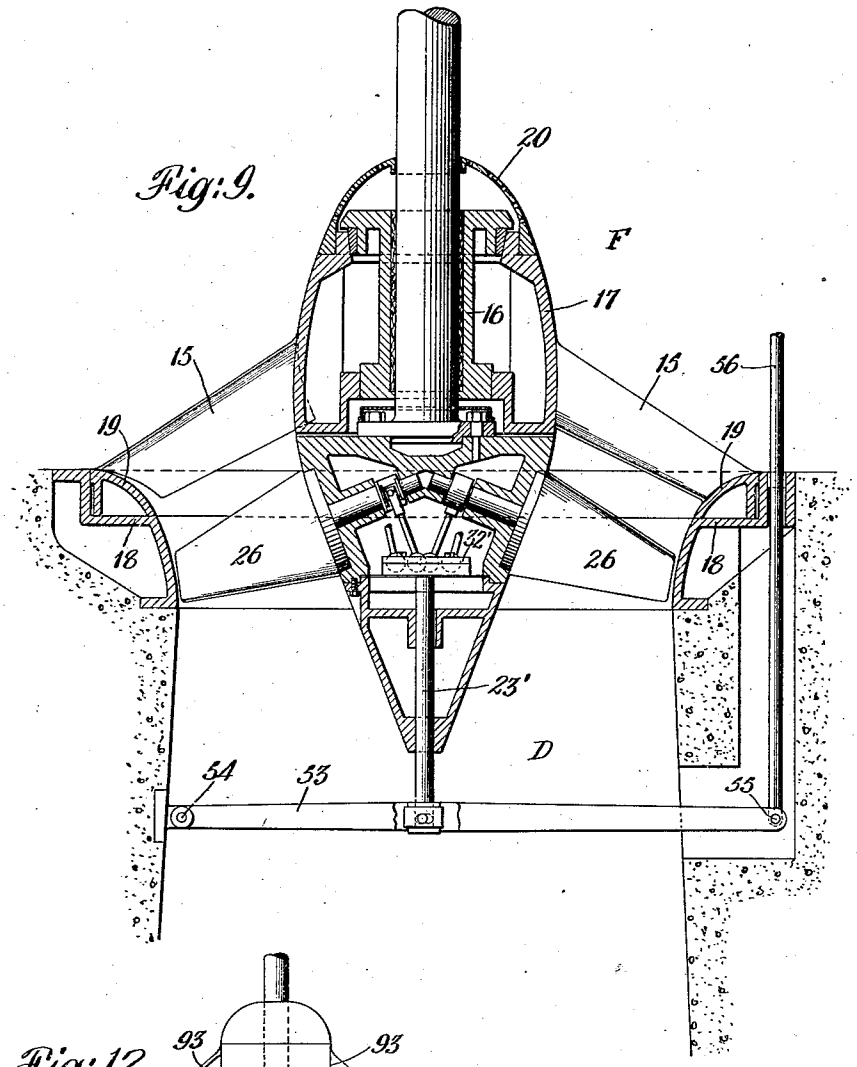
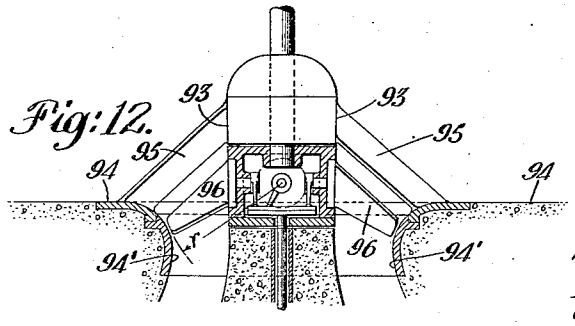


Fig: 12.



INVENTOR
Lewis F. Moody
BY
Edwards, Sager & Bower
ATTORNEYS

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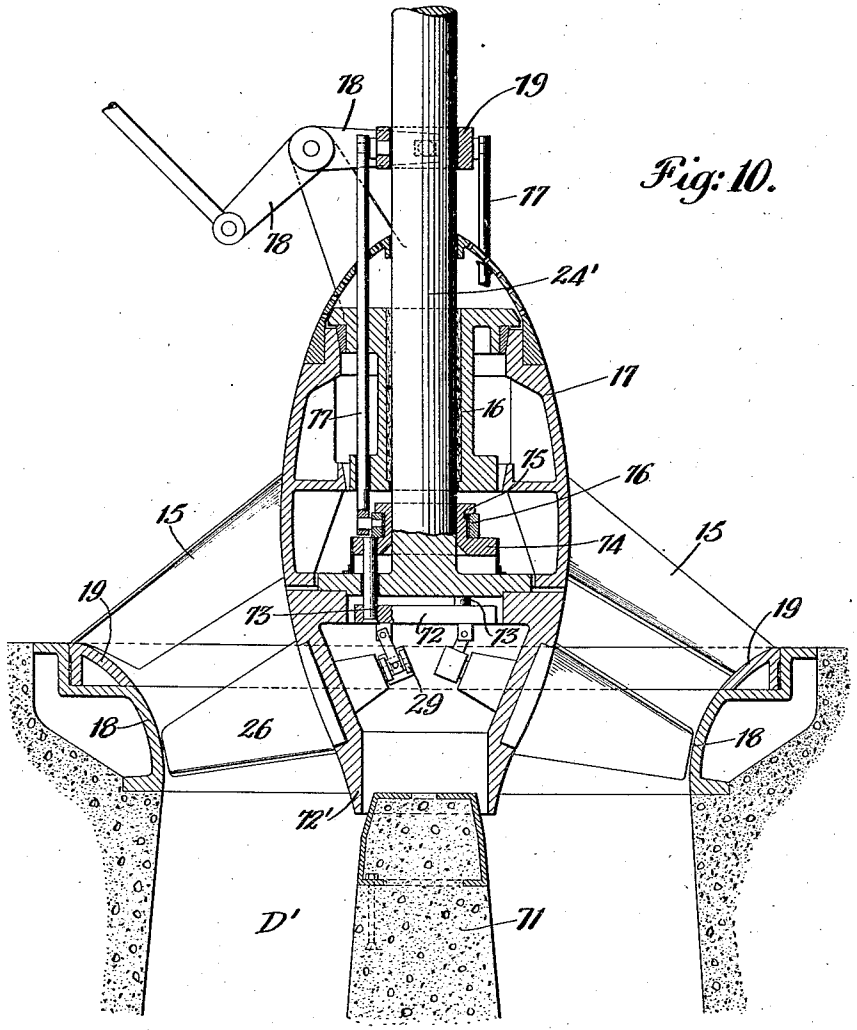


Fig: 10.

Inventor
Lewis F. Moody
By his Attorneys
Edwards, Sager & Bower

Patented Dec. 22, 1931 1,837,569

UNITED STATES PATENT OFFICE

LEWIS FERRY MOODY, OF PHILADELPHIA, PENNSYLVANIA

HYDRAULIC TURBINE

Original application filed April 14, 1923, Serial No. 631,985. Divided and this application filed June 1, 1925. Serial No. 33,940.

This invention relates to hydraulic turbines and particularly to turbines of the reaction type and of high specific speed. The object of the invention is to provide such a turbine which will be simple in form and inexpensive and at the same time efficient in operation.

It has been found particularly with turbines having high specific speed propeller-type runners that very high efficiencies can be attained, particularly at or near full load and in many installations it is highly desirable to maintain these efficiencies at partial loads or full loads. In large installations with a number of units where the load on each unit is almost invariable, part gate or overload efficiencies are not so important; but where, as in many smaller installations with only a few units, there are apt to be relatively large load variations, in such case the efficiencies at other loads than normal become an important factor.

A further object of this invention is to provide a turbine in which the efficiencies at part gate or overload will be maintained near the efficiency at normal load. This maintenance of efficiency throughout a large range of performance is attained by providing the runner with blades of simple strong formation adapted for the attainment of high specific speeds and having an adjustment of the blade surfaces to a variable angle with relation to the flow.

Further objects of the invention particularly in the specific means used to attain these results will be clear from the following specification taken in connection with the accompanying drawings in which

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

Fig. 2 is a plan view of a portion of the turbine shown in Fig. 1, showing the entrance guide vanes.

Figs. 3 and 4 are sectional views of these guide vanes on line 3—3 and 4—4 of Fig. 2.

Fig. 5 is a view similar to Fig. 1 illustrating a modified form of turbine.

Figs. 6, 7 and 8 are vertical sectional views illustrating modified forms of runners.

Figs. 9 and 10 are views similar to Fig. 1 illustrating modified forms of turbines.

Fig. 11 is a vertical elevational view of governing means showing connections for operating the runner blades, and

Fig. 12 is a view similar to Fig. 1 illustrating a further modification.

In the specific embodiment of the invention shown in Fig. 1 the invention is illustrated in connection with a vertical shaft turbine installed in an open flume F. It may however be installed in connection with any desired intake means and the axis of the runner shaft may be horizontal or at any desired inclination.

In Fig. 1 the turbine comprises a distributor containing fixed guide vanes 15 which also act as stay vanes to support the turbine bearing 16, the bearing casing 17 and guide vanes being cast in one piece as shown, and the casting 15, 17 being removable to permit the turbine to be dismantled and the runner withdrawn. The guide vane casting rests in a fixed base ring 18 set into the concrete, which forms the floor of the flume F, and the walls of the draft tube D. The guide vane ring and bearing casing may be made interchangeable with a radial, inward-flow distributor and head cover containing the ordinary wicket gates (see Fig. 5), so that turbines of standard sizes may be furnished with either fixed guide vanes or wicket gate regulation, as might be desirable in any given installation. When fixed guide vanes 15 are used as shown it is no longer necessary to make these vanes overlap in order that they may close off the flow for regulation purposes, a small number of such vanes 15 can be used widely spaced (see Fig. 2) and thereby the amount of surface exposed to the flow can be reduced with a corresponding reduction in the loss of head due to hydraulic surface resistance.

Since in turbines of the high specific speed propeller type here represented the amount of whirl component of the velocity of entrance of the water into the runner is considerably reduced below what would be required in turbines of lower specific speed, the water enters at a large angle with respect to

the tangential direction and therefore does not have to be deflected through a large angle in admitting it to the runner. A small number of guide vanes 15 is therefore sufficient to give the required direction. In designing a set of turbines of standard size for quantity manufacture, the patterns may be arranged to permit the guide vane angle to be adjusted to suit the particular range of horsepower and the speed required in any given installation. After the conditions are determined for an installation, the vanes will then be rigidly cast at the proper angle. These vanes may either be connected by a continuous ring 19 around their outer ends or in some cases each vane could be provided with a pad at the outer end fitting into a socket in the base ring 18, the surface of the pad conforming to the contour of the base ring.

The bearing casing 17 contains the bearing proper 16, which is lined with lignum vitæ or rubber, suitable for operation in the water. The bearing is covered with a strainer 20 to keep foreign matter out of the bearing. In the arrangement shown, a bell crank 21 is mounted above the bearing cover to transfer the governor motion from rod 22 to a rod 23 carried within the hollow shaft 24 of the runner 25. It may be desirable in some cases to enclose this bell crank within the bearing cover 20 or an extension of the cover, the point of support of the bell crank being dropped to a lower elevation to make the design more compact.

The runner 25 is of the movable blade type, the regulation being performed by a rotation of each blade 26 on an axis contained in a meridian plane, that is, a plane containing the turbine axis. As shown, the vane pins 27 are mounted in ball bearings 28, but this is not, of course, essential, although it may be advantageous particularly when the head is relatively high. Each vane stem 27 carries an arm 29 connected through universal joint 30 to a link member 31 swiveled in a lower member 32 mounted on the vertical rod 23 which passes upward within the hollow shaft 24. The link is pin-connected at the upper end and connected by a ball and socket joint to the block 32 at the lower end, thus providing a universal joint at each end.

The governor connected to rod 22 can be placed at any suitable location on the floor of the generator room and the rod 22 can be placed at any suitable angle, the bell crank 21 to which it is connected being given a corresponding angle between its arms while the governor G is rotated with the turbine runner by a belt and pulley or other suitable connection. This bell crank 21 raises and lowers the central rod 23 within the shaft 24 through a floating governor sleeve and pin connection 33 passing through slots in the shaft 24. The vertical motion of this central rod 23 rotates all the runner blades 26 equally and simultaneously. At the point of connection of each blade to its pin, a circular disk 34 is provided which is fitted in a recess in the runner hub 35 and has its exposed surface 36 conforming to the hub contour when the blade is in its normal position. The blade 26, disk 34 and stem 27 are preferably cast integrally.

The runner 25 is of the diagonal inflow type with a substantially axial discharge and receiving the flow axially and with inward components in meridian planes. A shroud ring is preferably omitted and the blades are of simple rather flat contour providing high speed propeller type runners. The blade edges are substantially straight lines as projected into meridian planes as shown for instance in Fig. 1. Tests which I have made on a runner having adjustable blades of this form show that a very flat efficiency curve can be secured, that is, the efficiency changes but little over a considerable range of power output corresponding to changes in the blade angle. This is true even when a fixed position of the guide vanes 15 is used. If both guide vanes and runner blades are made movable (see Fig. 5) a very wide range in capacity of the turbine can be secured and it can be adapted to a wide variation of speed. For any given installation, a better form of performance curve can be secured by moving the runner blades alone than it is possible to secure with fixed runner blades and movable guide vanes.

The fixed entrance guide vanes 15 of Figs. 1 and 2 are shown as varying in inclination from a more axial direction at their outer ends 15′ to a more tangential direction at their inner ends 15″ so that the entering flow is guided with increasing components of whirl toward the center. This varying angle from the outer tips of the guide vanes to the inner portions gives the most favorable degree of whirl at each point along the discharge edges of the vanes so that the flow lines proceed along natural whirling paths and the annular column of water is in the form of a freely rotating vortex as it enters the runner.

A diagonal arrangement of the guide vanes 15 is advantageous in that it reduces the length of path which must be traversed by the water after it reaches the increased velocity of flow through the turbine. This shortened path permits the hydraulic losses to be reduced, and the entire turbine structure is very compact and involves a minimum amount of material. With this simplicity of form and inexpensiveness is attained the high efficiency secured by the control of the position of the runner blades 26 for different loads and speeds. As ordinarily constructed the runner blades 26 will not be designed to close off the flow completely. They will, however, turn through a sufficient angle to decrease the

power output to zero. Under this zero output condition a considerable amount of water will still flow between the blades and it will therefore be necessary to provide head gates at the entrance to the flume F which will be closed whenever the turbine is shut down.

In the embodiment of the invention shown in Fig. 5 the adjustment of the runner blading 36 is effected by moving only a part of the runner blade, this adjustable part 37 being the outer portion of the blade mounted rotatably on the stem or shaft 38 extending through the fixed portion 39 of the blade to within the hollow hub 40 where it is provided with any desired form of operating means. Instead of the inclined guide vanes of Figs. 1 and 2 the turbine of Fig. 5 has a radial entrance for the flow through the speed ring 41 and wicket gates 42 with an intermediate transition space 43 between the wicket gates and the runner 36 wherein the flow turns toward an axial direction. Since in this embodiment of the invention both the movable runner blades and the movable guide vanes are used, they can be so arranged and their operating mechanisms so interconnected that very little drop in efficiency will be secured over a wide range of performance, the discharge from the runner under a wide range of conditions remaining nearly axial in direction and with but little whirl. If, however, a draft tube F′ of the spreading type or other equivalent type is used capable of regaining the energy of whirl contained in the water discharged from the runner, it is then of less importance to provide movable guide vanes in addition to movable runner blades, since the draft tube can handle whirling water and can efficiently reconvert the energy of the whirl into useful pressure head. In general, it is recommended to use this turbine with whirl-regaining draft tubes and to provide a central core in the draft tube extending up to and conforming with the runner hub (in place of the conical cap on the runner) as shown in Figs. 5 and 10. In some of the smaller installations, it will probably be the desire to omit the draft tube core for reasons of first cost.

In cases where both guide vane and runner blade regulation are provided, it is unnecessary that both sets of vanes be moved simultaneously by the governor. One set, such as the guide vanes, can be governor-operated and the other set either hand-operated or actuated by a slower automatic adjustment following and responding to any movement of the primary operating mechanism.

Another modification of this turbine will comprise the use of inclined, movable guide vanes, that is, wicket gates rotating about axes contained in meridian planes, but not parallel to the turbine axis and operated by mechanism similar to that shown for the runner blade regulation.

In Fig. 6 the runner regulation is produced by moving a small portion 44 of the runner blade 45 near the outer tips and comprising the discharge portion of the vane, the entrance portion 46 remaining fixed. As shown in Fig. 7 instead of having a free end on this adjustable portion a second stem or trunnion 47 may be provided at the outer end of the movable portion 44′ so that this movable portion is supported at both ends and is not overhung as in the other arrangements. This provides a better support for the movable portion and greater mechanical strength permitting the pins or stems to be made of smaller diameter. In these modifications of Figs. 6 and 7 the most effective part of the blade has been selected for the purpose of regulation and instead of moving the whole blade or a large portion of it, only this small section is moved and the force required to operate it is correspondingly reduced. At the same time a sufficient part of the blade is made movable to serve all the ordinary requirements of regulation.

In Fig. 8 an axial flow runner 48 is shown with the outer portions 49 of the blades adjustable on rotatable stems 50 operated from within the hollow hub 51 in a manner similar to the methods shown in the other figures. One advantage which the preferred diagonal runner has over the purely axial flow runner is that the hub of the diagonal runner can be enlarged so as to give a better arrangement of the operating mechanism with more room for the runner blade disks and stems and adjusting means.

The modified form of turbine shown in Fig. 9 is similar to the turbine of Fig. 1 but instead of moving the adjustable block 32′ for the blade links by means of a rod passing up through a hollow shaft, the control rod 23′ extends downward through the end of the hub and is moved by a horizontal lever 53 extending across the draft tube and pivoted at 54 and connected at 55 to the vertical rod 56 extending upward to be connected with the control mechanism. This rod 56 will pass upward through the floor of the generator room to the governor. Fig. 10 shows an arrangement similar to that of Fig. 1 but differing in the type of draft tube used and in the specific form of the operating mechanism used for the adjustable runner blades. The draft tube D′ of this figure is of annular form with a central core 71 extending up within the open lower end of the runner hub 72′. In the operating mechanism for the adjustable blades the member 72 for actuating the blade levers 29 is placed above them instead of below. Instead of moving this member 72 by a central rod in a hollow turbine shaft, it is connected through vertical rods 73 to a sleeve 74 surrounding the turbine shaft and rotating with it. This sleeve 74 carries a circumferential slot 75 within

which is engaged a non-rotatable collar 76 which in turn is moved vertically by the two vertical connecting rods 77 and a bell crank 78 placed above. A second sleeve 79 is shown at the top which is not in contact with the shaft 24' but merely serves for actuating the rods. This arrangement of Fig. 10 avoids the need for a hollow bored shaft. In Fig. 11 the governor means is shown connected through lever 89 and the intermediate collars to the rod 23, for instance within the hollow shaft 24 of Fig. 1. By this connecting mechanism tipping movements of the bell crank lever 89 are translated into turning movements of the adjustable blades 26. To control the position of the runner blades the lever 89 is connected by link 90 to the piston rod 91 of fluid pressure cylinder 92. The piston of this cylinder 92 has fluid pressure admitted to opposite sides of it by the governor means G according as the increase or decrease of the load makes desirable a shifting of the runner blade inclination.

In Fig. 12 a modified form of turbine is shown in which the inner upper wall is a cylinder 93 and the lower outer wall is a plane surface 94 rounding into a downwardly directed surface of revolution 94', these two walls being joined by diagonal stationary vanes 95. These vanes 95 can be few in number and widely spaced to reduce surface resistance and preferably of "twisted" or warped form to give the correct angle of guidance at every point as shown in Fig. 2. The runner blades 96 may be diagonally directed as shown and adjustable about radial axes, that is radial with respect to the turbine axis. Each point of the blade tips will then move in a spherical surface about the intersection of the axes of blade adjustment and the turbine axis. The blades 96 may terminate in a single spherical surface as indicated by the radius r in this Fig. 12 and also with relation to the blade tips of the runner shown in Fig. 5. It is obvious that this spherical formation of the blade tips may be used with any of the runners shown in the various figures. The wall of the runner chamber such as that indicated at 94' should be tangent to the sphere at about the center of the tip breadth, and should conform as closely as possible to the sphere to reduce leakage between the tips and the wall. These runner blades may be adjusted by any desired means such for instance as that shown in the turbine of Fig. 9.

The turbine of this invention permits the structural parts to be very simple in form and at the same time combines high specific speed of the runner with a sustained efficiency at all loads. The adjustable runner blades absorb a variable amount of whirl from the flow depending upon the load and it is therefore particularly advantageous with this type of runner to provide a draft tube capable of regaining the whirling components of the velocity and converting them into effective pressure head at all loads. Such a draft tube adapted to spread and decelerate the flow between inner and outer surfaces of revolution is shown for instance at F' in Fig. 5 and may be used with any of the runners shown to convert the variable whirl into pressure head and thus maintain the efficiency of the turbine throughout a wide variation in the load.

(This application is a division of co-pending application, No. 631,985, for hydraulic turbine, filed April 14, 1923.)

I claim:

1. A hydraulic turbine comprising a runner having a hub, a water passage for said runner bounded on the outside by an outer stationary wall and along the inner side by the rotating outer surface of said runner hub, guide vanes at entrance to said passage, said runner having a series of blades supported by its rotating wall and each blade being rotatably adjustable upon its axis, and mechanism entirely within the innermost portion of said hub for adjusting said blades, said mechanism including a slidable operating element and connecting means extending upwardly therefrom to said blades.

2. In a power plant of the character described, a water wheel comprising a hub having a central hollow portion and a series of unshrouded blades of the propeller type carried thereby and each being rotatable upon its axis, and a governing mechanism rotatable with said wheel and having connection within said central hollow portion with said blades at their inner ends at a point substantially in alignment with the blade axis thereby to change the pitch of the blade faces to maintain a uniform speed of said wheel, said connection including a reciprocable member rotatable with said runner, and means extending upwardly from said reciprocable member for connecting the blades therewith.

3. In combination with a water wheel comprising a series of blades of the propeller type, a tapered housing constituting a runner hub and having bearings in the larger end thereof for supporting said blades for rotation upon their axes, of means for rotating said blades, including crank arms connected to said blades on the inner side of said bearings and within the innermost portion of said hub, and means for actuating said crank arms including a reciprocating rod extending through said housing and connections extending upwardly from the lower end of said rod to said crank arms.

4. In combination with a water wheel comprising a series of blades of the propeller type, a housing constituting a runner hub and having bearings for supporting said blades for rotation upon their axes, of means

for rotating said blades including crank arms connected to said blades on the inner side of said bearings and within the innermost portion of said hub, means for actuating said crank arms including a reciprocating rod, and connecting means extending upwardly from said rod to said crank arms whereby said blades are disposable in the upper end of said housing, a shaft for supporting said hub having a bore through which said rod extends, and a bearing for said shaft adjacent said runner, whereby the arrangement of said blades and connecting means permits said bearing and blades to be relatively close to each other.

5. In combination, a water wheel comprising a series of blades of the propeller type, a housing constituting a runner hub and provided with blade supporting bearings, each of said blades having a shaft journaled in its respective bearing, means for rotating said blades, including a crank arm connected to the inner end of each shaft, and a reciprocating rod operatively connected to said crank arms by members lying in planes which everywhere are inclined to the runner axis, and a shaft for supporting said hub having a bore through which said rod extends.

6. In a hydraulic turbine the combination with fixed guide vanes adapted to impart a whirl to the entering flow, of a runner receiving said flow axially and with inward components, said blades being adjustable around axes inclined to the runner axis to different angles with relation to said flow, and a means for adjusting said runner blades while the runner is rotating comprising an axially movable rod.

7. In a hydraulic turbine the combination with fixed guide vanes adapted to impart a whirl to the entering flow, of a runner receiving said flow axially and with inward components, said blades being adjustable around axes inclined to the runner axis to different angles with relation to said flow, and a means for adjusting said runner blades while the runner is rotating, comprising a governor controlled member and connections between said member and said blades, said connections having an axially movable rod rotating with the runner.

8. In a hydraulic turbine the combination with a runner having blades rotatably adjustable about axes inclined to the runner axis during the rotation of the runner, of a hollow bored shaft carrying said runner, operating means for said blades comprising a central slidable rod within said shaft, and means for transferring from outside said shaft to said rod a relative axial motion between said rod and said shaft during the rotation of said runner.

9. A hydraulic turbine comprising a runner having unshrouded runner blades rotatable around axes extending outward from the runner, and operating means for moving said blades comprising a bell crank carrying an axially movable sleeve connected in turn to a slidable rod within the runner shaft so as to transfer motion from outside of said shaft to said rod while said runner is rotating.

10. In a hydraulic turbine the combination with a runner having blades rotatably adjustable around axes inclined to the runner axis, of operating means for adjusting said blades comprising a member slidably adjustable relative to the runner along the runner axis.

11. In a hydraulic turbine, in combination, a runner having blades rotatably adjustable around axes inclined to the runner axis, a runner shaft having a bore extending therethrough, and operating means for adjusting said blades comprising a rod disposed within said bore and axially slidable therethrough.

12. In a hydraulic turbine the combination with a runner having blades rotatably adjustable around axes inclined to the runner axis during the rotation of the runner, of operating means for adjusting said blades comprising a member slidably adjustable relatively to the runner along the runner axis.

13. In a hydraulic turbine the combination with a runner having blades rotatably adjustable around axes inclined to the runner axis during the rotation of the runner, of operating means for adjusting said blades comprising a member slidably adjustable relatively to the runner about the runner axis, said member being connected to each of said blades in similar manner.

14. In a hydraulic turbine the combination with a runner having unshrouded blades extending outward from a central hub and rotatably adjustable about axes inclined to the runner axis during the rotation of the runner, of operating means for adjusting said blades comprising a member axially adjustable relatively to the runner along the runner axis.

15. In a hydraulic turbine the combination with a runner having unshrouded blades extending outwardly from a central hub and rotatably adjustable during the rotation of the runner about axes inclined to the runner axis, of operating means for adjusting said blades comprising a member co-axially movable relative to the runner axis and rotatable with said runner, said member being connected to each of said blades in similar manner.

16. In a power plant of the character described, a water wheel comprising a series of blades of the propeller type, a tapered housing having bearings in which said blades are rotatably mounted, a hollow shaft connected with said housing, governing mechanism rotatable with said shaft, a rod in said shaft connected with said governing mecha-

nism whereby axial movement in opposite directions is imparted to said rod, a crank arm connected with each blade, a head connected with said rod in proximity to said crank arms, and connections extending upwardly in the smaller end of said tapered housing between said head and crank arms to rotate said blades by the movement of said rod.

17. In a power plant of the character described, a water wheel comprising a series of blades of the propeller type, a tapered housing having in the enlarged end thereof bearings in which said blades are rotatably mounted on axes inclined to the runner axis, a hollow shaft connected with said housing, governing mechanism rotatable with said shaft, a rod in said shaft connected with said governing mechanism whereby movement in opposite directions is adapted to be imparted to said rod, a crank arm connected with each blade, a head connected with said rod in proximity to said crank arms and in the smaller end of said housing, and connections extending upwardly between said head and crank arms to rotate said blades by the movement of said rod.

18. The combination in a hydraulic turbine comprising a flow passage and a runner having a hub with a central hollow portion, adjustable blades carried by said hub and rotatable on axes inclined to the runner axis, operating means adapted upon actuation to adjust said blades including crank arms connected to the inner ends of said blades within said central hollow portion, and means extending upwardly and connected to said crank arms for actuation thereof, and a shaft for supporting said runner connected thereto at the upper portion thereof and without passing through said central hollow portion.

19. The combination in a hydraulic turbine comprising a flow passage and a runner having a hub with a central hollow portion, adjustable blades carried by said hub and rotatable on axes inclined to the runner axis, operating means adapted upon actuation to adjust said blades including crank arms connected to the inner ends of said blades within said central hollow portion, a hollow shaft for supporting said runner and having its main point of connection with said hub at the upper portion thereof and without passing through said central hollow portion, and an operating rod extending through the hollow portion of said runner shaft and operatively connected to said crank arms by connecting members lying in planes which are everywhere inclined to the runner axis.

20. The combination in a hydraulic turbine comprising means forming a flow passage, and a runner disposed therein having a hub with a central hollow portion and bearings formed in the wall surrounding said hollow portion, blades having shafts rotatably supported in said bearings and extending inwardly within said hollow portion, crank arms secured to the inner ends of said shafts, an axially movable rod having upwardly extended connections with said crank arms to effect simultaneous operation of said blades, and a shaft for supporting said runner being connected to said runner hub at the upper portion thereof thereby to permit the central hollow portion to be substantially free to house said crank arms and the operative connection thereto.

21. The combination in a high specific speed propeller type hydraulic turbine comprising means forming a flow passage through which fluid symmetrically flows with respect to the turbine axis, and a runner disposed in said passage and having a hub with a central hollow portion and bearings formed in the hub wall surrounding said hollow portion, a hollow shaft for supporting said runner, blades rotatably supported in said bearings and each blade having an operating member extending within said hollow portion, a reciprocating rod extending through the hollow portion of said runner shaft and down into the lower part of said hollow portion, and elements connected to the lower end of said reciprocating rod and extending upwardly for connection to said blade operating means.

22. The combination in a high specific speed propeller type hydraulic turbine comprising means forming a flow passage through which fluid symmetrically flows with respect to the turbine axis, and a runner disposed in said passage and having a hub with a central hollow portion and bearings formed in the hub wall surrounding said hollow portion, a hollow shaft for supporting said runner, blades rotatably supported in said bearings and each blade having an operating member extending within said hollow portion, crank arms carried by the inner ends of said blade operating members within the hollow portion of said hub, an operating rod extending through the hollow portion of said runner shaft and down into the lower part of the hollow portion of said hub, and elements connected to the lower end of said rod and extending upwardly for connection to said crank arms.

LEWIS FERRY MOODY.