Dec. 22, 1931. L. F. MOODY 1,837,568

HYDRAULIC TURBINE

Filed April 14, 1923 7 Sheets-Sheet 1

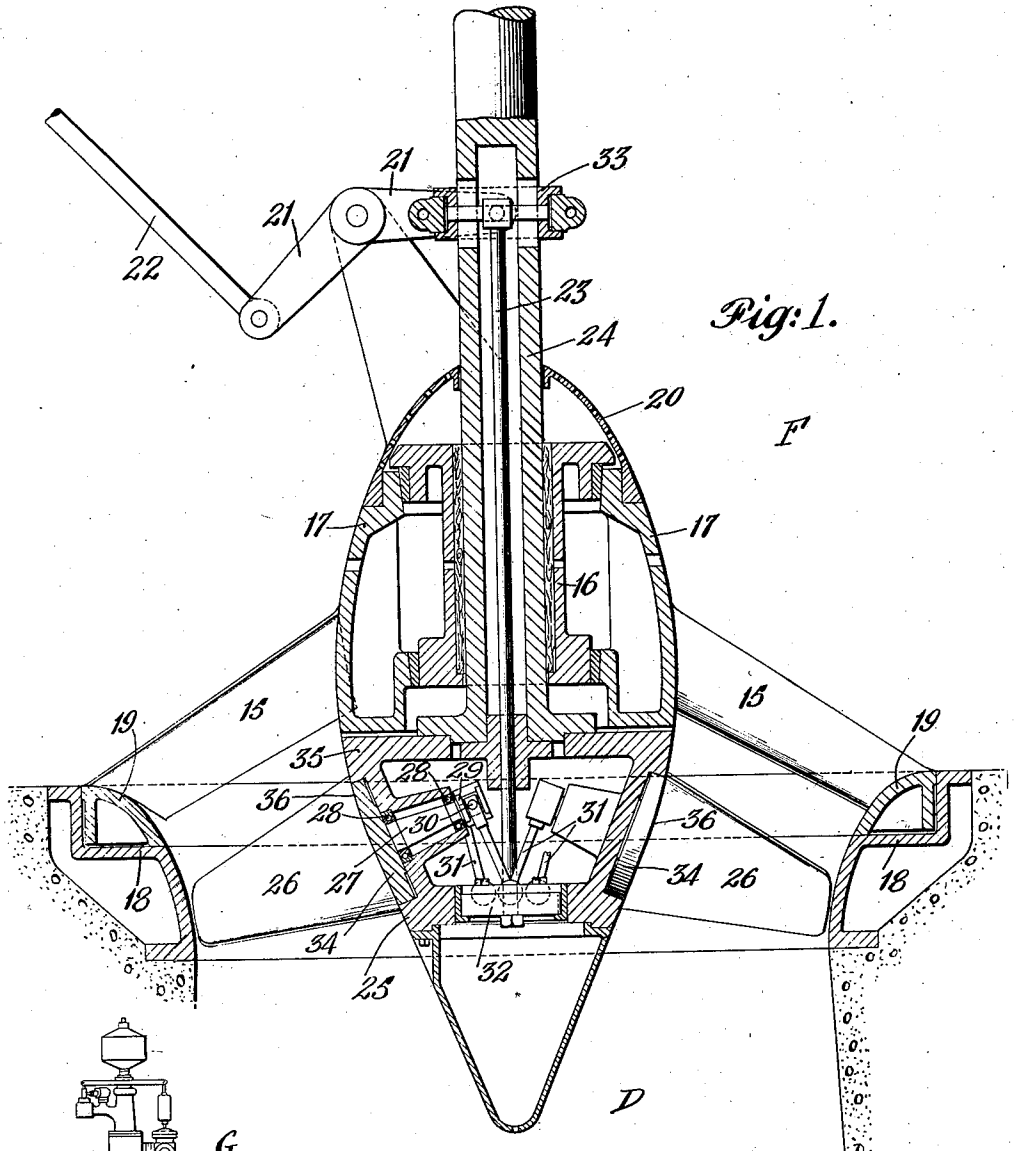


Fig:1.

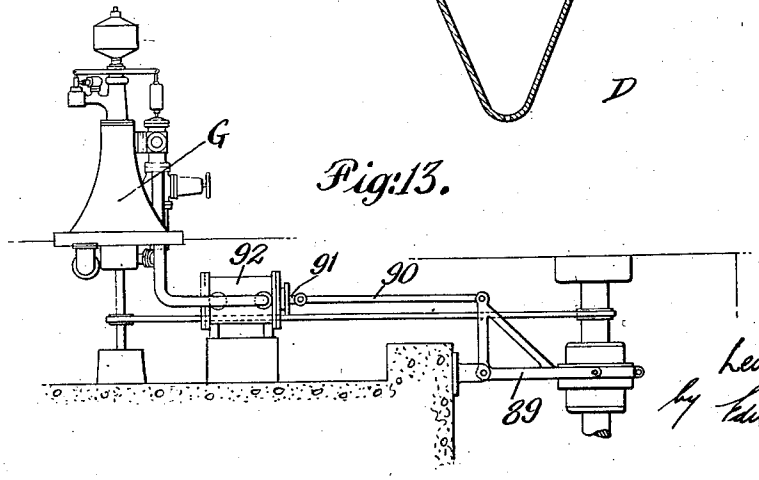


Fig:13.

Inventor
Lewis F. Moody
by Edwards, Sager & Bowen
his Attorneys

Dec. 22, 1931. L. F. MOODY 1,837,568

HYDRAULIC TURBINE

Filed April 14, 1923 7 Sheets-Sheet 2

Fig:2.

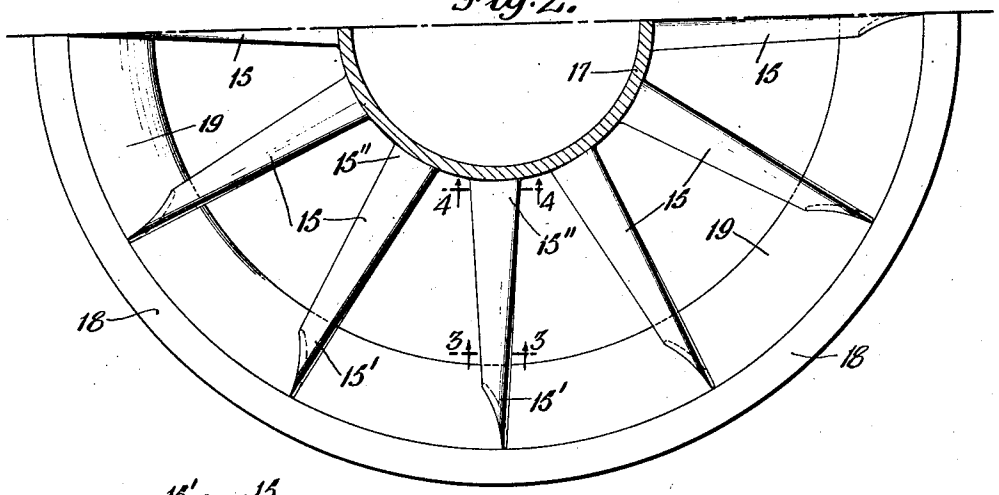


Fig:3.

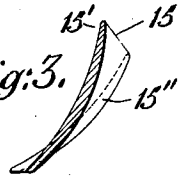


Fig:4.

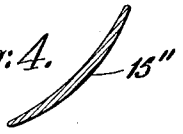


Fig:5.

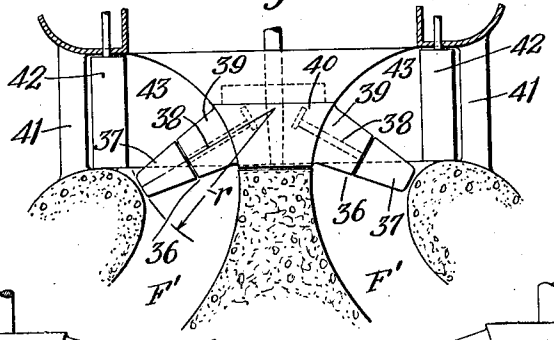


Fig:6.

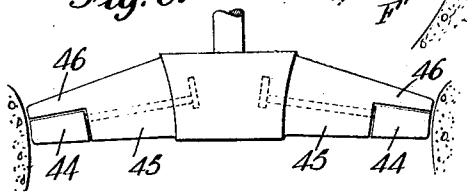
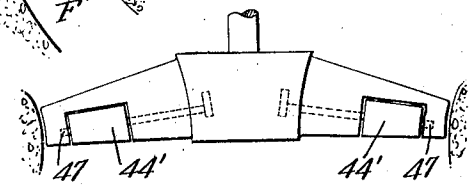


Fig:7.



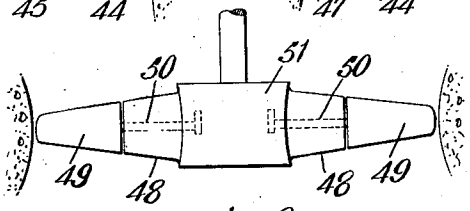


Fig:8.

Inventor
Lewis F. Moody
by Edwards, Sager & Brace
Attorneys

Dec. 22, 1931. L. F. MOODY 1,837,568

HYDRAULIC TURBINE

Filed April 14, 1923 7 Sheets-Sheet 3

Fig: 9.

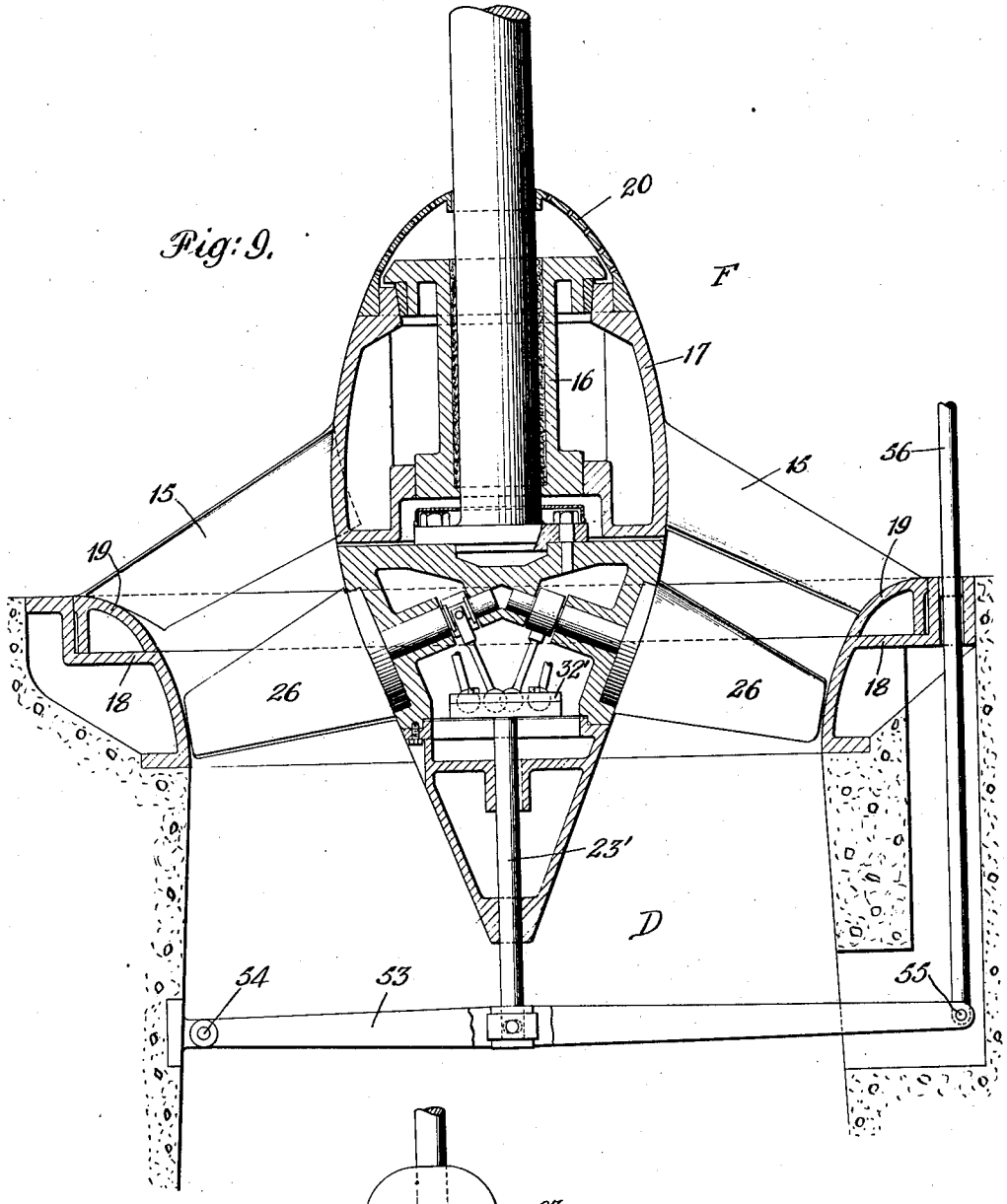
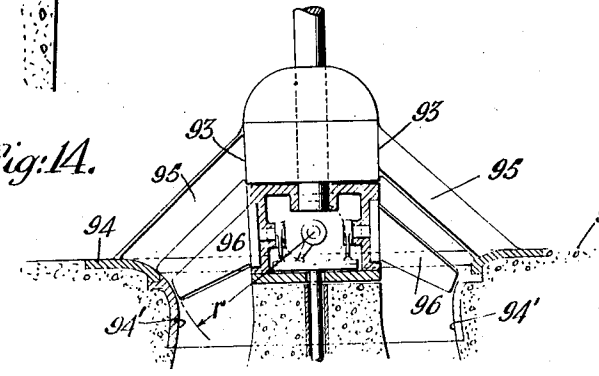


Fig: 14.



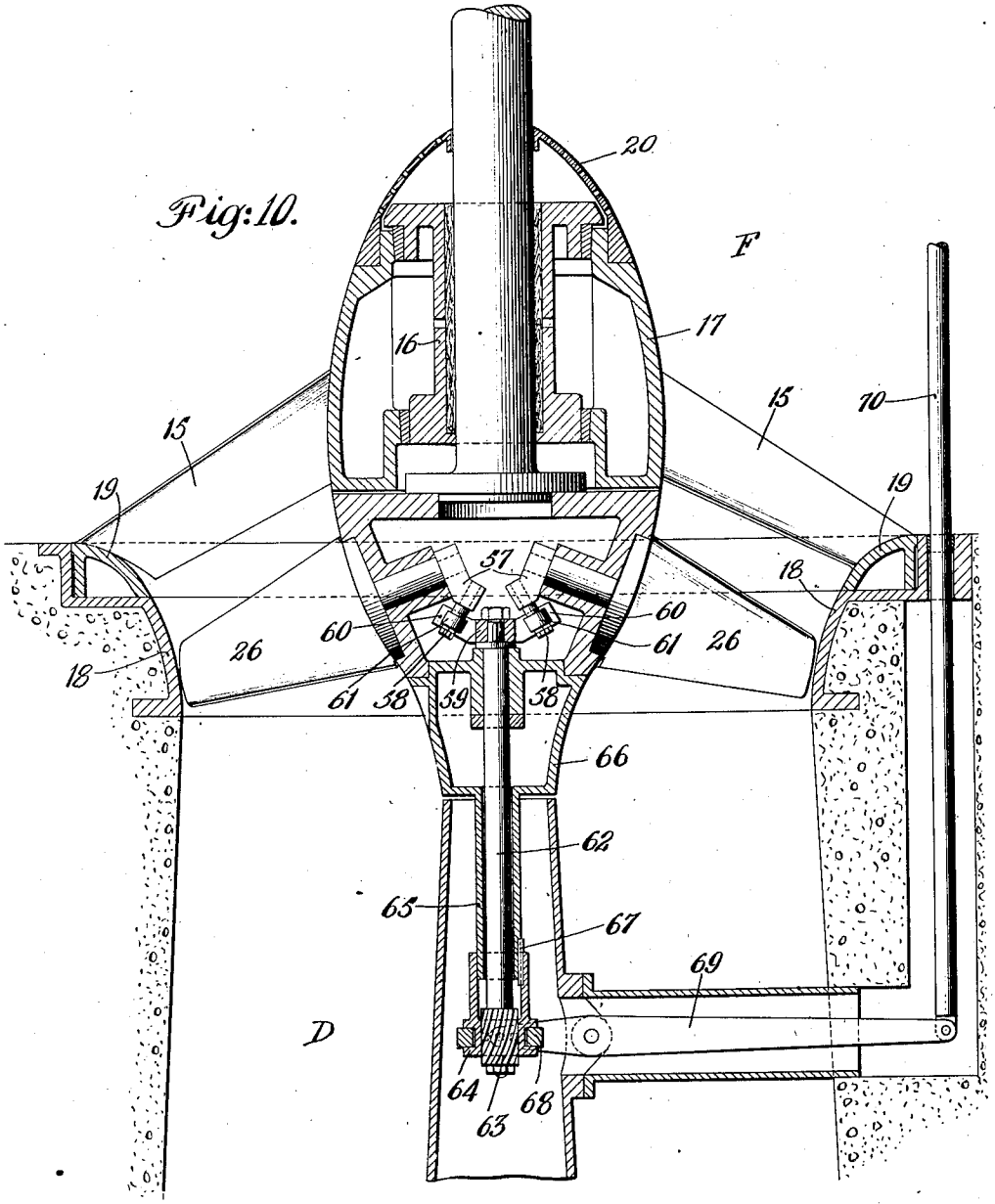
Inventor
Lewis F. Moody
by Edwards, Sager & Bauer
his Attorneys

Dec. 22, 1931. L. F. MOODY 1,837,568

HYDRAULIC TURBINE

Filed April 14, 1923 7 Sheets-Sheet 4

Fig: 10.



Inventor
Lewis F. Moody
by Edwards, Sager & Bowen
his attorneys

Dec. 22, 1931. L. F. MOODY 1,837,568

HYDRAULIC TURBINE

Filed April 14, 1923 7 Sheets-Sheet 5

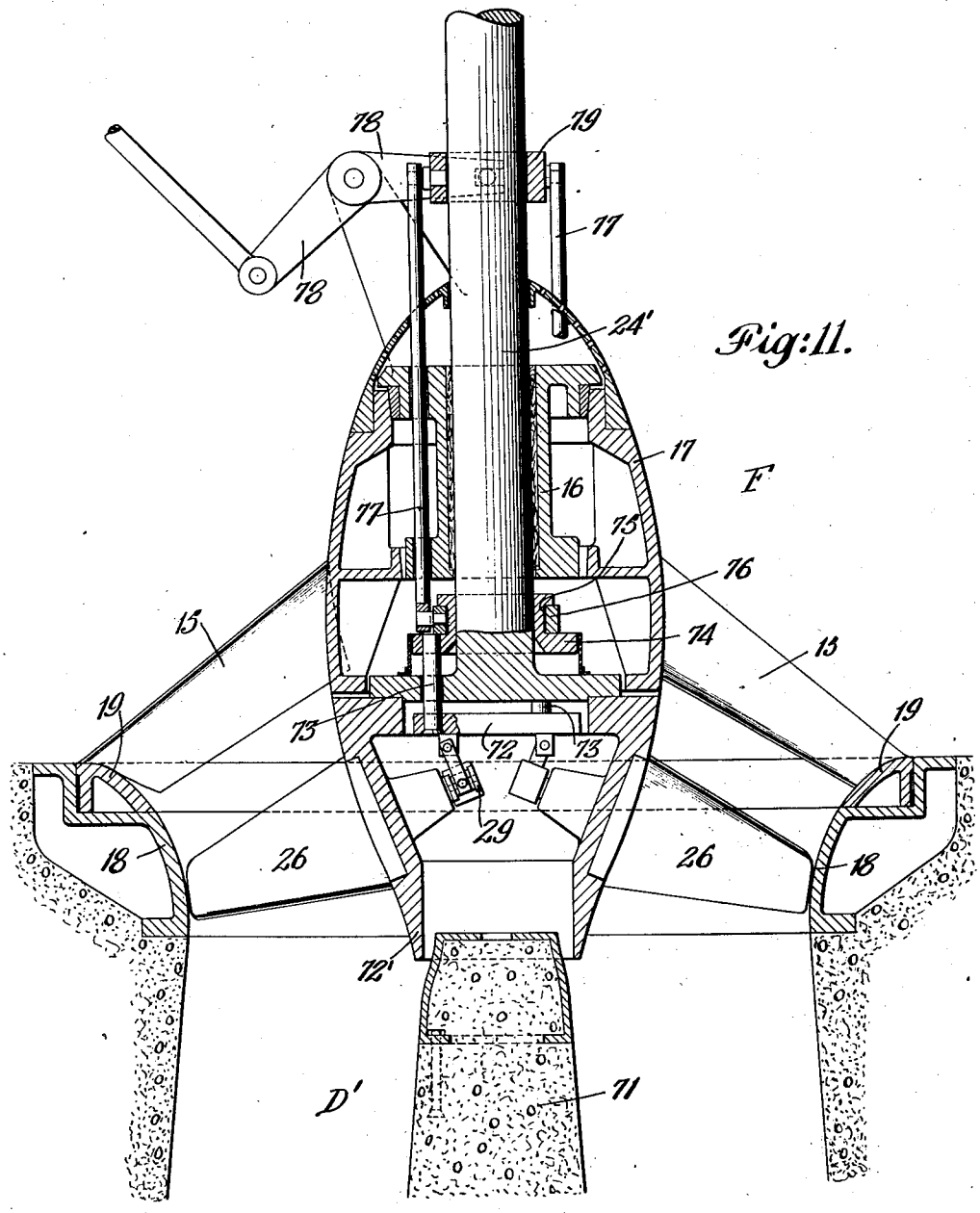


Fig:11.

Inventor
Lewis F. Moody
by Edwards, Sager & Bauer
his Attorneys

Dec. 22, 1931. L. F. MOODY 1,837,568

HYDRAULIC TURBINE

Filed April 14, 1923 7 Sheets-Sheet 6

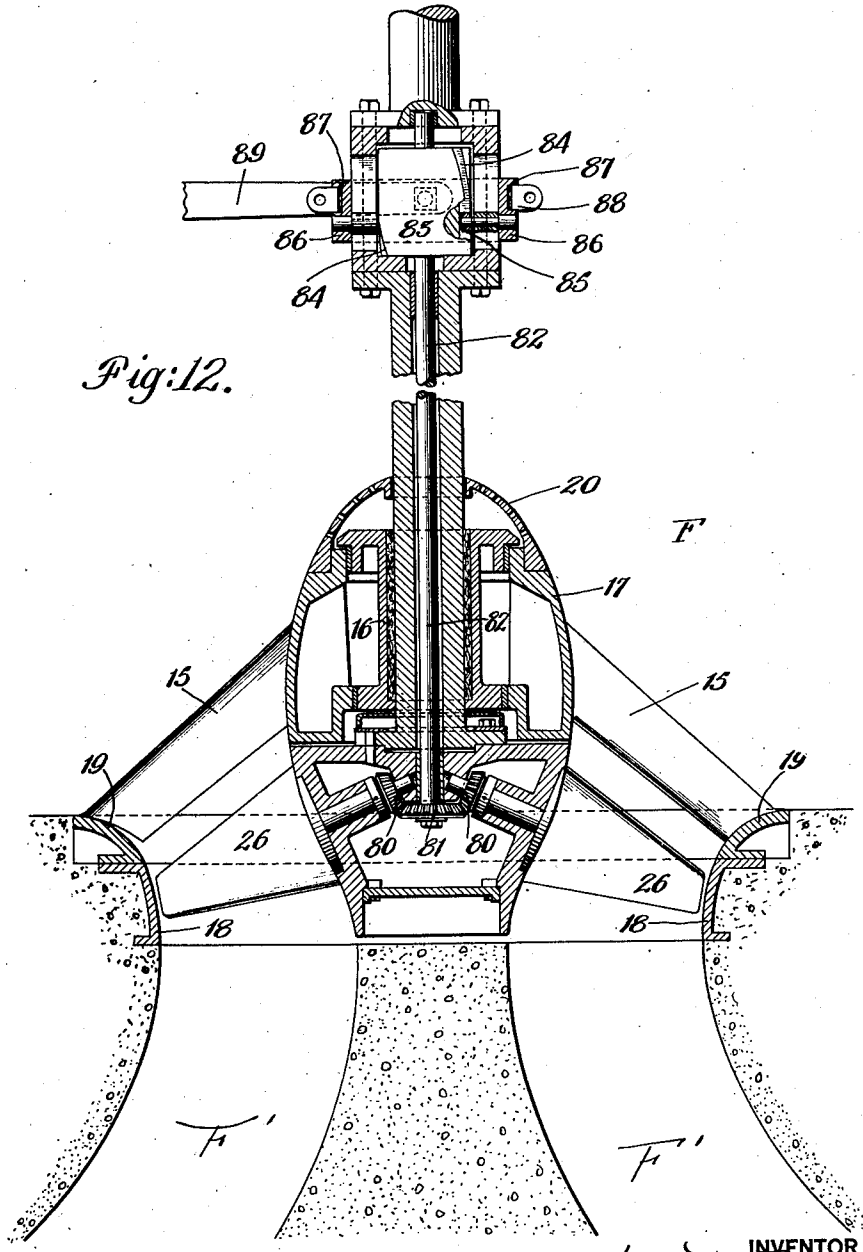


Fig:12.

INVENTOR
Lewis F. Moody
BY
Edwards, Sager & Bauer
ATTORNEY

Dec. 22, 1931. L. F. MOODY 1,837,568

HYDRAULIC TURBINE

Filed April 14, 1923 7 Sheets-Sheet 7

Fig. 15.

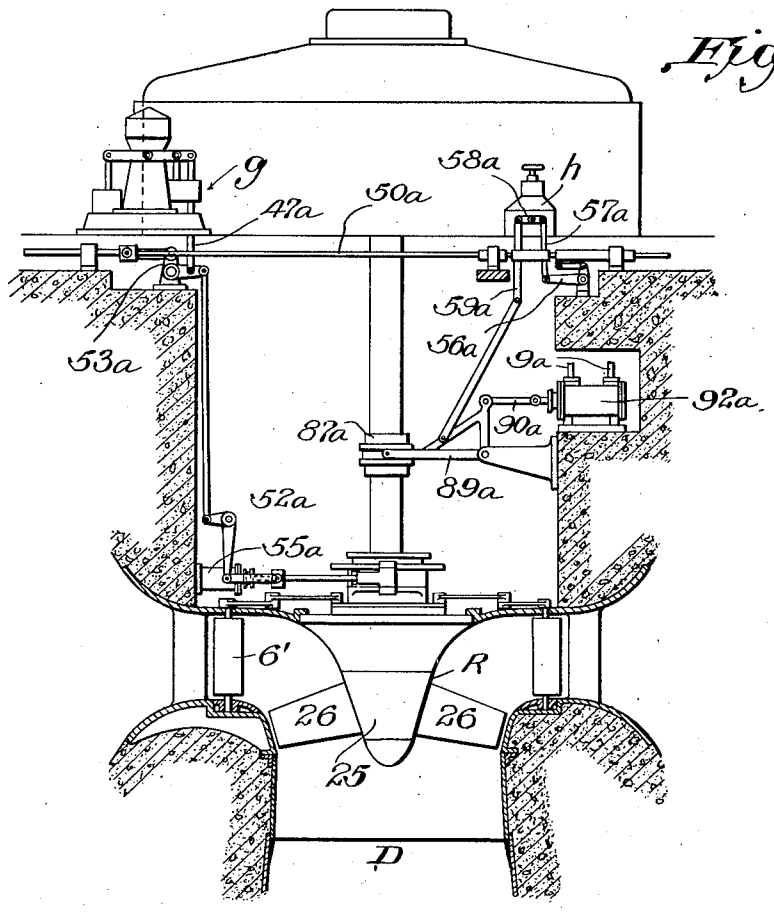
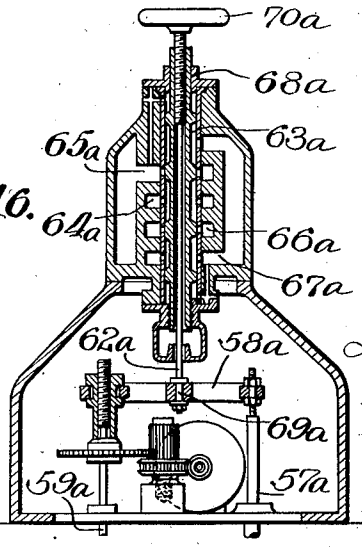


Fig. 16.



Inventor:
Lewis F. Moody
By Edward Whittemore
Atty.

Patented Dec. 22, 1931 1,837,568

UNITED STATES PATENT OFFICE

LEWIS FERRY MOODY, OF PHILADELPHIA, PENNSYLVANIA

HYDRAULIC TURBINE

Application filed April 14, 1923. Serial No. 631,985.

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 to 12 are views similar to Fig. 1 illustrating modified forms of turbines.

Fig. 13 is a vertical elevational view of governing means showing connections for operating the runner blades, and

Fig. 14 is a view similar to Fig. 1 illustrating a further modification.

Fig. 15 illustrates mechanism for effecting regulation of both the guide vanes and runner blades;

Fig. 16 is a view illustrating hand control for the runner blades.

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. This bell crank 21 raises and lowers the central rod 23 within the shaft 24 through a floating 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 along 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 to the water 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, 10 and 11. 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. Operating mechanism suitable for these conditions is shown in my co-pending applications, Serial No. 527,544, filed January 7, 1922, and the divisional application thereof, Serial No. 147,419, filed November 19, 1926. The operating mechanism thereof as applied herein to the guide vanes and runner blades comprises briefly a runner blade operating servo motor 92*a* connected through a link 90*a* and bellcrank 89*a* to the shifting collar 87*a*, such as shown in Fig. 12 while the linkage mechanism is of the form shown in Fig. 13. Details of the blade operating mechanism within the hub and runner shaft are not shown in connection with this particular figure as the details thereof are shown in various of the other figures such as Fig. 12. Fluid pressure is supplied to opposite sides of the piston of the blade adjusting servo-motor as through pipes 9*a*. The automatic speed governor *g* is suitably driven from the turbine to control the wicket gates G′. The governor which is of the usual centrifugal flyball type or equivalent device performing the same functions is adapted through usual linkages to control the admission and exhaust of fluid to the usual wicket gate operating servo-motor 55*a*, thereby operating the wicket gates in the usual manner, while usual primary and secondary restoring mechanism including elements 52*a*, 53*a*, and 47*a* act upon the governor to prevent hunting and to restore the turbine to its normal speed. To operate the runner blades by a slower automatic adjustment which follows and responds to any movement of the primary operating mechanism just described, there is provided an operating stand *h* and connecting mechanism capable of moving the runner blades at a relatively slow rate compared to the wicket gate motion. To attain this operation, connections are provided between the wicket gate operating mechanism and the control stand *h*, and include a rod 50*a* which will partake of the movement of the gates G′ through elements 52*a* and 53*a*. The secondary control stand is shown on a larger scale in Fig. 16 and is connected to the rod 50*a* by a bellcrank 56*a* and a vertical rod 57*a* running upward into the base of the control stand *h*. This rod 57*a* is connected to a horizontal floating lever 58*a*. The left end of this floating lever is connected by a link 59*a* to bellcrank 89*a*, thereby moving the left end of the floating lever 58*a* in accordance with movements of the runner blades. The center of the floating lever is connected to and actuates the stem 62*a* of a fluid pressure valve 63*a* contained in the upper portion of the control stand *h*.

The valve 63*a* is of the balanced piston type which when moved downward connects the pressure port 64*a* with port 66*a* to supply fluid through one of the pipes 9*a* to that end of the motor 92*a* which will move the runner blades so as to reduce power output. Upward movement of the valve 63*a* places port 66*a* and passage 67*a* in communication to ex-

haust fluid from one side of the servo-motor while simultaneously the ports 64*a* and 65*a* are placed in communication to conduct fluid pressure to the other side of said servo-motor thereby adjusting the runner blades to increase the power output. The valve stem 62*a* passes through the valve and is screw threaded therein at 68*a* and swiveled at 69*a* and provided with a hand-wheel 70*a* so that valve 63*a* may be moved either by vertical movement of the stem 62*a* or by rotational movement of the stem 62*a* when turned by the hand-wheel 70*a*.

Assuming the gates of the turbine to be at rest at any given moment, a change in the station load will cause the governor *g* to operate to move the gates G′ and these in turn will move the horizontal interconnecting rod 50*a*. The effect of this will be to raise or lower the right hand end of the floating lever 58*a*, the left-hand end of this lever being held stationary by its restoring rod connection 59*a* to the runner blades. The middle of the lever 58*a* will move the valve stem 62*a* with a motion corresponding to that of the inter-connecting rod 50*a*. This motion will open the hydraulic piston valve 63*a* admitting pressure to the servo-motor and move the runner blades in a direction to reduce power output. Shifting of the runner blades will be communicated to the left hand end of the floating lever 58*a* and when the runner blades have moved an amount corresponding to the motion of the interconnecting rod 50*a* the valve 63*a* will be restored to midposition. This blade motion will take place at a definitely restricted rate sufficiently slow so as not to interfere with the primary regulation of the unit. This restriction may be caused by a limited port area of the valve and a limited size of piping leading to the operating chamber of the blade servo-motor 92*a*.

The action just described will cause the runner blades to follow up the gate motion of the wicket gates and take up a corresponding position. While this automatic control by governor *g* is thus applied the hand control motion of hand-wheel 70*a* is always in gear, so that at any time an operator may superpose the hand control motion on all other controlled motions which are in progress. It is also possible to adjust the valve 63*a* so as to proportion the positions of the wicket gates and runner blades with relation to each other, in any desired manner.

The effect of the inter-connecting mechanism is always to cause the runner blades to follow up, and approach the position corresponding to that taken by the wicket gate. The action just described is very effectively brought about in that the wicket gate is adjusted for quick operation while the runner blades move more slowly.

Denoting the quick-acting flow controlling mechanism (here shown as wicket gates) the "primary gate mechanism", and the slow-acting mechanism (here shown as the runner blades) the "secondary blade mechanism", then as explained above, the effect of the inter-connecting mechanism is always to cause the secondary blade mechanism to follow up and approach the position corresponding to that taken by the primary gate mechanism under governor control due to a load change. After the first shift of the primary gates to take up practically the entire load change at a relatively rapid rate the effect will be for the primary gates gradually to unload a part of the load control upon the other blade mechanism, until only its proper share remains with the primary gate mechanism, that is, the secondary blade mechanism will gradually take up part of the control and relieve the primary gate until both the gate and blade mechanisms approach corresponding positions, leaving the unit with the adjustment of load then divided between both the blade and gate mechanisms. All quick fluctuations are taken by the primary gate mechanism and then the load adjustment is slowly distributed between the blade and gate mechanisms. If the load change is an increase in load, the primary gate mechanism will take the increase, its gates quickly opening so as to maintain as nearly as possible a constant speed of the unit. The secondary blade mechanism will then begin slowly to open and the primary gate will slowly close until both gates have reached an equilibrium as set by their respective governing valves.

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. One form of such inclined guide vanes is shown in my Patent No. 1,728,435.

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.

In Fig. 10 a different method is shown for operating the runner blades. Instead of connecting the blade levers 57 to a vertically movable member they are in this modification arranged to engage by studs 58 a central rotating member 59 concentric with the runner axis. This member 59 is radially slotted at 60 for each stud 58 carrying either a roller or slide block 61 engaging the walls of the corresponding slot 60. The axis of each stud 58 passes through the intersection of the axis of rotation of the blade and the turbine axis. The relative rotation of the rotating member 59 with respect to the runner will cause a corresponding rotary movement of each blade 26. To produce the relatively rotary movement of the member 59 it is rigidly mounted on the rod 62 provided at its lower end with a screw member 63 of steep pitch. A nut member 64 mating with this screw member 63 moves slidably on the sleeve 65 extending downward from the runner hub cap 66 and is keyed against rotation with respect to the hub by the key and slot connection at 67. To turn the screw 63 and rod 62 with relation to the runner the nut member 64 is moved up and down by the floating sleeve 68 operated by the lever 69 from the governer rod 70. A vertical movement of the nut will correspondingly adjust the runner blades 26.

Fig. 11 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. 11 avoids the need for a hollow bored shaft.

In the modification shown in Fig. 12 each blade stem is provided with a bevel pinion 80 meshing with a common bevel gear 81 keyed to a central rod 82 rotated by a cam 83 preferably placed at a point above the water level and within the turbine pit. The cam member 83 is provided with curved slots 84 engaged by rollers 85 of the rotating and sliding collar 86, the groove 87 of which contains the non-rotating collar 88 moved up and down by the lever 89 connected to any usual governor means diagrammatically shown for instance in Fig. 13 and one specific form of which is disclosed in the patent to Rogers, 1,559,782. 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. 14 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 spheical 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. 14 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.

I claim:

1. In a hydraulic turbine the combination with means for guiding the entering flow with a whirl around the axis of the turbine, of a runner receiving said flow axially and with inward components and having blades adjustable around axes inclined to the runner axis to different angles with relation to said flow while said runner is rotating.

2. 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, the blades of said runner being adjustable around axes inclined to the runner axis to different angles with relation to said flow.

3. 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.

4. 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.

5. In a turbine the combination with means for directing the flow against a runner with a whirl and combined radial and axial components, of a turbine runner comprising a hub portion and adjustable blades carried thereby said blades being rotatably mounted in said hub around axes inclined to a plane perpendicular to the axis of the runner, and means within said hub for adjusting said blades while the runner is rotating.

6. In a turbine the combination with means for directing the flow against a runner with a whirl and combined radial and axial components, of a turbine runner comprising a hub portion having a generally conical form and adjustable blades carried thereby, said blades being rotatably mounted in said hub around axes inclined to a plane perpendicular to the axis of the runner, and means within said hub for adjusting said blades while the runner is rotating.

7. In a turbine the combination with means for directing the flow against a runner with a whirl and combined radial and axial components, of a turbine runner comprising a hub portion and adjustable blades carried thereby, said blades being rotatably mounted in said hub around axes inclined to a plane perpendicular to the axis of the runner, and means within said hub for adjusting said blades while the runner is rotating, said runner vanes being unshrouded.

8. In a turbine the combination with means for directing the flow against a runner with a whirl and combined radial and axial components, of a turbine runner comprising a hub portion and adjustable blades carried thereby, said blades being rotatably mounted in said hub around axes inclined to a plane perpendicular to the axis of the runner, and means within said hub for adjusting said blades while the runner is rotating, said runner vanes having entrance and discharge edges which are straight lines when projected into meridian planes.

9. In a hydraulic turbine the combination with a runner, of guide means adapted to impart a whirl to the flow entering said runner and comprising fixed guide vanes at an angle inclined to the runner axis and adapted to direct flow with varying components of whirl at points at different distances from said axis, a part of said flow when passing through said guide vanes being in lines lying in a substantially cylindrical surface coaxial with the runner.

10. In a hydraulic turbine the combination with a runner, of guide means adapted to impart a whirl to the flow entering said runner and comprising guide vanes extending at an angle to a plane perpendicular to the axis of the turbine and adapted to direct flow with

varying components of whirl at points at different distances from said axis, said components of whirl increasing at points nearer and nearer to said axis.

11. In a hydraulic turbine the combination with a runner, of guide means adapted to impart a whirl to the flow entering said runner and comprising fixed guide vanes extending at an angle to a plane perpendicular to the axis of the turbine and adapted to direct flow with varying components of whirl at points at different distances from said axis, said components of whirl increasing at points nearer and nearer to said axis.

12. In a hydraulic turbine the combination with a runner, a guide means for the flow to said runner comprising inner and outer surfaces of revolution directing the flow axially and with inward components, and means for imparting a whirl to said flow comprising fixed guide vanes extending at an angle to a plane perpendicular to the axis of the turbine and rigidly supporting the inner surface from the outer surface.

13. In a hydraulic turbine the combination with a runner, of guide means for the flow to said runner comprising inner and outer surfaces of revolution directing the flow axially and with inward components, and means for imparting a whirl to said flow comprising fixed guide vanes extending at an angle to a plane perpendicular to the axis of the turbine and adapted to impart large components of whirl to the flow lines nearer said axis.

14. In a turbine the combination with means for directing the flow against a runner with a whirl and combined radial and axial components, of a runner for a hydraulic turbine comprising unshrouded runner blades rotatable around axes extending at an angle to a plane perpendicular to the runner axis and being adapted for adjustment around said axes while the runner is rotating.

15. In a hydraulic turbine the combination with fixed guide vanes extending diagonally with respect to the turbine axis and adapted to impart a whirl to the entering flow, of a bearing casing for the turbine shaft supported by said vanes, said bearing casing having an outer wall turning from an axial direction to a diagonal inward direction in smooth curves continuous with the runner hub.

16. In a hydraulic turbine having unshrouded runner blades extending outward from a conical hub, a bearing for the turbine shaft located above said hub, a casing surrounding said bearing enlarging in diameter above the runner hub and then diminishing in diameter along smooth curves.

17. 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 rod within said shaft, means for transferring from outside said shaft to said rod a relative motion between said rod and said shaft during the rotation of said runner and means for entirely enclosing that portion of the operating means adjacent said runner.

18. A hydraulic turbine comprising fixed guide vanes, a runner having blades rotatably adjustable while the runner is rotating and a draft tube formed to spread the flow around a central core member and turn the flow from axial toward an outward direction with respect to the turbine axis.

19. A turbine comprising fixed guide vanes, a runner with blades which are adjustable to different inclinations while the runner is rotating and a draft tube formed as an annular passage bounded by two concentric surfaces of revolution flaring outwardly from an axial to a radial direction.

20. A turbine comprising fixed guide vanes, a runner with blades which are adjustable to different inclinations while the runner is rotating and a draft tube adapted to decelerate both the axial and whirl components of the flow from the runner between a central expanding core and an outer surface of revolution.

21. A hydraulic turbine comprising fixed inclined guide vanes for directing the entrance flow with a whirl around the axis, a bearing carried by said guide vanes for the runner shaft, an outer guide vane ring curving inward toward the axial direction and a runner having entrance edges inclined in the direction of said entrance guide vanes.

22. A hydraulic turbine comprising fixed inclined guide vanes for directing the entrance flow with a whirl around the axis, a bearing carried by said guide vanes for the runner shaft, an outer guide vane ring curving inward toward the axial direction and a runner having entrance edges inclined in the direction of said entrance guide vanes and spaced therefrom.

23. 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 rod within the runner shaft so as to transform motion from outside of said shaft to said rod while said runner is rotating.

24. In a hydraulic turbine the combination with fixed guide vanes adapted to impart a whirl to the entering flow, of a runner having adjustable blades adapted to absorb a variable amount of said entering whirl, and a draft tube receiving the flow from said runner and decelerating it between inner and outer surfaces of revolution so as to convert

the whirling velocity of the discharge into effective pressure head.

25. 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 rotatably adjustable relatively to the runner about the runner axis.

26. 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 rotatably adjustable relatively to the runner about the runner axis, said member engaging each of said blades in similar manner.

27. In a hydraulic turbine the combination with a runner having unshrouded blades extending outward from a central hub and 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 rotatably adjustable relatively to the runner about the runner axis, and reciprocable means for effecting rotation of said adjustable member.

28. A turbine having a runner and fixed guide vanes extending diagonally from the outer portion of said runner to substantially adjacent the runner axis, said vanes being spaced by an appreciable distance from said runner to provide a transition space, and the width of said transition space between the guide vanes and runner being approximately the same for flow lines near the runner hub as for flow lines near the runner tips.

29. In combination, a turbine having a runner, means forming an inlet having fixed guide vanes, said vanes being diagonally disposed to the runner axis and so positioned relative to the runner that water passing to the runner near its hub enters in lines which lie in a substantially cylindrical surface extending approximately coaxial with the runner while water entering near the outer runner portion is turned from an initial direction which is approximately radial toward an axial direction.

30. In combination, a turbine having a runner and guide vanes therefor, and means whereby water flows through a portion of said vanes in lines which lie in a substantially cylindrical surface extending substantially coaxial with the runner and through another portion thereof in substantially a radial direction.

31. In combination, a turbine having a runner, a series of diagonal stationary guide vanes adapted to whirl the water flowing to the runner, said vanes being disposed above and spaced from said runner to form a transition space, means for removably supporting said guide vanes at the outer portion of said runner and at a point adjacent the runner axis, said supporting means constituting means whereby the vanes may be moved upwardly to permit removal of the runner.

32. In a power plant of the character described, a water wheel comprising a series of blades of the propeller type, a hollow 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 mechanism whereby movement in opposite directions is adapted to be imparted to said rod, a torque transmitting member connected with each blade, and a control member connected with said rod in proximity to said torque members, said control and torque members being operatively connected together in a similar manner and from a point below the axes of said blades to rotate said blades by the movement of said rod.

33. In a high specific speed propeller type hydraulic turbine, the combination comprising a runner having blades adjustable around axes inclined to the runner axis, means forming a passage for conducting fluid to and from said runner, means for whirling the inflowing fluid to said runner and being spaced therefrom to form a vane free transition space in which the fluid whirls, and operating means for moving said blades around their respective inclined axes.

34. In a high specific speed propeller type hydraulic turbine, the combination comprising a runner having blades adjustable around axes inclined to the runner axis, means forming a passage for conducting fluid to and from said runner, means for whirling the inflowing fluid to said runner and being spaced therefrom to form a vane free transition space in which the fluid whirls, and operating means for moving said blades around their respective inclined axes including a member extending in the direction of the runner axis, and movable in opposite directions to effect reverse blade movement.

35. In a high specific speed propeller type hydraulic turbine, the combination comprising a runner having a hollow shaft and blades adjustable around axes inclined to the runner axis, means forming a passage for conducting fluid to and from said runner, means for whirling the inflowing fluid to said runner and being spaced therefrom to form a vane free transition space in which the fluid whirls, and operating means for moving said blades around their respective inclined axes including a member disposed within said shaft and movable in opposite directions to effect movement of said blades in opposite directions.

36. In a high specific speed propeller type hydraulic turbine, the combination comprising a hollow shaft carrying a runner having blades adjustable around axes inclined to the

runner axis, means forming a passage for conducting fluid to and from said runner, means for whirling the fluid flowing to said runner and being spaced therefrom to form a vane free transition space in which the fluid whirls, and operating means for moving said blades around their respective inclined axes including a rotatable operating rod disposed within said shaft.

37. In a high specific speed propeller type hydraulic turbine, the combination comprising a runner having blades adjustable around axes inclined to the runner axis, means forming a passage for conducting fluid to and from said runner, means for whirling the fluid flowing to said runner and being spaced therefrom to form a vane free transition space in which the fluid whirls, and operating means for moving said blades around their respective inclined axes including a member coaxial with the runner axis and gears connecting said member and blades.

38. In a high specific speed propeller type hydraulic turbine, the combination comprising a runner having diagonal blades adjustable around axes inclined to the runner axis, means forming a passage for conducting fluid to and from said runner, means for whirling the fluid flowing to said runner and being spaced therefrom to form a vane free transition space in which the fluid whirls, and operating means for moving said blades around their respective inclined axes including a member coaxial with the runner axis, and substantially similar operating connections from each of said blades to said coaxial member.

39. In a high specific speed propeller type hydraulic turbine, the combination comprising a runner having a hollow shaft and diagonal blades adjustable around axes inclined to the runner axis, means forming a passage for conducting fluid to and from said runner, means for whirling the fluid flowing to said runner and being spaced therefrom to form a vane free transition space in which the fluid whirls, and operating means for moving said blades around their respective inclined axes including a rotatable member disposed within said shaft and carrying a central bevel gear, and each of said blades carrying a bevel gear meshing with said central gear.

40. In a hydraulic turbine, the combination with means for guiding a radially entering flow with a whirl around the axis of the turbine, of a high specific speed propeller type runner having diagonal blades receiving said flow axially and with inward components, said blades being adjustable around the diagonal axes of the blades with means to effect adjustment of the blades to different angles with relation to the flow.

41. In a hydraulic turbine, the combination of fixed guide vanes adapted to impart a whirl to a radially entering flow, of a high specific speed propeller type runner having diagonal blades 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 means for adjusting said runner vanes.

42. In a hydraulic turbine, the combination with means for directing the flow against a runner with a whirl and combined radial and axial components, of a turbine runner comprising a hub and adjustable blades carried thereby, said blades being diagonally disposed and rotatably mounted in said hub around the diagonal axes of said blades, and means within said hub for adjusting said blades.

43. The combination in a hydraulic turbine installation comprising a high specific speed propeller type runner having a hub with adjustable blades carried thereby, a shaft for supporting said runner, a bearing for supporting said shaft, and means for supporting said bearing including diagonal fixed guide vanes adapted to whirl the flow to said runner, and spaced therefrom to form a transition space.

44. The combination in a high specific speed hydraulic turbine installation comprising a propeller type runner having a relatively small number of adjustable unshrouded blades, and means for conducting fluid to and from said runner, including a draft tube having a central core therein throughout its whole length.

45. The combination in a hydraulic turbine installation comprising a high specific speed propeller type runner having unshrouded rotatably adjustable blades, means whereby fluid flows to said runner by turning from a radial to an axial direction, fixed guide vanes for whirling the fluid flowing to said runner, and a draft tube having an annular passage the inner wall of which is formed by a central core member the diameter of which near the runner is at least one sixth that of the outer wall.

46. The combination in a hydraulic turbine installation comprising means forming a passage turning from a radial to an axial direction, a runner disposed in said passage and having only unshrouded rotatably adjustable blades, guide vanes for whirling the flow to said runner and spaced therefrom to form a transition space in which the fluid whirls, and means including a rod rotatable on its own axis for effecting adjustment of said blades.

47. The combination in a high specific speed propeller type hydraulic turbine installation comprising means forming a passage turning from a radial to an axial direction, a runner in said passage, guide vanes in the radial portion of said passage for whirling fluid flow therethrough and being spaced from said runner to form a transition

space in which the fluid turns from a radial to an axial direction, said runner having a hollow hub carrying only rotatably adjustable blades, each of which has a bevel gear operatively connected thereto within the hollow portion of said hub, and a rotatable rod coaxial with the runner axis carrying a central bevel gear operatively connected to said other gears.

48. The combination in a hydraulic turbine installation comprising means forming a passage turning from a radial to an axial direction, a runner having only unshrouded rotatably adjustable blades, guide vanes for whirling the flow to said runner, and means for adjusting said blades including a rotatable rod disposed within a hollow shaft which supports said runner and connecting means extending upwardly from the lower end of said rod to said blades.

49. The combination in a hydraulic turbine installation comprising means forming a fluid conduit, a runner disposed therein having a hollow hub with rotatably adjustable blade members extending outwardly therefrom, said blades being journaled in said hub and each carrying a gear at their inner ends within the hollow portion of said hub, and a rotatable rod disposed within a hollow shaft which supports said runner, and carrying a central gear meshing with said blade gears.

50. The combination in a hydraulic turbine installation comprising means forming a fluid conduit, a runner disposed therein having a hollow hub with only rotatably adjustable blades extending outwardly therefrom, said blades being journaled in said hub and each carrying a bevel gear at their inner ends within the hollow portion of said hub, and a rotatable rod disposed within a hollow shaft which supports said runner, and carrying a central bevel gear meshing with said blade gears.

51. The combination in a hydraulic turbine installation comprising a runner having a hub and rotatably adjustable blades carried thereby, means for supporting said blades by said hub, each blade including an enlarged annular disc disposed within a cooperating recess in the hub, each of said blades having a shaft extending inwardly of said hub from its respective disc, the inner end of each of said shafts carrying a bevel gear, and a rotatable rod coaxial with the runner axis and having a central bevel gear meshing with said other bevel gears to effect adjustment of said blades.

52. The combination in a hydraulic turbine comprising a runner having a hub carrying blades rotatably adjustable on axes inclined to the runner axis, means forming a passage for directing fluid flow thereto, guide vanes for whirling the flow to said runner in the direction of rotation thereof, and means including a rod rotatable on its own axis and connecting means between said rod and blades disposed below the blade axes for effecting adjustment of said blades whereby when the turbine load decreases and said blades are moved so as to increase their transverse relation to the flow the proportion between the rotational speed of the runner and its load is increased.

53. The combination in a hydraulic open flume turbine installation comprising means forming an entrance passage or flume including a floor structure, a passage through said floor, an unshrouded high specific speed runner in said passage, inwardly extending fixed guide vanes supported from said floor structure above said runner and forming admission means for whirling flow to said turbine passage, whereby fluid flows through said admission means from above and around the same.

54. The combination in a hydraulic open flume turbine installation comprising an entrance passage or flume having a floor structure, a passage therethrough having at least a portion thereof contracting, and an unshrouded high specific speed propeller type runner in a contracted portion of said passage, and inwardly extending fixed guide vanes supported from said floor structure and supporting a bearing for the shaft of said runner and providing admission means for whirling flow to said turbine passage, whereby fluid flows through said admission means from around and above the same.

55. The combination in a hydraulic open flume turbine installation comprising means forming an entrance passage or flume including a floor structure, a passage through said floor having at least a portion thereof contracting in the direction of flow, an unshrouded high specific speed propeller type runner having diagonal blades so disposed that the tips thereof are in a contracted portion of said passage, a bearing for supporting said runner, inwardly extending fixed guide vanes supported from said floor structure and being transversely inclined and constituting the sole means for whirling flow to said turbine passage, said guide vanes supporting said bearing and forming admission means to said turbine passage, whereby fluid flows through said admission means from above and around the same.

56. The combination in a hydraulic turbine installation comprising a runner having a tapered hub with a central hollow portion so as to form an outer rotating wall blades adjustably supported in said wall, operating means for said blades connected to said blades from below the axes thereof and within said central hollow portion adjacent the smaller end of said tapered hub and a shaft for supporting said runner and being connected to said hub at the upper portion there-

of and not extending through said hollow portion.

57. The combination in a hydraulic turbine installation comprising a runner having a tapered hub with a central hollow portion so as to form an outer rotating wall, blades adjustably supported in said wall, operating means for said blades connected to said blades from below the axes thereof and within said central hollow portion adjacent the smaller end of said tapered hub, and a shaft for supporting said runner and having a main connection to said hub at the upper part thereof.

58. In a high specific speed propeller type turbine, an unshrouded rotor having a hollow hub and a plurality of blades associated therewith, each of said blades comprising an inlet section formed integral with said hub and a discharge section therefor pivotally supported by said integral section and having an operative connection extending within said hub.

59. A high specific speed propeller type hydraulic turbine comprising a rotor having a hub provided with a chamber therein, a plurality of blades carried by said hub and at least certain of said blades having a rigid inlet section and a variable discharge section therefor, and means disposed within said chamber for operating said variable blade sections.

60. A high specific speed propeller type hydraulic turbine comprising a rotor having a hub provided with a chamber therein, a plurality of blades carried by said hub, at least certain of said blades having an entire rigid inlet section and a variable discharge section, and means within said chamber for moving said variable discharge section relative to said rigid section.

61. A propeller type hydraulic turbine comprising an unshrouded rotor having a hub and plurality of blades carried thereby, each of said blades having relatively movable sections disposed on axes which are angularly disposed relative to each other, and means within said hub for effecting relative adjustment between said sections.

62. 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, a hollow shaft for supporting said runner, blades rotatably supported in said bearings on axes inclined to the runner axis, and each blade having an operating member extending within said hollow portion, an operating rod extending through the hollow portion of said shaft, and means for connecting said rod to each of said blade operating members for effecting blade adjustment, said connecting means being disposed within the hollow portion of said hub on the side of said blades which makes an acute angle with the runner axis.

63. The combination in a hydraulic turbine comprising a runner having a hub carrying adjustable blades, a shaft for supporting said runner and having flanged sections one of which is hollow, and means for adjusting said blades including an operating rod extending through the hollow portion of said shaft and actuating means therefor supported between the flanges of said shaft.

64. The combination set forth in claim 63 further characterized in that said flange support includes a removable spacing block interposed between the flanges of said shaft and carrying said actuating means.

LEWIS FERRY MOODY.