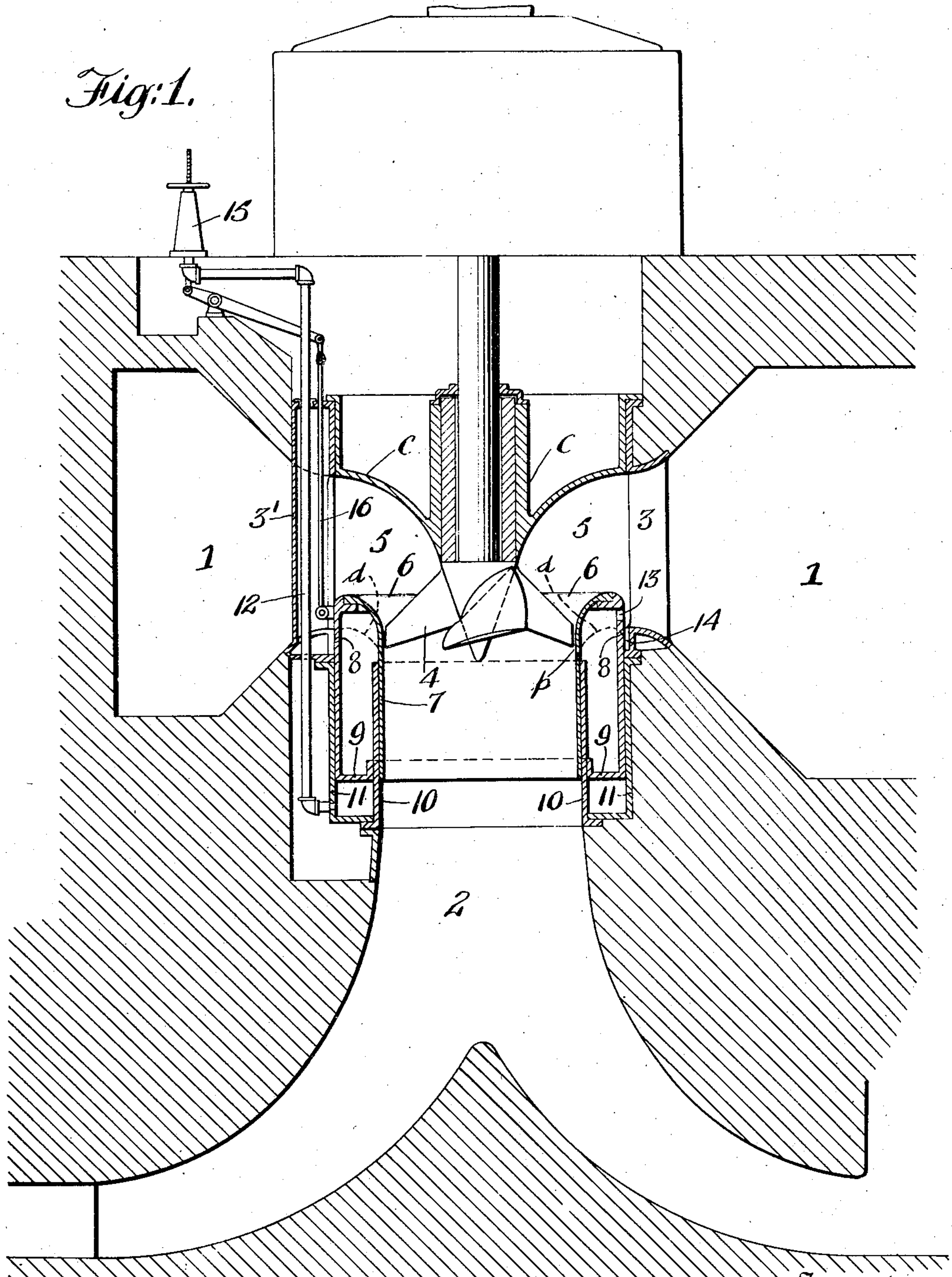
Sept. 1, 1925. 1,552,074

L. F. MOODY

HYDRAULIC TURBINE

Filed Aug. 31, 1920 2 Sheets-Sheet 1

Fig:1.



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

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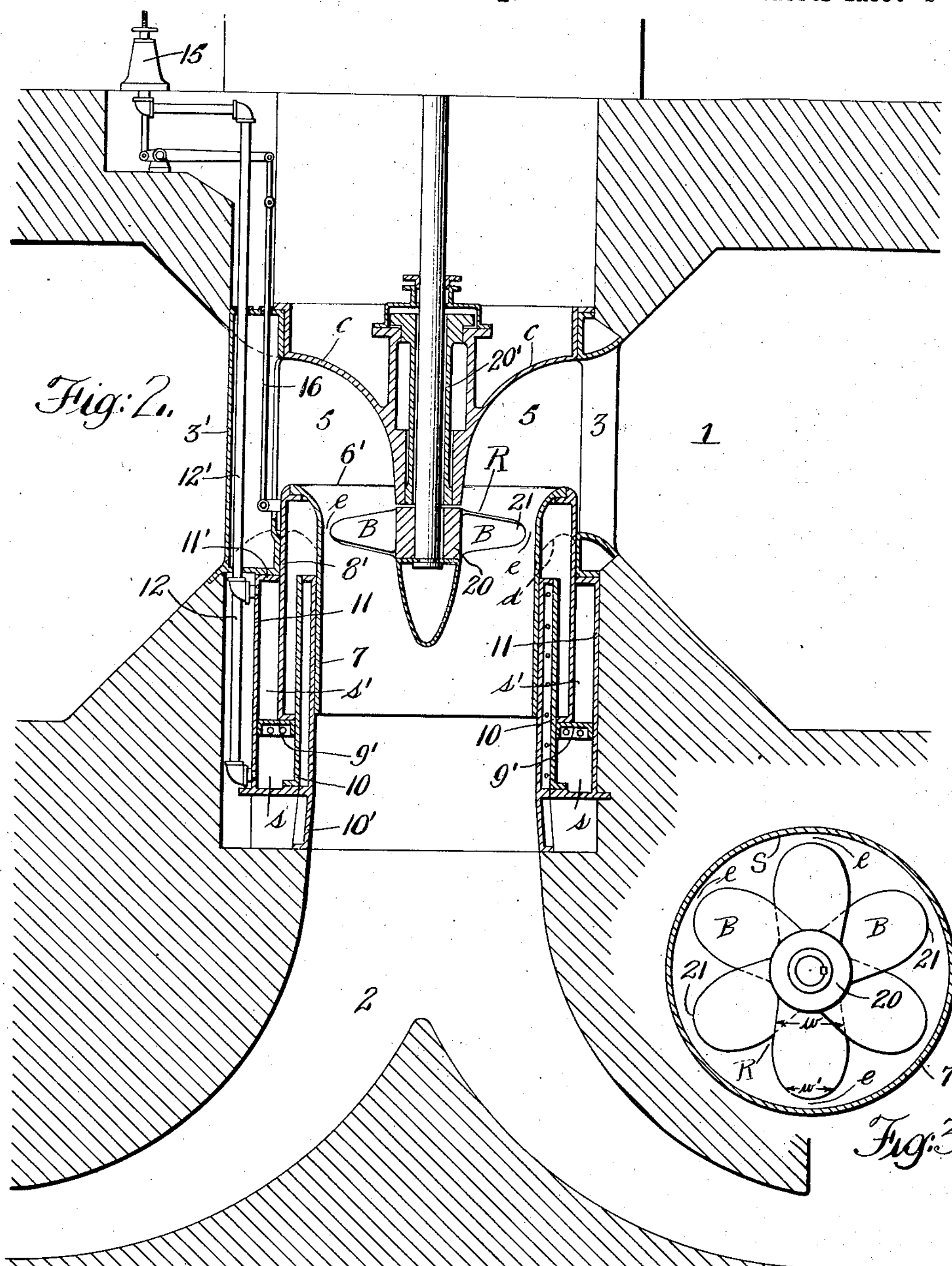

Fig: 2.

Fig: 3.

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UNITED STATES PATENT OFFICE.

LEWIS FERRY MOODY, OF PHILADELPHIA, PENNSYLVANIA.

HYDRAULIC TURBINE.

Application filed August 31, 1920. Serial No. 407,084.

To all whom it may concern:

Be it known that I, LEWIS FERRY MOODY, a citizen of the United States, residing at Philadelphia, in the county of Philadelphia and State of Pennsylvania, have invented certain new and useful Improvements in Hydraulic Turbines, of which the following is a specification.

This invention relates to hydraulic turbines and the chief object of the invention is to provide a turbine of simple and rugged construction having a small number of moving parts and adapted particularly for use under low and moderate heads.

A further object of the invention is to provide a runner of relatively simple blade formation and particularly adapted for high speeds.

Further objects of the invention in providing a turbine adapted to develop increased power particularly during times of reduced head or increased demand will appear in the following specification taken in connection with the accompanying drawing in which,

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

Fig. 2 is a similar view of a modification, and

Fig. 3 is a plan view of the runner shown in Fig. 2.

In the embodiment of the invention shown in the drawing a turbine of the vertical shaft type has an intake passage 1 for instance of volute form adapted to impart a whirl to the inflow and draft tube 2 preferably of the spreading type adapted to reconvert the velocity head of both the whirling and axial components of velocity into effective pressure head in the discharge. A vane ring 3 in the intake has its vanes inclined from the radial in direction of the flow to the turbine runner 4. Between the vane ring 3 and runner 4 intervenes the transition space 5 bounded above by the cover plate *c* and below by the upper end of the annular plunger 6 controlling the flow to the runner. This plunger 6 surrounds the runner 4 and has an inner cylindrical portion 7 fitting within the upper end of the draft tube 2, and forming the entrance portion thereof. The outer portion 8 of the plunger slides within the vane ring 3 and carries an annular piston portion 9 sliding in the space between the cylindrical walls 10 and 11 set in the foundation, the former forming the top end of the draft tube and the latter supporting the vane ring 3.

In order to raise the plunger, pressure—either penstock pressure or a higher pressure—would be admitted to the space below the lower flange 9 of the plunger by a pipe 12 from control or governor 15 on the power house floor above. A restoring rod connection 16 to the governing means is also provided and this pipe and rod may pass through a hollow vane or baffle 3′ as shown. This would overbalance the pressure on the top of the plunger which would be reduced by the velocity head of the water entering the turbine, and the plunger would move upward. To lower the plunger, the space below the lower plunger flange would be connected to the exhaust. The weight of the plunger in addition to the pressure on its upper curved face would then move the plunger downward. There would be a slight displacement of water as the plunger is lowered due to the volume of the draft tube wall entering this hollow space. To provide for this displacement of water small holes would communicate with this space from the entrance side of the plunger, one of these holes 13 being shown on the right hand side of Fig. 1 near the lower distributor plate. A corresponding cavity 14 would be left in the speed ring to communicate with this hole when the plunger is at the extreme lower limit of its stroke. The resulting arrangement is very simple and has few parts, so that it would be very suitable for turbines under low heads, particularly in small sizes where simplicity and cheapness are important.

The controlling means 15 may represent either a hand control or an automatic governor. When a governor is used, the action will be as follows: Upon overspeeding of the turbine runner the governor will act to admit pressure through pipe 12 to raise the plunger and shut off the guide vane orifices of the vane ring 3 and restrict the inflow at the same time moving the surfaces of transition space 5 closer together to accommodate the restricted flow. Upon underspeeding the pressure will be exhausted from pipe 12 to lower the plunger and open the guide vane orifices and simultaneously enlarge the space 5. Thus in effect the intake passage or transition space 5 itself expands and contracts to control the flow and plunger 6 always maintains smoothly rounded surfaces to guide the flow to the runner, avoiding the eddies and losses that would be set up if a sharp edged cylindrical gate were used.

Where desirable as for instance where flood conditions are likely to provide a surplus supply of water the plunger gate may be arranged to be lowered as indicated in dotted lines *d* and provide for overgating. The plunger can then be opened so far that a free passage *p* is provided outside of the runner, producing ejector action in the draft tube and lowering the back pressure therein under high tail water conditions.

The modified construction shown in Fig. 2 has an annular plunger of relatively less thickness between its cylinders 7 and 8′. The inner ring 10 is separate from the draft tube lining 10′ and the outer ring 11 has its upper end flanged over at 11′. The outer cylinder 8′ of the plunger carries the separate piston ring 9′ of greater diameter than the cylinder so that in addition to the space *s* below the piston for closing pressure the space *s*′ is left above the piston for opening pressure. Pipes 12 and 12′ respectively connect the spaces *s* and *s*′ with the governor 15 so that upon drop in the load pressure is exhausted from space *s*′ and admitted to space *s* to raise the plunger gate and upon increase in load pressure is exhausted from space *s* and admitted to space *s*′ to lower the plunger gate.

The control means of this invention is simple in form and easily and compactly assembled within the turbine speed ring. The annular plunger is accurately guided by a number of circular surfaces and is moved simply by fluid pressure evenly distributed above or below the piston portion 9. Upon removal of the cover plate *c* all the movable parts are accessible from above and are readily removable for inspection and repair. By making the plunger annular the surface exposed to the flow of the water can be properly rounded to give smooth flow lines for the water and to allow the water streams to continue in contact with the surface at all points. This latter condition cannot be obtained with cylinder gates such as have been used in the prior art. The radial thickness of the annular plunger provides space for piston surfaces and for the fluid pressure operation of the plunger.

A particular advantage obtainable with the method of this invention is also the possibility of arranging the plunger so that in the normal full gate position it will still be a moderate distance above the lower distributor plate or "curb plate." By opening the plunger still further as indicated in dotted lines *d*, Figs. 1 and 2 it can be designed to leave a clear space between the plunger and the tips of the runner vanes so that water will be freely by-passed around the runner and will be capable of producing ejector action in the draft tube. By this arrangement this ejector action can be produced by simply overgating the turbine, and this provision will be of great value in plants subject to flood conditions during which the tail water rises to an abnormal height and thus reduces the effective head by increasing the back pressure on the turbine. At such times there is a surplus of water available and efficiency is of no consequence, the problem being to discharge the surplus water and to maintain the turbine power if possible.

Another advantage of this arrangement is that a steady bearing 20′ can be placed close to the runner, the head cover *c* being rigidly supported by the vane ring 3, without the necessity of allowing a space within the head cover for the operation of the plunger. The plunger does not interfere with either the design of the head cover or the arrangement of the main shaft and bearings, and can be used with runners of greatly varying type, for example, it can be used with an inward flow, inward diagonal, mixed or axial flow runner, or even with an outward diagonal flow runner. When used with an outward flow runner the arrangement may be altered so that the plunger closes the outflow space of the runner rather than the inflow space as shown in the specific embodiment in the drawings.

In Figs. 2 and 3 a form of runner is shown particularly adapted for extremely high specific speed and suited for turbines operating under low and moderate heads such as the turbines shown in Figs. 1 and 2 either with the plunger gate or with other forms of controlling gates such as wicket gates or movable guide vanes. The special form of runner R consists of one having unshrouded blades B arranged either for axial or diagonal flow. It is a characteristic of the operation of the runner blades when rotating at high velocity compared to the head that since each portion of the water stream should for the attainment of high efficiency exert substantially the same turning moment of torque upon the runner, the force or reaction of the water upon the runner blades must be much greater in the parts of the runner near the axis than in the part near the outer tips of the runner blades. As a result of this relation the innermost portions of the runner blades must deflect the water through a considerably greater angle than the outermost portions. It is found that in runners designed for very high rotational speeds the portions of the runner blades at or near the outer tips are required to deflect the water only to a very slight extent. In order that the innermost portion of the blade may deflect the water through a considerable angle relative to the runner while the tip portions deflect the water through only a slight angle, the runner blade with a considerable width w is therefore formed in the neighborhood of the hub 20 and this width is reduced as the outer tips 21 are approached as at w'. Although in the plan view the width of the blade appears to increase slightly from the hub toward the middle portion of the blade, nevertheless this apparent increase is more than offset by the narrowing of the blade as viewed in profile, so that the actual width of the blade gradually decreases from the hub outward. The length of the vane section which must be traversed by the water is therefore reduced to a low value in the neighborhood of the outer tips 21, but is sufficient at all points to provide the necessary deflection of the direction of flow relatively to the runner. By thus forming the runner so that the length of surface traversed by the water will be no more than is necessary at each point the amount of surface friction between the vane and the water is reduced. Thus at the outermost portions of the blades where the relative velocity between the blades and water is high, the width w' of the surface is reduced and high friction losses avoided.

In special cases where extremely high speeds are desired with the permissible sacrifice of a small or moderate amount of efficiency the width of the blade is brought to zero before reaching the surrounding walls of the conduit or chamber in which the runner is placed; that is the runner is constructed so that the width w' of the blade diminishes rapidly as the walls of the runner chamber are approached and the inflow and outflow edges of the blade come together to form the runner tips 21 at a point a small distance e within the confining walls of the space in which the runner operates, leaving a clear annular space surrounding the tips of the runner within the walls of the runner chamber.

The annular clearances between the runner tips 21 and the boundary surface S of the space will serve to by-pass water freely around the runner from the runner entrance to the draft tube. This by-passed water while not acting directly upon the runner vanes will produce ejector action in the draft tube serving to accelerate the flow through the runner and to increase the power on the turbine. This same ejector function is performed to a limited extent in high speed runners as heretofore developed in which a wide space is left between the runner vanes through which a portion of the flow can pass freely with little or no deflection and practically no direct action on the wheel vanes. Instead of providing this space between the vanes, or in addition thereto, this invention provides an annular space surrounding the tips of the vanes. If the velocity head of the discharge from the runner is regained in a well formed draft tube, preferably of the spreading type, a large part of the energy of the by-passed flow may be made available for reducing the back pressure on the runner, and the energy of this water will by no means be completely lost, but a considerable portion of it made effective in increasing the power of the runner. The object of the modification just described is therefore to effect a considerable increase in the power of the runner at the expense of a small or moderate sacrifice in efficiency. When a runner of this design is used in combination with the annular plunger gate of this invention an opening of the gate beyond the normal full-gate position will provide an increase in the width of the annular by-pass opening around the runner, and by thus "overgating" the turbine an additional increase in power will be provided for use during periods of reduced head on the plant, as during times of flood or freshet, or other emergency conditions requiring an abnormal supply of power at a considerable sacrifice of efficiency.

I claim:

1. In a hydraulic turbine the combination with a radial inflow guide means, of a runner, and a movable annular plunger forming a guiding surface for the flow curving from said radial guide means to a substantially axial direction adjacent said runner and adapted to regulate said flow.

2. In a hydraulic turbine the combination with a runner having inflow guide means and a discharge, of coaxial cylinders joined at one end to form a hollow annular plunger providing a guiding surface between said guide means and said discharge and movable to vary the flow through said runner.

3. In a hydraulic turbine the combination with an intake passage and discharge passage, of a runner between said passages, coaxial cylinders joined at one end to form a hollow annular plunger surrounding said runner and having a rounded surface forming a portion of said intake passage and movable in a direction opposite to the discharge from said runner to restrict the flow to said turbine.

4. In a hydraulic turbine the combination with a turbine runner, of a draft tube receiving the discharge therefrom, an annular plunger surrounding said runner and fluid pressure operated means surrounding said draft tube for moving said plunger.

5. In a hydraulic turbine the combination with a runner of a draft tube receiving the

discharge therefrom, and a hollow annular plunger controlling the flow through said turbine and having its surface curving gradually from the radial to the axial direction and extended into said draft tube.

6. In a hydraulic turbine, means for controlling the flow therethrough comprising an annular plunger surrounding the turbine runner and having rounded surfaces guiding the flow from a substantially radial direction to a substantially axial direction at said runner.

7. In a hydraulic turbine means for controlling the flow therethrough comprising an annular plunger moving across the blade edges of the turbine runner and having rounded surfaces guiding the flow from a substantially radial direction to a substantially axial direction at said runner.

8. In a hydraulic turbine the combination with a runner, of intake an discharge passages therefor, a movable annular plunger forming the guiding surface of both of said passages adjacent said runner, and means for moving said plunger.

9. In a hydraulic turbine the combination with a runner, of intake and discharge passages therefor, a movable annular plunger forming the guiding surface of one of said passages adjacent said runner, and means for moving said plunger comprising fluid pressure operated means.

10. In a hydraulic turbine the combination with a runner, of intake and discharge passages therefor, a movable annular plunger forming the guiding surface of one of said passages adjacent said runner, and means for moving said plunger comprising fluid pressure operated means surrounding said discharge passage.

11. In a hydraulic turbine the combination with a runner and shaft, of a bearing for said shaft in close proximity to said runner, intake and discharge passages for the flow through said runner, and an annular plunger gate movable to surround said runner and bearing and control the flow through said turbine.

12. In a hydraulic turbine the combination with a runner having a vertical shaft, of a bearing for said shaft in close proximity to said runner, and water guiding surface surrounding said bearing, and an annular plunger gate surrounding said runner and movable upward toward said water guiding surface to restrict the flow through the turbine.

13. In a hydraulic turbine the combination with a runner having a shaft, of a bearing for said shaft adjacent said runner, intake and discharge passages for the flow through said runner, a head cover supporting said bearing and a speed ring supporting said head cover and positioned in said intake passage, the portion of said intake passage between the speed ring and runner forming a vane-free transition space.

14. In a hydraulic turbine the combination with a runner, of a draft tube therefor having walls a portion of which adjacent the runner is adjustable.

15. In a hydraulic turbine the combination with a runner, of a draft tube therefor having walls a portion of which adjacent the runner is adjustable to control the flow therethrough.

16. In a hydraulic turbine the combination with a runner, of a draft tube therefor comprising an adjustable portion adjacent the runner surrounding the runner and controlling the flow therethrough.

17. In a hydraulic turbine the combination with a runner, of a draft tube therefor comprising an adjustable portion adjacent the runner, and movable to by-pass a portion of the inflow around the runner.

18. In a hydraulic turbine the combination with a runner having unshrouded blades, of walls forming a chamber in which said runner rotates and spaced from the outermost diameter of the runner a distance providing an opening between the runner and said wall adapted to freely bypass water around the runner and produce an ejector action to accelerate the flow through said runner.

19. In a hydraulic turbine a water conduit bounded by walls formed as surfaces of revolution, an unshrouded runner rotating within said conduit said runner being smaller than the surrounding conduit and leaving a clear annular opening between the tips of the runner blades and the bounding conduit wall so as to freely bypass water around said runner from the runner entrance to the discharge passage.

20. In a rotary hydraulic machine a runner having unshrouded blades, the width of which measured in the direction of flow progressively decreases toward the outer tips of said blades and diminishes to zero at said tips.

21. In a rotary hydraulic machine a runner having unshrouded blades, the width of which measured in the direction of flow continuously decreases toward the outer tips of said blades and diminishes to zero at said tips.

22. In a hydraulic turbine a runner of substantially axial flow type, and means for controlling the flow therethrough comprising an annular plunger moving relatively to the turbine runner and having rounded surfaces guiding the flow to said runner.

23. In a rotary hydraulic machine the combination with a runner having unshrouded blades, of surrounding walls forming a chamber in which said runner rotates and spaced from the outermost diameter of said runner a distance at least ten per cent

of the radial distance between the runner hub and said wall so as to leave a clear annular space for by-passing water around the runner.

24. In a rotary hydraulic machine a water conduit bounded by walls formed as surfaces of revolution, an unshrouded runner rotating within said conduit said runner being smaller than the surrounding conduit and leaving a clear annular opening between the tips of the runner blades and the bounding conduit wall so as to freely bypass water around said runner from the runner entrance to the discharge passage.

25. In a hydraulic turbine the combination with a runner to which the entering flow passes axially of a surrounding wall forming a chamber in which said runner rotates, and means for moving said wall axially to regulate the flow to said runner.

26. In a hydraulic turbine the combination with a runner to which the entering flow passes axially, of surrounding walls forming a chamber in which the runner rotates, rounded entrance walls merging with said surrounding walls and means for moving said walls to regulate the flow through said runner.

27. In a hydraulic turbine the combination with a runner, of inwardly directed guiding means for the entrance flow, a transition space between said guiding means and said runner, a wall surrounding said runner and forming a chamber in which said runner rotates, and means for moving said wall axially to regulate the flow to said runner.

28. In a hydraulic turbine the combination with a runner, of inwardly directed guiding means for the entrance flow, a transition space between said guiding means and said runner and extending from a radial toward an axial direction, a circular wall in said transition space, and having its inner diameter greater than the diameter of the runner, and means for moving said wall axially to regulate the flow to said runner.

29. Apparatus for regulating the flow through a hydraulic turbine comprising relatively axially movable surfaces of the entrance space within the inflow guiding means and surrounding the runner so as to leave a by-pass between the runner and said surface.

30. Apparatus for regulating the flow through a hydraulic turbine having a substantially axial flow runner comprising means directing the flow inwardly into an entrance space in advance of the turbine runner, means discharging the flow from said runner into an axially directed passage, and means for regulating the flow through said turbine by movement of the surface of said entrance space which is on the discharge side thereof.

31. In a hydraulic machine a runner having unshrouded blades of curved outline, the width of which measured in the direction of flow continuously decreases on gradually curving lines toward the outer tips of said blades so that the blade edges merge together at said tips.

32. In a hydraulic turbine the combination with a runner, of guide vanes directing the flow inwardly toward the axis of said runner, and a transition space from the discharge end of the guide vanes to the entrance to the runner, the lower wall of said transition space being movable and curving from the radial toward the axial direction.

33. In a hydraulic turbine the combination with a runner having vanes extending diagonally with respect to a plane normal to the runner axis, of guide vanes directing the flow inwardly toward the axis of said runner, and a transition space from the discharge end of the guide vanes to the entrance to the runner, the lower wall of said transition space being movable and curving from the radial toward the axial direction.

34. In a hydraulic turbine the combination with a runner, of walls forming a conduit for the flow to said runner and comprising a guiding surface adjacent the runner tips movable to bypass a portion of the flow around the runner.

35. In a hydraulic turbine the combination with a vertical shaft runner, of walls forming a conduit for the flow to said runner and comprising an inwardly directed guiding surface adjacent the runner tips movable to bypass a portion of the flow around the runner.

36. In a hydraulic turbine the combination with a runner having a shaft, of a bearing for said shaft adjacent said runner, intake and discharge passages for the flow through said runner, a head cover supporting said bearing and a speed ring supporting said head cover and positioned in said intake passage, the portion of said intake passage between the speed ring and runner forming a vane-free transition space, and an axially movable gate in said transition space.

37. In a hydraulic turbine the combination with fixed guide vanes adapted to impart a whirl to the entering flow of a bearing for the turbine shaft and a casing surrounding said bearing 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.

38. In a hydraulic turbine the combination with an unshrouded propeller type runner receiving the flow in a nearly axial direction, of an intake passage guiding the flow inwardly and with a whirl around the axis, means forming a transition space guiding the flow from said inwardly directed intake

to said runner, and an axially movable gate having its inner diameter greater than the diameter of said runner and movable across said transition space to control the flow.

39. In a hydraulic turbine a runner through which fluid is adapted to flow in an axial direction, means forming a passage communicating with said runner and comprising radial and axial flow portions connected by a transition space at least one side of which is bounded by a surface curving gradually from a radial direction toward an axial direction, and means for moving said bounding surface of said transition space to expand or contract said space for controlling the flow through said runner.

40. In a hydraulic turbine a runner through which fluid is adapted to flow in an axial direction, a conduit for passing the fluid through said runner comprising an axial flow portion and a radial flow portion with a transition space adapted to turn the flow between said portions, at least one side of said transition space being bounded by a surface of revolution curving gradually from a radial direction toward an axial direction, and means for moving said bounding surface of said transition space to expand or contract said space for controlling the flow through said runner.

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