Dec. 23, 1930. L. F. MOODY 1,786,166

HYDRAULIC TURBINE

Original Filed June 28, 1918 2 Sheets-Sheet 1

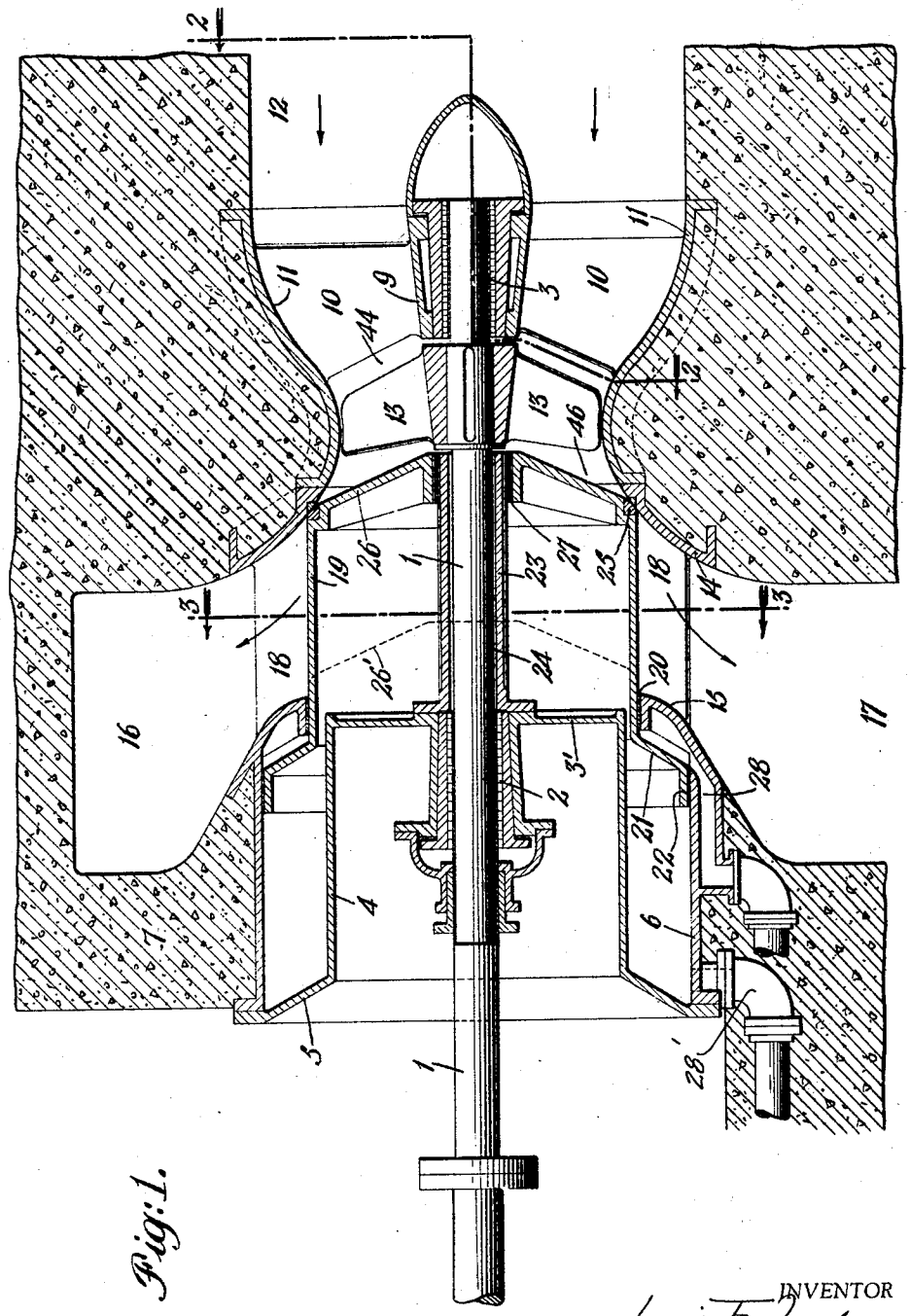


Fig. 1.

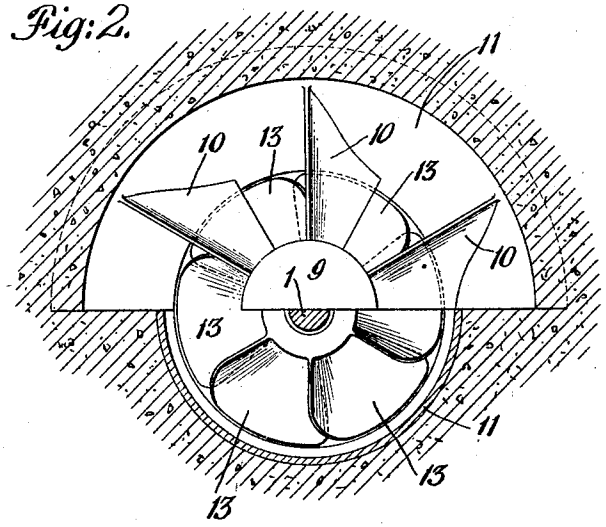
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Fig: 2.



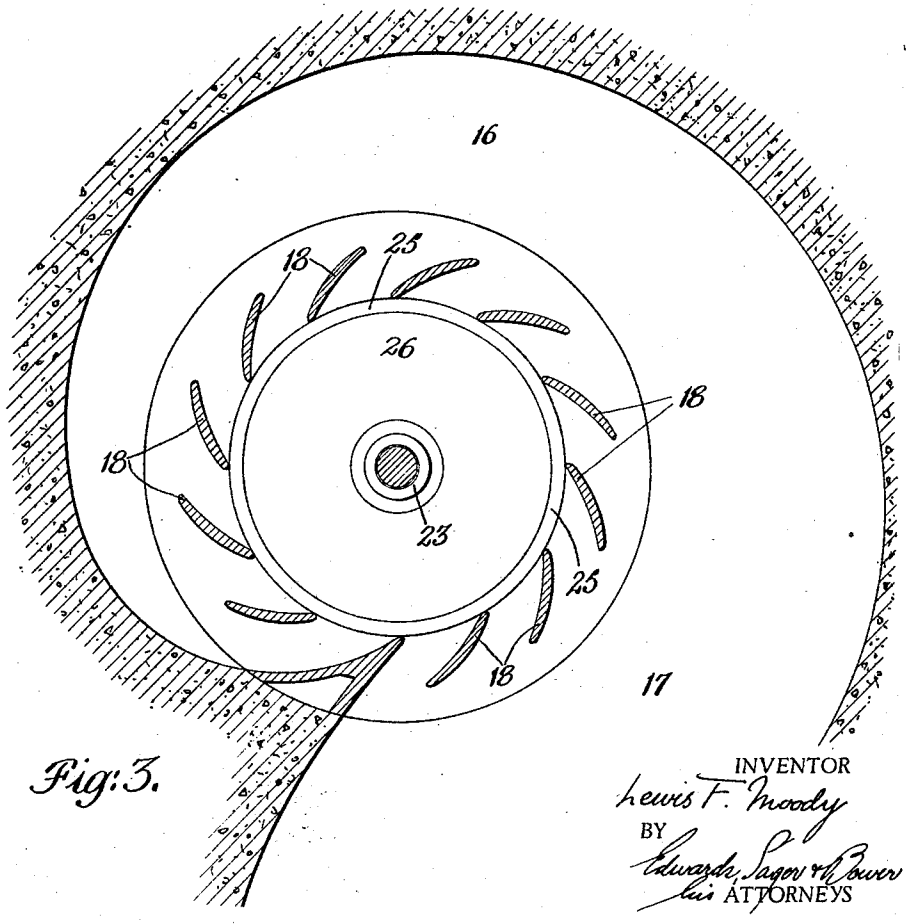


Fig: 3.

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UNITED STATES PATENT OFFICE

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HYDRAULIC TURBINE

Original application filed June 28, 1918, Serial No. 242,391. Divided and this application filed March 31, 1923. Serial No. 629,105.

The principal object of my invention is to provide a new and improved hydraulic turbine. Another object of my invention is to provide an improved hydraulic turbine that shall be well adapted for operation at high specific speed under comparatively low head. Still another object has to do with regulating the flow of water through such a turbine. These and various other objects of my invention will become apparent on consideration of a disclosure of a form in which the invention may be embodied as set forth in the following specification taken with the accompanying drawings. It will be understood that further modifications than those shown in the drawings can be made that will fall within the scope of my invention.

Fig. 1 is an axial section of a turbine embodying my invention,

Fig. 2 is a section on the line 2—2 of Fig. 1, and

Fig. 3 is a section on the line 3—3 of Fig. 1.

In the specific embodiment of the invention shown in the drawings the shaft of the turbine is horizontal and the control means for the flow is positioned on the discharge side of the runner. The shaft 1 runs in the bearing 2 supported in the fixed cylinder 4 which has its flange 5 bolted to the liner 6 supported in the concrete structure 7. Another bearing 3 for the shaft is provided in the head 9 supported by the vanes 10 in the casing 11 which forms a part of the axially extending intake passage 12. The shaft 1 carries the runner with vanes 13 receiving the flow from the guide vanes 10 with combined inward and axial components and discharging it substantially axially. On the entrance side of the runner, the diameter thereof measured around the vane tips adjacent the entrance edges is substantially equal to the diameter of the runner on the discharge side measured in a similar manner.

At its end the cylinder 6 carries a ring 15 extending from which are the stay vanes 18 with their opposite ends connected with the ring 14 which is bolted to the casing 11. Around the stay vanes 18 is the volute discharge chamber 16 of increasing cross section across the lines of flow so as to decrease the velocity of the water and deliver it with reduced velocity into the draft tube 17.

A plunger gate 19—26 has a cylindrical side wall 19 with the flatly conical wall 26 across its end. The inside edge of the ring 15 carries a bronze bushing 20 engaging the cylindrical surface 19 and the end of the cylinder 19 has a piston flange 21 with a bronze bushing 22 engaging the inner face of the cylindrical liner 6. The tube 23 is supported from the wall 3′ with a slight clearance 24 around the shaft 1 and the end wall 26 has a bronze bushing 27 engaging the outer surface of the tube 23. A bronze seat and bushing are also shown at 25 to facilitate a tight closure of the gate.

In the specific embodiment of the invention shown in the drawings there is no perforation through the head 26 so that the head 26 is subject at all times to the pressure in the space at the left of the runner 13, whatever that pressure may be. Pressure fluid admitted through port 28 acts on the annular piston 21 and is supplemented by the pressure on head 26 to move the gate to the left. On the contrary to close the gate pressure fluid is admitted through port 28′ and acts to the right on the whole annular piston 21—26 between the cylinder walls 6 and the sleeve 23. When pressure fluid is admitted at one port 28—28′ it is exhausted at the other port 28′ or 28. The pressure of the water in the penstock may under suitable conditions be utilized to operate the gate.

The water flows to the turbine through the conduit 12 and enters the contracting inflow passage in the casing 11 passing through the inclined guide vanes 10 so that it is delivered with a whirling motion and with increasing velocity to the runner vanes 13, these runner vanes being spaced from the guide vanes 10 a distance sufficient to permit the flow lines to come together to form a solid whirling column of water in the transition space 44 at the entrance to the runner. This whirling water engages the vanes 13 thereby impressing a torque on the shaft 1 and causing it to rotate and develop power. The transition space 44 throughout full or part-gate operations is of constant volume due to the

opposing walls of this space having a fixed relation during such operations, while in addition the intake passage is of constant width, that is, the distance between opposing walls normal to the flow. This results in smooth flow lines and absence of eddy currents in the flow passing to and through the runner.

As the water leaves the runner vanes 13 and enters the discharge space 46 it may retain some degree of whirling velocity. The discharge space 46 is bounded on the outside by the flaring surface of casings 11 and 14 and on the inside by the sleeve 23 and the conical end 26 of the plunger gate in open position 26'. In this discharge space 46 the whirling flow is turned from axial toward a radial outward direction and is decelerated on spreading or expanding spiral lines passing outward through the stay vanes 18 and into the expanding volute chamber 16 where the whirling velocity still remaining will be transformed into pressure head by the reduction of velocity due to the increasing cross section, thus further increasing the portion of the total head which is effective upon the runner 13.

The turbine is regulated by varying the magnitude of the stream of water flowing therethrough. For a normal load the plunger gate 19—26 will have a position shown in dotted lines 26' in Fig. 1 and will move outward for an overload or inward toward the runner for a partial load. When it is moved inward it decreases the annular outflow opening to the stay vanes 18. These stay vanes 18 are inclined in the direction of the whirling outflow, being primarily stay vanes but placed at a suitable angle to corresponding radii so as to offer a minimum resistance to the water which traverses the chamber 46 with a whirling movement. The volute conduit 16 receives this water in its natural whirling direction and conducts it in paths of expanding cross section so as everywhere to reduce its velocity and deliver the integral stream to the outflow conduit or draft tube 17.

The gate mechanism here disclosed is much more rugged in structure than can be obtained when wicket gates are used; the risk of breakage from trash, ice or other obstructions is greatly reduced; and it is reasonably assured that the gates can be easily closed at any time without obstruction from accumulated trash. This form of gate provides for much tighter closure than is possible with wicket gates, the bushing 25 engaging the seat to effect a tight closure, so that it will not ordinarily be necessary to close the head gates or to employ brakes to stop the turbine after the turbine gate is closed. The plunger gate is arranged so that it may readily be withdrawn in an axial direction for purposes of replacement or repair without disturbing the parts set in the concrete.

Among the advantages of my improved construction, in addition to the simplification, and to the certainty of operation of the regulating gate are the following: A simpler form of runner vane surface can be used than in other types of high speed turbines and this gives an advantage in design and manufacture. The runner can be made of lighter weight than in other types of turbines, thus reducing the weight of the rotating parts and reducing the load on the thrust bearing when the turbine is used in vertical shaft setting. Only a comparatively small number of vanes are necessary in the runner, six being shown in the drawing. The spaces between the runner vanes may be large so as to reduce the risk of clogging by trash, the vanes shown for instance being overlapping somewhat in the inner portion of their length when viewed in an axial direction (Fig. 2), and having clear spaces between them at their tips. The blades of the runner have entrance and discharge edges (Fig. 1) that are substantially straight lines transverse to the flow when projected into a plane containing the runner axis. When projected on a plane perpendicular the axis (Fig. 2) the blades have thus entrance and discharge edges joined to the outer tip portions by smoothly rounded curves. Viewed in axial projection (Fig. 2) the blades slightly overlap and their area is substantially equal to the disk area of a circle passing through the tips of the blades. It is also seen that the entrance and discharge edges of adjacent blades are disposed relatively close to a common meridian plane, that is a plane containing the runner axis and passing between said edges so that either the blade area or its projected area will approach the disk or annulus area between the runner hub and a circle passing through the runner periphery. Also the blades due to being of small vertical or axial extent and relatively large horizontal or circumferential extent, as shown in Figs. 1 and 2, are inclined at a smaller angle to the plane of runner rotation than to a plane containing the runner axis.

When referring herein to "axial flow" or "radial flow", according to the commonly-used forms of expression it is understood that the flow is referred to as projected in a meridian plane, that is, a plane containing the turbine axis, such as the plane of Figure 1, and that in addition to the meridian components referred to, the flow contains whirling components of motion about the axis. Thus, where the water enters the runner vanes 13, the components of its direction of flow are axial, radially inward and whirling, the flow being said to be axial and radially inward. Where the water leaves the runner vanes 13, the direction components are axial and whirling and the flow is said to be axial. In the discharge space 46, the axial components of motion are turned into the radial outward direction, the whirling components

being decelerated but remaining in some degree; and the flow through the stay vanes 18 is radially outward and whirling, being referred to as radial outward flow.

This application is a division of my copending application Serial No. 242,391, filed June 28, 1918, for hydraulic turbine, and subject matter shown but not claimed in this application is claimed in said original application No. 242,391 which is now Patent No. 1,583,415, issued May 4th, 1926.

I claim:

1. In a hydraulic turbine an axially directed contracting intake passage having vanes therein to impart a whirl to the entering flow, a runner coaxial with and in said passage receiving said flow and having a substantially axial discharge located at the smallest diameter of said passage, which contracts down to a point substantially adjacent said runner, and a spreading draft tube adapted to decelerate the runner discharge between inner and outer surfaces of revolution.

2. In a hydraulic turbine an axially directed contracting intake passage having vanes therein to impart a whirl to the entering flow, and a high speed unshrouded propeller type runner having an entrance diameter at least equal to its discharge diameter coaxial with said passage, having not more than six blades and receiving said flow and discharging it substantially axially.

3. In a hydraulic turbine an axially directed contracting intake passage having vanes therein to impart a whirl to the entering flow, a high speed runner having an entrance diameter at least equal to its discharge diameter, located at the smallest diameter of said intake passage coaxial with said passage, having not more than six blades and receiving said flow and discharging it substantially axially, said vanes and runner being spaced apart an appreciable distance to form a transition space, and a spreading draft tube adapted to decelerate the runner discharge between inner and outer surfaces of revolution.

4. In a hydraulic turbine an axially directed contracting intake passage having vanes therein to impart a whirl to the entering flow, an unshrouded high speed runner having its discharge side at the smallest diameter of said passage, coaxial with said passage, having not more than six blades and receiving said flow and discharging it substantially axially, said vanes and runner being spaced apart an appreciable distance to form a transition space, and a draft tube adapted to decelerate the runner discharge and turn the axial components to a radial direction.

5. In a hydraulic turbine an axially directed contracting intake passage contained within a circular ring having a surface of revolution and having guide vanes integral with said ring and said guide vanes being formed with an axial entrance and a diagonal discharge to impart a whirl to the entering flow, and a runner coaxial with said passage and receiving the flow therefrom and having a substantially axial discharge.

6. In a hydraulic turbine an axially directed horizontal contracting intake passage having means therein to impart a whirl to the entering flow, and an unshrouded high speed runner coaxial with said passage, and having blades with entrance and discharge edges that are substantially straight lines transverse to the flow when projected into a plane containing the runner axis, said runner having an entrance diameter at least equal to its discharge diameter.

7. In a hydraulic turbine a horizontal entrance casing contracting in the direction of flow and having stationary guide vanes with an axial entrance and a diagonal discharge adapted to impart a whirl to the flow so as to form it into a whirling axially progressing mass, a runner receiving the flow and discharging it substantially axially, a shaft for said runner, and a bearing for said shaft in proximity to said runner and supported by said guide vanes.

8. In a hydraulic turbine a horizontal entrance casing contracting in the direction of flow and having stationary guide vanes adapted to impart a whirl to the flow so as to form it into a whirling axially progressing mass, an unshrouded runner located at the smallest diameter of said casing receiving the flow and discharging it substantially axially, a shaft for said runner, and a bearing for said shaft in proximity to said runner and supported by said guide vanes.

9. In a hydraulic turbine a conduit enclosed by a casing and comprising an axial flow portion, a radial outward flow portion and a transition space between them surrounding the common axis, in which the meridian components of the out-flow change from axial to radial, an axial flow runner in said axial flow portion and a coaxial plunger gate forming a boundary wall for said transition space.

10. In a hydraulic turbine of the horizontal type having axial flow guide vanes, an axial flow runner and a flow decelerating draft tube having an inner surface formed as a conical deflector to engage and deflect water discharging from said runner into the outward flow direction with respect to the axis.

11. In a hydraulic turbine an axially directed contracting intake passage having stationary means to impart a whirl to the entering flow, a runner coaxial with said passage and receiving said flow and a substantial vane-free space between said stationary means and said runner, said stationary means providing a rigid support for a bearing of the turbine shaft.

12. In a hydraulic turbine an axially

directed contracting intake passage having stationary means to impart a whirl to the entering flow, a runner coaxial with said passage and receiving said flow and having a substantially axial discharge and a substantial vane-free space between said stationary means and said runner, said stationary means providing a rigid support for a bearing of the turbine shaft.

13. A hydraulic turbine installation comprising a horizontal intake passage bringing the flow axially to the runner, a runner having its shaft on the discharge side, and a discharge passage spreading around said shaft and turning the flow toward radial and discharging said flow downwardly.

14. A hydraulic turbine installation comprising a horizontal intake passage formed in a concrete structure bringing the flow axially to the runner, a runner having its shaft on the discharge side and projecting beyond the inner surface of said concrete structure, and a discharge passage spreading around said shaft and turning the flow toward radial and discharging said flow downward, said discharge passage being formed in said concrete.

15. In a hydraulic turbine installation a concrete structure having a horizontal passage therethrough, a turbine intake at one portion of said passage and a cover structure and shaft support at another portion of said passage, a draft tube between said intake and said cover structure, and a runner in said passage between said intake and draft tube, said runner having a shaft passing through said support.

16. In a hydraulic turbine installation a concrete structure having a horizontal passage therethrough, an axially directed turbine intake at one end of said passage and a cover structure and shaft support at the other end of said passage and adjacent the inner wall of said concrete structure, a draft tube between said intake and said cover structure, and a runner in said passage between said intake and draft tube, said runner having a shaft passing through said support.

17. In a hydraulic turbine installation a concrete structure having a horizontal passage therethrough, an axially directed turbine intake at one end of said passage and a cover structure and shaft support at the other end of said passage and adjacent the inner wall of said concrete structure, a draft tube between said intake and said cover structure adapted to turn the flow outward from axial toward a radial direction, and a runner in said passage between said intake and draft tube, said runner having a shaft passing through said support.

18. In a hydraulic turbine, a runner having a horizontal axis and a substantially axial discharge, a radial flow conduit at one end of said runner and coaxial therewith and a coaxial cylinder gate across said conduit.

19. In a hydraulic turbine, a runner having a horizontal axis and a substantially axial discharge, a radial flow conduit at one end of said runner and coaxial therewith and a coaxial cylinder gate across said conduit, said gate having a wall across its end.

20. In a hydraulic turbine, a runner having a horizontal axis and a substantially axial discharge, a radial flow conduit at one end of said runner and coaxial therewith and a coaxial cylinder gate across said conduit, and vanes across said radial flow conduit outside of said gates and adjacent thereto when the gate is in its closed position.

21. In a hydraulic turbine, a runner having a horizontal axis and a substantially axial discharge, a radial flow conduit at one end of said runner and coaxial therewith and a coaxial cylinder gate across said conduit, said conduit being of expanding cross section across the stream elements for sections more and more remote from the runner.

22. In a hydraulic turbine, a runner having a horizontal axis and a substantially axial discharge, a radial flow conduit at one end of said runner and coaxial therewith and a coaxial cylinder gate across said conduit, said conduit being in the form of a volute of expanding cross section for sections more and more remote from the runner.

23. In a hydraulic turbine a horizontal shaft runner having a substantially axial discharge and comprising unshrouded runner vanes, and a plunger gate of substantially cylindrical form and having an end surface movable along the axis to control the flow of water through said runner.

24. In a hydraulic turbine a horizontal shaft runner having a substantially axial discharge and comprising unshrouded runner vanes, and a plunger gate of substantially cylindrical form and having a conical end surface movable along the axis to control the flow of water through said runner.

25. In a hydraulic turbine a horizontal shaft runner having a substantially axial discharge, a conduit leading to the runner, means in said conduit to give the water a whirling approach to the runner with increasing velocity, a conduit leading away from the runner, means to guide the water in a whirling direction in said last named conduit and with decreasing velocity, one of said conduits being of radial flow type, and an adjustable cylindrical gate across said radial flow conduit.

26. A hydraulic turbine having a horizontal shaft runner and a gate in the form of a cylinder with an end wall rigidly united thereto and formed as a surface of revolution, said gate being capable of regulating the flow through the turbine by opening or closing with axial movement.

27. A hydraulic turbine having a horizon-

tal shaft runner, a gate in the form of a cylinder with an end wall rigidly united thereto and formed as a surface of revolution, said gate being capable of regulating the flow through the turbine by opening or closing with axial movement, and fluid pressure means to move said gate.

28. The combination in a hydraulic turbine of high specific speed comprising an axially directed intake and discharge passage, guide vanes in said axial intake for whirling the fluid flowing therethrough, and a high specific speed runner disposed in said passage, said runner having a small number of blades the area of which is not less than the disk area of the runner which receives and discharges the flow axially and said blades being inclined at a relatively small angle to the plane of runner rotation in comparison with the angle said blades have to a plane containing the runner axis.

29. The combination in a hydraulic turbine of high specific speed comprising an axially directed intake and discharge passage, guide vanes in said axial intake for whirling the fluid flowing therethrough, and a high specific speed runner disposed in said passage, and spaced from said guide vanes to form a transition space of constant volume throughout turbine operation, said runner having a small number of blades the area of which is not less than the disk area of the runner which receives and discharges the flow aixally.

30. The combination in a hydraulic turbine of high specific speed comprising an axially directed intake and discharge passage, guide vanes in said axial intake for whirling the fluid flowing therethrough, and a high specific speed runner disposed in said passage and spaced from said guide vanes to form a transition space, said runner having a small number of blades which have a greater circumferential than axial extent and the area of said blades being not less than the disk area of the runner which receives and discharges the flow axially, said blades also having a relatively small angle of inclination with respect to the plane of runner rotation in comparison with the angle said blades have to a plane containing the runner axis.

31. The combination in a hydraulic turbine of high specific speed comprising an axially directed intake and discharge passage, guide vanes in said axial intake for whirling the fluid flowing therethrough, and a high specific speed runner disposed in said passage, said runner having blades the area of which is not less than the disk area of the runner which receives and discharges the flow axially, said intake passage being a surface of revolution contracting down to a point near said runner.

32. The combination in a hydraulic turbine of high specific speed comprising an axially directed intake and discharge passage, guide vanes in said axial intake for whirling the fluid flowing therethrough, and a high specific speed runner disposed in said passage, said runner having blades so arranged that adjacent edges of successive blades are disposed relatively close to a common meridian plane containing the runner axis.

33. The combination in a hydraulic turbine of high specific speed comprising an axially directed intake and discharge passage, guide vanes in said axial intake for whirling the fluid flowing therethrough, and a high specific speed runner disposed in said passage, said runner having blades which have a greater circumferential than axial extent and are of such an area that adjacent edges of successive blades are disposed relatively close to a common meridian plane containing the runner axis.

34. The combination in a hydraulic turbine of high specific speed comprising an axially directed intake and discharge passage, guide vanes in said axial intake for whirling the fluid flowing therethrough, and a high specific speed runner disposed in said passage, said runner having not more than six unshrouded blades the area of which is not less than the disc area of the runner which receives and discharges the flow axially and said blades being inclined at a relatively small angle to the plane of runner rotation in comparison with the angle said blades have to a plane containing the runner axis.

35. The combination in a hydraulic turbine of high specific speed comprising an axially directed intake and discharge passage, guide vanes in said axial intake for whirling the fluid flowing therethrough, and a high specific speed runner disposed in said passage, and a gate having a cylindrical wall disposed in the discharge side of said passage.

36. The combination in a hydraulic turbine of high specific speed comprising an axially directed intake and discharge passage, guide vanes in said axial intake for whirling the fluid flowing therethrough, and a high specific speed runner disposed in said passage, and a gate having a cylindrical wall disposed in the discharge side of said passage and movable in a closing direction toward the turbine runner.

37. The combination in a hydraulic turbine of high specific speed comprising an axially directed intake and discharge passage, guide vanes in said axial intake for whirling the fluid flowing therethrough, and a high specific speed runner disposed in said passage, and a plunger gate disposed in the discharge side of said passage and movable in a closing direction toward the turbine runner.

38. The combination in a high specific speed turbine comprising a passage having intake and discharge portions, vanes adapted

to impart whirl to the fluid flowing through said intake which is of constant width during either full or part gate operation, and an unshrouded runner disposed in said passage and having a small number of blades which are inclined at a smaller angle to the plane of runner rotation than to a plane containing the runner axis, the entrance and discharge edges of adjacent blades being disposed relatively close to a common meridian plane passing between said edges, said runner being spaced from said vanes to form a transition space in which the fluid whirls while the walls thereof have the same spaced relation throughout operation of said turbine whereby a transition space of constant volume is obtained.

39. The combination in a high specific speed propeller type hydraulic turbine comprising a passage having intake and discharge portions, said intake being of constant width during full or part gate operation, means adapted to impart whirl to the fluid flowing through said intake and for effecting part-gate operations of said turbine including vanes disposed in said passage and an unshrouded runner disposed in said passage and having a small number of blades which are of relatively greater circumferential than axial extent thereby being disposed at a relatively small angle of inclination with respect to the plane of runner rotation, in comparison with the angle said blades have to a plane containing the runner axis the entrance and discharge edges of adjacent blades being disposed relatively close to a common meridian plane passing between said edges, said runner being spaced from said vanes to form a transition space in which the fluid whirls while the walls thereof have a fixed spaced relation throughout all turbine operations.

40. The combination in a high specific speed hydraulic turbine comprising a passage having intake and discharge portions, vanes adapted to impart a whirl to the fluid flowing through said intake which is of constant width, and an unshrouded runner disposed in said passage and spaced from said vanes to form a transition space in which the fluid whirls before engaging said runner, the walls of said space having the same spaced relation and the width of said intake being constant throughout operation of said turbine, said runner having a small number of blades which are disposed at a relatively small angle of inclination with respect to the plane of runner rotation, in comparison with the angle said blades have to a plane containing the runner axis, said blades having an area substantially equal to the disk area between the runner hub and a circle at the blade tips.

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