Sept. 17, 1929. L. F. MOODY 1,728,435

HYDRAULIC TURBINE

Filed Feb. 26, 1923 4 Sheets-Sheet 1

Fig:1.

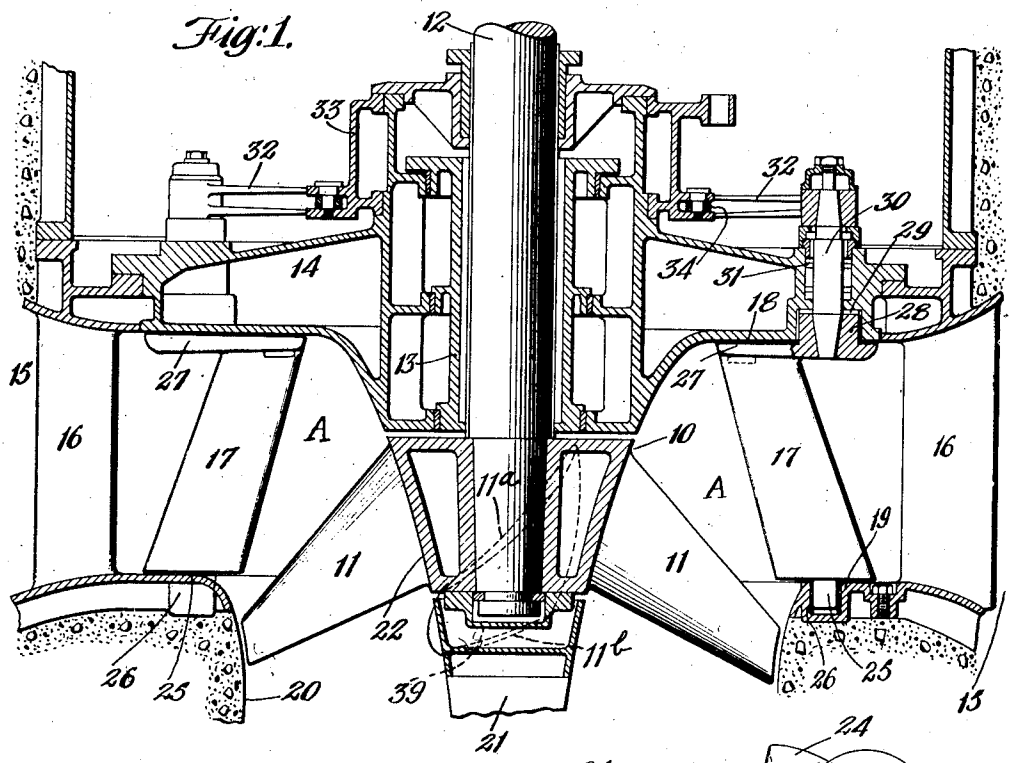


Fig:3.

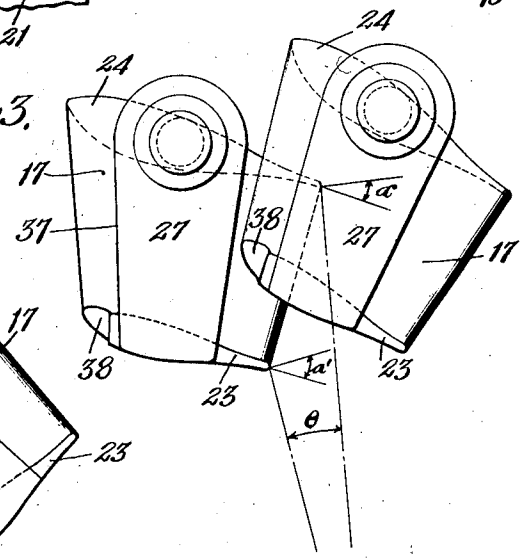
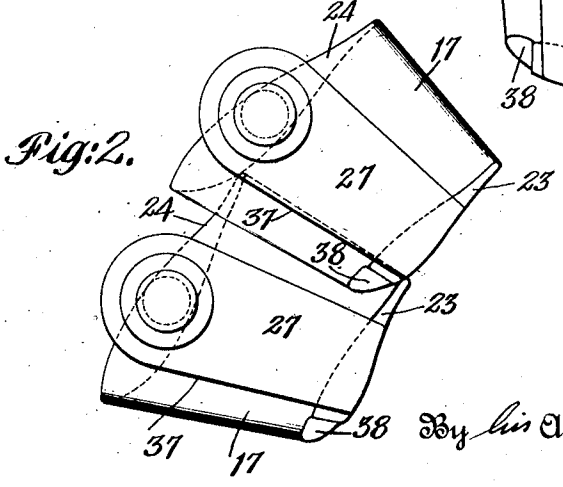


Fig:2.



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Sept. 17, 1929. L. F. MOODY 1,728,435

HYDRAULIC TURBINE

Filed Feb. 26, 1923 4 Sheets-Sheet 2

Fig:4.

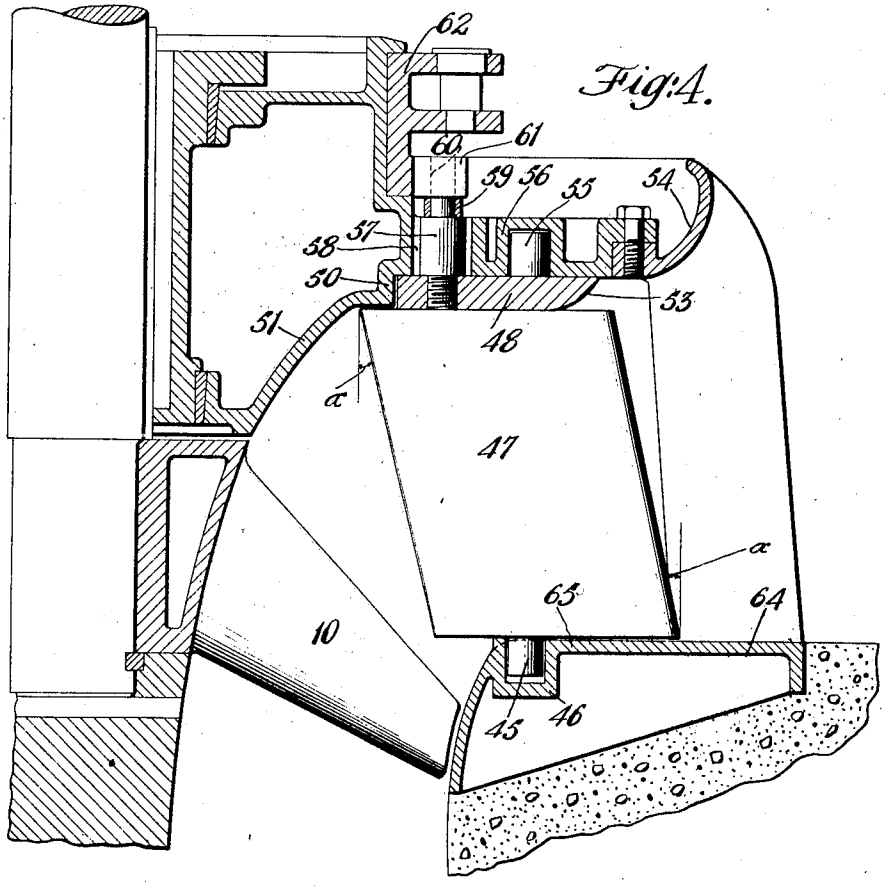


Fig:5.

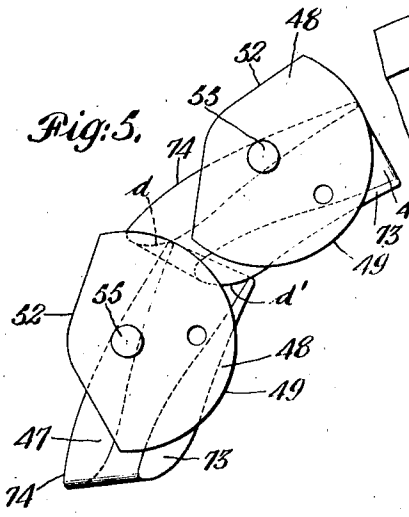
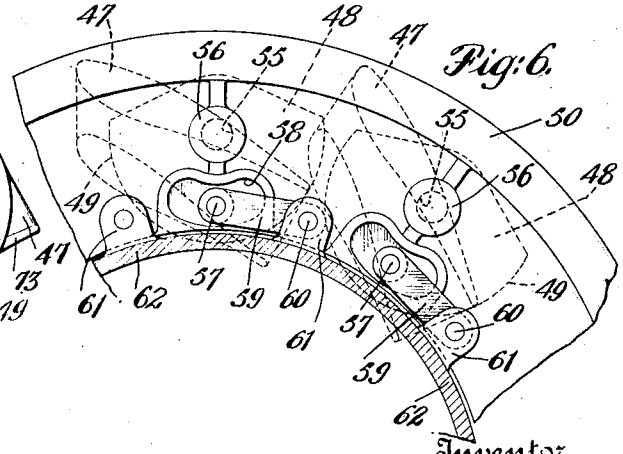


Fig:6.



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Sept. 17, 1929. L. F. MOODY 1,728,435

HYDRAULIC TURBINE

Filed Feb. 26, 1923 4 Sheets-Sheet 3

Fig: 4a

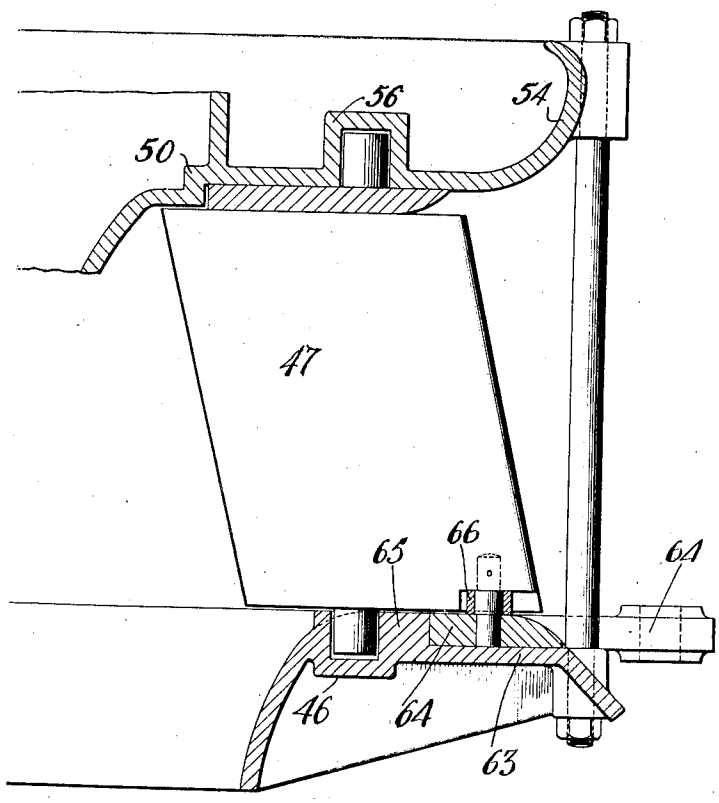
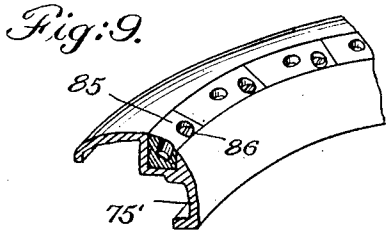


Fig: 9.



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Sept. 17, 1929. L. F. MOODY 1,728,435

HYDRAULIC TURBINE

Filed Feb. 26, 1923 4 Sheets-Sheet 4

Fig: 7.

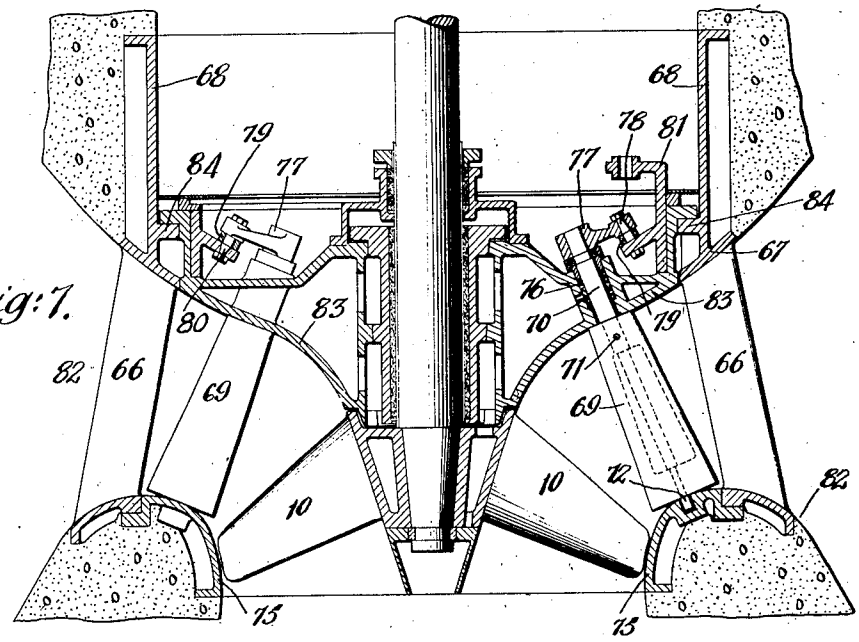
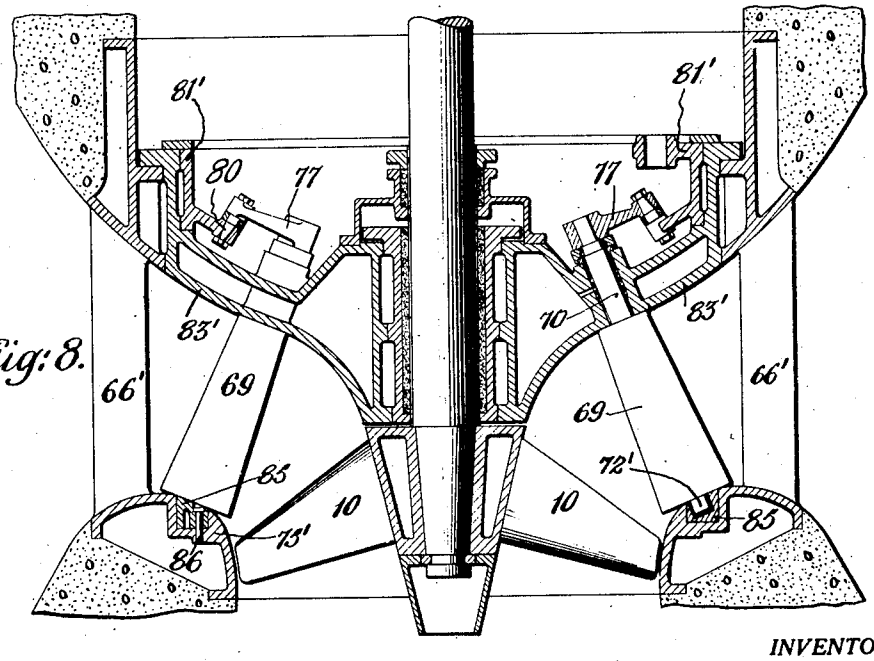


Fig: 8.



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Patented Sept. 17, 1929 1,728,435

UNITED STATES PATENT OFFICE

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HYDRAULIC TURBINE

Application filed February 26, 1923. Serial No. 621,140.

This invention relates to hydraulic turbines of the type in which the flow is regulated by means of guide vanes rotatably adjustable about their axes. It also relates particularly to such turbines of high specific speed, especially those equipped with a diagonal or axial flow runners. Very high specific speeds can be attained with good efficiency by the use of runners in which the flow through all parts of the runner is in a diagonal or approximately axial direction when considered in a plane containing the turbine axis, such runners usually being constructed of the propeller type having a relatively small number of blades unshrouded at their outer ends. When such runners are used with the usual type of wicket gates or adjustable guide vanes, the flow passing in a generally radial direction through the guide vanes must then be turned from radial to substantially axial and the elements of the stream which enter the runner nearest the axis must traverse a relatively long distance after being accelerated to a comparatively high velocity by the guide vanes, this distance being traversed in a spiral direction about the axis and the velocity being still further accelerated on the way.

One object of the present invention is to provide an improved construction whereby the length of this passage between the guide vanes and runner is shortened and in this manner frictional losses incident to the flow of the water to the runner are reduced, undue acceleration or variation of velocity in the long unguided path are avoided, more definite and determinate control of the flow is provided, and economy of material is secured in the turbine structure.

A further object of the invention is to provide an improved form and mounting of the adjustable guide vanes so that with their discharge edges inclined to the axis of the runner they can be conveniently operated and will furnish proper guidance to the flow and will enable high efficiency to be secured in a turbine under normal, overgate or part-gate conditions. The inclined inner edges of the guide vanes of this invention are positioned nearer to the entrance edges of the runner blades than would be the case if the usual wicket gates were used and they guide the flow lines in such manner as most efficiently to cooperate with the runner in all positions of the guide vanes.

Other objects and advantages will appear from the following description taken in connection with the accompanying drawings wherein

Fig. 1 is a fragmentary vertical section partly in elevation, of a turbine embodying one form of my invention.

Fig. 2 is a plan view of two of the movable guide vanes shown in Fig. 1, the vanes being shown in Fig. 2 in closed position.

Fig. 3 is a view similar to Fig. 2 showing the guide vanes opened to approximately normal position.

Fig. 4 is a fragmentary sectional view partly in elevation of a turbine embodying a modified form of my invention.

Fig. 4^a is a partial view similar to Fig. 4 illustrating a modified construction.

Fig. 5 is a fragmentary plan view of a plurality of movable guide vanes one of which is shown in Fig. 4.

Fig. 6 is a plan view showing the operating means for the guide vanes shown in Figs. 4 and 5.

Fig. 7 is a fragmentary sectional view partly in elevation of a further modified form of my invention.

Fig. 8 is a view similar to Fig. 7 but showing a still further modification.

Fig. 9 is a partial perspective view of a portion of the lower vane ring of Fig. 8.

Referring more particularly to Fig. 1 the turbine is provided with a runner 10 of the diagonal inward flow type formed with a series of blades 11 the upper ends of the entrance edges of which are nearer to the turbine axis than the lower ends of said edges. The blades are relatively flat in the direction of flow as indicated by the hub section 11^a and blade tips at 11^b, it also being noted that curvature of the sections is only slightly different from each other. The runner 10 is secured to a shaft 12 mounted to rotate in the bearing 13 formed in the head cover 14. Water from the intake conduit 15 passes into the turbine through stay vanes 16 thence through the

guide vanes 17 in the space A between the upper casing surface 18 and lower ring 19 in which space it is turned from a direction which is substantially radial to one which is downwardly and inwardly inclined, thence between the runner blades 11 and into the draft tube 20 The draft tube as shown is formed with a central core 21 whose outer surface is continuous with the surface 22 of the runner hub.

In the space A the movable guide vanes or wicket gates 17 are adjustable to control the flow. These vanes are of the form shown in Figs. 2 and 3 wherein 23 indicates the upper end surface of the vane and 24 the lower end surface. Between these surfaces the vane is formed of straight line elements which are inclined to the planes of these surfaces as shown. The vanes 17 are mounted so as to have a general upward and inward inclination as may be seen in Fig. 1. The lower end of the vane is formed with a trunnion 25 adapted to be seated in a bearing 26 formed in the ring 19. The upper end of the vane is secured to the outer end of an arm 27 which arm is formed with a boss or hub 28 adapted to be seated and rotate in an opening 29 formed in the head cover. This hub is rigidly secured to the lower end of a vertical stem 30 which is adapted to rotate in a bearing 31 formed in the head cover. The stem 30 has secured to its upper end an arm 32 which is adapted to be actuated from the operating ring 33 by means of a link 34. The axes of the stem 30 and trunnion 25 are in a line parallel to the turbine axis.

It will be noted that by the use of the arm 27 the vane may be pivoted so that its axis of rotation lies outside of the body of the vane at its upper portion and thus may be made to extend a considerable distance at its upper portion from its own axis in the direction of the runner.

The use of the usual wicket gates with axial or diagonal high speed runners is sometimes attended with disturbed flow conditions adjacent the runner hub due to the fact that the elements of the flow which enter the runner close to the hub are required to flow through a wide radial space without guidance after they leave the guide vanes. In such a free space, the elements of the flow will have a constant moment of momentum about the turbine axis since except for the friction of the guiding walls no tangential force is applied to the stream from the time it leaves the guide vanes until it enters the runner. It therefore results that the mass of any stream element multiplied by its velocity and by its radial distance from the axis remains constant throughout this space and therefore its velocity will increase as its radius decreases, the velocity and radius being inversely proportional. The comparatively great decrease in radius experienced by the innermost stream elements as they pass from the guide vanes to the runner therefore produces a very considerable increase in velocity, and as the guide vanes are closed into part-gate position and the velocity of flow through the guide vanes increases and the distance of the discharge edge of the guide vanes from the axis increases it is seen that the absolute velocity with which the water enters the runner will still further increase, frequently to an undesirable extent, under part-gate conditions of operation. The whirl component of velocity about the turbine axis of the water entering a high speed runner is therefore frequently large at normal gate and at part-gate becomes great enough to result in losses since under these part-gate conditions the angle of the entrance edges of the runner blade will be different from the relative direction of entrance of the water. By the use of the inclined guide vanes of this invention, it becomes possible to reduce the variation of velocity at entrance to the runner and to insure that this velocity will not reach excessive values at part-gate.

An objectionable effect of the above conditions in a turbine with the usual wicket gates is the tendency at part-gate for the flow to form a surface of discontinuity separated from the runner hub and the inner boundary of the transition space between the guide vanes and runner; leaving a region of water which does not partake of the general flow and in fact may have a reverse direction through the runner and may contain local eddies and turbulence. By the use of the inclined guide vanes here described the water is given positive guidance at a point nearer to the turbine axis and the tendency of the flow to leave the inner boundary surfaces of the transition and runner space is reduced or avoided. At the same time the advantages of the rotary adjustment of the guide vanes are retained, the guide vanes and regulating mechanism being subject to small hydraulic load and having small inertia and thus being adapted for quick regulation.

One method of designing the guide vanes by which they may be laid out in a simple manner is as follows: The horizontal sections of the guide vane taken at different distances from one end of the vane may be made geometrically similar to each other but increasing in size in proportion to the distance of each section from the turbine axis. The straight line elements of the vanes 17 are so arranged that when the vanes are in closed position as shown in Fig. 2 these elements if continued will all intersect the turbine axis at a single point. This enables the vane to be very simply designed and also provides that all the vanes shall come together along straight line elements and so effectively shut off the supply of water to the runner. When made desirable by the hydraulic conditions,

the guide vane may be composed of curved elements transverse to the flow instead of straight elements as shown in the figures. The use of straight elements is the preferred construction on account of the simple form of surface and suitability for machining the vane edges or surfaces. The arm 27 is tapered or rounded at its entrance edge 37 in order to give a smooth contour for the water flow. To avoid interference between the top of one vane and the arm of an adjacent vane when the vanes are moved to full open position the top of each vane is formed with a notch 38 so that the arm may move a certain distance over an adjacent vane. Instead of cutting away a portion of the vane 17 a notch may be formed in the arm 27. The stay vanes 16 will in the usual design be inclined to the radial so as to conform to any whirl of the incoming flow such as would be acquired by passage through a volute intake conduit.

Referring to Figs. 2 and 3 it will be noted that as the guide vanes 17 are rotated from their closed position (in a clockwise direction) every part of the guide vane will of course rotate through the same angle, the lower portion 24 of the guide vane will rotate without moving laterally, and in its open position the discharge tips of the vanes will be inclined in a direction making an angle α with the tangential direction as indicated in Fig. 3. The upper ends 23 of the guide vanes however will not only rotate but will change position due to their rotation being about the axis offset at some distance from the vane section. The vane tip will therefore be inclined in a direction forming an angle α' with respect to a tangent drawn at the new position of the tips and this angle will exceed the angle α by the amount θ, the angle between radii drawn to the two positions of the vane tips. This means that on account of the upper section of the vane of the form shown opening nearer the turbine axis it will open to a greater angle of admission than the lower end of the vane thus directing the water with a smaller whirl component at the top of the guide vane than at the bottom. This reduced whirl component will give favorable conditions of design for the runner since the water coming from the top of the guide vane enters the runner at a point nearer to the axis of the runner where the linear velocity of the runner vanes is reduced as compared with the vane tips which encounter the water flowing from the lower end of the guide vanes. By the use of guide vanes of inclined form therefore it becomes possible to design the runner with a less extreme variation of entrance angle of the runner vanes from the tips to the hub and to avoid any tendency toward the hooked form of runner vane near the hub. The outline of one of the runner vanes is shown in dotted lines at 39 in Fig. 1.

Besides introducing water at a greater angle α' and correspondingly smaller whirl component at the top of the vanes than the angle α at the bottom the difference in radius between the outflow tips of the guide vanes and the inflow tips of the runner vanes for the upper portion of the flow is reduced and therefore its increase in whirl due to the decrease in radius as the water passes through the transition space A is reduced in amount and therefore by introducing the water at a point nearer the axis as is provided by this form of guide vane in which the guide vane orifice occurs nearer the axis at the top the conditions of flow will be improved not only at normal and full gate but also at part gate and this form of guide vane will be of material value in improving the part gate performance of the turbine, that is, its operation under small loads. While the guide vanes are located near the entrance edges of runner blades the transition space is sufficient to permit the stream to form itself in a solid whirling mass which is directed to the runner in an efficient manner. The guide vanes may be designed and placed so that there are practically no crossings of the stream lines and the formation of eddies and cross currents is avoided.

In Figs. 4 to 6 I have shown a modified form of vane and operating means and also a somewhat modified form of speed ring, this modification being shown in an open flume setting. The vane 47 here shown is formed with a lower trunnion 45 mounted in the lower distributor ring 46 as in the previous figures. Secured to the top of the vane however is a disc 48 formed with a circular side 49 adapted to be seated within the curved wall 50 of a recessed portion of the head cover 51. The disc 48 is cut away along its edge 52 so as to permit its removal through the speed ring crown 54. The lower face of the disc is curved upwardly along its forward edge 53 to provide a smooth contour for the water flow. A trunnion 55 secured to the upper face of the disc 48 is adapted to rotate in a bearing 56 in the head cover. Secured in the disc is an operating pin 57 adapted to extend upwardly through a slot 58 formed in the head cover. This pin 57 is connected by means of a link 59 and pin 60 to a projection 61 extending outwardly from the operating ring 62. The disc 48 serves to maintain the slot 58 closed against the flow of water from beneath.

Another arrangement for operation of the guide vanes is shown at 63 in Fig. 4a. In this arrangement the operation is effected by means of a ring 64 set in the lower casing or distributor plate 65 and connected to each vane by a link 66. This ring 64 is adapted to receive motion by any suitable means such as links connected at one end to the ring and at the other to a crank which may be operated from a position above the intake. The in-

clined form and mounting of the vanes enables the two alternative arrangements of operating mechanism, namely that of an operating pin at the inner end of the top in one case and at the outer end of the bottom in the other case to be conveniently applied.

The upper end 73 of the vane 47 is not exactly similar to the lower end 74 of said vane but is somewhat smaller and differently shaped and directed at a different angle so that, as in Fig. 3, in open position of the vane the agle α' at the top of the vane is greater than the angle α at the bottom so that the lower portions of the vane will make a smaller angle with the tangential direction than the upper section does. Between the upper and lower sections the vane surfaces extend with straight line elements and in closed position successive vanes will contact (Fig. 5) along a line which at the bottom is nearer the entrance edge of the vane than at the top. That is the distance d (Fig. 5) is smaller than the distance d'.

By the use of the inclined guide vanes as shown in Figs. 1 to 6 it is possible to incline the stay vanes somewhat as indicated in Fig. 4 and so form the upper speed ring crown 54 of less diameter than would be the case if the usual vertical stay vanes were employed. This constitutes not only a saving of material but lessens the effective length of the narrow entrance passage and so lessens the distance that must be traversed by the water at high speed.

In Figs. 7 and 8 modifications are shown in which straight vanes are employed mounted however to rotate about axes which are inclined to the turbine axis and to each other. In Fig. 7, 66 indicates stay vanes and 67 the stay ring crown which is extended upwardly at 68 to form the pit liner. The guide vanes 69 are each secured to an inclined shaft 70 by means of a pin 71 and the shaft 70 is journaled at its lower end 72 in the combined gate and wear ring 75 and at its upper end passes through a bearing 76 formed in the casing. Secured to the outer end of the shaft 70 is an arm 77 which is pivoted by means of a pin 78 at its outer end to a link 79. A second pin 80 serves to connect the link 79 to the operating ring 81. The shaft 70 pins 78 and 80 and the axis of the ring 81 are all directed along radii of a sphere, that is, all parts move along arcs of concentric spheres whose center is on the axis of the turbine. This permits the operation of the inclined vanes 69 from the ring 81 without the use of universal joint or lost motion connections. The walls of the inlet passage 82 taper inwardly until they reach the inclined guide vanes 69. The construction as illustrated in Fig. 7 is designed to occupy a minimum space in radial directions. The casing 83 as shown in Fig. 7 is seated on a flange 84 extending inwardly from the pit liner 68. To lift the casing for inspection or repair it is merely necessary to remove the pins 71 and to move the shafts 70 along their axes sufficiently to free their lower ends from their bearings in the ring 75.

The construction shown in Fig. 8 differs from that of Fig. 7 in that the stay vanes 66' are vertical and the pit liner and operating ring 81' are made of somewhat larger diameter. The lower trunnions 72' of the inclined guide vanes are formed integral with the vanes and are seated within a removable sectional bearing ring 85 which is held in a recess formed in the ring 75'. There is a separate section of ring 85 for each vane as shown in Fig. 9; or instead of a ring there may be installed a separately removable circular socket for each vane. Bolts 86 connect the ring 75' and the sockets or ring sections.

The turbine of this invention receives the entering flow through the stay vanes in a radial or nearly radial direction and, while turning it toward the axial direction, controls it by the adjustment of the inclined guide vane surfaces along which the flow passes with combined axial and radial components. Beyond these inclined guide vanes the flow continues to turn toward the axial direction so that at the entrance to the runner it is largely, or it may be wholly, axial in direction. A whirl is imparted to the entering flow either by the intake casing or the stay vanes or both and this whirl is continued and variably increased by the pivoted inclined guide vanes so that the water is directed against the runner in a solid whirling mass rotating at high velocity. The high-speed propeller type runner is placed at or near the narrowest portion of this vortex-like flow and is carried around by it at a high rotational speed and with relatively low torque so that the discharge from the runner still continues to whirl with considerable velocity. To convert the tangential or whirling components of the velocity of the discharge into useful pressure head the draft tube is preferably of the annular form indicated in the drawings. The propeller type of runner will have only a few blades usually six or less and preferably will be unshrouded.

The interposition of the adjustable guiding surfaces in the form of inclined guide vanes in the flow intermediate between radial and axial not only shortens the length of the high velocity flow between the guide vanes and runner but also permits the whole turbine structure to be made more compact with reduced distance between the stay vane entrance and the runner. The velocity of the flow is thus quickly speeded up and controlled while being simultaneously accelerated and turned from radial toward axial and all of the space is most efficiently utilized. The high speed propeller type of runner with a high velocity whirl of the entering flow makes it particularly important to reduce the

areas in contact with this high velocity flow in order to reduce the frictional losses. The turbine of this invention therefore effects a saving not only in size and first cost of the turbine but also increases the power output by increasing the efficiency of the turbine in operation.

I claim:

1. In a turbine the combination with a high speed propeller type runner having blades with entrance edges receiving the flow with a greater axial than radial component, of guiding means for directing an inward and axial flow to said runner comprising pivoted guide vanes having surfaces diagonally inclined to the runner axis in the entrance flow to said runner and said vanes being spaced from said runner to form a transition space.

2. In a turbine the combination with a high speed propeller type runner having blades with entrance edges receiving the flow with a greater axial than radial component, of guiding means for directing an inward and axial flow to said runner including a transition space, and guide vanes having surfaces diagonally inclined to the runner axis in the entrance flow to said runner and so disposed with respect thereto that fluid flows over at least a portion of the guide vanes with an axial component.

3. In a hydraulic turbine the combination with an unshrouded runner having blades receiving the entrance flow with a greater axial than radial component, said blades having relatively flat curvature in the direction of flow and inclined forwardly at a large angle to a meridian plane passing through the runner axis, of a conduit turning from a radial to an axial direction for guiding the flow to said runner, and pivoted guide vanes in said conduit having surfaces inclined to the runner axis and spaced from said runner to form a transition space.

4. In a turbine the combination with an unshrouded runner having diagonal blades receiving the flow with a greater axial than radial component, of a guiding passage directing the flow to said runner and contracting and then expanding in the direction of flow, said runner being disposed above the expanding part thereof, and guide vanes in said passage rotatable around axes not parallel to the turbine axis, said vanes being spaced from said runner to form a transition space.

5. In a turbine the combination with an unshrouded runner receiving the flow with a greater axial than radial component, of a guiding passage directing the flow to said runner and contracting and then expanding in the direction of flow, said runner being disposed above the expanding part thereof, and guide vanes in said passage rotatable around axes not parallel to the turbine axis, the axes of said guide vanes intersecting the turbine axis in a common point.

6. In a turbine the combination with a high speed propeller type runner having blades with entrance edges receiving the flow with a greater axial than radial component, of guiding means for the inflow to said runner comprising pivoted guide vanes having discharge edges approaching nearer to the runner axis at points more remote from the runner, said vanes being spaced from said runner to form a transition space, and a stationary annular wall adjacent the runner tips radially contracting in the direction of axial flow.

7. In a turbine the combination with a high speed propeller type runner having blades with entrance edges receiving the flow with a greater axial than radial component, of fixed stay vanes in advance of said runner, and pivoted guide vanes having surfaces diagonally inclined to the runner axis between said stay vanes and said runner.

8. In a turbine the combination with a high speed propeller type runner having blades with entrance edges receiving the flow with a greater axial than radial component, of fixed stay vanes in advance of said runner and having discharge edges inclined to the turbine axis, and adjustable guide vanes disposed adjacent to said fixed vanes.

9. In a turbine the combination with a passage which contracts and then expands, a high speed propeller type runner having diagonal blades disposed in the contracting side of said passage with entrance edges receiving the flow with a greater axial than radial component, of fixed stay vanes in advance of said runner and having discharge edges inclined to the turbine axis, and pivoted guide vanes between said stay vanes and said runner and rotatable around axes inclined to the turbine axis.

10. In a turbine the combination with a high speed propeller type runner having blades with entrance edges receiving the flow with a greater axial than radial component, of fixed stay means in advance of said runner, and pivoted guide vanes between said means and said runner and having surfaces diagonally inclined to the runner axis in the entrance flow to said runner.

11. In a turbine the combination with a runner having blades with entrance edges receiving the flow with a greater axial than radial component, of fixed stay vanes in advance of said runner and having discharge edges inclined to the turbine axis, and pivoted guide vanes between said stay vanes and said runner and having discharge edges inclined to the turbine axis.

12. In a turbine the combination with a passage which contracts and then expands, a high speed propeller type runner disposed therein and having blades with entrance

edges receiving the flow with an axial component, of fixed stay vanes in advance of said runner and having discharge edges inclined to the turbine axis, and pivoted guide vanes between said stay vanes and said runner and rotatable around axes inclined to the turbine axis at a greater angle than the inclination of the discharge edges of said fixed stay vanes.

13. In a turbine the combination with a turbine conduit for the flow through the turbine of a runner in said conduit having blades with entrance edges receiving the flow with an axial component, pivoted guide vanes in said conduit in advance of said runner and fixed stay vanes in advance of said pivoted guide vanes, the ends of said runner blades and guide vanes and stay vanes being relatively closely spaced at one wall of said conduit and relatively widely spaced at the other wall of said conduit so that the flow turns toward an axial direction in passing through said vanes and blades.

14. In a turbine a conduit for the flow through the turbine having opposite substantially radially extending walls turning toward an axial direction at their inner portions, stay vanes at the entrance to said conduit, pivoted guide vanes having surfaces diagonally inclined with relation to the turbine axis and a runner having blades with entrance edges receiving the flow with an axial component.

15. In a turbine a conduit for the flow through the turbine having opposite substantially radially extending walls turning toward an axial direction at their inner portions, stay vanes at the entrance to said conduit, pivoted guide vanes having surfaces diagonally inclined with relation to the turbine axis and a runner having blades with entrance edges receiving the flow with an axial component, said runner discharging said flow with a substantially axial direction as to its meridian components.

16. In a hydraulic turbine the combination with a stay vane ring through which the meridian components of the inflow to the turbine runner are substantially radial in direction, a turbine runner discharging the flow with the meridian components in a substantially axial direction and guiding means between said stay vanes and said runner adapted to guide the flow while turning from radial toward the axial, comprising pivoted guide vanes through which the flow passes with combined radial and axial components.

17. In a hydraulic turbine the combination with a stay vane ring through which the meridian components of the inflow to the turbine runner are substantially radial in direction, a turbine runner discharging the flow with the meridian components in a substantially axial direction and guiding means between said stay vanes and said runner adapted to guide the flow while turning from radial toward the axial, comprising pivoted guide vanes through which the flow passes with combined radial and axial components, said pivoted guide vanes having discharge edges inclined to the runner axis.

18. In a hydraulic turbine the combination with a stay vane ring through which the meridian components of the inflow to the turbine runner are substantially radial in direction, a turbine runner discharging the flow with the meridian components in a substantially axial direction and guiding means between said stay vanes and said runner adapted to guide the flow while turning from radial toward the axial, comprising pivoted guide vanes through which the flow passes with combined radial and axial components, said pivoted guide vanes having discharge edges inclined to the runner axis and turning about axes inclined to the runner axis.

19. In a turbine, a runner having diagonal blades adapted to receive a flow, certain lines of said flow passing through the runner nearer to the axis of said runner than other lines, means forming a passage leading to the runner, and a series of upwardly and inwardly inclined guide vanes pivoted on axes inclined to the runner axis, said guide vanes being constructed and arranged to impart degrees of whirl to the various portions of the flow depending upon the distance of the portion of the flow, as it passes through the runner, from the axis.

20. In a hydraulic machine a runner provided with blades having entrance edges directed away from the axis of the runner, means forming a passage communicating with said runner and curving away from the axis, a series of guide vanes in said passage, said vanes being pivoted to move about axes inclined to the turbine axis, operating means rotatable about an axis inclined to the axes of said vanes and connecting means including pivot means, between said vanes and rotatable operating means, said vanes, rotatable means and connecting means being movable along arcs of concentric spheres.

21. In a hydraulic machine a turbine provided with blades having entrance edges directed away from the axis of said runner, means forming a short inlet passage communicating with said runner and curving away from the axis, a series of guide vanes in said passage near to the entrance edges of said blades, said vanes being pivoted to move about axes inclined to the turbine axis and operating means for said vanes, said vanes and operating means, including connecting pivot pins, being movable along arcs of concentric spheres.

22. In a turbine a plurality of guide vanes pivoted about axes inclined to one another, common means for operating said guide

vanes, said vanes and means being movable along arcs of concentric spheres and connected together through means providing surface contact.

23. In a hydraulic machine a runner provided with blades having entrance edges directed away from the axis of the runner, means forming a passage which communicates with said runner and curves away from said axis, guide vanes in said passage pivoted to move about axes which are inclined to the runner axis, an operating ring located outside of said passage and movable about the runner axis and pin connections between said ring and vanes, said vanes and connections being movable along arcs of concentric spheres whose center lies on the runner axis.

24. In a turbine a runner having blades whose entrance edges extend outwardly from its axis, means forming a passage which directs a flow to said runner said flow curving in a direction from radial toward axial, a series of upwardly and inwardly inclined stay vanes extending across said passage and a series of upwardly and inwardly inclined guide vanes located in said passage between said stay vanes and runner.

25. In a turbine a runner having blades whose entrance edges extend outwardly from its axis, means forming a passage which directs a flow to said runner said flow curving in a direction from radial toward axial, a series of upwardly and inwardly inclined stay vanes extending across said passage and a series of upwardly and inwardly inclined guide vanes located in said passage between said stay vanes and runner, said guide vanes being pivoted about axes inclined to said runner axis and spaced from said stay vanes a greater distance at the upper ends thereof than at the lower ends.

26. In a turbine a runner having blades whose entrance edges extend outwardly from its axis, means forming a passage which directs a flow to said runner said flow curving in a direction from radial toward axial, a series of upwardly and inwardly inclined stay vanes extending across said passage and a series of upwardly and inwardly inclined guide vanes located in said passage between said stay vanes and runner, said guide vanes being pivoted about axes inclined to said runner axis, means for operating said guide vanes comprising a ring rotatable about said turbine axis and pin connections between said ring and guide vanes, said ring being supported from said stay vane.

27. In a turbine, a runner, means forming a curved passage leading to said runner comprising an upper casing, and an upwardly and inwardly directed stay vane ring at the entrance to said passage, and inwardly inclined guide vanes pivoted in said casing and extending across said curved passage between said stay vanes and runner, said casing being supported by said stay vane ring and said pivoted vanes being removable with said casing by movement upwardly through said stay vane ring.

28. In a turbine means forming a curved passage leading to the runner comprising an upper casing, and lower ring, and a stay ring at the entrance to said passage, a series of upwardly and inwardly inclined guide vanes extending across said passage between said stay ring and said runner, upwardly and inwardly inclined shafts upon which said guide vanes are mounted said shafts being mounted in said casing and lower ring and said guide vanes being removable with said casing through said stay ring, said shafts being movable relatively to said vanes to provide for this engagement with said lower ring.

29. In a turbine a runner having blades whose entrance edges extend outwardly away from its axis there being but slight difference between the curvature of sections of said blades at the tips and at the hub, of means forming an inlet passage to said runner which curves from radial toward an axial direction, means for controlling the flow through said passage, said means being designed to impart a certain degree of whirl to that portion of the flow which passes near the inner wall of the passage and a greater whirl to the remaining portions of said flow.

30. In a turbine a conduit for the flow through the turbine having opposite substantially radially extending walls turning toward an axial direction at their inner portions, stay means at the entrance to said conduit, pivoted guide vanes having surfaces diagonally inclined with relation to the turbine axis and a runner having blades with entrance edges receiving the flow with an axial component.

31. In a turbine a conduit for the flow through the turbine having opposite substantially radially extending walls turning toward an axial direction at their inner portions, stay means at the entrance to said conduit, pivoted guide vanes having surfaces diagonally inclined with relation to the turbine axis and a runner having blades with entrance edges receiving the flow with an axial component, said runner discharging said flow with a substantially axial direction as to its meridian components.

32. In a turbine the combination with a high specific speed propeller type runner having blades with entrance edges receiving the flow with an axial component, of guide vanes for the inflow to said runner having surfaces which are everywhere inclined to the axial and radial directions.

33. In a turbine the combination with a high specific speed propeller type runner having unshrouded blades with entrance edges for receiving a substantially axial flow, of pivoted guide vanes for the inflow to said runner

having its surfaces everywhere inclined to the axial and radial directions.

34. In a turbine the combination with a high specific speed propeller type runner having blades with relatively flat curvature in the direction of flow thereover and inclined at a relatively large angle with respect to a meridian plane containing the turbine axis, of means forming a conduit for directing the flow inwardly and axially, and said runner being disposed in the axial portion of said conduit whereby the entrance edges of said runner receive the flow in a substantially axial direction, said axial portion of said conduit contracting in the direction of flow to a point substantially adjacent the blade tips and gradually enlarging in the direction of flow from a point substantially at or beyond the discharge side of said runner, and guide vanes inclined to an axial direction and spaced a substantial distance from said runner to form therebetween a transition space and said guide vanes being so disposed with respect to said transition space that the flow over the guide vanes has an axial component.

35. In a turbine the combination with a high speed propeller type runner having blades with entrance edges receiving the flow with an axial component, of guiding means for the inflow to said runner comprising a radial flow portion turning toward an axial direction and contracting and then expanding in the direction of flow said runner being disposed in the contracting side thereof, a transition space, and guide vanes pivoted on axes inclined to the runner axis and having diagonally inclined surfaces so disposed with respect to said transition space that fluid flows over said inclined surfaces with an axial component.

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