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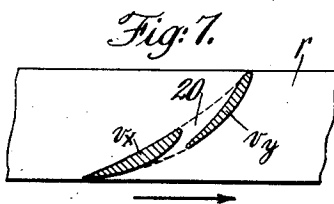
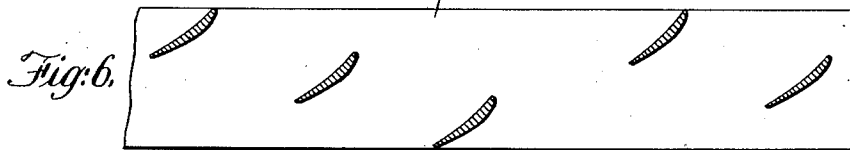
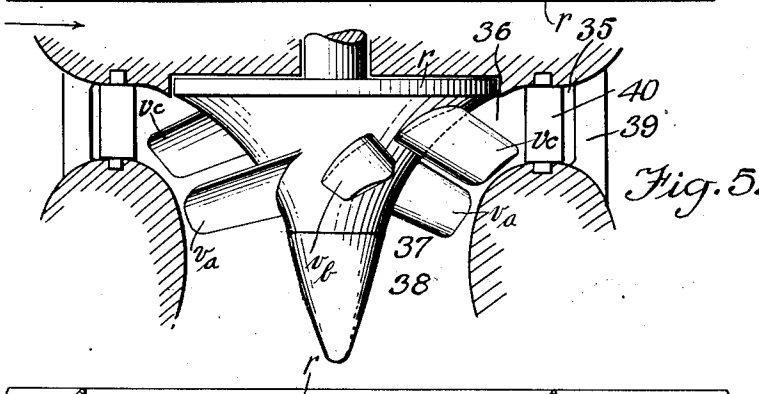
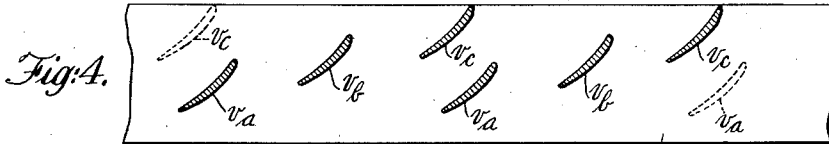
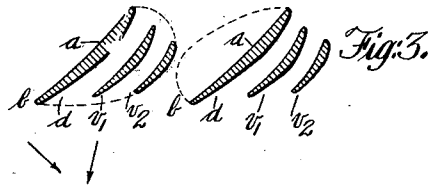
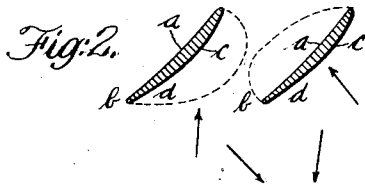
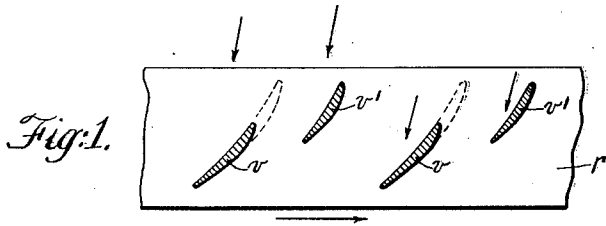
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VANE FORMATION FOR ROTARY ELEMENTS

Filed Jan. 29, 1921

2 Sheets-Sheet 1



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VANE FORMATION FOR ROTARY ELEMENTS

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2 Sheets-Sheet 2

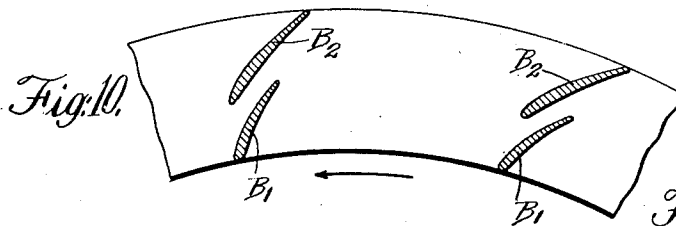
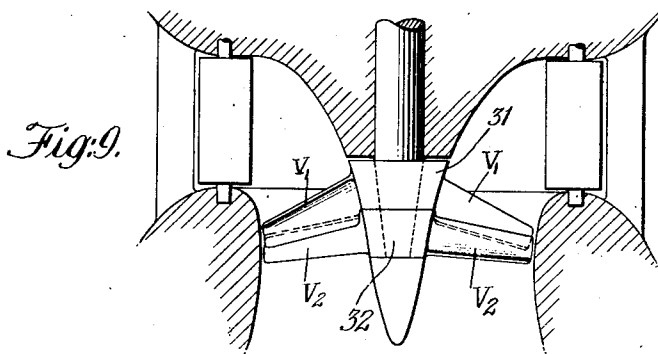
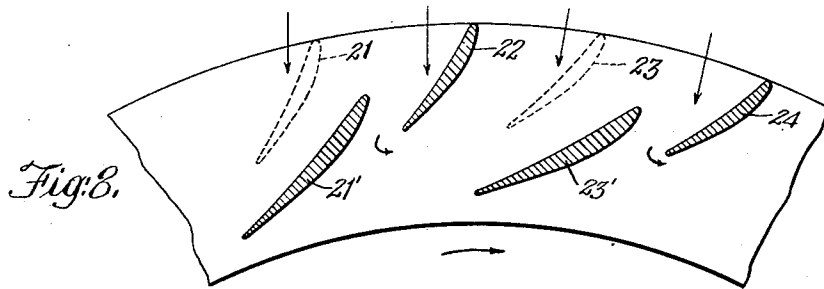
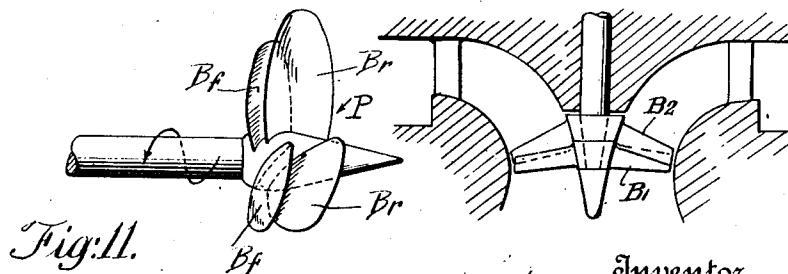


Fig. 10a.



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VANE FORMATION FOR ROTARY ELEMENTS

Application filed January 29, 1921. Serial No. 440,889.

This invention relates to rotary impellers or runners for turbines, pumps, blowers and the like and particularly to the blading of such rotary elements. Hitherto it has been the practice to form the blades of a rotary propeller or runner as a succession of similarly formed and equally spaced vanes so that all the channels between the vanes are exactly alike. In many cases this leads to complicated forms of vanes and to uncertain conditions of flow in the channels between the vanes so that the water tends to part from the surfaces or in other ways to form wasteful eddies and cross currents in the passing fluid, particularly under conditions of operation different from the normal or designed conditions.

The object of this invention is to provide an impeller or runner overcoming these objections and in which wasteful disturbances in the channels between the blades will be avoided.

In the accompanying drawings illustrating the invention,

Figs. 1 to 4 are diagrammatic developments of turbine runners.

Fig. 5 is a vertical elevation of the turbine runner shown in Fig. 4,

Figs. 6 to 8 are diagrams of modifications,

Fig. 9 is a vertical sectional view of a turbine having a runner in its conduit,

Fig. 10 is a diagrammatic development of a rotor for a pump,

Fig. 10^a is a diagrammatic view of a pump, embodying my invention, and

Fig. 11 is a vertical elevational view of a propeller.

In Fig. 1 a runner *r* of a hydraulic turbine is represented in diagrammatic development, the rotation or movement of the runner being from left to right and the vane structure shown being continued around the runner. Fluid flows to the runner through a radial passage 35, Figs. 5 and 9, surrounding the runner axis, a transition space 36 and axial passage 37 and discharges from the runner into a draft tube

38 which enlarges in the direction of flow so as to produce deceleration of the discharged fluid. These passages are defined by walls formed as surfaces of revolution. Fixed guide vanes 39 and the usual movable wicket gates 40 are also associated with the flow passages, the wicket gates imparting a whirl to the flow entering the transition space. The vanes are in the form of a series of groups, each group comprising a lower vane *v* and an upper vane *v'*. In another aspect the vanes may be considered as comprising an upper series *v'* and a lower series *v*, the series being offset with relation to each other. Vanes *v'* may be considered to take the place of an upward extension of the vanes *v*, as indicated by the dotted line continuation of these vanes *v* in Fig. 1. By this subdivided or grouped vane structure the guiding surfaces of the vanes may be positioned more advantageously with relation to each other than if they were contained in a single vane, for instance as illustrated in Fig. 2 there is often a tendency of the flow, particularly along the rear surfaces of the vanes, to develop wasteful eddies and disturbances. In the runner or impeller of a turbine or pump and also in the case of propellers and compressors the interaction of the fluid and vanes produces a region of increased pressure adjacent to the face or driving side *a* of each blade and a region of reduced pressure or partial vacuum adjacent to the back *c* of each vane. The flow at and near the face *a* (Figs. 2 and 3) is under conditions similar to those existing in a contracting nozzle and in this region the tendency toward eddy formation is reduced. At and near the back *c* of a blade, however, there is a tendency of the flow to lower in pressure and form eddies and leave the back surface of the vane, and particularly under part load the conditions of flow can be considerably improved by providing the vane *v'* above the vane *v* as shown in Fig. 1, tending to guide the flow against the back of the preceding

vane. This smaller vane v' may be given any desired form and inclination, for instance it may be given greater inclination than that of the vane v and increased curvature in order to deflect the water through a greater angle.

5 This auxiliary vane v' will have the effect of receiving the flow and deflecting it toward the back of the vane v in such a way as to prevent the formation of an eddy at this point. The

10 result of the use of the grouped vanes will be to enable the runner to handle the flow with better efficiency through a wide range of angles of the relative entrance velocity so that in the runner of this invention improved part

15 gate efficiencies and better performance under varying head will be attained. This grouping will also avoid the occurrence of unstable conditions in the runner such as

20 sometimes occur in runners of very high specific speed having a small number of vanes particularly at small gate openings or under conditions which differ from the normal designed condition.

Another grouping of the vanes also designed to improve the flow conditions between the vanes is shown in Fig. 3 wherein the intermediate vanes v_1 v_2 are positioned lower

25 down toward the low pressure or suction area at the back of the vane v . With the usual vanes under the conditions above described

30 the increased pressure at a on the vane face produces an increased velocity of the water at the discharge edge b and the reduced pressure at c on the vane back produces a reduced velocity or even a backward velocity at d . At

35 part gate or reduced speed of runner when the water impinges against the vanes at an angle requiring greater deflection than the vane is adapted to give efficiently, there is

40 probably a backward flow at d and an eddy behind the vane. There is thus acceleration of flow produced by the vane face and deceleration by the back. Most high-speed turbines are therefore "suction turbines" in the

45 portion of the buckets toward the backs of the vanes, and turbines with positive reaction in the portion of the buckets toward the vane faces. The inequality in velocity at d and b may be reduced by increasing the number of

50 vanes but this increases the surface friction. It then becomes a problem to design the runner for efficient guiding and diffusion of the flow at the backs of the vanes, the action at this point partaking of the nature of the flow

55 in a draft tube and the efficiency of the turbine suffering when the diffusion is too rapid and the water tends to leave the backs of the vanes and eddies are formed. In the modification illustrated in Fig. 3 the diffusion areas at the

60 back of the vanes v are broken up into a number of smaller diffusion channels by the auxiliary vanes v_1 v_2 , one or more for each vane v . The surfaces of this group of vanes v_1 , v_2 are arranged with relation to each other so

65 that the diffusion between them is gradual at

all points and not so rapid as to cause the flow to depart from the guides and set up wasteful disturbances. Thus in this figure a diffusing passage is formed between the back of vane a and auxiliary vanes v_1 and also between vanes v_1 and v_2 although the passage between the back of the vanes v_2 and the front of the following vanes a converges in the direction of flow thus causing acceleration of the flow. Hence broadly there are successive accelerating and decelerating passages, one following the other.

Another method of grouping the vanes with relation to each other is illustrated in Figs. 4 to 6 wherein each group of similar vanes is inclined with respect to its direction of rotation. This permits an advantageous respacing after the most favorable shape and arrangement of the individual vanes have been determined. In acting upon the face of a vane, the deflecting of the water sets up pressure, and on the back of the vane the pressure is reduced; the difference between the two pressures causes the useful driving force on the vanes. The frictional resistance of the vanes causes a backward drag on the vanes which reduces the effective driving force. An efficient form of vane is one which will exert a large force in the direction of motion, but a small resistance in the direction of flow. In an efficient vane the angle of the resultant force with the direction of motion will be small. In turbines of very high specific speed it becomes very important to secure an efficient shape of vane, and to arrange the vanes in proper relative positions, since high relative velocities and correspondingly high frictional resistance are involved. When the rotational speed of the runner is high, a small angle of inclination of the vanes to the tangential direction may be used, and a small number of vanes can be adopted and given a favorable arrangement. If the usual vanes are spaced too closely the water instead of having a tendency to leave the back of the vane and to reduce the pressure all over the back surface, as in Fig. 1 is directed back on the surface and the area of reduced pressure is brought down to only a small space near the entrance edge of the vane. If on the other hand the vane spacing is increased beyond a point where there ceases to be any further pressure reduction in the back of the vanes, there will, of course, be a loss due to the water passing between the vanes without having any effect upon them.

Suppose there has been found by experiment the most favorable arrangement of the vanes with respect to each other, as in Figure 1, and that it is desired to design a runner in which the inclination of the vanes to the direction of motion of the runner is greater, in order, for example, to obtain a greater discharge and higher power from a turbine of a given diameter. If the angle of the vanes is

changed by merely revolving them and keeping them in the same locations, their relation to each other will immediately be altered, and the favorable pressure conditions will be lost.

5 If however a group of vanes v_a , v_b , v_c for example as in Fig. 4, is inclined as a whole to a radial plane, keeping the same relative positions of the vanes, these can then be followed by a separate group spaced far enough
10 away to avoid disturbing the pressure conditions in the back of the vane immediately preceding the next group. In this manner a runner will be produced having vanes arranged in groups of say two or three to each
15 group, as shown in Figures 4, 6 and 7. The resulting arrangement may be viewed as if each vane in an ordinary runner were subdivided into two or three smaller vanes with intermediate passages between them. It thus
20 becomes possible to avoid the effect of too close or too wide spacing. Instead of the lower half of the vane being inefficient, due to the preceding vane directing water back against it, by opening the intermediate passage the lower half of the vane can be made
25 as effective as the first half without exposing any greater extent of surface to the water than in the first case. In these figures, as in Fig. 3, there are decelerating and accelerating passages, one followed by the other.
30 For instance the passage between vanes v_c and v_a enlarges in the direction of flow or permits deceleration while the passages between vanes v_b and v_c or vanes v_a and v_b contract in the direction of flow and thus cause acceleration. As shown in Fig. 6 the center
35 line of the group of vanes may be inclined downward to the right instead of to the left as shown in Fig. 4, and as illustrated in Fig. 7 the grouping may be provided by simply subdividing a single vane into two sub-vanes
40 v_x and v_y with a channel 20 between them. The best location for the intermediate passage 20 may not be in the middle of the vane, but the two subdivisions of the vane may be unequal in size, the proportions being subject to experimental determination for any particular type of runner. The subdivision
45 of a vane should not be carried too far, since additional losses will be imposed due to the expansion loss as the water leaves the discharge edge of each subdivision. The advantages to be secured will in many instances
50 more than offset the additional losses, and a subdivision of each vane into two parts will be particularly advantageous in high specific speed turbines and pumps.

In the modification illustrated in Fig. 8 the vanes 21', 22, 23' and 24 are so positioned that they will together have the minimum
55 retarding effect upon the flow and maximum useful thrust in the direction of rotation.

As one way of finding the best relative positions of the vanes of a group relatively adjustable hubs 31, 32 may be provided carry-

ing sets of blades V_1 , V_2 respectively arranged to alternate with each other as shown in Fig. 9. The two hubs will be rotated to give different relative positions of the vanes as by shifting the group of vanes 22, 24 (Fig. 8) to a different position, 21, 23, until the
70 best adjustment is found and the adjustment may be changed at any time to suit new requirements.

The principle of this invention is not confined to the runners of turbines as illustrated in the preceding figures but may be extended to pumps, blowers, rotary compressors and marine and air propellers. In Fig. 10 the blades of a centrifugal pump are shown arranged in groups of inner blades B_1 and outer blades B_2 inclined with relation to each other. In Fig. 11 the runner or propeller P has groups of dissimilar blades the forward auxiliary blades B_f being shorter than the rear
75 main blades B_r .

By this relative grouping of the vanes or blades of the rotor the flow through the rotor is made smooth and even and eddies and wasteful disturbances are avoided, thereby
80 reducing the loss of head and improving the efficiency of the energy conversion particularly when operating under conditions of speed and head or capacities different from the normal designed conditions.

When operating under other conditions than normal such that an eddy would be formed behind a blade of ordinary form, by subdividing the blade the formation of a single large eddy will be prevented and the eddy
85 will be broken up by the subdivision of the vanes into a number of smaller eddies, absorbing much less energy, and the better guidance provided for the water in the passages formed between the subdivisions will
90 considerably reduce the tendency toward eddy formation.

I claim:—

1. A hydraulic machine comprising a flow conduit having guiding walls and a rotor
95 having a hub carrying a circular series of vanes similar to each other and disposed in said conduit, and a second circular series of vanes having hydraulic cooperation with and disposed between the vanes of said first series, said second series also having their entrance edges axially displaced with relation to the entrance edges of the vanes of said first series and means adapted to impart
100 whirl to the fluid flowing to said rotor.

2. A hydraulic machine comprising a flow conduit having guiding walls and a rotor having a hub carrying a circular series of vanes similar to each other and disposed in said conduit, and a second circular series of
105 vanes having hydraulic cooperation with and disposed between the vanes of said first series, said second series also having their entrance and discharge edges axially displaced with relation to the entrance and discharge
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edges of the vanes of said first series and means adapted to impart whirl to the fluid flowing to said rotor.

3. A hydraulic machine comprising a flow conduit having guiding walls and a rotor having a hub carrying a plurality of similar vanes in a circular series around said hub in said conduit, and vanes intervening between said similar vanes and out of alignment therewith so as to differently control the flow lines in successive channels between said vanes.

4. A hydraulic machine comprising a flow conduit having guiding walls and a rotor having a hub carrying a plurality of similar vanes in a circular series around said hub in said conduit, and vanes intervening between said similar vanes each of said intervening vanes being relatively closely spaced to one of the adjacent vanes.

5. A hydraulic machine comprising a flow conduit having guiding walls and a rotor having a hub carrying a plurality of similar vanes in a circular series around said hub in said conduit, and vanes intervening between said similar vanes each of said intermediate vanes being relatively closely spaced to its preceding adjacent vane.

6. In a runner for a hydraulic turbine or pump, a plurality of similar vanes and intermediate vanes adjacent to the rear surfaces of said similar vanes to control the flow along said surfaces.

7. In a rotary impeller or runner, a rotor hub carrying a circular series of similar vanes and a plurality of intermediate vanes inclined with relation to said similar vanes so as to guide the flow along lines inclined thereto.

8. A hydraulic machine comprising a flow conduit having guiding walls, a rotor having a hub carrying a circular series of equally spaced vanes, and a second circular series of equally spaced vanes in said conduit between the vanes of said first series, each vane of the second series being spaced nearer to the rear surface of a preceding vane of the first series than to the front surface of the following vane of said first series.

9. In a rotary impeller or runner the combination with a circular series of equally spaced vanes, of a second circular series of equally spaced vanes between the vanes of said first series, each vane of the second series being inclined with relation to a corresponding vane of the first series and spaced nearer to the rear surface of said corresponding vane than to the front surface of the following vane of said first series.

10. In a rotary impeller or runner the combination with a circular series of equally spaced vanes, of a second circular series of equally spaced vanes between the vanes of said first series, each vane of the second series being inclined with relation to a correspond-

ing vane of the first series and spaced nearer to the rear surface of said corresponding vane than to the front surface of the following vane of said first series, the vanes of one series being of shapes different than the vanes of the other series.

11. In a rotary impeller or runner the combination with a series of vanes, of auxiliary diffuser guides between said vanes inclined with respect to said vanes to provide a passage enlarging in the direction of flow.

12. In a rotary impeller or runner a series of vanes forming passages between them and guides forming diffusers between said vanes inclined with respect to said vanes to provide a passage enlarging in the direction of flow.

13. In a rotor for a hydraulic turbine or pump the combination with a circular series of equally spaced blades, of a second series of blades between the blades of said first series and positioned with respect to the blades of said first series so as to provide between successive blades diffusing and accelerating passages one of which follows the other in alternating succession around the runner.

14. A hydraulic machine comprising a flow conduit having guiding walls and a rotor having a hub carrying a plurality of series of blades in said conduit, the blades in one series being similar to each other in form and position and equally spaced, but the blades in a second series being dissimilar in form to those in the said first series and offset in position with respect to the first series so as to subdivide unequally the spacing of the first series.

15. In a rotary runner for a hydraulic turbine or pump, a rotor hub carrying a series of similar blades equally spaced around the circumference and a series of subsidiary blades of smaller breadth measured in the direction of flow, said subsidiary blades being closer to the surfaces of reduced pressure of the first series and more distant from the pressure surfaces of the first series.

16. In a rotatable runner for a hydraulic turbine or pump, a hub and a plurality of groups of vanes thereon, the vanes of each group being offset with respect to each other circumferentially and in the direction of the axis of rotation, and the driving face of the leading vane of each group being directed toward the rear face of the succeeding vane.

17. In a rotatable runner for a hydraulic turbine or pump, a hub and a plurality of groups of vanes thereon, the vanes of each group being offset with respect to each other circumferentially and in the direction of the axis of rotation, and the driving face of the leading vane of each group being directed toward the rear face of the succeeding group.

18. In a rotatable runner for a hydraulic turbine or pump, a hub and a plurality of

groups of vanes thereon, the vanes of each group being offset with respect to each other circumferentially and in the direction of the axis of rotation, and the driving face of the leading vane of each group being directed toward the rear face of the succeeding vane, said vanes not being in the same spiral surface.

19. In a rotatable runner for a hydraulic turbine or pump, a hub and a plurality of groups of vanes thereon, the vanes of each group being offset with respect to each other circumferentially and in the direction of the axis of rotation, and the driving face of the leading vane of each group being directed toward the rear face of the succeeding group, said vanes not being in the same spiral surface.

20. A hydraulic turbine comprising in combination means forming a passage turning from radial to an axial direction, and a runner disposed in the axial portion of said passage for receiving an axial flow and having a hub carrying a circular group of vanes substantially similar to each other, and a second group of vanes between the vanes of said first group, said groups of vanes being relatively disposed so as to control the flow along the back surface of the vanes adjacent the discharge side of said runner.

21. A hydraulic turbine comprising in combination means forming a passage turning from a radial to an axial direction with a transition space therebetween, and a runner disposed in the axial passage having a hub carrying a circular group of vanes and auxiliary vanes between said other vanes, and means associated with the flow passage for imparting a whirling motion to the flow entering the transition space.

22. A hydraulic turbine comprising in combination means forming a passage turning from a radial to an axial direction with a transition space therebetween, and a runner disposed in the axial passage having a hub carrying a circular group of main vanes and auxiliary vanes between said main vanes for controlling the flow along the back surface of said main vanes adjacent the discharge side of said runner, and means associated with the flow passage for imparting a whirling motion to the flow entering said transition space.

23. A hydraulic turbine comprising in combination means forming a passage turning from a radial to an axial direction with a transition space therebetween, and a runner disposed in the axial passage having a hub carrying a plurality of circular groups of vanes, the entrance edge of the respective groups being axially offset with respect to each other, and means associated with the flow passage for imparting a whirling motion to the flow entering said transition space.

24. A hydraulic turbine comprising in combination means forming a passage turning

from a radial to an axial direction with a transition space therebetween, and a runner disposed in the axial passage having a hub carrying a circular group of vanes and auxiliary vanes between said other vanes for controlling the flow along the back surface of said main vanes adjacent the discharge side of said runner, and wicket gates disposed in the radial portion of said passage whereby a whirling component is adapted to be imparted to the flow entering said transition space.

25. A hydraulic turbine comprising in combination means forming a passage turning from a radial to an axial direction, and a runner disposed in the axial portion of said passage for receiving an axial flow and having a hub carrying a circular group of vanes substantially similar to each other, and a second group of vanes between the vanes of said first group, said groups of vanes being relatively disposed so as to control the flow along the back surface of the vanes adjacent the discharge side of said runner, and a discharge passage leading from said runner and enlarging in the direction of flow thereby to decelerate fluid discharged from said runner.

26. A hydraulic turbine or pump comprising in combination means forming a flow passage, and a rotor disposed therein and having a hub provided with groups of co-operating vanes, the center line of each group being inclined with respect to the rotor axis and certain of the vanes in each group having relatively axially displaced entrance edges.

27. A hydraulic turbine or pump comprising in combination means forming a flow passage, and a rotor disposed therein and having a hub provided with groups of co-operating vanes, each group having a main vane and a plurality of auxiliary vanes which successively have a shorter dimension in the direction of flow than an adjacent vane of the group.

28. A hydraulic turbine or pump comprising in combination means forming a flow passage, and a rotor disposed therein and having a hub provided with groups of co-operating vanes, each vane in a group being shorter than its succeeding vane in said group, and each vane being disposed in advance of its succeeding vane and having its entrance and discharge edges disposed substantially within the axial limits of the corresponding edges of said succeeding vane, and the vanes in each group being inclined with respect to each other so that passages enlarging in the direction of flow are formed therebetween.

29. A hydraulic turbine comprising in combination means forming a passage turning from a radial to an axial direction with a transition space therebetween, and a runner disposed in the axial passage having a hub carrying a plurality of circular groups of unshrouded vanes, the entrance edge of the respective groups being axially offset with re-

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spect to each other, and means associated with the flow passage for imparting a whirling action to the flow entering said transition space.

- 5 30. A high specific speed propeller type hydraulic turbine or pump comprising in combination means forming a flow passage, and a rotor disposed therein and having a hub provided with groups of cooperating
10 vanes, the center line of each group being inclined with respect to the rotor axis and certain of the vanes in each group having relatively axially displaced entrance edges.

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