

April 5, 1927.

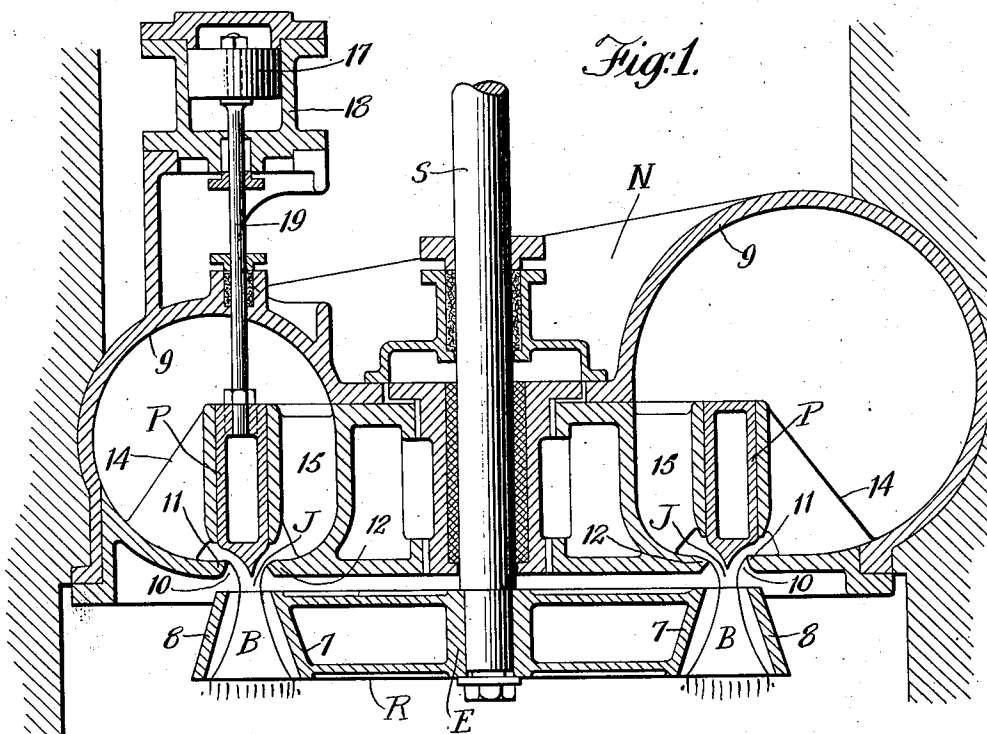
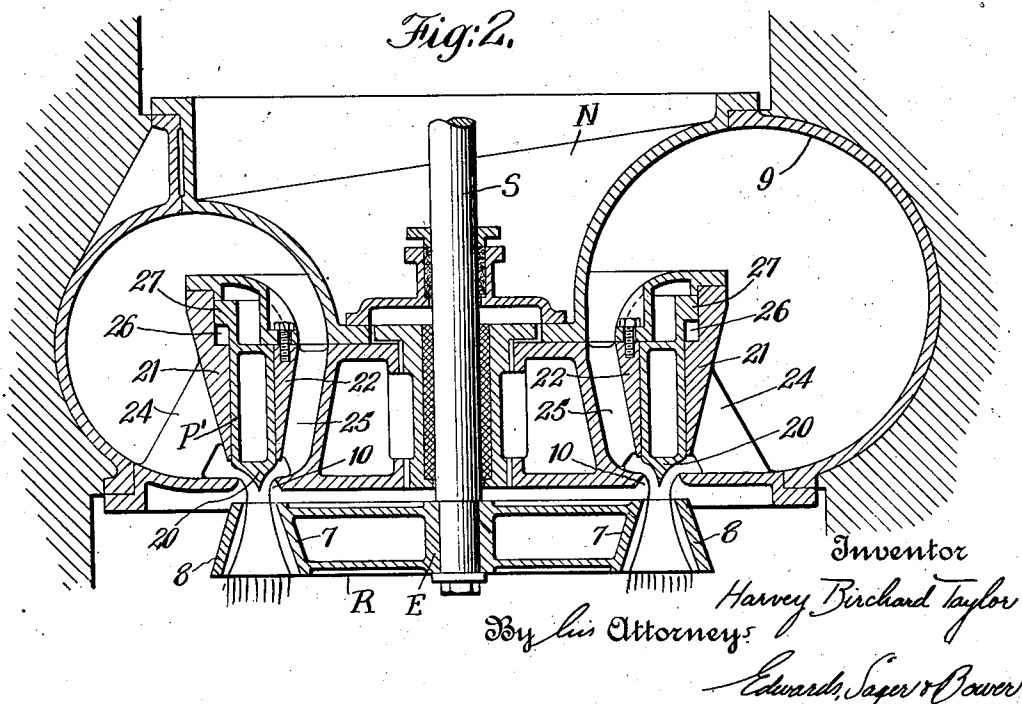
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H. B. TAYLOR

IMPULSE TURBINE.

Filed Nov. 20, 1920

6 Sheets-Sheet 1



Inventor

Harvey Birchard Taylor
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By his Attorneys:

Edwards, Sager & Bower

April 5, 1927.

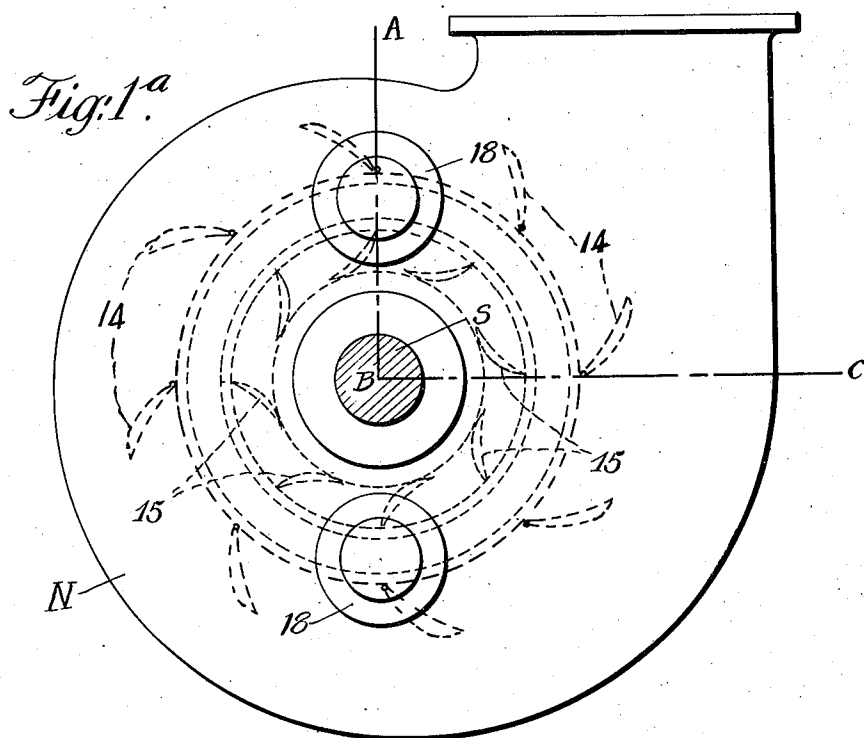
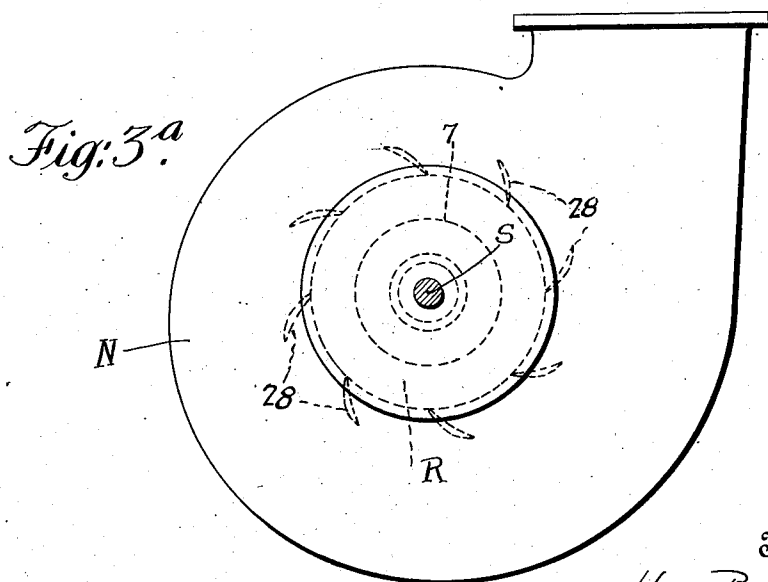
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IMPULSE TURBINE

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6 Sheets-Sheet 2



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IMPULSE TURBINE

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6 Sheets-Sheet 3

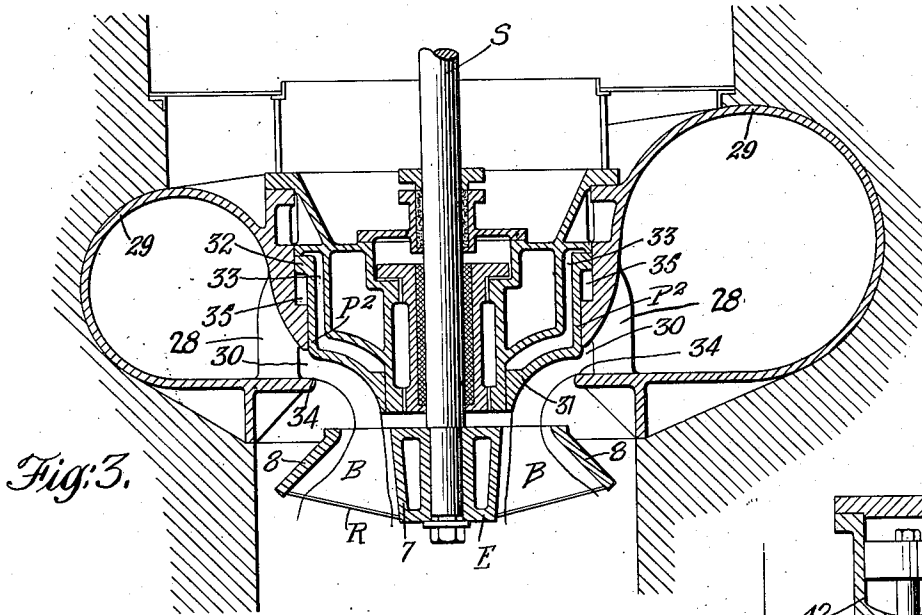


Fig. 3.

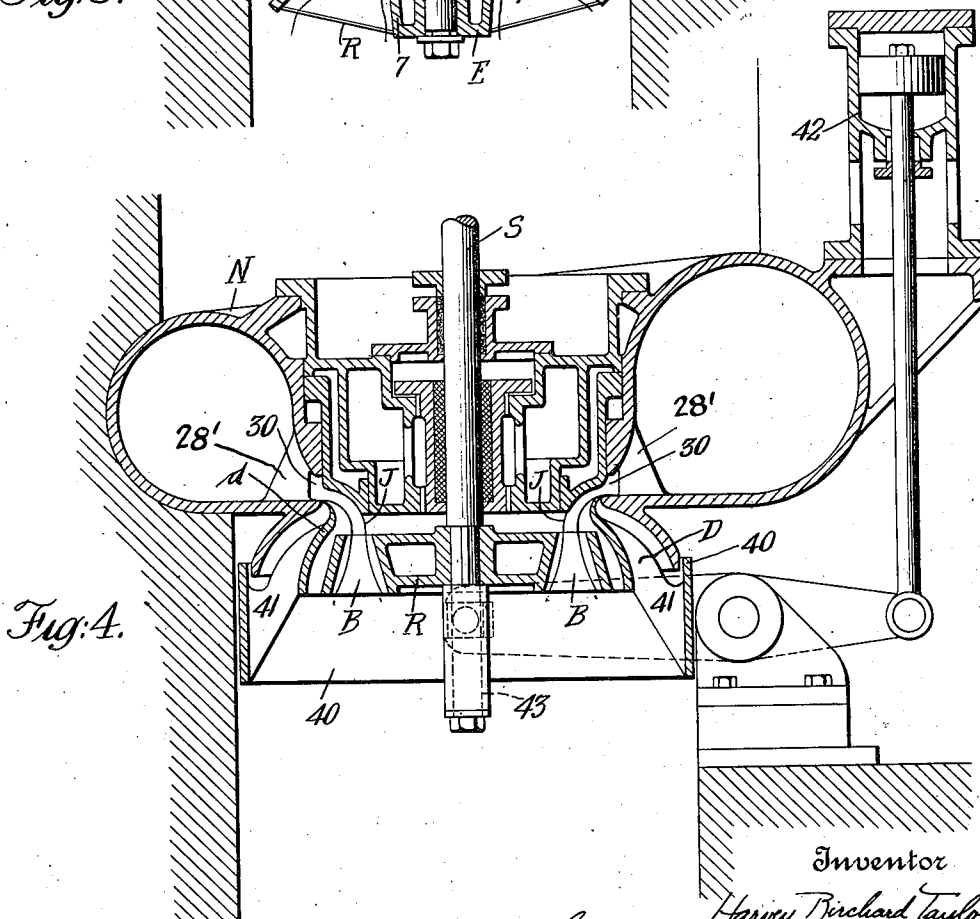


Fig. 4.

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Fig. 3^b.

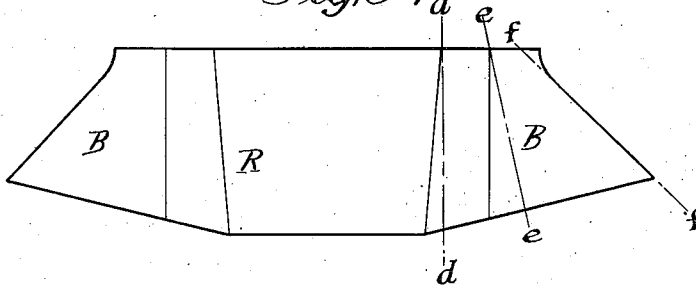


Fig. 3^c.

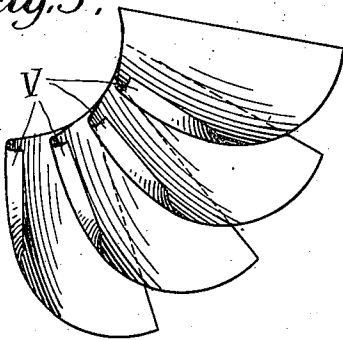
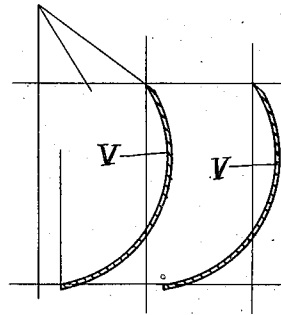


Fig. 3^d.

Fig. 3^e.

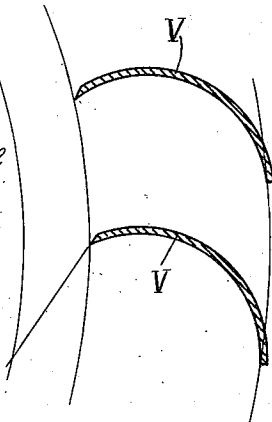
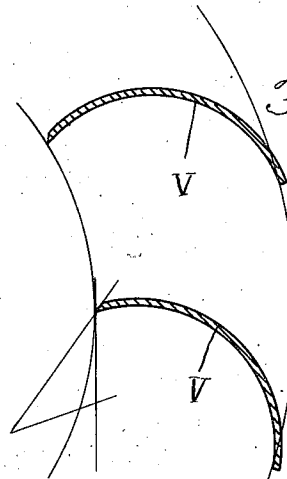


Fig. 3^f.



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6 Sheets-Sheet 5

Fig. 4^a.

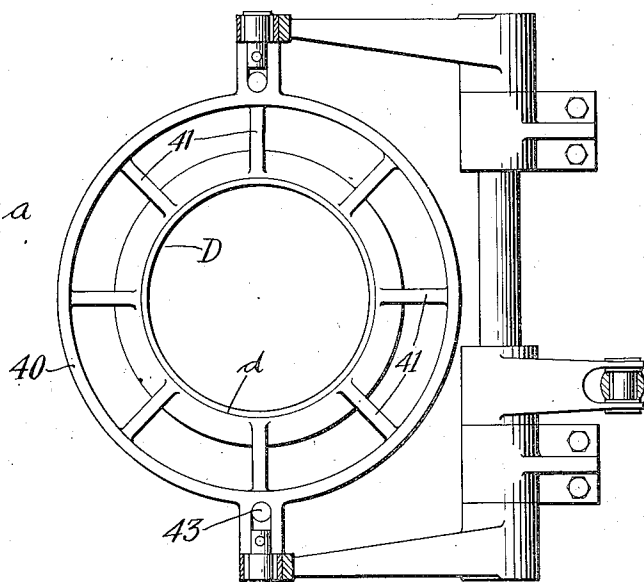
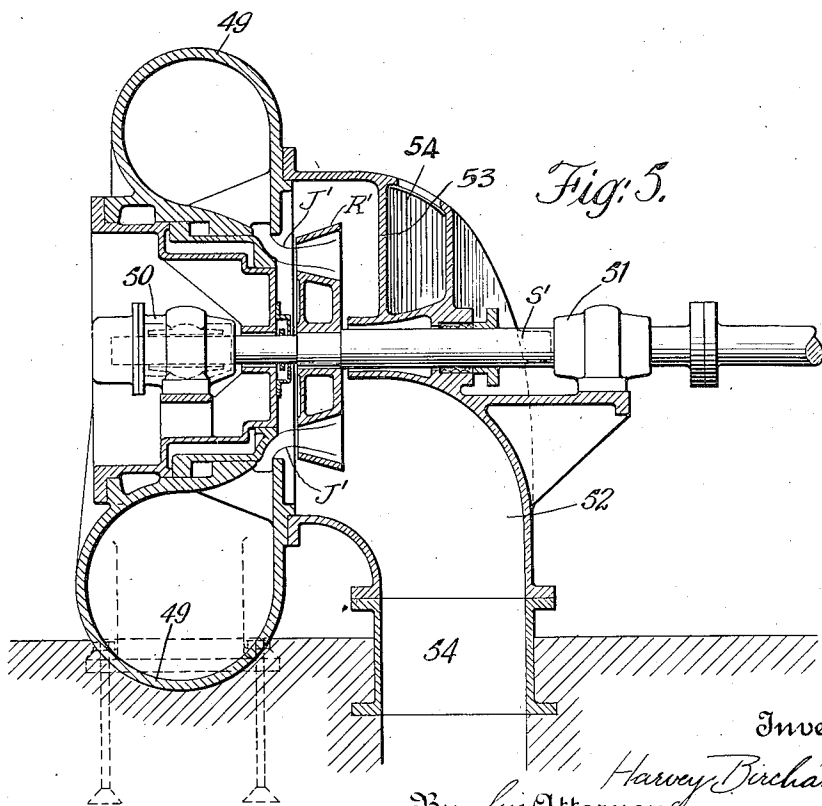


Fig. 5.

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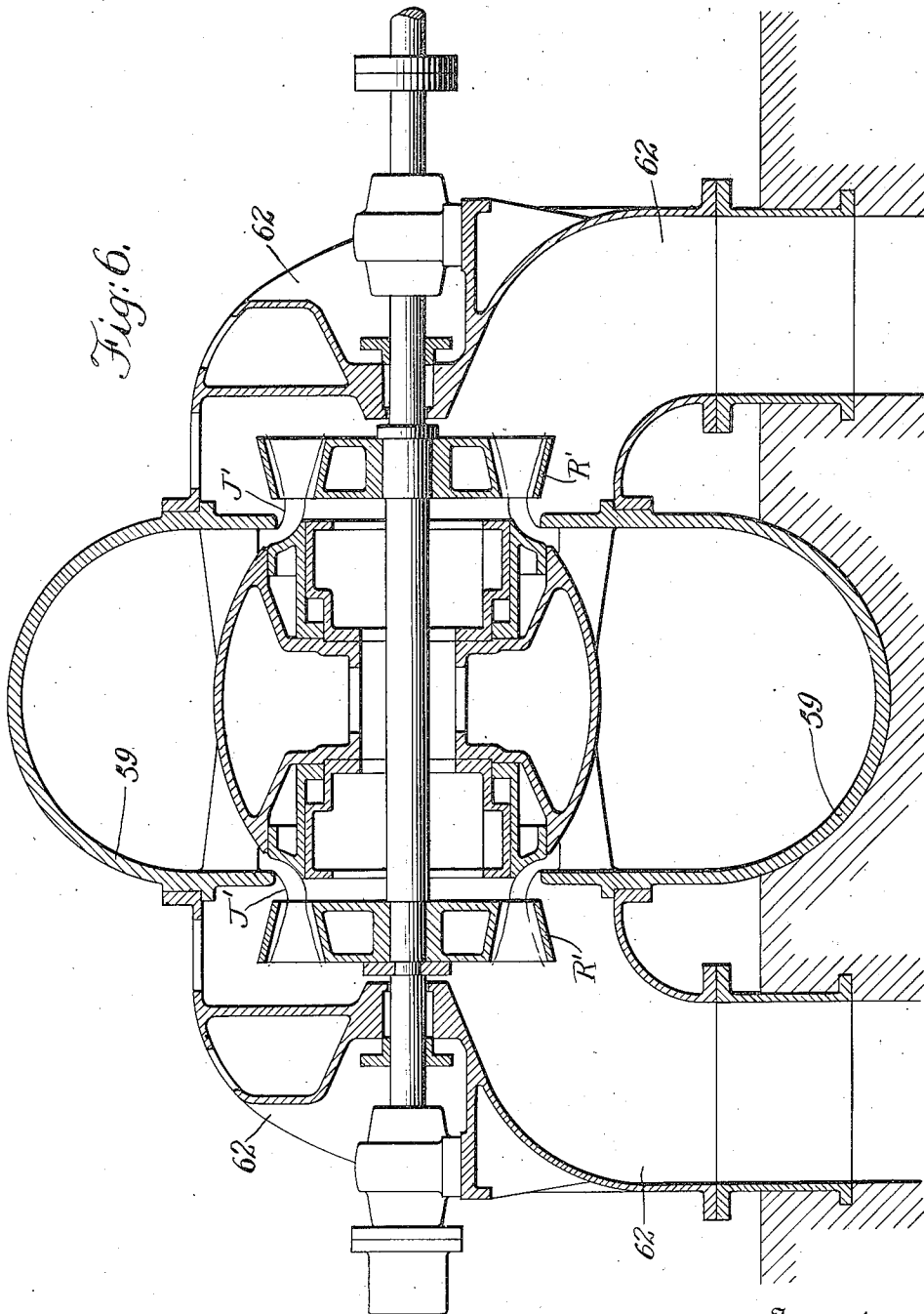
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IMPULSE TURBINE

Filed Nov. 20, 1920

6 Sheets-Sheet 6



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UNITED STATES PATENT OFFICE.

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IMPULSE TURBINE.

Application filed November 20, 1920. Serial No. 425,318.

This invention relates to hydraulic turbines and particularly to turbines of the free jet or impulse type. Such turbines are advantageous over reaction turbines in many ways and especially in maintaining the efficiency under conditions of variable output and in avoiding the injurious corrosion which frequently occurs in reaction turbines. Impulse turbines have been limited in application, however, to relatively high head installations due to their relatively low specific speeds since such low specific speeds increase the sizes of the parts and make the first cost of installation excessive, affecting not only the turbines but also the generators or other driven machinery and the entire power station.

By the term "impulse turbine" is meant a turbine having a free jet acting upon the vanes of the turbine runner, in which the energy due to the head is converted into the kinetic form before the water enters the runner, and in which the water has free surfaces exposed to the air during its passage through the runner.

The chief object of this invention is to provide an impulse turbine adapted for both high and moderate heads, and one which will have a high specific speed enabling it to take the place of reaction turbines in many installations where according to prior practice only reaction turbines would have been used. A further object of the invention is to provide an impulse turbine in which the action of the jet on the wheel will be continuous around the wheel so that all the buckets are in uninterrupted operation and each bucket continuously develops its full quota of power. A further object of my invention is to provide an improved means for forming a free annular jet having tangential velocity components around the axis. Further objects of the invention involving, among other things, the provision of a compact inexpensive structure which may be accurately machined by simple boring and turning processes, and containing simple means of controlling and of effectually shutting off the flow, will appear from the following description taken in connection with the accompanying drawings, in which—

Figure 1 is a vertical sectional view through a vertical shaft turbine illustrating one embodiment of the invention, taken on

line A—B—C— of Figure 1^a; Figure 1^a is a plan view of the turbine of Figure 1; Figures 2 and 3 are sectional views of modified forms; Figure 3^a is a plan view of the turbine of Figure 3; Figure 3^b is a diagrammatic view showing in outline a vertical section of a runner adapted for use in the turbine of this invention; Figure 3^c is a diagrammatic view showing in plan four of the vanes of the runner outlined in Figure 3^b; Figure 3^d is a diagrammatic developed cylindrical section of the runner vanes along the line *d, d* of Figure 3^b; Figures 3^e and 3^f are respectively diagrammatic conical sections of the runner along the lines *e, e* and *f, f* respectively of Figure 3^b; Figure 4 is a vertical sectional view of a modified form of the turbine equipped with a deflector; Figure 4^a is a plan view showing the deflector of Figure 4 and its operating mechanism; Figure 5 is a vertical sectional view of a horizontal shaft turbine embodying the invention; and Figure 6 is a vertical sectional view of a double horizontal shaft turbine.

In the specific embodiment of the invention shown in Figure 1 a runner R has a vertical shaft S and a hub E carrying the buckets B between the inner band 7 and the outer shroud ring 8. The flow through these buckets is downward in a direction which in turbines designed for very high specific speeds is inclined at only a moderate angle to the axial direction, and in such turbines of very high speed the buckets are inclined forward in the direction of rotation of the runner at their entrance edges. In turbines of more moderate specific speed the jet is inclined at a greater angle to the axial direction, that is with the direction of flow more nearly at right angles to a meridian plane, and the entrance portions of the buckets occupy a general direction which is much nearer axial, that is more nearly parallel to a meridian plane.

The water is directed onto the buckets as a free jet J in the form of a ring of water contained between an inner and an outer surface of revolution and continuous around the entire runner. These surfaces of revolution are indicated by light lines extending across the buckets B in Figures 1 and 2. The jet J is formed by the nozzle N comprising the hollow casing 9 passing around the shaft S and having an annular orifice 10 opening toward the runner R, the inner and

outer edges 12, 11 of the orifice being circularly concentric around the axis of the turbine so that each section of the orifice is bounded inside and outside by concentric arcs. The flow may be led into this casing in any desired manner, and in the specific embodiment shown the casing is of general spiral or volute form of varying cross-section around the circumference. The final guiding edges 11, 12 of the casing approach the orifice aperture 10 at sufficient angles to cause the jet J to be narrowed in section beyond the aperture by the convergence of the flow lines. Thus at the area of highest velocity the jet is free and not in contact with guiding surfaces.

The directions of lines of flow of the jet J may be such that their meridian components, that is their components in planes containing the runner axis, are either parallel to the axis of the runner or inclined inward or outward. In either of the latter cases the jet becomes generally conical instead of approximately cylindrical as shown in the figures. The runner of this invention is particularly adapted for high specific speeds of rotation, and when designed for very high speeds its buckets or vanes B are inclined at relatively large angles across the lines of flow so that a given increment of jet movement in a direction at a small angle with the axis will correspond to a relatively large rotational movement of the runner. The tangential components of flow of the issuing jet are given by guide vanes 14, 15 in the casing 9 in advance of the orifice 10, these guide vanes in Figure 1 being in the form of curved or inclined fins projecting from the inner and outer walls. Although the tangential components of flow of the free jet will in general be moderate in amount, they are necessary to permit the runner to develop the required torque while permitting the water to leave the runner in directions as nearly as possible in meridian planes, that is, in planes containing the turbine axis. By designing the runner for high circumferential velocities and correspondingly low torque, the tangential components of motion of the jet may be kept moderate in comparison with the axial components of flow.

The turbine is regulated by varying the thickness of the jet J for instance by increasing or decreasing the cross sectional area of the orifice 10 as by an annular plunger P shaped to have a circular wedge interposed in the orifice and movable to vary the flow therethrough. In the embodiment shown in Figure 1 the plunger P may be seated against the edges of the jet orifice 10 to shut off the flow altogether, the plunger being actuated by two or more fluid pressure operated pistons 17 working in cylinders 18 on top of the casing 9 and connected to the

plunger by rods 19. The fluid pressure for these pistons is controlled by the governing means for the turbine.

On account of the tangential velocity components introduced into the jet by the inclined guide vanes 14, 15, care must be taken to give sufficient contraction to the nozzle so that there will be no diffusion of the jet up to the point where it enters the runner R, because if the nozzle is not formed to cause the jet to contract after it leaves the nozzle edges, the tangential or whirling components of the jet lines will cause the jet to spread outward so as to become diffused. Particularly at the outer surface of the jet the contraction must be considerable, since the jet contour for a series of inclined straight lines would be a hyperboloid of revolution and it is desirable to have the jet enter the runner within the contracting portion of the hyperboloid surface. The jet must be formed so as to contract in area until it enters the runner R. The "gorge circle" of the hyperboloid should be at or below the runner entrance. The jet contour should fall outside of the hyperboloid and gradually come into coincidence with it or approach it at the runner entrance.

The turbine of this invention is capable of producing extremely high specific speeds, as much as five or ten times those heretofore realized in impulse turbines, and at the same time high efficiencies will be secured. The losses due to surface friction are greatly diminished as compared to a reaction turbine, since the jet although moving with a higher velocity than is commonly employed in reaction turbines, that is, in this case a velocity corresponding to the entire initial head, does not flow in contact with stationary surfaces while it is traveling at its high velocity. The nozzle being designed to have a considerable amount of contraction, the water does not reach its full velocity until it is clear of the nozzle surface, and then travels in contact with the air until it enters the runner. In the runner it is in contact only with the faces of the runner vanes B, and is in contact with air on three sides of the jet as it passes through the wheel, the blades being formed to have their rear surfaces clear the flow. It is proposed to employ high velocities of revolution of the runner, and in consequence there will be high relative velocities between the water and wheel vanes, but a reduction in area of surface exposed to the water will keep the surface friction loss from becoming excessive.

An important advantage of the impulse turbine of this invention is that while securing the hydraulic benefits just described it also retains a valuable property of the circular jet needle nozzle impulse turbine, namely, the use of a nozzle which can be ac-

curately machined by boring and turning processes, and which can be closed by a plunger machined by similar processes, and so arranged that the plunger may be forced against its seats with considerable pressure and thus provide tight closure. The turbine is simple in structure and capable of economical manufacture, and has few moving parts. While in practice impulse turbines have heretofore been restricted to specific speeds below ten, the turbine constructed in accordance with my invention permits the attainment of specific speeds of 50 (ft.-lb. units) and over without involving any factors which would make high efficiency impossible. It is believed that specific speeds as high as 75 can be secured without undue sacrifice of efficiency. This will make it possible to employ impulse turbines in many places where reaction turbines are now the only type which can be used. It will frequently be very desirable to use impulse turbines instead of reaction turbines for moderate heads. Under such heads as 200 ft., for example, dangerous corrosion sometimes occurs in reaction turbines. One of the chief causes of corrosion is the confining of the water in closed conduits at high velocity, these conduits having varying areas and curvature. In such conduits points of high local velocity and corresponding low pressure are likely to occur, resulting in conditions favorable to hydraulic corrosion. In the impulse turbine the flow is open to the atmosphere or to air at a pressure not greatly different from that of the atmosphere, and hydraulic corrosion is unlikely to occur. The turbine of this invention will also be particularly valuable when used for units of extremely high power under moderate heads, for example, heads or between 500 and 1000 ft., and unit capacities in the neighborhood of 50,000 H. P. Under these conditions, impulse turbines of the prior art are of too low specific speed to be used, since the actual speed would be so low as to require a very expensive installation. Under the same conditions, reaction turbines are commonly used, but are objectionable in many cases due to rapid corrosion and wear and loss of efficiency due to increasing leakage during the life of the unit.

In the modified form of turbine shown in Figure 2 the plunger P' is in the form of a hollow ring having an annular wedge 20 moving to control the flow through the orifice 10. The body of the plunger forms an annular piston fitting between the cylinder walls 21, 22 of the casing and operated by fluid pressure in the space above it. A secondary cylinder space 26 is provided when desired to assist in opening the plunger. Fluid pressure when admitted to this space acts upon the outer flange 27 of the plunger P' , and adds to the upward force of the

water on the lower face of the plunger. The sliding fit between the plunger and flanges may be made as deep as desirable to avoid canting or cocking of the plunger. Guide vanes 24, 25 extend from the casing to the walls 21, 22 across the lines of flow and impart the desired whirl to the jet, as shown in connection with the guide vanes 14, 15 of Fig. 1.

In Figure 3 the casing 29 has an inward radially directed orifice 30 and across this orifice moves the plunger P^2 having its lower end 31 curved to turn the jet axially onto the runner R below. Axial movement of this plunger P^2 varies the size of the orifice 30 to vary the size of the jet which continues to form a circular sheet of water and simply changes in thickness. The plunger P^2 has its upper part 32 fitted into a chamber 33 so as to be controlled by fluid pressure. In both Figures 2 and 3 the upward movement of the plunger may be due to the pressure of the water on the face of the plunger, the pressure above being released, and to initially unseat the plunger it may be made so that when closed it extends from its seat 34 upward and outward away from its axis so that there is a component of the pressure against the plunger tending to force the same upward; or a secondary piston space 35 may be added as shown to provide or to increase the necessary upward force. The inclination of the stay vanes 28 from a radial direction so as to impart tangential components to the flow is shown in Fig. 3^a.

In Figs. 3^b to 3^c a form of runner is shown having vanes B suitable for the turbine of this invention. When extremely high specific speed is desired, the form of the vane sections shown in Fig. 3^d will be modified particularly in inclining the upper or entrance portions of the vanes more forward in the direction of rotation of the runner which is from left to right in the view shown. The runner surface receiving the jet is thus of generally concave or cup shape so as to turn and spread the flow lines and the surfaces expand in the direction of flow as shown clearly in Figs. 3^b and 3^c.

Where the regulation of the turbine by restriction of the flow is liable to cause excessive changes in pressure at sudden variations of the load a deflector may be provided to temporarily turn aside a portion of the jet. Figures 4 and 4^a show the turbine equipped with an annular deflector D , comprising a ring d which can be moved axially into the jet for the purpose of diverting an annular sheet of water and bypassing it around the runner. In cases of sudden load changes the deflector would act temporarily to regulate the flow to runner, the action of the deflector being followed by the adjustment of the slower moving plunger. In the specific embodiment shown the deflector d is

supported by a ring 40 through connecting ribs 41, and ring 40 is actuated by the fluid pressure cylinder 42 and connecting mechanism shown. The ring 40 is guided by the vertical pins 43 which are carried by the turbine casing. Instead of using a deflector, the turbine may be equipped with a relief valve or separate bypass nozzle connected to the penstock or casing. The stay vanes 28' are inclined to a radial direction, so as to impart tangential components to the flow as shown in Fig. 3^a in connection with the stay vanes of the Fig. 3 turbine.

In Figure 5 the invention is illustrated as embodied in a horizontal shaft unit, the flow entering the volute inlet casing 49 from below and being passed through the runner R' and collected in the discharge casing 52 and carried down through the station floor. The horizontal shaft S' is carried by the bearings 50, 51 shown, one of which, 50, is a thrust bearing to carry the axial component of the impulse of the jet. The discharge passage increases in area downwardly not only in a radial direction but also in a direction parallel to the shaft S'. The rear casing wall approaches the runner most closely at the apex 53, thus forming at this point a central dividing wedge meeting at the apex 53. The passage may be said to have a form of a double spiral of two helicoidal surfaces.

Figure 6 shows a double horizontal shaft turbine having a common casing 59 discharging annular jets in opposite directions upon two oppositely arranged runners R'. Two discharge casings 62 similar to that of Figure 5 receive the runner discharge. The axial thrusts of the two runners are balanced, a desirable feature in a horizontal shaft turbine since it obviates the use of a large thrust bearing.

Under usual conditions the turbine of this invention will be designed for a jet thickness of roughly one-tenth its outer radius, that is the distance from the axis of the runner to the outer surface of the jet at a point where the outer surface is nearest the axis; but for very high specific speeds the turbine will be designed for a jet thickness as much as one-quarter or even one-third the outer jet radius.

In the free jet turbine of this invention a single jet with a single plunger control supplies and controls the flow to all of the runner buckets continuously and thus does the work of a number of jets and their respective controls usual in prior impulse turbines, which at most acted upon the runner buckets for only a small part of their travel. The windage loss of the idle buckets is thus eliminated. The turbine of this invention is also advantageous in simplicity and compactness of structure and in the attainment of greatly increased specific speed,

enabling the whole installation for a given power output to be reduced in size with resultant saving in cost.

I claim:—

1. An impulse turbine having a runner provided with a circular series of buckets and means forming an inlet passage having an annular orifice for directing an axially progressing continuous circular jet against all of said buckets simultaneously.

2. An impulse turbine provided with a runner and an inlet casing having an annular jet forming orifice facing downward around the runner shaft adapted to direct a jet with axial components against said runner.

3. An impulse turbine provided with a runner and an inlet casing having an annular jet forming orifice around the runner shaft adapted to direct a jet axially against said runner.

4. An impulse turbine provided with a runner and an inlet casing having an annular jet forming orifice around the runner shaft adapted to direct the jet against the runner and separate plunger means cooperating with said orifice for controlling the flow of liquid therethrough.

5. In an impulse turbine the combination with a runner, of an inlet casing having an annular jet forming orifice around the runner shaft adapted to direct a jet against said runner, and a separate annular plunger controlling the flow through said orifice.

6. In an impulse turbine the combination with a runner, of an inlet casing having an annular jet forming orifice around the runner shaft adapted to direct a jet against said runner, and an axially movable annular plunger controlling the flow through said orifice.

7. An impulse turbine having in combination with a runner of the free jet or impulse type, means for forming a jet having in section a form which is bounded by concentric arcs and means for imparting to the flow of said jet a component of velocity tangential to said arcs.

8. In an impulse turbine the combination with a runner of the free jet or impulse type, of an inlet passage having an annular orifice directing a continuous circular jet against said runner and means in said passage for imparting to said jet tangential components of flow with respect to the axis of said runner.

9. An impulse turbine having means for forming an axially progressing circular jet containing tangential components of motion and a runner having a circular series of buckets continuously acted upon by said jet.

10. In an impulse turbine the combination with means for forming an axially progressing circular jet containing tangential components of motion of a runner having a cir-

cular series of buckets continuously acted upon by said jet and means for varying the thickness of said jet to control the speed of said runner.

5 11. In an impulse turbine the combination with means for forming an axially progressing circular jet containing tangential components of motion of a runner having a circular series of buckets continuously acted
10 upon by said jet and axially movable means for varying the thickness of said jet to control the speed of said runner.

12. An impulse turbine provided with a runner and a spiral entrance casing having
15 an annular jet forming orifice adapted to direct a circular jet against said runner.

13. In an impulse turbine the combination with a runner, of a spiral entrance casing having an annular jet forming orifice adapted
20 to direct a circular jet against said runner and guide vanes in said casing adapted to impart to said jet tangential components of flow around the axis of the runner.

14. In a turbine the combination with an
25 annular nozzle forming a circular jet directed over all of the runner vanes simultaneously, of a runner having vanes receiving said jet, said vanes being constructed to rotate the runner at a rate corresponding
30 to a specific speed of over 50 for the turbine.

15. In a hydraulic turbine the combination with a runner of the impulse type, of a
nozzle forming an annular jet bounded by inner and outer surfaces of revolution.

35 16. In a hydraulic turbine the combination with a runner of the impulse type, of a nozzle forming an annular jet bounded by inner and outer surfaces of revolution and control means in said nozzle for varying the
40 thickness of said jet by varying the distance between said surfaces.

17. An impulse turbine having in combination with an inlet casing having guiding
45 means forming a free annular jet with axial components around a central axis, a runner coaxial with said jet and means controlling said jet.

18. In an impulse turbine the combination with an inlet casing having guiding means
50 forming a free annular jet with axial components around a central axis, of a runner coaxial with said jet and means controlling said jet by varying its thickness.

19. An impulse turbine provided with an
55 inlet casing having guiding means having surfaces converging toward a downwardly directed annular orifice discharging the water axially around a central axis, and a runner coaxial with said guiding means.

60 20. An impulse turbine provided with an inlet casing having guiding means having surfaces converging toward an annular orifice discharging the water around a central axis in a general axial direction, and an axial
65 flow runner coaxial with said guiding means.

21. An impulse turbine provided with a nozzle having guiding means discharging the water in an annular space around a central axis, the distance between the surface
70 of the stream nearer the axis and that farther from the axis being at least one fourth of the radius of said space.

22. An impulse turbine provided with a nozzle having guiding means discharging the water as an annular jet around a central
75 axis, the sectional area of said jet normal to said axis being at least one fifth of the area of its outer circle.

23. In an impulse turbine the combination with a nozzle having guiding means dis-
80 charging the water in an annular space around a central axis with axial components, of a runner spaced from said nozzle to permit a contraction of the flow in the space between the nozzle and the runner.

24. In an impulse turbine the combination with a nozzle having guiding means dis-
85 charging the water in an annular space around a central axis, of a runner spaced from said nozzle, the streams converging so as to contract the flow in said annular space between said nozzle and said runner.

25. In an impulse turbine the combination with an annular jet forming means and a
90 runner, of means for temporarily bypassing a portion of the flow around the runner.

26. In an impulse turbine the combination with an annular jet forming means and a
95 runner, of means acting upon said jet between said jet forming means and the runner thereby diverting a portion of the flow so that it will not pass through the runner.

27. In an impulse turbine the combination with an annular jet forming means, of means
100 for shutting off said jet comprising an annular plunger closing with motion normal to the seat.

28. In a hydraulic turbine a nozzle circularly symmetrical about an axis adapted to
105 produce a free annular jet and containing guiding means to give the jet both meridian and tangential components of flow with respect to said axis, and said jet forming a continuous body of fluid around the axis.

29. In a hydraulic turbine a nozzle circularly symmetrical about an axis adapted to
110 produce a free annular jet containing guiding means to give the jet both meridian and tangential components of flow with respect to said axis, and the walls of said nozzle
115 being formed to direct the outer and innermost stream elements convergently toward each other to preserve a continuous body of fluid from the nozzle to the runner entrance.

30. In a hydraulic impulse turbine the
120 combination with a nozzle adapted to form a hollow circular free jet with axial components of a runner receiving said jet and rotated thereby.

31. In an impulse turbine the combination 130

with a runner, of an entrance casing having an annular jet forming orifice adapted to direct a circular jet against said runner, and guide vanes in said casing adjacent said orifice and adapted to impart to said jet tangential components of flow around the axis of the runner.

32. In an impulse turbine the combination with a runner, of an entrance casing having an orifice adapted to form a jet having a free surface and to direct said jet against said runner, and inclined guide vanes in said casing extending in close proximity to the edge of said orifice forming said free surface of said jet and adapted to impart to said jet tangential components of flow around the axis of the runner.

33. An impulse turbine having in combination with a runner of the free jet type means for forming a jet, directed against said runner, having in transverse section a form which is bounded by an inner arc and an outer concentric arc of longer radius.

34. In a turbine the combination with means for forming a circular jet with axial components which is directed over all of the runner vanes simultaneously, of a runner having vanes inclined in the direction of rotation of the runner so that the runner rotates at a rate corresponding to a specific speed of over 10 for the turbine.

35. In a turbine the combination with an annular nozzle for forming a circular jet with axial components which is directed over all of the runner vanes simultaneously, of a runner having vanes inclined in the direction of rotation of the runner so that the runner rotates at a rate corresponding to a specific speed of over 10 for the turbine, and means for controlling the thickness of said jet.

36. Apparatus for converting hydraulic energy into useful work comprising a runner and means for guiding water under pressure into an annular stream and discharging said stream as an annular axially progressing jet having an inner cylindrical free surface and an outer cylindrical free surface, and projecting said jet axially against the blades of said runner to use the kinetic energy of the jet to rotate said runner.

37. Apparatus for converting hydraulic energy into useful work comprising a runner and means for guiding water under pressure into an annular stream with rotational components around its axis and discharging said stream as an annular axially progressing jet having an inner cylindrical free surface and outer cylindrical free surface, and projecting said jet axially against the blades of said runner to use the kinetic energy of the jet to rotate said runner.

38. In an impulse turbine the combination with a runner, of an inlet casing having an annular jet forming orifice around the runner shaft adapted to direct a jet against said runner, and an axially movable annular plunger controlling the flow through said orifice, said annular plunger having a curved annular surface turning the flow lines from a radial toward an axial direction.

39. In an impulse turbine the combination with a runner, of an inlet casing having an annular jet forming orifice around the runner shaft adapted to direct a jet against said runner, and an axially movable annular plunger controlling the flow through said orifice, said annular plunger having a curved annular outer surface turning the flow lines from an inward direction toward an axial direction.

40. In an impulse turbine the combination with a runner, of an inlet casing having an annular jet forming orifice around the runner shaft adapted to direct a jet against said runner, and an axially movable annular plunger controlling the flow through said orifice, said annular plunger having a curved outer surface adapted to turn the entire flow toward an axial direction.

41. In an impulse turbine the combination with a runner, of an inlet casing having an annular jet forming orifice around the runner shaft adapted to direct a jet against said runner, and an axially movable annular plunger controlling the flow through said orifice, said annular plunger having a curved outer surface adapted to turn the entire flow toward an axial direction and forming the inner surface of the jet.

42. An impulse turbine having means for forming an axially progressing circular jet containing tangential components of motion and a runner having a circular series of buckets continuously acted upon by said jet, said means comprising a spiral intake chamber.

43. An impulse turbine having means for forming an axially progressing circular jet containing tangential components of motion and a runner having a circular series of buckets continuously acted upon by said jet, said means comprising a spiral intake chamber with an annular jet opening disposed in a side wall of said chamber.

44. An impulse turbine having means for forming an axially progressing circular jet containing tangential components of motion and a runner having a circular series of buckets continuously acted upon by said jet, said means comprising a spiral intake chamber with a tangential entrance and an annular jet opening disposed in a side wall of said chamber.

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