Oct. 26, 1926. 1,604,362

L. F. MOODY

IMPULSE TURBINE

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Fig:1.

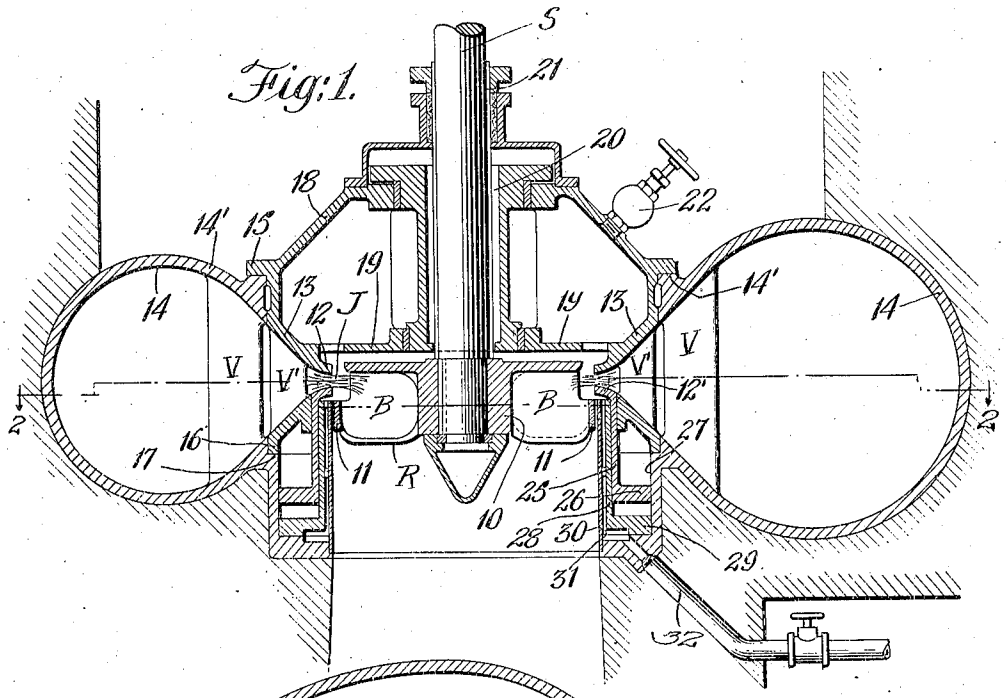


Fig:2.

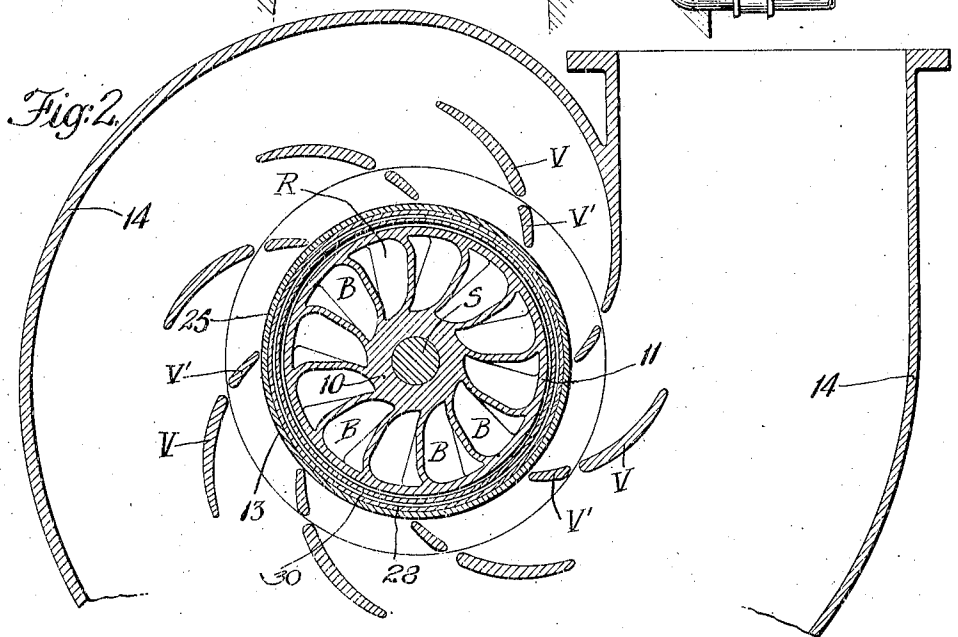
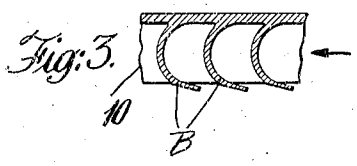


Fig:3.



Lewis F. Moody Inventor

By his Attorneys

Edwards, Sager & Bowers

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Fig. 4.

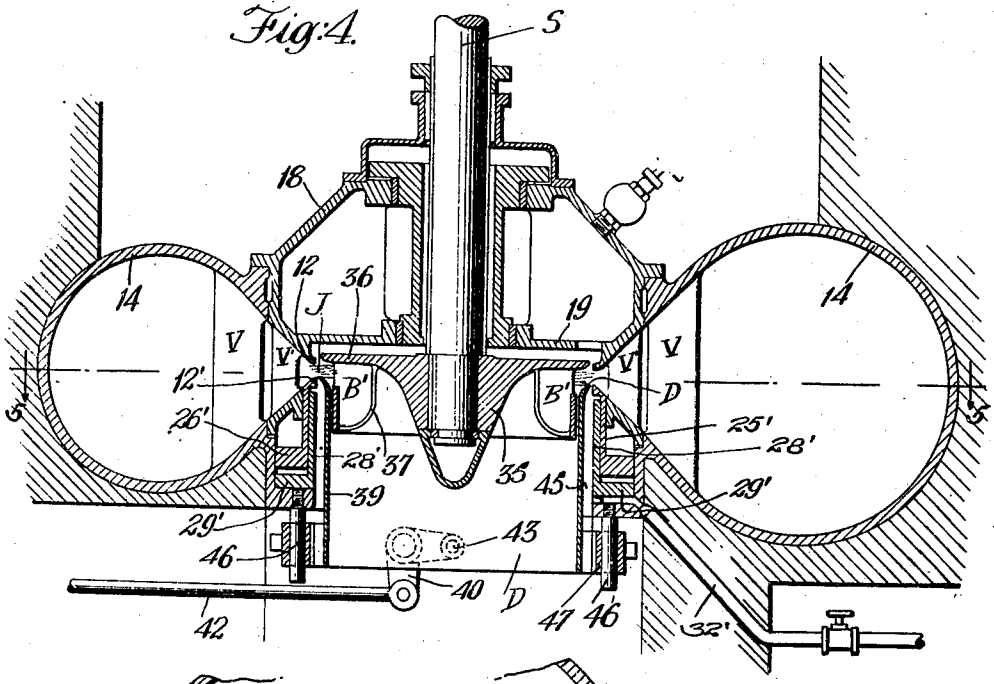
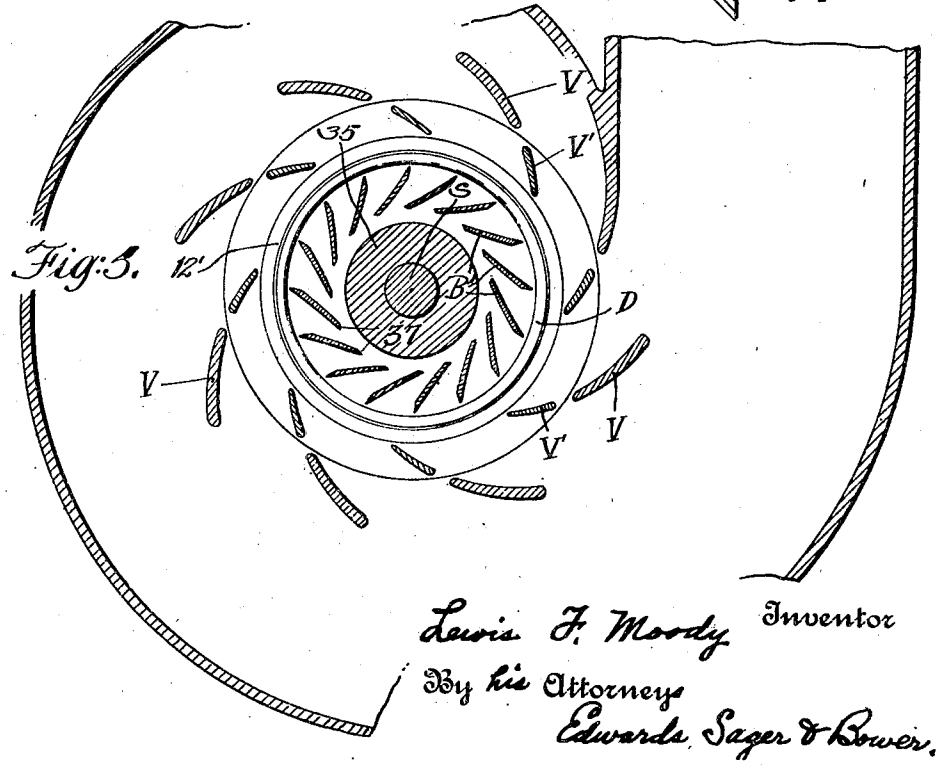


Fig. 3.



Lewis F. Moody Inventor

By his Attorneys

Edwards, Sager & Bower.

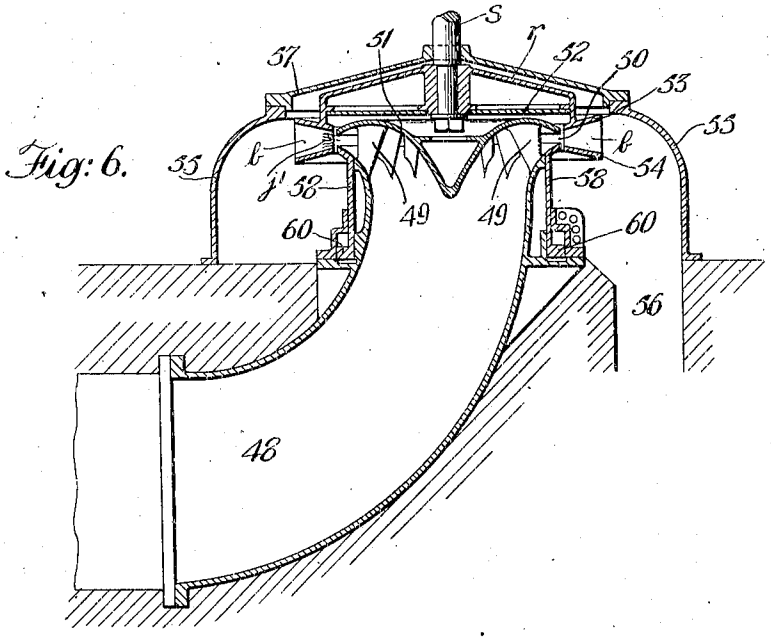
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IMPULSE TURBINE

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Fig: 6.



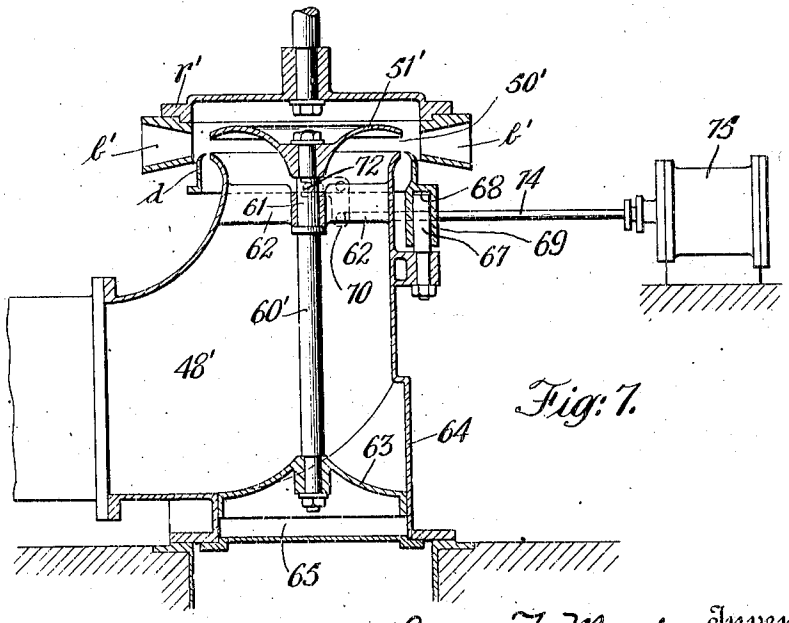


Fig: 7.

Lewis F. Moody Inventor

By his Attorneys

Edwards, Sager & Bowers

Patented Oct. 26, 1926. 1,604,362

UNITED STATES PATENT OFFICE.

LEWIS FERRY MOODY, OF PHILADELPHIA, PENNSYLVANIA.

IMPULSE TURBINE.

Application filed February 15, 1921. Serial No. 445,067.

This invention relates to impulse turbines and particularly to turbines having a high specific speed. The object of the invention is to provide an impulse turbine of the radial flow type in which the jet is continuous around the periphery of the runner so as to simultaneously act on all the buckets at once and in similar manner. Further objects of the invention in providing simple and inexpensive control means for the flow will appear from the following specification taken in connection with the accompanying drawings in which,

Fig. 1 is a vertical sectional view of one embodiment of the invention in an inward flow turbine,

Fig. 2 is a horizontal sectional view of a portion of Fig. 1, on line 2—2 of Fig. 1.

Fig. 3 is a sectional view of a detail.

Fig. 4 is a vertical sectional view of a modification.

Fig. 5 is a horizontal sectional view of a portion of Fig. 4, on line 5—5 of Fig. 4 and

Figs. 6 and 7 are vertical sectional views of further modifications illustrating the invention in connection with outward flow runners.

In the specific embodiment of the invention illustrated in Fig. 1 a vertical shaft runner R carries buckets B extending between the hub 10 of the runner and the outer shroud ring 11. This ring may be omitted if desired. The buckets B receive the flow tangentially and radially at their upper outer edges and discharge it downwardly in an axial direction. The inlet edges of the buckets are cut away as indicated and spaced from the nozzle edges 12, 12′ of the intake casing ring 13 to provide clear air spaces above and below the jet J. The flow enters by the intake volute 14 and passes through the inclined guide vanes V of this volute and into the inner ring 13 which may be provided with the inner vanes V′ alined with the outer vanes V. These inner vanes may be fixed or adjustable. The volute 14 is separate from the inner casing ring 13 which is fitted down into the volute with flange 15 resting on the top of the inner stay vane ring 14′ and the lower edge 16 fitted in the annular notch 17 and spaced slightly from the bottom thereof. The casing ring 13 is extended upward at 18 and inward at 19 to support the bearing 20 for the shaft S and the shaft is packed at 21 so that the casing is air tight and the pressure within it and on the upper surface of the annular jet J may be controlled by adjustment of the air inlet valve 22. The nozzle edges 12, 12′ converge toward each other inwardly and are rounded off and formed as surfaces of revolution around the runner. The lower edge 12′ of the nozzle orifice is axially adjustable, being formed as the upper end of the ring 25 having its piston 26 sliding in the annular cylinder 27 and raised or lowered therein by fluid pressure below or above the piston, means for supplying fluid pressure not being shown. The cylinder space 27 is contained between the guide ring 28 and its flange 29 and the lower cylindrical flange of the casing ring 13 and within this guide ring 28 is the top of the draft tube liner 30 set into the flange of the casing ring 14. A space 31 is left between the draft tube liner and the guide 28 and the air supply to this space is controlled through pipe 32 and a suitable valve so as to control the pressure on the under surface of the free jet J so that the pressure against which the jet discharges is controlled by valve 22 above and the valve of piping 32 below. The jet is continuous around the entire periphery and acts on all the buckets at once so that each bucket is in full operation throughout its whole revolution. The jet flow lines may be directed radially or the inclined vanes V V′ (Fig. 2) may be used to give the jet lines any desired inclination in the direction of rotation of the runner. In the form shown in Fig. 1 the buckets B receive the jet at their outer edges and turn it downward and discharge it axially at the bottom. Each bucket is cup shaped (see Fig. 3) in order to divert the water from radial to axial with the least possible amount of exposed surface, in order to reduce the frictional resistance to a minimum. In these buckets the direction of flow relative to the runner is turned backward. The general direction of the buckets with relation to the runner shaft may be inclined to the radial and the buckets may also be formed separately and bolted in place for easy removal and replacement. The form of the working surface of the bucket is such that it curves into and merges with a plane perpendicular to the turbine axis at the upper surface of the entering jet. This plane surface is continuous between the buckets and tangent to the bucket surfaces so that

the jet is received by this surface and then gradually curved downward in the separate buckets.

In the modification shown in Figs. 4 and 5 the buckets or blades B′ are not extended all the way to the runner hub 35 but are carried by the circular top piece 36 and have their inner edges 37 spaced from the hub which is curved and tapered toward the axial direction. The jet J is received radially by the outer edges of the buckets which spread and turn the flow partly toward the axial direction, the remainder of the change to axial taking place after the flow leaves the buckets. The jet is controlled by ring 25′ having its piston 26′ sliding around the ring 28′ and above the flange 29′. The buckets B′, as shown in Fig. 5, are inclined to the radial in the direction of rotation of the runner and this inclination combined with the inclined direction of the jet flow lines gives a high speed of rotation to the runner. In order to divert a portion of the jet from the runner during a sudden decrease in the load the deflector D may be provided having a curved upper edge interposed between the nozzle edges 12, 12′ and the buckets. The deflector extends downward as a cylinder 39 adjustably supported by the bell cranks 40 operated by the rods 42 and engaging the pins 43 extending laterally from the walls of the deflector. The deflector is guided vertically by studs 46 screwed into the lower flange of the turbine casing ring 14 and engaged by the sleeves 47 of the deflector ring. The operating rods 42 will be actuated by the piston of a hydraulic cylinder controlled by the governor or in any other suitable manner. As an alternative to this arrangement the deflector could be operated by an annular piston fluid operation similar to that for the nozzle edge 12′. In the modification of Fig. 4 the air pressure on the under surfaces of the jet may be controlled through piping connections as indicated at 32′. Upon the sudden falling off of the load the deflector D will be moved up into the jet so that its edge will divert an annular sheet of the lower portion of the jet and turn it down through the space 45 and by-pass it into the draft tube. The lower nozzle edge 12′ will then be actuated to slowly rise and so gradually restrict the size of the jet in a manner avoiding undue rise of pressure in the supply line, the edge of the deflector D being clear of the jet in the finally adjusted position of the nozzle edge 12′.

In the turbine shown in Fig. 6 the flow enters through the intake 48 passes upward and outward through the inclined stay and guide vanes 49 and out of the nozzle 50 radially with an inclination or whirl due to the inclination of the guides 49 and the upper part 51 of the intake casing supported on vanes 49 is conically curved to smoothly guide the flow to the nozzle. The runner r of this modification carries the outward flow buckets b receiving the jet j' at their inner edges and discharging it at their outer edges. The runner r is formed with an upper bucket ring 53 and a lower bucket ring 54 between which the blades or vanes b extend and are preferably inclined to the radial in the direction of rotation of the runner so that a relatively high speed of rotation is attained. The channel between the rings 53 and 54 expands outwardly to accommodate the spread of the flow against the bucket surfaces. The runner may also be provided with an auxiliary cover 52 over the intake. The discharge from the runner is collected in the casing 55 and carried to the outlet 56 connecting with the tail water and the casing 55 is preferably provided with a top 57 forming an air tight enclosure within which the air pressure may be controlled by suitable connections. In this modification the lower edge of the nozzle 50 is adjustably carried by the cylinder 58 actuated by the fluid pressure operated piston 60 guided as shown.

In the modification shown in Fig. 7 the outward flow turbine has its intake 48′ provided with an adjustable top 51′ forming an adjustable annular nozzle 50′. The top 51′ is supported by the rod 60′ guided in the bearing 61 carried by the stays 62 from the walls of the intake casing, the lower end of the rod 60′ is provided with the piston 63 working in the cylinder 64 and raised by fluid pressure in the space 65 beneath the piston. The jet is directed outward into the buckets b' of the runner r' and between the nozzle 50′ and the buckets b' is the deflector d adjustably mounted on rods 67 extending through holes 68 in projections 69 of the deflector. The deflector is moved by the bell cranks 70 engaging the pins 72 at opposite sides of the deflector and the bell cranks in turn are moved by the piston rods 74 moved by pistons in the fluid pressure cylinders 75. This deflector d operates in a manner similar to the deflector D of Fig. 4 to temporarily rise and divert a portion of the jet when there is a sudden decrease in the load, the head 51′ gradually moving down to reduce the jet and the deflector d after its first upward movement being lowered away from the jet.

The turbine of this invention provides a continuous radial jet and at the same time enables the direction of the jet to be given any desired inclination or whirl around the axis so as to increase the speed of the runner. The runner vane surfaces may also be given a flat curvature and large angle to the radial direction so that a relatively small movement of the jet stream will cause a large rotative movement of the runner and correspondingly high speed of rotation. At the same time the torque on the runner may

be maintained high compared to impulse turbines of the tangential type for though the driving pressure on each bucket is small all of the buckets are continuously in operation. For very high specific speeds the flow into the runner may be directed more nearly in the radial than the tangential direction, that is, at angles of 45° or more with the tangent. The control means for the flow comprise simple axially movable parts and all the surfaces of the jet forming and control parts are circular and may be easily turned to accurate fit. The guiding surfaces at the nozzle edges are steeply inclined to give sufficient contraction so that the jet does not attain its maximum velocity until clear of the nozzle edges and diffusion of the jet is avoided. A passage continuous around the circumference is provided between the discharge ends of the guide vanes and the nozzle orifice to permit the separate streams discharged between the vanes to come together in a continuous stream; and sufficient contraction of the passage is provided in the direction of flow to insure the formation of a solid stream, the outermost filaments of the jet continuing to approach each other so as to overcome any tendency of the jet to spread out or diffuse. In the runner the flow spreads out against the surfaces of the buckets or vanes and is surrounded by air on the other three sides. The tendency of the discharge to entrap air and carry it out with the water it utilized to produce a partial vacuum within the surrounding air-tight casing thus lowering the pressure against which the jet discharges and increasing the effective head on the turbine. The adjustable air inlet means permits this vacuum to be controlled and limited so that the tail water will not be drawn up to a height sufficient to submerge the runner.

By directing the water into the runner in radial planes without axial components of flow, the water may be given a high radial component of motion and a reduced tangential component, in order to produce a comparatively low torque and correspondingly high speed of rotation of the runner, as has already been mentioned. This can be done without subjecting the runner to a high axial thrust, since all of the radial components of the impulse of the entering water are balanced. In the turbine of Fig. 1 there is a small axial thrust due to the axial direction of discharge from the runner but the velocity of this discharge has been reduced to a low value during the passage of water through the runner so that the amount of axial thrust is small. In a number of the embodiments described, the water both enters and leaves in substantially radial planes, and no axial thrust is produced. In all of the embodiments described there is no side thrust upon the runner in a direction normal to the axis such as exists in impulse turbines of the so-called tangential type in which the water is admitted at only one point in the periphery.

I claim:—

1. In apparatus for converting hydraulic energy into useful work the combination with a nozzle adapted to form the water flow into a free circular jet with the elements of said jet moving in substantially radial planes, of means for imparting tangential components to the flow lines of said jet, and a circular series of buckets receiving said jet so as to be continuously acted upon by said jet.

2. In an impulse turbine the combination with a runner of the free jet or impulse type, of an inlet passage having a cylindrical orifice directing a continuous circular jet in a substantially radial plane 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.

3. In an impulse turbine the combination with means for forming a radially progressing circular jet containing tangential components of motion of a runner having a circular series of buckets continuously acted upon by said jet.

4. In an impulse turbine the combination with means for forming a radially progressing circular jet containing tangential components of motion of a runner having a circular 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. In an impulse turbine the combination with a runner, of a spiral entrance casing having a cylindrical jet forming orifice adapted to direct a circular jet in a substantially radial plane against said runner.

6. In an impulse turbine the combination with a runner, of a spiral entrance casing having a cylindrical jet forming orifice adapted to direct a circular jet in a substantially radial plane 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.

7. In an impulse turbine the combination with a nozzle having guiding means discharging the water inwardly in an annular space around a central axis, of a runner having the entrance edge of its buckets spaced from said nozzle to permit a contraction of the flow in the space between the nozzle and the runner.

8. In a hydraulic turbine a nozzle circularly symmetrical about an axis adapted to produce a free jet in a substantially radial plane and containing guiding means to give the jet both radial and tangential components of flow with respect to said axis, and

the walls of said nozzle being formed to direct the outermost stream elements convergently toward each other to preserve a continuous body of fluid from the nozzle to the runner entrance.

9. In a hydraulic turbine the combination with flow guiding means forming a jet extending around the axis of the turbine runner, of a casing enclosing said means to control the pressure therein.

10. In a hydraulic turbine the combination with a jet forming means adapted to form a jet extending around the axis of the turbine runner, of a casing enclosing said means to control the pressure against the free surfaces of said jet.

11. In a hydraulic turbine the combination with a jet forming means adapted to form a jet extending around the axis of the turbine runner, of a casing enclosing said means to control the pressure against the free surfaces of said jet, and air admission means to regulate said pressure.

12. In a hydraulic turbine the combination with a nozzle forming a free jet extending around the axis of the turbine runner, of a runner receiving said jet, and a casing enclosing said nozzle and runner, the flow through said turbine being adapted to entrap air and carry it out so as to reduce the pressure in said casing, and air admission means for controlling the pressures on the opposite free surfaces of the jet.

13. In an impulse turbine the combination with a runner having vanes inclined forward in the direction of rotation of the runner, of a nozzle adapted to form a jet directed inward toward the runner axis, and means for guiding said jet against said runner with tangential components and in a direction more nearly radial than tangential.

14. In an impulse turbine the combination with a runner, of a nozzle adapted to form an inwardly directed jet continuous around the axis of said runner, and guiding means directing the flow lines of said jet between the radial and tangential direction.

15. In an impulse turbine the combination with a runner, of a nozzle adapted to form an inwardly directed jet continuous around the axis of said runner, guiding means directing the flow lines of said jet between the radial and tangential direction, and vanes on said runner with their entrance edges inclined forward in the direction of rotation.

16. In a turbine runner the combination with a hub of a crown extending radially therefrom, buckets extending on one side of said crown and having outer entrance edges receiving the jet, the faces of said buckets smoothly merging with the surface of said crown.

17. In a turbine runner the combination with a hub, of a crown extending radially from said hub in a plane normal to the axis, and buckets extending between said crown and hub and having their surfaces merging therewith.

18. In a turbine runner the combination with a hub, of a crown extending radially from said hub in a plane normal to the axis, and buckets extending between said crown and hub and having their surfaces merging tangentially therewith, said buckets being adapted to receive the flow at their outer edges and turn it toward the axial direction.

19. In an impulse turbine the combination with a jet forming means adapted to direct a jet inward with radial and tangential components at the entrance to the runner buckets, of a runner having buckets receiving said flow at their outer edges and turning it toward an axial direction and discharging it.

20. In an impulse turbine the combination with a jet forming means adapted to direct a jet inward with radial and tangential components at the entrance to the runner buckets, of a runner having buckets receiving said flow at their outer edges and turning it toward an axial direction and discharging it, said radial component being at least as large as said axial component.

21. In an impulse turbine means for forming a free jet substantially in a plane perpendicular to the runner axis, and a runner having a hub and buckets directed outward from the periphery of said hub and receiving said jet and turning all of it toward the axial direction and discharging it on one side of the runner, the surfaces of said buckets being cupped to turn the flow backward.

22. In an impulse turbine means for forming a free jet substantially in a plane perpendicular to the runner axis, and a runner having a hub and buckets directed outward from the periphery of said hub and receiving said jet and turning all of it toward the axial direction and discharging it in a generally axial direction on one side of the runner, and the discharge edges of the buckets extending in a direction opposite to the rotation of the runner.

23. In an impulse turbine means for forming a free jet substantially in a plane perpendicular to the runner axis, and a runner having a hub and buckets directed outward from the periphery of said hub and with faces inclined forward and outward and turning all of said jet to one side of said plane and discharging it in a generally axial direction, said jet at the point of entrance to the buckets having both radial and tangential components, and the surfaces of said buckets curving in the same general direction from entrance to discharge edge to turn the flow backward.

LEWIS FERRY MOODY.