No. 810,955. PATENTED JAN. 30, 1906.

A. LUND.

MEANS FOR REGULATING TURBINES.

APPLICATION FILED MAR. 9, 1904.

3 SHEETS—SHEET 1.

Fig. 1.

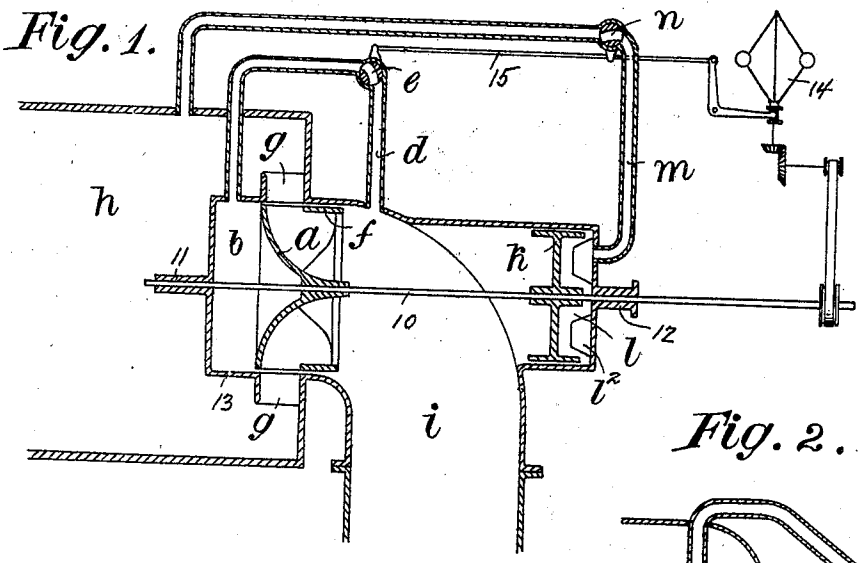


Fig. 2.

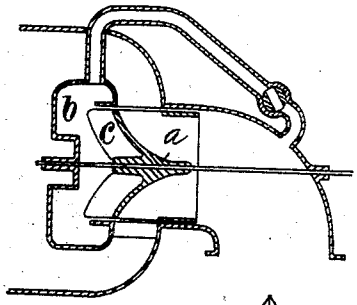
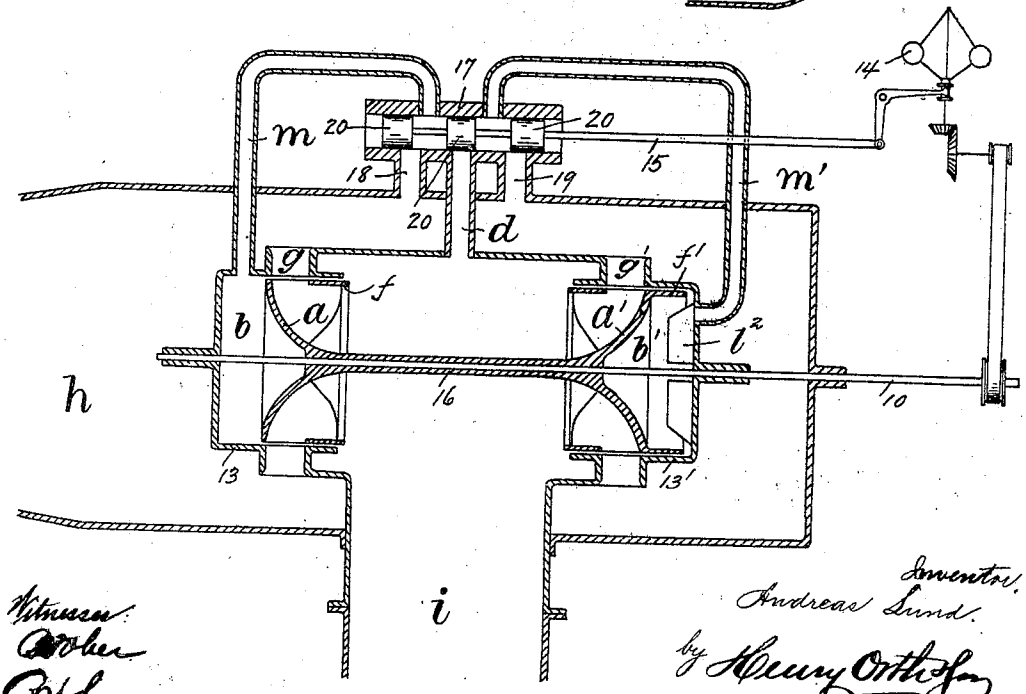


Fig. 3.



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3 SHEETS—SHEET 2.

Fig. 4.

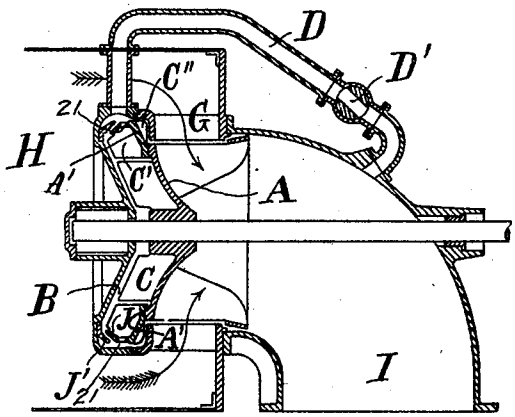


Fig. 5a.

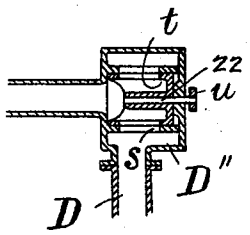
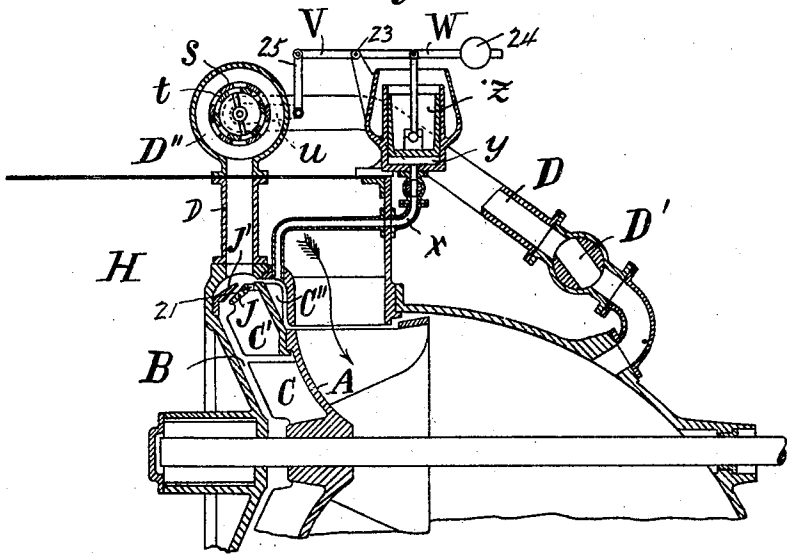


Fig. 5.



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3 SHEETS—SHEET 3.

Fig. 6.

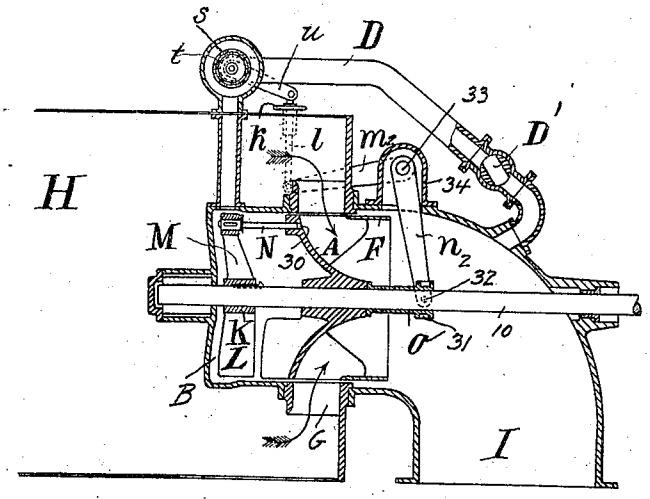


Fig. 7.

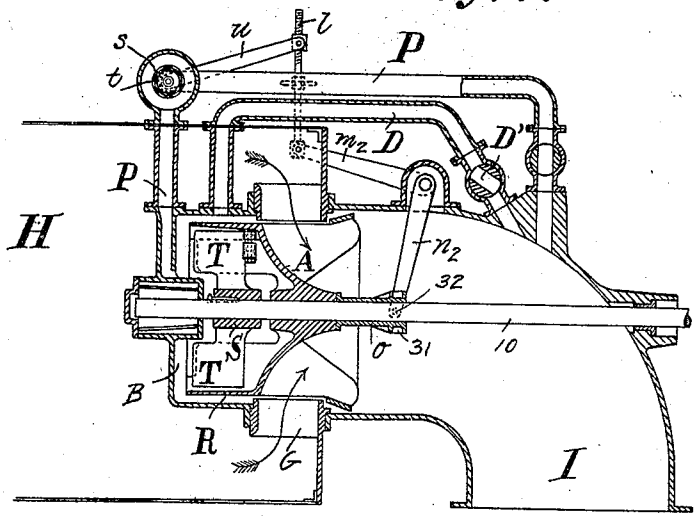
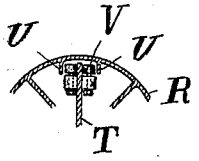


Fig. 7a.



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UNITED STATES PATENT OFFICE.

ANDREAS LUND, OF CHRISTIANIA, NORWAY.

MEANS FOR REGULATING TURBINES.

No. 810,955. Specification of Letters Patent. Patented Jan. 30, 1906.

Application filed March 9, 1904. Serial No. 197,210.

To all whom it may concern:

Be it known that I, ANDREAS LUND, a subject of the King of Sweden and Norway, residing at Christiania, Norway, have invented certain new and useful Improvements in Means for Regulating Turbines; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same, reference being had to the accompanying drawings, and to letters and figures of reference marked thereon, which form a part of this specification.

This invention relates to turbines, and especially to means for regulating or controlling the speed by means of a water-actuated element and automatically operated, as will hereinafter be particularly described and claimed.

Referring to the drawings, in which like parts are similarly designated, Figure 1 is a sectional diagrammatic view of one form of mechanism. Fig. 2 is a similar view of a modification. Fig. 3 is a sectional view illustrating two turbines on a shaft common to both of them. Fig. 4 is a longitudinal section of a turbine combined with a brake device. Fig. 5 is a similar view of a modification. Fig. 5^a is a longitudinal section of the valve shown in transverse section in Fig. 5. Fig. 6 is a longitudinal section of a further modification. Fig. 7 is a modification of Fig. 6. Fig. 7^a is a detail view of the mounting for the blades T.

Referring to Fig. 1, *h* is the penstock or pressure-pipe; *i*, the suction-pipe or fall-pipe leading to the tail-race, and between the two pipes is located the turbine-wheel *a*, of suitable form, secured to a shaft 10, mounted in bearings 11 and 12 and in which said shaft has axial movement. A housing 13 surrounds the wheel and is provided with fixed inlet-chutes *g*. The turbine-wheel itself is provided with a ring-gate *f*, capable of coöperating with chutes *g* to control the quantity of water passing through the turbine-wheel. Behind the turbine-wheel in casing 13 is a chamber *b*, closed by the back of the turbine-wheel and having a pipe connection *d* with draft-tube *i* and controlled by a valve *e*. The turbine-wheel *a* being axially movable on or with the shaft will tend to force the water from the chamber *b* through *d* into *i*, allowing the wheel *a* to move axially into chamber *b* and causing the ring-gate *f* to reduce the quantity of water passing through the chutes *g* and the turbine-wheel. This movement is controlled by valve *e*, operated by the governor when the speed is too great, thereby releasing the water-cushion in chamber *b* and permitting the wheel to move into the chamber. This action can be increased by having a piston aid in moving the turbine-wheel axially, and to this end there is an auxiliary chamber *l*, forming part of the suction-pipe. Within this chamber is a piston *k*, secured to the axially-movable shaft 10, the chamber being directly connected to a source of water-pressure, in this case directly with the penstock by means of pipe *m*, having a valve *n*. Both of the valves *e* and *n* are connected to rod 15, operated by the governor 14, so that when the speed of the turbine-wheel *a* increases the valves *e* and *n* are opened more or less, releasing the water-cushion in *b* and admitting water-pressure behind the piston *k*, tending to force said piston out of its chamber *l*, thereby increasing the effective movement of the turbine-wheel and making the axial movement more rapid.

In Fig. 2 the back of the turbine-wheel *a*, that works in chamber *b*, is provided with blades *c*, that act as a centrifugal pump on the water and cause the pressure to vary with the number of revolutions and cause the axial movement of the turbine-wheel. Such an arrangement need not necessarily be connected directly to the turbine-wheel, since the pressure-chamber may be arranged at another place in the system.

In Fig. 3 I have shown two turbine-wheels on a single shaft and axially movable. The two wheels *a* and *a'* are connected by a sleeve 16 on shaft 10, and each turbine has a casing 13 and 13', and in which are the chambers *b* and *b'*. Each turbine-wheel is provided with a ring-gate *f* and *f'*, adapted to coöperate with the inlet-chutes *g* and *g'*, through which water is admitted from the penstock *h*. Each chamber *b* and *b'* is connected to a piston-valve casing 17 by means of pipes *m* and *m'*, and said casing has inlet-ports 18 and 19 communicating with the penstock *h* and an outlet-port *d* to the suction-pipe *i*. The piston-valve 20 controls the admission of water

to the chambers *b* and *b'* through the pipes *m* and *m'* and outlet-port *d*. The valve 20 is actuated from the governor 14, that is operatively connected to the turbine-shaft 10. The position of the turbine-wheels is a medial one. Now if the speed increases the governor will draw the valve to the right, thus gradually cutting off port 18, and finally closing the connection between the penstock and chamber *b* and at the same time opening the outlet-port *d*. The pressure in chamber *b* will diminish and the turbine will move to the left. In addition to this the chamber *b'* will be put in communication with the penstock by valve 20 opening port 19, thereby causing an increased pressure to the left. The chambers are kept normally full of water that enters through the annular space or play between the wheel and its casing.

As will be understood from the foregoing explanations, the object of my invention is to provide a turbine that is axially movable either on or with its shaft with regulating means of such a nature that these regulating means come into action when the turbine is caused to move axially, and this axial movement is accomplished by a water-cushion that controls the axial position of the wheel in accordance with the volume of said cushion. An object of said invention is then to provide means whereby the volume of said cushion is changed automatically as the speed of the turbine changes. When the chamber forming the cushion is made a part of a water-passage connecting, for example, the penstock and draft-tube, the volume of water in said chamber will be increased when the area of said passage between the chamber and the draft-tube is diminished by means of a valve, here shown as controlled by a centrifugal governor, or if I cause the water in the chamber to take part in the rotation of the wheel by means of blades the increase of speed will increase the centrifugal pressure in the chamber and directly cause a reduction of volume in the same. The axial movement of the wheel is due to unbalanced reaction of the entering water on the surface of the wheel, here shown as curved, and constantly tends to move the wheel axially toward the chamber back of the wheel.

In Figs. 4, 5, 6, and 7, A designates the turbine-wheel proper; H, the penstock or pressure-pipe; I, the suction-pipe; G, the guide-blades or gates between the penstock and wheel that admit water to the latter, and C the blades on the back of the turbine-wheel.

In Fig. 4 the turbine-wheel A is provided with an auxiliary rim A' on its back and with a brake-flange J, said rim carrying two sets of blades C' and C''. The wall of chamber B that incloses the back of the wheel is provided with a fixed complementary brake-flange J', both of which flanges are shown as conical. The pipe D, controlled by valve D', connects the chamber B with the suction-pipe I. When the speed is increased, the centrifugal force in chamber B will be increased, expelling the water from said chamber and allowing the brake-ring J to move against that, J', to frictionally retard the revolution of the turbine-wheel. The slower the speed of the wheel the greater is the static pressure of the water upon the back thereof, and as the speed increases water is withdrawn from the center and forced toward the periphery, thereby lessening said static pressure and converting a portion thereof into radial pressure that is ineffective in balancing the reaction upon the front of the wheel, the total axial pressure upon the back of the wheel becoming reduced as the speed increases, and vice versa, with the effect set forth. Holes 21 are provided in the ring A' to prevent communication between the central and peripheral parts of the chamber from being entirely cut off when the brake-rings are in contact. The vanes C'' are for causing a reduction in the pressure at the annular opening between the turbine-wheel and the gate wheel or ring G to counteract the passage of water from the chamber B to the turbine-wheel A at this point.

In Fig. 5 I have shown a structure of turbine like that in Fig. 4, but supplied with an automatic valve to control the outlet of water from chamber B into pipe D. The pipe D has an enlargement D'', that contains a stationary cylinder *s*, having peripheral ports, the interior of which communicates with the continuation of pipe D. In the cylinder *s* is mounted a hollow cylinder-valve *t*, also provided with ports, and on the stem 22 of which is mounted a lever *u*. A cylinder *y* has communication through pipe *x* with that part of the pressure-chamber B in which the auxiliary vanes C'' work. In the cylinder *y* is a piston *z*, connected to a lever pivoted at 23, one arm W of which carries a weight 24 and the other arm V is connected by a link 25 to the end of lever *u*. The valve *t* is set so that when the speed of the turbine increases water forced under the piston *z* by the auxiliary vanes C'' will rotate the valve and increase the free area of the opening through the ports in cylinder *s* and valve *t*, thereby automatically effecting the governing of the turbine-wheel and a forcible braking will result, due to a rapid reduction of the water resistance in chamber B.

In Fig. 6 is shown a turbine-wheel A, axially movable on its shaft 10 and having a ring-gate F, that forms an extension of the wheel. In the chamber B there is keyed on shaft 10 a hub K, carrying vanes L and having one or more spider-arms M in which are secured the ends of rods N, whose free ends extend into guide-holes 30 in the turbine-wheel. The hub of the turbine-wheel A is provided with a sleeve *o*, having a groove 31,

in which takes a pin or bowl 32 on an arm n^2, pivoted at 33 within an extension 34 on the suction-pipe *i*. On the pivot-pin 33 is secured an arm m^2, that engages the lower end of a lift-rod *l*, that moves lever *u*, connected to valve *t* in the ported cylinder *s*. This valve is the same as that described in reference to Fig. 5. The axial movement of the turbine on its shaft will operate levers n^2 m^2, rod *l*, and lever *u*, to actuate the valve *t*. A hand-wheel and sleeve *k* is provided on rod *l* to adjust the opening of the valve relatively to the extent of the axial movement of the turbine-wheel. Instead of or in connection with this arrangement I may connect the valve D′ with a governor driven from the shaft 10, as shown in Fig. 1. The valves, if desired, may be so set as to counteract the regulating action of the ring-gate F—that is to say, they may be set so as to increase the resistance in the passage D when the speed of the turbine increases, and not as explained with reference to Fig. 5, so as to diminish this resistance. In this manner the turbine-wheel is prevented from sliding too quickly in either direction on the shaft.

In the arrangement shown in Fig. 7 the turbine-wheel A is mounted to be axially movable on its shaft 10, but instead of moving inwardly, as in the preceding figures, it works outwardly when the speed increases and carries a ring-gate R on the back of the turbine-wheel that closes the openings or inlet-chutes *g*. A hub S is keyed on the shaft 10 in pressure-chamber B, that carries vanes T, each of which extend between pairs of guide-ribs U on the interior of the ring-gate and having friction-rollers V, as shown in Fig. 7ª. A pipe P connects the central part of chamber B with the suction-pipe I and contains a valve *s t*, like that in Figs. 5 and 5ª, connected by similar levers to the sleeve *o*, as clearly shown. The peripheral part of chamber B is connected by pipe D to the suction-pipe I and contains a valve D′, that may be automatically operated by a governor, as indicated in Fig. 1. The increase of speed tends to close valve D′, Fig. 7, that is governor-controlled and causes the pressure in chamber B to rise, causing wheel A to move to the right, and the movement to the right in turn causing the valve *s t* to open, thus affording an exit for the water in said chamber and reducing the pressure tending to force wheel A to the right. Thus the axial movement primarily due to the speed of the wheel controls this valve also. It will be understood that to obtain an outward movement of the turbine-wheel upon an increase of speed there must exist a suitable relation between the pressures in the two pipes P and D.

I have shown turbines of the axial-radial type, but my invention is also applicable to other types of turbine-wheels.

In some of the figures I have shown stationary blades I^2 in the pressure-chambers to prevent the rotation of the water therein when a centrifugal action is not made use of.

Having thus described my invention, what I claim as new therein, and desire to secure by Letters Patent, is—

1. In a turbine, the combination with an axially-movable turbine-wheel, of a water-cushion to regulate the axial position of the wheel, means to vary the hydraulic pressure of said cushion on the wheel and means set in operation by the axial movement of the wheel to vary its speed, substantially as described.

2. In a turbine, the combination with an axially-movable turbine-wheel, of a water-cushion to regulate the axial movement of the wheel, means operated by the rotary movement of the wheel to vary the pressure and volume of the cushion, and means set in operation by the axial movement of the wheel to vary its speed, substantially as described.

3. In a turbine, the combination with an axially-movable turbine-wheel, of a water-cushion behind the wheel to regulate the axial movement of the wheel, a valve to control the hydraulic pressure of said cushion on the wheel and means set in operation by the axial movement of the wheel to vary its speed, substantially as described.

4. In a turbine, the combination with the casing having a draft-tube and the turbine-wheel, of a chamber formed back of the wheel, means to maintain a constant and separate circulation of water from between the wheel and casing through the chamber and into the draft-tube, and means to control the volume of water passing through the chamber and thereby controlling the pressure within the chamber, substantially as described.

5. In a turbine, the combination with an axially-movable turbine-wheel, of a chamber back of the wheel and containing a water-cushion, vanes back of the wheel in said chamber to act as a pump, a pipe connection between the chamber and the water-exit from the wheel, a valve in said pipe and means to operate the valve from the turbine-wheel, substantially as described.

6. In a turbine, the combination with an axially-movable turbine-wheel, of a chamber back of the wheel and containing a water-cushion, vanes in the chamber rotatable with the wheel to act as a centrifugal pump, a valve-controlled pipe connecting the chamber with the draft-tube, and mechanism between the turbine-wheel and the valve to automatically operate the latter, substantially as described.

7. In a turbine, the combination with an axially-movable turbine-wheel, of a water-cushion to counteract the axial thrust of the wheel, means to vary the hydraulic pressure

of said cushion to axially move the wheel, and a brake actuated by the wheel, substantially as described.

8. In a turbine, the combination with an axially-movable turbine-wheel, of a water-cushion to counteract the axial thrust of the wheel, a stationary brake element and a co-operating brake element carried by the wheel, and means to automatically vary the hydraulic pressure of the water-cushion to axially move the turbine-wheel and operate the brake, substantially as described.

9. In a turbine, the combination with an axially-movable turbine-wheel, of a chamber back of the wheel and containing a water-cushion, vanes in the chamber secured to the wheel, a stationary brake-ring and a brake-ring secured to the wheel, and means to automatically vary the hydraulic pressure of the water in said chamber to axially move the wheel, substantially as described.

10. In a turbine, the combination with an axially-movable turbine-wheel, a penstock and a draft-tube; of a chamber back of the wheel, a pipe connecting the chamber to the draft-tube, a valve in said pipe, means to cause a difference in hydraulic pressures between the central and peripheral portion of said chamber and mechanism actuated by the peripheral hydraulic pressure to control said valve, substantially as described.

11. In a turbine, the combination with an axially-movable turbine-wheel and its casing, a penstock and a draft-tube, of a chamber back of the wheel connected to the draft-tube, a set of pump-blades on the back of the wheel in said chamber and a second set of pump-blades on the wheel to act on the water passing between the wheel and casing into the chamber, substantially as described.

12. In a turbine, the combination with an axially-movable turbine-wheel and its casing, a penstock and draft-tube, of a chamber back of the wheel connected to the draft-tube, blades in the back of the wheel in said chamber, a pipe connecting the chamber and draft-tube, a fixed brake member and a movable brake member coöperating therewith and operated by the axial movement of the wheel, substantially as described.

13. In a turbine, the combination with an axially-movable turbine-wheel and its casing, a penstock and a draft-tube, of a chamber back of the wheel, a pipe connecting the chamber and draft-tube, a valve in said pipe, a set of pump-blades on the wheel and in said chamber, a set of pump-blades to act on the water passing into the chamber from between the wheel and its casing and means to operate said valve actuated by the water pumped by the second set of blades, substantially as described.

14. In a turbine, the combination with an axially-movable turbine-wheel and its casing, a penstock and draft-tube, of a chamber back of the wheel, a pipe connecting the chamber and draft-tube, a valve in said pipe, a fixed brake member in the chamber and a coöperating brake member on the wheel, a set of pump-blades back of the wheel in the chamber, a set of pump-blades positioned to act on the water passing between the wheel and casing into the chamber, a receptacle to receive water pumped by the second set of blades and mechanism operated by the varying water-level in said receiver to actuate the valve, substantially as described.

15. In a turbine, the combination with an axially-movable turbine-wheel, a penstock and a draft-tube; of a chamber back of the wheel, a pipe connecting the chamber to the draft-tube, two valves in said pipe, means to cause a difference of hydraulic pressure between the central and peripheral portions of said chamber, means to control one of the valves by the speed of the wheel and means to control the other by the hydraulic pressure in the peripheral part of the chamber.

In witness whereof I have hereunto set my hand in presence of two witnesses.

A. LUND.

Witnesses:
HENRY BORDEWICH,
MICHAEL ALGER.