No. 664,394. Patented Dec. 25, 1900.

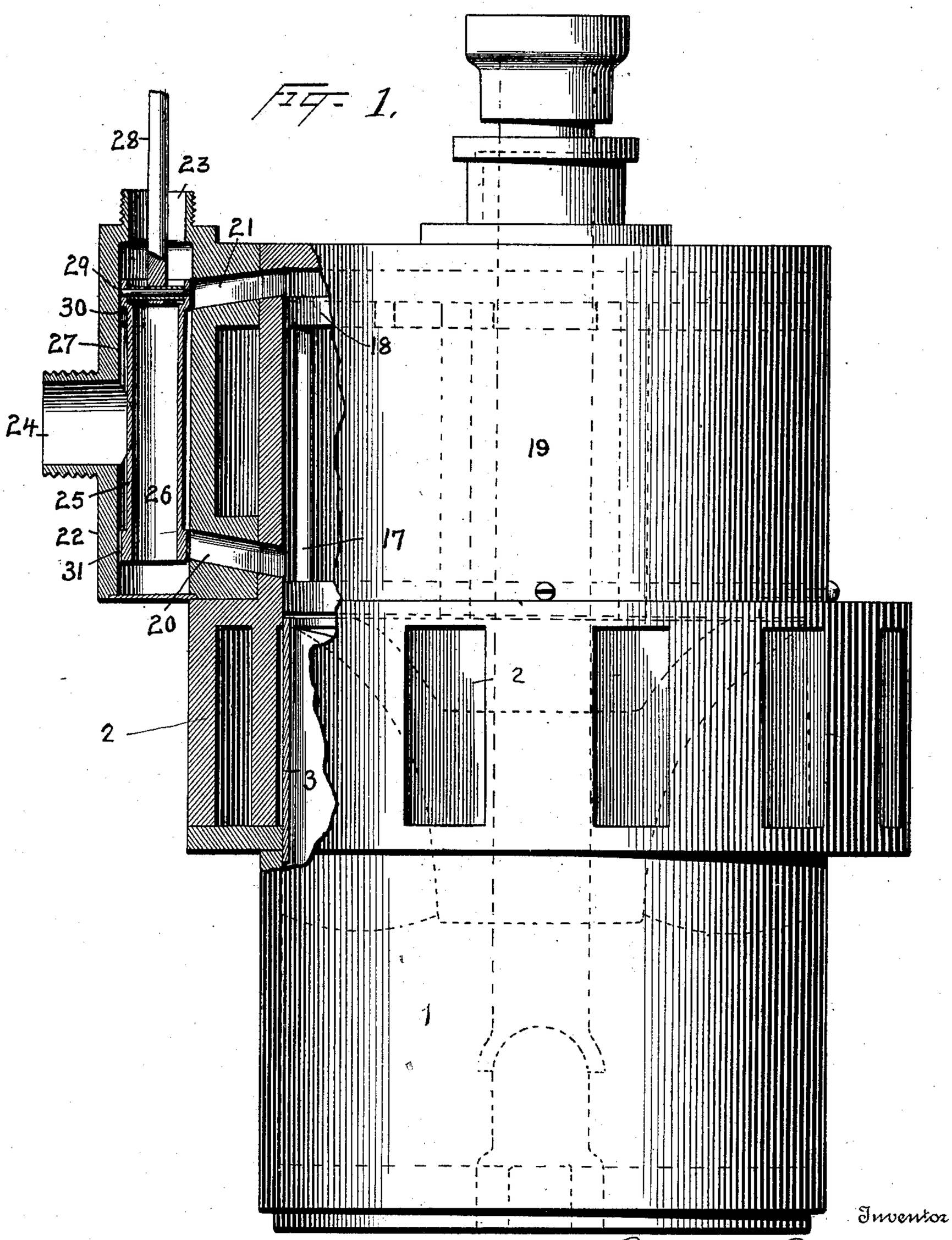
F. ELLICOTT.

GOVERNOR FOR PRIME MOTORS.

(Application filed Sept. 13, 1899. Renewed Oct. 26, 1900.)

(No Model.) 4 Sheets—Sheet 1.

Fig. 1.



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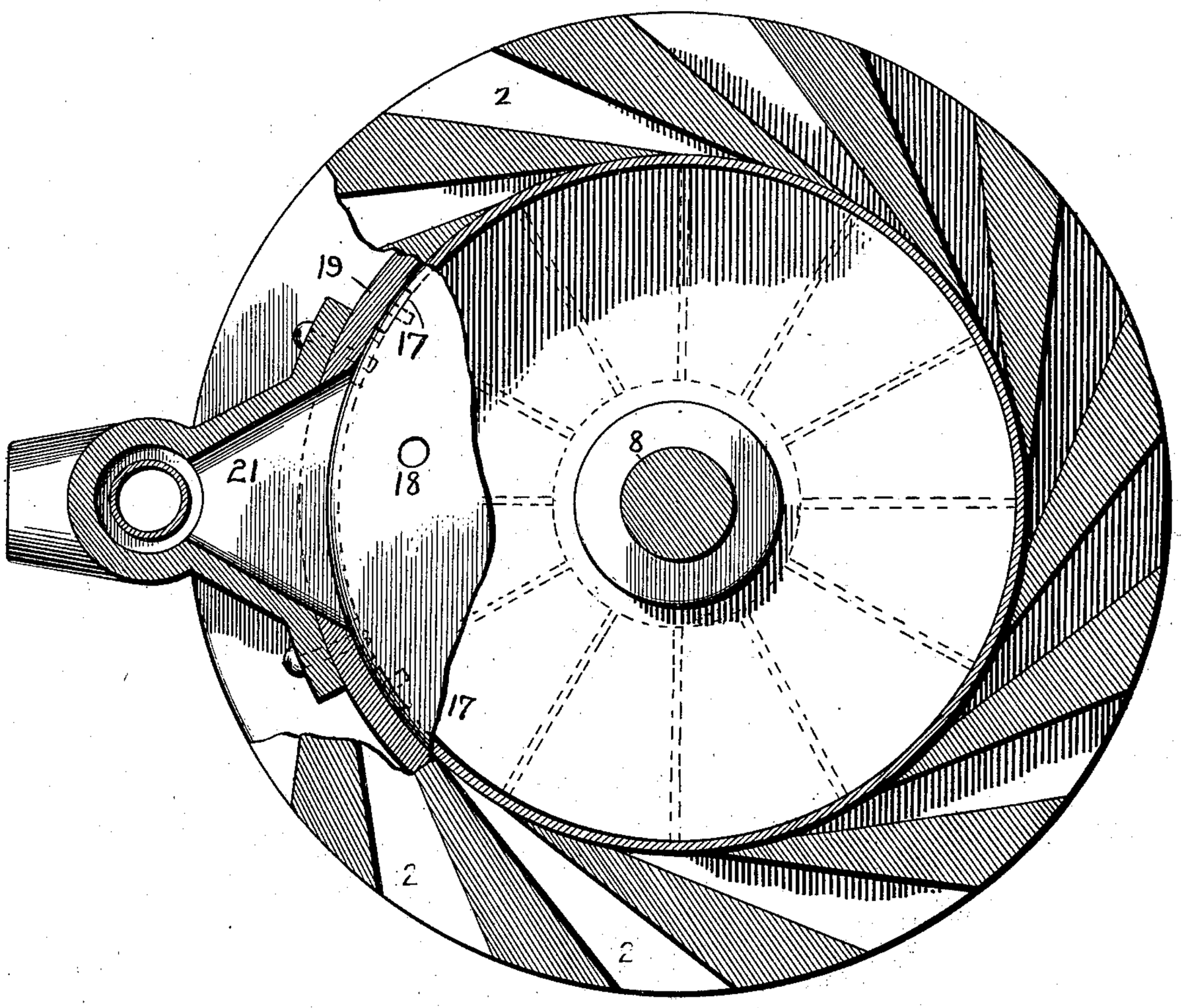
(No Model.) 4 Sheets—Sheet 2.

Fig. 2.



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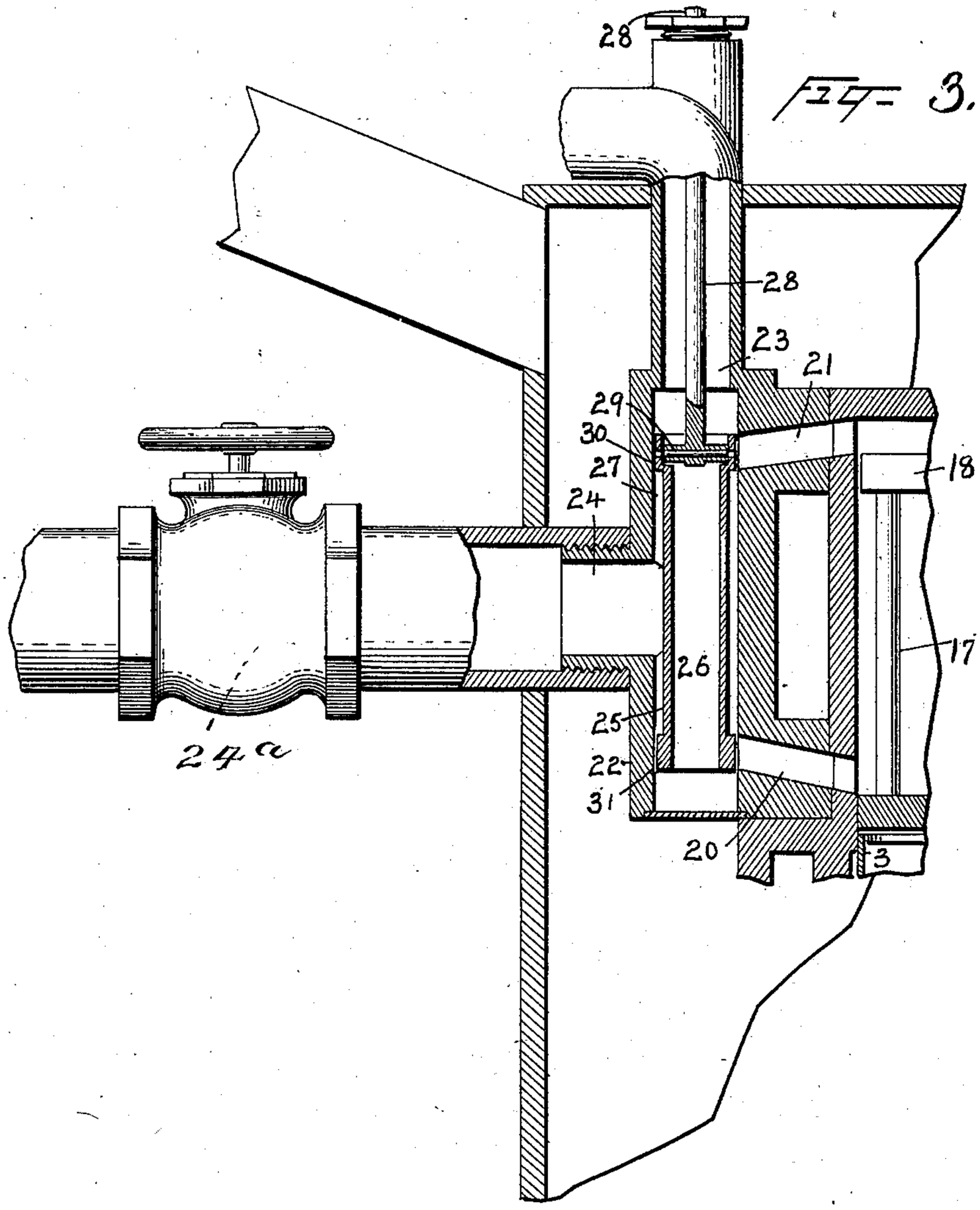
(No Model.) 4 Sheets—Sheet 3.

Fig. 3.



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(Application filed Sept. 13, 1899. Renewed Oct. 26, 1900.)

(No Model.) 4 Sheets—Sheet 4.

Fig. 4.

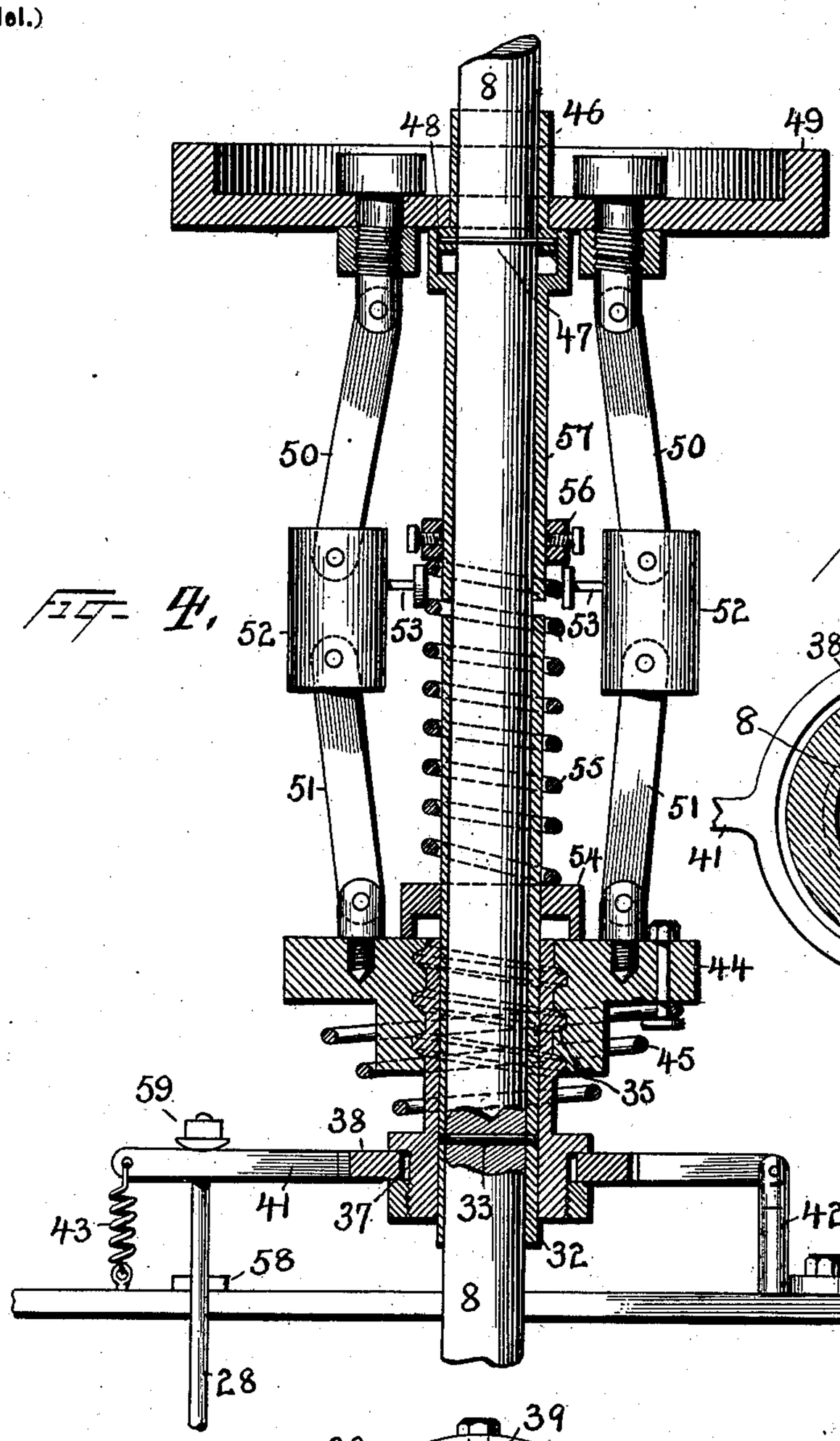


Fig. 6.

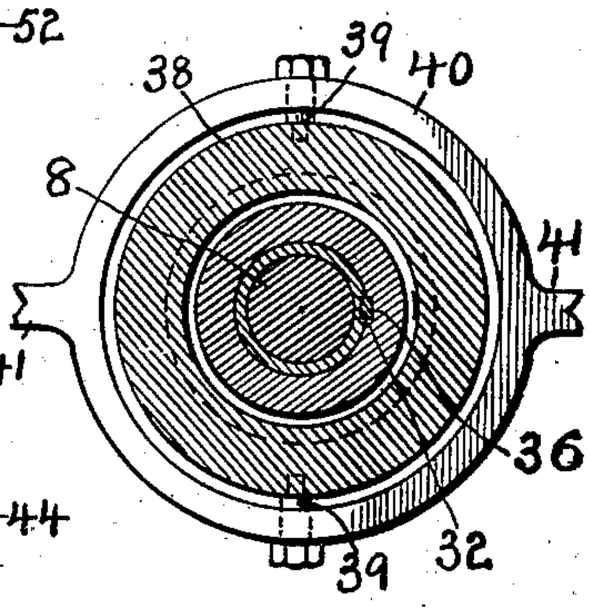
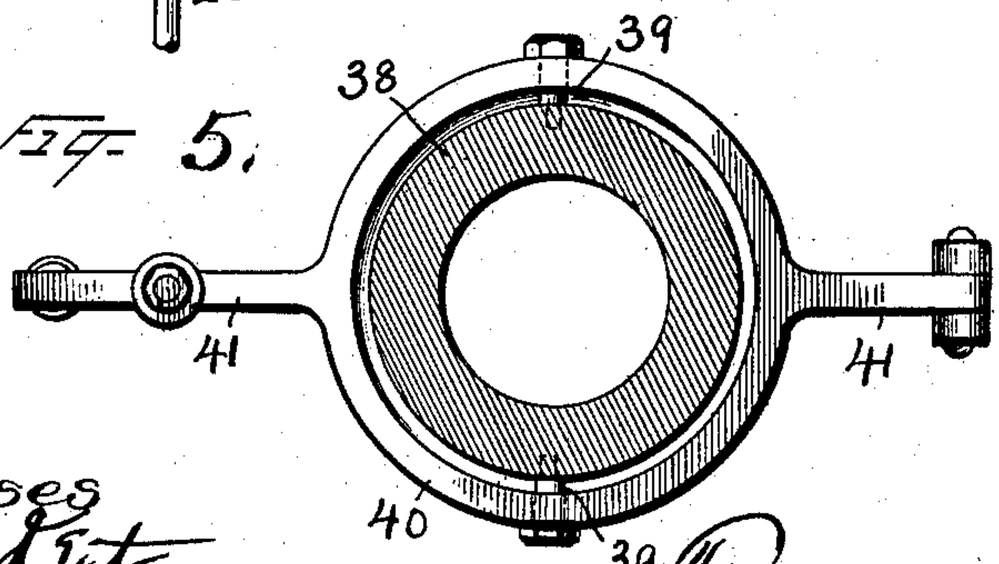


Fig. 5.



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UNITED STATES PATENT OFFICE.

FRANCIS ELLICOTT, OF BALTIMORE COUNTY, MARYLAND.

GOVERNOR FOR PRIME MOTORS.

SPECIFICATION forming part of Letters Patent No. 664,394, dated December 25, 1900.

Application filed September 13, 1899. Renewed October 26, 1900. Serial No. 34,522. (No model.)

To all whom it may concern:

Be it known that I, FRANCIS ELLICOTT, a citizen of the United States, and a resident of Baltimore county, in the State of Maryland, (Ruxton P. O.,) have invented certain new and useful Improvements in Water-Wheel Governors for Prime Motors, of which the following is a specification.

My invention relates to a governor for controlling automatically the speed of a prime motor. I have shown it in this case applied to a water-wheel; but it may be used to govern any other prime motor, such as a steam-engine or electric motor. When applied to a water-wheel, the governor is, as shown in this case, caused to operate the gate by which water is admitted to the runner in greater or less quantity proportional to the load. In the case of a steam-engine the governor may be made to control either the throttle or cut-off, and thus control the speed. If applied to an electric motor, the governor may be made to control a rheostat, cut-out, or choking-coil.

In the drawings similar characters of reference indicate similar parts in all the figures.

Figure 1 is a vertical external elevation of the wheel-casing with the governor-casing mounted upon it, the valve and valve-chest of the governor being in section. Fig. 2 is a horizontal section of the wheel-case and gate, showing the top of the runner. It also is a full plan of a part of the governor-piston and a horizontal section of the governor-valve chest and valve, taken through the upper port. Fig. 3 is a vertical section of valve-chest, valve, and part of piston and penstock and exhaust-valve beyond penstock. Fig. 4 is a side elevation, partly in section, of the centrifugal device of the governor. Fig. 5 is a plan view of the governor-lever, showing part of the centrifugal device in horizontal section. Fig. 6 is a horizontal section of the nut, the screw, the sleeve, and the driving-shaft, showing the connection of the nut with the governor-lever.

Referring to Fig. 1, 1 is a casing surrounding the runner and shaft. 2 2 are water-inlets through the wall of the casing, introduced at an angle such that the inner edge of each inlet shall be approximately tangent to the periphery of the runner—*i. e.*, to a circle described by the external edge of the buckets as they revolve. The outer wall of each inlet is tangent to a somewhat smaller circle. I have found the highest efficiency to result from making the walls of the inlets with an angle of about twenty degrees between them. 3 is a cylindrical gate fitting closely into the wheel-casing and suitably connected to mechanism by which it is raised and lowered to cover more or less of the mouths of the inlets, and thus admit a greater or less quantity of water to the runner.

Automatic regulator.—The mechanism by which the wheel is governed is shown in the drawings. The cylindrical gate 3 is connected by means of rods or bars 17 17 to a piston 18, which surrounds the driving-shaft 8, in which it is loosely fitted and is contained in a casing 19. The piston fits the casing loosely, so that there is always a certain amount of leakage around the piston and around the shaft. The sides of the casing are perforated with two ports 20 and 21, which are above and below the extreme positions of the piston, those positions being such as exist when the gate is fully closed or fully opened. 22 is a valve-chest mounted on the side of the casing and communicating with the casing by means of the ports 20 and 21. The valve-chest 22 is open at the upper end to penstock-pressure by the inlet 23 and is provided with an exhaust 24, which delivers its contents beyond the penstock. The exhaust 24 is provided with a valve 24ª, the purpose of which will be hereinafter described. The valve-chest is cylindrical in form, and in it is loosely fitted a cylindrical valve 25. Through the center of the valve there is an aperture 26, open at both ends, and around the exterior there is a channel 27, the ends of the cylinder being of greater diameter than the center. 28 is a valve-stem secured to the valve by a pin 29, which crosses without obstructing the channel 26. 30 and 31 are two collars or portions of the cylindrical valve, larger in diameter than the body and of a width about equal to the width of the ports 20 and 21. The operation of this device will be readily understood. If the wheel be mounted in a vertical position, the weight of the piston and the gate will cause both of them to have a tendency to fall and open the gate. Hence an excessive pressure must in this case be maintained below the pis-

ton 18 in order to counterbalance the weight of the parts. If the wheel is horizontal, however, the pressure on both sides of the piston must be maintained at an equal amount, so as to prevent the motion of the piston and the gate except when desired. When the parts are vertical, the slight leakage around the piston and the shaft would disturb the balance of the piston unless there was some flow of water continually entering the casing below the piston. Hence the lower port 20 is kept always slightly open to penstock-pressure and the port 21 always slightly open to exhaust except when the position of the gate is being changed. The parts are all made loose, so that they may be said to "float" under the influence of opposing pressures, so that at all times there will be some escape of water through the exhaust-valve 24ª. The valve 25 is balanced, so that it may be moved by the governor with the greatest promptitude and the least resistance. The constant flow of fluid through and around the piston will maintain upon both sides of the piston a constant pressure, the balance of which can be controlled by the exhaust. The effect of maintaining this constant pressure upon both sides of the piston is to keep the piston in a state of balance between active opposing pressures, with the result that as soon as the pressure on one side or the other of the piston is relieved by any means the active pressure upon the opposite side of the piston will immediately force it in the direction in which the pressure has been relieved. This combination produces an instantaneous action of the piston and a corresponding quick government of the wheel. An important element of my invention and one which I believe to be broadly new with me is the maintenance of a piston in a state of balance between opposing active pressures, in combination with means for relieving the active pressure on one side or the other of the piston, and thus causing instantaneous action of the piston and its connected part, which as I construct my wheel is a cylindrical gate, by which the admission of water to the runner is controlled. It will be perceived, however, that the part or parts connected to the piston might be the throttle or cut-off valve of a steam or other fluid engine or the controlling device of an electric motor, and therefore I have claimed my governor in combination with the controlling device of any prime motor. If it is desired to open the gate, the valve-stem 28 is pushed slightly down, closing port 20 to pressure and opening it to exhaust and closing 21 to exhaust and opening it to pressure. Water-pressure is thereby admitted from the penstock through 23 and 21 above the piston, and the water below the piston is simultaneously exhausted to 20, 27, and 24. If it is desired to close the wheel, the valve is drawn up, so as to open a communication between 23, 26, and 20, thus admitting penstock-pressure below the piston, and at the same time a communication will be opened between 23, 21, and 24. It will be perceived that the pressure may be admitted by the pipe 24 and exhausted through the pipe 23 with exactly the same result as is obtained from the operation described herein.

The operation of government in my wheel consists in automatically actuating the valve-stem 28 by a mechanism which is actuated from the main driving-shaft and which will shift this valve in such a manner as to move the gate up or down to supply the runner with the requisite quantity of water to maintain a constant speed under fluctuating load. In the government of a plant the speed of government required depends upon the character of work done by the plant and the magnitude of its changes of load. Great changes of load and perishable character of plant require a very quick government, to accomplish which overgovernment usually results. Moderate changes of load or comparatively indestructible character of plant will permit slow government and overgovernment is avoided. My invention is capable of adjustment so as to perform either of these operations, as occasion may require, and to change from one to the other at will by the adjustment of parts which are outside of the penstock and can be gotten at while the wheel is in operation.

Referring to Figs. 4 and 5, 8 is a driving-shaft. 32 is a sleeve secured to the driving-shaft by a pin 33 and provided on one side with a feather-way 32. (Shown in Fig. 6.) 35 is a screw having a central aperture and fitting upon the sleeve 32. It has a feather on one side, 36, which fits into and slides into the feather-way in the sleeve. The screw is therefore able to rise and fall on the sleeve while being turned by the shaft and sleeve. On the lower end of the screw is a projecting flange and thread. Upon the thread is screwed a ring, so as to form between the flange and the ring an annular groove 37. In this annular groove is contained a ring 38, which is pivoted at two opposite points 39 39 in a ring 40, which forms a part of a lever 41, one end of which is pivoted to a post 42 and the other end of which projects on the opposite side of the ring 40 and through which passes the valve-stem 28. The valve-stem is threaded above the lever and fitted with a nut to maintain its relation to the lever. 43 is a spring secured to the lever at one end and to a stationary part at the other, by which a desired tension is maintained upon the lever to counteract the upper pull of the governor. If the whole apparatus is erected vertically, the weight of the valve-stem and valve would be sufficient to counterbalance the pull of the governor. If it is horizontal or if the governor be located vertically and the valve horizontally and connected to the governor by a bell-crank lever or other device, the spring may be necessary. 44 is a nut threaded upon the screw 35 and secured to it by a spring 45, one end of which

is secured to the nut and the other end to the screw. The rotary motion of the shaft is thus communicated to the nut by means of the spring 45 and the screw will be screwed into the nut until the resistance of the spring overcomes the inertia of the nut and its connected parts, when the two will move in unison. 46 is a sleeve secured to the shaft 8 by a pin 47. The sleeve 46 has upon its lower end an annular flange 48, upon which rests a fly-wheel 49, which is caused to revolve upon the sleeve 46. The fly-wheel 49 is connected to the nut 44 by means of two links 50 and 51 and a weight 52, which are duplicated on the two sides. The primary adjustment of the parts is such that the links 50 and 51 are maintained at an angle with one another, and this angle is determined by the set-screws 53 53. 54 is a chair surrounding the sleeve 32, hollowed out on the under side and resting upon the nut 44. Upon the chair is a spiral spring 55. The upper end of the spring is confined by a collar 56, secured to a sleeve 57, which surrounds the shaft 8. At the upper end the sleeve 57 has an annular extension which surrounds the annular flange of the sleeve 46 and bears upon the under side of the fly-wheel 49. The operation of this device is as follows: When the driving-shaft turns, it turns the sleeve 32, which through the feather 34 turns the screw 35. The screw 35 is screwed into the nut 44 until the tension of the spring 45 overcomes the inertia of the nut, the fly-wheel, and the governor-weights. The upward motion of the screw will raise the lever 41 a corresponding degree. As the weights 52 52 revolve they will be extended by centrifugal force. The fly-wheel being supported by the flange 48 of the collar 46 cannot descend. Therefore as the governor-weights 52 52 are extended the whole structure connected with them, the nut, the screw, and the lever 41 will be drawn up together, compressing spring 55. To stop the wheel, the valve-rod is drawn up and the nut 58 screwed down on the valve-stem until the port 20 is opened to pressure, and the port 21 to exhaust the gate will thus be maintained closed and the wheel at rest. To start the wheel, the nut 58 is screwed upon the valve-stem one or two turns until the valve 25 is lowered enough to open port 21 to penstock-pressure and port 20 to exhaust, when the piston will descend at a speed dependent upon the aperture thus created, and as the gate is opened the speed of the wheel will begin to build up. It is important that the time allowed for opening the gate should not be greater than the time in which the wheel can with safety build up its speed. The speed of the gate can be regulated with accuracy by the nut 58. When the wheel has built up its speed to the desired number of revolutions and the governor-weights are at a mean position, the lever 41 will be in a certain position surrounding the valve-stem. The nut 59 is then screwed down on the lever, and any further acceleration of speed will lift the lever and valve-stem and reverse the direction of the gate. It will be perceived that there is a position thus established for the lever 41, at which the speed of the wheel will remain constant, while any rise of the lever will cause the gate to be closed somewhat and any lowering will cause it to open. In actual governing it is necessary that the gate should move more rapidly than when merely starting the wheel. To accomplish this, the nut 58 is screwed up on the valve-stem a short distance, so that when the lever 41 drops below the mean line the nut 58 will allow the valve-stem to move down and the valve 25 to be opened somewhat wider than was allowed for starting, and consequently more water will be admitted above the piston and the gate opened more rapidly. It will be remembered that the speed at which the gate is allowed to move is always under the control of the valve 24^a, by which any desired back pressure may be maintained in the exhaust.

It will be noticed that when a sudden increase or drop of load occurs the increase or decrease of resistance to the runner will instantly decrease or increase the speed of the runner. This change is very quick, and if the governor structure be rigidly connected with the shaft the momentum of the fly-wheel and the governor-weights will not permit a change of the gate quickly enough to compensate for the sudden change of load. The sudden change of gate is accomplished by the action of the screw 35, which, turning with the shaft and turning the governor by means of the spring 45, will under a sudden change of speed in a shaft be screwed into or out of the nut 44, and the tension of the spring 45 will be suddenly increased or decreased in consequence. The action of the screw 35 in entering or withdrawing from the nut 44 under the influence of a sudden change of speed in the driving-shaft will with equal quickness move the valve 25, which will cause the gate to open or close it, as the case may be, at a speed predetermined by the setting of the valve 24^a. The tendency of the spring 45 is to maintain a constant tension and constant relation between the nut and the screw, and if the tension of the spring be suddenly increased by an acceleration of speed and the screwing of the screw into the nut the tension of the spring will gradually reassert itself and gradually unscrew the screw from the nut. Thus with a sudden decrease in load and acceleration of speed the screw will be screwed from the nut, the tension of the spring decreased, the lever 41 raised, carrying with it valve-stem 28, which will open the port below the piston 18, admitting pressure thereto while exhausting the other side of the piston, and the gate will be to some extent closed. As the speed of the wheel drops the tension of the spring 45 will reassert itself, and the nut 44, being pressed down by the spring 55, will reëstablish a normal tension of the spring

45, and the nut and screw will be forced downward, thus forcing the valve-stem 28 downward, closing the port 20 and opening the port 21 slightly to pressure, with the result that the gate will be opened and more water admitted to the wheel. The period between the time of operating the gate by the first action of the screw 35 and the time of the readjustment of the gate to load by the main governor is the period of overgovernment. This period can be varied by varying the tension of the spring 45 and also by varying the aperture of the valve 24ª. If the valve 24ª is open wide, so as to offer no resistance to the exhaust-water from the piston-casing, and a very flexible spring be used, the governor will seesaw—that is to say, an excessive change of load will cause a wide fluctuation in the position of the nut 44, and consequently a correspondingly great motion in the valve 25, and a consequently great inrush of pressure to the casing, and with a free exhaust the piston will be driven up or down, so as to open or close the gate, and the extent of the overthrow in one direction will cause a corresponding overthrow in the other direction, with a corresponding acceleration and diminution of the speed of the wheel. This capacity for fluctuation through wide limits, which would be detrimental, is controlled by the tension of the spring 45 and the aperture of the valve 24ª. If the aperture of the valve 24ª be made less than the pressure-inlet, the action of the piston will be retarded and its speed when moved lessened, with the result that it can be more easily checked at a proper point. It is, however, very important that the amount of the overthrow should be under control, and this is accomplished by the adjustment of the valve 24ª. As the tension of the spring 45 is increased the amount of overthrow which will be given to the gate is decreased, and it may even be reduced to zero, in which case the spring 45 may be entirely dispensed with, and the screw and nut also, the parts being rigidly connected. Such a structure will satisfactorily govern a plant in which the fluctuations of load are not very great, or if great are gradual. The too great overthrow is also controlled by my governor as constructed. It will be noticed that the pitch of the screw 35 is about twice the depth of the recess in the under side of the chair 54. If, therefore, a very sudden change of load occurs, sufficient to cause the screw or the nut to change their positions an amount equal to something more than a half-revolution of the nut, the screw will protrude into the recess in the chair 54, and bearing upon the under side of that chair will lift it up against the tension of the spring 55. This increased resistance to the screw will serve to check the overthrow. If the overthrow be still greater and the spring 55 be so much compressed as to overcome the weight of the fly-wheel, the whole structure, including the fly-wheel, the governor-weights, the nut, and the screw, will be lifted up by the sleeve 57, which bears on the under side of the fly-wheel. This will relieve the fly-wheel 49 from the support of the flange 48, and the governor-weights will be forced still farther out by the compression of the spring 55 by the weight of the fly-wheel, and the weights and the valve-stem will be drawn up and the gate almost, if not wholly, closed.

It will be perceived that the object of my governing device is to maintain the balanced valve 25 in a position fixed relatively to the ports 20 and 21 when the load and speed are constant. When the load fluctuates and the speed with it, the valve 25 is simply raised or lowered, as the case may be, the valve 24ª having been previously set to retard the exhaust and produce a requisite amount of back pressure upon the piston, so as to prevent its too rapid motion.

In describing the action of my governor I have described the apparatus as using penstock-pressure, because in practice this is convenient; but it will be perceived that any other source of water-pressure, such as a pump, may be substituted, or the water may be replaced by air, gas, or steam pressure, or a vacuum may be produced to utilize atmospheric pressure. It is equally true that the piston-casing and piston may be located outside of the penstock and supplied with any fluid and attached to govern any wheel already in use, no matter what the form of the gate. It will also be equally apparent that the valve by which pressure is admitted to the piston-casing may be actuated electrically as well as mechanically. The lever 41 may be made to close the circuit of one or two magnets, so arranged as to pull the valve-stem up or down as one or the other is energized.

In the construction described in this application and shown in the drawings a single balanced valve is employed, which by a single motion of one valve-stem admits pressure to one side of the piston and exhausts from the other. It will be at once perceived that this structure might be varied so as to operate two or more valves by the same motion of the valve-stem, whereby the same result might be accomplished. It will also be perceived that the structure of this case may be varied by closing the pressure-inlet to the valve 25 and opening pressure-inlets on both sides of the piston. The piston will then be subject to penstock-pressure on both sides, which penstock-pressure above or below the piston, as the case may be, will be relieved by the exhaust caused by the position of the valve 25, and the speed of this exhaust may be checked and controlled by the valve 24ª.

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

1. In a turbine water-wheel the combination of a casing having water-inlets, a gate controlling the admission of water to the inlets, and a runner operated upon by the inlet-water with a governor for controlling the

gate, consisting of a piston balanced between opposing pressures and connected to the gate so as to move it, a balanced valve capable of admitting pressure on one or the other side of said piston and means actuated by the motion of the runner for changing the position of said valve to admit pressure on one side or the other of the piston as the speed of the runner varies from the normal.

2. In a turbine water-wheel the combination of a casing having water-inlets, a gate controlling the admission of water to the inlets and a runner operated upon by the inlet-water, with a governor for controlling the gate according to changes of speed due to change of load which consists of a piston balanced between pressures, connected to the gate, so as to move it to open or close, a balanced valve capable of admitting pressure to one side and relieving pressure from the other side of said piston as it is moved, and means actuated by the motion of the runner connected to and actuating said valve to admit pressure on one side and exhaust from the other side of said piston or vice versa as the case may be as the speed of the runner varies from normal.

3. In a turbine water-wheel a combination of a casing having water-inlets and a runner operated upon by the inlet-water, with a governor for controlling the gate according to the changes of speed due to changes of load, which consists of a piston balanced between pressures, connected to the gate so as to move it to open or close a balanced valve capable of admitting pressure to one side or relieving pressure from the other side of said piston as it is moved from one position to another, means actuated by the motion of the runner connected to and actuating said valve to admit pressure above and exhaust from below said piston, or vice versa as the case may be as the speed of the runner varies from normal, and a pressure-regulating valve located in the exhaust-pipe as and for the purpose specified.

4. In a turbine water-wheel the combination of a casing having water-inlets, a gate controlling the admission of water to the inlets, a runner operated upon by the inlet-water, with a governor for controlling the gate according to changes of speed due to changes of load, which consists of a piston inclosed in a suitable casing, water-passages through or around said piston admitting water from one side of it to the other in limited quantities, said piston being balanced between pressures and connected to the gate so as to move it to open and close, a balanced valve capable of admitting pressure to one side and relieving pressure from the other side of said piston as it is moved, and means actuated by the motion of the runner connected to and actuating said valve to admit pressure to one side and exhaust from the other side of said piston or vice versa as the case may be, as the speed of the runner varies from normal.

5. In a turbine water-wheel the combination of a casing having water-inlets, a gate controlling the admission of water to the inlets and a runner operated upon by the inlet-water, with a governor for controlling the gate according to changes of speed due to change of load which consists of a piston balanced between pressures, connected to the gate, so as to move it to open or close, a series of valves capable of admitting pressure to one side and relieving pressure from the other side of said piston as they are moved, and means actuated by the motion of the runner connected to and actuating said valve to admit pressure above and exhaust from below said piston or vice versa, as the case may be as the speed of the runner varies from normal.

6. In a turbine water-wheel the combination of a casing having water-inlets, a gate controlling the admission of water to the inlets and a runner operated upon by the inlet-water, with a governor for controlling the gate according to changes of speed due to changes of load which consists of a piston balanced between pressures and connected to the gate so as to move it to open or close inclosed in a suitable casing, said casing being open to penstock-pressure above and below the piston, a balanced valve connected to both ends of the casing above and below the piston and to an exhaust emptying outside the penstock whereby the penstock-pressure above or below the piston may be reduced in accordance with the position of the valve, and means actuated by the motion of the runner connected to and actuating the valve to exhaust the pressure on one side or the other side of the piston or vice versa, as the case may be, as the speed of the runner varies from normal.

7. In a turbine water-wheel the combination of a casing having water-inlets, a gate controlling the admission of water to the inlets and a runner operated upon by the inlet-water, with a governor for controlling the gate according to changes of speed due to changes of load which consists of a piston balanced between pressures connected to the gate so as to move it to open or close, a casing surrounding the piston, a valve-chest open to penstock-pressure and having ports connected to the two ends of the casing above and below the piston, a balanced valve in said valve-chest capable of admitting pressure to one side and relieving it from the other side of the piston as the valve is moved, and means actuated by the motion of the runner connected to and actuating said valve to admit pressure on one side and exhaust from the other side of said piston or vice versa, as the case may be, as the speed of the runner varies from normal.

8. In a turbine water-wheel the combination of a casing having water-inlets, a gate controlling the admission of water to the inlets and a runner operated upon by the inlet-

water with a governor for controlling the gate according to changes of speed due to changes of load which consists of a piston balanced between pressures connected to the gate so as to move it to open or close, a balanced valve capable of relieving the pressure from one or the other side of said piston as it is moved, and a centrifugal governor connected to and actuating said valve, consisting of a screw, a nut, a pair of governor-weights and a fly-wheel, the screw having a rotary and a vertical motion, the nut being threaded upon the screw and secured to it by means of a coiled spring one end of which is connected to the screw and the other to the nut, a pair of governor-weights connected to links which are secured at one end to the nut, and at the other end to a fly-wheel, the nut being separated from the fly-wheel by a compression-spring, substantially as described.

9. In a turbine-water-wheel governor, the combination of a casing for the wheel, of a gate admitting water to the wheel, a cylinder open at both ends to fluid-pressure, a piston within the cylinder connected to and operating the gate, and balanced between opposing pressures, and means for exhausting the pressure above or below the piston, as and for the purpose specified.

10. In a turbine-water-wheel governor, the combination of a casing for the wheel, of a gate admitting water to the wheel, a cylinder open at both ends to fluid-pressure, a piston within the cylinder connected to and operating the gate, and balanced between opposing pressures, and means for exhausting the pressure above or below the piston, controlled by the speed of the wheel.

11. In a turbine-water-wheel governor, the combination of a casing for the wheel, of a gate admitting water to the wheel, a cylinder open at both ends to fluid-pressure, a piston within the cylinder connected to and operating the gate, and balanced between opposing pressures, and a valve connected to an outlet from the piston, adapted to exhaust pressure from above or below the piston, controlled by the speed of the wheel.

12. In a turbine-water-wheel governor, the combination of a casing for the wheel, of a cylindrical gate within the casing, a cylinder open at both ends to fluid-pressure, a piston within the cylinder connected to and operating the gate, and balanced between opposing pressures, an outlet in the top of the cylinder, and one in the bottom of the cylinder, exhausting pressure above or below the piston, and means for controlling said outlets.

13. In a turbine-water-wheel governor, the combination of a casing for the wheel, of a gate admitting water to the wheel, a cylinder open at both ends to penstock-pressure, a piston within the cylinder connected to and operating the gate, and balanced between opposing pressures, an outlet in the top of the cylinder, and one in the bottom of the cylinder, exhausting pressures above or below the piston, and means controlled by the speed of the wheel for opening one or the other of said outlets, substantially as described.

14. In a turbine water-wheel, the combination of a casing, a gate admitting water to the wheel, a cylinder, a piston within the cylinder connected to and operating the gate and balanced between opposing pressures, and means for admitting pressure above and below the piston, and means for exhausting the pressure above or below the piston.

15. In a turbine water-wheel, the combination of a casing, a gate supplying water to the wheel, a cylinder, a piston within the cylinder, connected to and operating the gate and balanced between opposing pressures, means for admitting pressure above and below the piston, means for exhausting pressure above and below the piston, and means for controlling the pressure and exhaust by the speed of the wheel.

16. In a turbine water-wheel, the combination of a casing, of a gate supplying water to the wheel, a cylinder, a piston within the cylinder, connected to and operating the gate and balanced between opposing pressures, means for admitting pressure above and below the piston, means for exhausting the pressure above and below the piston, and means for controlling the pressure and exhaust.

17. In a turbine water-wheel, the combination of a casing, of a gate supplying water to the wheel, a cylinder, a piston within the cylinder, connected to and operating the gate and balanced between opposing pressures, means for supplying pressure above and below the piston, controlled by the speed of the wheel, and means for exhausting the pressure above and below the piston.

18. In a turbine water-wheel, the combination of a casing, a gate supplying water to the wheel, a cylinder, a piston within the cylinder, connected to and operating the gate and balanced between opposing pressures, means for supplying pressure above and below the piston, means for exhausting the pressure above and below the piston, and means for controlling the exhaust of pressure above and below the piston.

19. In a turbine water-wheel, the combination of a casing, a gate supplying water to the wheel, a cylinder, a piston within the cylinder, connected to and operating the gate and balanced between opposing pressures, means for admitting pressure above and below the piston, means for exhausting the pressure above and below the piston, means for regulating the pressure admitted, and a valve in the discharge-outlet, for regulating the discharge of exhaust.

20. In a turbine water-wheel, the combination of a casing having water-inlets, a cylindrical gate controlling the admission of water to the inlets, a runner operated upon by the inlet-water, with a governor for controlling the gate, according to changes of speed, due to changes of load, which consists of a piston

inclosed in a suitable casing, water-passages through or around said piston, admitting water from one side of it to the other, in limited quantities, said piston being balanced between pressures and connected to the gate so as to move it to open and close, a balanced valve loosely fitted in a valve-chest, to permit the passage of pressure around the valve in limited quantities, and having water-passages through and around it for the passage of pressure and exhaust, and adapted to admit pressure to one side, and relieve pressure from the other side, of said piston, as it is moved, substantially as described.

21. In a turbine water-wheel, the combination of a casing having water-inlets, a cylindrical gate controlling the admission of water to the inlets, a runner operated upon by the inlet-water, with a governor for controlling the gate, according to changes of speed, due to changes of load, which consists of a piston inclosed in a suitable cylinder, passages through or around said piston, admitting pressures from one side of it to the other, in limited quantities, said piston being balanced between pressures and connected to the gate so as to move it to open and close, a balanced valve adapted to admit pressure to one side, and relieve pressure from the other side, of said piston, as it is moved, substantially as described.

22. In a turbine water-wheel, the combination of a casing having water-inlets, a cylindrical gate controlling the admission of water to the inlets, a runner operated upon by the inlet-water, with a governor for controlling the gate, according to changes of speed, due to changes of load, which consists of a piston inclosed in a suitable cylinder, passages through or around said piston admitting pressure from one side of the piston to the other, in limited quantities, said piston being balanced between pressures and connected to the gate so as to move it to open and close, a balanced valve fitted loosely in a suitable valve-chest, and permitting the passage of pressure around the valve, in limited quantities, passages from the valve-chest to the top and to the bottom of the cylinder, and an exhaust-passage from said valve-chest, the valve being adapted to admit pressure on one side, and relieve pressure from the other side, of said piston, as it is moved, and means actuated by the motion of the runner, connected to and actuating said valve to admit pressure to one side of the piston and exhaust from the other side of said piston, or vice versa, as the case may be, as the speed of the runner varies from normal.

23. In a prime-motor governor the combination of a controlling device for the prime motor, a cylinder open at both ends to fluid-pressure, a piston within the cylinder connected to the controller and balanced between opposing pressures, and means for exhausting the pressure on one or the other side of the piston, as and for the purpose specified.

24. In a prime-motor governor the combination of a controlling device for the prime motor a cylinder means for supplying pressure to both ends of said cylinder, a piston within the cylinder connected to the controller and balanced between opposing pressures, and means for exhausting the pressure on one or the other side of the piston, as and for the purpose specified.

25. In a prime-motor governor the combination of a controlling device for the prime motor a cylinder open at both ends to fluid-pressure, a piston within the cylinder connected to the controller and balanced between opposing pressures, and means for exhausting the pressure on one side of the piston controlled by the speed of the prime motor.

26. In a prime-motor governor the combination of a controlling device for the prime motor a cylinder, means for admitting fluid-pressure to both ends of the cylinder, a piston within the cylinder connected to the controller and balanced between opposing pressures, means for exhausting pressure from one or the other side of the piston, and means for controlling the pressure admitted and the exhaust by the speed of the prime motor.

27. In a prime-motor governor the combination of a controller for the prime motor a cylinder, means for admitting fluid-pressure to both ends thereof, a piston within the cylinder connected to the controller and balanced between opposing pressures, means for exhausting pressure on one or the other side of the piston, and means for controlling the pressure admitted by the speed of the wheel, and a valve controlling the exhaust.

28. In a prime-motor governor the combination of a piston balanced between opposing pressures, means for admitting pressure to both sides of the piston, means for exhausting pressure from both sides of the piston with a centrifugal governor controlling the admission and exhaust of pressure to and from the piston consisting of a screw driven by the prime motor, a nut, a pair of governor-weights and a fly-wheel, the screw having a rotary and vertical motion, the nut being threaded upon the screw and secured to it by means of a coiled spring, one end of which is connected with the nut and the other end to the screw, the governor-weights being connected to links which are secured at one end of the nut and at the other end to the fly-wheel, the nut being separated from the fly-wheel by a compression-spring, substantially as described.

Signed at Baltimore, Maryland, September 6, 1899.

FRANCIS ELLICOTT.

Witnesses:

JOSEPH S. MACURLLEAN,

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