No. 713,463. Patented Nov. 11, 1902.

J. A. LIGHTHIPE.

GOVERNOR.

(Application filed Aug. 26, 1898.)

(No Model.) 4 Sheets—Sheet 1.

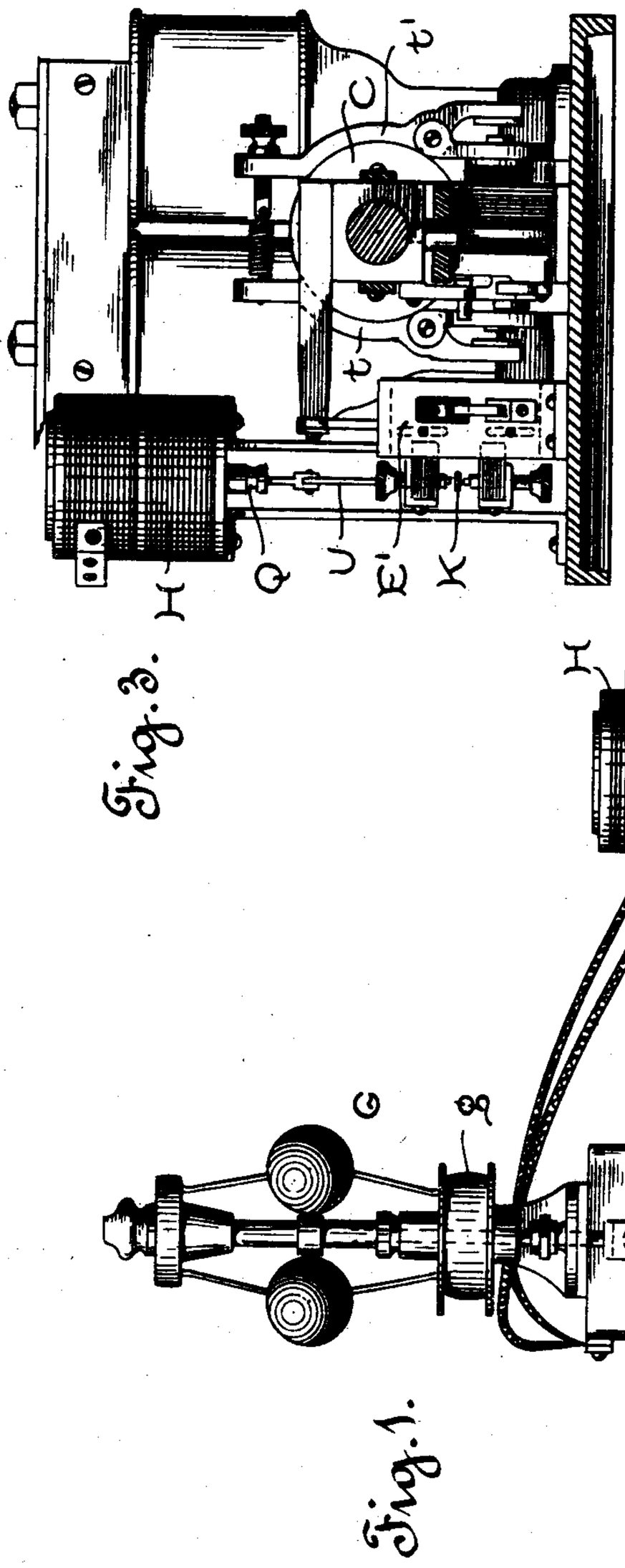

Fig. 3.

Fig. 1.

Witnesses.

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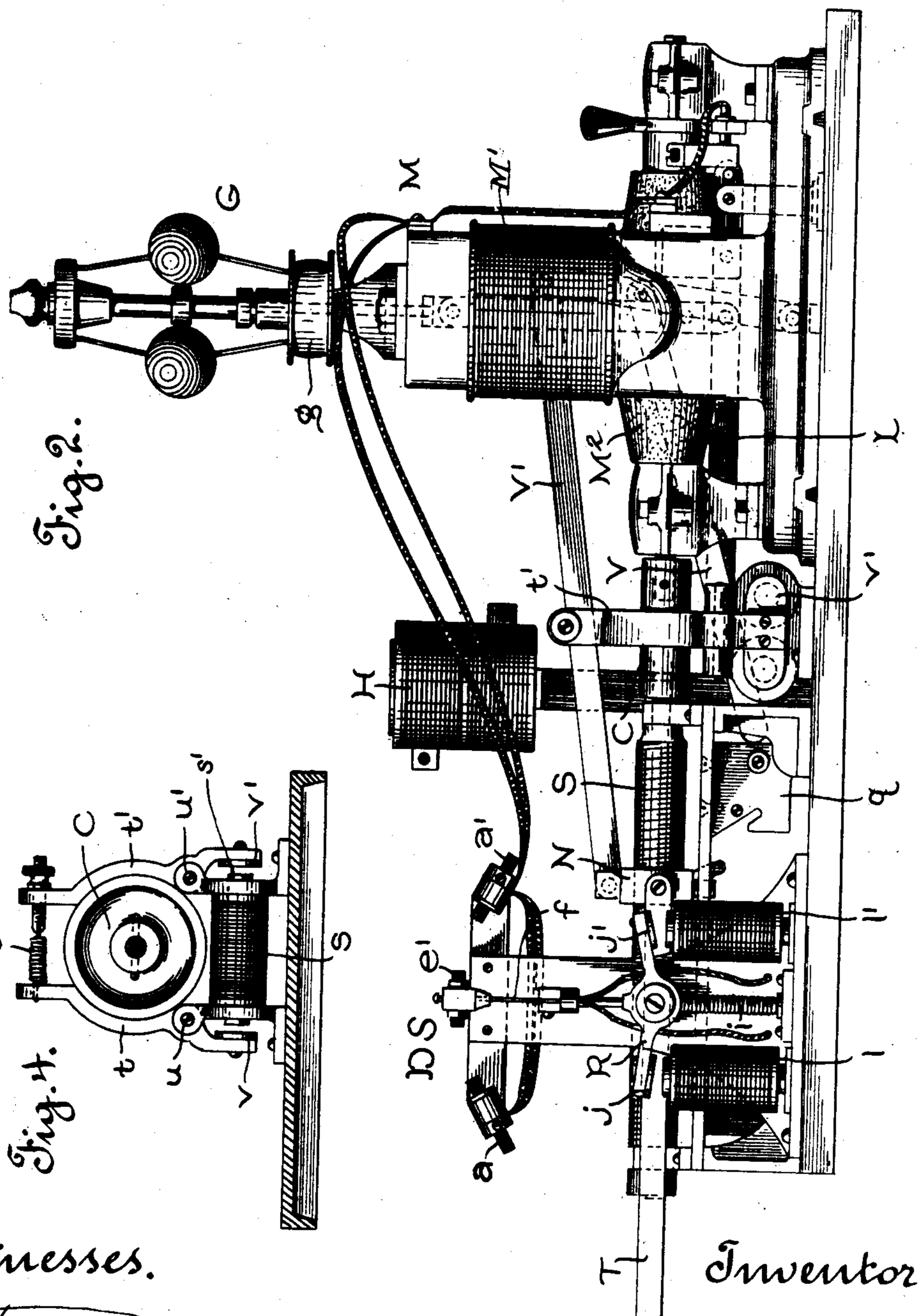
4 Sheets—Sheet 2.



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(No Model.) 4 Sheets—Sheet 3.

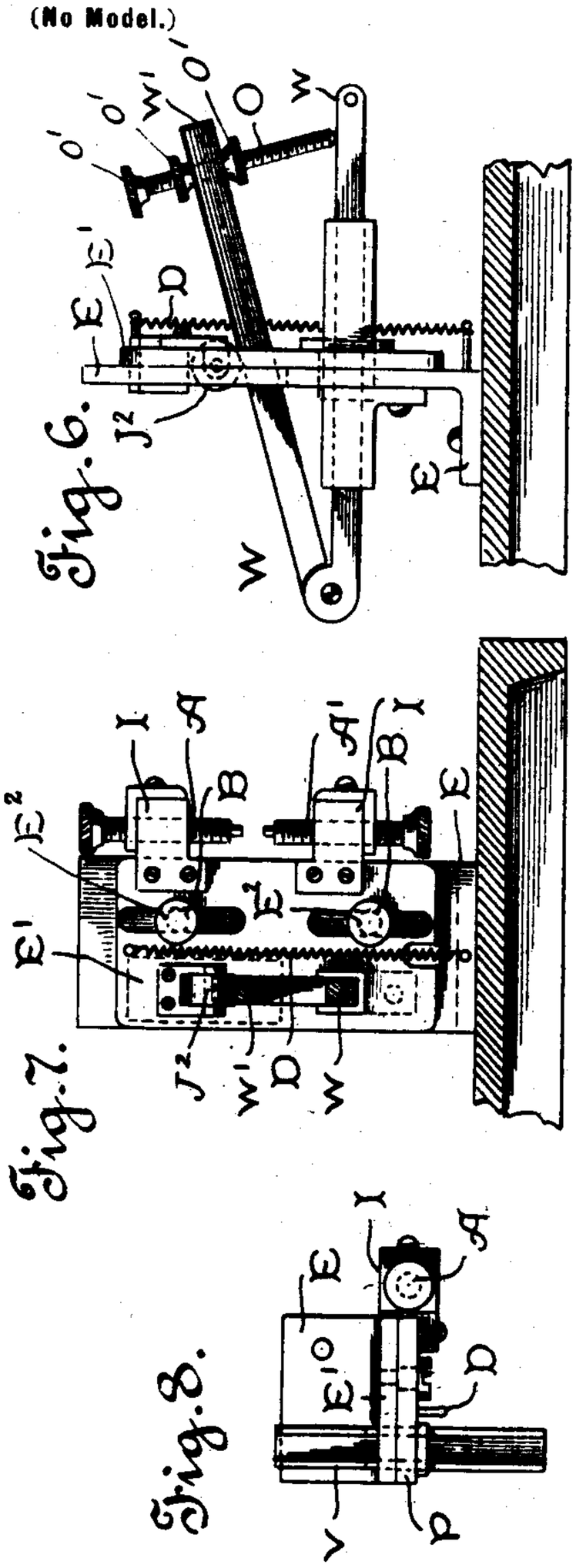

Fig. 6.

Fig. 7.

Fig. 8.

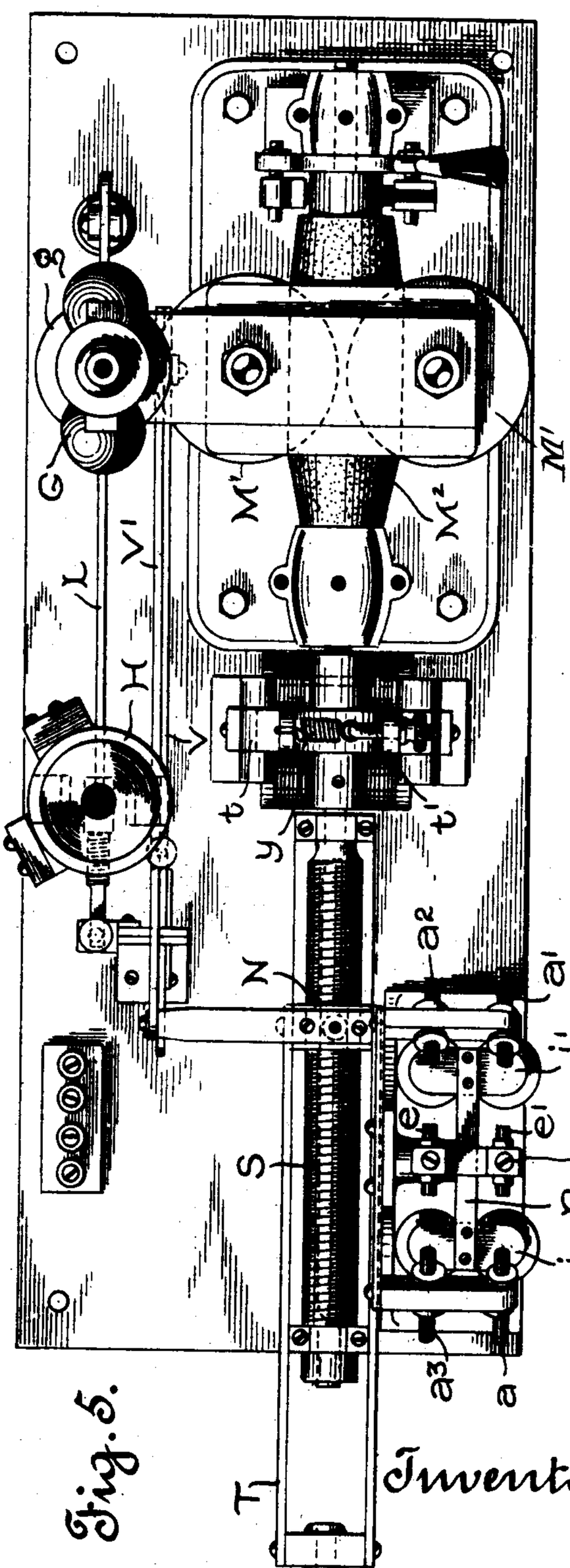

Fig. 5.

Witnesses.

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(No Model.) 4 Sheets—Sheet 4.

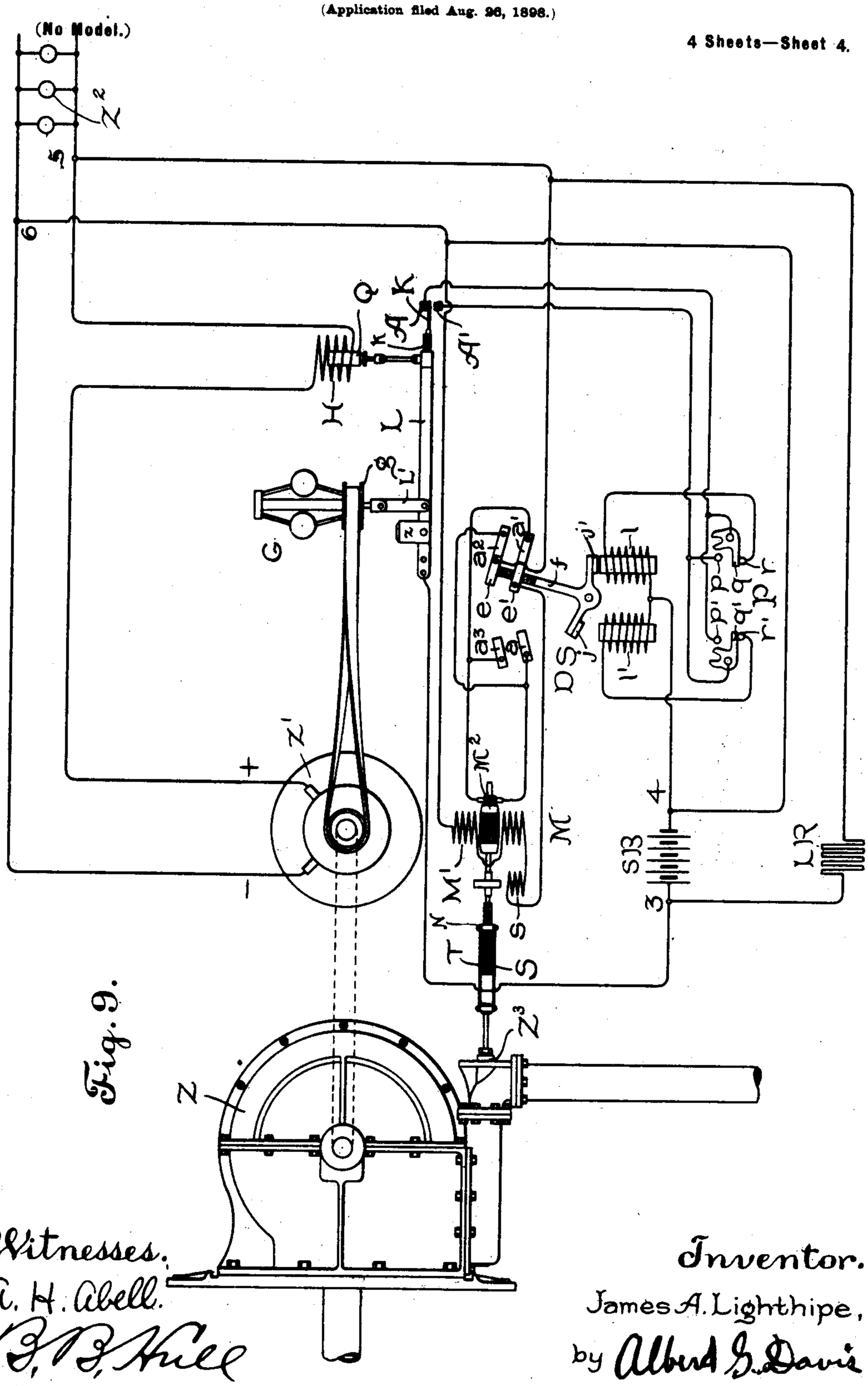

Fig. 9.

Witnesses.
A. H. Abell.
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THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

JAMES A. LIGHTHIPE, OF SAN FRANCISCO, CALIFORNIA, ASSIGNOR TO THE GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

GOVERNOR.

SPECIFICATION forming part of Letters Patent No. 713,463, dated November 11, 1902.

Application filed August 26, 1898. Serial No. 689,550. (No model.)

To all whom it may concern:

Be it known that I, JAMES A. LIGHTHIPE, a citizen of the United States, residing at San Francisco, in the county of San Francisco and State of California, have invented certain new and useful Improvements in Governors, of which the following is a specification.

My invention relates to governors of prime movers of any type, and is especially adapted for use with devices driving dynamo-electric machines. I have illustrated it in the drawings hereto attached as applied to the government of a water-wheel direct-connected to a dynamo-electric machine, for which purpose it is particularly fitted.

The ordinary governor consists of a centrifugal device and means for varying the speed of the prime mover in accordance with the position of some part of the centrifugal device, and thus in accordance with the speed. Such an apparatus necessarily causes the prime mover to run more slowly at full load than at no load, since the different positions of the valves or other controlling device must necessarily correspond to different positions of the centrifugal devices. Such a governor is further responsive to changes of speed and does not act until after the change of speed has taken place, which tends to cause imperfect regulation and "hunting."

One feature of my invention consists in combining with such a governor a device so arranged that a change of load has the same effect upon the governor as a change of speed. In the particular application shown a ball-governor serves to control the admission of water to a water-wheel driving a dynamo-electric machine, and in carrying out this feature of my invention I have provided means whereby an increase in the current taken from the dynamo-electric machine will cause an increase in the amount of water supplied to the water-wheel independent of the effect of speed on the ball-governor. In this way I am able to cause the speed of the water-wheel to remain constant at all loads or, if desirable, to be increased as the load comes on, which has the effect of compounding the dynamo-electric machine, so that a shunt-wound machine may be used to take the place of a compound wound machine either for straight compounding or for overcompounding.

Another feature of my invention resides in a device for preventing hunting, so arranged that the adjustment of the valve is automatically stopped before the machine has fully responded to the change.

My invention further comprises an arrangement for supplying current to a motor-controlling device which, though here shown in connection with a motor controlling a water-wheel, is applicable in various relations.

I further provide an automatic arrangement for preventing an excessive travel of the valve or other regulating device and various other improvements to be hereinafter more particularly described and claimed.

In the accompanying drawings, which show an embodiment of my invention, Figures 1 and 2 are side elevations. Fig. 3 is an end elevation, partly in section. Fig. 4 is a detail end elevation, showing the friction-brake. Fig. 5 is a plan of the device. Figs. 6, 7, and 8 are enlarged views showing the apparatus for preventing hunting, and Fig. 9 is a diagram of the circuits.

Referring more particularly to Fig. 9, Z is a water-wheel, shown direct-connected to a direct-current generator Z′, which feeds translating devices, such as lamps Z^2. Z^3 is a valve controlling the speed of the water-wheel. This valve is opened and closed by links T, which are reciprocated by the action of a screw S upon the block or cross-head nut N. This screw is rotated by an electric motor M, as is shown more in detail in Figs. 1, 2 and 5. The field-magnets M′ of this motor are excited in series with its armature M^2 by current taken from any suitable source of electricity—as, for example, from the lines, as shown.

DS is a direction-switch or reversing-switch for determining the direction of motion of the motor M. The structure of this switch is shown best in Figs. 2 and 5, while its electrical connections may be easily understood by reference to Fig. 9. It will be seen that there are four stationary contacts $a\ a'\ a^2\ a^3$, which are held rigidly in place upon a fixed member of the apparatus. The switch-lever carries two armatures $j\ j'$ and a

flexible strip *f*, supporting the contact-points *e e'*. A spring *i* tends to hold the contacts in the intermediate position shown in Fig. 2. Electromagnets *l l'* are arranged to act upon the armatures *j j'* to force the points to make contact either with the points *a' a²* or with the points *a a³*. It will thus be seen that when no current flows in either of the magnets *l l'* the motor M remains stationary; but when current does flow in either one of the magnets the switch DS is caused to close the circuit of the motor, so that it will run in one direction or the other, according to which one of the magnets *l l'* is energized. It is evident that these magnets may be excited from any suitable source of current; but I prefer to excite them from a storage battery or polarized cell SB, connnected in multiple with the mains in series with the resistance LR, which may be composed of a bank of lamps. The result of this arrangement is that the battery is kept continually charged and is at all times ready to supply current at low potential to the magnets *l l'*. The terminal 3 of the battery is connected to the lever L, while the terminal 4 is connected to both of the magnet-coils *l l'*, which in turn are connected, respectively, to the contacts A A' through the safety-switch P, which will be hereinafter more fully described.

The lever L (shown more fully in Fig. 1) is pivoted at the point F and is provided with a contact-strip K, supported from the free end of the lever by a spring *k*. A link L' connects the lever with the ball-governor G, which is driven by means of the pulley at a speed corresponding to the speed of the governed mechanism. The details of construction of the governor will be evident from inspection and are such as to cause the free end of the lever L to rise when the speed is too low and to fall when the speed becomes too high. An adjustable weight *z* is fastened to the lever in such a way as to normally balance it at the proper point.

It will be seen in Fig. 9 that when the speed becomes too slow the free end of the lever L rises and carries up the contact-strip K, so that current flows from the terminal 3 of the storage battery to the lever L, strip K, contact A, thence through the contacts *q r* of the safety-switch P, through the magnet *l*, and back to the storage battery at 4. This energizes the magnet *l* and draws the arm *f* of the direction-switch to the right, so that the points *a'* and *e'* and *a²* and *e*, respectively, come in contact with each other. Current now flows from the mains at 5 to the contact *e*, contact *a²*, through the commutator on the armature M², to the contact *a'*, contact *e'*, through the brake-retracting coil *s*, whose function will be more fully described hereinafter, through the field-magnets M', and back to line at 6. The motor now starts up and runs and drives the screw S in such a direction as to cause the links T to open the valve Z³. The speed of the prime mover then rises until the lever L drops sufficiently to allow the strip K to leave the contact A. If, however, the machines are run too fast, the magnet *l'* will be energized, the arm *f* will be pulled to the left, and the circuit through the motor M will be closed in such a way that it will run in the opposite direction.

When no regulation is required, the spring *i*, Fig. 2, holds the spring-points *e e'* in the central or off position, so that the circuit of the motor is interrupted. In this condition the motor is prevented from rotating by a friction-brake. (Shown in the end elevation, Fig. 3, and also shown more in detail in the section, Fig. 4.)

C is a drum attached to the shaft of the motor, on which bears a friction-brake composed of two arms *t t'*, which are pivoted at *u u'*. These arms are drawn together by the adjustable spring *y* when no current flows in the motor-circuit; but when current flows through the motor it also flows through the coil *s*, which serves to energize the core *s'* and attract the armatures *v v'*, so as to retract the arms *t t'* from the drum C. It will be seen that the action of this brake will be to immediately stop the motor when the valve is brought to the regulating position and also to hold it stopped when no regulation is needed, though it does not in any way interfere with the action of the regulator.

The safety-switch P is designed to prevent the motor M from driving the valve beyond the extreme limit of its travel in either direction when any abnormal condition arises—as, for example, when the machine Z' is shut down and the lever L should remain in contact with A. The construction of this switch is shown in Fig. 1. It will be seen that the cross-head or nut N carries an extension *m*, provided with two roller projections *m' m²*. These projections act upon the switches *q q'*, which consist of irregularly-shaped pieces, as shown, held in the position shown by a spring *n*, which spring is "overset," so that it tends to maintain the switch in whichever one of its extreme positions it may then be. Suppose, for example, that the water-wheel is shut down by means of an external valve, as shown. The cross-head N evidently travels to the right in Fig. 1 under the action of the governor until finally the roller *m'* reaches and throws over the switch *q*. Referring to Fig. 9, it will be seen that this action will tend to cause current to flow from *q* to *p* instead of from *q* to *r*, so that the magnet *l* will be deënergized and the magnet *l'* will be energized. This will reverse the motor M, which will cause the cross-head N to stop and to draw back toward the right until the switch *q* is placed in a position intermediate the two contacts *p* and *r*. Extreme travel in the other direction is prevented by the switch *q'*, which acts in the same way as does the switch *q*.

To prevent the governor from racing, it is necessary that when any change of speed oc-

curs which tends to open or close the valve this action be stopped just before the water-wheel or other prime mover has fully responded to the movement; otherwise the water-wheel would come to the desired speed, with the motor M′ still in motion and still tending to move the valve. This would cause excessive correction, which would cause the governor to act in the other direction, and racing or hunting would occur. To prevent this action, I provide a means whereby the contact between the lever K and the contacts A A′ is broken before the valve has completely responded to the governor. In other words, I provide an arrangement such that the very action which results from the closing of a contact tends to open that contact.

Referring to Figs. 1, 6, 7, and 8, it will be seen that the contacts A A′ are mounted on a frame E′, which reciprocates on the standard E, being attached thereto by bolts E^2, extending through slots in the frame. This frame is drawn downward by a spring D and is forced upward by a device W, which consists of a horizontal arm *w* and an inclined arm *w′*, whose angle of inclination is adjusted through the screw O and the milled heads O′ O′. The frame E′ carries the roller J^2, and it will be obvious that a lateral reciprocating motion of the arm *w* (a right and left movement, Fig. 6) will cause a vertical reciprocating motion of the plate E′.

Referring now to Fig. 1, it will be seen that the cross-head nut N has pivoted to it a link V′, which in turn is pivoted to an arm Y, pivoted at Y′, and an arm V is pivoted at one end to the arm Y. The arm V is pivoted at its other end to the arm *w* of the device W. This apparatus constitutes means for reducing motion, such that any motion of the cross-head N will be accompanied by a corresponding motion of the arm *w*, though on a reduced scale. Suppose now that the lever L, Fig. 9, rises, so that the stop K makes contact with the contact A. This action will cause the cross-head nut N to move to the right in Fig. 1, which will cause the arm *w* to move to the right and raise the contact A away from the strip K. If this action takes place too soon, a further rise of the lever L will cause a further travel of the motor, valve, and contact A. In this way the action of the governor is made more gradual and hunting is prevented.

The device, as thus far described, is responsive alone to speed in the prime mover; but I provide a solenoid H, (shown in Figs. 1, 2, 3, 5, and 9,) so arranged that an increase of current in the main circuit, which of course corresponds to increased load upon the prime mover, will have the same tendency as decrease of speed—namely, a tendency to raise the lever L. This action is practically instantaneous and takes place irrespective of and before any change in speed of the prime mover. Correspondingly, any decrease in the current in the circuit will drop the arm L and partially close the valve of the prime mover, and thus anticipate the regulation which will normally be caused by the increased speed resulting from the decreased load. It will be readily seen that as the load suddenly changes the governor and the solenoid coöperate or oppose each other, as the case may be. Thus upon a sudden increase in load the solenoid causes an upward pull on the lever L in opposition to the centrifugal action of the governor, while a directly contrary effect is produced upon a sudden decrease in load, in which latter case the solenoid decreases its pull upon the lever L, which with its attached weight moves in the same direction as would be produced by the centrifugal action of the governor.

It will be seen at once that the various regulating devices and safety devices, such as the safety-switch P and the antihunting device W, operate as well in response to the solenoid H as they do in response to the governor G. I have thus provided a governor which is responsive both to changes of speed and changes of load and which, therefore, is capable of maintaining constant speed over all loads or of maintaining slightly-increased speed at full loads, if preferred. Further, it is positive and satisfactory in its action, does not hunt, and is provided with all necessary safety devices. It will be evident that the form and structure may be varied without departing from the spirit of my invention.

My improved governor is useful not only for use in connection with water-wheels, but also with any kind of prime mover and in some respects whether or not the prime mover is driving an electric generator. It is also obvious that the principle is applicable to the regulation of an electric motor driving a load as well as to the regulation of a prime mover driving an electric generator. Certain features of my invention are useful in electrical distributing systems generally, as well as in other branches of the electrical art and in other arts, and I therefore do not limit my invention or any part thereof to any specific application or use.

What I claim as new, and desire to secure by Letters Patent of the United States, is—

1. The combination with an electric generator, of an electric motor operated from the mains from the generator to control the application of power to the latter, an electromagnetically-operated reversing-switch for the motor, a storage battery connected to the mains and adapted to actuate said switch-magnet, and a governor for the generator which controls the operation of the reversing-switch.

2. The combination with an electric generator, of means for controlling the application of power thereto, electromagnetically-operated controlling means for the same, and a switch controlled by the speed and load of the generator for controlling said electromagnetic means.

3. The combination with a machine, of a governor therefor, an electric motor for controlling the application of power to the machine, an electromagnetically-operated controller for the motor, movable terminals for the circuits of the electromagnets, a switch-lever coöperating with said terminals which is operated by the governor, and means operated by the motor for moving said terminals away from the switch-lever before the machine has been too greatly affected by the motor.

4. The combination with the mains of an electrical circuit of an electric motor driven from said mains, a storage battery in series with a resistance shunted across the mains, and an electrically-actuated controlling device for the motor shunted around the storage battery.

5. The combination of a motive device, a means for regulating the application of power to said device, an electrical switch for controlling said means, and a device for actuating said switch, which is controlled by the speed of and by the load on said motive device and by said regulating means.

6. A regulator for prime movers, comprising a speed-responsive device, such as a centrifugal governor, a motor operating the valve or other regulating means of the prime mover, a source of power for the motor, movable contacts engaged by the speed-responsive device and controlling the motor, and a device for shifting the contacts.

7. A regulator for a machine, which comprises an electric motor, a source of power therefor, a device responsive to the varying conditions of the machine, and an electromagnetically-operated reversing-switch for the motor, said switch being controlled by the responsive device.

8. A regulator for prime movers driving dynamo-electric machines, comprising a motor for operating the valve, a source of power for the motor, contacts and connections by which the power is applied to drive the motor in one direction or the other, a coil in the main circuit and a centrifugal governor both operating the contact-maker controlling the motor; whereby the motor is caused to run in one direction by an increase of load or a drop of speed in the prime mover, and in the other direction by a decrease of load or a rise in speed.

9. The combination in a regulator for prime movers driving dynamo-electric machinery, of controlling means for the engine, a motor for regulating the controlling means, a source of power for the motor, contacts controlling the application of the power to the motor to drive it in either direction, a solenoid in the main circuit connected to the contact-maker, and a device for shifting the contacts.

10. A regulator for a prime mover driving a dynamo, comprising a motor for operating the valve of the prime mover, a source of power for the motor, a pair of contacts, and a contact-maker, the latter geared to a centrifugal governor and to the core of a solenoid in the main circuit, with an adjustable relaying device for the contacts.

11. The combination with an electric machine, of means for regulating the application of power thereto, an electric switch for said means adapted to be actuated by variations in the speed and load of said machine, and by said regulating means.

12. The combination with a machine, of a governor therefor, means for controlling the application of power to the machine, electromagnetically-operated means for controlling said means, movable contact-terminals for the circuits of said electromagnetic means, a switch coöperating with said terminals and controlled by the governor, and means controlled by the power-controlling means for moving said contacts away from the switch before the condition of the machine has been too greatly affected by the power-controlling means.

13. In a regulating apparatus for a motive device, the combination with an electric motor for regulating the application of power to the apparatus, of a normally acting brake for the motor, electromagnetically-actuated means for releasing the brake when current flows through the motor, and a governor for the motive device which controls the electric motor.

14. The combination with a machine, of a governor therefor, an electric motor for regulating the application of power to the machine, and a controller for the motor, the operation of which is controlled both by the governor and the motor.

15. The combination with an electric machine, of a second electric machine controlled by the speed or load of the first, for regulating the application of power to the first machine, and means operated by the second machine for checking its operation before the first machine has completely responded to the effect of such operation.

16. The combination with an electric machine, of an electric motor arranged to vary the power thereof, electric contacts controlling the operation of said device, a coil in the circuit supplied by the machine, for moving one contact against another, and means controlled by the operation of the electric motor, for moving one contact away from the contact controlled by the coil.

17. The combination with an electric machine, of an electric motor arranged to vary the power of the machine, two electric contacts controlling the operation of said device, a coil in the circuit supplied by the machine, which coil moves one of the contacts to engage the other, a spring tending to move the latter contact in one direction, and means controlled by the operation of the electric motor, for moving said contact in the opposite direction.

18. The combination with an electric machine, of an electric motor arranged to vary

the power thereof, two freely-movable contacts controlling the operation of said device, a device responsive to variations of the demands upon the machine, for moving one contact against the other, and means controlled by the operation of the electric motor, for moving the latter contact away from the first.

19. The combination with an electric machine, of a governor therefor, an electric motor controlled by said governor and adapted to regulate the application of power to said machine, and means operated by the motor for checking its movement before the electric machine has completely responded to the effect of said motor.

20. The combination with an electric machine, of a device responsive to variations of the demands made upon the machine, an electromagnetic device acting directly to vary the power of the machine, an electric contact moved by said responsive device to cause said electromagnetic device to operate, and a device responsive to the operation of the electromagnetic device to stop the operation of the latter.

21. In a regulator for a motive device, the combination with an electric motor for regulating the application of power to the motive device, a reversing-switch for the motor, which is normally in an inoperative position, means for electromagnetically operating said switch, and a governor for the motive device which makes and breaks the circuits of said electromagnetic means.

22. The combination with a motive device, of an electric motor for regulating the application of power thereto, a switch-piece moving with variations in the state of said motive device, and contacts for said switch-piece whereby said electric motor can be operated in each direction, said contacts being adapted to be moved with respect to said switch-piece by the continued movement of said electric motor.

23. The combination with a machine, of a governor therefor, an electric motor for controlling the application of power to the machine, an electromagnetically-operated controller for the motor, and a switch operated by the governor for controlling the circuits of said electromagnetic controller.

24. The combination with a motive device, of a governor therefor, an electric motor controlled by said governor for varying the application of power to said device, and an electromagnetic reversing-switch for said electric motor, said governor making and breaking the circuits of said reverse-switch magnets.

25. The combination with a motive device, of a governor therefor, an electric motor controlled by said governor and adapted to regulate the application of power to said device, a brake for the shaft of said motor, and an electromagnet in the motor-circuit for holding said brake normally from operative engagement.

26. The combination with a motive device, a motor for regulating the application of power thereto, and for controlling the motor and adapted to be actuated by changes both in the speed and load of the motor device.

27. The combination of a prime mover, means for controlling the power supplied thereto, and means actuating said latter means, under the influence of a speed-responsive device, a load-responsive device and the said power-supply-controlling means; substantially as described.

28. The combination of a prime mover, an electric generator driven thereby, a valve for said prime mover, means for actuating said valve, an electric circuit controlling said actuating means, a switch for said circuit, and means for controlling said switch, including a load-responsive device, a speed-responsive device and means associated with the valve.

29. The combination of a prime mover, an electric generator driven thereby, a valve for said prime mover, a load-responsive device adapted to cause a movement of said valve with changes in load, and means for causing said movement to cease before the valve position corresponding to such increased load has been reached; substantially as described.

30. The combination of a prime mover, a valve therefor, a speed-responsive device for actuating said valve, a load-responsive device also adapted to actuate said valve, and means operated by the valve for stopping such actuation when its proper movement has been effected; substantially as described.

31. The combination of a prime mover, a valve therefor, an electric generator, a speed-responsive device, and a load-responsive device, coöperatively controlling said valve, and means for stopping the movement of the valve, when it has reached a given position; substantially as described.

32. The combination of an electric generator, a controlling mechanism therefor, coöperatively actuated by a speed-responsive device and a load-responsive device, and means for automatically causing the stoppage of said mechanism when the proper control has been effected; substantially as described.

33. The combination of a prime mover, a valve therefor, and a controlling mechanism for the valve coöperatively actuated by a speed-responsive device, a load-responsive device and a device responsive to the valve movement; substantially as described.

34. The combination of a prime mover, an electric generator driven thereby and means for undercompensating in the power-supply of the prime mover for an increase or decrease in load upon the generator.

35. The combination with a prime mover, of a dynamo-electric machine adapted to be driven thereby, a valve for the prime mover, a controlling element for said valve, a speed-responsive device adapted by its movement to bring said element into a position of control, a load-responsive device also adapted by

its movement to bring said element into a position of control, and means to negative their effect on the controlling element by the movement of the valve; substantially as described.

36. The combination of a prime mover, a dynamo-electric machine driven thereby, means for controlling the power supplied to the prime mover, means actuating said latter means under the influence of a speed-responsive device and a load-responsive device, and connections between the power-supply-controlling means, and the actuating means whereby the effect of the latter is modified; substantially as described.

37. The combination of a prime mover, a dynamo-electric machine driven thereby, means for controlling the power supplied to the prime mover, a speed-responsive device and a load-responsive device actuating said controlling means and adapted to coöperate or oppose each other's action, and means associated with the valve to negative the action of either or both by the movement of the valve; substantially as described.

In witness whereof I have hereunto set my hand this 18th day of August, 1898.

JAMES A. LIGHTHIPE.

Witnesses:
S. E. KEARNEY,
GUY H. BORLAND.