No. 796,606. PATENTED AUG. 8, 1905.

J. L. ROUTIN.

ELECTROMECHANICAL REGULATOR.

APPLICATION FILED JULY 17, 1901.

5 SHEETS—SHEET 1.

Fig. 1.

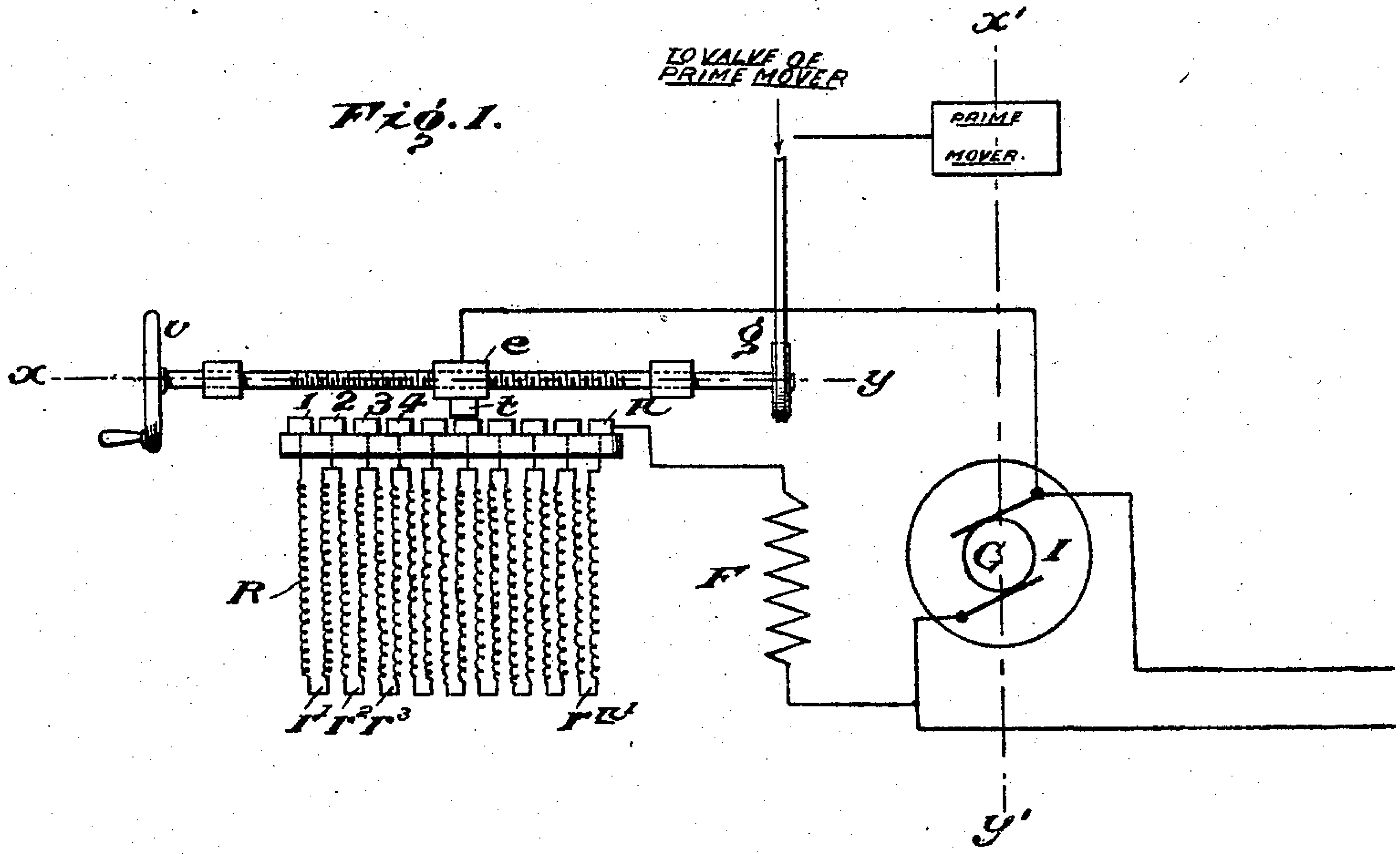
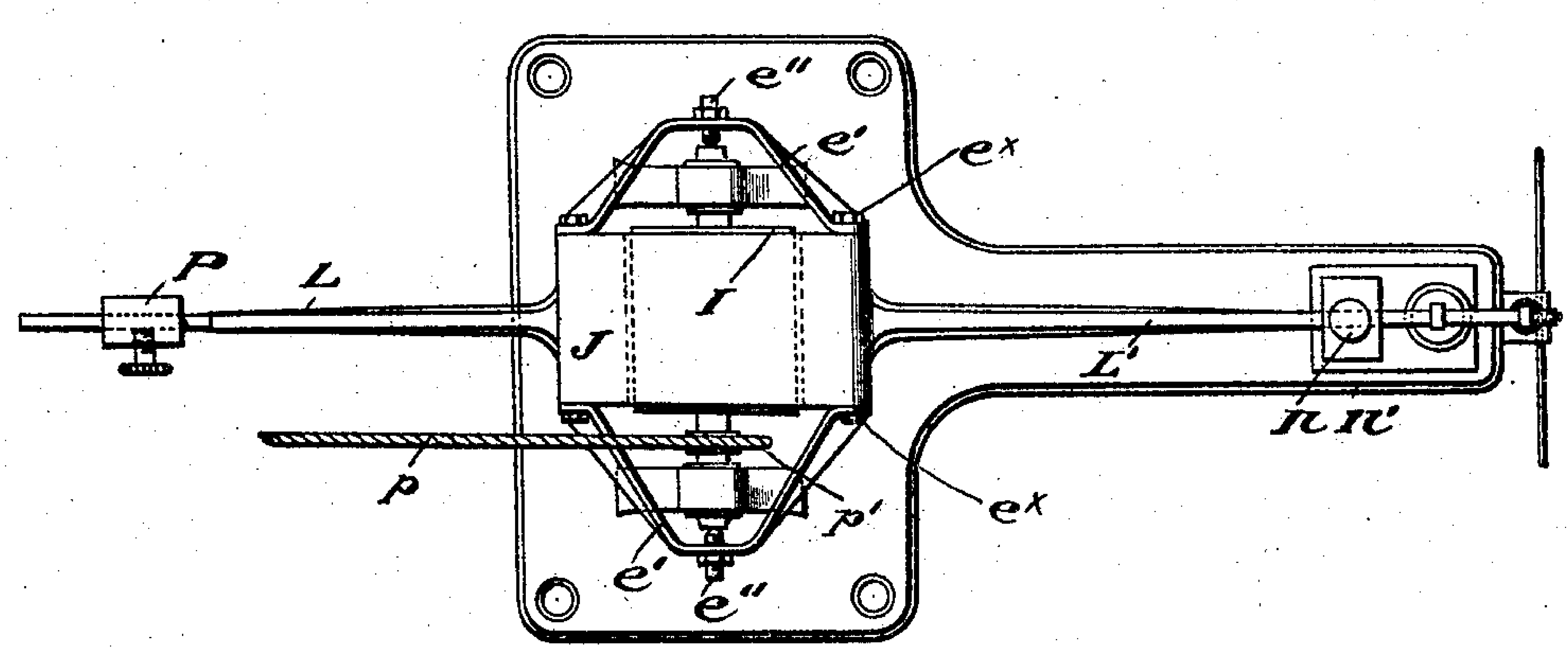


Fig. 4.



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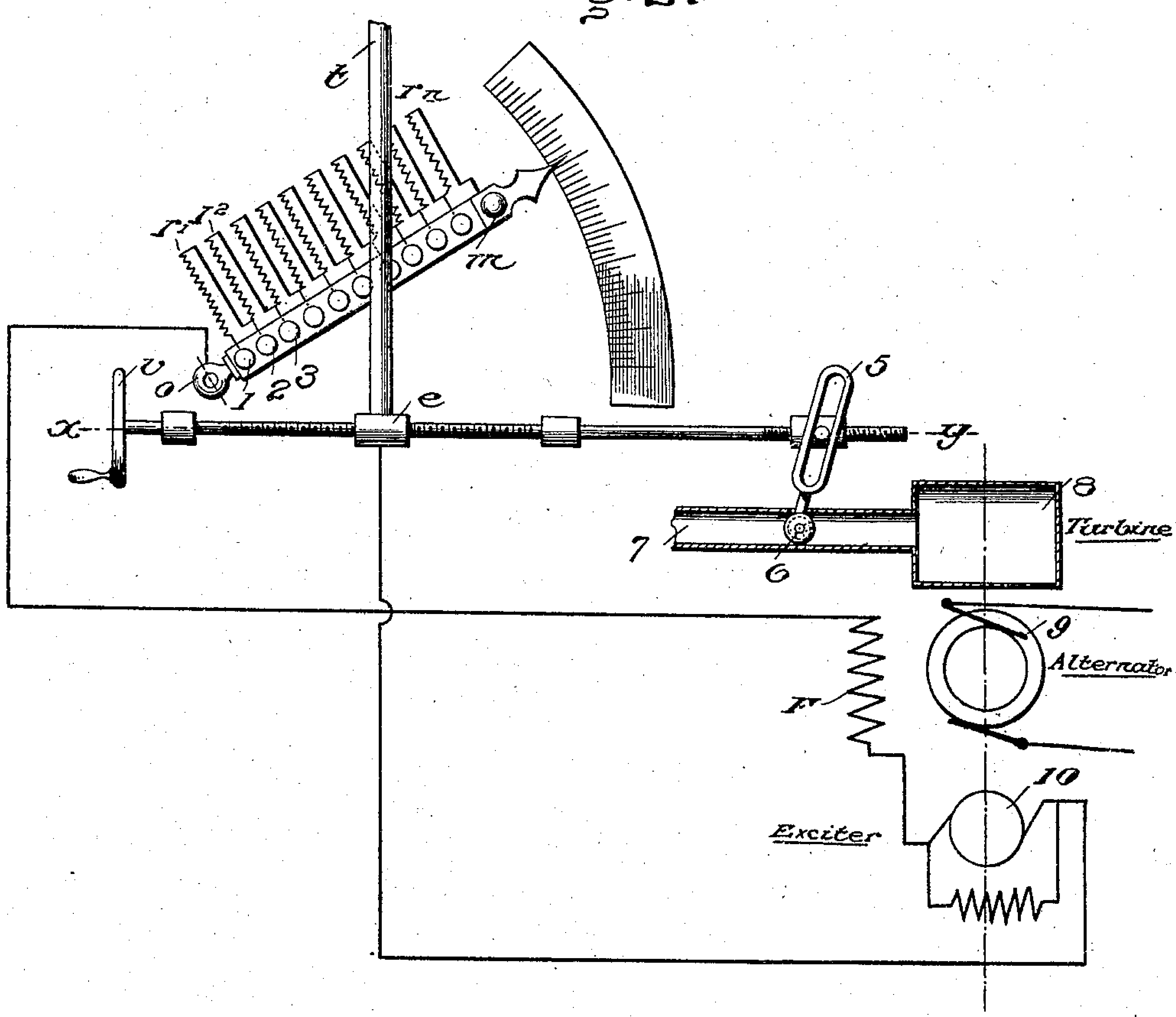
5 SHEETS—SHEET 2.

Fig. 2.



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5 SHEETS—SHEET 3.

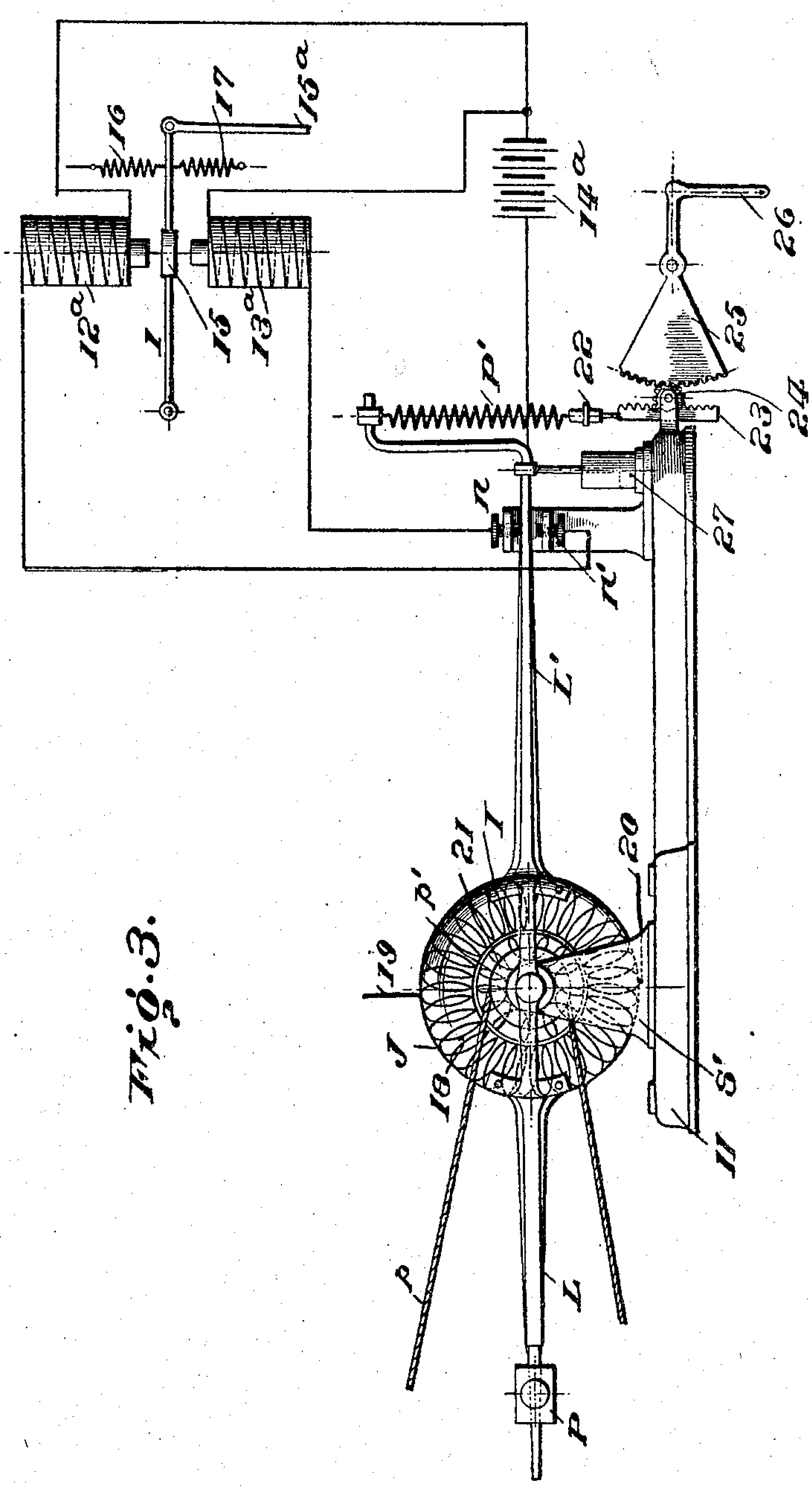

Fig. 3.

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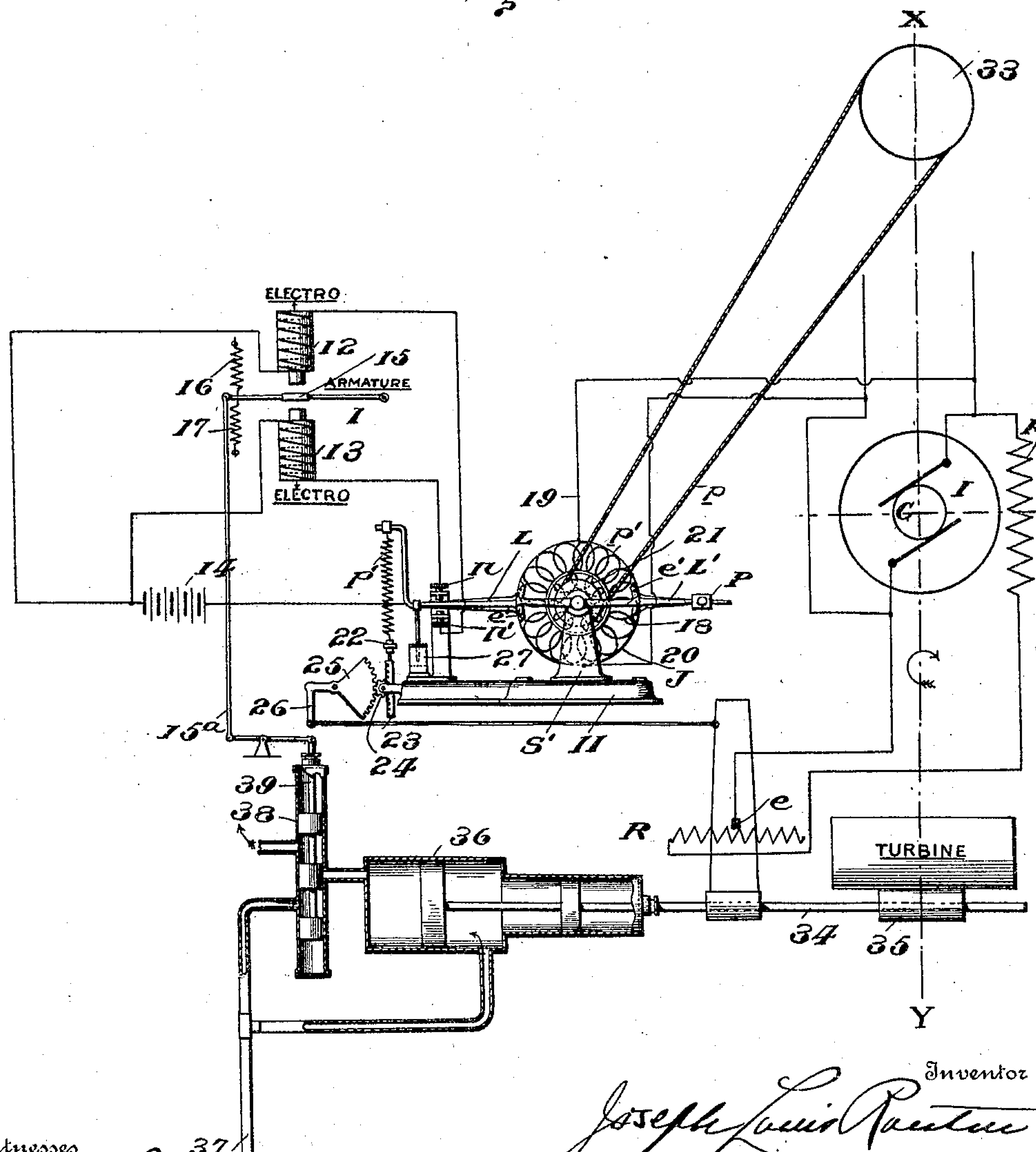
5 SHEETS—SHEET 4.

Fig. 3.a



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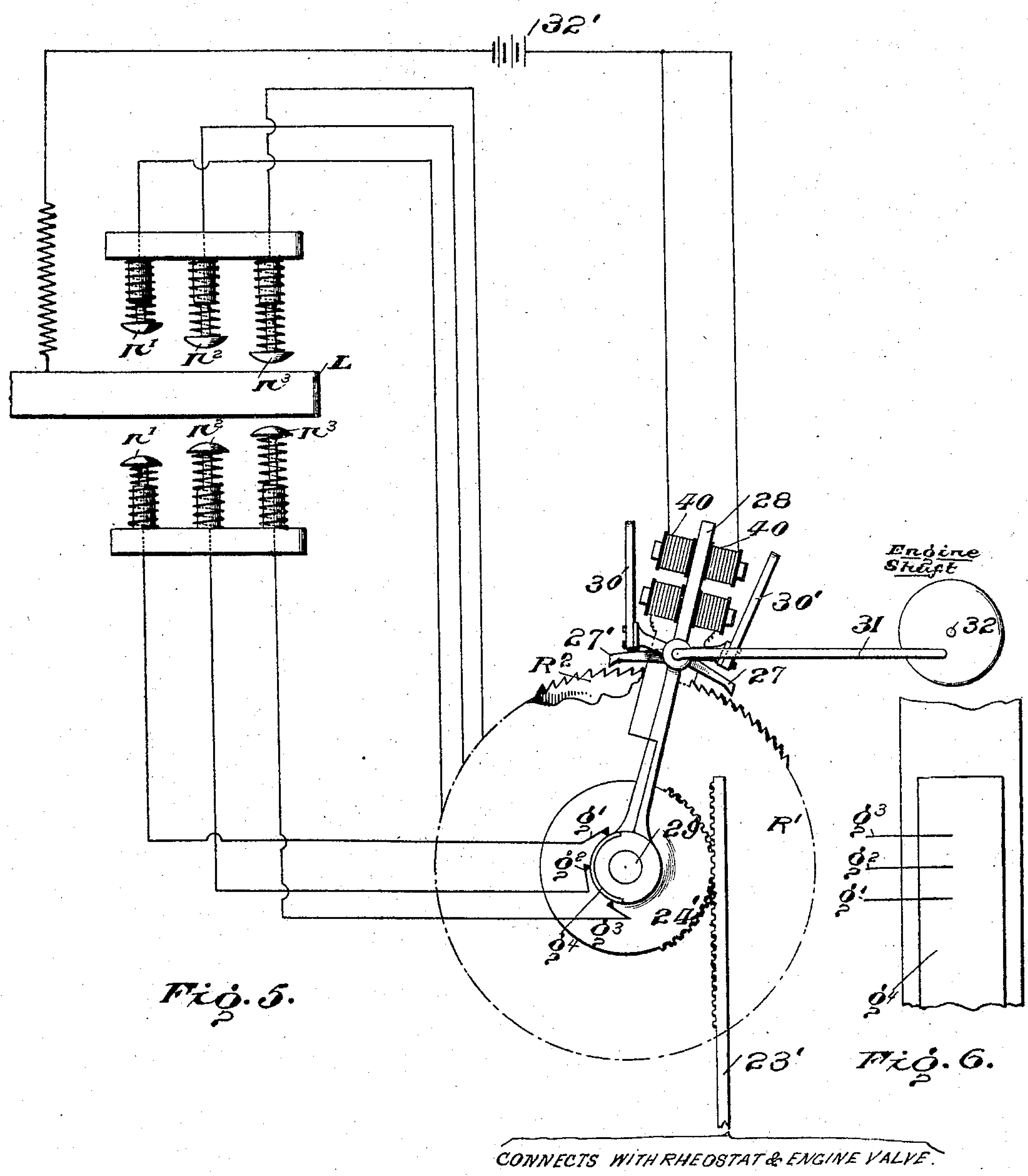
5 SHEETS—SHEET 5.



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UNITED STATES PATENT OFFICE.

JOSEPH LOUIS ROUTIN, OF LYON, FRANCE.

ELECTROMECHANICAL REGULATOR.

No. 796,606 Specification of Letters Patent. Patented Aug. 8, 1905.

Application filed July 17, 1901. Serial No. 68,669.

To all whom it may concern:

Be it known that I, JOSEPH LOUIS ROUTIN, engineer, a resident of 79 Rue St. Dominique, Lyon, in the Republic of France, have invented a new and useful Improvement Relating to Electromechanical Regulators, which improvement is fully set forth in the following specification.

My invention relates generally to the regulation of translating devices, whether generators or motors, but more especially to regulators for dynamo machinery.

The object of my invention is to provide means, either automatic or manual, for the regulation of dynamo machinery and the like by varying simultaneously the supply of motive fluid or other power to the prime mover and the resistance in one or more of the electric circuits supplied by the generator.

Certain mechanical expressions of the inventive idea involved are shown in the accompanying drawings, which are designed merely as illustrations to assist in the description of the invention and not as defining the limits thereof.

Figure 1 shows diagrammatically the regulating device for controlling the fluid to the prime mover which operates the dynamo and for controlling the circulation of the latter. Fig. 2 shows a form of field-rheostat that I employ with alternators when carrying a variable induction-load. Figs. 3 and 4 show in elevation and plan, respectively, an automatic control device. Fig. 3[a] is a diagrammatic illustration showing the electric connections of the controlling device shown in Figs. 3 and 4, together with the connecting means between the controlling device and the prime mover. Fig. 5 shows diagrammatically a ratchet mechanism driven by the prime mover or generator to be used in connection with the control device shown in Figs. 3 and 4. Fig. 6 is a developed view of the cylindrical contact utilized in the device shown in Fig. 5.

Referring to Fig. 1, R is a rheostat for the field-winding of the dynamo G, which is shunt-wound. This rheostat comprises an insulating-base carrying the contacts 1, 2, 3, 4 . . . n, to which are connected the respective resistance-coils r_1, r_2, r_3 . . . r_{n-1}. Sliding over the contacts is a coöperative contact carried by the traveler e, which is worked back and forth by means of the screw-threaded spindle x y, the latter being turned by hand-wheel v. The end y of the spindle is prolonged and carries a pulley g and is connected by suitable belt or chain to a valve for controlling the intake of the prime mover which operates the dynamo G and is shown in Fig. 1 as on the axis x' y' of the latter. F is the field, and I the armature. To operate this form of regulator, the hand-wheel v is turned, whereby the influx of steam or water or the angle of intake of the latter may be altered to compensate for variations in the load being carried. At the same time the turning of the hand-wheel and its spindle results in moving the traveler e. The individual resistances are adjusted so as to vary the current passing through the field, and thus control the excitation of the electric generator. It is quite possible by this simple means to compensate perfectly as well as very rapidly, even by hand, for it is apparent that for each position of the valve controlling the steam or other fluid to the prime mover there is a corresponding position of the traveler e, and by varying the individual resistances the attendant may follow the variations indicated by his voltmeter by a simple turn of the hand, compensating by altering the field strength and the power exerted by the prime mover simultaneously.

The degrees for the opening of the intake-valve of the engine or prime mover, which correspond to the different loads at constant speed and the values of the resistances r_1, r_2, . . . r_{n-1}, are experimentally determined in the calibration of the controller.

While the apparatus indicated in Fig. 1 is quite satisfactory for direct-current systems, it does not answer perfectly for those in which alternating currents are employed, owing to the following reasons: In central stations the character of the load naturally varies from time to time, the principal characteristic difference being observable between a day load and a night load. The night load of any station is usually entirely composed of lamps whose resistance is non-inductive, while the day load is commonly made up of electromagnetic apparatus, such as motors, whose resistance is of course inductive and whose counter electromotive force must be taken into account in the regulation. Given the same speed and other conditions at central, there would therefore be a greater drop in potential due to the day load than the night load. Ordinarily in regulating both engine and dynamo output we assume but one position of the rheostat-switch arm for each position of the throttle or intake-valve; but this only holds where the load is constant in character, and it is therefore necessary to provide compensating means whereby for the same adjustment of the intake or throttle the field-strength adjustment may be altered. In Fig. 2 an apparatus is shown which accomplishes this end. Here the insulating-base carrying the contacts 1 2 3 . . . n is in the form of a strip, pivoted at o and provided with a handle m, which is associated with a pointer adapted to move over a graduated arc when the pivoted arm is turned. x y is a spindle provided at one extremity with a hand-wheel v for imparting rotation and at the other with adjustable means, such as a nut and link 5, connected to a valve 6 in the intake 7 of a prime mover, such as a turbine 8, which latter actuates the alternator 9 and its exciter 10. F is the field-winding of the alternator and is in the circuit of the exciter. Carried upon the traveler e is an elongated contact spring or brush t, which passes over the contacts 1 2 3, &c., and throws in and out of the exciting field F the resistances r' r^2, &c., in whatever angular position they may be placed. It is to be noted, however, that if the contact-strip be assumed to occupy a horizontal position the conditions of operation and the relative changes in field strength and in power will be the same as in Fig. 1. As the handle m is moved up, however, carrying the strip around on its pivot o, the greater the change in resistance of the field-circuit for each revolution of the spindle will become until as the strip reaches a vertical position the entire resistance would be cut in and out by a movement through the unit distance of one contact. By placing the pivoted strip in various intermediate positions between horizontal and vertical it is apparent that different field strengths may be determined for each unit movement in regulating the steam or water admission. Thus with the same power the drop in potential, due to the character of the load carried, may be compensated simply by adjusting the handle m and its strip of contacts. The arc may be graduated to read directly in any units desired. The resistance-coils r', &c., may of course be stationary and connected with the contacts 1 2 3 through a flexible conductor or they may be carried on the strip.

Figs. 3, 3ª, and 4 show what I call my "automatic" controller. This is a device which may be adjusted to respond to the slightest variation in the circuit due to variations in load or in power, its own resulting variations being in the ratio of the third power. This controller may be used with either direct or alternating current; but, as will appear hereinafter, its principal uses are with alternating currents. I will first describe it for use with direct currents. Upon a suitable base 11 are mounted standards S′, in which is journaled a shaft carrying the armature I, rotated by a belt and pulley p p', taking its power from the prime mover. J is the field-magnet, which is supported in U-shaped members e', bolted to the field-magnet at $e^{\times}$ and provided with pivot-screws e'', which take into the ends of the armature-shaft and enable the field-magnets to oscillate symmetrically about the armature. Extending in opposite directions from the field-magnets are the lever-arms L L′. The former arm carries a balancing-weight P, while the latter has its extremity interposed between two adjustable screws n n' on a suitable support. 12 and 13 are electromagnets, one terminal of each connected with screws n n', while the others are connected to a terminal of the battery 14, which latter has its other terminal connected to the arm L′. 15 is a pivotally-supported armature between the two magnets and normally held in an intermediate position by springs 16 and 17. 15ª is an arm connecting with a valve-stem, to be described below. 18 designates the field-winding with its terminals at 19 and 20. The armature-windings I are shown short-circuited. The outer end of the arm L′ is shown bent up to accommodate a spring P′, which is connected by an adjustable thumb-nut 22, rack 23, pinion 24, and sector 25 to a rod 26, which is actuated by the movement of the valve-stem of the prime mover. This auxiliary device serves as the means for effecting the adjustment and for controlling the apparatus. For adjusting it is only necessary to operate the screw-nut 22, and the subsidiary connection causes the effort to be transmitted through the spring P′ and so limit the action of the apparatus, thereby insuring an automatic regulation with instantaneous effect.

In Fig. 3ª the controller of Fig. 3 is shown connected up with the prime mover, the rheostat of the dynamo, and the intake-valve of the prime mover. The pulley p' on the armature-shaft of the controller receives motion from a pulley 33 on the shaft of a prime mover—such, for example, as a turbine. The terminals 19 20 of the field of the controller are connected across the terminals of the dynamo G. The sector 25 is connected by rod 26 with the sliding contact e, which is carried by the valve-stem 34 of the intake-valve 35 of the turbine. 36 is an auxiliary hydraulic motor for effecting the opening and closing of the intake to the turbine and throwing in or out of the resistances of the rheostat R. 37 is a pipe for supplying the hydraulic motor with fluid. 38 is a valve for controlling the supply and has its valve-stem 39 connected with the end of armature-lever 15 by connection 15ª. The operation of this form of controller is as follows: Assume the armature I of the controller increases its speed for any cause and that the rotation is right-handed, Fig. 3ª. The field-magnet J will tend to follow the armature and bring the lever-arm L in contact with the upper contact-screw n. The lower electromagnet is energized, causing armature 15 to be pulled down. The rod 15^a, through its connections, lifts valve 38, causing the hydraulic motor to partly close the intake-valve of the turbine and throw resistance into the field F of the dynamo G. The movement of the sliding contact e to the right rotates the sector 25 upward and pulls the rack 23 down, thereby drawing the spring P′ and arm L down and breaking the circuit of the magnet 13, whereupon the arm 15 returns to its middle position and returns the valves in 33 to their original position.

In the form of controller above described a magnetic field is thus created across the armature I, and the speed ω of the armature I, and the resistance R and self-induction L of the controller-circuits are so adjusted as to satisfy the condition

$$\omega < \frac{R}{L}.$$

Under these conditions the moment of the couple developed increases with the speed of the armature, and by proper design this increase may be made regular. Furthermore, the turning force or the moment of the couple developed is proportional to the square of the flux produced by the field-magnet, which itself, with constant excitation, is proportional to the speed, provided care is taken that the iron is not saturated. (A condition which it is always possible to realize.) It thus becomes apparent that the moment of the couple tending to turn the field upon its axis at any given instant is proportionate to the cube of the speed, and therefore any changes in speed will produce variations of the couple proportional to the cubes of the original variations. It need hardly be said that such an apparatus is sensitive in the highest degree. It will be noted that where the electric generator which is to be regulated and which supplies the field of the controller has a certain armature reaction the controller will come into operation instantly in response to variations in the electric potential before the engine fly-wheel has permitted any variation in speed. This is a highly-important result, being in strong contrast with the results produced by mechanical governors or electrical apparatus, which requires an actual increase in speed before any change takes place.

Instead of having the regulating appliance controlled electromagnetically in some cases I contemplate the use of mechanism driven from the shaft of the prime mover or of the generator. In such a case it is possible to provide successive steps in the regulation as produced by the movements of the lever-arm L of the controller. Such a device is shown in Fig. 5. R′ is a ratchet-wheel broken away at one portion to show a second ratchet-wheel R^2, having teeth directed oppositely to those of the first. 24′ is a gear-wheel fast on shaft 29, as are wheels R′ R^2. 28 is an arm loosely journaled on a hub on shaft 29. On the outer end of the arm 28 are electromagnets 40, whose armatures 30 30′ control the position of the pawls 27 27′, which normally occupy the position shown. The pawl-carrying lever-arm is adapted to be oscillated by the reciprocation of a member 31 connected to engine-shaft 32. The magnets 40 are included in electric circuits with battery 32′. In order to procure this electric circuit, as required for the purpose of regulation, I provide three spring-pressed plungers n' n^2 n^3 on one side of arm L and a similar set on the opposite side. The lower set will here be described, the upper set being in all respects similar. The heads of the plungers lie in different planes, each being connected to an individual contact-brush g' g^2 g^3, resting on a contact-strip g^4 on the hub of the lever-arm 28. These brushes are arranged in sequence around the periphery of the hub, as shown. The positions of the brushes are indicated in Fig. 6, which is a developed view of the strip g^4. It will be observed in Fig. 6 that the contact-strip g^4 has its end at a determinate distance from the point of contact of the brush g^3, a fixed interval then separating this from the brush g^2, and a further interval from the last point of contact of spring g'. While the lever-arm L of the regulator is in an intermediate position between the plungers n' n^2 n^3 the arm 28 merely oscillates on its support, responding to the movements of member 31. When the arm L depresses one of the plungers—n^3, for example—the circuit through the left-hand magnet is closed. The armature 30 is drawn to the right, depressing pawl 27, rotating ratchet-wheel R′ and gear 24′ to the right, and forcing rack 23′ downward. If the controller-arm L moves far enough to reach plunger n^2, the circuit is closed through the second brush g^2 on the hub, and therefore the stroke is longer by that much. Similarly, if the circuit is closed through n' the length of stroke will be a maximum. An upward vibration of arm L will cause a reverse movement of the rack 23′. The rack 23′ operates the intake-valve of the prime mover and the movable contact of the rheostat, and thereby actuates the electro-mechanical regulating mechanism previously described.

The controller illustrated in Figs. 3 and 4 is particularly adapted for use in alternating-current systems. It will be observed that I do not limit myself to any particular method of arranging the pole-pieces or windings of the controller. This piece of mechanism is really a motor and may be treated as such, its effects being produced by measuring directly the moment of the couple tending to turn the field.

I have previously stated that when the speed ω, the resistance R, and the self-induction λ

of the armature are arranged in such a manner that the condition $\omega < \frac{R}{L}$ is satisfied, the couple C increases with the speed and that for a given speed of the system under consideration the construction may be such as to cause this increase to follow a linear path. This demonstration may be summed up as follows: By taking Φ_o as the maximum flux traversing a movable frame when the latter is perpendicular to the lines of force the effective electromotive force developed at the angular speed ω is

$$\frac{\Phi\ \omega}{\sqrt{2}}$$

and the effective current

$$\frac{\Phi\ \omega}{\sqrt{2}\ \sqrt{R^2 + \omega^2\ \lambda^2}}.$$

To find the mean power P required to turn the frame. This power is entirely recovered in heat.

$$\text{Thus giving } P = R\ \frac{\Phi_o^2\ \omega^2}{2\ (R^2 + \omega^2\ \lambda^2)}.$$

The couple C is connected to the power P by the formula

$$P = C\ \omega,$$

from which is deducted

$$C = \frac{R\ \Phi_o^2\ \omega}{2\ (R^2 + \omega^2\ \lambda)}.$$

Taking the derivative of the above formula, it follows that

$$\frac{d\ C}{d\ \omega} = \frac{\Phi_o^2\ R}{2}\ \frac{R^2 - \omega^2\ \lambda^2}{(R^2 + \omega^2\ \lambda^2)^2},$$

and as $\omega < \frac{B}{\lambda}$

the derivative, is positive, the couple starts in increasing. The derivative is annulled, for at this moment the couple passed through a maximum, then the derivative becomes negative, the couple diminishes again to fall toward O, when the speed increases indefinitely. It will be seen that by being in the position of $\omega < \frac{R}{\lambda}$ it is possible within certain limits around the speed of the system to replace without error the curve by its tangent and obtain proportionality of the couple to the speed.

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

1. In a system of power generation and transmission, a prime mover, a generator, drive connections between them, a regulator for the prime mover, a regulator for the generator, means to compound forces due to the prime mover and to the generator to produce a resultant force, and means whereby said resultant force, as it is varied by the variations in load on the system, will actuate the regulators to compensate for said variations, substantially as described.

2. In a system of power generation and transmission, a prime mover, a generator, drive connections between them, a regulator for the prime mover, a regulator for the generator, means to compound the forces due to the prime mover and to the generator respectively to produce a resultant force, and means whereby variations in said resultant force due to variations in either or both of its components, will actuate the regulators conjointly and symmetrically to compensate for said variations, substantially as described.

3. In a system of power generation and transmission, a prime mover, a generator auxiliary to and driven by the prime mover, and a regulating system comprising the following instrumentalities: a regulator adapted to produce changes in the power delivered for transmission, a mechanism adapted to receive and compound forces derived from the driving and from the driven sides of the power system, respectively, to produce a resultant force. a movable member of the mechanism acted upon by said resultant force, with means to maintain the same normally in equilibrium, and a connection between said movable member and the said regulator whereby changes in the resultant force due to cnanges in either or both of its components will produce a compensating action of the regulator, substantially as described.

4. In a system of power generation and transmission, a prime mover, a generator auxiliary to and driven by the prime mover, and a regulating system comprising the following instrumentalities: a regulator adapted to produce changes in the power delivered for transmission, a mechanism adapted to receive and compound forces derived from the driving and from the driven sides of the power system, respectively, to produce a resultant force, a movable member of the mechanism acted upon by said resultant force, with means to maintain the same normally in equilibrium, and a connection between said movable member and the said regulator, together with means to adjust the balancing force acting on the movable member to maintain the sensitiveness of the same after an increase or decrease in power or speed shall have been produced by the action of the regulator, substantially as described.

5. In a system of power generation and transmission, a prime mover, a generator, regulating mechanism therefor, and a controller for said regulating mechanism comprising the following instrumentalities: an electric motor having armature and field members, one member deriving current from the circuit of the generator, the other member in-

cluded in a closed or local circuit, a lever-arm carried by one member, a balancing spring or weight adjusted to said lever-arm to normally maintain the same in equilibrium against the torque of the motor, and a connection from the lever-arm to the regulating mechanism, substantially as described.

6. In a system of power generation and transmission, a prime mover, a generator, regulating mechanism therefor, and a controller for said regulating mechanism comprising the following instrumentalities: an electric motor having armature and field members, one member deriving current from the circuit of the generator, the other member included in a closed or local circuit, a lever-arm carried by one member, a balancing spring or weight adjusted to said lever-arm to normally maintain the same in equilibrium against the torque of the motor, power-controlling mechanism for the regulating mechanism driven from the prime mover, a clutch connection controlling the drive, and means connected with the lever-arm of the motor to control the clutch, substantially as described.

7. In a system of power generation and transmission, a prime mover, a generator, regulating mechanism therefor, and a controller for said regulating mechanism comprising the following instrumentalities: an electric motor having armature and field members, one member deriving current from the circuit of the generator, the other member included in a closed or local circuit, a lever-arm carried by one member, a balancing spring or weight adjusted to said lever-arm to normally maintain the same in equilibrium against the torque of the motor, controlling mechanism for the regulating mechanism, a power-drive therefor, a clutch connection between the two having a variable stroke, with means under the control of the lever-arm of the motor to determine the particular length of stroke and the consequent movement of the regulator in accordance with the degree of movement of the lever-arm and hence the degree of variation in the power or the load, substantially as described.

8. In a system of power generation and transmission, a regulator, and a controller therefor comprising the following instrumentalities: a base, standards supported upon the base, journal-bearings in said standards, a motor having its armature-shaft journaled in said bearings, a field structure also supported upon said bearings and normally balanced thereon, a pair of oppositely-extending lever-arms carried by one member of the motor, a counterbalance-weight on one of said arms, and a balancing-spring connected to the other, with means to adjust the latter, operative connections from one of the arms to the regulator, and means to drive a second member of the motor, substantially as described.

9. In a device for simultaneously regulating prime movers and current-generators at central stations, the combination of a prime mover, a current-generator driven thereby supplying current to a working circuit, an exciter-circuit for said generator, means for gradually and progressively regulating the resistances in said exciter-circuit, means for gradually and progressively regulating the driving power of said prime mover, and means for simultaneously actuating both the regulating means of the prime mover and of the current-generator, whereby mechanical and electrical regulation can be simultaneously effected at a single operation.

In testimony whereof I have signed this specification in the presence of two subscribing witnesses.

JOSEPH LOUIS ROUTIN.

Witnesses:

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