No. 725,799. PATENTED APR. 21, 1903.

A. A. TIRRILL.

AUTOMATIC POTENTIAL REGULATOR FOR DYNAMOS.

APPLICATION FILED APR. 13, 1900.

NO MODEL. 9 SHEETS—SHEET 1.

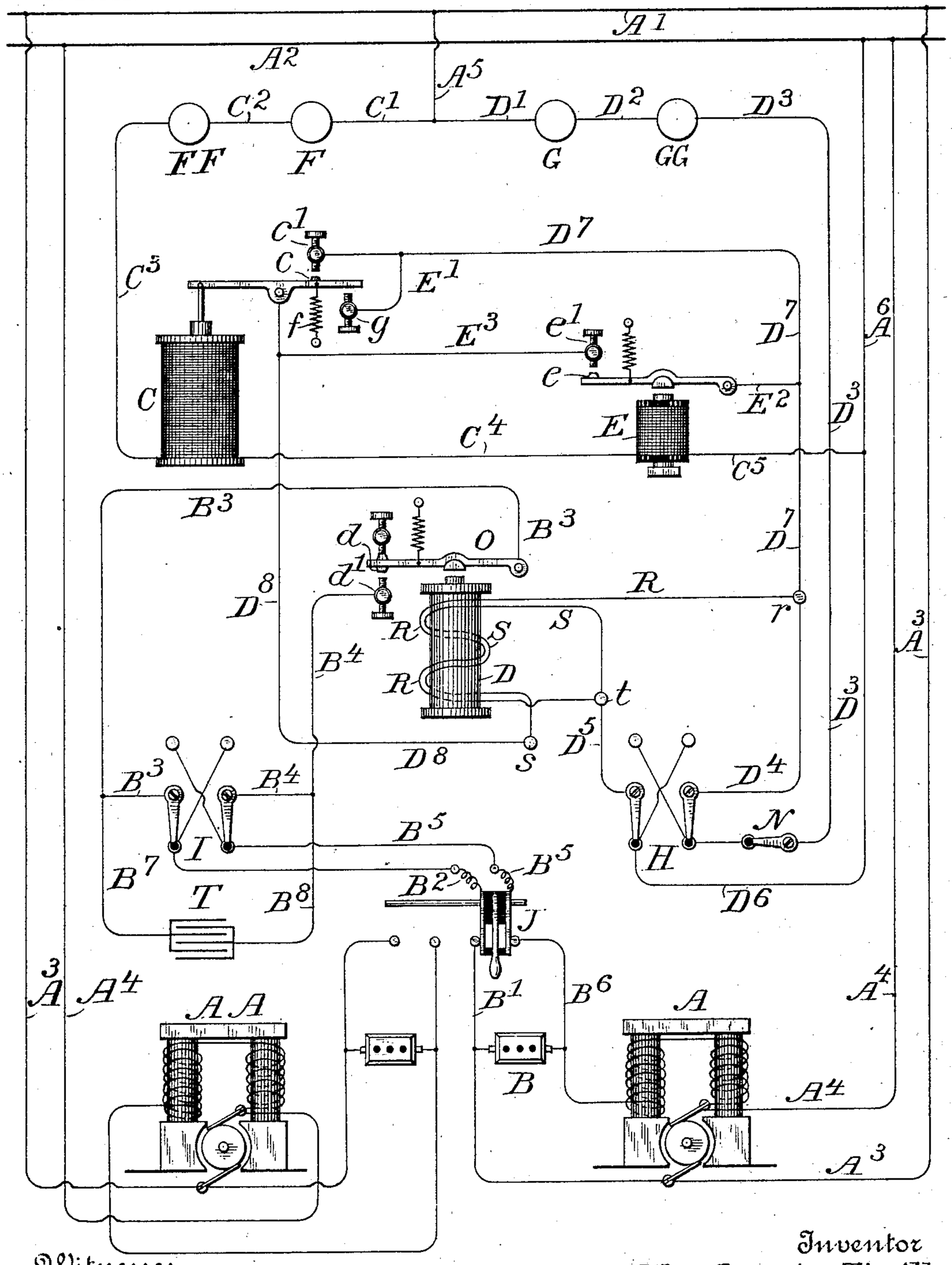

Fig. 1.

Witnesses
Jos. S. Latimer
M. E. Torrence.

Inventor
Allen Augustus Tirrill
by Edmund Towne
his Attorney

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NO MODEL. 9 SHEETS—SHEET 2.

Fig. 2.

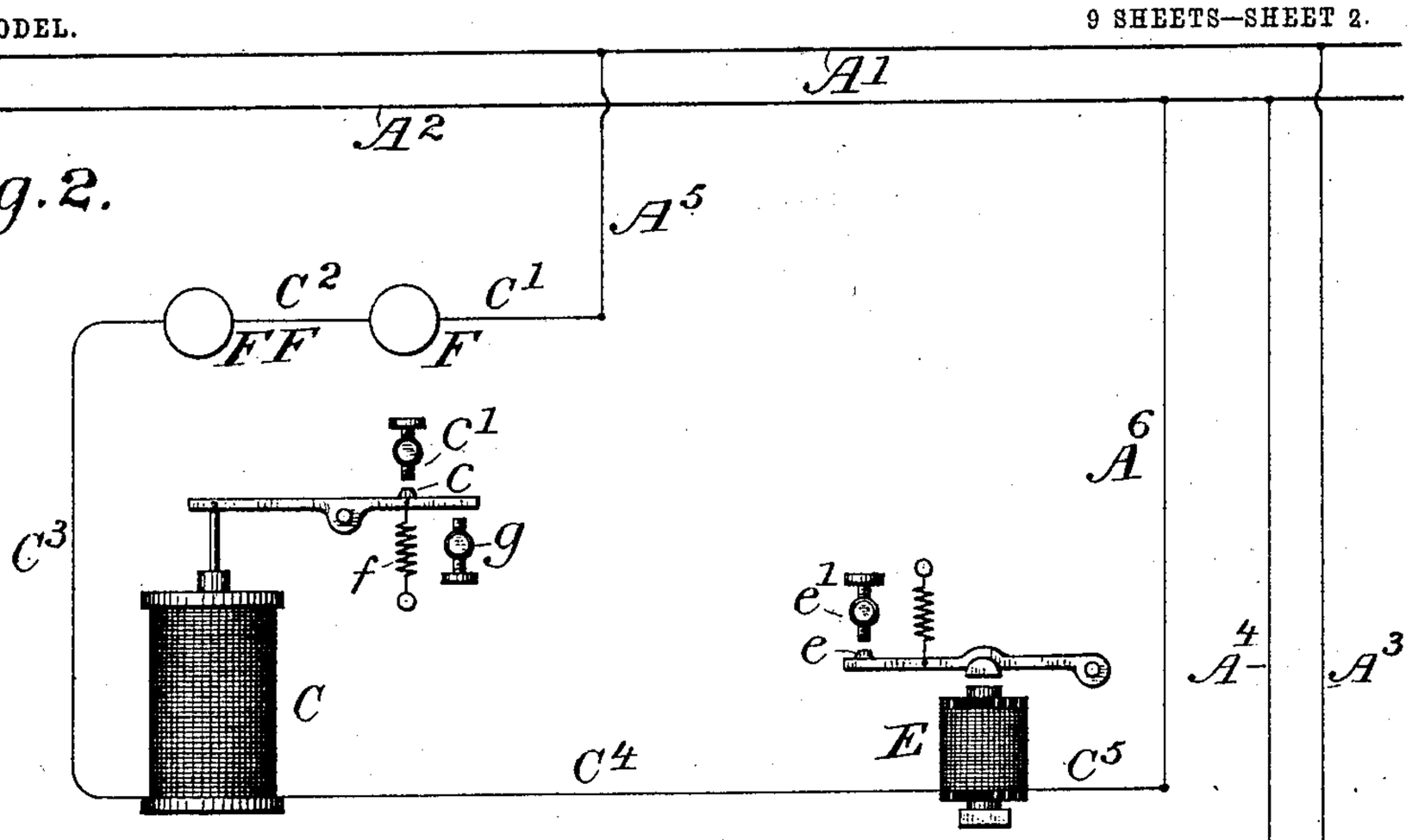
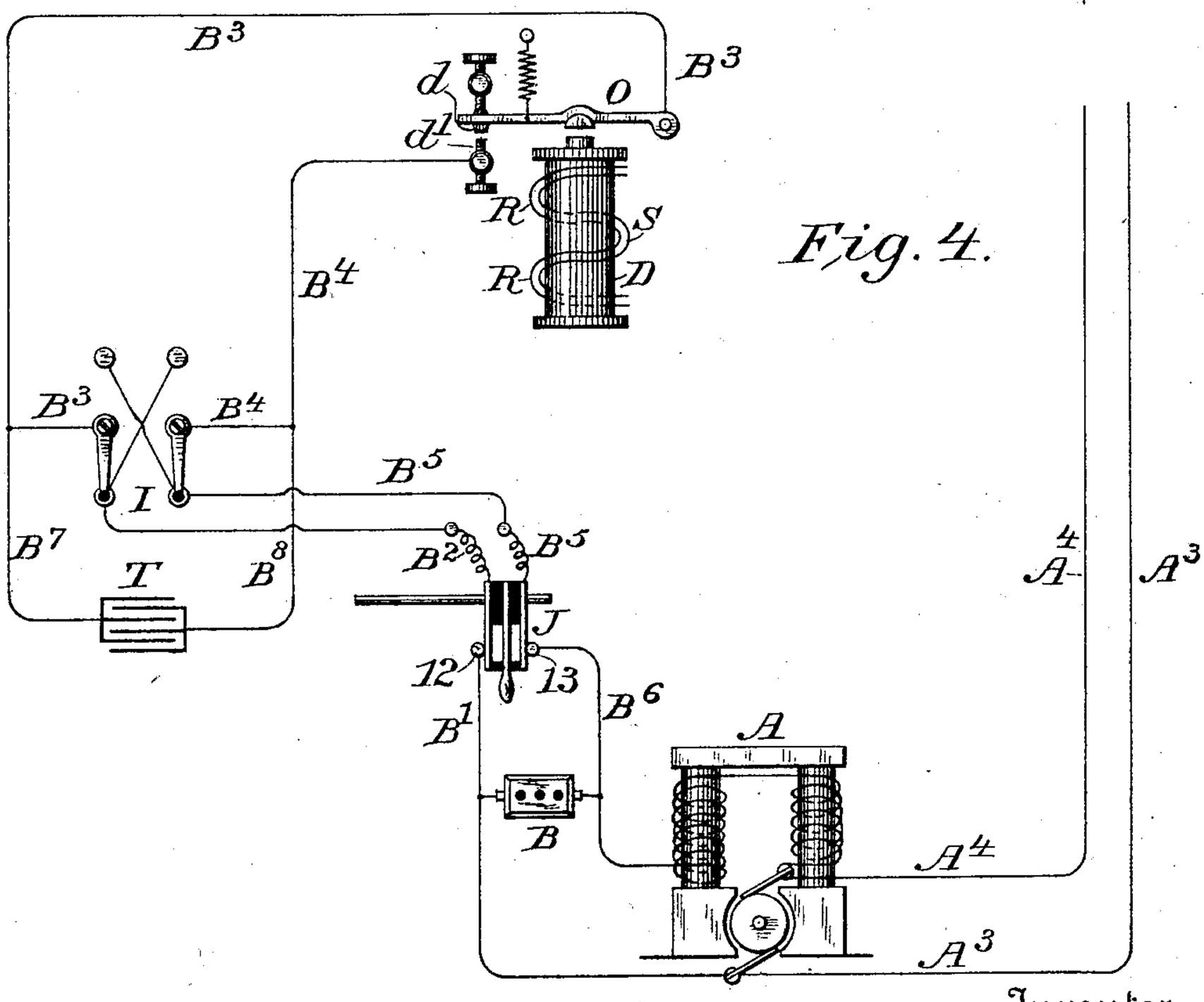


Fig. 4.



Witnesses
Jos. S. Latimer
M. E. Tornuel.

Inventor
Allen Augustus Tirrill
by Arthur J. Brown
his Attorney

THE HAER'S PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

No. 725,799. PATENTED APR. 21, 1903.

A. A. TIRRILL.

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NO MODEL. 9 SHEETS—SHEET 3.

Fig. 3.

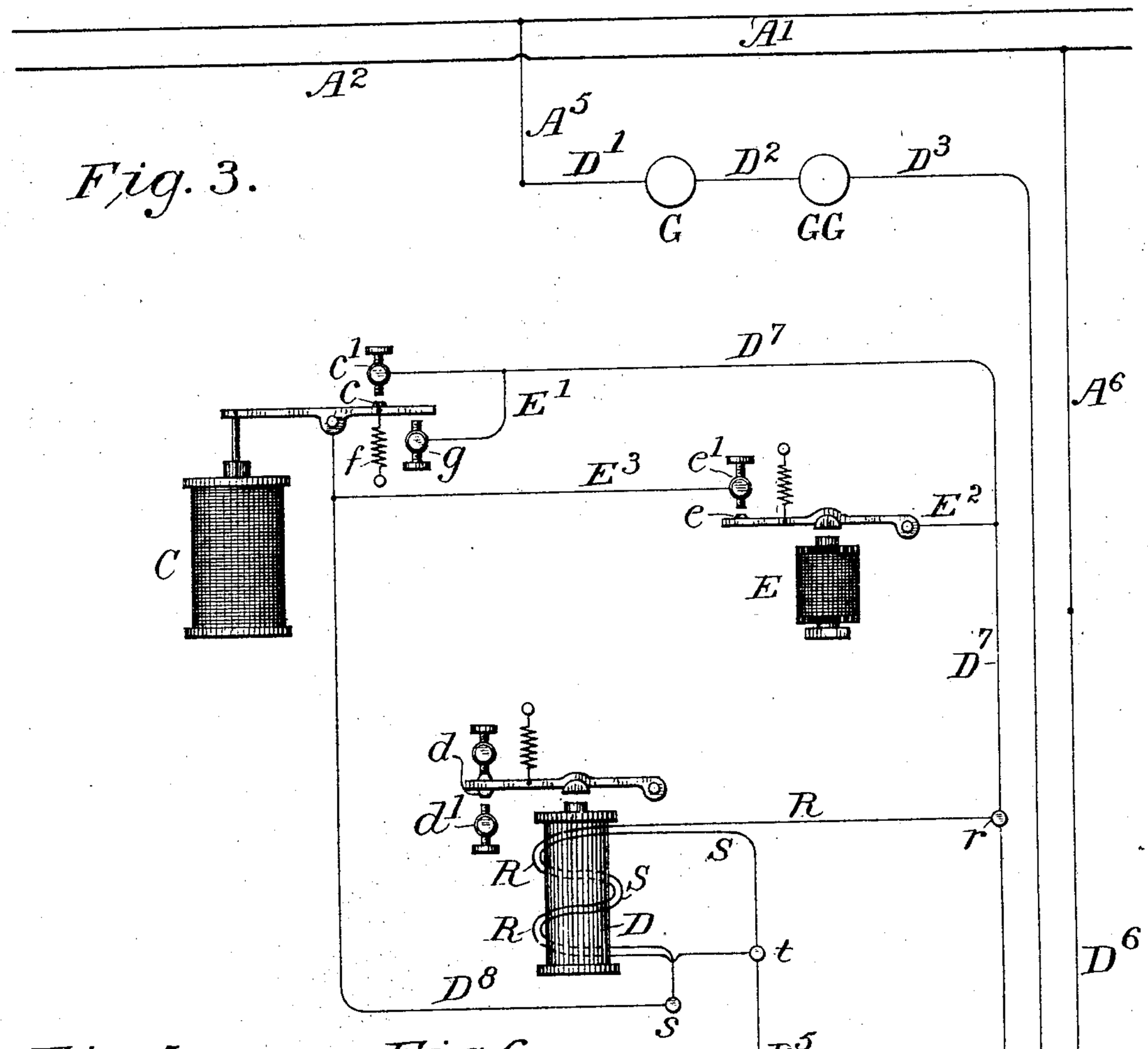


Fig. 5.

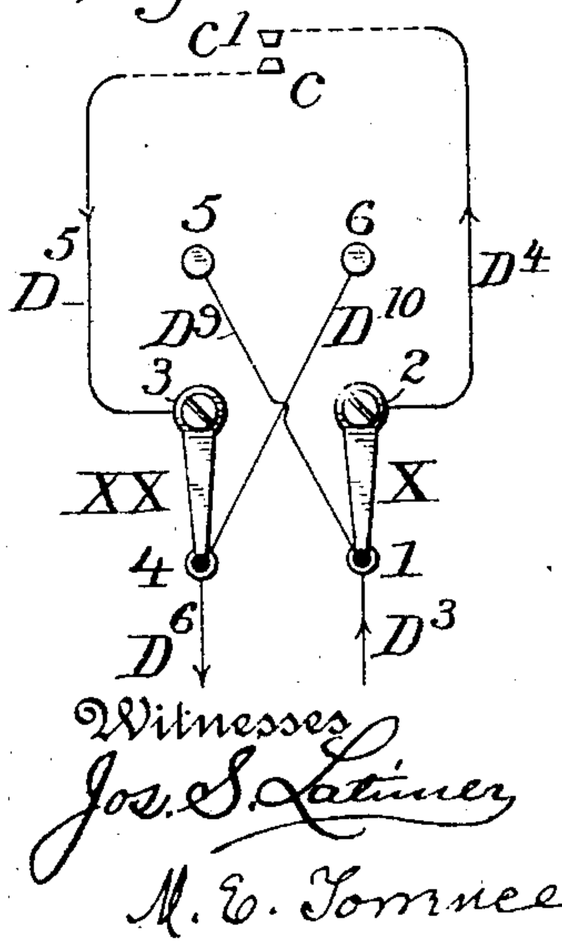
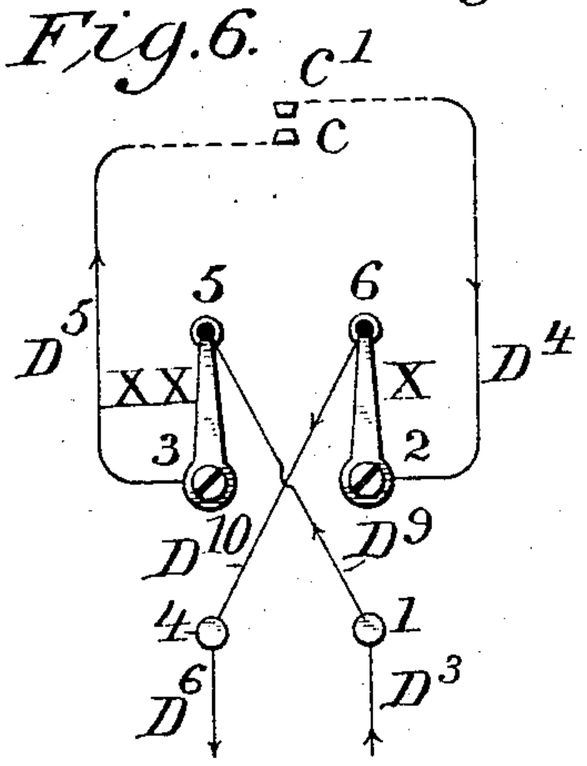


Fig. 6.



Witnesses
Jos. S. Latimer
M. E. Tormee.

Inventor
Allen Augustus Tirrill
by William L. Browne
his Attorney

No. 725,799. PATENTED APR. 21, 1903.

A. A. TIRRILL.

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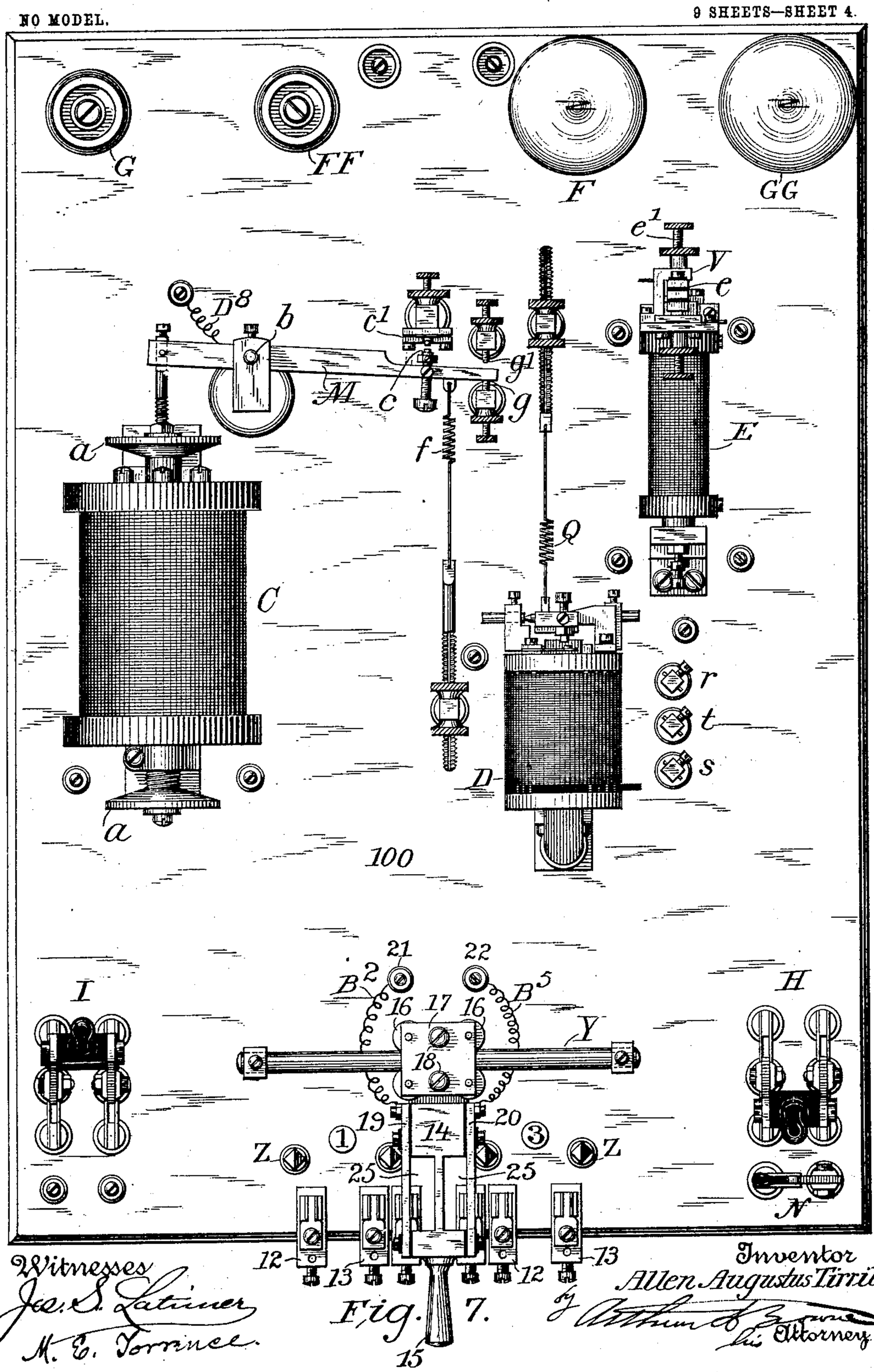
NO MODEL. 9 SHEETS—SHEET 4.



Witnesses
Jos. S. Latimer
M. E. Torrance.

Fig. 7.

Inventor
Allen Augustus Tirrill
by Arthur O. Brown
his Attorney

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A. A. TIRRILL.

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Fig. 8.

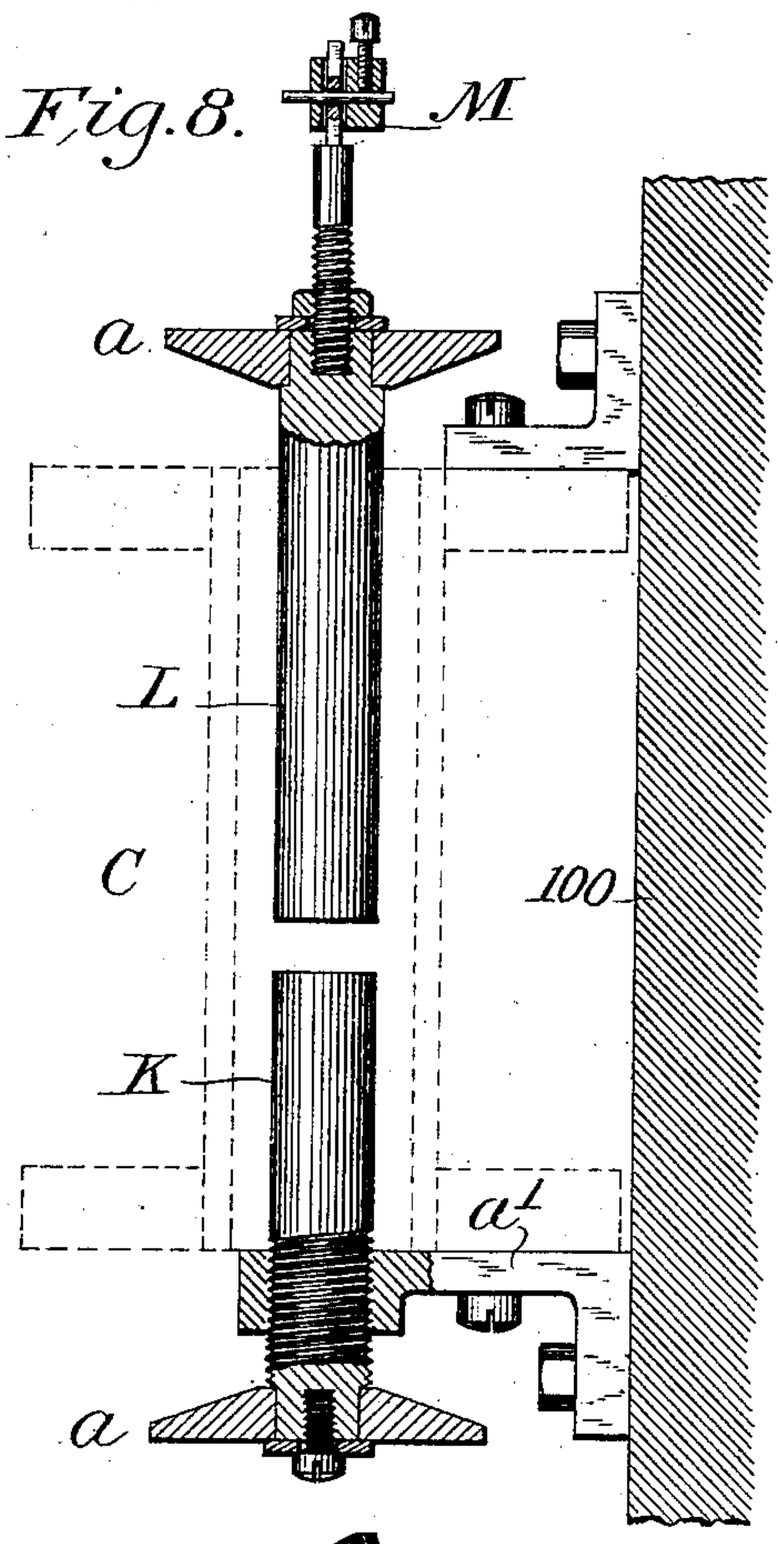


Fig. 9.

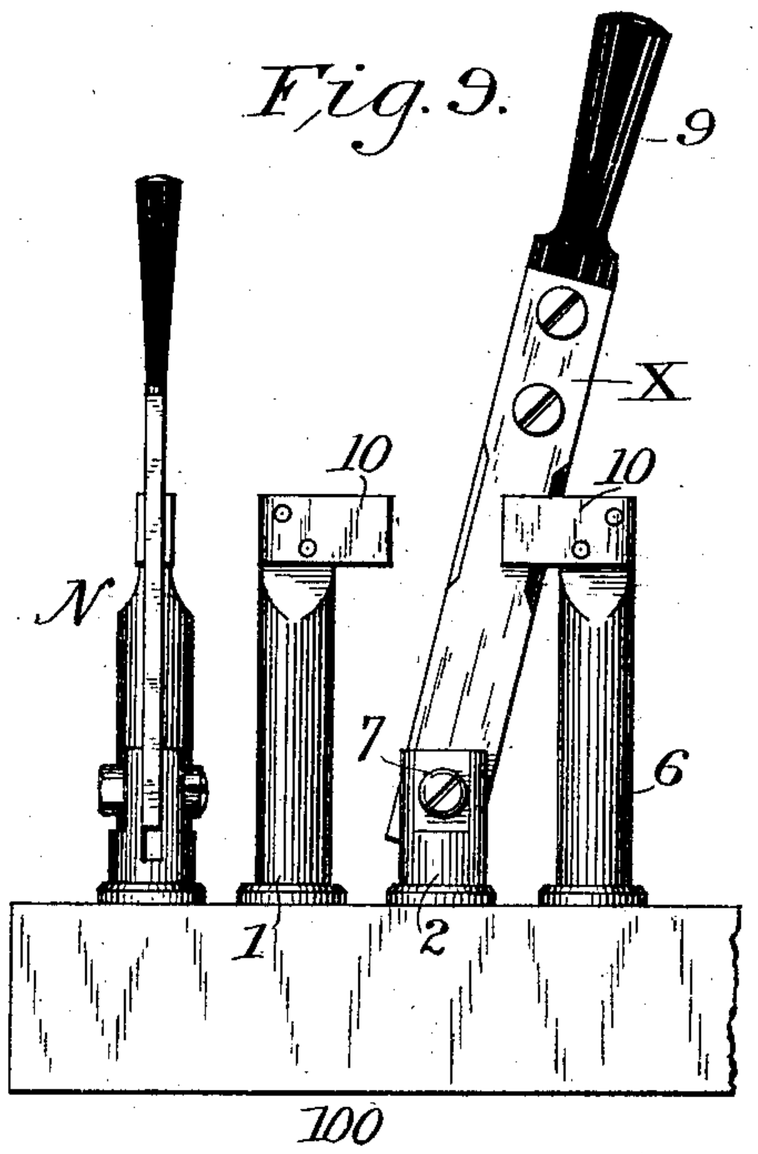


Fig. 10.

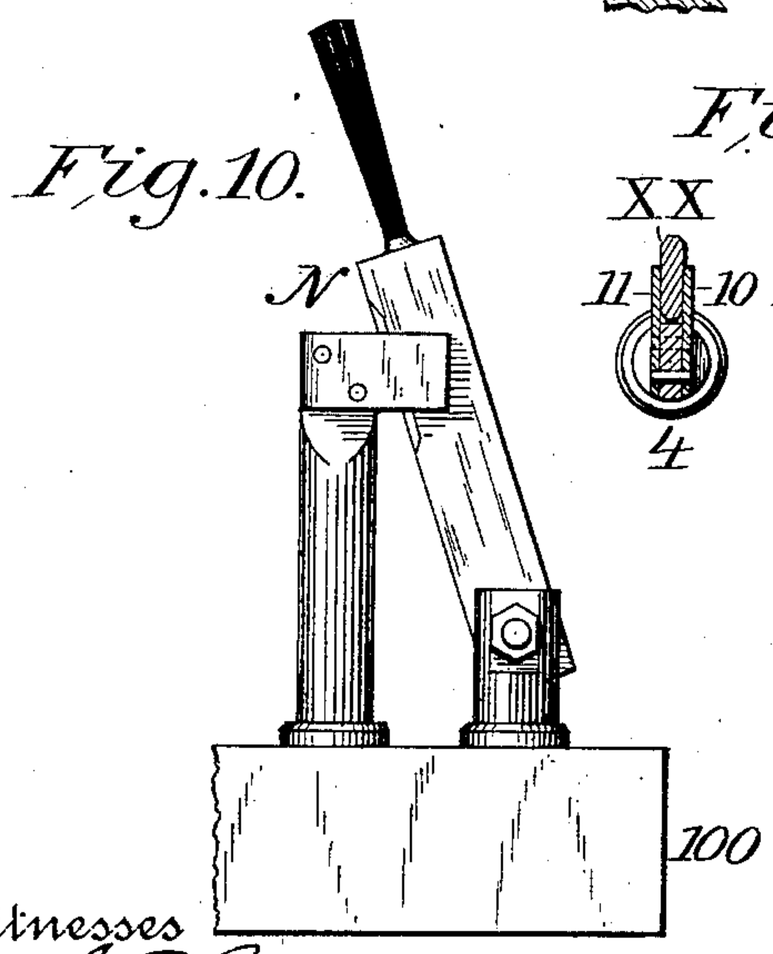
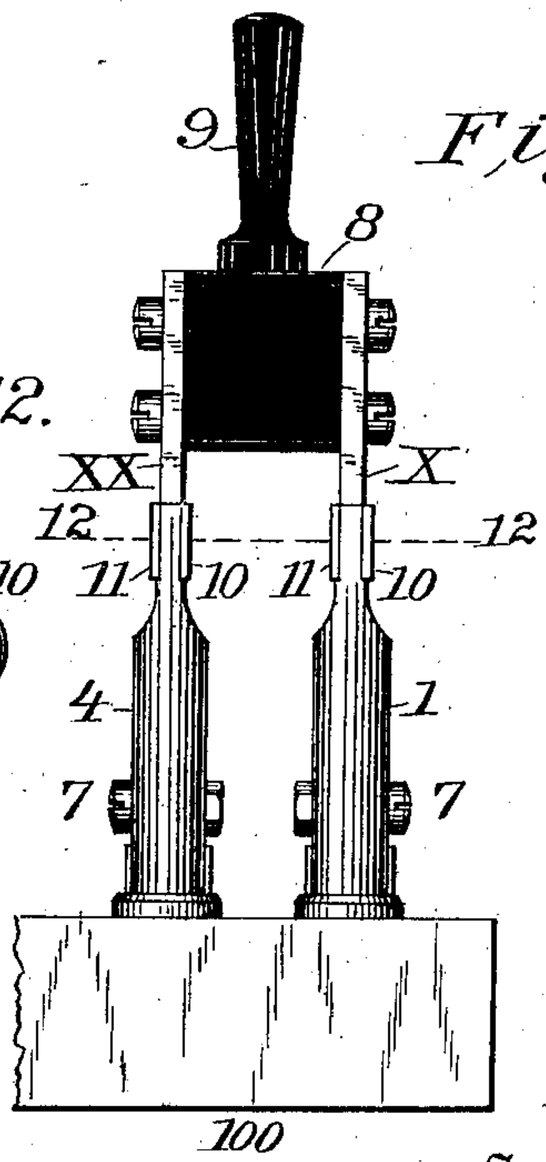


Fig. 12.

Fig. 11.



Witnesses
Jas. S. Latimer
M. E. Torrence.

Inventor
Allen Augustus Tirrill
by Wilfred J. Crowe
his Attorney

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

No. 725,799. PATENTED APR. 21, 1903.

A. A. TIRRILL.

AUTOMATIC POTENTIAL REGULATOR FOR DYNAMOS.

APPLICATION FILED APR. 13, 1900.

NO MODEL. 9 SHEETS—SHEET 6.

Fig. 13.

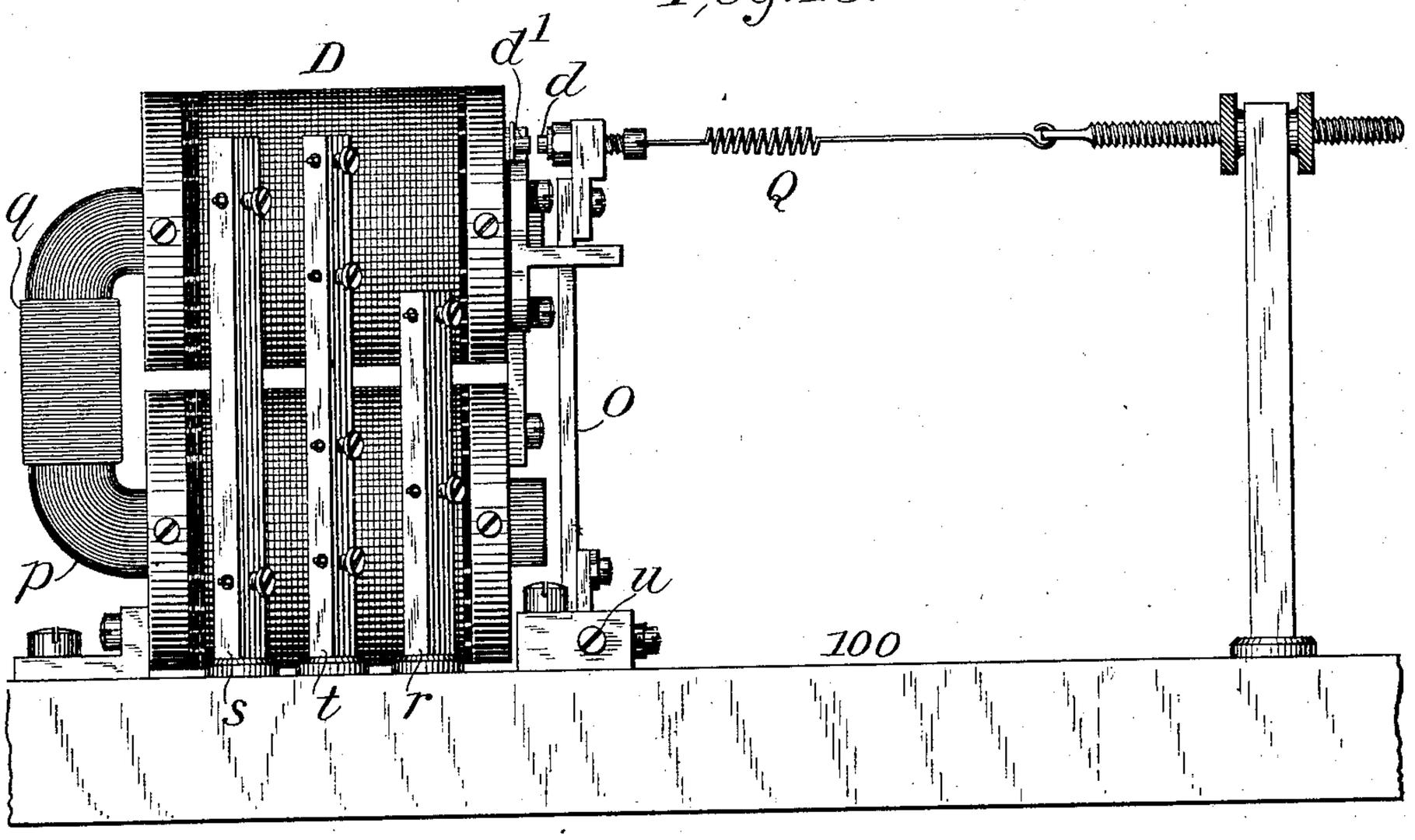


Fig. 14.

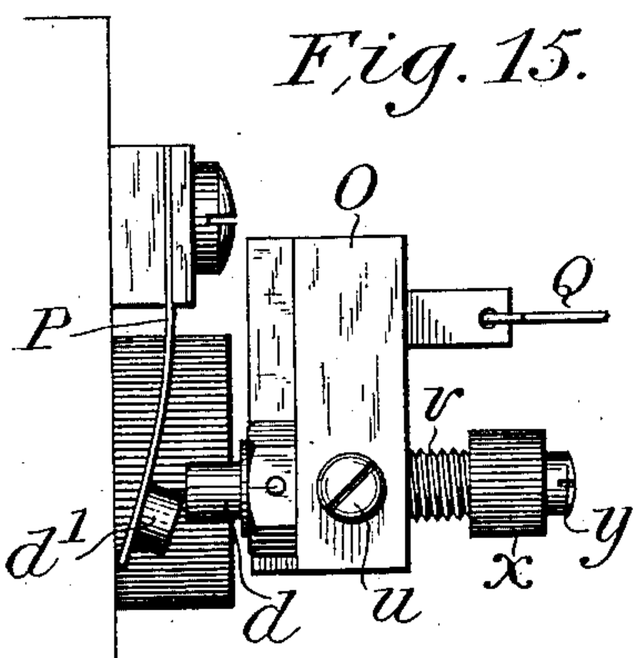


Fig. 15.

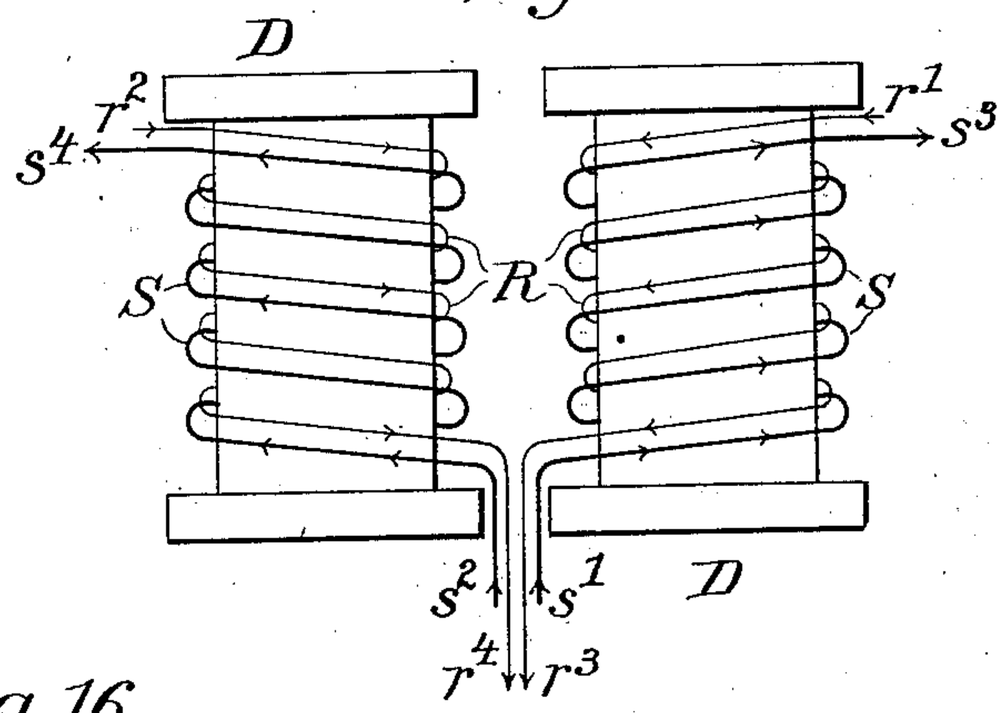


Fig. 16.

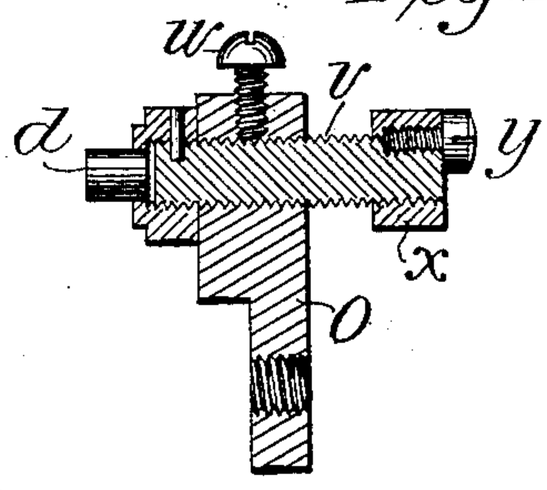
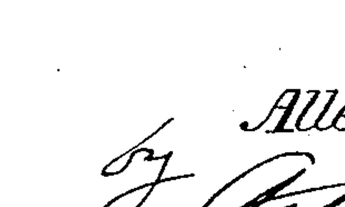


Fig. 17.



Witnesses
Jos. S. Latimer
M. E. Torrence.

Inventor
Allen Augustus Tirrill
by Arthur L. Browne
his Attorney

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

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A. A. TIRRILL.

AUTOMATIC POTENTIAL REGULATOR FOR DYNAMOS.

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Fig. 19.

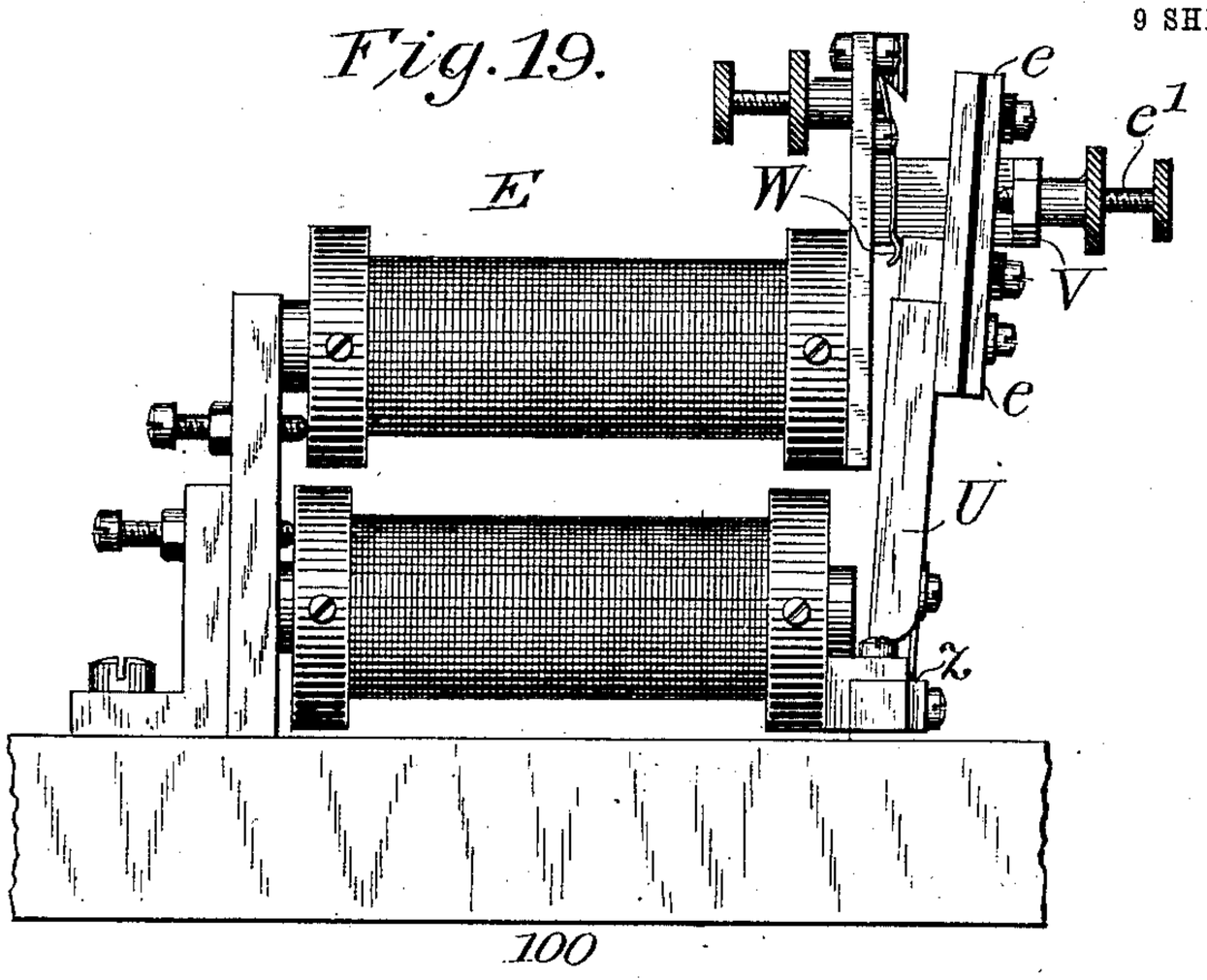


Fig. 20.

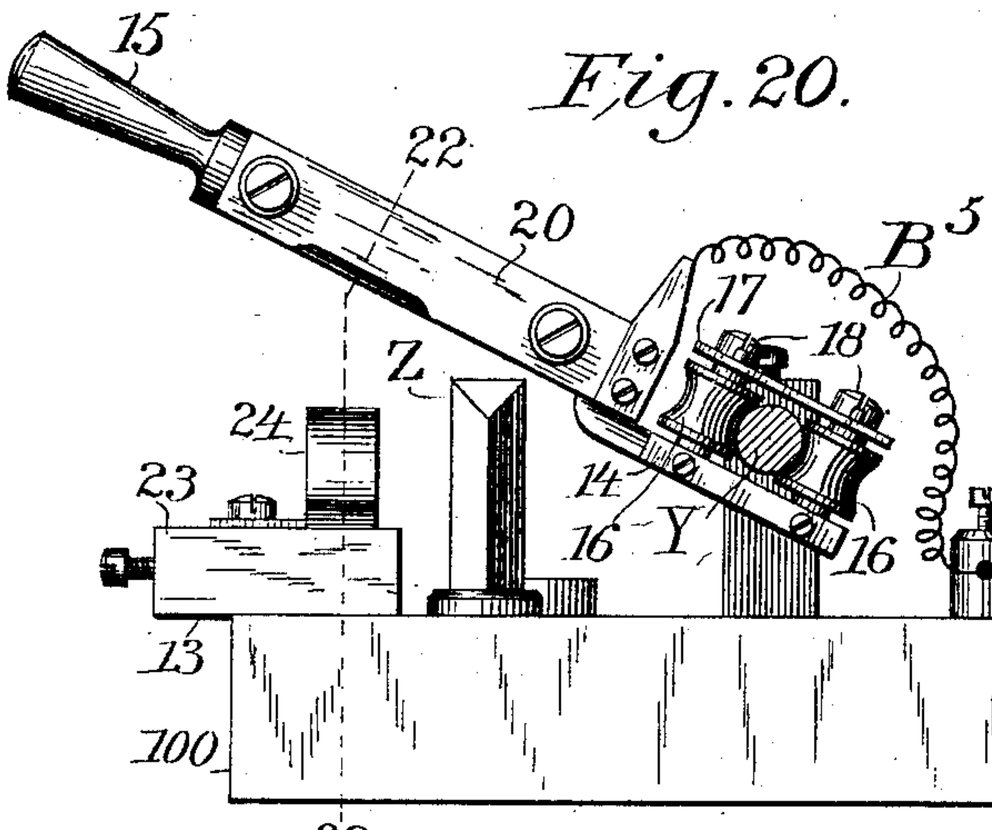


Fig. 21.

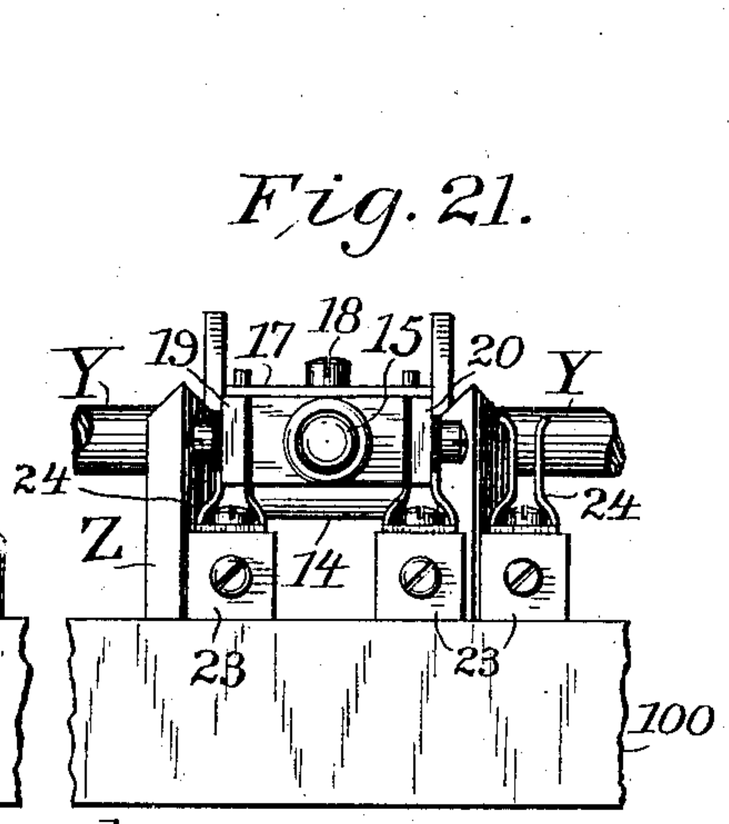


Fig. 22.

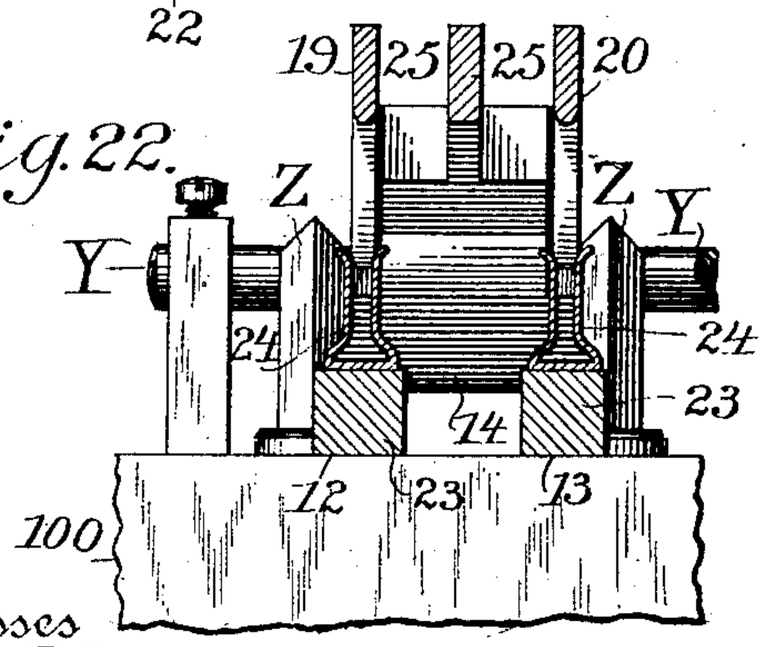
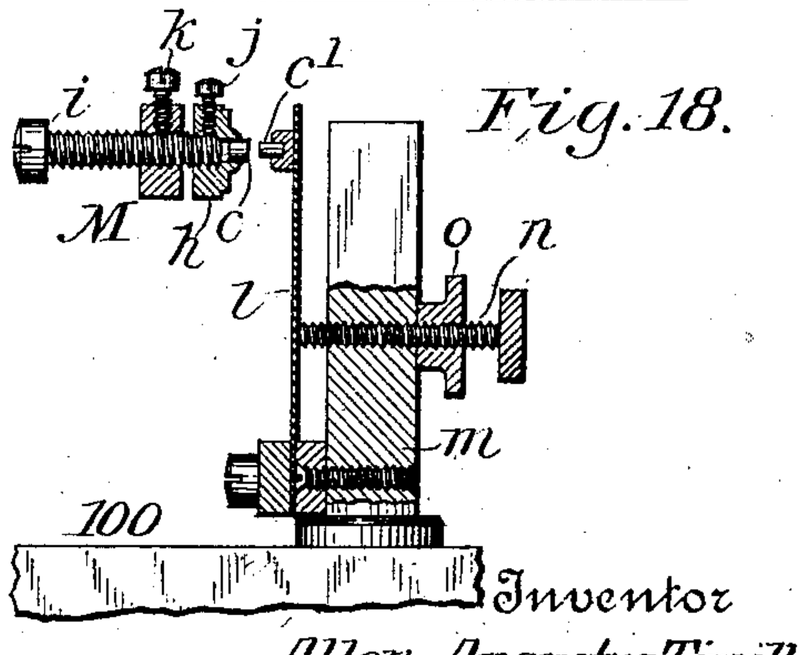


Fig. 18.



Witnesses
Jos. S. Latimer
M. E. Torrence

Inventor
Allen Augustus Tirrill
by Arthur O. Brown
his Attorney

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

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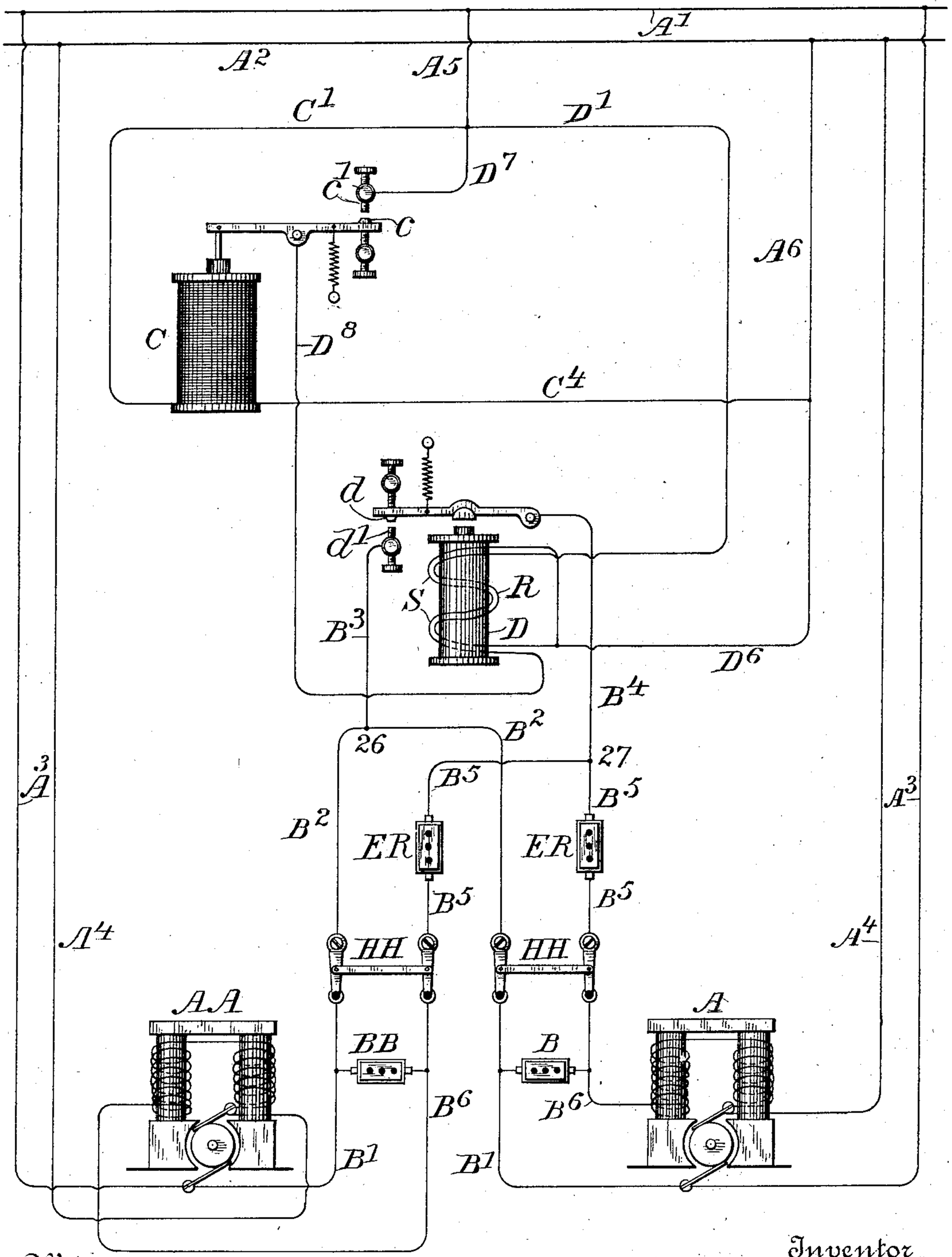
A. A. TIRRILL.

AUTOMATIC POTENTIAL REGULATOR FOR DYNAMOS.

APPLICATION FILED APR. 13, 1900.

NO MODEL. 9 SHEETS—SHEET 8.



Witnesses
Jos. S. Latimer
M. C. Tornee.

Fig. 23.

Inventor
Allen Augustus Tirrill
by Arthur O. Brown
his Attorney

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

No. 725,799. PATENTED APR. 21, 1903.

A. A. TIRRILL.

AUTOMATIC POTENTIAL REGULATOR FOR DYNAMOS.

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NO MODEL. 9 SHEETS—SHEET 9.

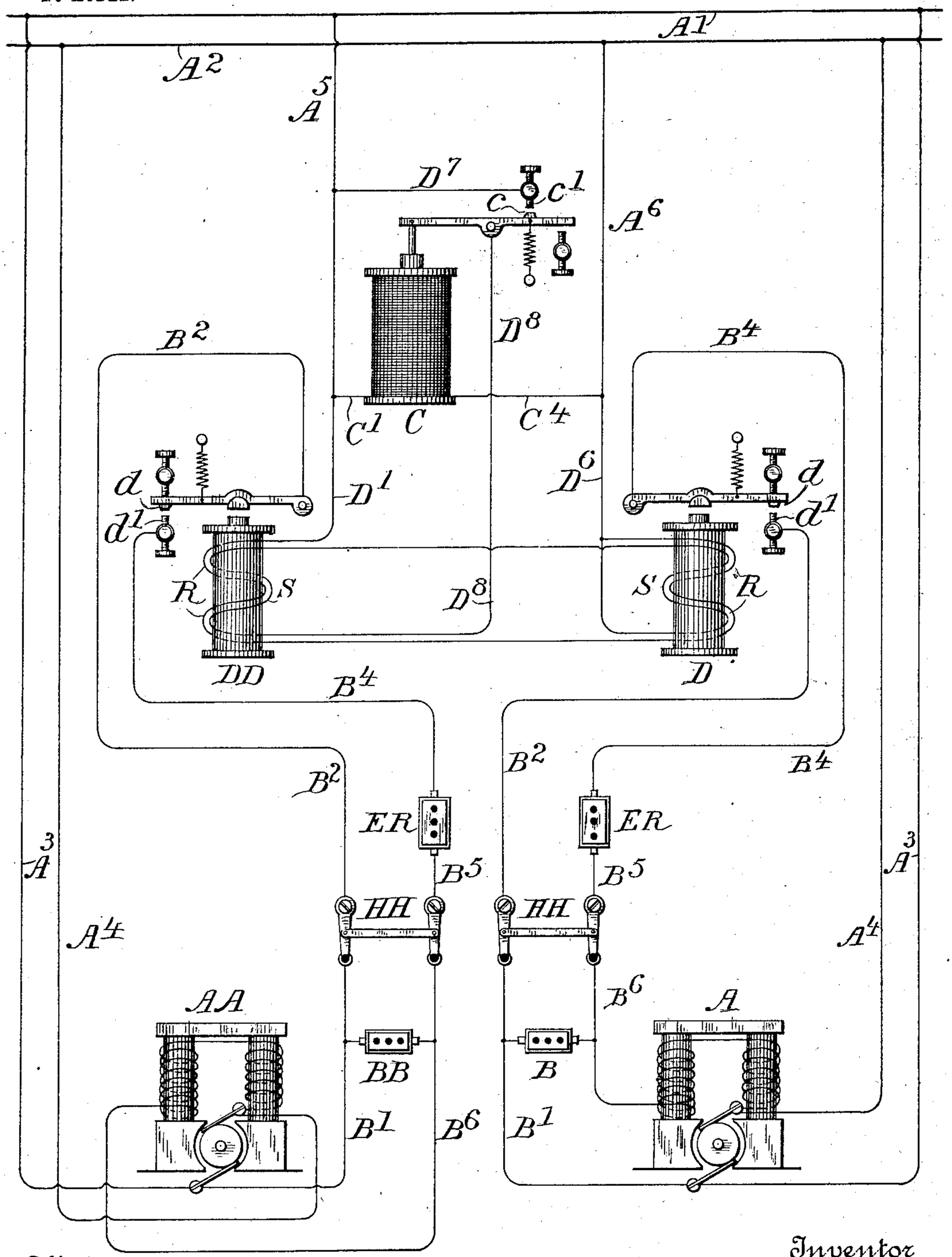

Fig. 24.

Witnesses
Jas. S. Latimer
M. E. Torrence.

Inventor
Allen Augustus Tirrill
by Whitmore Brown
his Attorney

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

UNITED STATES PATENT OFFICE.

ALLEN AUGUSTUS TIRRILL, OF LACONIA, NEW HAMPSHIRE, ASSIGNOR, BY MESNE ASSIGNMENTS, TO GENERAL ELECTRIC COMPANY, OF SCHENECTADY, NEW YORK, A CORPORATION.

AUTOMATIC POTENTIAL-REGULATOR FOR DYNAMOS.

SPECIFICATION forming part of Letters Patent No. 725,799, dated April 21, 1903.

Application filed April 13, 1900. Serial No. 12,721. (No model.)

To all whom it may concern:

Be it known that I, ALLEN AUGUSTUS TIRRILL, of Laconia, in the county of Belknap, State of New Hampshire, have invented certain new and useful Improvements in Automatic Potential-Regulators for Dynamos, of which the following is a specification.

The present improvements are illustrated in the accompanying drawings, in which—

Figure 1 is a diagram of all of the circuits and devices. Fig. 2 is a diagram of the solenoid-circuit. Fig. 3 is a diagram of the relay-circuit. Fig. 4 is a diagram of the regulating-circuit. Figs. 5 and 6 are diagrams of the reversing-circuits. Fig. 7 is a front view of the regulating apparatus. Fig. 8 is a detail view of the solenoid-cores. Fig. 9 is a side view of one of the reversing-switches and an end view of the main switch. Fig. 10 is a side view of the main switch. Fig. 11 is an end view of one of the reversing-switches. Fig. 12 is a detail section in a plane indicated by the line 12 12 in Fig. 11. Fig. 13 is a side view of the relay-magnet. Fig. 14 is a diagram of the relay-windings. Figs. 15 and 16 are detail views of the relay-contacts. Fig. 17 is a cross-section of the relay-core at its bend. Fig. 18 is a detail view of the solenoid-contacts. Fig. 19 is a side view of the protecting-magnet. Fig. 20 is a side view of the trolley-switch. Fig. 21 is an end view of the trolley-switch. Fig. 22 is a section on a plane indicated by the line 22 22 in Fig. 20. Figs. 23 and 24 are diagrams of modifications.

In Letters Patent of the United States No. 620,514, granted February 28, 1899, to my assignee, there is described an automatic potential-regulator for dynamos which comprises as its fundamental features, first, a dynamo having a rheostat in a shunt-circuit; second, a solenoid-regulator in a shunt from the supply-wires leading from the dynamo, the solenoid by its operation controlling a pair of solenoid-contacts; third, a relay-magnet in a shunt from the supply-wires of the dynamo, which shunt also includes the solenoid-contacts, so that the relay-shunt is opened and closed by the action of the solenoid, the relay in turn by its operation controlling a pair of relay-contacts in the dynamo-shunt, so as to cut in and out the rheostat, and, fourth, a protecting-magnet which is in the solenoid-circuit and which controls a pair of protecting-contacts in the relay-circuit. These several features are shown in the diagrammatic Fig. 1 of the present drawings, wherein A is a dynamo. B is the regulating resistance or rheostat in the dynamo-shunt. C is the solenoid, $c\,c'$ being the solenoid-contacts controlled by it. D is the relay, $d\,d'$ being the relay-contacts controlled by it, and E is the protecting-magnet, $e\,e'$ being the contacts controlled by it. The dynamo shunt-circuit is indicated by reference characters B′ to B^6, by which it will be seen that the relay-contacts $d\,d'$ control the dynamo shunt-circuit. The solenoid-circuit is indicated by the reference characters C′ to C^5, by which it will be seen that this circuit is always normally operative and that the protecting-magnet E is included in it. The relay-circuit is indicated by the reference characters D′ to D^8, by which it will be seen that it includes both the solenoid-contacts $c\,c'$ and the protecting-contacts $e\,e'$. The solenoid and relay circuits are both shunts from the supply-circuit A′ A^2. The protecting-magnet E of said patent being in a permanently-operative circuit when the system was in proper order, its contacts $e\,e'$ were normally together, so that under ordinary working conditions only the solenoid-contacts $c\,c'$ and the relay-contacts $d\,d'$ are to be considered. Assuming these latter contacts $d\,d'$ to be opened—that is, separated—the rheostat B of said patent (or so much of it as is employed for regulating purposes) was then in circuit. Should there then have been a fall in potential, the solenoid received less energy, and as the result of its structural relation to its contacts $c\,c'$ the latter would then close, (as the apparatus of the said patent was constructed,) thus closing the relay-circuit D′ to D^6, thereby energizing the relay and closing its contacts $d\,d'$, as the relay of said patent was constructed and arranged. The diagram shows the relay and solenoid of the present invention, which in this respect are different, though having the same effect

on the regulating-circuit. The result of closing the contacts d d' was thereby to close the dynamo shunt or regulating circuit B′ to B⁶ and to shunt entirely out the entire regulating resistance B, so that the potential of the dynamo instantly rose. Owing to the rise in potential, the solenoid received additional energy, thereby separating (in said patented construction) its contacts c c', thus breaking the relay-circuit, which in turn broke the dynamo shunt-circuit at that point, thus again putting in circuit the entire regulating resistance. The regulator thus acted automatically to at once cut in and out the entire regulating resistance. By having this regulating resistance equal to or greater than necessary to compensate for the maximum variations in the load on the dynamo the potential on the supply-wires was maintained constant by this mode of automatic regulation, notwithstanding the varying tax or demand made upon the supply-wires by the starting or stopping of electric motors or by rendering active or idle other electricity-users. As pointed out in said Patent No. 620,514, the purpose of the relay was to lessen sparking at and sticking of the solenoid-contacts c c', which would interfere with the sensitiveness of the regulation and cause flickering of lights in the supply-circuit and rapidly destroy the contacts. The purpose of the protecting-magnet E was to prevent the danger which would arise in case of an accidental break in the solenoid-circuit. Such a break would otherwise cut out the solenoid, (thus having the same effect on it as a fall in potential,) thus permanently closing its contacts, and consequently permanently closing the relay-contacts, thereby closing the dynamo-shunt and permanently closing a shunt across the entire regulating resistance. As a result the potential on the supply-line would run up to a high and dangerous pitch. To prevent this, the protecting-magnet controlled a second break in the relay-circuit, which break was normally closed as long as the solenoid-circuit in which the protecting-magnet was located remained intact. Should the solenoid-circuit be accidentally broken, the protecting-magnet would lose its energy and its contacts would open, thereby permanently opening the relay-circuit, thus leaving the dynamo shunt-circuit permanently broken at the relay-contacts d d'. Consequently the entire regulating resistance would then be at all times operative, and as the automatic regulator would be inoperative the dynamo would act like any ordinary dynamo of the same type with a permanent rheostat. The said prior patent, No. 620,514, describes these features and their mode of operation in detail.

The present invention consists in improvements upon the system of automatic regulation constituted by these prior features, and has for its objects, first, the extension of the system, so that a plurality of dynamos may be regulated by the same regulator; second, increasing the sensitiveness of the regulation, and, third, the improvement of the structure of the parts of the apparatus.

The principal features of improvement are as follows:

First. The solenoid C (which is preferably single instead of double, as specifically illustrated in said Patent No. 620,514) is a stopped-core and plunger magnet having an adjustable soft-iron stop-core and laterally-extending soft-iron heads to both the stop and the movable core. By the employment of this device greater power is given, due to the shortening of the air traverse of the magnetic lines of force. Also fluctuations in voltage due to the heating effect on the solenoid when starting are prevented and greater speed of action is given to the movable core, thereby increasing the sensitiveness of the regulation.

Second. Permanent non-inductive resistance (consisting, preferably, of two incandescent electric lamps F and FF) is introduced into the solenoid-circuit. This is of advantage, since the resistance quickly heats to its maximum temperature, thus preventing fluctuation due to heating. The effect of heating is to increase the resistance of the solenoid, and hence more current would be required for its operation if the entire resistance should be in the coils. Hence the external resistance economizes the current consumed in regulation.

Third. Special means are employed for adjusting the contacts of the solenoid.

Fourth. The relay D is a horseshoe-electromagnet having a laminated core of soft-iron wire, which renders it more sensitive and increases the rapidity of its action.

Fifth. The relay D is differentially wound. One winding is always in circuit. The other winding is in circuit with the solenoid-contacts c c'. Hence when the contacts c c' separate the counter electromotive force thereby generated, which otherwise would cause sparking, is avoided, because the current is always flowing through the relay.

Sixth. Permanent non-inductive resistance, consisting, preferably, of two incandescent electric lamps G and GG (see Figs. 1, 3, and 6) is introduced in the relay-circuit. This obviates sparking and sticking at the solenoid-contacts c c', because it preserves a constant and automatically uniform resistance through the relay D, whether one or both of the differential windings or coils is in circuit.

Seventh. The construction of the relay-contacts d d' is such as to prevent them sticking together, this action being that of a mechanical weld or interlock breaker.

Eighth. Reversing-switches H I, of novel construction, are employed for the purpose of reversing the flow of current through the solenoid-contacts c c' and the relay-contacts

d d', respectively. By reversing the current from time to time unequal wearing of the contacts of each pair is avoided.

Ninth. A condenser is introduced in the dynamo-shunt to avoid sparking at the relay-contacts d d'.

Tenth. When a plurality of dynamos are regulated by the same regulator, any one of the dynamos can be used singly or as the regulating-dynamo of several dynamos running simultaneously. To enable this to be done, a "trolley-switch" J of novel construction is employed.

The circuit connections for all the foregoing features are illustrated in Fig. 1; but the various structural features are indicated diagrammatically only in Figs. 1 to 6, inclusive. The structural features are illustrated in detail in Figs. 7 to 22, inclusive. As Fig. 1 is rendered somewhat obscure, because of the multiplicity of the circuits, the several independent circuits embraced in it are separately illustrated in Fig. 2, (the solenoid-circuit,) Fig. 3, (the relay-circuit,) Fig. 4, (the dynamo shunt or regulating circuit,) and Figs. 5 and 6, (one of the reversing-circuits.)

In Fig. 1 two dynamos A AA are illustrated, and of these A is shown as the regulating-dynamo for the time being. A' A^2 are the main supply or bus wires connected with the dynamos by wires A^3 A^4.

Referring to Figs. 1 and 2, the solenoid-circuit starts from the shunt-wire A^5, leading from the supply-wire A', thence by wire C' to the first lamp F, thence by wire C^2 to the second lamp FF, thence by wire C^3 to the coils of the solenoid C, thence by wire C^4 to the coils of the protecting-magnet E, thence by wire C^5 to the return shunt-wire A^6, leading to the return supply-wire A^2. Whenever, therefore, there is current in the supply-wire and the system is intact, the solenoid C and the protecting-magnet E are energized. The lamps F and FF in this circuit are ordinary incandescent electric lights, which are used because they furnish non-inductive resistance, as already explained, and at the same time give visual indication of the continuity of the solenoid-circuit. In Fig. 7 the lamp F is shown, while only the socket for the lamp FF is indicated.

The novel features of construction of the solenoid are illustrated in Figs. 7 and 8. The lower supporting-bracket a' of the solenoid extends beneath the central passage of the coils and is there female-threaded to receive and longitudinally adjust the adjustable soft-iron stop-core K. This permits the normal adjustment of the stop-core relatively to the electrically-controlled moving core L to regulate the action of the solenoid. Both cores extend beyond the solenoid-coil, and each at its outwardly-projecting end is provided with a laterally expanded or extending soft-iron head a. These heads shorten the air traverse of the magnetic lines of force, as already explained. The moving core L is adjustably suspended from one end of the lever M, which is pivoted at b, (see Fig. 7,) and at its other end carries the solenoid-contact c. The pull of the solenoid on the lever is resisted by an adjustable spring f. (See Fig. 7.) The free end of the solenoid-lever M plays between two adjustable limiting-stops g g', Fig. 7. The movable solenoid-contact c on the lever M cooperates with fixed contacts c'. The detail construction and adjustment of these contacts is shown in Fig. 18. The contact c is of platinum or other non-corrodible metal and is secured to a cap h, which screws on the end of stem i and is held in place thereon by set-screw j. The stem i screws adjustably in lever M and is held in place by set-screw k. Thus the contact c is rendered adjustable and is electrically integral with lever M. The other contact c' (also of similar metal) is secured at one end of a yielding support consisting of an elastic strip l of thin spring metal, which is fastened at its other end to bracket m, and this spring-support is adjustable by means of set-screw n and lock-nut o. When the voltage on the line is below the normal, the spring f overcomes the pull of the solenoid, and the contacts c c' are separated. An increase of potential gives greater energy to the solenoid and pulls harder upon its moving core, thereby overcoming spring f and bringing the contacts c c' together, thus closing the relay-circuit D' to D^8, of which they constitute terminals.

The relay D is a differentially-wound horseshoe electromagnet, the details of which are best shown in Figs. 13 to 17. As shown in Figs. 13 and 17, the core is laminated, being composed of a bundle of soft-iron wires p, independently shellacked for lamination, which are bent to horseshoe shape and are bound together by a wire winding q. Fig. 17 is a cross-section through the winding q. The differential windings R and S of the relay-coils are diagrammatically shown in Fig. 14. The current traverses these two windings in opposite directions, as indicated by appropriate arrows in Fig. 14. The ingoing wires r' r^2 of winding R are connected to binding-post r, Fig. 13. The ingoing wires s' s^2 of winding S are connected to binding-post s, while the outgoing wires r^3 r^4 s^3 s^4 of both windings are all connected to the common binding-post t. One of the windings, as R, is always in circuit, the connections (see Figs. 1 and 3) being as follows: The relay-circuit starts from the main shunt-wire A^5, thence by wire D' to incandescent lamp G, thence by wire D^2 to incandescent lamp G G, thence by wire D^3 to main switch N and reversing-switch H, thence by wire D^4 to binding-post r, thence by winding R to binding-post t, thence by wire D^5 to reversing-switch H, and thence by wire D^6 to main shunt-wire A^6. Winding R is hence always in circuit and always in circuit with the non-inductive external resistances G and GG. Of these latter the lamp GG is shown in Fig. 7, but only

the socket for the lamp G. The other winding S is in circuit with the solenoid-contacts. The binding-post *r* is connected by wire D^7 with solenoid-contact *c'*, and binding-post *s* is connected by wire D^8 with the solenoid-lever M and by said lever with the other solenoid-contact *c*. Whenever, therefore, the contacts *c c'* come together by the action of the solenoid, the current flows through winding S, but in contrary direction to its direction through winding R. Hence when the solenoid-contacts are open the relay is energized by the current flowing through coil R; but when said contacts are closed the current through winding S neutralizes that through winding R, thus destroying the magnetic force of the relay. This changing status of the relay is utilized (as will be hereinafter shown) to govern the dynamo-regulating shunt-circuit. The non-inductive external resistance, consisting of the lamps G and GG, it will be noted, is in circuit both when the solenoid-contacts are open and when they are closed. The windings R and S can hence have very low resistance, thus avoiding induction, and since the lamps G and GG afford in themselves the necessary resistance the flow of current is substantially the same whether one or both windings are in operation. Hence sparking at and sticking of the solenoid-contacts is avoided. The lamps G and GG also give visual indication that the regulator is in working condition. The changing status of the relay D controls the action of the relay-contacts *d d'*, which are terminals of the regulating-circuit B' to B^6. The armature O, pivoted at *u*, carries the movable relay-contact *d*, which is adjustable thereon and electrically integral therewith. The contact *d* is of platinum or other suitable non-corrodible metal and is secured to the end of a stem *v*, screwing in the armature and held in place by a set-screw *w*, Figs. 15 and 16. The stem *v* has a milled head *x* for operating it, held in place by set-screw *y*. Hence the contact *d* may be adjusted at will relatively to the stationary contact *d'*. Said stationary contact *d'* is of platinum or similar metal and is mounted at one end of a yielding support P, consisting of a thin strip of elastic metal firmly clamped at the other end, as shown. The armature is pulled away from the relay-magnet to separate the relay-contacts *d d'* by an adjustable spring Q. When the current passes only through winding R, the relay-magnet is energized and the contacts *d d'* are in contact and the circuit controlled by them is closed. When, however, current also passes through winding S (by virtue of increase in potential on the line) the relay is rendered inactive and the spring Q separates the relay-contacts, thereby breaking the circuit controlled by them. The flexible yielding mounting of the stationary contact *d'* acts as a mechanical weld-breaker or interlock-breaker to prevent the contacts *d d'* sticking or welding together. When said contacts are closed, as shown in Fig. 15, their faces are not parallel, since contact *d'* tilts, because its support yields at its free end. Consequently there is a rocking movement between the two contacts as they separate from each other, thus mechanically breaking any weld or interlock between them.

The dynamo shunt-circuit or regulating-circuit connections are shown in Figs. 1 and 4 and are as follows: The circuit starts with shunt-wire B', which extends to trolley-switch J, thence by wire B^2 to reversing-switch I, thence by wire B^3 to the relay-armature O and relay-contact *d*, thence to contact *d'*, when the circuit is closed, thence by wire B^4 to the reversing-switch I, thence by wire B^5 to trolley-switch J, and completes the circuit through the shunt-wire B^6. When, therefore, the potential is below the normal, the solenoid-contacts are open, the relay-contacts are closed, the regulating-circuit is closed, and the regulating resistance B is shunted out. Consequently the potential on the line quickly rises, and thereupon the solenoid-contacts close, the relay-contacts open, the regulating-circuit is broken, and the regulating resistance B is thrown into action. While the effect thus produced is the same, the mode of operation here present is different from that of the regulator of the said prior patent, No. 620,514, in which the fall of potential closed the solenoid-contacts, and thereby closed the relay-contacts.

To avoid sparking at the relay-contacts *d d'*, a condenser T is located in a bridge B^7 B^8 across said contacts. (See Figs. 1 and 4.)

To prevent dangerous rise in potential due to permanent shunting of the regulating resistance B in case of defect in the solenoid-circuit C' to C^5, two means of protection are shown, which can be used conjointly or independently. As shown in Figs. 1 and 3, the limiting-stop *g* (against which the solenoid-lever M is pulled by spring *f* when the solenoid-coil is rendered inoperative) is connected by bridge-wire E' with a solenoid-contact *c'*, thus bringing both contacts *c c'* in circuit and having the same effect as a rise in potential—that is to say, putting winding S of the relay permanently in circuit, thus permanently opening the relay-contacts and leaving the regulating resistance B permanently active. The same effect is produced by the protecting-magnet E. This magnet controls two contacts *e e'*, which are connected, respectively, by wires E^2 and E^3 with wires D^7 and D^8 of the relay-winding S, bridging across the solenoid-contacts *c c'*. As long as current flows through the protecting-magnet its contacts *e e'* are separated; but in case of accident to the solenoid-circuit (in which protecting-magnet is located) the contacts *e e'* come together and the same effect is produced as by the bridge-wire E'. As shown in Fig. 19, the armature U of the protecting-magnet, pivoted at *z*, carries the contact *e*, contact *e'* being adjustable in fixed bracket V. An ad-

justable spring W forces the contacts together on failure of current in the magnet E.

In order to prevent unequal wearing of the solenoid-contacts and of the relay-contacts, reversing-switches H and I are used to reverse from time to time at will the direction of the current flowing through said contacts. Both reversing-switches are alike, so that the description will be confined to the switch H for reversing the current through the portion of the relay-circuit which includes the solenoid-contacts. The switch is a two-pole switch, and its circuit connections are shown in Figs. 5 and 6, which show the different portions of the switch. The switch comprises two movable metal bars X and XX, which are permanently electrically connected to posts 2 and 3, respectively, and which can be moved from the position shown in Fig. 5, where they are in electric connection, respectively, with posts 1 and 4, to the position shown in Fig. 6, where they are in electric connection respectively with posts 6 and 5. Post 1 is connected with the leading-in wire D^3, post 4 with the leading-in wire D^6, post 2 with the wire D^4, leading to the solenoid-contacts, and post 3 with the wire D^5, leading from said contacts, as shown in Figs. 1 and 3, as well as in Figs. 5 and 6. Posts 1 and 5 are connected by wire D^9 and posts 4 and 6 by wire D^{10}. When the bars X and XX are in the position of Fig. 5, the current flows along wire D^3, post 1, bar X, post 2, wire D^4 to contacts c' c, wire D^5, post 3, bar XX, post 4, and wire D^6. When, however, the bars X and XX are in the position of Fig. 6, the current flows along wire D^3, post 1, wire D^9, post 5, bar XX, post 3, wire D^5 to contacts c c', wire D^4, post 2, bar X, post 6, wire D^{10}, post 4, and wire D^6, thus flowing through the contacts in the opposite direction.

The construction of the reversing-switch is shown in Figs. 7, 9, 11, and 12. As there shown, the two bars X and XX are pivoted at 7 in slots at the outer end of the short posts 2 and 3, respectively, and are connected at their outer ends by insulating-block 8, having manipulating-handle 9. Each of the posts 1, 4, 5, and 6 is a long one and has at outer end a pair of resilient metal contacts 10 and 11, between which the corresponding bar X or XX is grasped to make electric connection. Hence when the switch occupies one position its bars are gripped by the contacts of one set of the reversing-posts, and when it is moved to the other position its bars are gripped by the contacts of the other set of posts. To facilitate making contact, the edges of the bars are beveled, as shown in Fig. 12.

As shown in Fig. 1, two dynamos, A and AA are illustrated, both connected with the same mains A' A^2. The resistance-circuit of either of these dynamos may be connected with the regulator by means of the switch J, and in exactly the same manner a larger number of dynamos may be controlled. As illustrated in Figs. 7, 20, 21, and 22, the switch J is adapted for use with three dynamos. Whatever may be the number of dynamos, the regulating-circuit of each can be brought into operative relation with the regulator, so that each dynamo can be used independently, or all of the dynamos may be used simultaneously, in which case the particular dynamo connected with the regulator serves to regulate the entire output of current. Of course in the last-named case the regulating resistance B or BB, which is in operation with the regulator, should be sufficient to compensate for any probable or expected variation in potential on the line, and such being the case the regulation will be efficient whatever number of dynamos may be employed.

The switch J, which is adapted to bring any one of the regulating resistances into operative relation with the regulator, is of novel construction and is aptly termed a "trolley-switch." The trolley-switch is adapted to both swing and glide along a track Y, swinging on said track to be brought into and out of connection with electrical contacts 12 13 and sliding on said track so as to be brought in register with one of several groups of such contacts. The switch J comprises a base 14, having at one end a manipulating-handle 15 and at the opposite end four trucks or rollers 16 16, suitably journaled thereon and in a cap-plate 17, secured thereto by screws 18. These rollers embrace the track Y, as best shown in Fig. 20, and are shaped on their peripheries to conform to the cylindrical sectional shape of said track. Hence said switch can be both swung on the track as a pivot, and also slid along the same. The base 14 carries on opposite sides metal bars 19 and 20, secured thereto but insulated therefrom, the switch being thus a "two-pole" switch. One bar, 19, is connected by a flexible insulated cable B^2 (constituting a part of the correspondingly-lettered circuit connection) to a suitable binding-post 21, and the other bar, 20, is connected by a flexible insulated cable B^5 (constituting a part of the correspondingly-lettered circuit connection) to a suitable binding-post 22. As shown in Fig. 7, the trolley-switch is adapted to be brought into coöperation with any one of three groups of contacts 12 13. Each contact 12 or 13 comprises a base-plate 23, having secured thereto a strip of resilient sheet metal having two clasping-prongs 24, (see Fig. 22,) between which one of the bars 19 or 20 of the switch is adapted to enter and to be grasped, the bar being beveled to facilitate its entrance. As indicated in Fig. 4, each contact 12 is connected to wire B' and each contact 13 to wire B^6 of the regulating-circuit of the dynamo to which it corresponds. Consequently when the trolley-switch is swung down with its bars grasped by one of the groups of contacts 12 13 it connects the external conductors B' B^6 with the respective conductors B^2 B^5 of the regulating apparatus. To permit

each bar 19 and 20 to be straddled by the prongs 24, the base 14 is cut away to form openings 25 for this purpose. (See Fig. 7.) To insure the proper operation of the trolley-switch, fixed guide and positioning posts Z, spaced apart and beveled on their upper ends, Fig. 21, are provided between the track Y and the contacts 12 13, against one of which the base 14 of the switch will abut except only when the switch is in proper position along the track to have its bars 19 20 register with a group of the prongs 24.

The main switch N is a "single-pole" switch and is illustrated in detail in Figs. 9 and 10. It and its adjuncts are constructed like a single bar X or XX of the reversing-switch and the posts 2 and 3 thereof, so that further description of its construction seems unnecessary. By means of it the relay-circuit D′ to D⁶ may be opened and closed at will. When said switch is opened, the entire regulator is rendered inoperative. There then being no current in the relay-circuit, the relay-contacts *d d′* are separated by the spring Q, so that the dynamo resistance is then operative just as in an ordinary dynamo of this type.

The several parts of the regulating apparatus are mounted upon a suitable insulating-base 100, preferably of marble.

Fig. 23 is a diagram similar to Fig. 1, but simplified, so as to show the principal circuits only, which illustrates a plurality of dynamos (two being shown, but the principle being the same for a larger number) connected to a single regulating-relay, but so arranged that the independent rheostats B and BB for the dynamos are both used for regulating purposes. Simple two-pole switches (not reversing) are indicated at HH to control the regulating-circuit of each dynamo independently. As here shown, the conductors B′ B′ of the regulating-circuits of both dynamos merge at 26, and the return-conductors B⁶ B⁶ of both merge at 27. An adjustable equalizing resistance ER is introduced in each inpendent regulating-circuit, so that the two dynamos may be equalized when both are in operation. When the relay-contacts *d d′* are separated, both equalizing resistances ER are inoperative and both rheostats B and BB are operative. When, however, the contacts *d d′* are brought together, (when the potential on the line falls,) both rheostats B and BB are inoperative and both equalizing resistances are in operation.

Fig. 24 is a diagram of another modification in which there are as many relays D DD, &c., as there are dynamos, two relays and two dynamos being shown. Both relays are governed by the same solenoid and both dynamos feed the same supply-wires. In this case each dynamo-regulating circuit terminates in a pair of relay-contacts, as in Fig. 1, but is also equipped with an equalizing resistance ER, as in Fig. 23. In this modification the action of the rheostats and equalizing resistances is the same as in the modification shown in Fig. 23.

I claim as my invention—

1. Adjustable electrical contacts comprising, in combination, a lever, a stud electrically connected with said lever, and screwing therein for adjustment, a contact on said stud, and a second contact mounted on a flexible resilient support, substantially as set forth.

2. The combination with a dynamo having mains extending therefrom, of an automatic potential-regulator having a relay-magnet which controls the approach and separation of electrical contacts constituting terminals of a regulating-circuit, said relay being differentially wound, one winding of which is in a normally closed circuit, and the other of which is in a shunt from said normally closed circuit terminating in a pair of controlling-contacts, and a controlling-magnet or solenoid in a shunt from the mains which controls the approach and separation of said controlling-contacts, substantially as set forth.

3. A differentially-wound relay having two windings, one of which is normally in circuit and the other of which is adapted to be opened and closed, in combination with external resistance in circuit with said windings, substantially as set forth.

4. The combination with a dynamo having mains extending therefrom, of an automatic potential-regulator having a regulating resistance in a shunt from the dynamo, a regulating-circuit terminating in a pair of relay-contacts which control the operativeness of the regulating resistance, a relay-magnet controlling said relay-contacts, a condenser in a bridge across the regulating shunt-circuit, and a controlling-magnet or solenoid in a shunt from the mains controlling contacts constituting the terminals of the said shunt which includes said relay, substantially as set forth.

5. The combination of a dynamo, the mains fed by it, a regulating shunt-circuit terminating in relay-contacts, a relay-magnet controlling said relay-contacts, controlling-contacts constituting terminals of the relay-magnet circuit, a controlling-magnet or solenoid in a shunt from the mains controlling said controlling-contacts, and operatively connected with one of said contacts so as to bring it into electrical connection with the other contact when the potential on the mains rises, and a protecting-stop with which said contact (operatively connected with the controlling-magnet or solenoid) becomes electrically connected upon failure of current in said controlling-magnet, or solenoid, said protecting-stop being in electrical connection with the relay-circuit so that said circuit is thereby closed, substantially as set forth, whereby failure of current in the controlling-circuit has the same effect as an increase in potential.

6. A plurality of dynamos, all of which supply the same mains, a regulating resistance for each dynamo, and a regulating-circuit for each dynamo, only one of which is operative

at a time, in combination with an automatic potential-regulator common to all of said dynamos, and a switch which is adapted to connect in turn and at will the regulating-circuit of each dynamo to the regulator, substantially as set forth.

7. A plurality of dynamos all of which feed the same mains, independent regulating resistances therefor, adapted to be coupled in parallel with a single regulating-magnet, in combination with said magnet adapted to concurrently control said resistances, and equalizing resistances in the separate circuits of said regulating resistances, substantially as set forth.

8. A plurality of dynamos, all of which feed the same mains, independent regulating resistances for said dynamos, and relay-magnets for controlling said resistances, in combination with a single controlling-magnet or solenoid which simultaneously controls said relays, substantially as set forth.

9. A switch adapted to move in two paths, in combination with a plurality of contacts, the movement of said switch in one path carrying it from register with one contact to the next, and its movement in the other path carrying it into and out of electrical connection with the contact with which it is then in register, substantially as set forth.

10. A two-pole trolley-switch comprising two mechanically-connected but electrically-insulated conducting-bars, said switch being adapted to both swing and slide, in combination with a plurality of groups or pairs of contacts, the sliding movement of the switch carrying its bars successively into register with each group or pair of contacts, and its swinging movement carrying said bars into and out of electrical connection with the pair of contacts with which they are for the time being in register, substantially as set forth.

11. The track circular in cross-section, in combination with the swinging and sliding trolley-switch having a plurality of grooved rollers which embrace turn and slide along said track, substantially as set forth.

12. The swinging and sliding trolley-switch, and the plurality of contacts with which it cooperates, in combination with guide and register posts which permit the completion of the swinging movement of the switch toward the contacts only when in register therewith, substantially as set forth.

13. A differentially-wound relay having two windings, one of which is normally in circuit and the other of which is adapted to be opened and closed, in combination with external resistance in circuit with said windings.

14. A two-pole reversing-switch comprising, in combination, four outside contacts the diagonals of which are permanently electrically connected with each other, and one pair of which are terminals of an electric circuit, two intermediate posts which are located between the two pairs of said outside contacts, said posts being the terminals of the circuit in which the current is to be reversed; and two mechanically-connected but insulated bars normally electrically and mechanically connected to said intermediate posts, and adapted to be moved into electrical connection with either pair of said outside contacts, substantially as set forth.

15. The combination with a dynamo having mains extending therefrom, of an automatic potential-regulator having a controlling-magnet or solenoid in a shunt from the mains which controls the regulation of the voltage in the mains, permanent non-inductive resistance in said shunt external to said magnet, and a regulating-circuit which is controlled by contacts governed by said controlling-magnet or solenoid, said contacts operating to simultaneously cut in or out the entire regulating resistance, substantially as set forth.

16. The combination of a plurality of dynamos all of which feed the same mains, regulating resistance for said dynamos, a single automatic potential-regulator which simultaneously regulates all of the dynamos which may be in use, said regulator operating to simultaneously cut in or out the entire regulating resistance, substantially as set forth.

17. The combination with a dynamo having mains extending therefrom, of an automatic potential-regulator having a controlling-magnet in a shunt from the mains which controls the regulation of the voltage in the mains, said magnet being a stopped-core and plunger magnet having an adjustable stop-core, and a movable core, one of said cores having a laterally-expanded head, substantially as set forth.

18. The combination with a dynamo having mains extending therefrom, of an automatic potential-regulator having a controlling-magnet in a shunt from the mains which controls the regulation of the voltage in the mains, said magnet being a stopped-core and plunger magnet having a stop-core, and a movable core, one of said cores having a laterally-expanded head, substantially as set forth.

19. The combination with a dynamo having mains extending therefrom, of an automatic potential-regulator having a controlling-magnet in a shunt from the mains for controlling the regulation of the voltage in the mains, said magnet being a stopped-core and plunger magnet having a stop-core and a movable core, one of said cores having a laterally-expanded head.

In witness whereof I have hereunto signed my name in the presence of two subscribing witnesses.

ALLEN AUGUSTUS TIRRILL.

Witnesses:

STEPHEN S. JEWETT,

ERASTUS P. JEWELL.