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W. H. KNIGHT & W. B. POTTER.

METHOD OF REGULATING ELECTRICALLY DRIVEN MECHANISM.

No. 587,442. Patented Aug. 3, 1897.

FIG. 1.

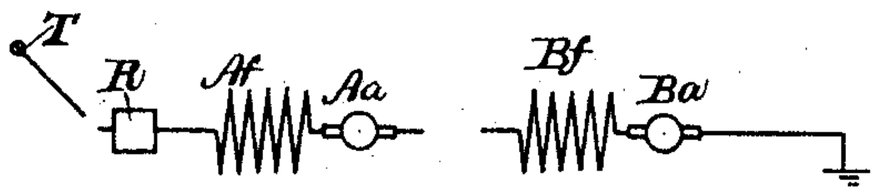


FIG. 2.

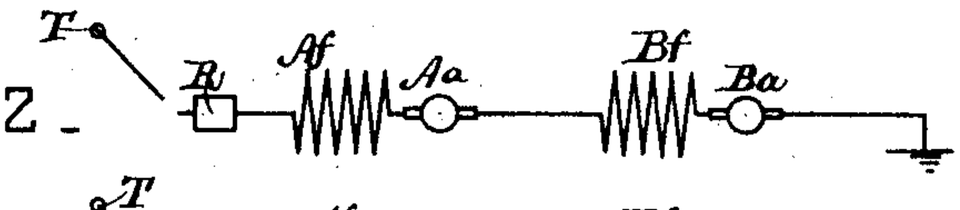


FIG. 3.

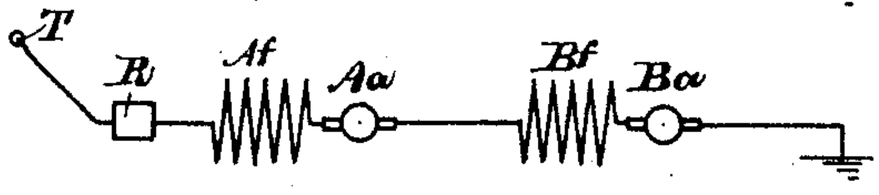


FIG. 4.

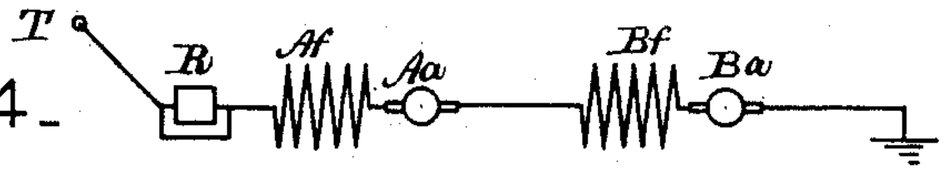


FIG. 5.

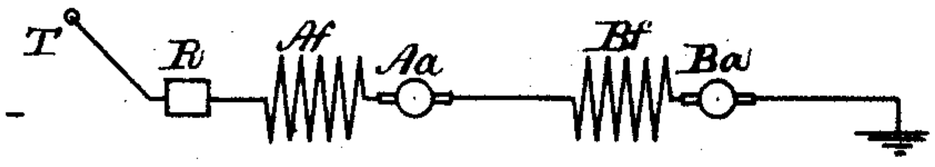


FIG. 6.

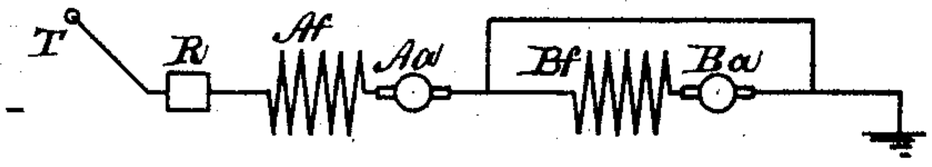


FIG. 7.

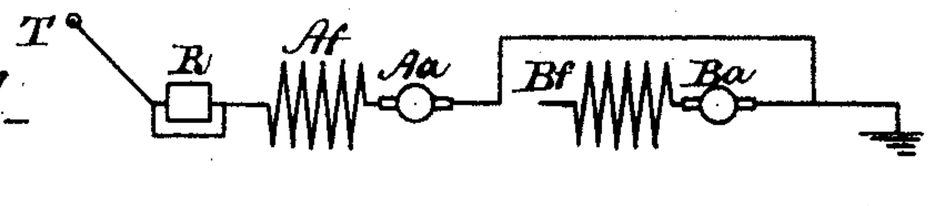


FIG. 8.

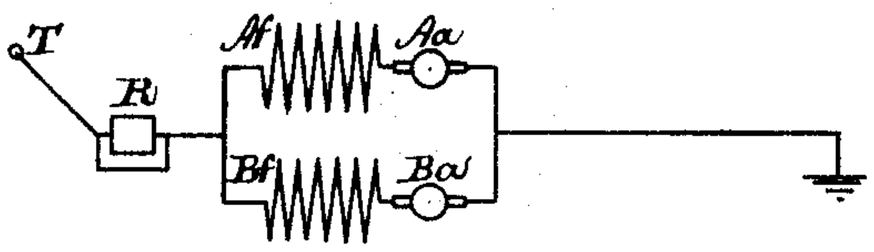
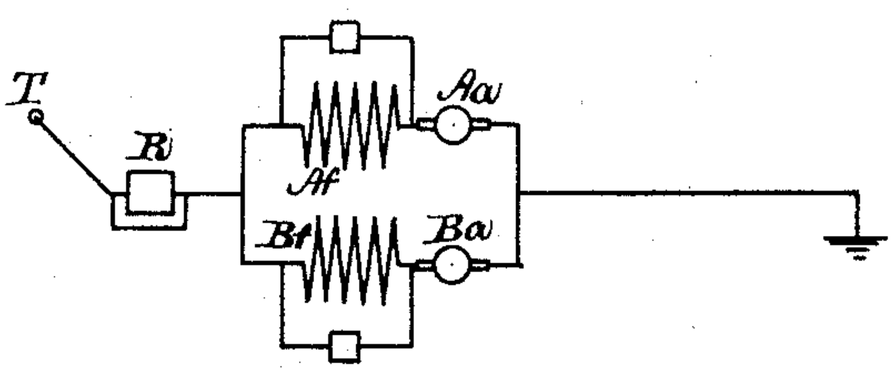


FIG. 9.



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(No Model.) 6 Sheets—Sheet 2.

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METHOD OF REGULATING ELECTRICALLY DRIVEN MECHANISM.

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Fig 10.

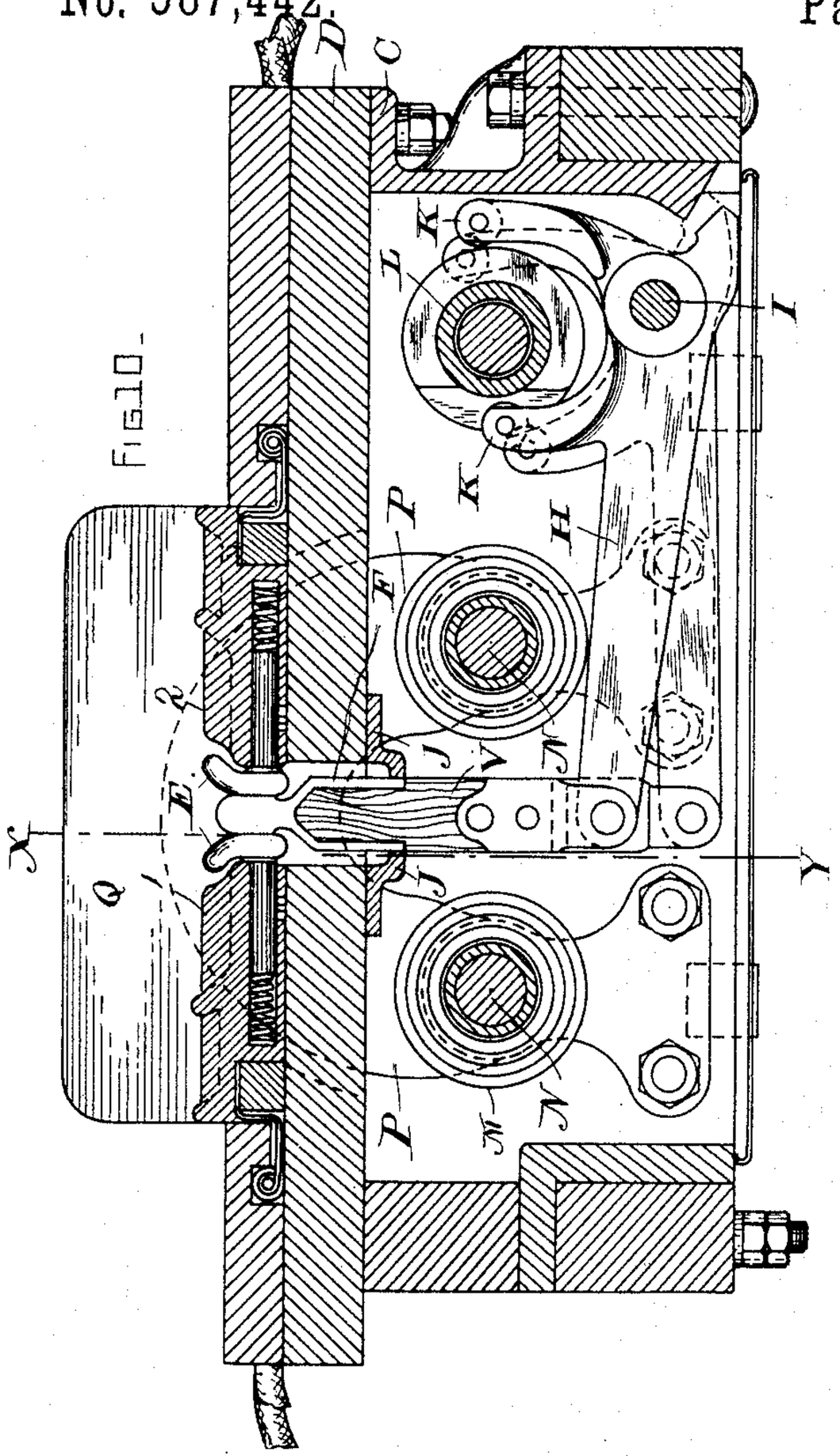
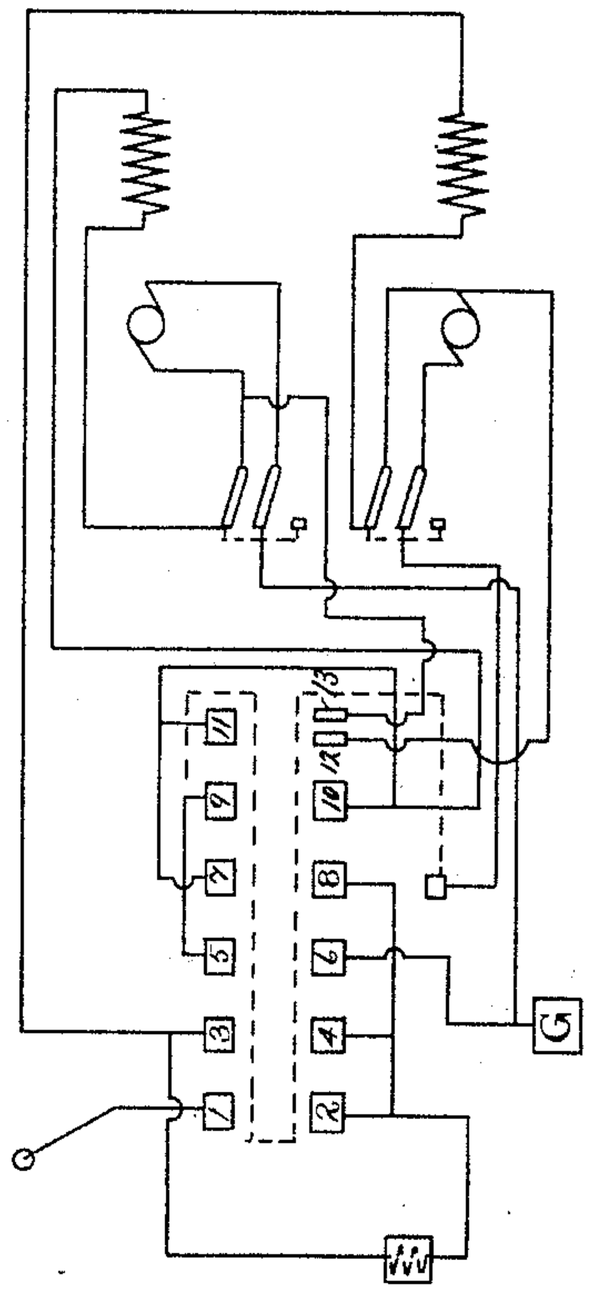


Fig 11.



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METHOD OF REGULATING ELECTRICALLY DRIVEN MECHANISM.

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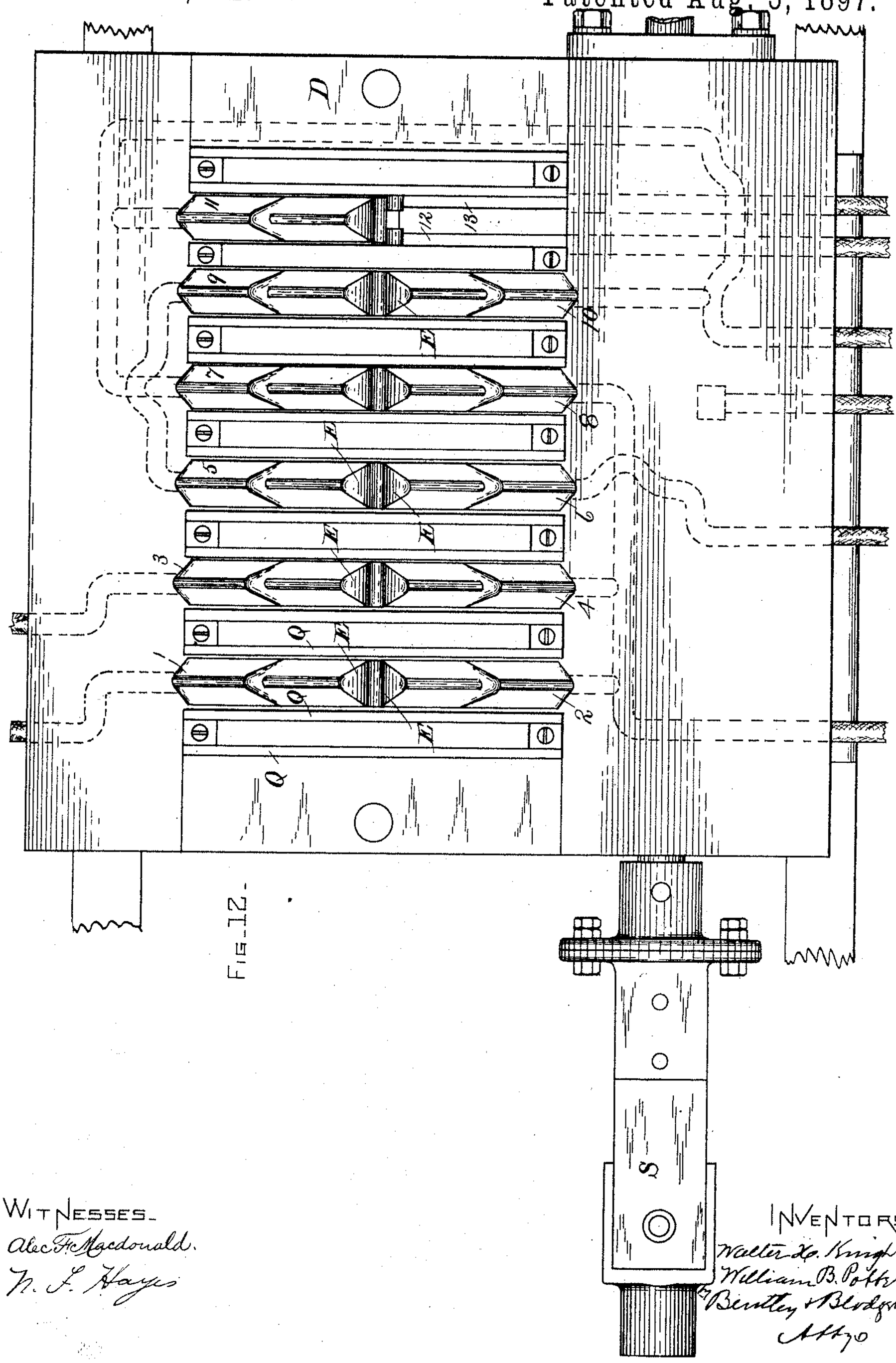

FIG. 12.

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METHOD OF REGULATING ELECTRICALLY DRIVEN MECHANISM.

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FIG. 13.

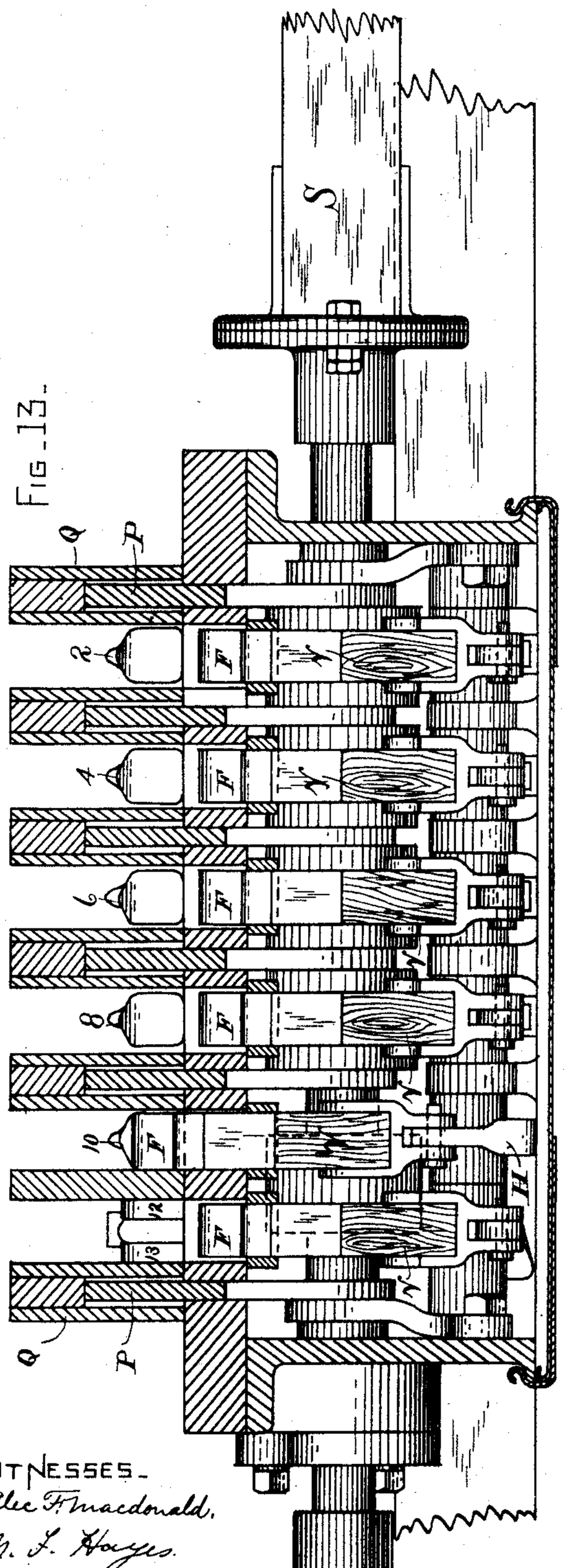

FIG. 16.

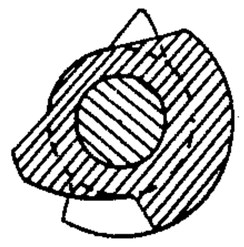

FIG. 15.

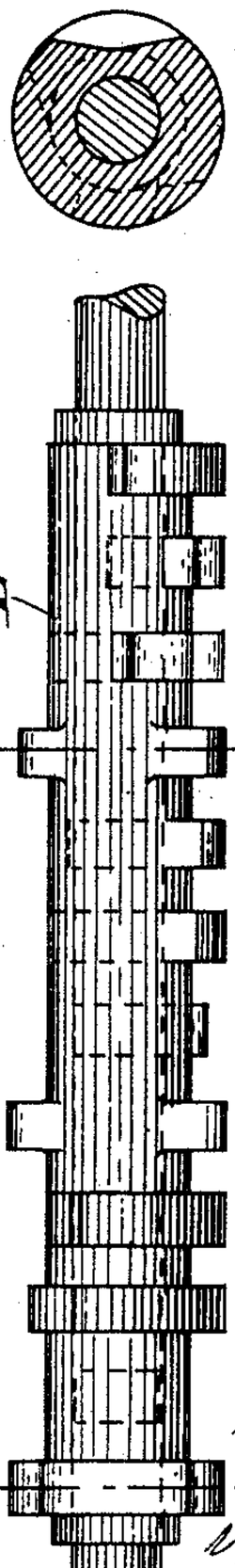

FIG. 14.

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METHOD OF REGULATING ELECTRICALLY DRIVEN MECHANISM.

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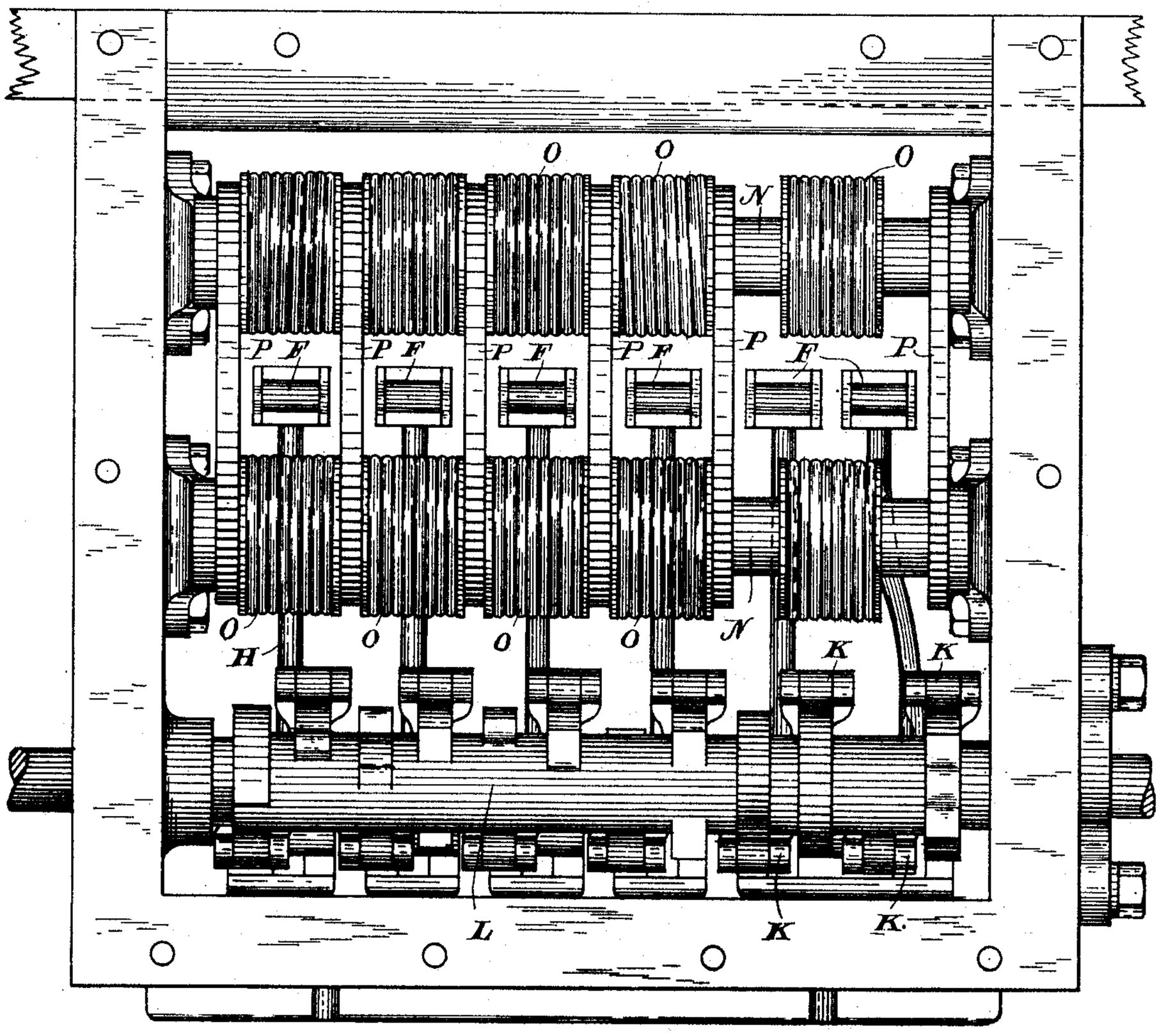

FIG. 17.

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METHOD OF REGULATING ELECTRICALLY DRIVEN MECHANISM.

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FIG. 18.

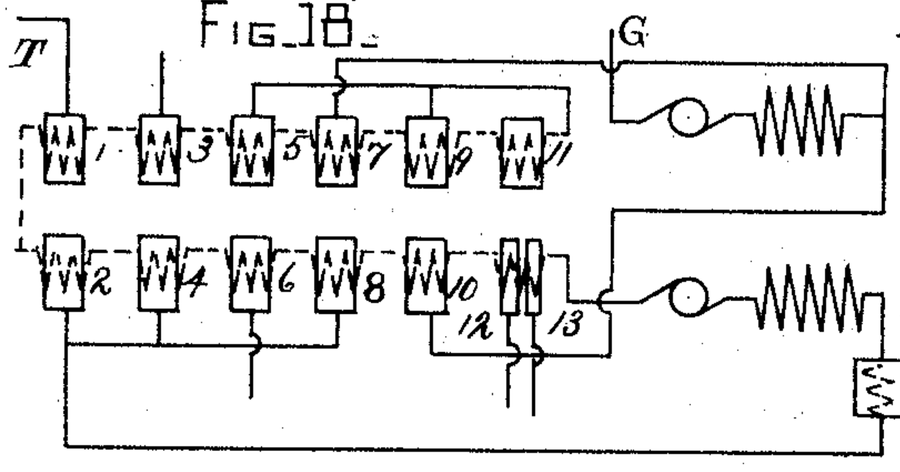


FIG. 19.

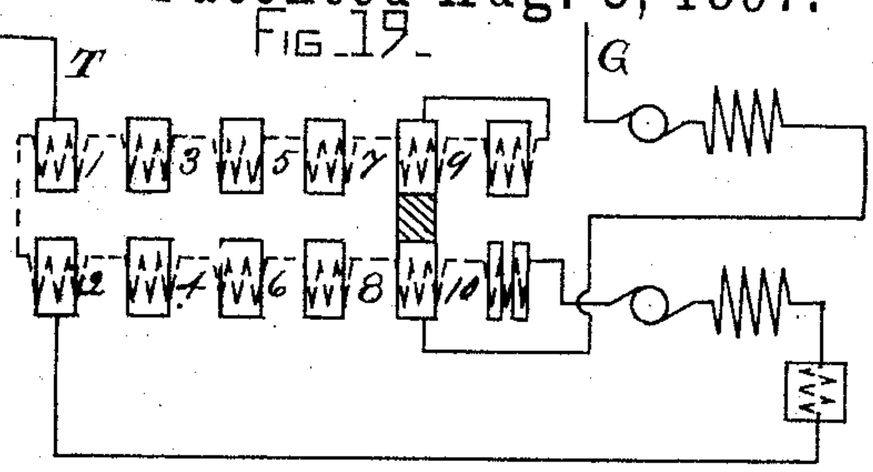


FIG. 20.

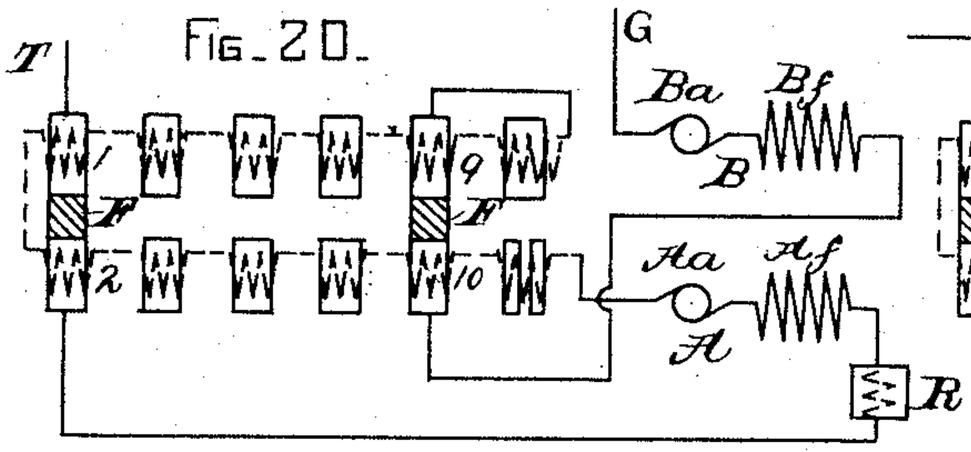


FIG. 21.

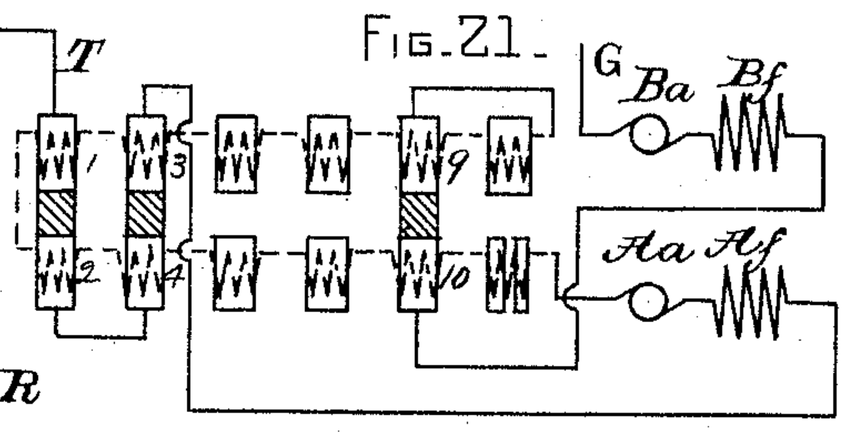


FIG. 22.

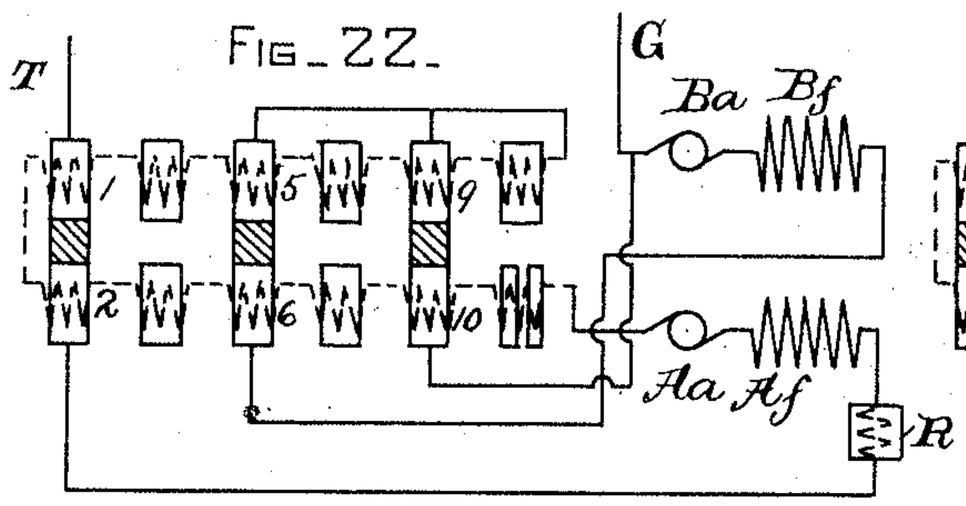


FIG. 23.

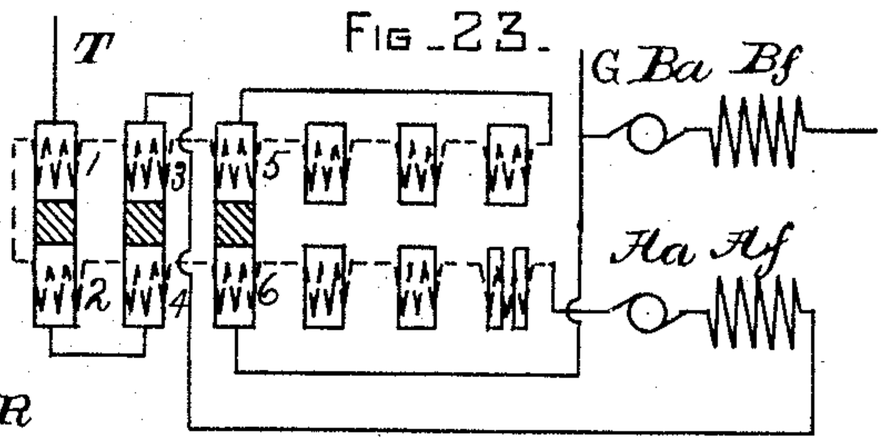


FIG. 24.

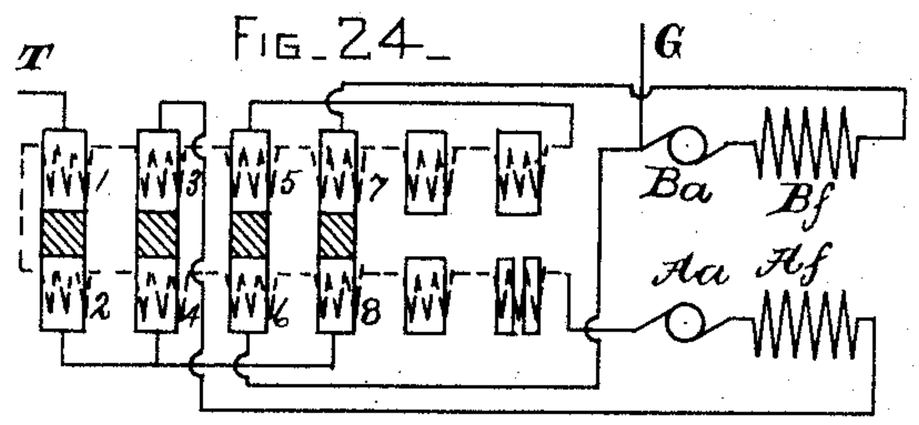
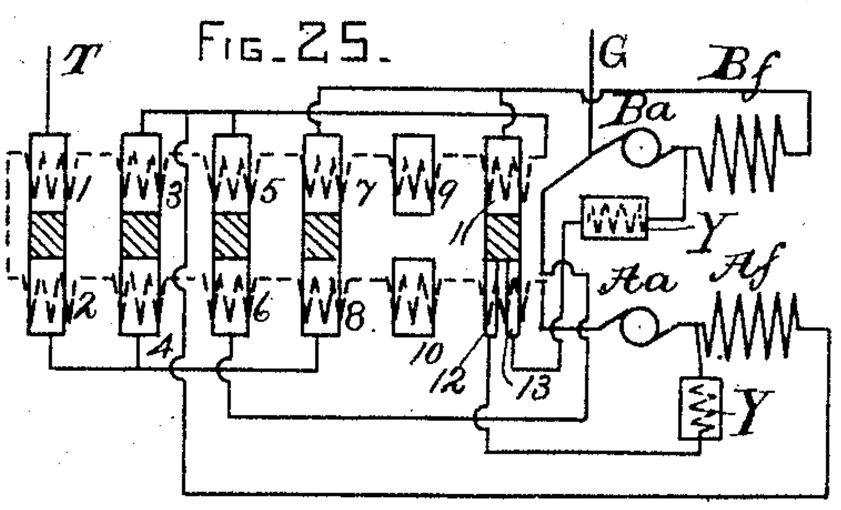


FIG. 25.



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UNITED STATES PATENT OFFICE.

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METHOD OF REGULATING ELECTRICALLY-DRIVEN MECHANISM.

SPECIFICATION forming part of Letters Patent No. 587,442, dated August 3, 1897.

Application filed May 21, 1892. Serial No. 433,907. (No model.)

To all whom it may concern:

Be it known that we, WALTER H. KNIGHT, residing at Newton, in the county of Middlesex, and WILLIAM B. POTTER, residing at Lynn, in the county of Essex and State of Massachusetts, citizens of the United States, have invented certain new and useful Improvements in Methods of Regulating Electrically-Driven Mechanism, of which the following is a specification.

Our invention relates to the method of regulating the power and speed of mechanism driven by two electric motors by placing them in series for low speed and in multiple for a higher speed. Heretofore this method, although understood to be one capable of affording greater economy than the usual method of regulating by means of artificial resistance, has not come into general use by reason principally of the difficulty encountered in making the change of motor connections from series to multiple. This difficulty has been due not only to the destructive arc produced on the rupture of such current-bearing circuits as it might be necessary to break in making the change in circuit connections, but also to the wide variation in motor resistance—both ohmic and inductive—between the series and the multiple arrangements, which resistance variation produced correspondingly violent speed variation in the driven mechanism. Our invention is designed to overcome these objections to this desirable method of regulation and has demonstrated its capacity for accomplishing this result in a thoroughly practicable manner.

It consists in a method of controlling the speed and power of mechanism driven by two electric motors by gradually or progressively effecting the change of motors from series to multiple by first shunting one of them, so as to leave in circuit the other one only, which continues in an active condition and is connected directly to the main circuit, as in the multiple arrangement, but is protected against the effect of the full voltage of the main circuit by an auxiliary or supplementary resistance, such as an artificial resistance of wire or any other suitable material, which is inserted in the circuit at the time of the aforesaid shunting and is maintained in circuit a sufficient length of time to bring the unshunted motor to its multiple rate of speed under the increased voltage at its terminals. The other motor, after being shunted, is disconnected from the circuit, so that for a brief period no current passes through it. It is then connected in multiple with its mate and the auxiliary resistance withdrawn.

Our invention includes also the contrary method of changing from multiple to series by performing the aforesaid series of acts in a reverse order.

We have, moreover, designed certain mechanism that may be conveniently used in practicing the aforesaid method, and we have disclosed the same herein as an assistance to the ready understanding in all its details of our novel method; but we make no claim herein to such mechanism, as it is embraced by another application for patent bearing Serial No. 433,906, filed May 21, 1892.

Referring to the drawings which accompany this specification, Figures 1 to 9 show in diagram the several combinations of circuits which are produced in succession in the practice of our method according to the manner we have found best suited for use in connection with the service for which it is particularly adapted—to wit, the control of railway-cars operated by two electric motors. Fig. 10 is a transverse section of the switching apparatus which we have shown to illustrate our invention. The section is taken through one pair of contact-plates. Fig. 11 is a diagram of the switch connection. Fig. 12 is a plan of the switch. Fig. 13 is a longitudinal section on the line $x\ y$ in Fig. 10. Figs. 14, 15, and 16 show in detail the cam-cylinder. Fig. 17 is a plan of the switch with the cover removed. Figs. 18 to 25 show in detail the connections for each step in the method.

Referring to the diagrams in Figs. 1 to 9, it will be observed that in Fig. 1, which represents the first condition of motor-circuits established by the switch, the two motors are out of action and there are two breaks in the circuit, one between the trolley T and resistance R and the other between the armature Aa of the motor A and the field-magnet Bf of

the motor B. The first step in the series is to close the latter of these two breaks, when the two motors will be in series, as shown in Fig. 2, but still disconnected from the trolley. The second step is to close the remaining break, when the condition will be as shown in Fig. 3. This condition is the first one in which a complete circuit is made, and it gives the lowest rate of speed, the two motors being in series with each other and with a resistance. The third step is to short-circuit the resistance, when the condition shown in Fig. 4 is produced, giving a higher rate of speed, although it is to be understood that it is also of importance that the resistance be adapted to prevent the sudden influx of an undue volume of current at the moment the circuit is completed. The fourth step introduces the resistance once more into the circuit, as shown in Fig. 5, and the fifth completes a shunt-circuit around one of the motors—to wit, motor D—as appears in Fig. 6. With these two steps the process of gradually changing the motors from series to multiple begins. The shunting of one motor is a preparation for its entire removal from the series connection, and it acts at the same time to connect the unshunted motor directly to the main line-circuit, which is the connection it has when in multiple; but the effect of this change is modified by the reintroduction of the resistance, which prevents an undue degree of acceleration in speed and protects the unshunted motor from injury by an undue volume of current. The sixth step, continuing the series-multiple change, produces the condition indicated in Fig. 7, in which the circuit of the shunted motor is severed, so that no current passes therein, while at the seventh step this motor is connected in multiple with its mate, which, it will be observed, has continued its active operation, the resistance at the same time being short-circuited. This completes the change of motor connections and the two motors which were formerly in series without resistance are now in multiple without resistance, as the resistance has performed its designed function of assisting in the changing-over process, which by its aid has been accomplisned gradually and safely. The eighth and last step is one which we have provided for giving an extra rate of speed to the motors in multiple, and this is accomplished by shunting the field-magnets of the two motors through a suitable resistance, as is indicated in Fig. 9.

The above-described series of circuit combinations provides for several distinct rates of speed, between which the conditions may be regarded as more or less temporary and transitional. Thus the first rate of speed will be given by the condition in Fig. 3; the second by the condition in Fig. 4; the third by the condition in Fig. 6; the fourth by the condition in Fig. 8, and the fifth by the condition in Fig. 9.

Turning now to the switch mechanism employed for producing the above-described combinations, it will be found to consist of two principal parts: first, an inclosing metallic box or casing C, in which are placed a series of contact-levers with a cam for operating them and blow-out magnets having their poles adjacent to the circuit-breaking surfaces of the switch, so as to disrupt any arc which may be formed on the rupture of a current-bearing circuit; second, a cover D for the said box or casing C, upon which are placed a series of contact-plates and circuit-wires leading therefrom, with which plates the contact-levers aforesaid are adapted to make connection. The said contact-plates are arranged in pairs, as shown in Fig. 12, the respective pairs being marked 1, 2 3, 4 5, 6 7, 8 9, 10 and 11 12 13, the last plate of the last pair being divided into two insulated parts for a purpose hereinafter explained. The construction of these plates is shown best in Figs. 10 and 12, from which it will appear that they are placed along opposite sides of a series of openings in the cover D and are provided on their opposing ends with small spring-buffers E, the two buffers of each pair of plates resting normally opposite to each other, but out of contact. The buffers of each pair of plates are adapted to be forced apart by the tip F of a vertically-moving rod V, the said tip being so shaped that when the rod is forced upward by the pressure of lever H, to the extremity of which it is hinged, it will enter the space between the two buffers E, spreading them slightly apart and establishing a good electrical connection between them. The tip F is of metal, while the rod V is of wood or other insulating material. In Fig. 12 the upper surfaces of the aforesaid contact-plates are shown, and it appears that each plate is provided with a central longitudinal rib and also with two transverse ribs, one at the center of the plate and the other at its outer extremity. The purpose of this ribbed form of the contact-plates will be described later.

The contact-levers aforesaid contained within the box or casing C are lettered H, Figs. 10 and 17, and are six in number and placed side by side along a common shaft or pivotal rod I, which is placed horizontally in the lower right-hand corner of the box, Fig. 10. To the end of each lever H is jointed the wooden rod V, whose vertical movement is directed by guides J J, and each rod carries an insulated tip F, which, as above described, is designed to connect together the two plates of one of the pairs of contact-plates E. Each of the levers H is provided with two short arms K K, Fig. 10, extending upwardly therefrom upon opposite sides of the shaft I and embracing the cam-cylinder L. This cylinder is shown in detail in Fig. 14, from which it will be seen that there are one or more cams for each of the several levers H, and they are

arranged at different points around the periphery of the cylinder according to a predetermined order and are adapted to engage with the arms K, and as they turn will act in succession on one or the other of said arms, and thereby actuate the levers positively in one direction or the other. There is a friction-roller on the tip of each arm K. It will also be noted in Fig. 14 that each of the arms K K has its own actuating cam or cams, the two arms being in different adjacent planes. It will be apparent from the description already given that if the cam-cylinder L be rotated the resulting action of the mechanism will be to vibrate the wooden rods V up and down in a predetermined sequence, and thereby establish connection between the several pairs of contact-plates, respectively, in a corresponding sequence, each connection occurring at a definite time and continuing during a definite period.

We made reference above to the blow-out magnet, to which attention is now called. It is best illustrated in Figs. 10 to 17. It consists of two rods N, of soft iron, extending through the box on opposite sides of the wooden rods V, and upon the soft-iron rods are wound coils of insulated wire in a series of spools O O, &c., the winding in two adjacent spools being reversed, so as to produce a magnetic pole between them. From these polar points project arched polar extensions P, having the form indicated in Fig. 10. These polar extensions project through the cover D of the box or casing to a point somewhat higher than the contact-plates, and they are faced outside of the box with thin strips of fiber Q, Figs. 12 and 13, on both sides. In connection with these polar extensions we would revert to the above-described ribbed formation on the upper surfaces of the contact-plates. Referring to Fig. 10, in which the tip on wooden rod V is shown as establishing electrical connection between the buffers E of contact-plates 1 and 2, it will be evident that if the said tip were withdrawn from between the two buffers at a moment when a strong current was passing between the two plates there would be an arc formed between the buffers, but as the blow-out magnet is always energized while the apparatus is in use such an arc would be within the magnetic field between two adjacent polar extensions, and according to the well-known physical law it would be forced to expand upward and outward, its two ends traveling along the central rib on the contact-plates until they reach the intermediate or perhaps the terminal transverse ribs when its length would be so great that it could no longer be maintained and it would break and disappear. In practice this action takes place so quickly that there is no material burning or fusing of the contact-plates, but whatever there may be takes place on the ribs, where it can have no bad effect.

The means for operating the cam-cylinder are shown in Figs. 12 and 13. It consists of a shaft forming an extension of the shaft of the cylinder and connected thereto by an insulated coupling S.

The terminals of the several electric circuits may be connected with the contact-plates in any desired manner, such connections being as indicated by the diagram in Fig. 11, while in Figs. 10 and 12 the wires leading to the several contact-plates are shown as located on the outside of the cover D and covered in turn by a supplementary insulating-plate above the cover D.

The arrangement of cams on the cylinder L is such that during one complete rotation of the cylinder the rods V are operated in a sequence illustrated by Figs. 18 to 25. In these figures the several pairs of contact-plates are shown numbered 1 2 3 4, &c., while the dotted line represents the circuit including the coils of the blow-out magnet. In each of the figures the pairs of plates which are connected by their respective tips F are so indicated. Thus in Fig. 18 none of the plates are connected and the circuit is open. In Fig. 19 plates 9 and 10 are connected. In Fig. 20 plates 1 2 and 9 10 are connected, and so on. By these different figures each of the several combinations established by the series of steps in the regulating method is illustrated, there being shown in each figure only those circuits which are active. Thus referring to Fig. 20, which illustrates the combination of Fig. 3, wherein the circuit is completed for the first time, we may trace such circuit as follows: from trolley T to plates 1 and 2, to resistance R, to field-magnet A*f*, to armature A*a*, to blow-out magnet, to plates 9 and 10, to field-magnet B*f*, to armature B*a*, to ground G. This includes the two motors in series with a resistance. In Fig. 21 the circuit is from trolley T to plates 1 2, to plates 4 3, to field-magnet A*f*, to armature A*a*, to blow-out magnet, to plates 9 10, to field-magnet B*f*, to armature B*a*, to ground G, giving the combination indicated in Fig. 4. In Fig. 22 the circuit is from trolley T to plates 1 2, to resistance R, to field-magnet A*f*, to armature A*a*, to blow-out magnet, to plates 5 6, to field-magnet B*f*, to armature B*a*, to ground G, giving the combination shown in Fig. 6, with the motor B shunted by connection through plates 9 10 to ground G. In passing from the condition of Fig. 21 to that of Fig. 22 the connection between plates 3 and 4 is withdrawn at the same time or a little in advance of the establishment of the connection between plates 5 and 6, thus producing in rapid succession the combinations of Figs. 5 and 6. In Fig. 23 the circuit is from trolley T to plates 1 2, to plates 4 3, to field-magnet A*f*, to armature A*a*, to blow-out magnet, to plates 5 6, to ground G, giving the combination shown in Fig. 7. In Fig. 24 the circuit is from trolley T to plates 1 2, where it divides, one branch going by plates 4 3 to

field-magnet A*f*, to armature A*a*, to blow-out magnet, to plates 5 6, to ground G, while the other branch goes by plates 8 7 to field-magnet B*f*, to armature B*a*, and to ground G, giving the combination shown in Fig. 8. The change from the condition of Fig. 22 to that of Fig. 24 takes place rapidly through the intervening temporary condition of Fig. 23 and represents the transition from the condition in Fig. 6 to that in Fig. 8, with Fig. 7 as the temporary condition, just as the transition from the combination of Fig. 4 to that of Fig. 6 was through the temporary condition of Fig. 5. We have illustrated Fig. 7 by Fig. 23, but have not regarded it necessary to illustrate Fig. 5, it being just like Fig. 3, which is illustrated by Fig. 20. In Fig. 25 the circuit is from trolley T to plates 1 2 and then divides, one branch going by plates 4 3 to field-magnet A*f*, to armature A*a*, to blow-out magnet, to plates 5 6, to ground G, with a subbranch going from plate 4 to plates 8 7, to plates 11 12, to armature A*a*, thus establishing a shunt around the field-magnet A*f*, containing resistance Y. The other branch goes from plate 4 to plates 8 7, to field-magnet B*f*, to armature B*a*, and to ground at G, with a subbranch from plate 7 to plates 11 13 and by a resistance Y to armature B*a*, to ground G, thus shunting the field-magnet E*f*. This gives the last combination—to wit, that indicated in Fig. 9.

It will be apparent that many other forms of switching apparatus may be designed for use in practicing the method which we have above described, and while we consider the apparatus above described to be well adapted for the purpose we do not limit ourselves in any manner to this particular form as being the only one capable of use in carrying out our method.

In conclusion, it will be understood from the foregoing description of the successive combinations of motor-circuits which we establish by the aid of the switch between the two main conductors carrying a constant electromotive force that we have first placed a plurality of motors in series for slow speed, as in Fig. 4, and have then changed them to multiple for a higher speed in a safe and gradual manner by shunting one portion and at the same time protecting and controlling the action of the unshunted and operating portion by means of an auxiliary resistance, by then interrupting the circuit of the shunted portion, and by finally reconnecting the shunted portion in multiple with the other, the resistance being removed. It will be also understood that the contrary change from multiple to series will be accomplished by the same series of steps followed in the reverse order.

What we claim as new, and desire to secure by Letters Patent, is—

1. The method of regulating the power and speed of mechanism driven by a plurality of electric motors, which consists in first coupling the motors in series, then shunting a part of the motors and protecting the remaining unshunted part thereof from the increased voltage delivered thereto by, for example, an external resistance, and finally reconnecting the motors in multiple.

2. The method of regulating the power and speed of mechanism driven by a plurality of electric motors, which consists in first coupling the motors in series, then shunting a part of the motors and protecting the remaining unshunted part thereof from the increased voltage delivered thereto by, for example, an external resistance, and finally reconnecting the motors in multiple with the protecting resistance removed.

3. The method of regulating a car or vehicle driven by a pair of electric motors, which consists in connecting the motors in series, shunting one motor while maintaining a circuit through the remaining motor and through a resistance protecting the same, opening the circuit of the shunted motor and connecting the two motors in multiple.

4. The method of regulating the power and speed of mechanism driven by a pair of series-wound electric motors receiving current from a constant potential circuit, which consists in first connecting the motors in series and in circuit with a resistance, then reducing the resistance until it is substantially cut out, then shunting one motor and again making use of the resistance to protect the unshunted motor, then disconnecting the shunted motor from circuit and finally reconnecting the motors in multiple.

5. The method of regulating the power and speed of mechanism driven by two electric motors, which consists in placing them in series with each other and with a resistance, cutting out the resistance, shunting one motor, disconnecting one motor leaving the other in series with a resistance, and connecting the two motors in multiple.

6. The method of regulating the power and speed of mechanism driven by two electric motors, which consists in placing them in series with each other and with a resistance, cutting out the resistance, shunting one motor, disconnecting one motor leaving the other in circuit with a resistance, and finally connecting the two motors in multiple with the resistance removed.

7. The method of changing motors from series to multiple connection, which consists in inserting a resistance, disconnecting one motor so as to leave the other motor in series with the said resistance, and then connecting them both in multiple.

8. The method of changing motors from series to multiple connection which consists in

disconnecting one motor from the circuit leaving the other motor in series with a resistance, and then connecting them both in multiple.

9. The method of regulating the power and speed of mechanism driven by two electric motors, which consists in placing the two motors in series for slow speed, and changing them from series to multiple for higher speed by first cutting one motor out of circuit, replacing it by a resistance in series with the other motor, and finally placing the two motors in multiple with the resistance cut out.

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