(No Model.)

3 Sheets—Sheet 1.

F. J. SPRAGUE.

ELECTRO DYNAMIC MOTOR.

No. 335,781. Patented Feb. 9, 1886.

Fig 1.

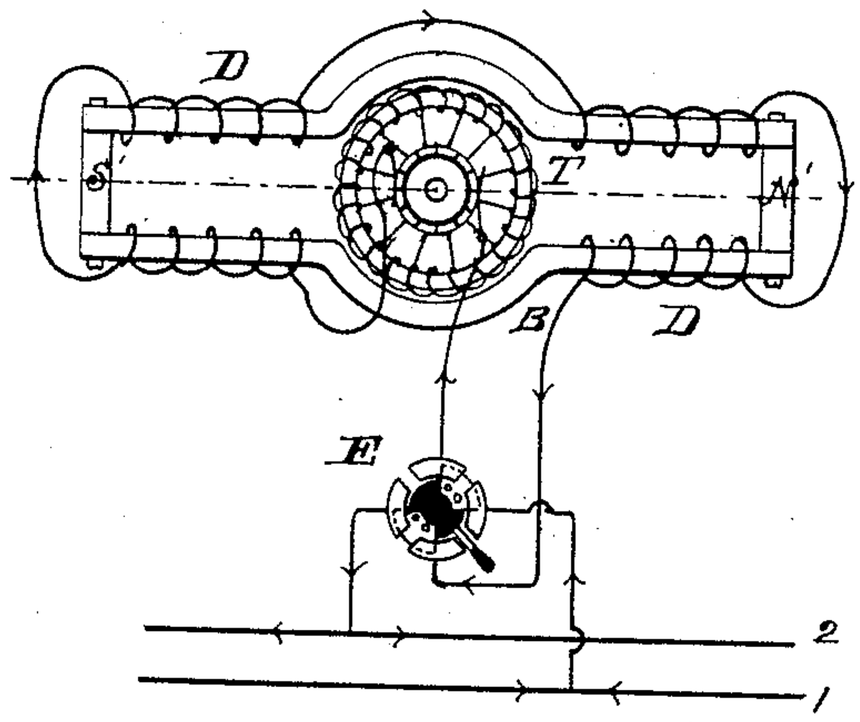


Fig 2.

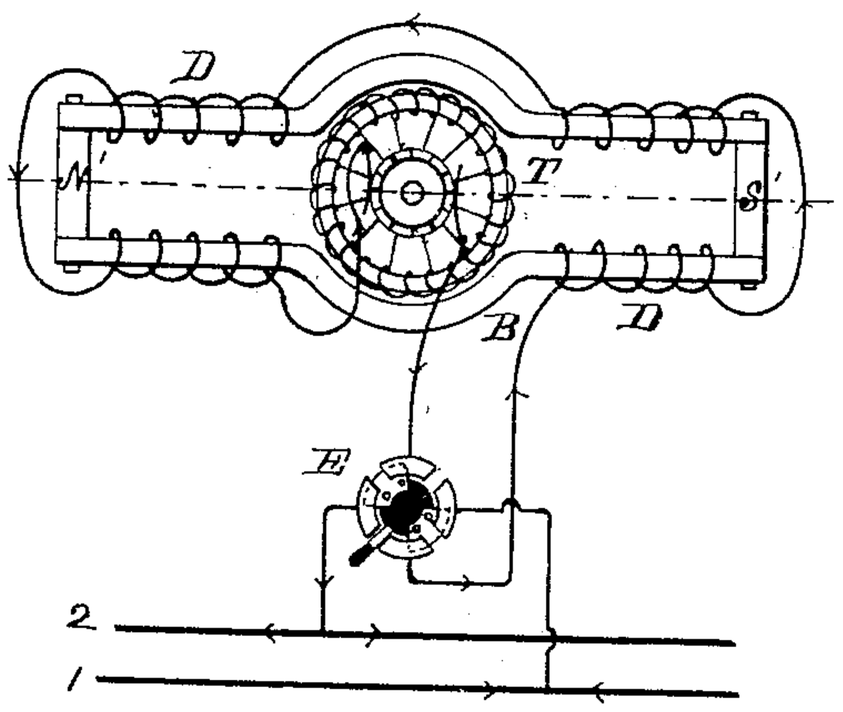


Fig 3.

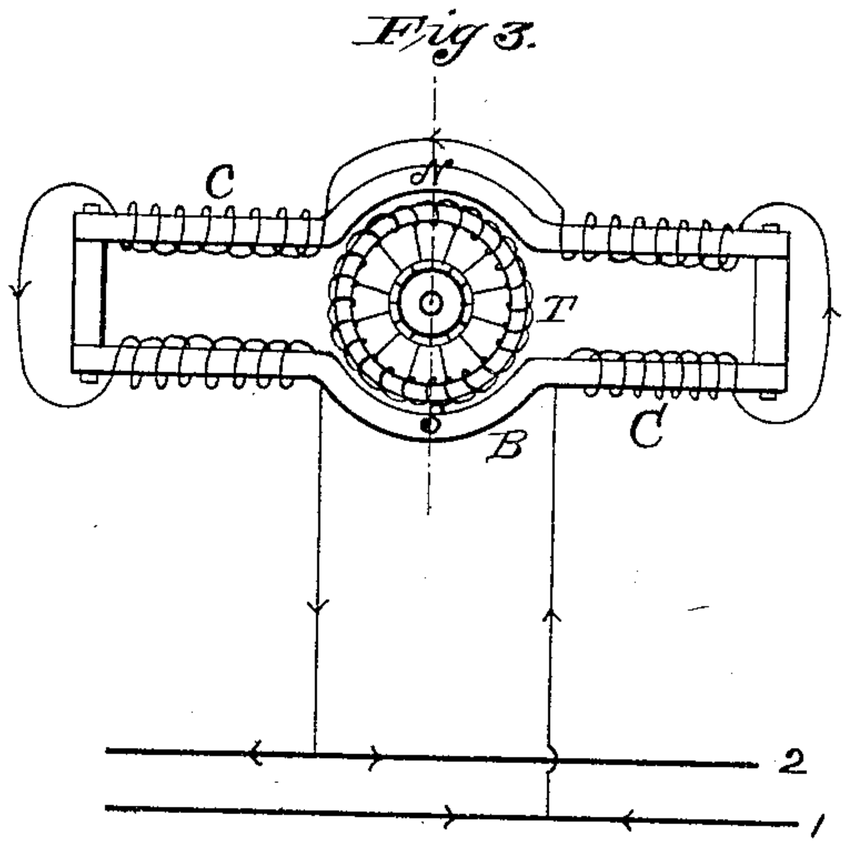


Fig 4.

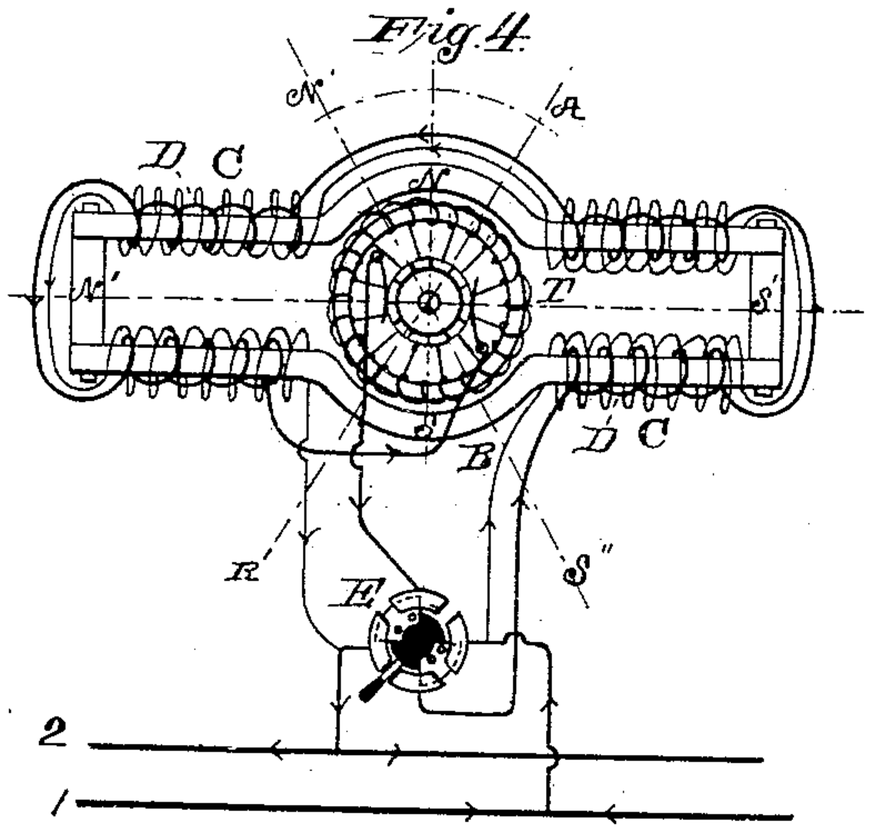
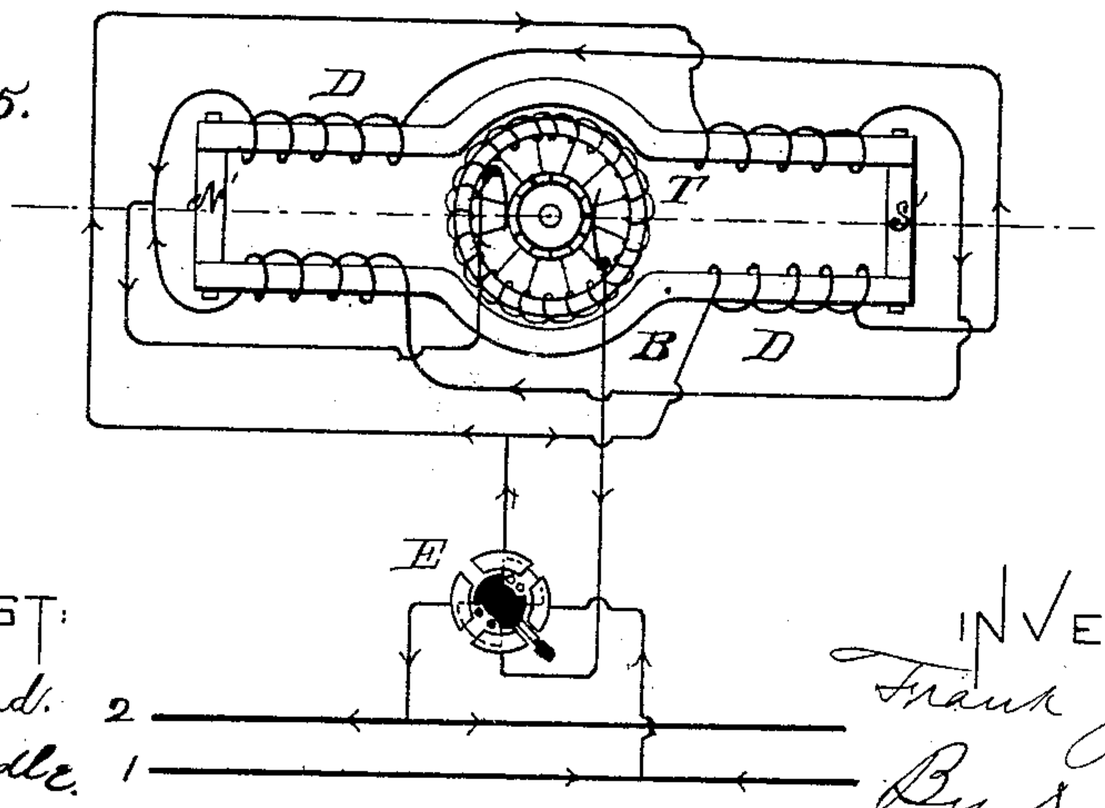


Fig 5.



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(No Model.)

3 Sheets—Sheet 2.

F. J. SPRAGUE.

ELECTRO DYNAMIC MOTOR.

No. 335,781. Patented Feb. 9, 1886.

Fig. 6.

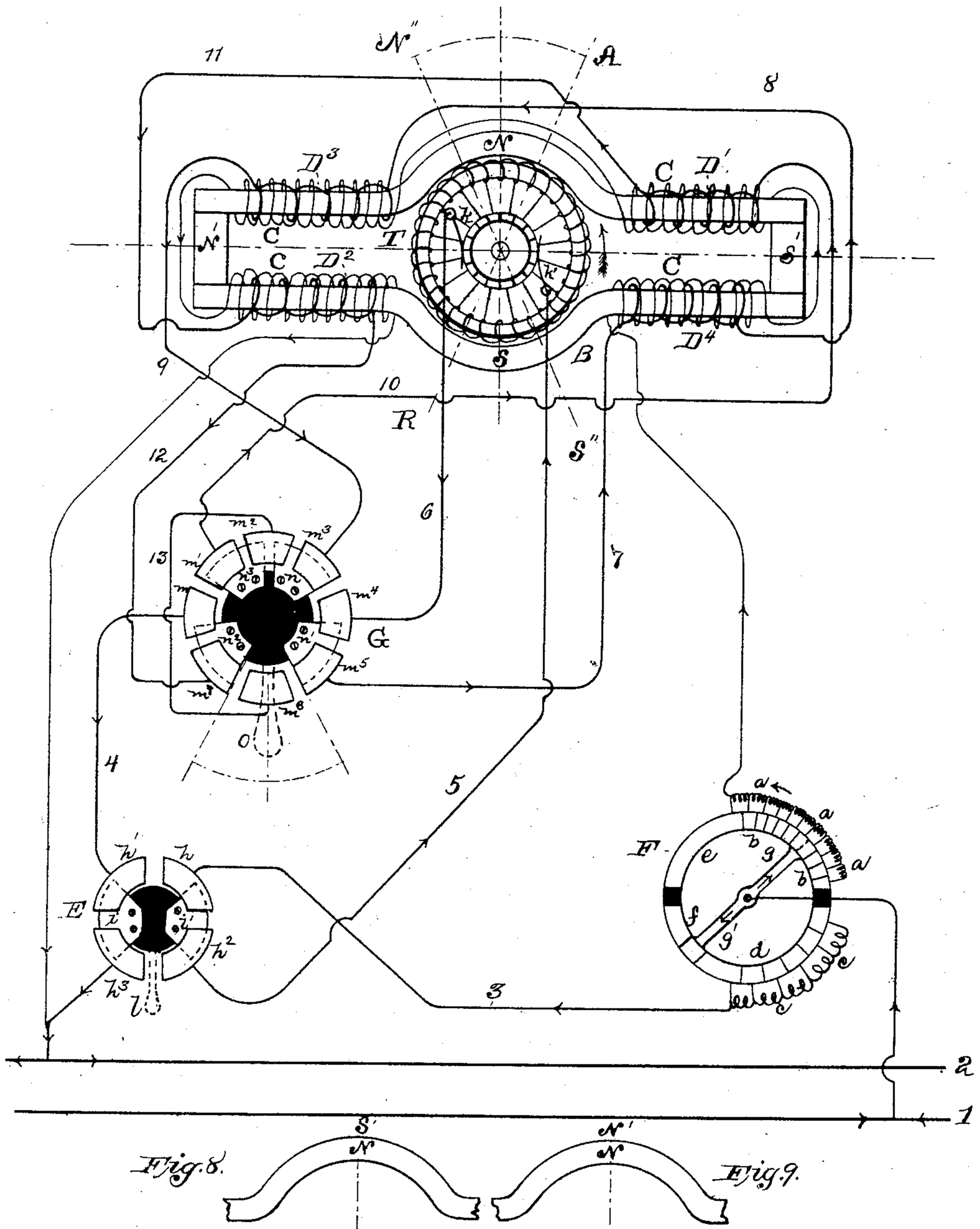


Fig. 8.

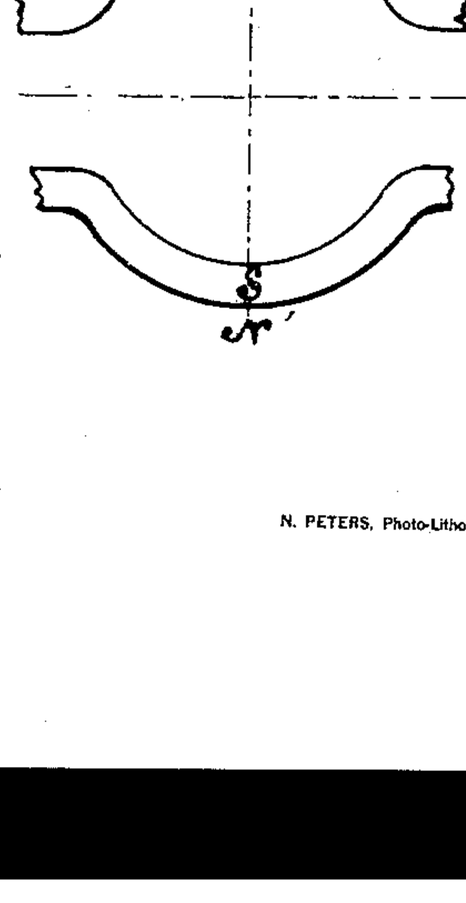
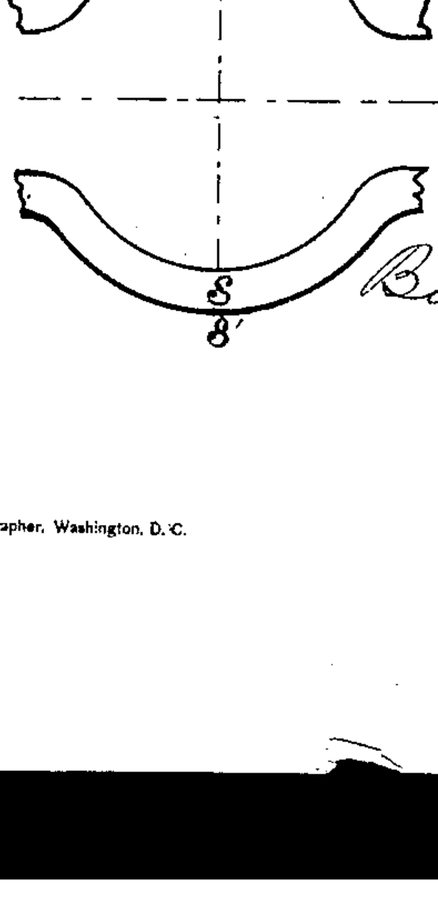


Fig. 9.



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ELECTRO DYNAMIC MOTOR.

No. 335,781. Patented Feb. 9, 1886.

Fig 7.

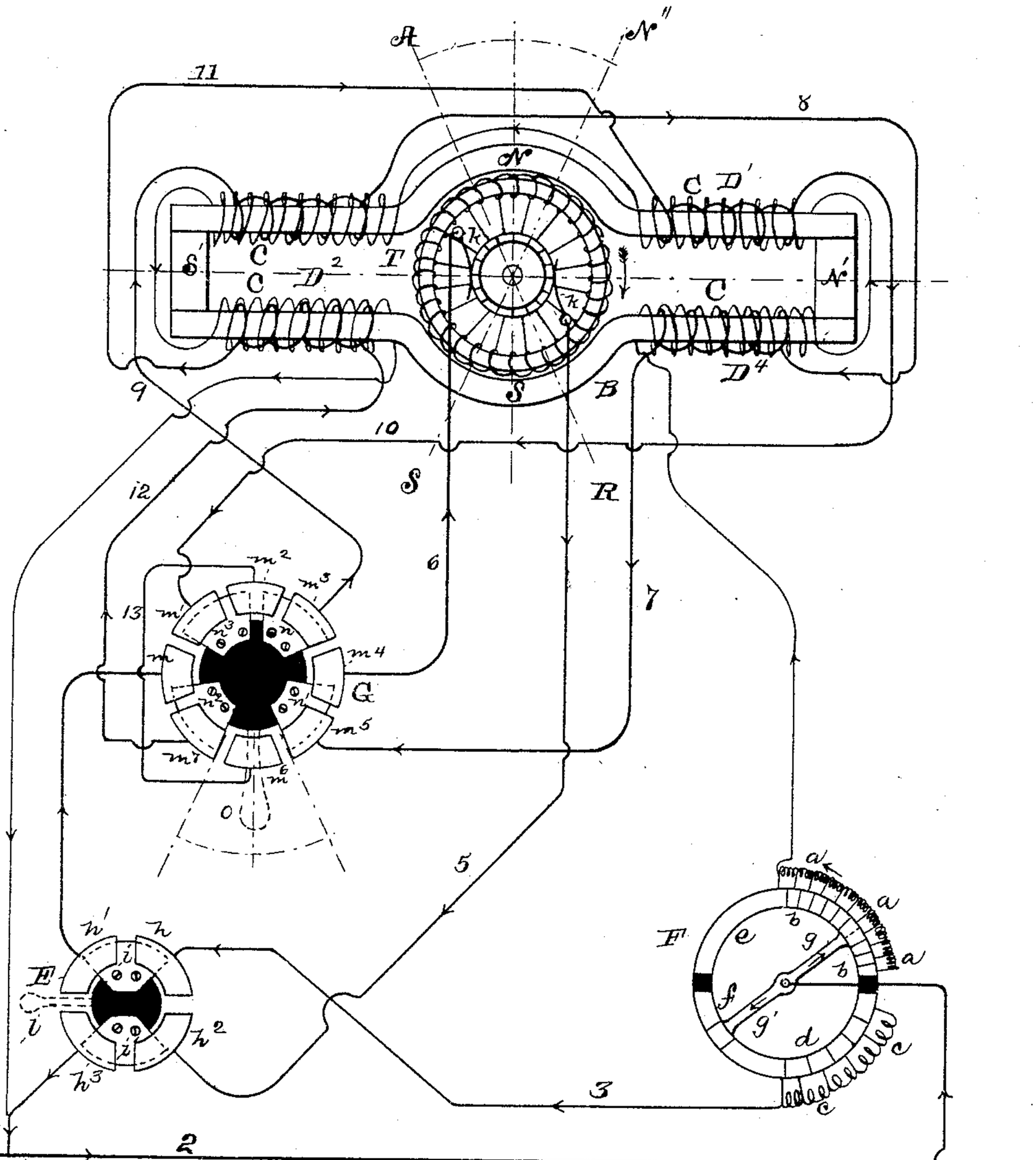


Fig 10.

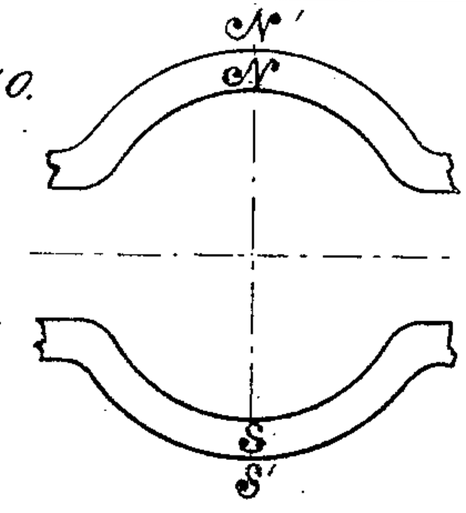
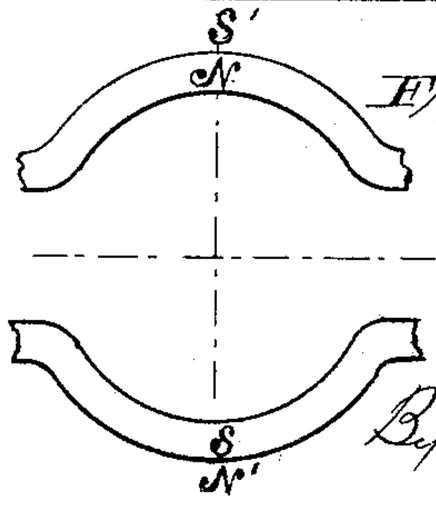


Fig 11.



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UNITED STATES PATENT OFFICE.

FRANK J. SPRAGUE, OF NEW YORK, N. Y.

ELECTRO-DYNAMIC MOTOR.

SPECIFICATION forming part of Letters Patent No. 335,781, dated February 9, 1886.

Application filed September 26, 1885. Serial No. 178,220. (No model.)

To all whom it may concern:

Be it known that I, FRANK J. SPRAGUE, of New York, in the county and State of New York, have invented a certain new and useful Improvement in Electro-Dynamic Motors, of which the following is a specification.

In the use of electro-dynamic motors difficulty has heretofore arisen from the necessity of shifting the commutator-brushes when the armature-current is varied or reversed.

The object of the present invention is mainly to obviate this difficulty, though the invention relates further to certain means of regulation employed in conjunction with the main features of the invention.

My invention is especially applicable for use with railway-motors, and motors for working elevators, and other motors in parallel circuit in the operation of which it is necessary to vary the speed and to reverse the direction of rotation of the armature, and sometimes, also, to change the motor into a generator and to regulate it while in this condition, as set forth in my Patent No. 318,668, dated May 26, 1885.

As is well known, the reversal of direction of rotation of the armature of a motor or generator causes the reversal of the direction of lead of the brushes, and this lead is proportional to the armature-current, and is also dependent inversely to the strength of the free field.

In motors heretofore built for railroad work, it has been customary to provide two sets of commutator-brushes, one adapted to be used when the motor runs in one direction and the other for the opposite direction of rotation. These are set for different leads, and means are usually provided for changing the lead of each set. A single set of tangential brushes could not be employed because of the changes of lead and the sparking and burning which must attend such changes. Automatically-operating devices have been proposed for changing the lead, but these are complicated contrivances, and are therefore not well adapted for railway purposes, where only the simplest apparatus should be employed.

In my Patent No. 324,891 is set forth a mode of winding for a motor, by which the non-sparking points are maintained constant under varying armature-current. In this arrangement there is a set of series field-coils and a set of shunt field-coils, part of the series coils being wound on two diagonally-opposite legs of the field magnet in a manner to act cumulatively with the main or shunt field-coils, and the rest wound on the other two legs in a manner to differentiate the shunt coils, the differential being stronger than the cumulative series coils. This method is only for a machine running always in the same direction and at a determined speed on a constant potential circuit, and keeps the non-sparking point at a fixed position by opposing the distortion caused by the armature-current by a counter-distortion set up by the governing or series coil. While, if the current in the armature, and consequently the direction of rotation, is reversed, the distortion and counter-distortion are also reversed, yet because of the uneven magnetizing effect of the two series coils the amount of distortion is not the same as when running in the normal direction. This arrangement also therefore cannot be used for the purposes above set forth. By my present invention, however, I construct a machine with such a system of winding that it may run in either direction on a circuit of constant or of varying potential with a single or double set of tangential or end contact-brushes, with no change of lead, and consequently no necessity for changing the position of the brushes. By it the position of the brushes having been once properly adjusted is made independent of the amount of work the machine is doing, or the speed at which it is running, or whether it is acting as a motor or as a generator. It is independent also of the strength of field or armature current, and hence of the speed and power developed. I further provide means for varying strength of field and armature current either independently or simultaneously.

In the accompanying drawings, Figure 1 is a diagram of a motor, showing the arrangement and effect of the series field-coils; Fig. 2, a diagram showing the effect of said coils when the current is reversed from its direction in Fig. 1; Fig. 3, a diagram showing the arrangement and effect of the shunt field-coils; Fig. 4, a diagram showing the combined arrangement and effect of both sets of field-coils; Fig. 5, a diagram showing a modified

arrangement of the series field-coils; Fig. 6, a diagram of a motor embodying all the features of my invention, including the field-coils and the various regulating devices employed; Fig. 7, a diagram of the same with the armature-current reversed from its direction in Fig. 6; and Figs. 8, 9, 10, and 11 are diagrams illustrating the different polar conditions which occur in the operation of my invention.

In each of the motor diagrams 1 2 is the line. T is the armature, and B the field-magnet of the motor. C C are fine or shunt field-coils, and D D′, &c., are coarse or series field-coils.

In carrying my invention into effect I prefer to use a machine, as shown, having a field-magnet such as is commonly known as the "Siemens form"—that is, one having two poles, each produced by the combined action of two oppositely-placed sets of coils. This field-magnet is wound with two sets of coils, one a fine coil in shunt relation to the armature, which is wound to produce the main poles in the part of the field-magnet adjacent to the armature, the other, of very low resistance, is in series with the armature either inside or outside the terminals of the main field-shunt, and is wound equally upon all the cores in such manner as to produce magnetic poles in a line at right angles to that of the poles produced by the fine coil and less powerful ones. On two diagonally-opposite legs the coarse coils act cumulatively with the fine coils, and on the other two they act differentially, as set forth in my patent already referred to, but differing from the arrangement of that patent in that the coils are wound equally on all the legs. A reversing-switch is preferably placed in the series coil and armature-circuit, and preferably also an adjustable resistance. In the fine-coil shunt-circuit an adjustable resistance also may be placed, and this may also have a reversing-switch. A circuit making and breaking switch, preferably forming part of the reversing-switches, may be placed in each circuit. I also place in the coarse-coil circuit a switch whose construction will be presently explained, whose function is to reverse either diagonal portion of the coarse coils, leaving the rest unchanged, whereby all the coarse coils may be made cumulative or all differential at will.

In the normal arrangement of circuits just described the two sets of field-coils, fine and coarse, combine to set up a resultant polar line which is distorted or rotated in the plane of rotation of the armature, or so as to counteract the distortion due to the armature or to the main field-coils.

Since any increase in the armature-current is just the same in the series field-coils, the tendency to distortion by these two elements will always vary to the same extent, and the resultant position will be always the same no matter what is the extent of variation of current. If the field-magnet strength is varied independently of the armature, by changing the resistance in the shunt field-circuit or by a variation of potential on the line, while there is a tendency to change the armature distortion there is an equal and opposite tendency to change the distortion due to the series field-coils, and so this, also, has no effect. If the direction of the armature-current is changed, so also is that of the current in the series field, and so the direction of each distortion is changed; but they still oppose each other and vary equally and oppositely as before, and there is still no change in the non-sparking points. It is immaterial whether the change in direction of armature-current is due to a change of terminals in changing direction of rotation of the motor, or is caused in changing the motor into a generator by strengthening the field, as set forth in my Patent No. 318,668, dated May 26, 1885. Reversal of direction of rotation of the motor can also be accomplished by reversing the main field, but in this case also the non-sparking points are still governed in the same way.

In Figure 1 only the series coils D are shown. These are wound in the manner shown, equally on all the legs of the magnet, so as to produce poles at N′ S′, at opposite ends of the magnet.

Fig. 2 shows the same motor with the poles due to the series coil reversed by reversing the armature-current—that is, by throwing switch E to the left.

Fig. 3 shows the fine main or shunt coils alone. These also are wound equally on all the magnet-legs, but so as to produce poles in the usual manner at N S.

Fig. 4 shows the motor complete with both shunt and series coils. The resultant polar line produced by the combined action of the shunt and series coils is at N″ S″, while the line of distortion due to the armature and main field is at A R. The consequent polar line then is at N S, and it is evident from what has already been explained that it will always remain so. For if the armature-current is increased so that A R tends to turn against the direction of rotation, then the magnetizing effect of D D is also increased and N″ S″ equally tend to turn in the opposite direction, and if the magnetizing effect of C C is increased, then while A R tends to move toward N S, so also does N″ S″, and vice versa; and if the armature rotation is reversed, A R assumes the position N″ S″, but then the poles N′ S′ are reversed also, and N″ S″ assumes the position A R, so that N S remains the same. The fine and coarse coils can be wound side by side instead of superposed.

Figs. 6 and 7 show the same motor provided with the various regulating devices, which have been already briefly referred to.

F is the resistance apparatus for armature and main field-circuits. It is such as is set forth in my Patent No. 321,150, dated June 30, 1885.

Resistance-coils *a a* are in the shunt field-circuit, and are connected to contact-blocks

b b. Coils *c c* are in the armature-circuit and are connected to blocks *d d*. Long block *e* is for the field-circuit, and long block *f* for the armature-circuit. Moving arms *g g'* travel on the blocks and are both connected with the line, and preferably move together. When arm *g* moves on blocks *b b* and varies field-resistance, arm *g'* is on block *f*, and armature-resistance is not affected. On the other hand, when arm *g* is on blocks *d*, to vary armature-resistance, *g'* is on *c*, and field-resistance is not affected.

From the terminal of coils *c* armature-circuit wire 3 extends to block *h* of switch E. From block *h'* wire 4 extends, which is finally connected through switch G with commutator-brush *k*. From h^2 wire 5 goes to brush *k'*. From h^3 a wire extends to main conductor 1. Bridging-plates *i i'* are carried by pivoted switch-arm *l*. When the switch-arm is down, as in Fig. 6, the current is in one direction in the armature and series field, and when in the horizontal position of Fig. 7 the armature and series field-current is reversed. The arrow-heads in all cases show direction of current.

G is the switch or commutator for reversing portions of the series field-coils. It consists of eight plates, *m m'* m^2, &c., arranged in a circle, and four moving bridging-plates, *n*, *n'*, n^2, and n^3, carried by pivoted arm *o*.

As has been stated, a portion of the series coils D' D^2 is wound to act cumulatively with the shunt-coils C, and a portion, D^3 D^4, is wound to differentiate them. The function of switch G is to make all the series coils cumulative, so as to make a very strong field as in starting the machine, or to make them all differential, if desired, so as to weaken the field.

In Fig. 6 all the coils are normal. Here the armature and series coils-circuit is, by wire 5 to brush *k'*, brush *k*, wire 6 to m^4, plate *n'* to m^5, wire 7 to coils D^4, 8 to D^3, 9 to plates m^3 *n* m^2 n^3 *m'*, wire 10 to D', 11 to D^2, 12 to m^7, n^2 to *m*, and wire 4 back to switch E, and to the line. Now, if handle *o* of switch G is thrown to its right-hand position, (shown by dotted line,) the circuit is: 5, *k'*, *k*, 6, m^4, *n'*, m^5, 7, D^4, 8, D^3, 9, m^3, *n*, m^2, wire 13, m^6, n^2, m^7, 12, D^2, 11, D', 10, *m'*, n^3, *m*, and 4. Coils D' and D^2 are thus reversed and made differential, instead of cumulative. Throwing handle *o* to its left-hand position likewise reverses D^3 and D^4, and makes all the coils cumulative. This last is what is done in starting the motor when switch E is down, as in Fig. 6. Its effect is shown in Fig. 9. That is, it makes the polar line N' S' disappear from the normal position and brings it to N S, and so makes a very strong field, so that the motor starts slowly with a strong torque or rotary effort.

Fig. 8 shows the polar condition when the coils are all differential, S' being then brought to N and N' to S. This is a condition which will rarely occur in practice. It will be noticed that in starting the motor in this way no provision is made for the maintenance of the non-sparking points. I find that this is unnecessary, for there is at this time so low a potential between the commutator-blocks that there is practically no sparking, and consequently it makes less difference where the commutator-brushes are. When the motor has come up to speed, however, the switch G is maintained at its middle position, and the regulation of the non-sparking points goes on in the manner explained.

In starting the motor, further, the resistance-coils *c* are placed in circuit, and coils *a* all out of circuit. Coils *c* are then gradually cut out, and such of coils *a* as described are placed in circuit. The regulation while running is performed by varying the shunt field strength by coils *a*.

Fig. 7 shows the armature and series coils circuit reversed at switch E, and with Figs. 10 and 11 illustrates the fact that when this reversal has taken place the operation of switch G must be reversed also—that is, when the motor is to run in the direction of Fig. 6, switch *o* is thrown to the left in starting, and when, as in Fig. 7, it is thrown to the right. In practice, the proper positions for the switches may be indicated upon them, so as that an inexperienced engineer can readily handle the motor, if necessary.

Fig. 5 shows an arrangement in which one part of the series coils is in parallel circuit to the other part. Such arrangement may be used if desired.

It is to be understood that the series coils can be either inside or outside, or part inside and part outside, the fine-shunt-coil terminal.

What I claim is—

1. An electro-dynamic motor having a field-magnet whose main poles are formed by cores extending in opposite directions, having a set of shunt-coils wound evenly on all said cores, and a set of series coils, also wound evenly thereon, said sets being arranged to form polar lines at right angles to each other, substantially as set forth.

2. An electro-dynamic motor having a set of shunt field-coils, and a set of series field-coils arranged to form polar lines at right angles to each other, in combination with means for modifying the action of the series coils, substantially as set forth.

3. An electro-dynamic motor having a field-magnet of the character described, and having shunt field-coils wound evenly on all the cores of said magnet, and series field-coils also evenly wound, such coils being normally differential to the shunt-coils in two diagonally-situated cores and normally cumulative thereto on the other two cores, substantially as set forth.

4. An electro-dynamic motor having shunt field-coils and series field-coils arranged to form polar lines at right angles to each other, and said series coils being part differential and part cumulative with relation to the shunt-coils, in combination with means for reversing

the effect either of said cumulative or said differential series coils, substantially as set forth.

5. An electro-dynamic motor having shunt field-coils and series field-coils arranged to produce polar lines at right angles with each other, in combination with a circuit-reverser in the armature-circuit, substantially as set forth.

6. An electro-dynamic motor having series and shunt field-coils wound to maintain the non-sparking points on the commutator at a fixed position, in combination with means for reversing the armature-circuit, substantially as set forth.

7. An electro-dynamic motor having series and shunt field-coils arranged to produce polar lines at right angles with each other, in combination with means for regulating the armature-current, substantially as set forth.

8. An electro-dynamic motor having series and shunt field-coils arranged to produce polar lines at right angles with each other, in combination with means for regulating the magnetizing effect of the shunt field-coils, substantially as set forth.

9. An electro-dynamic motor having series and shunt field-coils arranged to produce polar lines at right angles with each other, in combination with an adjustable resistance and a circuit-reverser in the armature-circuit, substantially as set forth.

10. An electro-dynamic motor having series and shunt field-coils arranged to produce polar lines at right angles to each other, in combination with an adjustable resistance in the shunt field-circuit, substantially as set forth.

11. An electro-dynamic motor having series and shunt field-coils arranged to produce polar lines at right angles to each other, in combination with an adjustable resistance in the armature-circuit and an adjustable resistance in the shunt field-circuit, substantially as set forth.

12. An electro-dynamic motor having series and shunt field-coils arranged to produce polar lines at right angles to each other, in combination with an adjustable resistance and a circuit-reverser in the armature-circuit, and an adjustable resistance in the shunt field-circuit, substantially as set forth.

13. An electro-dynamic motor having series and shunt field-coils wound so that the series coils distort the poles set up by the shunt-coils, in combination with means for reversing the direction of distortion, substantially as set forth.

This specification signed and witnessed this 23d day of September, 1885.

FRANK J. SPRAGUE.

Witnesses:
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E. C. ROWLAND.