

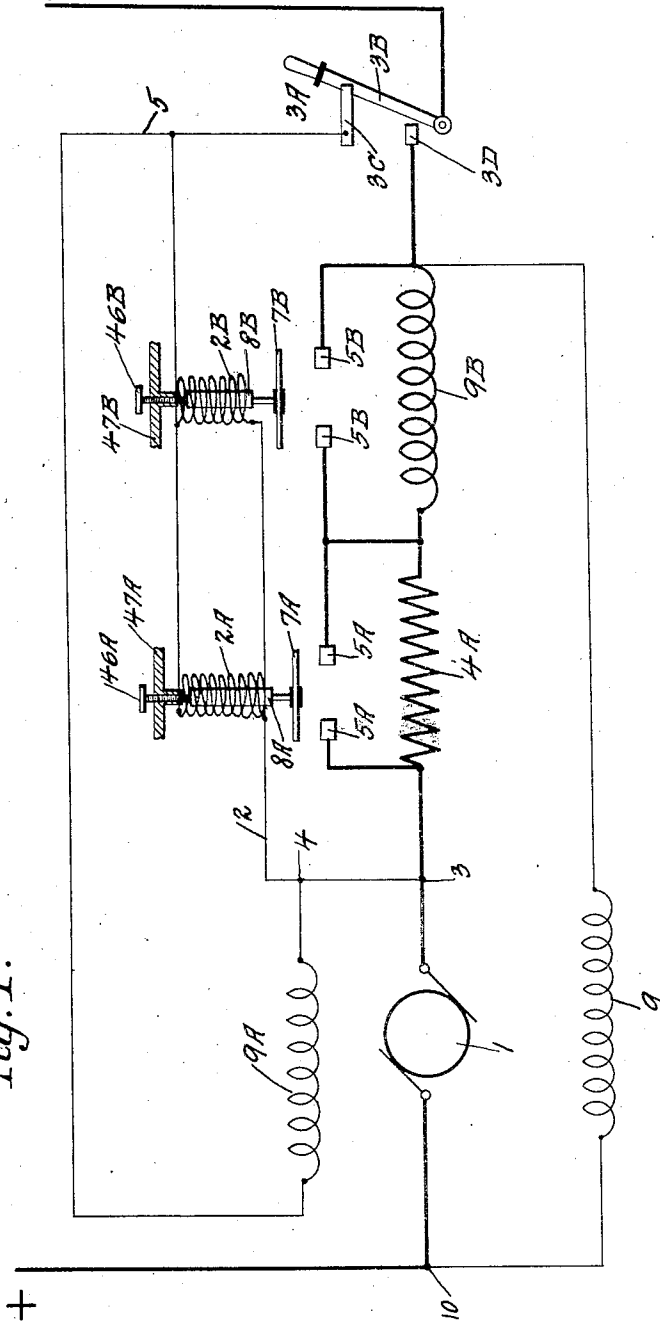
E. L. GALE, SR.  
CURRENT CONTROLLING APPARATUS.  
APPLICATION FILED JUNE 11, 1907.

1,120,708.

Patented Dec. 15, 1914.

2 SHEETS-SHEET 1.

Fig. 1.



Witnesses:

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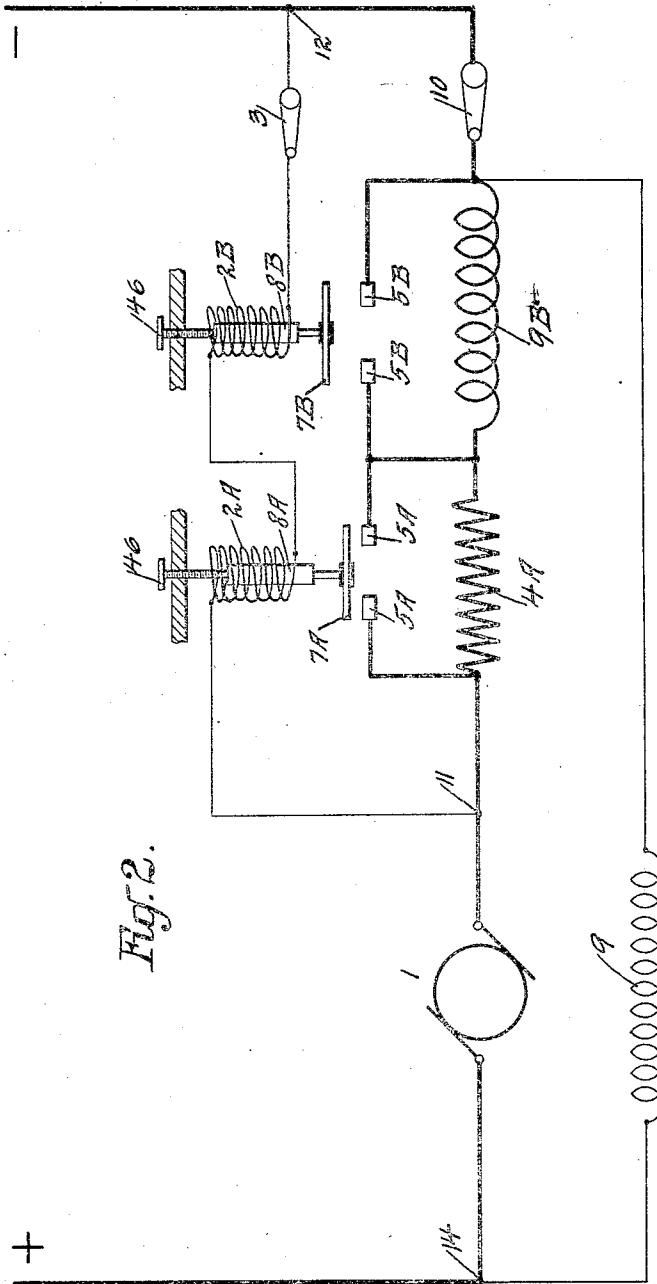


Fig. 2.

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# UNITED STATES PATENT OFFICE.

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## CURRENT-CONTROLLING APPARATUS.

1,120,708.

Specification of Letters Patent.

Patented Dec. 15, 1914.

Original application filed May 1, 1905, Serial No. 258,378. Divided and this application filed June 11, 1907, Serial No. 378,408.

*To all whom it may concern:*

Be it known that I, ERNEST L. GALE, Sr., a citizen of the United States, residing at Yonkers, in the county of Westchester and State of New York, have invented a new and useful Improvement in Current-Controlling Apparatus, of which the following is a specification.

My invention relates to apparatus for controlling electric currents, and more particularly those used for starting and controlling electric motors, but it should be understood that it may have a general application.

This application is a division of my co-pending application, Serial No. 258,378, filed May 1, 1905, for an improvement in current controlling apparatus.

One of the objects of my invention is the provision of simple and efficient means for starting an electric motor. Another object of my invention is the provision of an improved and simplified construction for starting and operating electric motors with minimum consumption of current.

Other objects of the invention will appear hereinafter, the novel combinations of elements being pointed out in the claims.

In the accompanying drawing Figure 1 illustrates diagrammatically the circuits and connections of an electric motor and of my invention applied thereto; Fig. 2 represents a modification.

1 designates a translating device, which in this instance is shown as the armature of a rotary electric motor.

4<sup>A</sup> designates one section of the starting resistance and 9<sup>B</sup> another section of the starting resistance, which is also the series field which is placed in circuit when the motor is started in order to increase the torque.

The starting resistance is proportioned in a well known way to prevent too much current from flowing through the motor while the same is being accelerated. The mains are designated by the signs + and —, and are connected directly to the motor-armature and the switch lever 3<sup>B</sup>, respectively, as shown. The shunt field circuit 9 may be connected to the positive main to the left of the motor-armature and to the fixed contact 3<sup>D</sup> of the manual switch 3<sup>A</sup>.

Connected between the resistance section 4<sup>A</sup> and the fixed contact 3<sup>D</sup> is a series field

circuit 9<sup>B</sup>, the latter being, therefore, in that part of the main armature circuit extending between the right-hand armature brush and the negative main. In a controlling circuit 2 connected between the point 3 and the fixed contact 3<sup>C</sup> are the solenoids 2<sup>A</sup> and 2<sup>B</sup>. The conductor 2 including the solenoids 2<sup>A</sup>, 2<sup>B</sup> may be termed a controlling circuit in parallel to the starting resistance when the switch 3<sup>A</sup> is entirely closed. It should be noted that the solenoids 2<sup>A</sup>, 2<sup>B</sup> are connected in parallel with each other. Connected across or in parallel with the controlling circuit is an extra field circuit 9<sup>A</sup>. In this instance this extra field circuit is represented as connected between the points 4 and 5, or in effect between the point 3 and the fixed contact 3<sup>C</sup>.

As it is desirable to have the controlling circuit closed before the main armature circuit is closed, the lever 3<sup>B</sup> is arranged to make contact with the conductor 3<sup>C</sup> to which the controlling circuit is connected, before said lever 3<sup>B</sup> comes into contact with the fixed member 3<sup>D</sup>. Therefore, when the lever 3<sup>B</sup> is moved to the position shown in the figure, the armature 1 will be placed in series with the controlling circuit and the extra field circuit, the two latter being parallel to each other. At the same time the shunt field circuit 9 together with the series field 9<sup>B</sup> and resistance 4<sup>A</sup>, are connected between the points 10 and 3 to the armature 1. If the current were sufficient the armature would start, but preferably the resistances of the solenoids 2<sup>A</sup> and 2<sup>B</sup> are sufficiently great to prevent the armature from receiving sufficient current to permit the latter to start.

Normally the resistance-varying member 7<sup>A</sup> is in its lowermost position in engagement with the contacts 5<sup>A</sup> electrically connecting them and short-circuiting the resistance 4<sup>A</sup>. Also normally the resistance-varying member 7<sup>B</sup> electrically connects the contacts 5<sup>B</sup> and thus short-circuits the series field circuit 9<sup>B</sup>. The resistance-varying members 7<sup>A</sup> and 7<sup>B</sup> are connected to the plungers or cores 8<sup>A</sup> and 8<sup>B</sup>, respectively, but insulated therefrom. The weight of the cores is sufficient to secure good electrical connections, and to effect the return of the resistance-varying members when the cores are released by their respective solenoids. The solenoids 2<sup>A</sup> and 2<sup>B</sup> are mounted in proper position in any suitable

manner, and there may be only one of such solenoids or there may be several, depending upon the refinement desired in accelerating the motor to full speed. I prefer to arrange these solenoids so that they will be effective in lifting their cores successively and releasing them successively. In this instance I have provided fixed supports 47<sup>A</sup>, 47<sup>B</sup>, for adjustable stop screws 46<sup>A</sup> and 46<sup>B</sup>, respectively, which project into the upper ends of the solenoids 2<sup>A</sup> and 2<sup>B</sup> to limit the upward movements of the cores 8<sup>A</sup>, 8<sup>B</sup>. In the normal positions of the resistance-varying members 7<sup>A</sup> and 7<sup>B</sup>, the core 8<sup>A</sup> will occupy such a position relative to the solenoid 2<sup>A</sup> that a greater force acts on said core 8<sup>A</sup> in lifting it than the solenoid 2<sup>B</sup> exerts on the core 8<sup>B</sup>, for a given strength of current. The cores 8<sup>A</sup> and 8<sup>B</sup> will therefore be lifted successively. The same results may be obtained in other ways, that just given being merely by way of illustration. It is more important, however, that the solenoids should release their cores successively, as in some instances it is immaterial whether the cores are lifted successively or simultaneously so long as they are lifted before the lever 3<sup>B</sup> closes the main armature circuit by engaging the contact 3<sup>D</sup>. Whenever current flows through the solenoids 2<sup>A</sup>, 2<sup>B</sup>, the various magnetic parts will be energized, and the tendency will be to lift the cores 8<sup>A</sup>, 8<sup>B</sup> until they respectively reach the stop screws 46<sup>A</sup>, 46<sup>B</sup>. The stop screws determine the final positions of the cores in the solenoids after being energized, and this is a matter of adjustment. It is evident that this predetermines the strength which is required to hold the core in its upper position, and this determines the time at which the core will be released and permitted to descend as the current in the controlling circuit is gradually reduced. It is of course understood that the stop screws are of non-magnetic material.

When the cores 8<sup>A</sup> and 8<sup>B</sup> reach their limiting positions, more of the core 8<sup>B</sup> will be projected into the solenoid 2<sup>B</sup> than of the core 8<sup>A</sup> into the solenoid 2<sup>A</sup>. Therefore, although the solenoid 2<sup>A</sup> will lift its core 8<sup>A</sup> first, it will also release it first, as the current in the controlling circuit gradually diminishes.

The operation will now be fully explained. Assuming that the mains have the proper potential to effect the operation of the translating device 1, in this instance the motor-armature, let the switch lever 3<sup>B</sup> be moved onto the fixed contact 3<sup>C</sup>. At once the motor will receive current and this current will pass in series through the armature and controlling circuit. As heretofore stated, the controlling circuit is preferably of high resistance and the current which passes through it will not be of sufficient strength

to have any appreciable effect upon the motor-armature, but this does not limit me to so proportioning the resistances of the solenoid windings 2<sup>A</sup>, 2<sup>B</sup>, that the motor-armature will not start at this time if it is so desired. As soon as this controlling circuit is thus closed to receive current, the resistance-varying members 7<sup>A</sup> and 7<sup>B</sup> will be lifted successively in the order mentioned; this is done very quickly. At this time the shunt field 9 and extra field 9<sup>A</sup> will be excited with current and so also the series field 9<sup>B</sup>, but the current through the latter at this time will be comparatively small. Now upon further movement of the lever 3<sup>B</sup>, the contact 3<sup>D</sup> is engaged thereby to complete the main armature circuit from the positive main through the motor-armature, resistance 4<sup>A</sup>, series field circuit 9<sup>B</sup>, contact 3<sup>D</sup>, lever 3<sup>B</sup>, to the negative main. The controlling circuit and the extra field circuit will now each be connected in parallel to the opposition partial circuit including the resistance 4<sup>A</sup>, and series field 9<sup>B</sup>. The motor now starts with a very strong torque by reason of the series field 9<sup>B</sup> and the extra field 9<sup>A</sup>. After the motor starts, and its counter-electro-motive force gradually increases to gradually decrease the current flow through the resistance 4<sup>A</sup> and series field 9<sup>B</sup>, the potential between the points 3 and 3<sup>D</sup> gradually diminishes, thereby gradually weakening the current in the controlling circuit to cause the solenoid 2<sup>A</sup> to release its core 8<sup>A</sup> and permit the bridge piece or contact-maker 7<sup>A</sup> to descend, although still being acted upon by the weakened solenoid. The solenoid, however, is not of sufficient strength to hold its core in its uppermost position, and, therefore, the core will finally reach its lowermost position where the contact-member 7<sup>A</sup> again electrically connects the contacts 5<sup>A</sup>, 5<sup>A</sup>, thereby short-circuiting the resistance 4<sup>A</sup>. This will allow the armature to receive greater potential at this time, and will, therefore, cause its acceleration to a higher speed. This in turn increases the counter-electro motive force of the armature, and, therefore, a further drop in potential between the points 3 and 3<sup>D</sup> until the current in the solenoid 2<sup>B</sup> is no longer sufficient to hold its core 8<sup>B</sup> in its uppermost position. The latter will, therefore, gradually descend as the current in the controlling circuit gradually diminishes until the contact-member 7<sup>B</sup> electrically connects the contacts 5<sup>B</sup>, when, not only will the series field 9<sup>B</sup> be short-circuited, but also the extra field 9<sup>A</sup> and the entire controlling circuit, including the solenoids 2<sup>A</sup> and 2<sup>B</sup>. The motor will now run to full speed and operate as a shunt motor connected directly across the mains, the only parts receiving current of appreciable value being the motor-armature 1 and the shunt field circuit 9, the other

electro-receptive elements having been short-circuited or cut out. The controlling circuit, therefore, is itself controlled by the varying potential across the starting resistance. When the contact-makers bridge the contacts  $5^A$  and  $5^B$ , the controlling circuit and the extra field are short-circuited so that the latter will take little if any current while the motor is running as desired. It is, therefore, seen that the starting resistance is short-circuited and the current in the controlling circuit and extra field circuit is substantially eliminated. This I consider a valuable feature of my invention. In other words, it is the variation of potential across the starting resistance that is utilized to influence the controlling circuit and to cause the same to actuate and release means for varying the armature resistance or other current-opposing means.

It should be particularly noted that not only is the current in the portion of the main armature circuit including the motor-armature varied by the gradual cutting out step-by-step of the starting resistance, but that the current in the controlling circuit itself is reduced gradually during the operation of the apparatus heretofore described; furthermore, that the magnets in the controlling circuit receive maximum current at the time they are called upon to actuate their cores, and that this current is gradually reduced to practically zero after said magnets have performed their work. When the switch lever  $3^B$  is moved onto the fixed contact  $3^C$ , the members  $7^A$ ,  $7^B$  are automatically lifted to insert the resistance  $4^A$  and the series field  $9^B$  in the main armature circuit normally opened at  $3^D$ . Upon further movement of the lever  $3^B$  onto the contact  $3^D$  to effect the closure of the main armature circuit, the controlling circuit, including the solenoids  $2^A$ ,  $2^B$ , operate automatically to successively release the members  $7^A$ ,  $7^B$  to effect the gradual cutting out of the resistance  $4^A$  and series field  $9^B$ , and the acceleration of the motor up to full speed. Because of this automatic operation and the final cutting out of the solenoids  $2^A$ ,  $2^B$ , the magnets in the controlling circuit may be made smaller than they otherwise might, and the whole apparatus may be made simpler and less expensive.

In Fig. 2 are shown adjustable screws to limit the upward movement of the cores  $8^A$  and  $8^B$  so that they may be maintained in different positions within the solenoids  $2^A$  and  $2^B$ . In the present instance it is immaterial in what order the contact-makers  $7^A$ ,  $7^B$  are lifted, but it is desired that the bridge piece  $7^A$  should be permitted to descend before the bridge piece  $7^B$ . The core  $8^A$  being held by the solenoid  $2^A$  at a lower position than the core  $8^B$  within its solenoid  $2^B$ , will be released at a predeter-

mined value of the current before the core  $8^B$ . In this manner, with a given value of the controlling current which passes through these solenoids, the retardation effect of the solenoids upon their cores will be varied. Now as the potential between the points 11, 12 decreases, the amount of the controlling current consequently becomes less, and at a predetermined value the solenoid  $2^A$  will no longer be able to hold its core in the uppermost position, and the latter will, therefore, begin to descend while the core  $8^B$  is still being retained in its uppermost position. While the core  $8^A$  is descending, it is evident that the controlling circuit still receives current, and, therefore, the solenoid  $2^A$  still exerts some force on the core  $8^A$  while the latter is descending. Therefore, the core  $8^A$  will descend with a retarded movement. As the potential diminishes still further, the core  $8^B$  will also be permitted to descend. The time at which these cores begin to descend may be readily regulated by the adjustable stop screws 46.

There are many specifically different ways by which the successive or serial operation of the electro-magnetic switches may be effected, for example, the solenoids themselves may be so formed or so wound as to have different tractive forces with the same amount of current. That is, the solenoids may be wound so as to have a different number of ampere turns so that those having the larger number of ampere turns will retain their cores in uppermost position the longer.

In Fig. 2 the solenoids  $2^A$  and  $2^B$  are arranged in series with each other, while in Fig. 1 they are in parallel. The extra field  $9^A$  is omitted from Fig. 2, but the series field  $9^B$  is retained. In Fig. 1 a single switch mechanism  $3^A$  is employed, which at the same time also takes the place of the usual main line two-pole switch, if desired, for connecting the source of current supply to the motor circuits. In Fig. 2, two small switches 3 and 10 are used, one for the controlling circuit, and the other for the main armature circuit. Normally the switch 10 is open. If the main line switch is closed or if the motor circuits are connected with the source of current supply, and the switch 3 is closed, current will flow through the armature 1 and the solenoids  $2^A$ ,  $2^B$ , in series. Preferably these solenoids are of sufficient resistance to prevent the armature from starting at this time. When the current thus flows through the solenoids, the latter lift their cores so as to move the resistance-varying members  $7^A$  and  $7^B$  from the contacts  $5^A$ ,  $5^B$ , and thus remove the circuits around the starting resistance  $4^A$  and the series field circuit  $9^B$ . Upon the closure of the switch 10 the motor will start and

accelerate to full speed in the manner heretofore explained.

As to Fig. 1, it will be seen that when the motor is started up with the opposition element in, the extra field 9<sup>A</sup> will be fully energized since it receives current depending upon the potential across the starting resistance or between the points 3 and 5. During the operation of this system, this potential gradually diminishes until it is practically negligible, and, therefore, the current through this extra field 9<sup>A</sup> will die out as the motor approaches full speed.

The magnetic field coil of the motor may be excited in any desired manner, and may comprise, for example, a shunt field coil 9 connected across the mains, as shown, when the switch 3<sup>A</sup> is entirely closed. This by itself will maintain the magnetic field at its normal strength. When the main circuit is closed to start the motor, the extra field will increase the strength of the magnetic field due to the shunt coil 9, and when the series field 9<sup>B</sup> is inserted, by the closure of the main armature circuit, the strength of the magnetic field will be still further increased. This increase of the magnetic field will have the effect of increasing the starting torque of the motor, or make it possible to have the same starting torque with less consumption of current in the armature. As the motor increases in speed this extra field gradually diminishes in strength, and the decrease in strength of the field assists a gradual increase in speed of the motor, because as the opposition or resistance is reduced, the current in the extra field is gradually or automatically reduced to practically zero. This, it will be noticed, is accomplished without any additional switches, which is an advantage over present practice. With the arrangement shown in Fig. 1, substantially at the same time that the extra field circuit and the controlling circuit are short-circuited, the series field 9<sup>B</sup> is short-circuited, after which the motor runs as a simple shunt motor.

Obviously those skilled in the art may make various changes in the details and arrangement of parts without departing from the spirit and scope of my invention, and I desire, therefore, not to be limited to the precise construction herein disclosed.

What I claim is:—

1. In motor controlling apparatus, the combination with a motor armature and a field circuit, of starting resistance, a controlling circuit in parallel to the starting resistance, an extra field circuit permanently connected in parallel to said controlling circuit, and means operated by said controlling circuit for cutting out said starting resistance and said extra field circuit.

2. In motor controlling apparatus, the combination with a motor armature and a

shunt field circuit, of starting resistance in series with the said motor armature, a controlling circuit, an extra field circuit in parallel with the said controlling circuit, a switch for first connecting the motor armature in series with the extra field circuit and in series with said controlling circuit and thereafter closing the main armature circuit including the motor armature and said starting resistance, and means operated by the controlling circuit for controlling said starting resistance.

3. In motor-controlling apparatus, the combination with a motor-armature, of a shunt field circuit, a series field winding, starting resistance including said series field winding, an extra field circuit, a controlling circuit, said extra field circuit and controlling circuit being permanently connected in parallel, and means operated by said controlling circuit for cutting out said resistance, said series field and said extra field.

4. In motor-controlling apparatus, the combination with a motor-armature, of a shunt field circuit, a series field winding, starting resistance including said series field winding, a controlling circuit, an extra field circuit in parallel with said controlling circuit, and a switch for first connecting the motor-armature in series with the extra field circuit and controlling circuit and then closing the main armature circuit including the motor-armature and the said starting resistances in series with each other, and effecting the connection of the controlling circuit and extra field circuit in shunt to the said starting resistance.

5. In current controlling apparatus, the combination with a motor, of a field circuit starting resistance, means for controlling said starting resistance to vary the current passing through said motor, a controlling circuit for operating the controlling means and to eliminate the current passing through itself, an extra field circuit permanently connected in parallel with the controlling circuit, and a single switch mechanism for first closing the controlling circuit in series with the motor-armature and then the main armature circuit including the motor-armature and starting resistance in series with each other, and controlling circuit across the starting resistance.

6. In motor controlling apparatus, the combination with a motor armature, of three field windings, one being connected across the mains, another in series with the motor armature and the third as an extra field also in series with the motor armature, a controlling circuit in series with the motor armature and in parallel with the extra field winding at all times, starting resistance comprising as one of its sections the series field winding, and electro-magnetic switches operated by said controlling circuit

for initially inserting the starting resistance and thereafter gradually cutting out the same and also cutting out the controlling circuit itself and the extra field winding, only the armature and shunt field winding taking current at full speed, and a switch for first establishing the circuit through the controlling circuit and extra field winding and thereafter closing the main armature circuit including the motor armature and the starting resistance comprising said series field winding.

7. In motor controlling apparatus, the combination with a motor, of starting resistance therefor, a plurality of electro-magnets in parallel with each other in a circuit in parallel with the starting resistance, a field winding permanently connected across the terminals of the said electromagnets, means operated by said electro-magnets to insert the starting resistance and then gradually cut out the same, and a switch for controlling said electro-magnets to be dependent in their operation upon the potential across the said starting resistance.

8. In motor controlling apparatus, the combination with a motor armature and a field circuit, of starting resistance in series with the motor armature, a series of electro-magnets in parallel with each other and each having a single winding, an extra field winding permanently connected in parallel with said electro-magnets, a switch for closing the circuit including said electro-magnets and for closing the main armature circuit including the motor armature and said resistance in series with each other, and means operated by said electro-magnets for successively cutting out said starting resistance.

9. The combination with an electric mo-

tor having an extra field winding, of starting resistance for the motor, a series of electro-magnets in a circuit in series with the motor armature permanently connected in parallel with said extra field winding, a switch for connecting the controlling circuit across the starting resistance and closing the main armature circuit, and means operated by said electro-magnets for initially inserting said starting resistance and then gradually cutting out the same and also the controlling circuit and said extra field winding.

10. The combination with an electric motor having an extra field winding in series with the armature, of a controlling circuit permanently in parallel with said extra field winding, starting resistance in series with the armature, a switch for closing the controlling circuit, the extra field winding circuit and the main armature circuit, said controlling circuit including a plurality of electro-magnets each having a single winding and a plunger movable within the same, a plurality of electric switches one connected to each of said plungers and to sections of said starting resistance, and means associated with said electric switches to effect a gradual cutting out of the starting resistance and as the motor armature increases in speed and the current in the controlling circuit decreases to substantially zero.

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

ERNEST L. GALE, SR.

Witnesses:

ALFRED C. BECHET,

ERNEST L. GALE, JR.