No. 713,574. Patented Nov. 11, 1902.

C. P. STEINMETZ.

ADJUSTING COMPOUND WOUND GENERATOR.

(Application filed Mar. 24, 1902.)

(No Model.) 2 Sheets—Sheet 1.

Fig. 1.

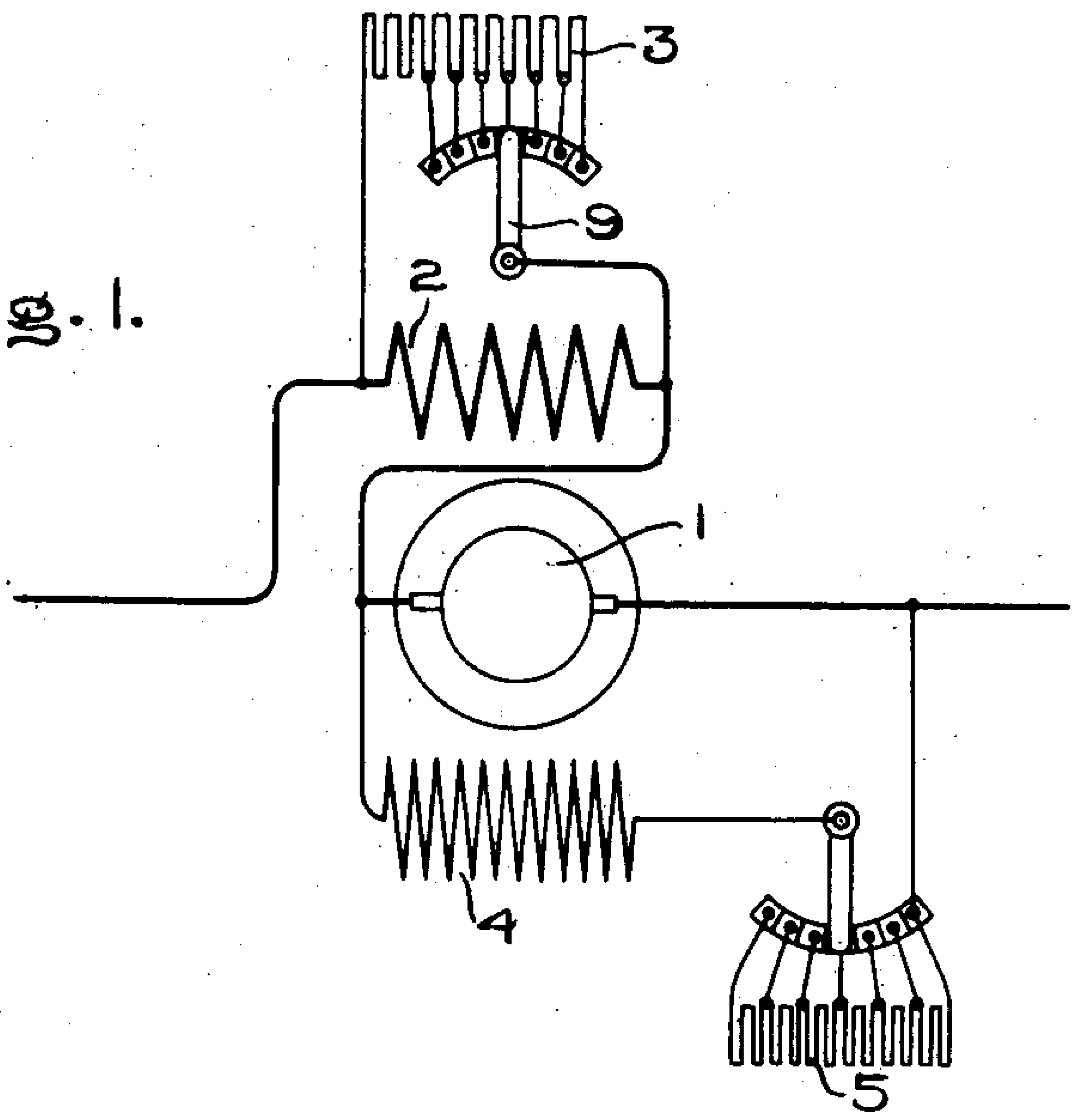


Fig. 2.

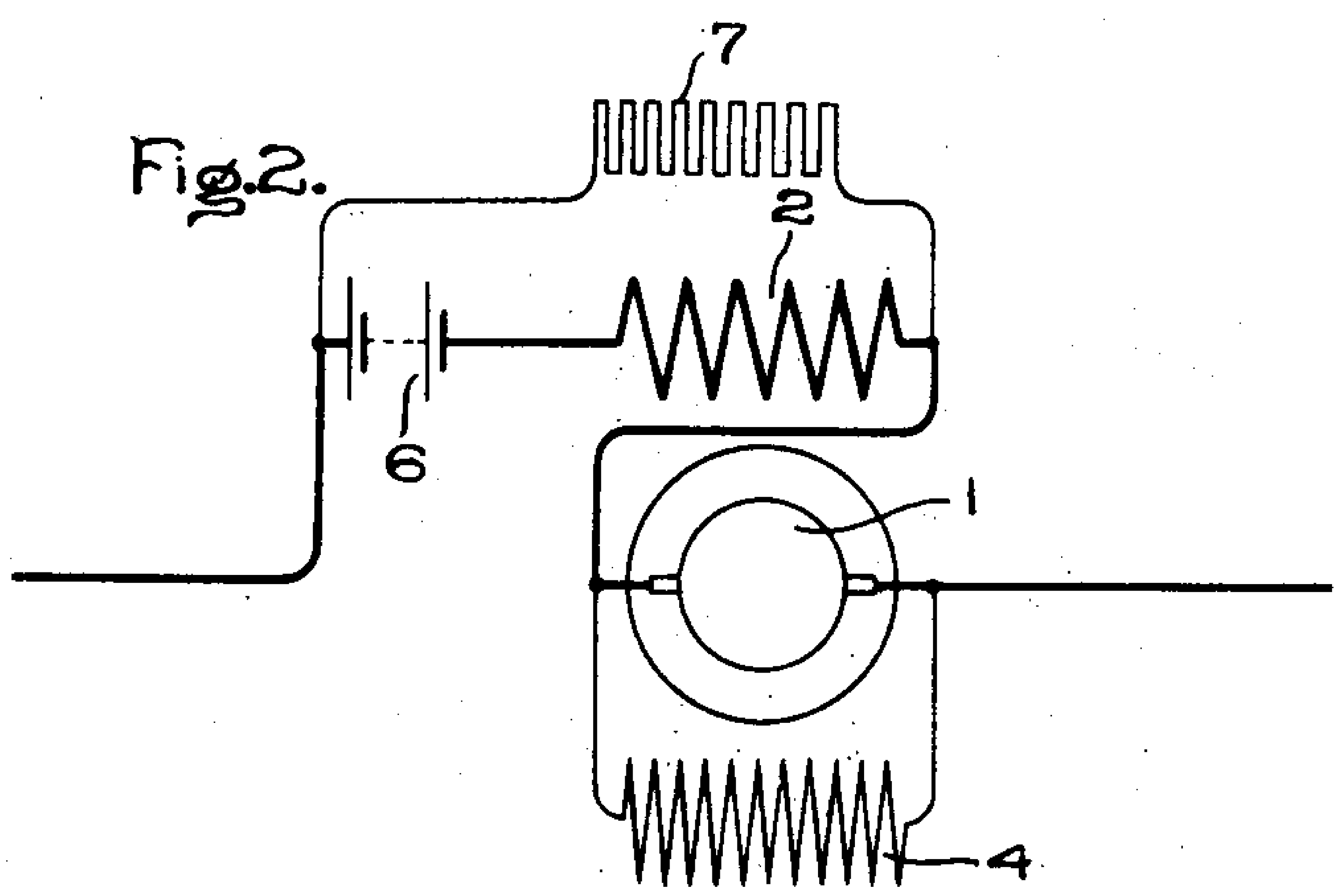
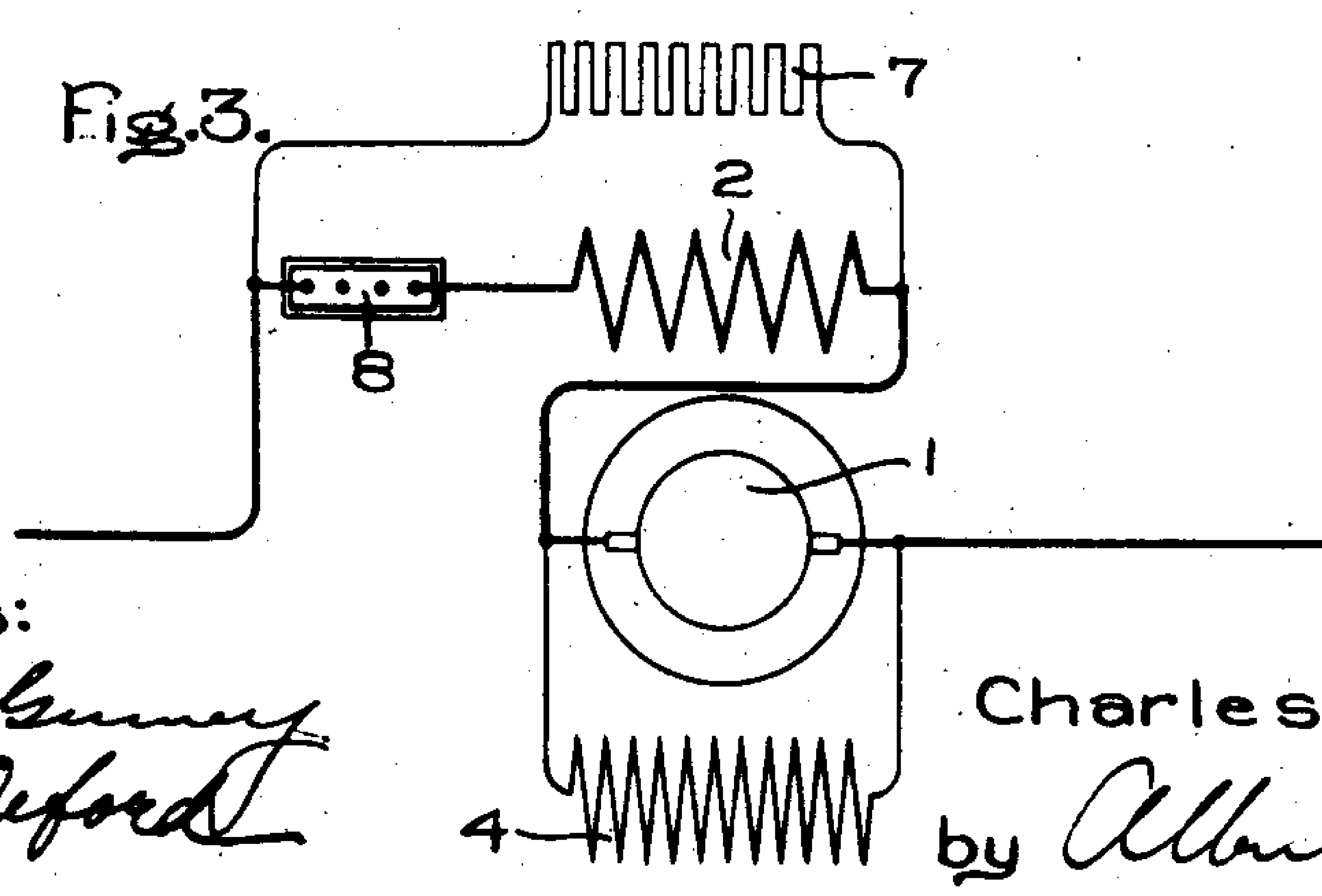


Fig. 3.



Witnesses:
Erving R. Gurney
Helen Orford

Inventor:
Charles P. Steinmetz,
by Albert G. Davis
Att'y

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

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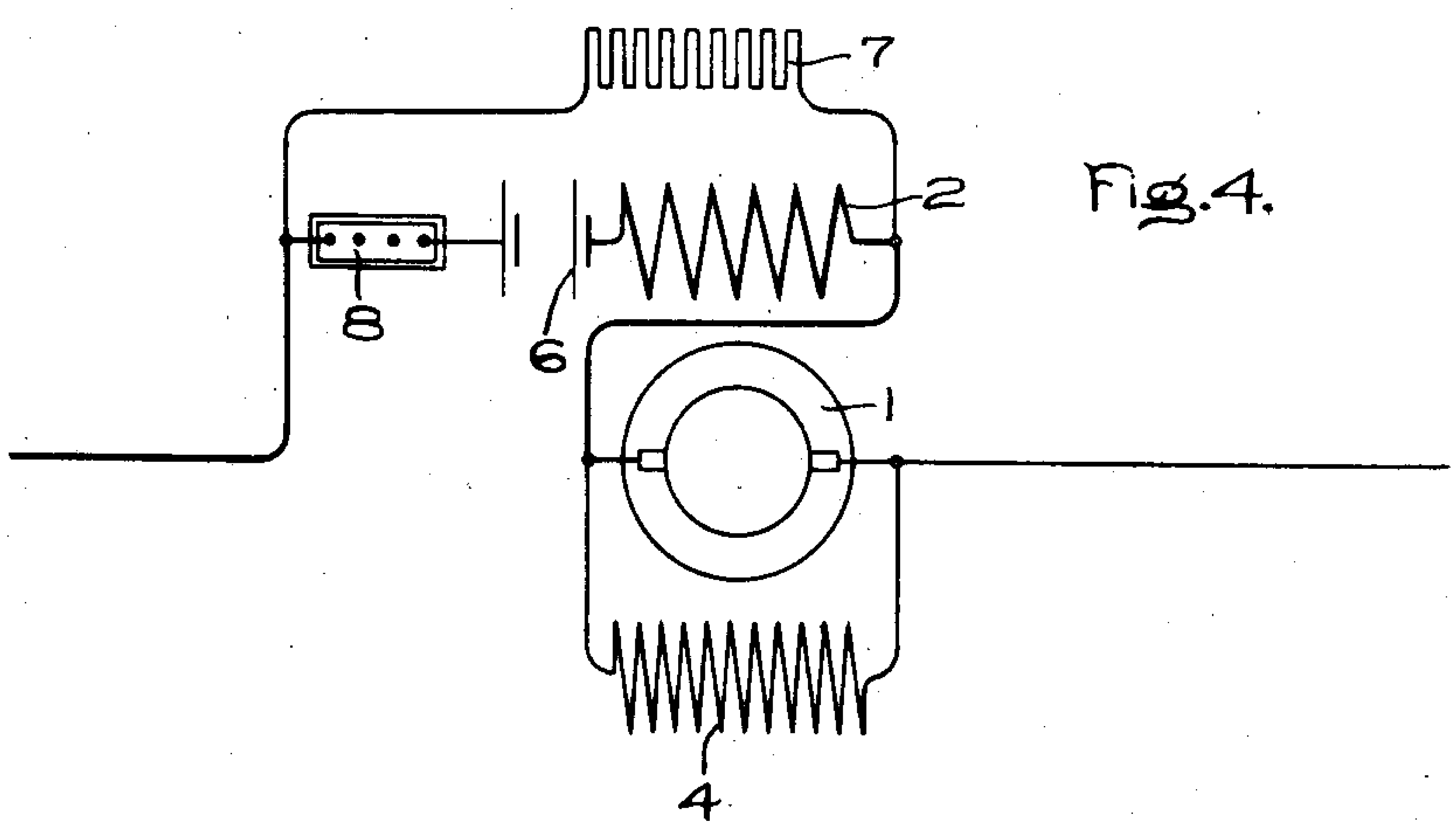

Fig. 4.

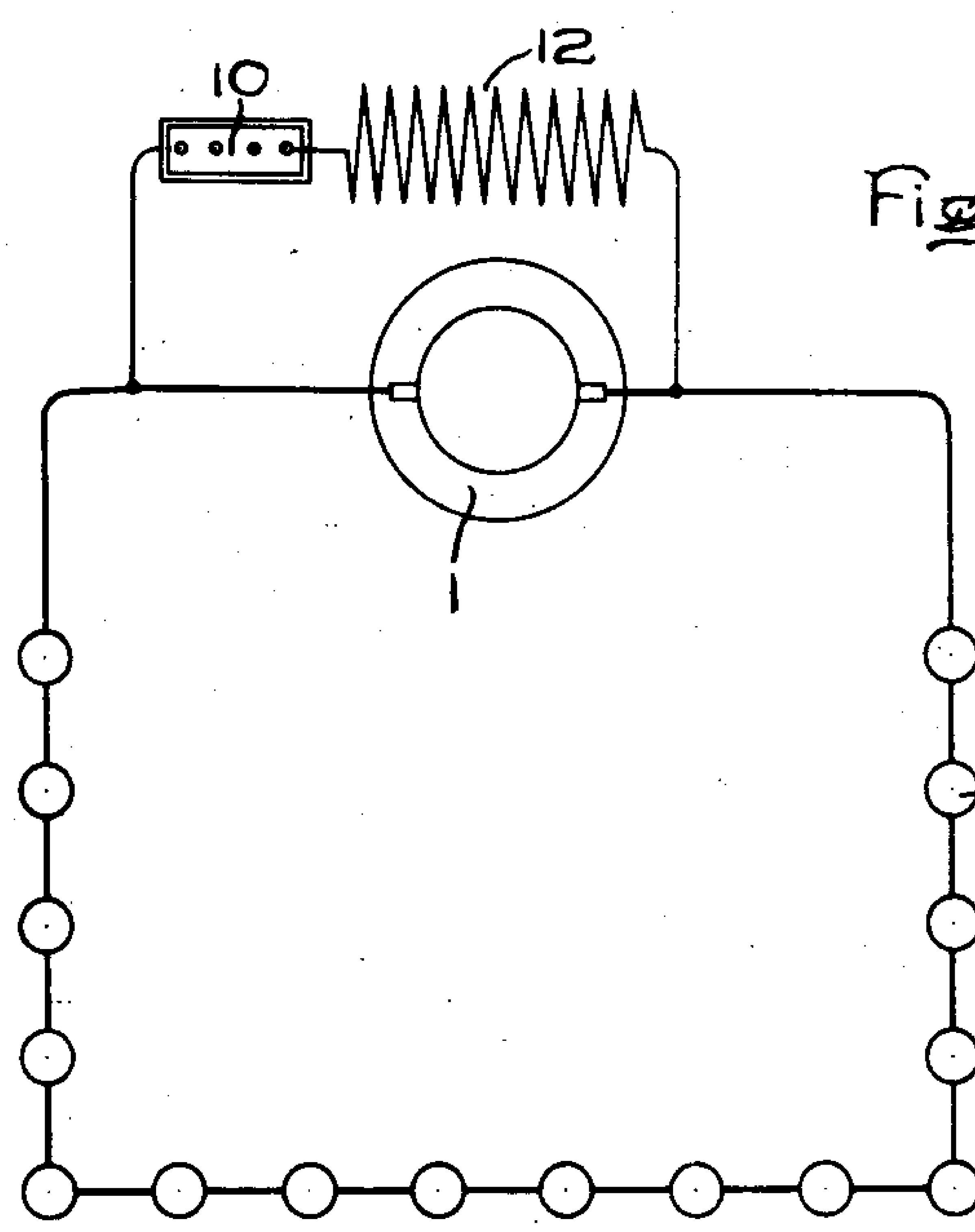

Fig. 5.

Witnesses:
Erving R. Gurney.
Helen Orford

Inventor
Charles P. Steinmetz,
by Albert G. Davis
Att'y.

UNITED STATES PATENT OFFICE.

CHARLES P. STEINMETZ, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

ADJUSTING COMPOUND-WOUND GENERATOR.

SPECIFICATION forming part of Letters Patent No. 713,574, dated November 11, 1902.

Original application filed August 24, 1898, Serial No. 689,392. Divided and this application filed March 24, 1902. Serial No. 99,617. (No model.)

To all whom it may concern:

Be it known that I, CHARLES P. STEINMETZ, a citizen of the United States, residing at Schenectady, in the county of Schenectady, State of New York, have invented certain new and useful Improvements in Adjusting Compound-Wound Generators, (Case No. 2,785, division of my prior application, Serial No. 689,392, filed August 24, 1898,) of which the following is a specification.

The magnetic characteristic or saturation curve of a dynamo-electric machine is always to a certain extent curved, for the reason that the magnetization does not increase at the same rate as the increase of magnetizing or exciting current. Since the external characteristic or load curve of a dynamo-electric machine is always to a certain extent dependent for its shape upon the magnetic, characteristic, or saturation curve of the magnetic circuit of the machine, it follows that the load-curve or external characteristic is correspondingly curved. Thus when compounding a self-exciting direct-current generator for constant potential the voltage at half-load will be higher than at no load and at full load. In a similar manner when overcompounding such a machine by the use of a series field the ampere-turns of which are proportial to the load the voltage does not rise proportionally to the increase in load, but rises at a decreasing rate corresponding to the decreasing rate of increase of flux in the magnetic circuit. The voltage thus rises more from no load to half-load than from half-load to full load. It is the purpose of my invention to compensate for this variation in voltage due to the variation in permeability of the magnetic circuit, and I accomplish the result by varying the field magnetomotive force or forces at a rate greater than the rate of variation of load.

I believe myself to be the first to accomplish the result described, and although the various means devised by me and disclosed in this application operate without the aid of moving parts I nevertheless deem my invention a generic one and broad enough to include the use of automatically-actuated moving parts for the purpose described.

I have described in the specification and illustrated in the accompanying drawings several modes of carrying out my invention; but I do not wish to be understood as limiting myself specifically to any one of the means described, but consider my invention to cover, broadly, the idea of varying the exciting power of a magnetizing coil or coils of a dynamo-electric machine at a rate greater than the rate of change of load.

Figure 1 illustrates one mode of carrying out my invention, and Figs. 2 to 5, inclusive, show modified forms of the same.

In Fig. 1 I have shown my invention as applied to a self-exciting direct-current dynamo-electric machine having series and shunt coils. In order to straighten the external characteristic of the machine, it is necessary to increase the ampere-turns of the series winding at a rate greater than the increase of load on the machine. This result I accomplish in the present instance by shunting the series coil with a resistance having a temperature coefficient greater than that of the series coil—in other words, by a device the resistance of which increases with increase of current faster than the resistance of the series coil increases under similar conditions. If, as is usually the case, the series coil is formed of copper, I may employ iron as the material of which to form the shunt about the series coil, though it is obvious that the use of any other material is equally within the scope of my invention.

In the drawings, 1 represents the armature of the direct-current dynamo-electric machine. Connected in series therewith in the usual manner is the series exciting-coil 2. Shunted around the series coil is the variable resistance-coil 3 of the character described—that is to say, having a temperature coefficient higher than that of the series coil. This resistance is arranged to be varied simply for the purpose of initial adjustment, and it is not in general intended to be altered during the normal operation of the machine, although, if desired, such use is not prohibited. For this purpose a switch-arm 9, with coöperating contacts, may be employed. In shunt with the brushes in the usual manner is the shunt-exciting coil 4, having in series therewith the usual variable regulating-resistance 5.

In the operation of the form of my invention described it will be obvious that as the current supplied either to or from the machine increases the current through the series coil and the resistance in shunt thereto will divide in certain proportions. As the current through the machine increases the branch currents through the series coil 2 and its shunted resistance 3 increase. Owing to the fact, however, that the resistance of the shunt 3 increases with increase of current faster than the resistance of series coil 2, it follows that a greater proportion of current will pass through the series coil at higher values of load than at lower. By suitably adjusting the resistance of the shunt 3 a value may be found such that the current passing through the series coil 2 increases faster than the load by an amount just sufficient to compensate for the drop in voltage due to the decreasing permeability of the magnetic circuit. The load-curve thus becomes a straight line.

In Fig. 2 is shown a somewhat-different arrangement for accomplishing the same purpose. As before, 1 denotes the armature of a dynamo-electric machine, around the brushes of which is connected the shunt-winding 4. In series with the armature is a series exciting-coil 2. In order to increase the ampere-turns of the series field faster than the increase of load, I place in series with said coil a counter-electromotive-force device 6, the counter electromotive force of which increases at a rate less than proportional to the current passing through said device. For this purpose I preferably employ polarization-cells or a suitable number of elements of a storage battery. The electromotive force consumed in passing current through a device of this character is composed of two quantities. One is the counter electromotive force proper of the device and is sensibly constant through considerable variations of current. The other is the electromotive force consumed by the resistance of the device, and this is proportional to the current. It consequently follows that the electromotive force consumed in the counter-electromotive-force device is less than proportional to the current passing through the same.

Referring again to Fig. 2, it will be noted that the series coil 2 and the counter-electromotive-force device 6 are shunted by the resistance 7. For the present purpose this resistance may preferably have as low a temperature coefficient as possible, so as to remain practically constant with changes of current. The mode of operation will be apparent from what has been said. The current passing either to or from the machine will divide, part going through the series coil and the counter-electromotive-force device, the other part going through the shunt about the same. Since the resistance of the shunt 7 is nearly constant, the drop of potential across the same will be almost exactly proportional to the current passing. With respect to the series coil, however, the state of affairs is different. The electromotive force lost in passing the current through the same varies with the current, being less in proportion when the current is large than when it is small. It will be seen, therefore, that the ratio in which current will divide between the series coil and the shunt 7 will vary with the load. A greater proportion of the current will pass through the series coil at heavy loads than at light ones, and thus compensate for the drop in potential due to the curving magnetic characteristic of the machine.

In Fig. 3 is shown another modification in the embodiment of my invention. In this case, as in the others, 1 represents the armature of a dynamo-electric machine, shunted around the brushes of which is the shunt-exciting coil 4. The series magnetizing-coil is shown at 2, and this coil has in series therewith a resistance 8, having a negative temperature coefficient—that is, a resistance which decreases in value with increase in temperature or, what amounts to the same thing, with increase of current passing through it. The resistance 7 is shunted around the series coil 2 and the resistance 8. The shunt-resistance 7 should have as low a temperature coefficient as possible, so as to vary but little in resistance with the varying value of current passing through it. In the operation of the machine as thus arranged current will divide between the two branch circuits described in inverse proportion to their respective resistances. Owing to the fact that the resistance 8 decreases with increase of current while the resistance of the shunt 7 remains sensibly constant, it follows that a greater proportion of current will pass through the series field-coil at heavy loads than at light loads, and thus obtain the same result accomplished by the two modifications of my invention already described. I preferably employ carbon as the material from which to construct the resistance 8. It will be evident that instead of employing a resistance 8, having a negative temperature coefficient, it will be sufficient if I employ materials having temperature coefficients such that the ratio between the resistance 7 and the combined resistance of the series coil and its resistance 8 becomes greater as the load increases. I find it convenient to construct the shunt-resistance 7 of German silver.

Although in connection with Figs. 2 and 3 of the drawings I have described certain modifications of my invention in which the regulating shunt resistance 7 has a low-temperature coefficient, it is evident that the same result may be produced, but in a greater degree, by making the regulating resistance 7 of material having a high-temperature coefficient, since the conditions requisite to carrying out my invention are effected so long as the current through the series coil is caused to vary at a rate greater than the variation of load on the machine.

My invention is to be sharply distinguished from the commonly-used structure in which a German-silver shunt is placed about the series winding of a compound machine in order to initially adjust its magnetizing power. In this case the mode of action is radically different from that of my invention, since a smaller instead of a larger proportion of the total current will pass through the series coil at heavy loads than at light loads, thus tending to destroy rather than help the regulation.

Instead of relying upon any particular one of the instrumentalities described I may, if deemed expedient, employ them in conjunction, as illustrated in Fig. 4. In this figure 1 designates, as before, the armature of a dynamo-electric machine having the shunt field-winding 4 and series compounding-coil 2. A resistance 8, of negative temperature coefficient, and polarization-cells 6 are included in series with each other and with the series coil 2. A resistance of iron or other material of high temperature coefficient forms a derived circuit in parallel with the circuit, including the series coil 2, resistance 8, and polarization-cells 6. From what has already been said in connection with the other figures of the drawings it will readily be seen that as the load on the machine increases the current through the series compounding-coil will also increase, but at a rate greater than the rate of increase of load.

Still another application of my invention is found in the case where a shunt-wound generator is used as a constant-current machine to supply translating devices in series, in which case the machine is worked within the range included by the bend in its characteristic curve. With machines specially designed to be operated in this manner the voltage may be varied through a considerable range without varying the current to any great extent. So long as saturation is not reached or closely approached the voltage at the terminals of the machine is proportional to the excitation and the excitation is approximately proportional to the resistance of the work-circuit. As the load increases, however, the magnetization of the field approaches saturation, so that the voltage of the machine does not increase in proportion to the current through the shunt-field, and the current in the work-circuit therefore decreases instead of remaining constant, as desired. To compensate for the effect of saturation in the case described, I insert in the shunt-field a resistance having a high negative temperature coefficient the effect of which is to cause an increase of current through the shunt-winding more than proportional to the increase of electromotive force at the terminals of the machine. By a suitable proportioning of parts the effect of changing permeability of the magnetic circuit of the machine may thus be compensated for.

Fig. 5 is a diagrammatic illustration of the form of my invention just described, in which 1 represents the armature of a shunt-wound generator having the field-winding 12. In series with said winding is a resistance 10, having a negative temperature coefficient. This resistance is preferably formed of carbon. The external circuit contains lamps or other translating devices 11 in series. The current through the translating devices 11 is maintained constant in the manner described.

It will be evident to those skilled in the art that my invention is not limited to dynamo-electric generators, but is equally applicable in connection with the speed regulation of motors. It will therefore be understood that when I speak of a "load" on a dynamo-electric machine the term is intended to include both the electrical load when the machine is used as a generator and the mechanical load when the machine is used as a motor.

What I claim as new, and desire to secure by Letters Patent of the United States, is—

1. In a dynamo-electric machine, the combination of a winding on the field-magnet, and a shunt about said winding having a higher temperature coefficient than said winding.

2. In a dynamo-electric machine, a divided circuit including in one of its branches a winding on the field of the machine, and so constituted that with variation of load on the machine the rate of change of current in the branch including the winding is greater than the rate of change of current in the other branch.

3. In a dynamo-electric machine, a divided circuit traversed by the main current of the machine, and including in one of its branches a winding on the field of the machine, the divided circuit being so constituted that with variations of load on the machine the rate of change of current in the branch including the winding is greater than the rate of change of current in the other branch.

4. A dynamo-electric machine having a field-exciting coil and means for automatically diverting current therefrom at a rate less than the rate of variation of load on the machine.

5. A dynamo-electric machine having series and shunt field-exciting coils, and means for automatically varying the current passing through the series coil at a rate greater than the rate of change of load on the machine.

6. The combination of a compound-wound dynamo-electric machine and a resistance of iron in shunt about the series coil.

7. The combination of a compound-wound dynamo-electric machine, and a shunt about the series coil having a higher temperature coefficient than that of the coil.

8. In a dynamo-electric machine, the combination of a field-exciting coil having in se-

ries therewith a resistance of negative temperature coefficient, and a shunt about said coil and resistance.

9. In a dynamo-electric machine, the combination of a field-exciting coil, a carbon resistance in series therewith, and a shunt about said coil and resistance.

10. In a dynamo-electric machine, the combination of a field-exciting coil, a polarization-cell in series with said coil, and a shunt about said coil and polarization-cell.

In witness whereof I have hereunto set my hand this 22d day of March, 1902.

CHARLES P. STEINMETZ.

Witnesses:
BENJAMIN B. HULL,
HELEN ORFORD.