(No Model.) 3 Sheets—Sheet 1.

F. P. IDE.

REGULATION OF ALTERNATING GENERATORS.

No. 549,644. Patented Nov. 12, 1895.

Fig. 1.

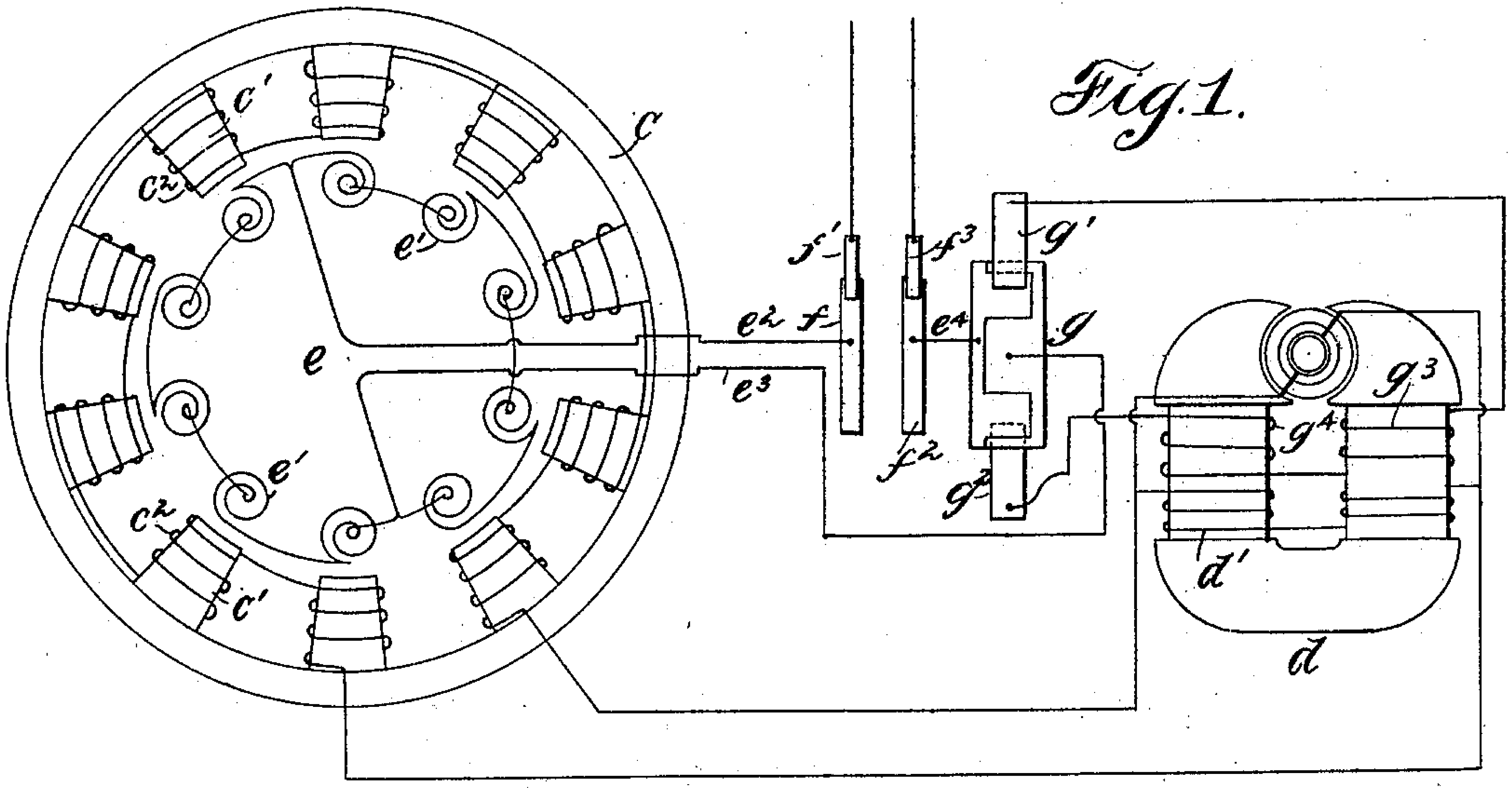


Fig. 2.

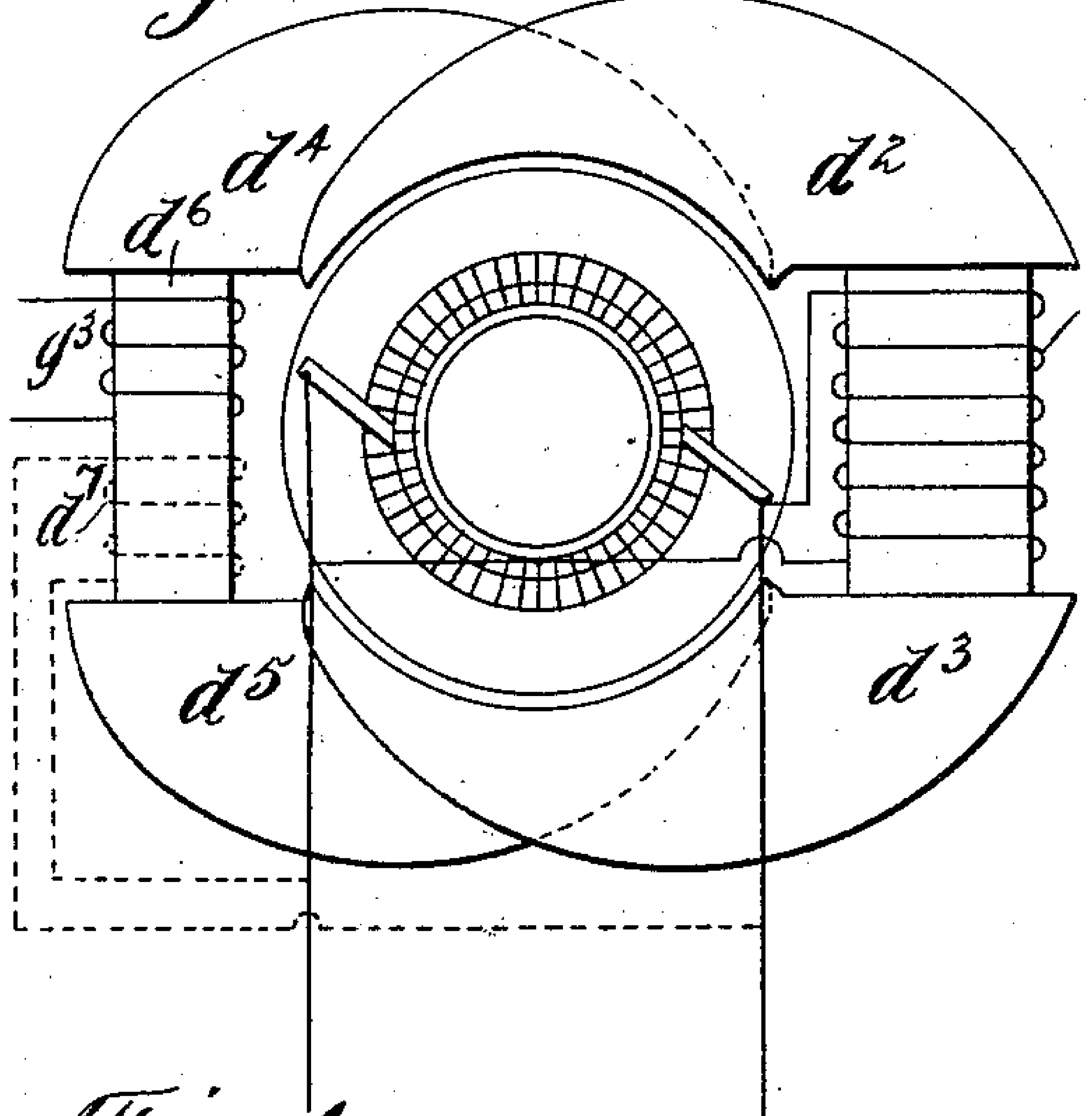


Fig. 3.

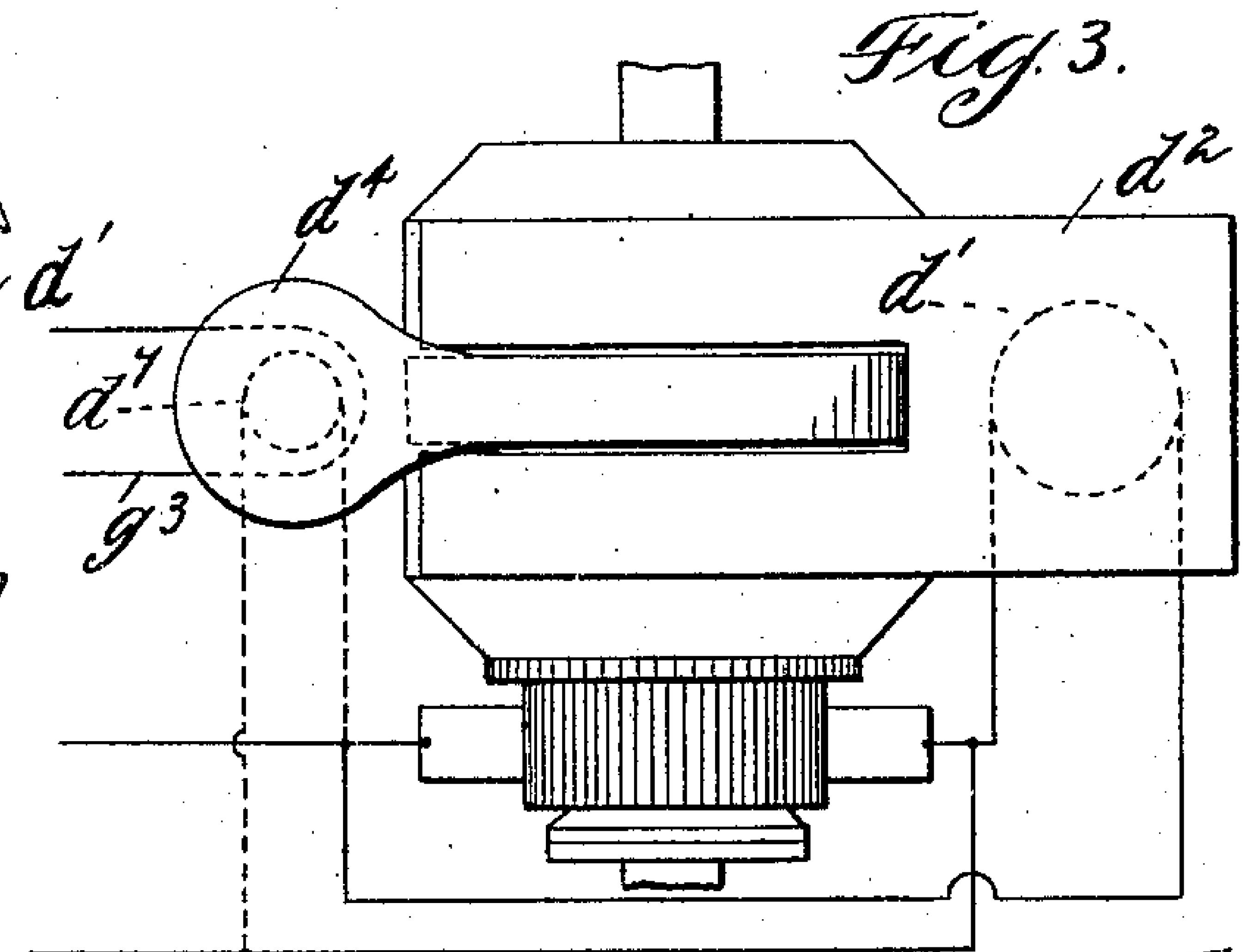


Fig. 4.

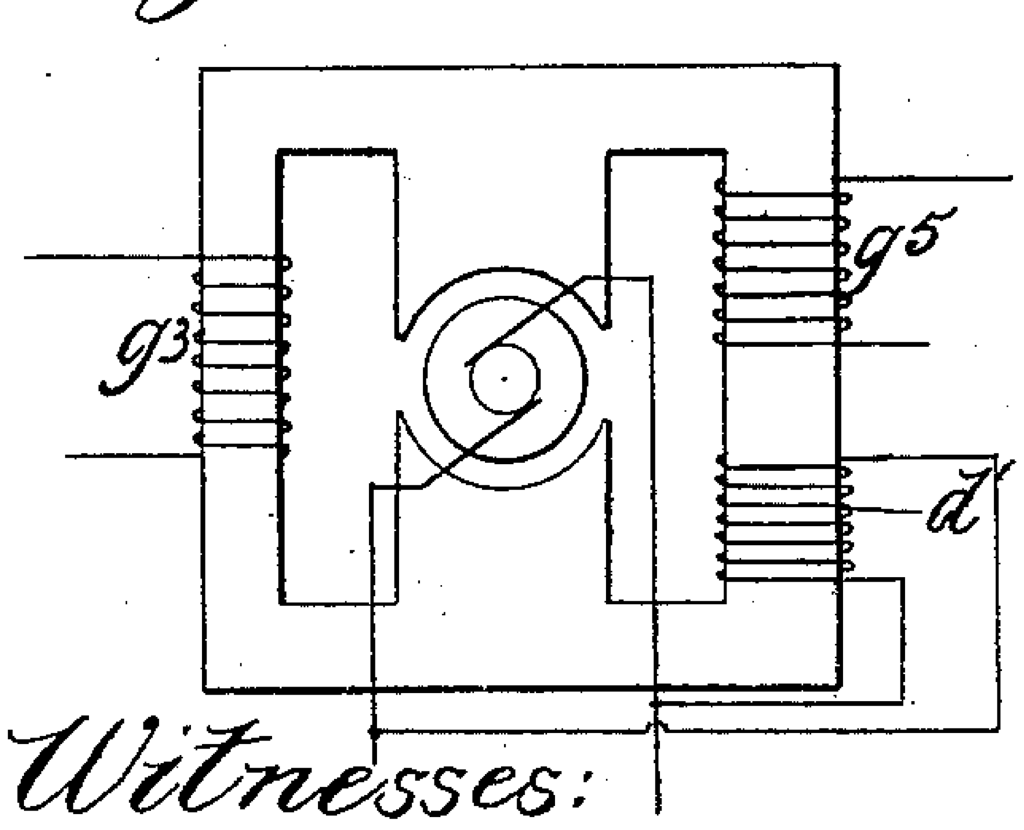
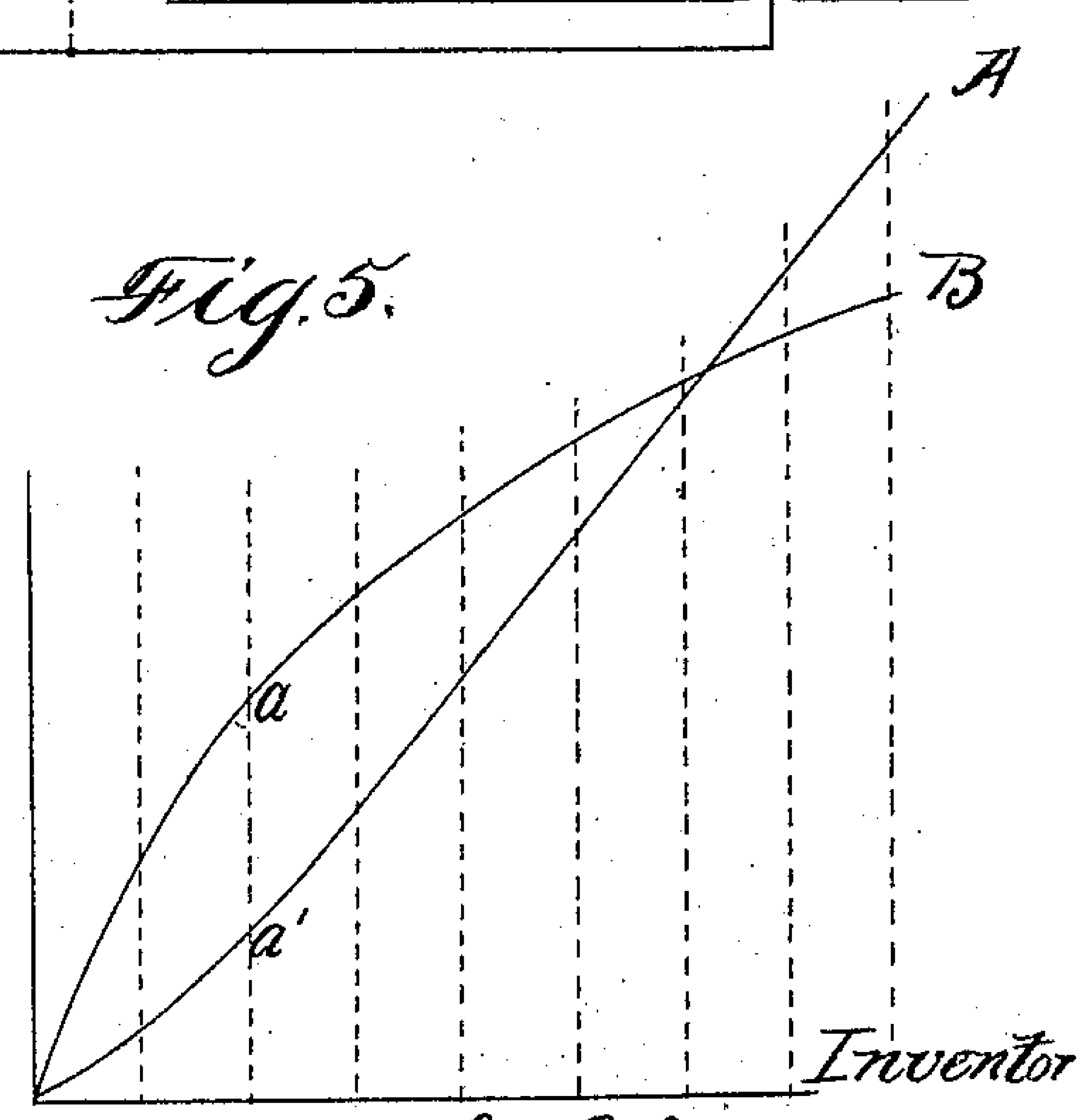


Fig. 5.



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(No Model.) 3 Sheets—Sheet 2.

F. P. IDE.

REGULATION OF ALTERNATING GENERATORS.

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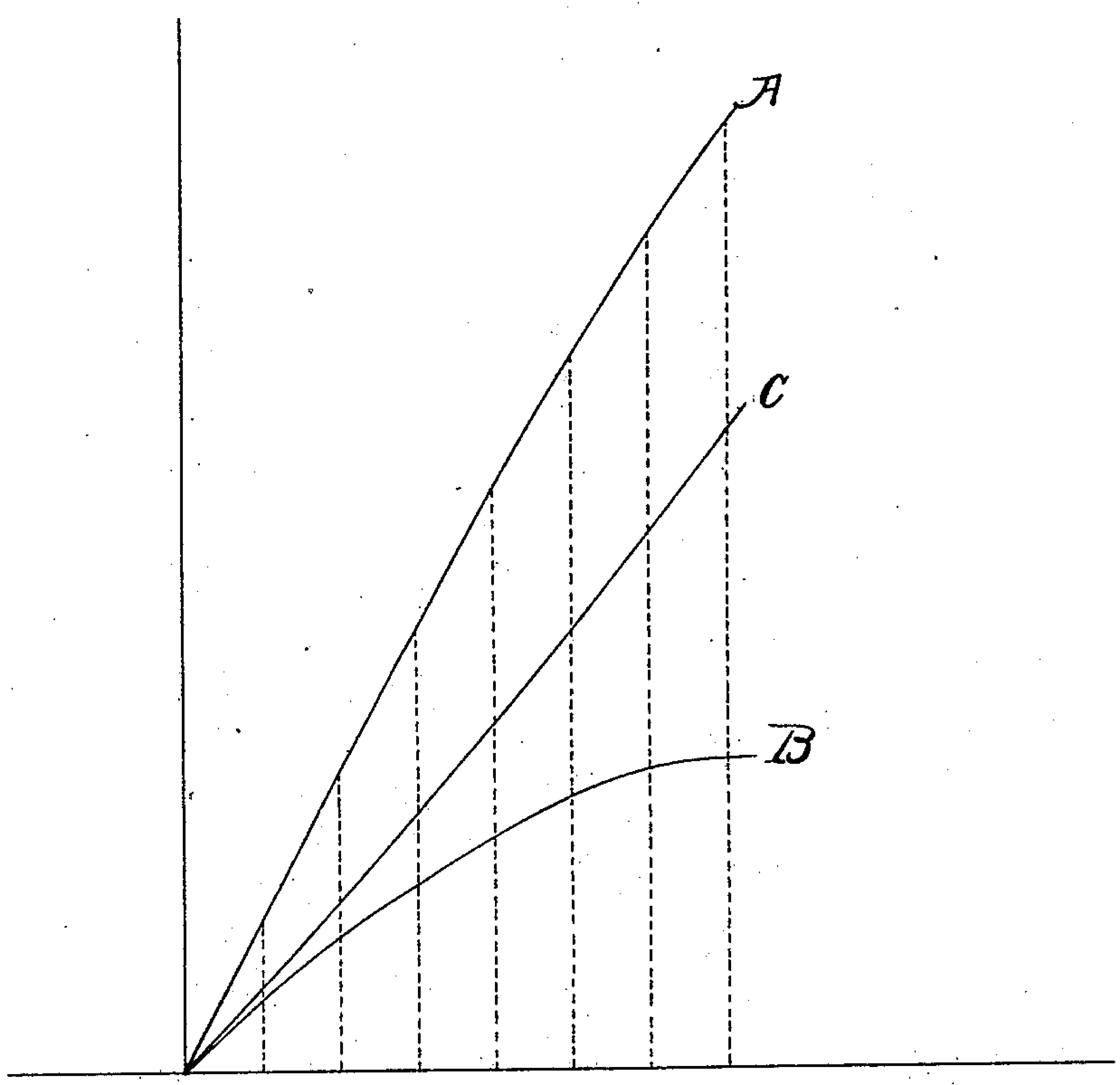

Fig. 6.

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(No Model.) 3 Sheets—Sheet 3.

F. P. IDE.

REGULATION OF ALTERNATING GENERATORS.

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Fig. 7.

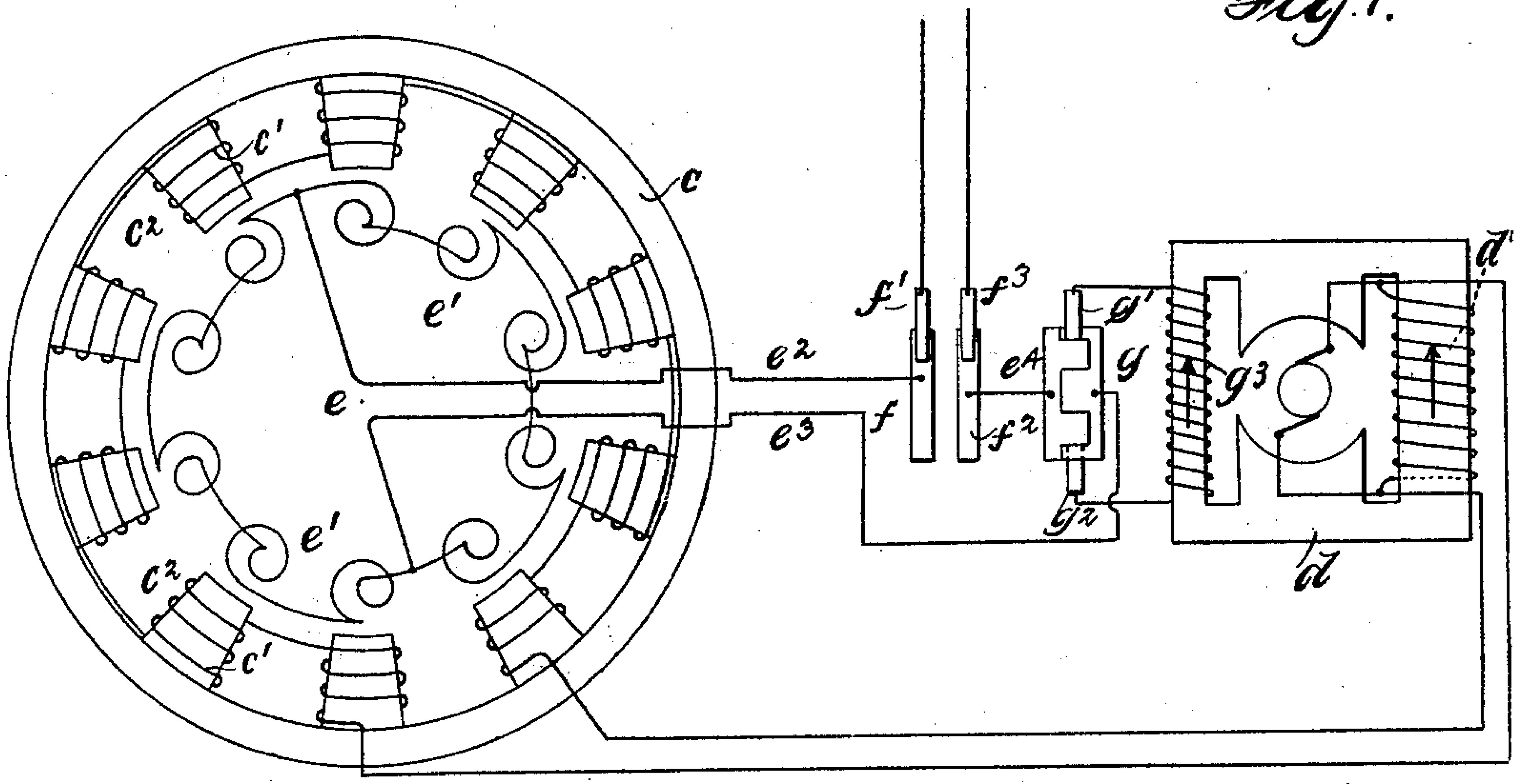
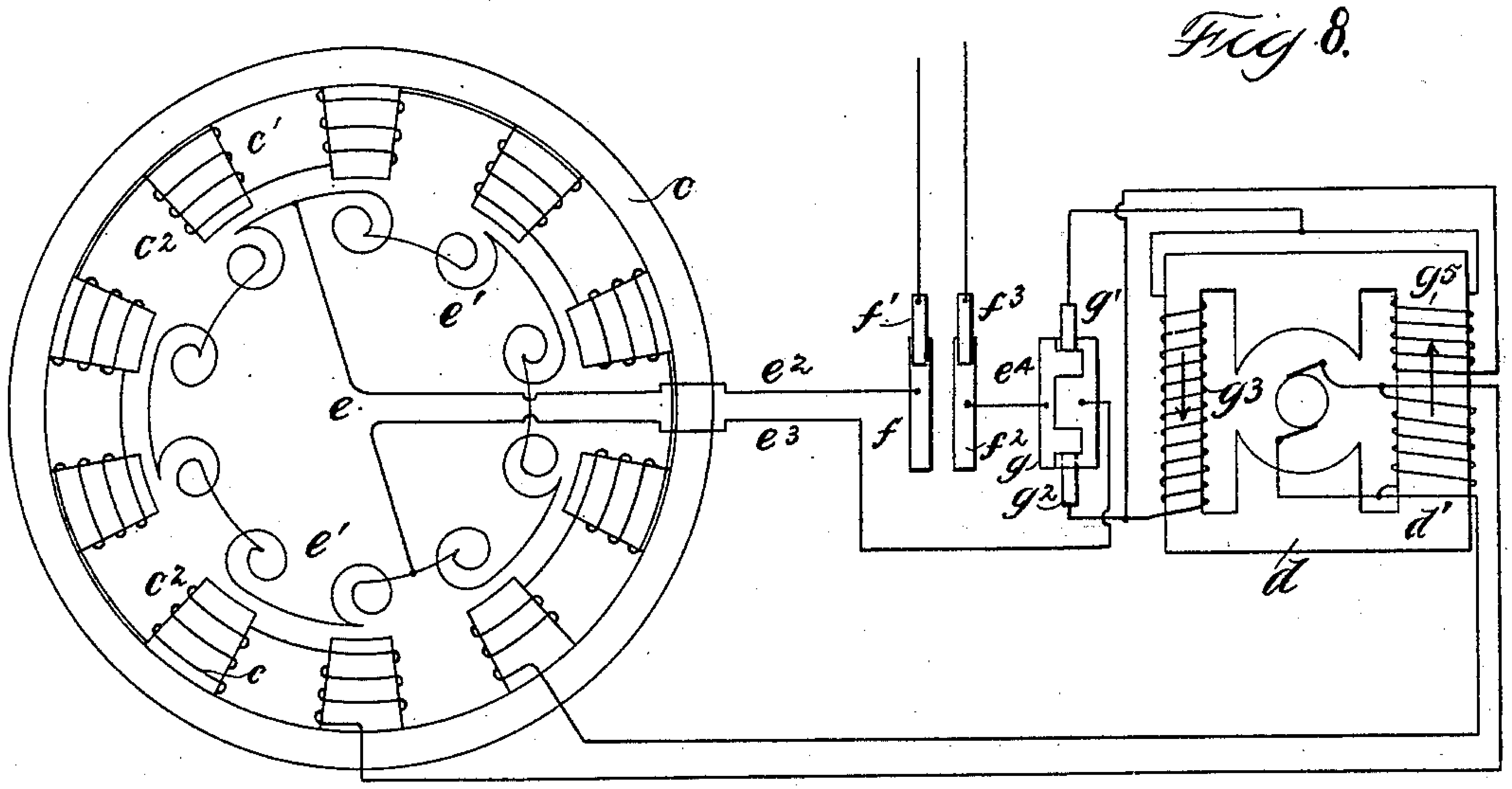


Fig. 8.



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UNITED STATES PATENT OFFICE.

FRANCIS P. IDE, OF EAU CLAIRE, WISCONSIN.

REGULATION OF ALTERNATING GENERATORS.

SPECIFICATION forming part of Letters Patent No. 549,644, dated November 12, 1895.

Application filed April 6, 1895. Serial No. 544,753. (No model.)

To all whom it may concern:

Be it known that I, FRANCIS P. IDE, a citizen of the United States, residing at Eau Claire, in the county of Eau Claire and State of Wisconsin, have invented a certain new and useful Improvement in the Regulation of Alternating-Current Generators, (Case No. 1,) of which the following is a full, clear, concise, and exact description, reference being had to the accompanying drawings, forming a part of this specification.

My invention relates to the regulation of alternating-current generators, and its object is to improve the construction of the alternating-current apparatus whereby more nearly ideal regulation may be obtained than has been possible heretofore.

Alternating-current dynamos have been constructed having a number of polar projections alternating in polarity, in front of which the armature is adapted to rotate, the field-coils being supplied by a continuous current from a separate machine or exciter. In machines as thus constructed it is impossible to maintain a constant potential at the terminals of the alternating-current machine under varying loads, for although the field is maintained constant the increased armature reaction, due to the flow of an increased current as the output of the machine is increased, cuts down the effective field strength, this, with other causes, reducing the potential of the machine. It has been proposed to compound machines as thus constructed to automatically vary the field strength with the change of current-output, thus compensating for the increased armature reaction. To accomplish this result, a rectifier has been interposed in the circuit of the armature adapted to change the alternating current induced in the armature into a direct or pulsating current, the current thus rectified being passed through field-coils provided upon a few or all of the field-poles, the current being then transformed back into an alternating current and conducted to the line. The coils thus traversed by the rectified current are in series with the load and act as the series winding of a compound-wound machine to increase the field as the current-output of the machine is increased. Instead of providing coils for the main field adapted to be traversed by the rectified current, additional field-coils may be provided upon the exciter, through which the rectified current is adapted to be passed, so that as the output of the generator is increased the field of the exciter is correspondingly increased, thus increasing the potential of the exciter and causing an increased current to flow through the field-coils of the generator. By providing the field-coils for the rectified current upon the exciter instead of upon the generator itself the apparatus may be greatly simplified, since it is necessary to provide only one or two field-coils upon the exciter, whereas by the former method it was necessary for best results to provide a coil for the rectified current upon each of the several pole-pieces of the generator, usually ten or more in number. As the series coil of the exciter consists of but few turns and as the iron which it magnetizes is a small mass, the tendency to spark at the rectifying-commutator is reduced proportionately, and it is possible to rectify the entire current of the generator without the slightest sparking and without the use of shunts either around the rectifier or around the series coil to act as a discharge-path. As the rectified current is pulsatory in character, varying from zero to a maximum at each pulsation, the rectified current meets considerable inductive resistance in passing through the field-coils, and when the rectified current is passed through a few coils upon the exciter the field-magnet of which may be made of laminated sheets or bundles of iron wire, the inductive resistance is a great deal less than that encountered by the rectified current in passing through the several coils on the generator. As the energizing action of the rectified current is applied to the exciter-field, such action is many times multiplied through the resulting current-output of the exciter. The magnetizing force of the generator-field is multiplied in like proportion, and there is therefore an abundance of magnetizing force to produce any desired result, a sensitive regulation being thus permitted.

A further advantage arising from the employment of the coils of the rectified current upon the exciter is that a special form of exciter, which forms a feature of my invention, may be employed whereby practically perfect ideal regulation can be secured. With an exciter of the ordinary type it will be found that for equal increments of current applied to the magnetizing-coil the potential of the exciter is not increased by the same increments, but that equal increments of magnetizing power produce continuously-diminishing increments of potential. If the increments of magnetizing force be plotted as abscissas and the resulting exciter potential as ordinates, the resulting curve will be concave to the axis of abscissas, thus indicating that for equal increments of magnetizing force the potential of the exciter increases at a diminishing rate. If the curve of exciter potential for ideal regulation be plotted, however, it will be found that the curve is convex to the axis of the abscissas, lying below the former curve for low magnetizing force and rising above it as the magnetizing force increases, thus indicating that for small loads the exciter potential is greater than is necessary for ideal regulation, while at higher loads the exciter potential is less than that necessary for ideal regulation.

I have been able by means of my invention to cut down the exciter potential for small loads and to increase the potential for large loads, whereby the potential of the exciter is caused to follow the curve for ideal regulation within such narrow limits as to make regulation ideal for all practical purposes. To accomplish this, I provide a magnetic circuit adapted to act as a shunt about the armature of the exciter, whereby for small loads a portion of the main field of the exciter is shunted around the armature, thus reducing the field in which the armature rotates and cutting down the potential of the exciter for small loads. By means of the coils traversed by the rectified current I increase the flux through the armature through the agency of the rectified current, thus causing the field of the exciter to vary in such a manner as to cause the potential of the exciter to practically follow the ideal curve.

I will describe my invention more in particular by reference to the accompanying drawings, in which—

Figure 1 is a diagram illustrating an alternating-current generator and an exciter equipped after the manner of my invention. Fig. 2 is a view in elevation of an exciter constructed in accordance with my invention, the windings being illustrated diagrammatically. Fig. 3 is an end view thereof. Fig. 4 is a view of a modification. Fig. 5 is a diagram illustrating generator loads as abscissas and exciter potentials as ordinates, the curve A defining the exciter potential necessary for ideal regulation under changing loads on the generator, while curve B defines the relation as existing in a simple series shunt or compound dynamo used as an exciter with a rectified current-coil but without a shunting-core. Fig. 6 is a diagram illustrating the distribution of the magnetic field in the modification shown in Fig. 4. Fig. 7 is a diagram illustrating the manner of connecting the exciter shown in Fig. 2 with the generator. Fig. 8 is a similar view showing the manner of connecting the exciter shown in Fig. 4 with the generator.

Like letters refer to like parts in the several views.

As illustrated in Fig. 1, the generator *c* is provided with a number of polar projections *c' c'*, in front of which the armature is adapted to rotate. Field-coils c^2 c^2 are provided upon the polar projection *c'* and connected with the brushes of the exciter *d*. The exciter *d* is provided with a shunt (or series) field winding *d'*. The armature *e* of the generator is provided with coils *e' e'*, the armature-circuit being connected with a conductor e^2, which extends to a collecting-ring *f*, upon which bears a brush *f'*, connected with one side of the line. The armature-circuit is also connected with conductor e^3, which extends to one side of the rectifying-commutator *g*, the armature-circuit being thus connected with the alternate segments of the rectifier. The other segments of the rectifier are connected by conductor e^4 with collecting-ring f^2, upon which bears the brush f^3, connected with the opposite side of the line. Upon the rectifier *g* rest brushes g' g^2, which are connected with the field-coils g^3 g^4, provided upon the exciter *d*.

The alternating current generated in the armature passes through the rectifier *g*, whereby the alternating current is transformed into an intermittent direct current. The rectified current then passes through the coils g^3 g^4 upon the exciter back to the rectifier *g*, which converts the intermittent direct current into an alternating current, which passes to the ring f^2 and thence to the line, returning to the ring *f* and passing back to the armature. The current generated by the exciter *d* passes through the field-coils c^2 to maintain the field excitation of the generator. As more load is thrown upon the generator—that is, as a greater current flows through the working circuit—the rectified current flowing through the coils g^3 g^4 increases, thus increasing the field of the exciter proportionately to the increase of current in the working circuit, and the potential of the exciter is increased to cause a greater flow of current through the field-coils c^2, thereby increasing the field excitation of the generator to maintain the increased current-output. When the current-output is decreased, the field excitation of the exciter is correspondingly diminished, thus decreasing the exciter potential and thereby decreasing the field excitation of the generator.

If exciter magnetizing force or ampère turns be plotted as abscissas and exciter voltages as ordinates, some such curve as curve B, Fig. 5, will be obtained, the curve being concave to the axle of abscissas, thus indicating that for equal increments of current applied to the field the potentials increase at a decreasing rate. If a similar curve be plotted to represent the potential of the exciter for the same equal increments, in order that ideal regulation may result, a curve similar to curve A will be obtained. The curve is convex to the axis of abscissas, thus indicating that the potential of the exciter should increase at an increasing rate instead of a decreasing rate, as actually obtained.

In order to cause the potential of the exciter to follow the curve A it is necessary to reduce the potential of the exciter for small loads and to increase the potential for large loads.

In Figs. 2 and 3 I have illustrated an exciter provided with a shunt (or series) coil d' adapted to excite the field. The pole-pieces d^2 d^3 are slotted or cut away at the middle and auxiliary pole-pieces d^4 d^5 are inserted therein, an air-space being left between the two pairs of pole-pieces. The coil g^3, adapted to be traversed by the rectified current, is wound about the core d^6, uniting the pole-pieces d^4 d^5. The pole-pieces d^4 d^5 and the core d^6 thus form a magnetic shunt about the armature, through which a portion of the field generated by the main winding d' is adapted to pass. The coil g^3 is wound to oppose the lines of force thus shunted, so that as the current through the coil g^3 is increased a greater number of the lines of force are reverted through the armature. Thus for small loads a considerable portion of the field is shunted past the armature, so that the potential of the exciter falls below that which it would attain were the magnetic shunt absent—that is, if in the absence of the shunt the potential were that indicated by the point a on the curve B, Fig. 5, due to the presence of the magnetic shunt the potential would fall to that indicated by the point a' upon the curve A. If the load upon the generator is increased, increased current will flow through the coil g^3, which is in series with the load, and a portion of the shunted lines of force will be reverted through the armature, thus increasing the potential of the exciter. Thus while small loads are on the generator the coil g^3 acts to merely revert the shunted lines of force through the armature; but as the load increases the coil g^3 acts to positively direct lines of force through the armature. By this arrangement I am able to secure practically ideal regulation, the curve of the exciter potential being caused to follow the curve A instead of the curve B, as heretofore. Instead of providing slots in the pole-pieces d^2 d^3 for the reception of the pole-pieces d^4 d^5, the auxiliary pole-piece may be placed to one side of the main pole-piece or the two sets of pole-pieces be cast in one piece. In the latter case, due to the absence of the air-space between the two sets of pole-pieces, it will be found desirable to place an auxiliary coil d^7 (shunt or series) upon the magnetic shunt, which may be adjusted to permit the desired number of lines of force to be shunted past the armature. It may also be found desirable to employ the auxiliary coil d^7 when the air-spaces are present.

In Fig. 4 I have illustrated a modification in which the coil g^3, placed around the shunt of the magnetic field, is adapted to aid the shunting of the field around the armature instead of opposing it, as shown in Fig. 2. Around the main field is provided a coil g^5, adapted to be traversed by the rectified currents. The main field of the exciter is thus increased as the load increases, due to the coil g^5; but the current through the coil g^3 being likewise increased the number of lines of force shunted past the armature is also increased. The shunt magnetic circuit is so proportioned that the metal composing it becomes gradually saturated, so that equal increments of current through the coil g^3 have a decreasing shunting effect upon the lines of force. The field through the armature is thus caused to increase at an increasing rate.

In Fig. 6 is illustrated graphically the distribution of the magnetic field of the above-described modification. The curve A is obtained by plotting magnetizing current as abscissas and the total number of magnetic lines in the main exciter field as ordinates, the curve A thus indicating the relation between the total number of magnetic lines in the main exciter field and the exciting-current. Curve B is obtained by plotting magnetizing current as abscissas and the number of magnetic lines in the magnetic shunt as ordinates, curve B thus indicating the relation between the number of magnetic lines in the magnetic shunt and the exciting-current. The magnetic field in which the armature revolves will be that produced by the main exciter field reduced by that of the magnetic shunt—that is, the curve C is obtained by subtracting the ordinates of the curve B from the ordinates of the curve A, the curve C thus representing the field in which the armature rotates. It will be observed that the main exciter field, as shown by the curve A, is so proportioned that it does not produce saturation throughout the entire working range, while the magnetic shunt, as shown by curve B, is of such proportion that it reaches saturation at some desired point in its working range. The curve C is thus modified, so as to be convex to the axis of X, which, as shown in connection with Fig. 5, is the curve for ideal regulation, the strength of the field through the exciter armature thus increasing at an increasing rate.

In Fig. 7 I have illustrated the exciter shown in Fig. 2 connected with the generator, the field-coil d' of the exciter being connected either in shunt or in series with the working circuit of the exciter, a shunt connection being illustrated. The coil g^3 is connected in circuit with the rectifier and is traversed by the rectified currents, the coil g^3 being so wound relatively to the coil d' that the two coils act to direct lines of force through the armature in the same direction, as indicated by the arrows. Since the working circuit of the exciter is of practically constant resistance under all loads, the magnetizing power of the coil d' gradually increases as the voltage of the exciter increases, the main field generated by the coil d' thus continuously increasing as the voltage of the exciter increases. Were the exciter subjected to the influence of the coil d' alone the voltage of the exciter would increase at a decreasing rate; but since a magnetic shunt is provided about the armature a portion of the lines of force that would otherwise pass through the armature at small loads is diverted through the magnetic shunt encircled by the coil g^3. As the current in the working circuit of the generator increases, the current traversing the coil g^3 increases and opposes the passage of the diverted lines of force and causes an increase of the number of lines of force passing through the armature. The two coils d' and g^3 thus act together to cause the number of lines of force passing through the armature and in consequence the voltage of the exciter to increase at an increasing rate. It will thus be observed that the voltage of the exciter depends upon three quantities: first, the lines of force generated by the coil d'; second, the lines of force generated by the coil g^3, and, third, the field diverted past the armature and passing through the magnetic shunt encircled by the coil g^3, the number of lines of force passing through the armature at any instant being equal to the sum of the lines of force generated by the coils d' and g^3, minus the number of lines of force diverted past the armature and passing through the magnetic shunt. The number of lines of force passing through the armature is thus caused to increase at an increasing rate, and in consequence the voltage of the exciter increases at an increasing rate.

In Fig. 8 I have illustrated the exciter shown in Fig. 4 connected with the generator, the coil d' being illustrated as connected in shunt with the working circuit of the exciter and being thus traversed by a current which increases as the voltage of the exciter increases. The coils g^3 and g^5, adapted to be traversed by the rectified current, are shown as connected in multiple, though they may be connected in series, as may be desired. The coil g^5 is wound to assist the coil d', so that the main magnetic field generated by the coils d' and g^5 increases at a decreasing rate, as explained in connection with Fig. 1, and in consequence the voltage of the exciter would increase at a decreasing rate were it not for the presence of the magnetic shunt encircled by the coil g^3. A portion of the magnetic lines of the main field are thus diverted past the armature at small loads. The coil g^3 is wound, as indicated by the arrow, to assist the diversion of the lines of force past the armature. The coil g^3 is most effective in assisting the diversion of the lines of force at small loads, and as the load increases and the point of saturation of the magnetic shunt is approached the coil g^3 has a less and less effect in diverting the lines of force past the armature, and in consequence the number of lines of force passing through the armature increases at an increasing rate and the voltage of the exciter increases at an increasing rate.

Having described my invention, what I claim as new, and desire to secure by Letters Patent, is—

1. The combination with an alternating current generator, of a continuous or direct current exciter adapted to energize the field of said generator, a rectifier for rectifying the alternating current of the generator, a shunt magnetic core for said exciter field coils provided upon the exciter adapted to be traversed by said rectified current, said field coils being arranged to coact with the main field coils of the exciter and with said shunt magnetic core to effect the reduction of the strength of the field for small loads and the increase of the strength for larger loads; substantially as described.

2. The combination with an alternating current generator, of a direct or continuous current exciter adapted to energize the field thereof, a rectifier for rectifying the alternating current, a shunt magnetic circuit about the armature of the exciter, and a field coil provided upon said shunt magnetic circuit adapted to be traversed by the rectified current; substantially as described.

3. The combination with an alternating current generator of a direct or continuous current exciter, adapted to energize the field thereof, a rectifier for rectifying the alternating current, a shunt magnetic circuit provided about the armature of the exciter, a field coil adapted to be traversed by the rectified current provided upon said shunt magnetic circuit and wound to oppose the field diverted through the shunt magnetic circuit; substantially as and for the purpose set forth.

4. The method of regulating the potential of an alternating current generator, which consists in energizing the field thereof by means of a continuous or direct current supplied by an exciter, rectifying the current produced by the generator, and then through the agency of said rectified current variably shunting lines of force around the armature, thereby effecting the reduction of the strength of the field for small loads and the increase of the strength for larger loads; substantially as described.

5. The method of regulating the potential of an alternating current generator, which consists in energizing the field of the generator by a continuous or direct current supplied by an exciter, rectifying the current of the generator, shunting a portion of the mag-

netic field of the exciter around the armature thereof, to cut down the field of the exciter for small loads, and subjecting the magnetic shunt to the influence of said rectified current to revert the shunted lines of force through the armature as the current output of the generator increases, and finally to assist the field coils of the exciter in producing a field through the armature; substantially as described.

In witness whereof I hereunto subscribe my name this 2d day of April, A. D. 1895.

FRANCIS P. IDE.

Witnesses:

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ROY W. IDE.