No. 613,206. Patented Oct. 25, 1898.

M. HUTIN & M. LEBLANC.

METHOD OF AND MEANS FOR SYNCHRONIZING.

(Application filed Dec. 30, 1897.)

(No Model.) 3 Sheets—Sheet I.

Fig. 1.

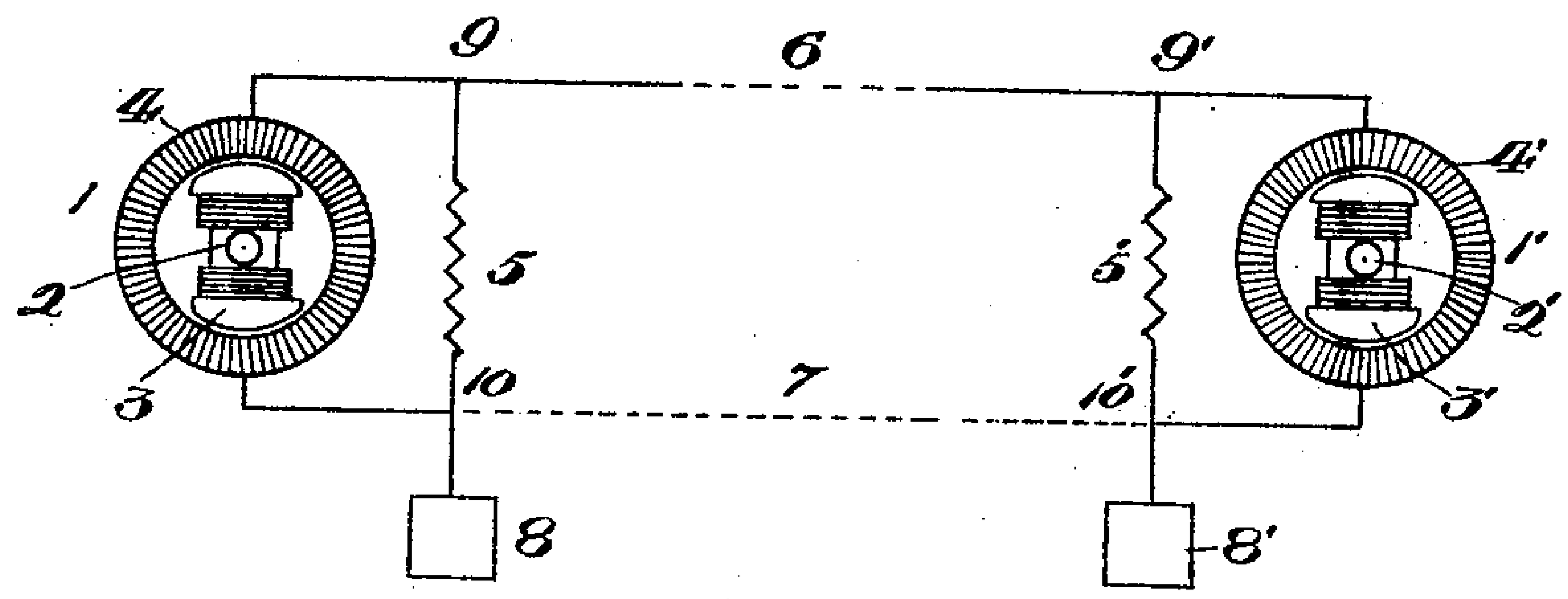

Fig. 2.

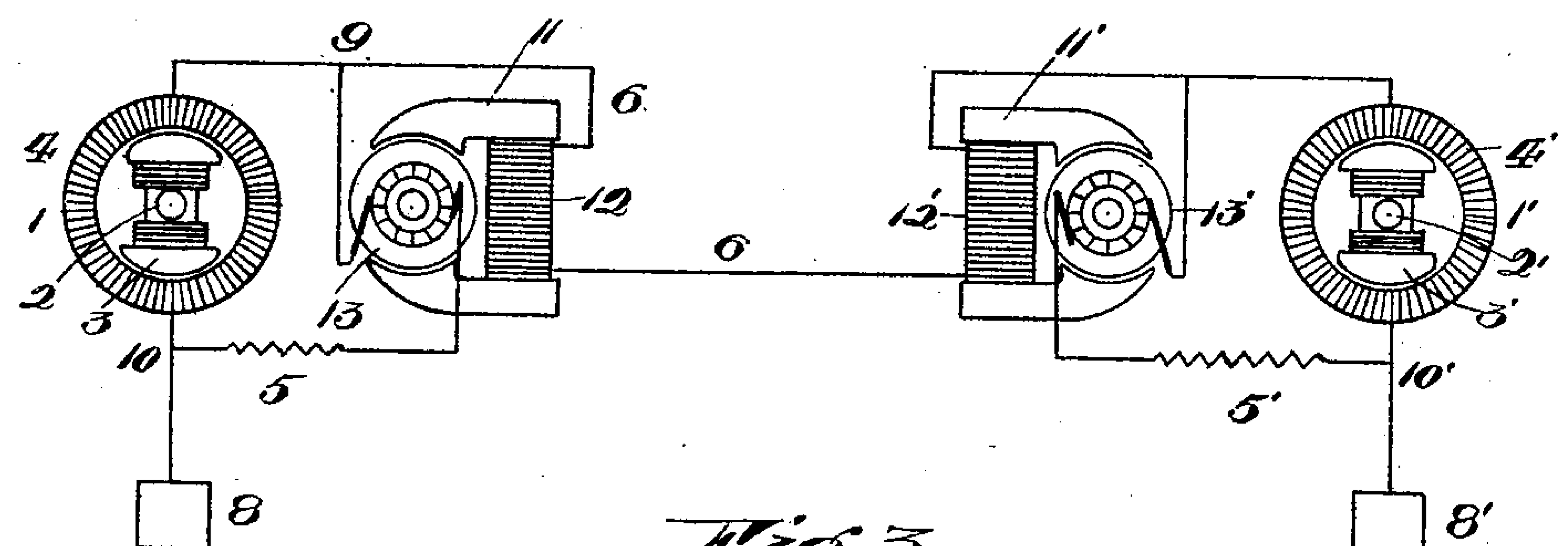

Fig. 3.

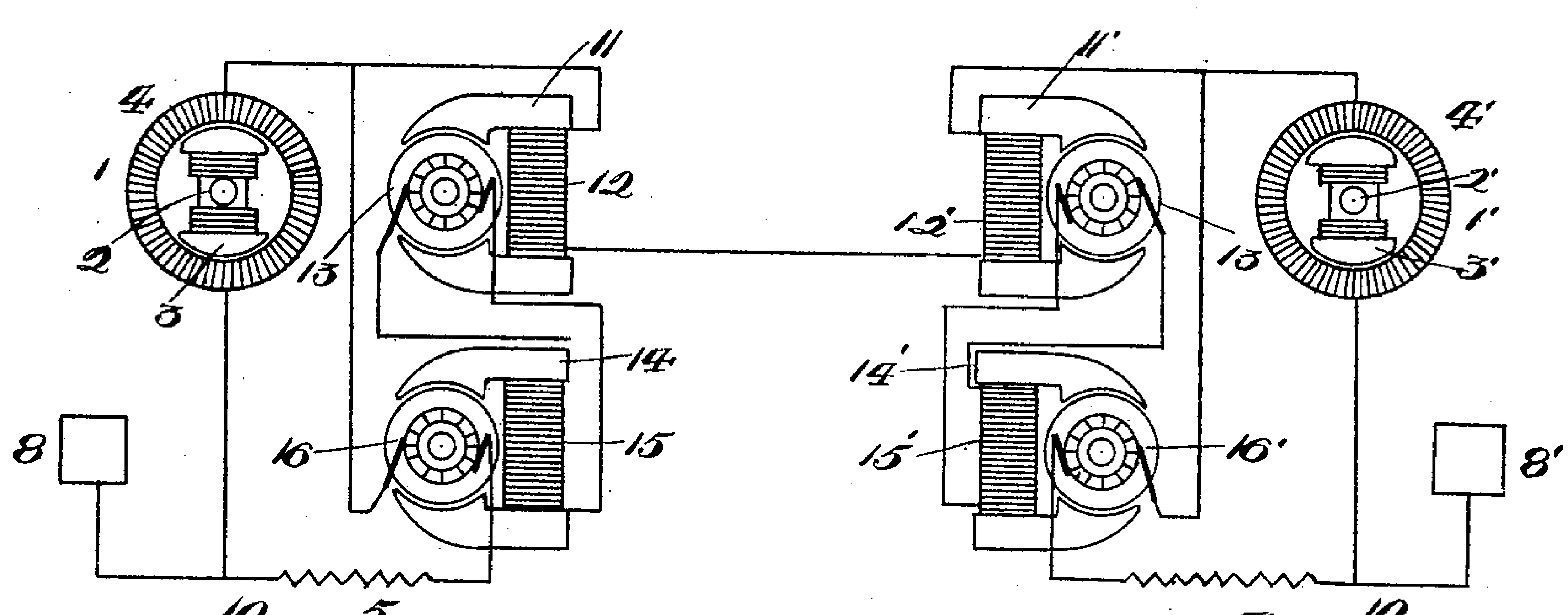

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Fig. 4.

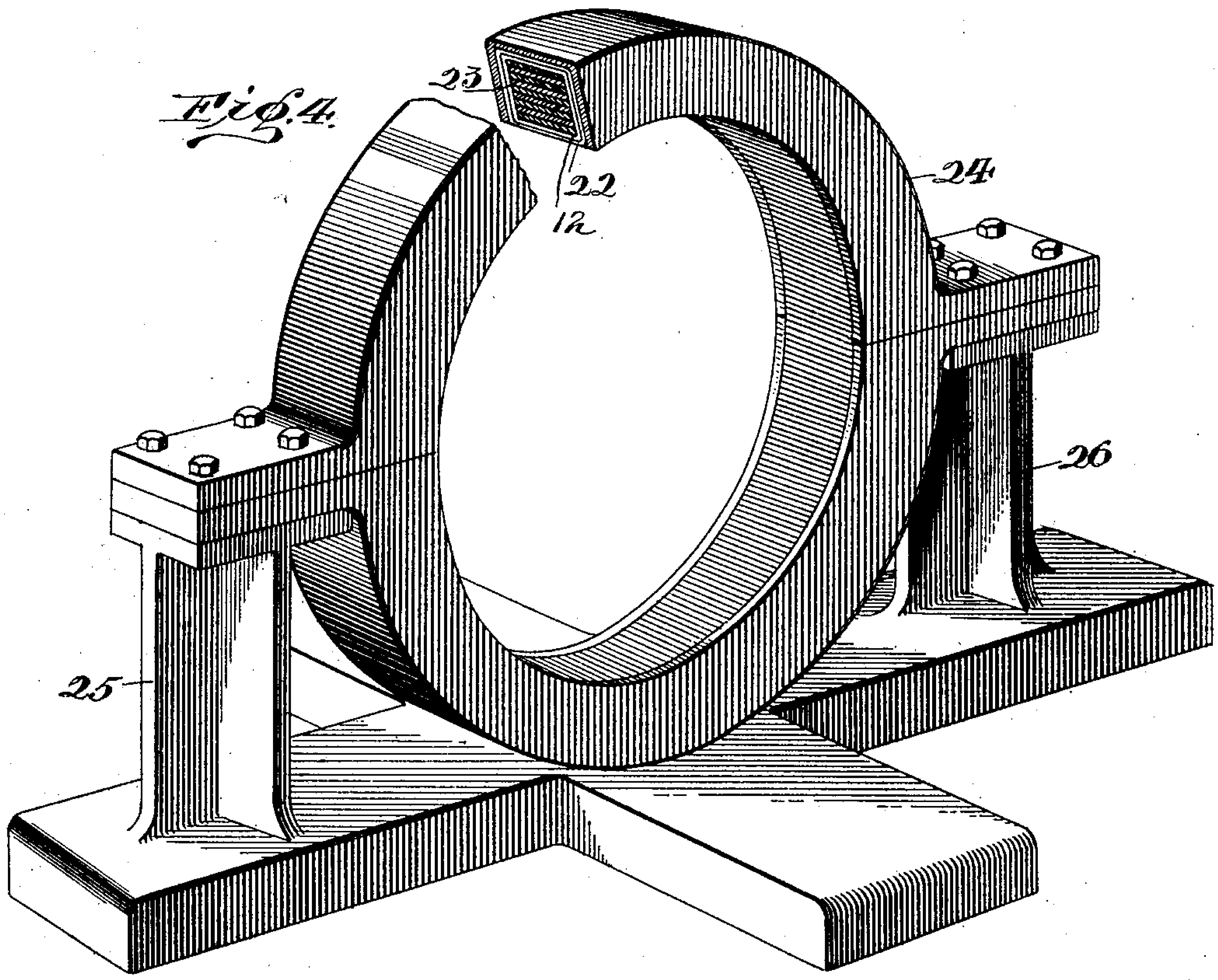

Fig. 5.

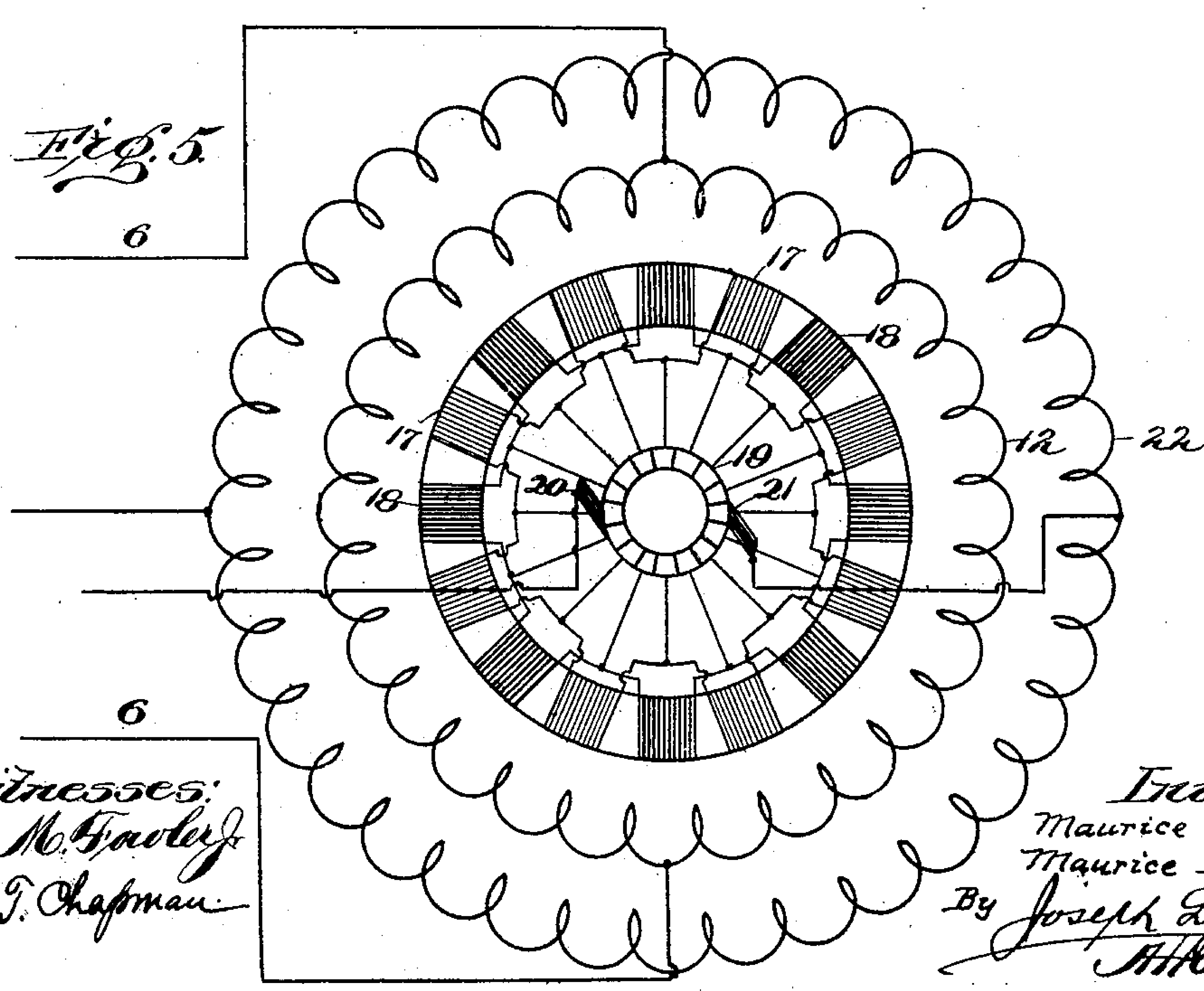

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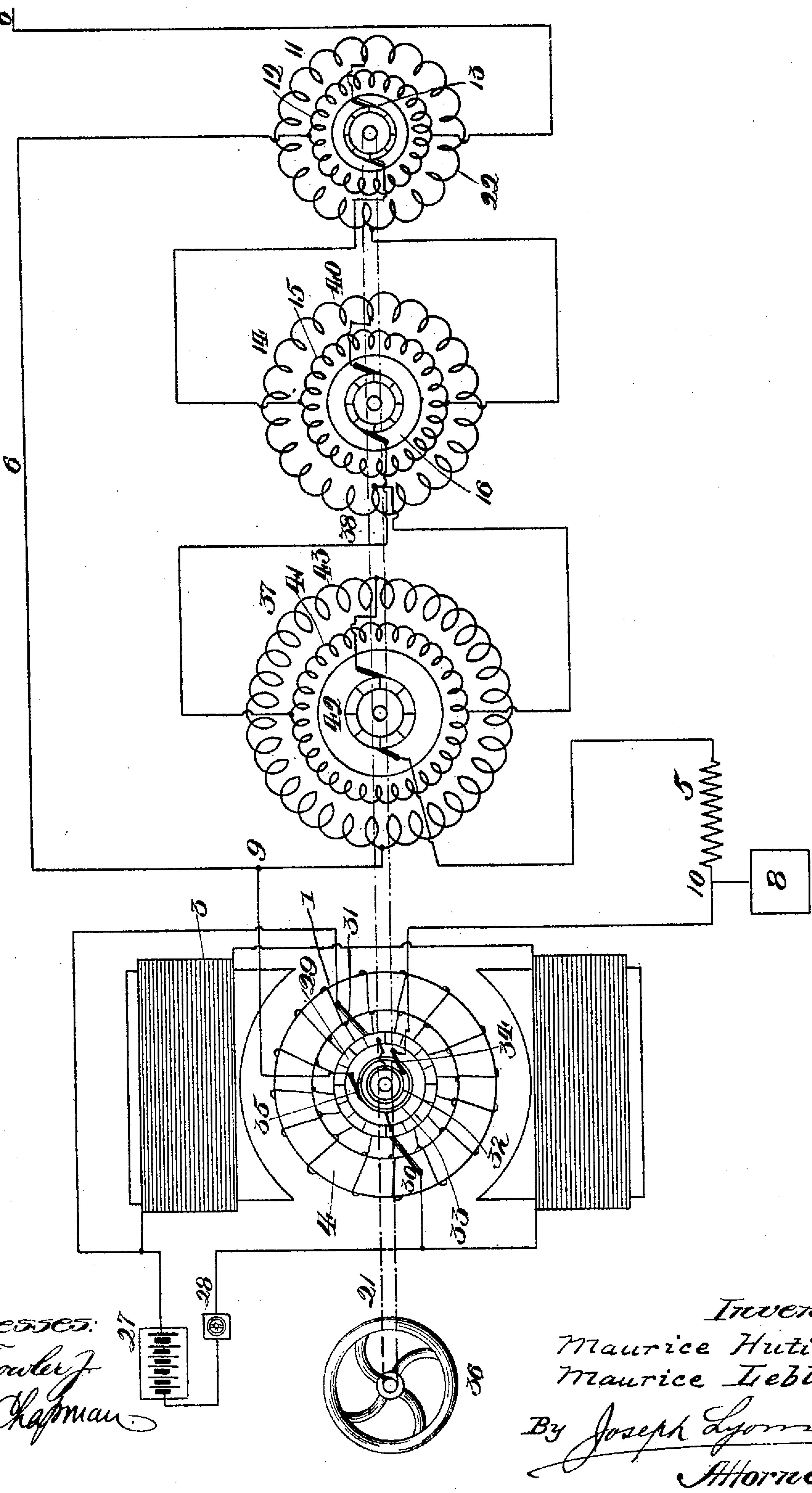
Fig. 6.



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UNITED STATES PATENT OFFICE.

MAURICE HUTIN AND MAURICE LEBLANC, OF PARIS, FRANCE.

METHOD OF AND MEANS FOR SYNCHRONIZING.

SPECIFICATION forming part of Letters Patent No. 613,206, dated October 25, 1898.

Application filed December 30, 1897. Serial No. 664,719. (No model.) Patented in France February 9, 1897, No. 263,905; in Austria February 23, 1897, No. 47/2,427; in Belgium July 24, 1897, No. 129,681; in Switzerland July 24, 1897, No. 14,722, and in Italy July 29, 1897, No. 45,440/479.

To all whom it may concern:

Be it known that we, MAURICE HUTIN and MAURICE LEBLANC, citizens of the Republic of France, and residents of Paris, France, have invented certain new and useful Improvements in the Methods of and Means for Synchronizing, of which the following is a specification, and for which we have received patents in the following countries: France, February 9, 1897, No. 263,905; Austria, February 23, 1897, No. 47/2,427; Belgium, July 24, 1897, No. 129,681; Switzerland, provisional patent, July 24, 1897, No. 14,722, and Italy, July 29, 1897, No. 45,440/479.

Our invention relates to a method of and apparatus for securing the synchronous movement or rotation of two bodies or shafts placed at different points, and, though useful in various relations, is particularly adapted for use in connection with systems of multiplex telephony or telegraphy, as, for example, those systems set forth in our application for Letters Patent, Serial No. 664,720, filed December 30, 1897.

Our invention also comprises a new method of and apparatus for impressing upon a circuit an electromotive force proportional to a given periodic electric current, and various other improvements to be hereinafter more particularly described and claimed.

In the drawings attached to this specification, Figure 1 is an illustrative diagram. Fig. 2 is a view of our improved synchronizing system in a simple form. Fig. 3 is a diagram of our improved system provided with two reinforcing-generators at each station connected in cascade. Fig. 4 is a perspective view of the field-magnet structure of the preferred form of our improved reinforcing-generator. Fig. 5 is a diagram of the connections of the reinforcing-generator, and Fig. 6 is a general diagrammatic view of a station completely equipped with our improved synchronizing device in its preferred form.

In our application above mentioned we have disclosed systems of multiplex telephony and telegraphy based upon the presence, at each end of the line, of a distributer serving to connect the line-wire successively to a number of local circuits. If these distributers are driven at sufficient speed and in absolute synchronism in any suitable way, it is possible to treat each coördinate pair of local circuits—that is to say, the pair of local circuits, one at each end of the line, upon which the distributers bear at the same instant of time—as if they were connected by a special and independent line-wire. The distributers are driven at each end of the line by direct-current motors, whose armature-windings are connected at diametrically opposite points to a pair of rings in such a way that each motor acts not only to produce power for driving the distributer, but also to generate single-phase alternating current of a frequency depending upon the rate of rotation of the motor. If now the brushes bearing on these rings be so connected that the two motors act as two electrically-connected alternating-current dynamo-electric machines, the motors will tend to run in synchronism, since the leading motor will furnish an alternating current which will tend to increase its load and to decrease the load of the other machine. We have also shown in the said application how it is possible to transmit this synchronizing-current over the same line wire or wires over which the signaling-currents flow without interfering with the operation either of the motor or of the signals.

Though we have, as illustrating one of the uses to which our present invention may be put, mentioned its application to systems of multiplex telephony and telegraphy it is obvious that it is useful in various other relations.

In general let 1 1′, Fig. 1, represent two alternating-current dynamo-electric machines, which in the particular application shown are of the single-phase type mounted upon shafts 2 2′, which are driven by mechanical power in any preferred way, and let us suppose that it is desired to maintain these shafts accurately in synchronism. The alternating-current dynamo-electric machines shown are composed of similar shuttle-shaped direct-current field-magnets 3 3′, mounted on the shafts 2 2′, and single-phase external stationary armatures 4 4′ in inductive relation to the field-magnets. The two armatures may be placed in parallel by lines 6 7, though ordinarily the line 7 is replaced by the earth connections 8 8′.

It will be seen, supposing that the motive power applied to each of the two shafts 2 2′ is approximately the same, as would be the case if they were driven by similar direct-current motors supplied with current at the same voltage, and also supposing that the loads on the two shafts are alike, that the two shafts will tend to be maintained in synchronous rotation, and we will have in the line 6 merely a synchronizing-current—that is to say, a current which exists only at times when the machines tend to depart from synchronism and whose magnitude is dependent on the amount of this departure. When the machines are running rigidly in synchronism, no current whatever will flow in the line 6. Such an arrangement is satisfactory wherever the line is short and of low resistance; but in certain cases, and notably in the application to telephony and telegraphy, it is necessary that the line should be of high resistance as compared with the lines of ordinary power-distribution systems, and it is highly inconvenient to give to the generators 1 1′ a sufficiently-high electromotive force to overcome this resistance; but whatever may be the resistance of the line it is in the system shown always necessary that energy be transported over the line-wire from one station to the other sufficient to check any departure from synchronism. Our invention is designed to avoid these difficulties and to require of the line that it transmit only certain weak currents which serve merely, as it were, to indicate when the two machines are out of synchronism and to set in motion other apparatus which will correct the difficulty. To effect this object, we connect around each of the alternators 1 1′ a branch circuit containing a resistance, preferably non-inductive, as 5 5′. The alternators will evidently normally supply current to these resistances, which resistances may be said to consume at all times part or all of the energy generated by the alternators, and thus to constitute an extra load upon each of the machines, the normal load being of course the line-current. If now in any way we could vary the amount of energy consumed by one of these resistances, as by causing the resistance of one machine to consume less than its normal amount of energy when that particular machine lagged and to consume more than its normal amount when that particular machine ran in advance, we could obviously greatly increase the correcting-torque, tending to restore synchronism. Further, if the energy consumed by both resistances could be made to vary simultaneously and inversely with any departure from synchronism the corrective torque would be still further augmented. There are a number of ways in which this result may be brought about; but we prefer to accomplish it by inserting in each of the branch circuits containing a resistance a source of electromotive force proportional to the synchronizing-current on the line.

Let i be the intensity of the synchronizing currents which actually flow in the line 6 with any given departure from synchronism. It will be evident that i is in general a periodic function. Suppose also that we are able in some way to develop in the shunt-circuits 9 10 and 9′ 10′, in which the resistances 5 5′ are introduced, an electromotive force e proportional to the current i—that is to say, such an electromotive force that where K is a constant factor $e=K\,i$. Let us also suppose that we are able to give the factor K any value whatever.

Designating by ρ the resistance of the line 6, by h' and h^2 the instantaneous values of the potentials with reference to the earth at the points 9 9′, respectively, by I′ and I² the currents which flow in the coils 5 5′, and by R R the resistances of the branches 9 10 9′ 10′, which resistances are supposed to be equal, we have

$$I' = \frac{h'+e}{R};$$

but

$$e = K\,i,$$

therefore

$$I' = \frac{h'}{R} + \frac{K\,i}{R},$$

but

$$i = \frac{h'-h^2}{\rho},$$

from which it follows that

$$I' = \frac{h'}{R} + \frac{K(h'-h^2)}{\rho\,R}.$$

Similarly it may be proved that

$$I^2 = \frac{h^2}{R} - \frac{K(h'-h^2)}{\rho\,R}.$$

Now the current actually flowing through the armature 4 of the alternator 1 when no synchronizing-current is flowing on the line 6—that is to say, when $h'=h^2$, is $\frac{h'}{R}$.

Suppose that by reason of some departure from synchronism the potentials h' and h^2 vary, so that $h'-h^2=a$, the current due to the alternator 1 will be

$$\frac{h'}{R} + \frac{K(h'-h^2)}{\rho\,R} + \frac{h'-h^2}{\rho},$$

where the first term represents the current flowing to earth from the point 9, owing to the potential h', the second term represents the current 1′ flowing to earth from the point 9, due to the electromotive force e, and the third term represents the current flowing through the line 6, due to the difference of potential $h'-h^2$. The change of output of the generator 1, due to the change of potential difference a, then becomes $\frac{h'-h^2}{\rho}\left(1+\frac{K}{R}\right)$. In the same manner it may be proved that the corresponding change of output of the generator 1' is equal to $\frac{-h'-h^2}{\rho}\left(1+\frac{K}{R}\right)$; but if the electromotive force e had not been interposed in the circuits 9 10 this variation of output would have simply been $\frac{h'-h^2}{\rho}$. It thus appears that by introducing into the branch circuit an electromotive force e equal to K i we are able to increase the change in output due to the given departure from synchronism as if we had actually reduced the resistance of the line by dividing the resistance ρ by the factor $\left(1+\frac{K}{R}\right)$, which factor we can evidently render as great as we choose by simply varying the constant K. From this it follows that by interposing in the branch circuits 9 10 and 9' 10' electromotive forces of the proper values and at all times proportional to the synchronizing-current flowing in the line we are able to increase the output of the generators 1 and 1' with a given departure from synchronism, and thus to increase the correcting-torque, which tends to restore synchronism, in such a way as to entirely neutralize the deleterious effect of a long and high-resistance transmission-line. This desired electromotive force may be procured in various ways; but the method which we prefer is to place in circuit with each of the resistances 5 5' a current-reinforcer, such as we have described and illustrated in our former application, Serial No. 635,035, filed May 4, 1897. This improved reinforcer may consist simply of an ordinary dynamo-electric machine of the direct-current type interposed in the circuit, as shown at 11 11', Fig. 2. It is known that the electromotive force of such a machine is proportional in magnitude and has the same direction as the current flowing through its field-magnet coils. If, therefore, we excite the field-magnets with a current i, the electromotive force generated in the armature will be equal to K i or to e, using the notation above explained, and the electromotive force e will be, practically speaking, in phase with the current i. We therefore pass through the field-magnet windings 12 12' of the two machines 11 11' the current flowing on the line 6 by making the connections shown in Fig. 2 and insert the armatures 13 13' of the two machines in series with the resistances 5 5', respectively. It is preferable to make these connections between the line 6 and the field-magnets 12 12' directly rather than inductively.

By the use of such a machine properly designed we are able to increase the factor K to a value as large as thirty-three, which will in many cases be sufficient; but when we desire that this factor shall have a still larger value we mount two or more of the reinforcing-machines in cascade, as shown in Fig. 3, where the line-circuit feeds, as in Fig. 2, the field-magnets 12 12' of the reinforcing-machines 11 11'; but the armatures 13 13' of these machines feed the field-magnet windings 15 15' of the reinforcers 14 14', whose armatures 16 16' in turn supply current at an electromotive force $e=$K i to the resistances 5 and 5', respectively. In this way we are able to give K a very large value and to maintain rigid synchronism between two shafts which are situated at a great distance from each other and connected only by an ordinary telegraph-wire without passing over the line anything more than feeble indicating-currents, which, as above explained, do not themselves act directly to restore synchronism, but merely set in action the reinforcing-machines.

As an illustration of the value which K may practically attain by such arrangement it may be observed that if the current furnished by the armature of any one of the reinforcing-machines is thirty-three times as great as the current supplied to its field-magnets then each of the reinforcing-machines mounted in cascade will operate to multiply the factor K by thirty-three. Thus if there are two reinforcing-machines the factor K becomes approximately one thousand, and if there are three reinforcing-machines mounted in cascade the factor K becomes thirty-six thousand. From this it will be seen that the very slight synchronizing impulses on the line are converted into very powerful synchronizing impulses in the branch circuits 9 10 9' 10' by the action of the reinforcing-machines.

Where our improvements are to be used merely for synchronous telegraphic and telephonic distributers, the amount of work to be done by the motive power applied to the shafts 2 2' is very small and it is easy by the addition of a fly-wheel of suitable dimensions to cause any departure from synchronism to be so slow as to be readily corrected by the devices shown; but it is well in the use of our invention to anul the self-induction and reaction of the armature-circuits of the reinforcing-machines, and we have therefore devised the forms shown in Figs. 4 and 5. Fig. 5 shows the connections of the reinforcer. 12 is the field-magnet winding in series with the line 6, as shown in Fig. 2, while 13 is the armature. As the field-magnet excitation is alternating, it is well to make some special provisions to avoid sparking, which we accomplish in the manner set out in our former application, Serial No. 631,625, filed April 10, 1897, by dividing the armature-winding into two sets of coils 17 17, &c., and 18 18, &c., wound alternately upon the armature and connected, respectively, to alternate segments of the commutator 19. This construction amounts to two Gramme rings, wound upon the same core and connected alternately to the commutator. In the position shown the brushes 20 21 bear on such segments that the winding 18 only is in circuit. An instant later both of the windings 17 18 will be energized in multiple, and still later the winding 17 only will be in circuit. It results from this construction, as more fully explained in our said former application, Serial No. 631,625, that unless the brushes are wide enough to span two commutator-segments no one of the armature-coils can ever be short-circuited by a brush, which removes the chief cause of sparking in dynamo-electric machines.

To neutralize the self-induction and reaction of the armature, we wind upon the field-magnets the additional or neutralizing coil 22, more fully described in our above-mentioned former application, Serial No. 635,035. This coil is connected in series with the armature and is so proportioned that the magnetomotive force which it generates is at all times equal and opposite to the magnetomotive force generated by the armature.

In order to prevent the magnetomotive force of the coil 22 from being short-circuited through the frame of the machine and to force it to balance and neutralize the armature magnetomotive forces, we prefer to support the ring 23, (shown in Fig. 4,) upon which the field-magnet windings are carried, by an annulus 24, preferably of copper or other non-magnetic metal, which in turn is carried by the supports 25 26. This annulus is made in two parts, as shown, for convenience in assembling the machine and incloses the field-core on all sides except toward the air-gap, as shown in the drawings. The field and armature cores are preferably laminated, as is usual in alternating machinery.

Fig. 6 shows a complete station equipped with our improved synchronizing devices with the reinforcing-generators. The shaft 2 to be synchronized is driven by the direct-current motor 1, consisting of an armature 4 and a field-magnet 3, preferably supplied with current in multiple from the direct-current source 27, here shown as a storage battery, through the regulating-rheostat 28. The armature is of the ordinary Gramme type or of any other preferred form provided with a commutator 29 and brushes 30 31.

To avoid the necessity of a separate alternating generator, we may connect two diametrically opposite sections of the commutator 29 respectively with the rings 32 33, on which bear the brushes 34 35. The ring 32 and brush 34 are connected to the earth-plate 8 or to the return 7 (shown in Fig. 1) if a complete metallic circuit is used, while the ring 33 and the brush 35 are connected to the line 6, in which is interposed the field-magnet winding 12 of the first reinforcing-generator 11. Similar connections are made at the opposite end of the line.

Upon the shaft 2 is shown the fly-wheel 36 for the purpose above set forth. The three reinforcing-generators 11, 14, and 37 are mounted on the shaft 38 and driven by any suitable power independently of the direct-current motor 1 or may be placed on the same shaft with the direct-current motor. The first of these reinforcing-machines 11 has its field-magnet winding 12 mounted in series with the line 6, as already stated, while its armature 13 supplies the neutralizing-winding 22 and also supplies the field-magnet winding 15 of the second reinforcing-machine 14. The armature 16 of the second reinforcer supplies its own neutralizing-winding 40 and also supplies the field-magnet winding 41 of the third, and in this case the last, reinforcer 37. The armature 42 of the machine 37 in turn supplies its own neutralizing-winding 43 and further supplies current due to an electromotive force $e=\mathrm{K}\ i$ to the resistance 5, connected, as in Figs. 1, 2, and 3, between the line 6 and the earth 8 or return-wire and in series with the armature 42.

As the output of each of the various reinforcing-generators 14 and 37 is greater than that of the one which feeds its field-magnet their sizes are correspondingly increased, as indicated roughly in the drawings.

Obviously any desired device whose motion is required to be synchronized may be carried by the shaft 2.

The operation of the system thus constituted is as follows: Normally the two shafts 2 and 2′, Figs. 1, 2, and 3, are driven approximately at the same speed by the direct-current motors or other sources of power. Any considerable tendency to depart from synchronism may be roughly corrected by the rheostat 28, Fig. 6, aided by the balancing action of the fly-wheel 36. As long as absolute synchronism is maintaining each of the alternating generators mounted on the shafts to be synchronized, no matter how many may be connected to each line, feeds current to its own particular resistance 5 5′, but no current of synchronization passes over the line 6; but if one machine tends to run slightly ahead of the other the field-magnets of the first reinforcing-machine of each of the alternators are excited, which, through the operation of the several reinforcers connected in cascade, supplies an electromotive force $e=\mathrm{K}\ i$ to each of the branch circuits containing the resistances 5 5′. The operation of these electromotive forces will be to increase the output of one machine—that which tends to run in advance—and to decrease the output of the other machine—that which tends to lag—and synchronism will be restored. It thus appears that while one set of the reinforcing-machines is running as generators the other set may be running as motors, absorbing energy from the particular generator to which they are connected.

Though we prefer to provide each of the alternators to be synchronized with a branch circuit—such as 910, Figs. 2 and 3—provided with one or more reinforcers, it will be apparent that this is not essential, as one such circuit will tend strongly to synchronize a pair of alternators. In all cases, however, superior results are obtained by providing each alternator with its own separate branch circuit and reinforcer.

We do not limit ourselves to the particular forms shown and described, as it is evident that they may be greatly varied without departing from the spirit and scope of our invention; but

We claim as our invention and desire to secure by Letters Patent—

1. The method of synchronizing two or more alternate-current dynamo-electric machines, electrically connected together, which consists in varying an extra load on one or more of these machines, by and in accordance with any departure from synchronism, substantially as described.

2. The method of synchronizing two alternating-current dynamo-electric machines, electrically connected together, which consists in feeding current from one or more of the machines to one or more branch circuits, and varying the amount of energy consumed by said branch circuit or circuits by and in accordance with any departure from synchronism, substantially as described.

3. The method of synchronizing two alternating-current dynamo-electric machines, electrically connected together, which consists in generating, by and in accordance with any departure from synchronism, in a branch circuit shunted around one or both of said dynamo-electric machines, an electromotive force proportional to the synchronizing-current passing on the line, and thereby altering the load of the dynamo-electric machines by such an amount as to restore synchronism, substantially as described.

4. The method of synchronizing two or more alternate-current dynamo-electric machines, electrically connected together, which consists in magnifying the natural synchronizing impulses, by producing by the same a field of force, and generating artificial synchronizing impulses by the relative rotation between an armature and said field, substantially as described.

5. The combination with two axes situated at distant points, and means for rotating the same in approximate synchronism, of two alternating-current dynamo-electric machines each mechanically connected to one of the axes, the two dynamo-electric machines being electrically connected together, by a high-resistance circuit; a branch current around one or each of the dynamo-machines, and means for altering the amount of energy consumed by said branch circuit or circuits by and in accordance with any departure from synchronism, substantially as described.

6. The combination with a number of axes situated at a distance from each other, of a like number of alternating-current dynamo-electric machines, each mechanically connected to one of the said axes, electrical connections between said dynamo-electric machines, a shunt circuit or circuits for one or more of the dynamos, and means for generating in each shunt-circuit an electromotive force proportional to the synchronizing-current passing on the line connecting the dynamo-machines, substantially as described.

7. As a means for synchronizing two independently-driven axes, a pair of alternating-current dynamo-electric machines, one mechanically connected to each of the axes, a circuit connecting the machines, and a shunt around each of the dynamo-machines, containing each a source of electromotive force proportional to the current in the line, substantially as described.

8. As a means for correcting any departure from synchronism in the rotation of two axes situated at distant points, an alternating-current dynamo-electric machine mechanically connected to each of the axes, a line-wire connecting the two machines, a return, a branch circuit adapted to consume energy shunted around each of the dynamo-electric machines, and two reinforcing dynamo-electric machines of the direct-current type each having its field-magnet supplied with current from the line and its armature supplying current acting to vary the amount of energy consumed in one of the branch circuits, substantially as described.

9. As a means for synchronizing the rotation of two axes at distant points, a pair of alternating-current dynamo-electric machines, one mechanically connected to each of the axes, a line-wire connecting the machines, a return, a branch circuit adapted to consume energy shunted around each of the machines, and two sets of reinforcing-machines connected in cascade, the field of the first machine of each set being in series with the line, and the armature of the last machine of each set being interposed in one of the branch circuits, substantially as described.

10. The combination with two axes situated at distant points, of a direct-current electric motor upon each axis, a source of current-supply for each of the motors, connections for taking alternating current from each motor to a separate branch circuit, a line-wire and a return connecting the said branch circuits and machines, and a source of an electromotive force, varying in accordance with the current in the line-wire, interposed in each of the branch circuits, substantially as described.

11. The combination with two axes situated at distant points, of a fly-wheel and a direct-current electric motor upon each shaft, a source of current-supply for each of the motors, independent means for regulating the speed of the motors, connections for taking

alternating current from each motor to a separate branch circuit, a line-wire and a return connecting the said branch circuits and motors, and a source of an electromotive force varying in accordance with the current in the line-wire, interposed in each of the branch circuits, substantially as described.

In testimony whereof we have signed our names to this specification in the presence of two subscribing witnesses.

MAURICE HUTIN.
MAURICE LEBLANC.

Witnesses:
EDWARD P. MACLEAN,
PAUL BOUR.