No. 644,555. Patented Feb. 27, 1900.

M. HUTIN & M. LEBLANC.

PROCESS OF REDUCING THE APPARENT INDUCTANCE OF ELECTRICAL CIRCUITS.

(Application filed Dec. 26, 1899.)

(No Model.) 2 Sheets—Sheet 1.

Fig. 1.

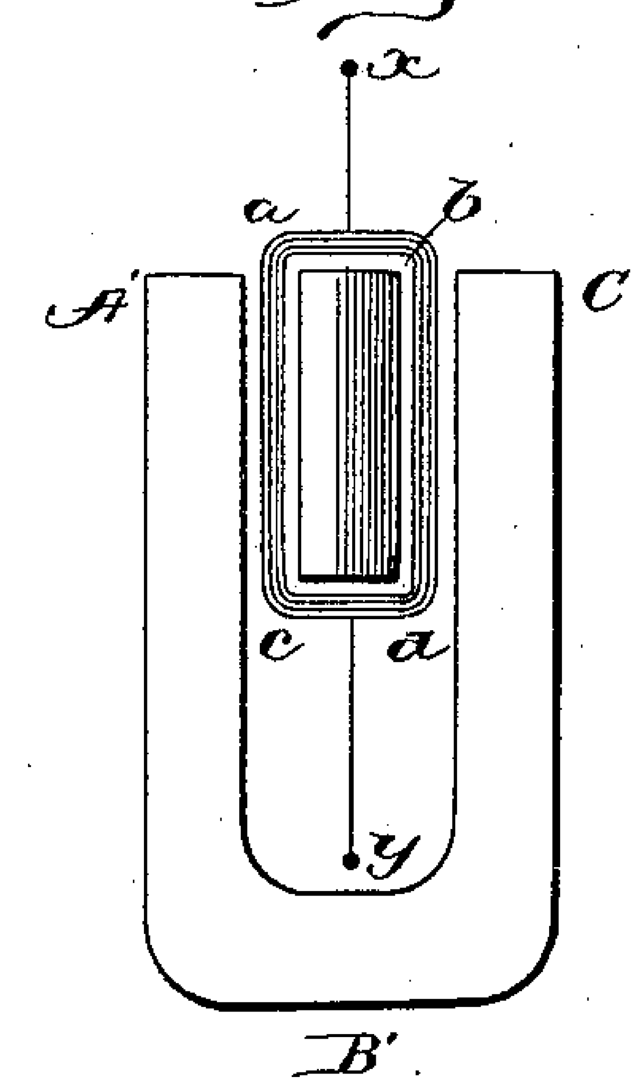
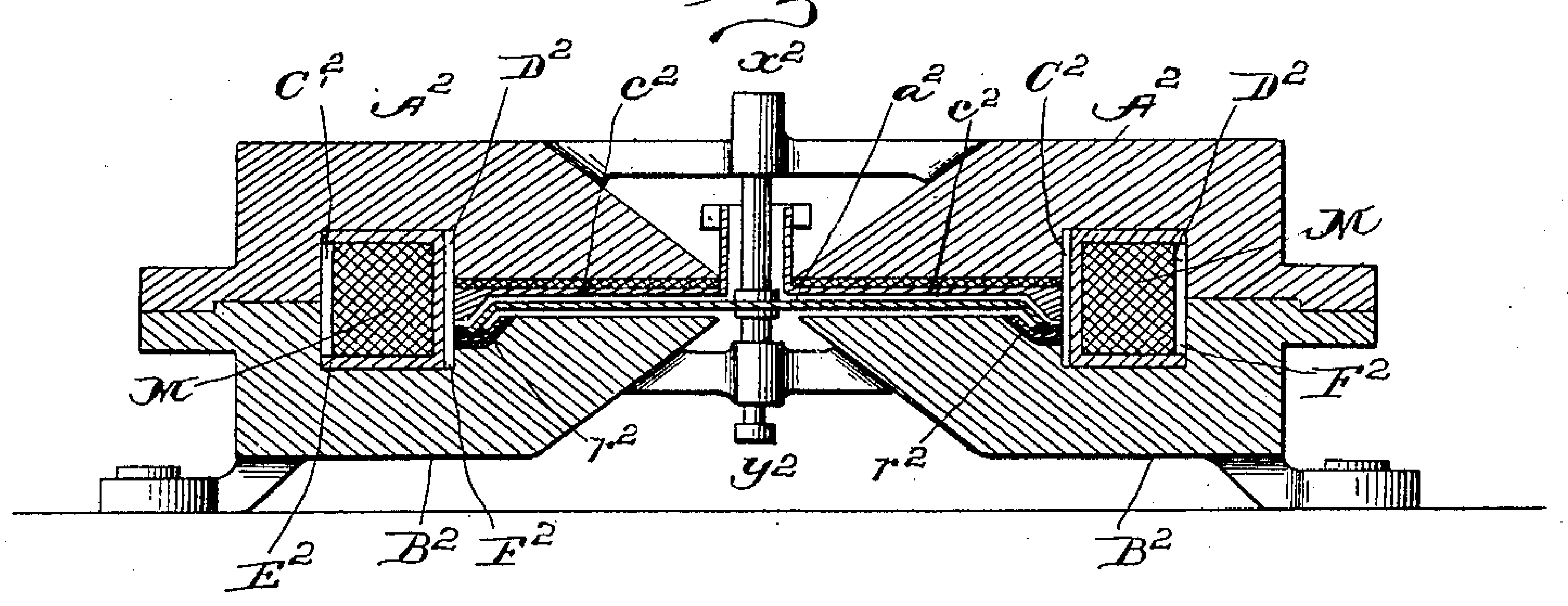


Fig. 2



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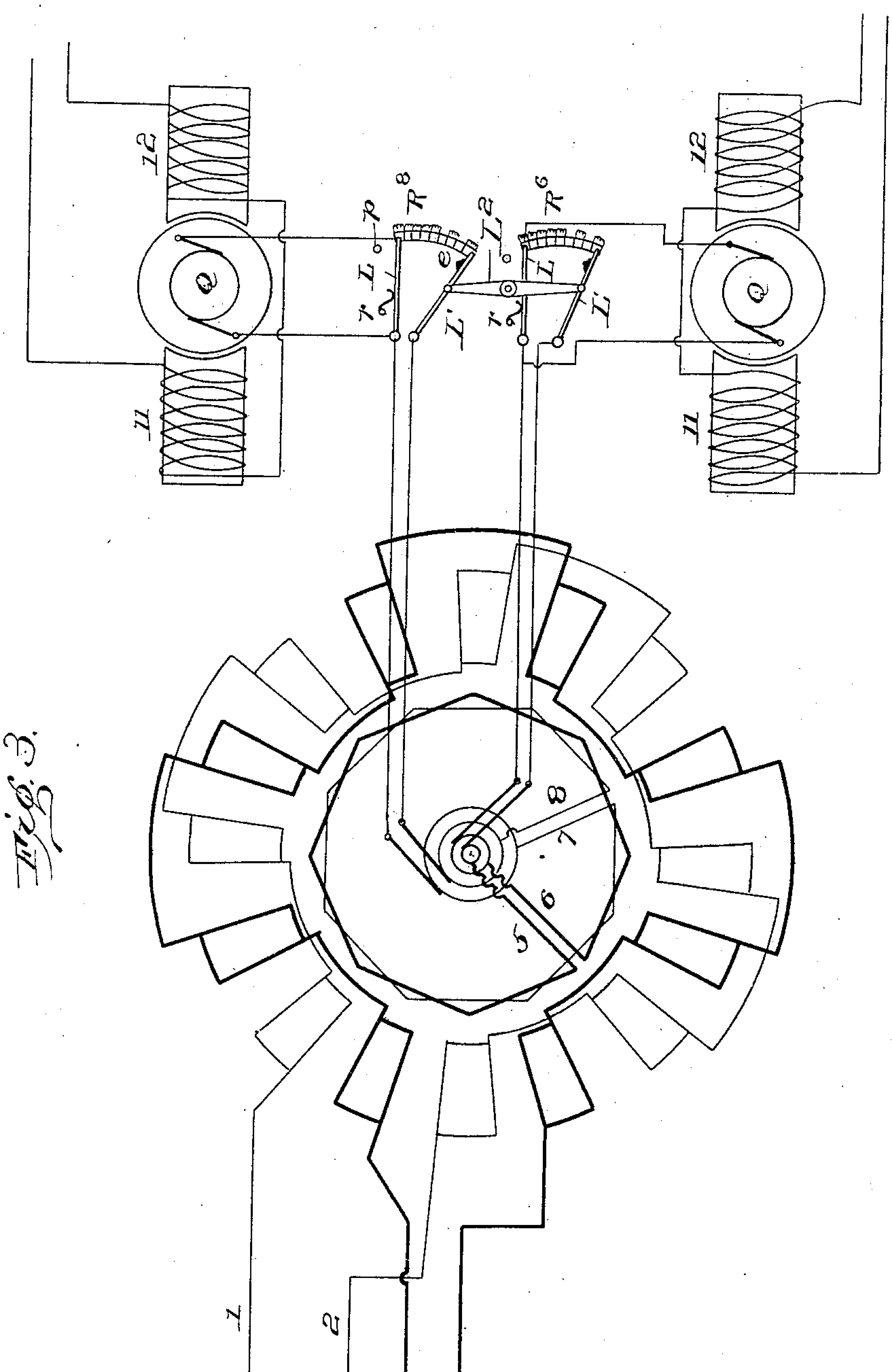

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UNITED STATES PATENT OFFICE.

MAURICE HUTIN AND MAURICE LEBLANC, OF PARIS, FRANCE.

PROCESS OF REDUCING APPARENT INDUCTANCE OF ELECTRICAL CIRCUITS.

SPECIFICATION forming part of Letters Patent No. 644,555, dated February 27, 1900.

Original application filed June 19, 1899, Serial No. 721,050. Divided and this application filed December 26, 1899. Serial No. 741,623. (No specimens.)

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 Process of Reducing the Apparent Inductance of Electrical Circuits, of which the following is a specification.

As is well known, circuits traversed by alternating currents offer a retarding influence to such currents in addition to that which they would offer to unidirectional or constant currents, and this retardation, as is also well known, is produced by what is called the "inductance" of the circuit. It is furthermore well known that if a condenser is placed within such circuit, either in series or in parallel therewith, the effect of this condenser is to apparently reduce the inductance of the circuit. Now it is often desirable to reduce or neutralize the apparent inductance of circuits for many purposes which need not be detailed here; but the use of condensers in this connection is exceedingly inconvenient, for, as is well known, a condenser is not only an expensive but a very unsatisfactory piece of electrical apparatus, one that it is very difficult to keep in order and which can never be relied upon with certainty. The condenser acts according to the laws of electrostatic induction.

The object of our invention is to reduce the apparent self-induction of circuits by a process which shall follow the laws of electrodynamic induction. We thus, in effect, replace the condenser whose operation is unreliable by an instrument which is as simple and of the same general character as the common electrodynamic machinery, which electrical engineers have commonly about them and with which they are familiar and whose mode of operation is entirely reliable. Such an instrument, which we may call a "recuperator," will not get out of order, is inexpensive, and the process according to which it operates is in every way superior to that of the condenser.

In the drawings, Figure 1 represents a diagram of a simple form which the apparatus executing our process may assume. Fig. 2 shows a cross-section of a form adapted for commercial use, and Fig. 3 represents in diagram the use of our invention with an alternating-current motor.

The apparatus for executing our process may be considered as comprising a movable galvanometric circuit or coil traversed by the alternating current which is to be reacted upon and freely oscillating in a uniform magnetic field. We proceed to show that if such a type of apparatus is properly proportioned there will be developed in the circuit of the coil the same electromotive forces as would be developed in a condenser which occupied its place. In other words, we shall show that the effect of such circuit oscillating within a uniform magnetic field is to reduce the apparent self-induction of the circuit carrying the alternating current with which it is connected. To this end we refer to Fig. 1, in which A′ B′ C′ represent a magnet creating a field of intensity J. An alternating current $i = a \sin. 2 \pi w t$ is supposed to traverse the galvanometric circuit or frame $a\ b\ c\ d$, of which the moment of inertia is u and which is mounted on the filar suspension $x\ y$. We shall suppose that the resistance of the moving frame is r and its coefficient of self-induction l.

When the angle which the medium plane of the galvanometric frame makes with the plane passing through the axis of suspension $x\ y$ and the center of the polar pieces has a value θ, the elastic reaction of the filar suspension is $K\,\theta$, since manifestly the elastic reaction increases with the angle of displacement. The deadening force due to the viscosity of the medium being proportional to the angular velocity may be represented by $q \frac{d\,\theta}{d\,t}$. The frame will be submitted at each instant to the effects of a motor-couple M proportional to the intensity of the field J and to the intensity of the current i. Designating by A a constant which depends upon the mode of construction of the apparatus and which varies in different apparatuses with the effect of the field on the frame, we have

$$M = A\ J\ a \sin. 2\ \pi\ w\ t.$$

The law of movement of the frame will be given by the following equation:

$$u \frac{d^2 \theta}{d t^2} + q \frac{d \theta}{d t} + K\ \theta = A\ J\ a \sin. 2\ \pi\ w\ t.$$

The voltage E, which will be developed between the electrical extremities of the frame, will depend on its resistance r, on its coefficient of self-induction l, and on its displacement from the center of the magnetic field. Designating by B a constant, depending upon the mode of construction of the apparatus, which constant is similar in character to A, we have

$$E = r\ i + l \frac{d\ i}{d\ t} + B\ J \frac{d\ \theta}{d\ t}.$$

Solving these differential equations by a process not necessary here to mention we find

$$E = \left[r + \frac{4\pi^2 w^2 q ABJ^2}{4\pi^2 w^2 q^2 + (K - 4\pi^2 w^2 u)^2} \right] a \sin. 2\pi w t + 2\pi w \left[l + \frac{(K - 4\pi^2 w^2 u) ABJ^2}{4\pi^2 w^2 q^2 + (K - 4\pi^2 w^2 u)^2} \right] a \cos. 2\pi w t.$$

It results from this equation that the galvanometric frame acts like a circuit having a resistance

$$\rho = r + \frac{4\ \pi^2\ w^2\ q\ A\ B\ J^2}{4\ \pi^2\ w^2\ q^2 + (K - 4\ \pi^2\ w^2\ u)^2}$$

and a self-induction

$$\lambda = l + \frac{(K - 4\ \pi^2\ w^2\ u)\ A\ B\ J^2}{4\ \pi^2\ w^2\ q^2 + (K - 4\ \pi^2\ w^2\ u)^2}.$$

We have not gone into any minute particulars as to the exact mode in which the above equations are deduced or by which they are solved. To one skilled in the science of mathematical physics what we have above said will be sufficient to make the matter clear. All that it is necessary here to point out is that we have obtained a value for the apparent coefficient of self-induction λ of the galvanometric coil moving in a constant magnetic field. As will be seen, this apparent coefficient of self-induction λ is the sum of the normal coefficient of self-induction l of the coil and of another quantity represented by the fraction to the right of the plus-mark. It will be plain, therefore, by making this fraction negative the effective or apparent self-induction of the coil will be lessened. If we make the fraction negative by an amount equal to l, then the self-induction of the coil will be neutralized and the apparent self-induction λ of the coil will be zero. If we make the fraction negative by an amount greater than l, then the apparent coefficient of self-induction λ of the coil will be negative and the coil will act as a condenser.

The equation for λ will be much simplified by making k equal to zero, which means that the filar suspension is no longer elastic, tending to return the galvanometric coil to a mean position. In such case we employ ordinary pivots instead of an elastic filar suspension. When, then, such pivots are employed and k equals zero, the equation for the self-induction of the coil becomes

$$\lambda = l - \frac{A\ B\ J^2}{q^2 + 4\ \pi^2\ w^2\ u}.$$

Examining this fraction we notice that the quantity q is found in the denominator added to a term involving the moment of inertia u; but the quantity q represents the deadening force, which is small with respect to the force of inertia, so that we may neglect the term q^2 before the term $4\ \pi^2\ w^2\ u$, and we shall have

$$\lambda = l - \frac{A\ B\ J^2}{4\ \pi^2\ w^2\ u}.$$

In order that the galvanometric coil may act to reduce the apparent inductance, it is manifestly necessary that the λ quantity should be negative, which means that the fraction prefixed by the minus sign in the last equation shall be as large as possible. To this end we may either make the intensity of the magnetic field J as large as possible, since this quantity J appears in the numerator of the fraction, or we may make the moment of inertia u of the frame or the frequency w of the current as small as possible, since these two quantities u and w appear in the denominator of the fraction. To make the frequency w small, means that there shall be but few alternations of the current in a second. To make the moment of inertia u small, means in a general way to make the galvanometric frame light. The action of the apparatus may be varied at will by varying the intensity J of the inductor-field. This field is regulable in intensity, but is constant for each adjustment.

In the apparatus which we have just described it will be seen that the galvanometric frame oscillates about a certain mean position; but it will be evident that the amplitude of the oscillations will not be over one hundred and eighty degrees. After the frame has moved ninety degrees from its original position the alternating current in the frame will be at its maximum and will decrease, thus allowing the frame to return to its mean position. When the alternating current reverses, the galvanometric frame will move in the opposite direction from the mean position, but no farther than ninety degrees therefrom. With the construction of apparatus shown in Fig. 2, however, we render it possible for the amplitude of the oscillation to have any desired magnitude—that is to say, the oscillating or moving member carrying the current may make several complete rotations in one direction so long as the alternating current is passing therethrough in a given direction and may thereafter make a number of rotations in the opposite direction when the direction of the alternating current has changed. The oscillating member of the apparatus in Fig 2, in other words, moves in one direction and then in the other direction, but the amplitude of each of these oscillations may be many times three hundred and sixty degrees.

Two solids of revolution A^2 and B^2, of steel, have between them an annular space C^2 D^2 E^2 F^2, in which there is a circular magnetizing-bobbin M^2, the passage of a continuous current in the bobbin creating a magnetic field across the air-space separating the solids. In this air-space is disposed a copper disk a^2, keyed upon the axis x^2 y^2 and movable with the axis. The edges of the disk are slightly inclined downwardly. The lower face of the solid A^2 is covered by a copper disk c^2, provided with a flanged edge. The disk c^2 is insulated from the solid A^2. The solid B^2 carries a circular metallic trough r^2, insulated from the solid. This trough is filled with mercury and places the disk c^2 in electrical communication with the moving disk a^2. If an alternating current enters by the axis, it will cross the moving disk, pass through the mercury into the fixed disk, and come back by the fixed disk to the center of the apparatus, where it is taken off by the contact S. The mercury contact may be replaced by properly-disposed brushes. It will be seen that the coefficient of self-induction of the circuit constituted by the disk will be substantially zero, for the only flux which may be developed by any current sent into the apparatus will be the annular flux which is developed in the very narrow air-space which separates the two disks.

We may remark, as will become evident, that any continuous-current dynamo in which the field is excited by an independent current may, when the parts are properly proportioned, be used to carry out our invention. As the moving parts, however, must be light, it is advisable to use an induced member without iron—such, for instance, as the disk type of Desrozier's, patented in the United States on September 15, 1891, under No. 459,610. The bobbin M^2 of Fig. 2 in such cases corresponds to the field-bobbins of the dynamo, and the solids A^2 B^2 correspond to the frame of the dynamo. It is thus clear that many different types of apparatus may be used to execute our process.

As an example of the practical application of our invention we may refer to Fig. 3, which shows what we have called a "recuperator," used in connection with the armature-circuits of a diphase motor of the induction type. As the motor, which is indicated diagrammatically in the drawings, is fully described in our Patent No. 553,469, of January 21, 1896, we may merely say that a rotary field is produced by the action of dephased currents passed through the circuit 1 2 (shown in light lines) and the circuit 3 4, (shown in heavy lines.) The armature-circuit 5 6 (shown in heavy lines) is closed through brushes upon a resistance R^6, and the armature-circuit 7 8 (shown in light lines) is closed through brushes upon a resistance R^8. The resistance R^6 R^8 may be varied simultaneously by the action of the arms L' L', connected by the arm L^2. Arms L, pressed downwardly by springs r, normally close short circuits around the armatures Q Q of our recuperator, the fields 11 12 of which are fed with constant current.

When the motor is set in operation, the levers L' are in the lowest position. As the armature increases in speed these levers are gradually raised, thus cutting out the resistances R^6 R^8. When the motor has attained its normal speed, the insulating-stops e on the levers L', operating against the levers L, move said levers L against the action of the springs r to throw these levers onto the dead-points p. This breaks the short circuits about the armature of the recuperators. It will therefore be seen that when the motor-armatures have attained full speed one of the motor-armature circuits is closed upon the moving parts of one of the recuperators and the other motor-armature circuit is closed upon the moving part of the other recuperator.

The armature-circuits of the motor are the seat of alternating electromotive forces which have a frequency proportional to what is technically known as the "slip." Thus if the dephased alternating current passing through the field-circuits 1 2 and 3 4 of the motor have a frequency of fifty per second and the armature of the motor makes forty-eight turns a second, the difference in frequency representing the slip, it will be found that the armature-circuits of the motor are the seat of electromotive forces having a frequency of two per second. The recuperators which we have described have a mode of operation which is particularly adapted, as was above made clear, to neutralize the apparent self-induction of circuits traversed by alternating currents of such low frequencies. This permits us, in the case of alternating-current motors, to use a large air-space in the motors without altering their power, for the effect of magnetic leakage will be destroyed. Again, should the alternating-current motors be used as generators, they may supply both wattless as well as watt currents, as will be readily understood.

It will be seen that we have in each case referred to the magnetic field of force as occupying a fixed position in space and the conductor carrying the alternating current as movable. It is clear, however, that, theoretically at least, this arrangement might be reversed. In such case it will be necessary to make the inertia of the moving magnetic field very small, which means that its intensity would also be small. Such arrangement would therefore have little or no practical utility.

Our invention comprises both an apparatus and a process. In this application we claim the process, the apparatus being covered by our application Serial No. 721,050, filed June 19, 1899, of which this application is a division.

What we claim is—

1. The process of reducing or neutralizing the apparent self-induction of a circuit carrying an alternating current, which consists in passing the current through a conductor mounted to oscillate with relation to a constant magnetic field of force, in the manner described for the purpose stated.

2. The process of reducing or neutralizing the apparent self-induction of a circuit carrying an alternating current, which consists in passing the current through a conductor mounted to oscillate with relation to a constant magnetic field of force, the inertia of the conductor, the intensity of the field and the frequency of the current having the relation substantially as described for the purpose stated.

3. The process of reducing or neutralizing the apparent self-induction of a circuit carrying alternating current, which consists in passing the current through a conductor mounted to oscillate with relation to a constant but regulable magnetic field of force and varying the intensity of the field with relation to the frequency of the current and the inertia of the conductor in the manner substantially as described.

4. The process of reducing or neutralizing the apparent self-induction of a circuit carrying an alternating current of abnormally-low frequency, which consists in passing the current through a conductor mounted to oscillate with relation to a constant magnetic field of force, the inertia of the conductor and the intensity of the field having a relation to the periodicity of the low-frequency current, 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,
ALBERT DELAS.