

M. LEBLANC.
 APPARATUS FOR TRANSFORMING CONTINUOUS CURRENTS.
 APPLICATION FILED NOV. 30, 1903.

3 SHEETS—SHEET 1.

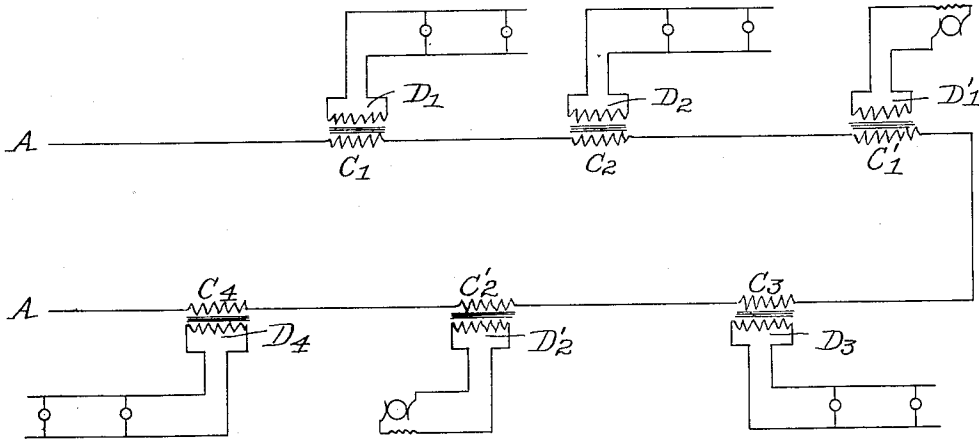


Fig. 1.

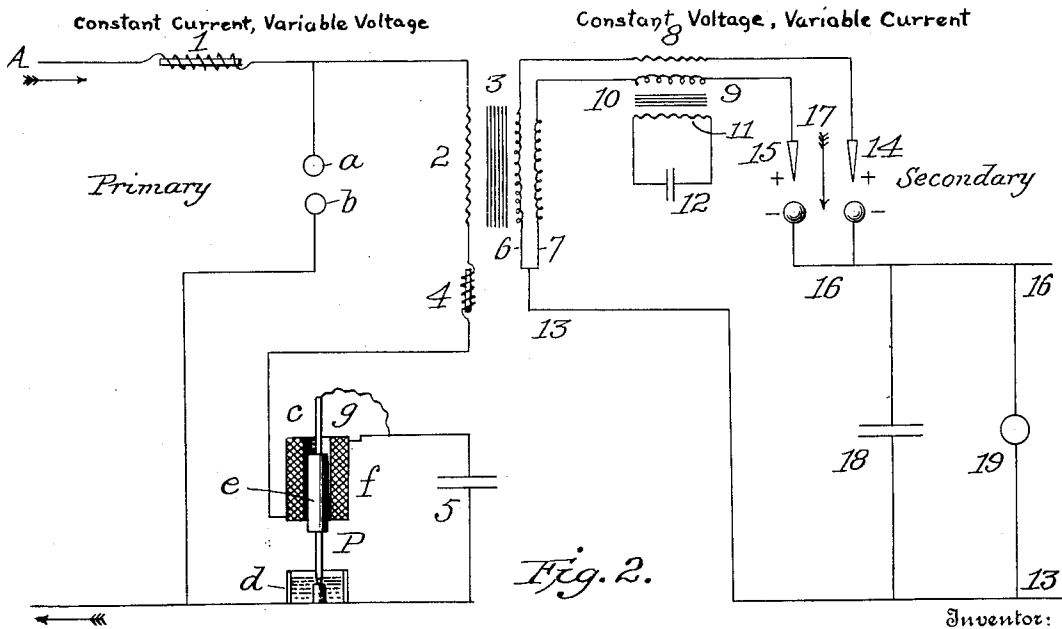


Fig. 2.

Inventor:

Witnesses:

Edwin L. Yewell.
 F. T. Chapman.

Maurice Leblanc,

By

Lyons & Bissin.

Attorneys.

No. 857,080.

PATENTED JUNE 18, 1907.

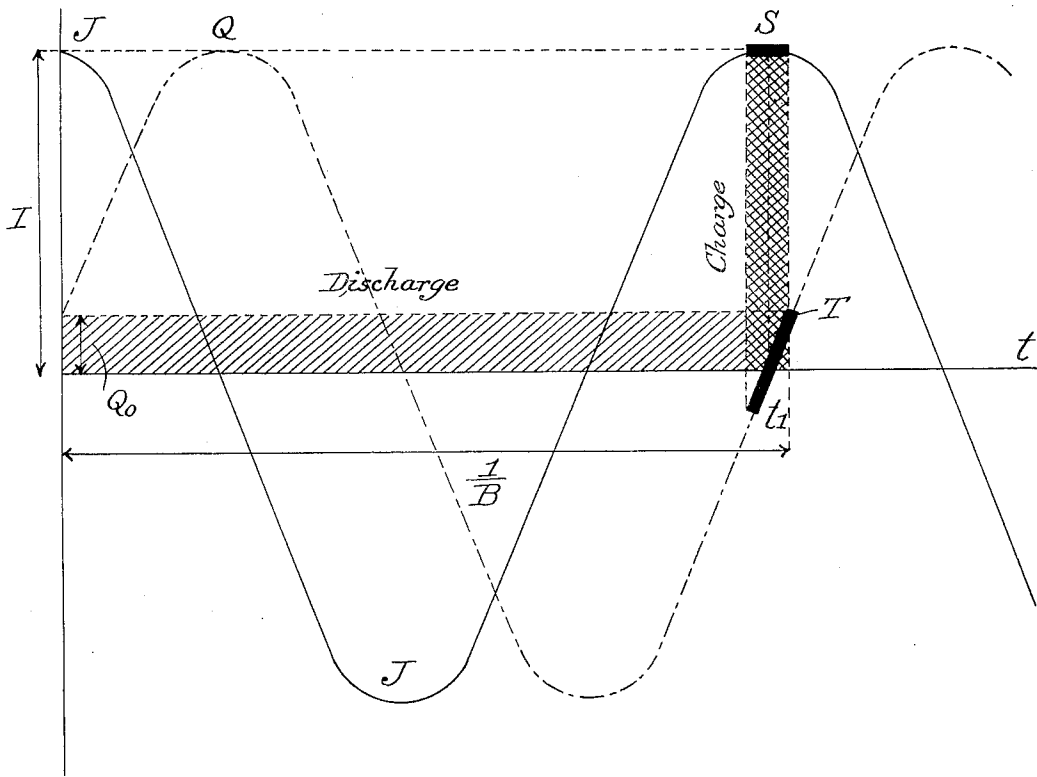
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3 SHEETS—SHEET 2.

Fig. 3.



Inventor:

Maurice Leblanc,

Witnesses:

Edwin L. Yewell,
F. T. Chapman

By

Lynn & Bissing.

Attorneys.

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3 SHEETS—SHEET 3.

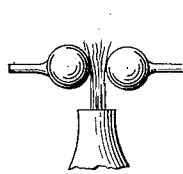


Fig. 4.

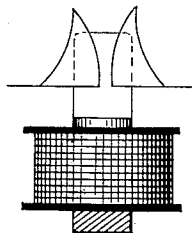


Fig. 5.

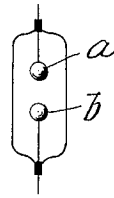


Fig. 6.

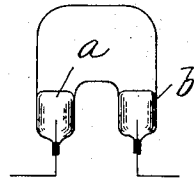


Fig. 7.

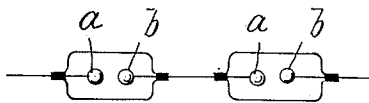


Fig. 8.

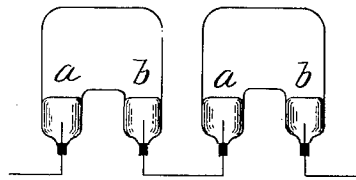


Fig. 9.

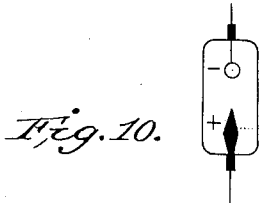


Fig. 10.

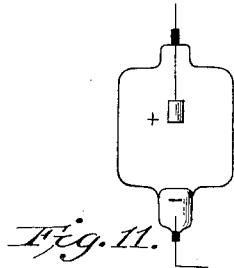


Fig. 11.

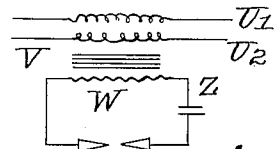


Fig. 12.

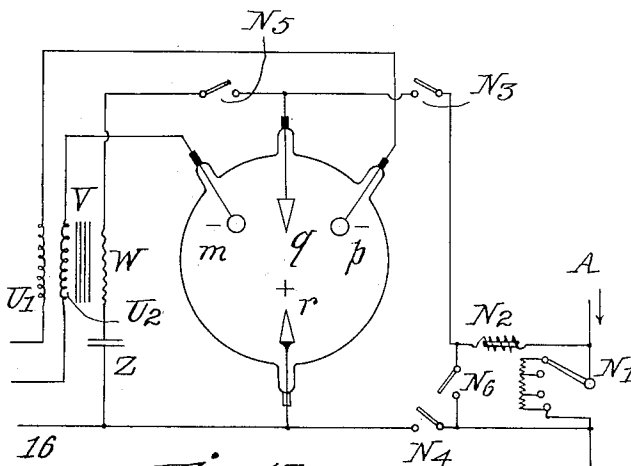


Fig. 13.

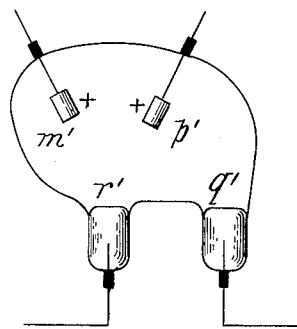


Fig. 14.

WITNESSES:

Edwin L. Jewell,
F. T. Chapman

INVENTOR:

Maurice Leblanc,
By Lyons & Bissing,
Attorneys

UNITED STATES PATENT OFFICE.

MAURICE LEBLANC, OF PARIS, FRANCE, ASSIGNOR TO WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY, A CORPORATION OF PENNSYLVANIA.

APPARATUS FOR TRANSFORMING CONTINUOUS CURRENTS.

No. 857,080.

Specification of Letters Patent.

Patented June 18, 1907.

Application filed November 30, 1903. Serial No. 183,247.

To all whom it may concern:

Be it known that I, MAURICE LEBLANC, a citizen of the Republic of France, and a resident of Paris, France, have invented a new and useful Apparatus for Transforming Continuous Currents of Constant Intensity into Continuous Currents of Constant Voltage or of Constant Intensity, of which the following is a specification.

The process of producing continuous currents of constant intensity under the highest voltages has been solved. In fact, in a companion application, Ser. No. 183,246, filed Nov. 30, 1903 I have shown how this result may be obtained by means of a dynamo unprovided with commutators, the function ordinarily performed by such commutators being executed by electric-exploders. Now such continuous currents of high voltage are particularly suitable for the transportation of electric energy to a great distance, since the lines which conduct them are as simple as possible and there is no such super-elevation of voltage as frequently manifests itself upon long lines traversed by alternating currents. But manifestly it is desirable to transform these continuous currents of high voltages into continuous currents of the usual voltages. Besides it will manifestly be further desirable to be able to transform such a primary current of constant intensity into a secondary current of variable intensity but constant voltage, for although continuous currents of constant intensity are best adapted for the transportation of energy, currents of variable intensity but of constant voltage are most suitable for its distribution. The problems of transformation here indicated I have solved in the manner to be described in the present application.

In the drawings Figure 1 shows a general diagram of the distribution system. Fig. 2 shows my static transformer for continuous currents. Fig. 3 is intended to represent the electrical actions which go on therein. Figs. 4 and 5 show electric exploders provided with arc extinguishers. Figs. 6, 7, 8 and 9 show electric exploders in vacuum tubes. Figs. 10 and 11 show electric valves for permitting the flow of current in one direction only. Fig. 12 shows a transformer for supplying auxiliary current to maintain the arc in such valve. Figs. 13 and 14 show the

manner of combining the device of Fig. 12 with the rest of my system.

In Fig. 1, I have indicated, in a general way, a line of transmission A for a continuous current of constant intensity, having transformers $C_1 D_1$, $C_2 D_2$, $C_1' D_1'$, etc., mounted in series therein. The object of this figure is to indicate that in my system I may either supply, to the secondary circuits, a continuous current of constant voltage under a variable intensity, which appears from the fact that the translating devices in the secondary circuits of the transformer $C_1 D_1$, are mounted in parallel, or I may supply to the secondary circuits a continuous current of constant intensity, which appears from the fact that there is a motor, assumed to be turning at a variable velocity, included in the secondary circuit of the transformer, $C_1' D_1'$.

Coming now to the description of the static transformer, which is shown in Fig. 2, I may say that, considered in its entirety, the continuous primary current which is fed thereto is (first) transformed into an alternating current through the intervention of an electric exploder; that this alternating current is (second) transformed into another alternating current of the same frequency but of a different voltage; and that this last named current is (third) rectified by means of electric valves, which permit the passage of currents in a given direction only. The principal primary circuit of this transformer passes through a self-induction coil 1, a primary circuit 2 of a transformer 3, a self-induction coil 4, and a condenser 5 in series with the primary circuit 2. If the primary circuit has sufficient self-induction in itself, the coil 4 is unnecessary. Since the self-induction coil 4 and the condenser 5 constitute a circuit having both capacity and self-induction, it may be looked upon as an electric resonator in shunt of which, as is seen, is mounted an electric exploder which may be formed of two metallic balls *a*, *b*, separated by an air space. Such electric exploders or space gaps, as is well known, require a certain voltage to establish an arc across their terminals, which arc is disestablished when the current traversing the terminals becomes zero or less than a certain quantity. The continuous current coming over the line A, and passing into this resona-

tor, charges the condenser 5 for a certain time, at the end of which an arc is established in the exploder, *a*, *b*. This arc once established, the resistance of the exploder becomes practically zero so that we have the well known phenomena of a charged condenser discharging through a small external resistance. This means that an oscillatory discharge will be set up giving rise to an alternating current. The electrical constants are so chosen, however, that before the end of one complete oscillation of this discharge, that is, shortly before the end of one complete period of the alternating current set up by the discharge, the arc in the exploder is disestablished. The condenser is thereupon charged by the continuous current from the main line until matters are in the same state in which they were when the arc in the exploder was first established. But matters being in the same state in which they were at the moment when the exploder arc was established for the first time, it follows that the exploder arc will be again established, that there will be another oscillating discharge of the condenser and another alternating current comprising one complete positive and one complete negative period and so on. The alternating current thus generated will not gradually die down, as in the discharge of the ordinary Leyden jar, for the reason that the condenser is recharged from the main line at the end of each complete alternation.

I may remark that the self-induction coil 1 helps to maintain constant the intensity *I* of the continuous current in the line *A* despite the establishment of the exploder arc.

We thus see how, by the arrangement thus far described, a continuous current is transformed into an alternating current in the winding 2. If the continuous current is of constant intensity, it can be shown that the alternating current into which it is transformed is also of constant intensity.

It remains to describe the function of the automatic circuit breaker *P* which, as will be seen in Fig. 2, closes a short circuit about the condenser 5 when it is out of action. This automatic circuit breaker *P* comprises a solenoid *f* in series with the condenser 5, a core *e* mounted on the rod *c* connected, at its upper end, to one side of the condenser 5 by a flexible conductor and dipping, at its lower end, into a mercury bath *d*, which is connected to the other side of the condenser 5. When current passes through the resonator circuit 4, 5, the solenoid is raised and the short circuit about the condenser is broken, so that the resonator circuit and exploder are in condition for the operation above described. The circuit interrupter *P* is designed to maintain its core raised throughout the normal operation of the apparatus. It does not go into and out of action at each

oscillatory discharge of the condenser. But should, for any accidental reason, the arc in the exploder not disestablish itself at the proper time toward the end of any complete oscillation, then the core *e* of the solenoid *f* is arranged to drop and establish a by pass around the exploder which short circuits the arc in the exploder. This exploder arc is therefore now extinguished, as it should be. Thereupon the solenoid again raises its core to break the short circuit about the condenser. The automatic circuit breaker *P* has therefore the function of preventing the disarrangement of the normal operation of the system by reason of the failure of the exploder to disestablish its arc at the proper time.

It is manifest that other types of automatic circuit breakers may be employed instead of the circuit breaker *P*, and it is equally manifest that, in order to insure the rapid interruption of the circuit at the terminals of the circuit breaker, it will be advisable to use any of the well known arc extinguishing devices, such as currents of air or electro-magnets, in connection with the terminals of the circuit breaker.

I now come to a description of the secondary circuits of my static transformer in which the alternating current which has been induced therein by alternating current in the primary circuit 2 is rectified into a continuous current. To this end, I employ, as shown in Fig. 2, two secondary windings 6 and 7 on the step-down transformer 3, each of which windings is connected at one end to a terminal of the local or consumption circuit 13. The windings 6 and 7 each contain the same number of turns and are juxtaposed or superposed in such a manner that each of them has the same coefficient of self-induction and the same coefficient of mutual induction with respect to the primary circuit 2. At the same time the circuit 6 is wound in one direction and the circuit 7 is wound in the other direction. Connected to the secondary circuits 6 and 7 of the transformer 3 are the primary circuits 8 and 9 of a transformer 10. These two primary circuits have each the same number of turns, but the circuit 8 is wound in the same direction as the circuit 6, and the circuit 9 in the same direction as the circuit 7. Besides these windings 8 and 9 are juxtaposed or superposed in such a manner that each of them has the same coefficient of self-induction and the same coefficient of mutual induction with respect to the secondary circuit 11 of the transformer 10. I may further state, at this point, that one terminal of the electric valve 14 is connected to the winding 8, and one terminal of the electric valve 15 is connected to the wind-

ing 9, each of these valves being so constructed as to permit the passage of current in the direction of the arrow 17 and to oppose the passage of current in the opposite direction, and that the other terminal or terminals of these electric valves are connected to the leads 16 of the local or consumption circuit of the transformer, which includes translating devices 19.

It will now be apparent that the sum of the ampere turns developed in the transformer 3 by the secondary circuit 6 and 7 is the same as if there were present a single secondary circuit traversed by an alternating current and having a number of turns equal to that of one of the circuits 6 or 7. A similar remark applies to the primary circuits 8 and 9, of the transformer 10. That these remarks are true follows at once when we consider that of the alternating electro-motive-forces induced in the circuits 6, 8, 14, and 7, 9, 15, by the transformer 3, the positive waves, say, alone are able to generate current in the former circuit and the negative waves alone generate current in the latter circuit. It is equally plain that the condenser 12, in the secondary 11 of the transformer 10, acts as if the transformer 3 has only a single secondary circuit and the transformer 10 only a single primary circuit, connected in series therewith, this single secondary circuit having a coefficient of self-induction equal to that of the circuit 6 or 7 and the single primary circuit having a coefficient of self-induction equal to that of the circuits 8 or 10. Since the frequency of the current which traverses the primary circuit 2 of the transformer 3 is practically constant and the curve which represents it is practically sinusoidal in form, we may manifestly determine the capacity of the condenser 12 in such a manner as to render zero the total coefficient of apparent self-induction of the circuits 6, 8, and 7, 9. Then the variations of flux caused in the transformer 3 by the currents which traverse the secondary circuits 6 and 7 only act to change the effective resistance of its primary circuit 2 without changing its coefficient of apparent self-induction. The effective value of the intensity of the current in the primary 2, of transformer 3, being constant, the electro-motive-force developed in the secondary circuits of this transformer by the variation of the intensity of the primary current is also constant. Since the apparent self-induction of the secondary circuits in which this electro-motive-force is developed is rendered zero by the action of the condenser 12, the electric valves 14 and 15 support a constant voltage whatever be their output, which means that a constant voltage will be maintained between the conductors 13 and 16 of the local consumption circuits.

A transformer, such as I have now described, thus acts to transform a continuous

current of constant intensity at variable voltage into a continuous current of variable intensity at constant voltage. The fact that the current of constant intensity is changed into a current of constant voltage is due, as has already appeared, to the action of the condenser 12 in the secondary circuit of the transformer 10. If this transformer 10 and its condenser 12 are suppressed, the transformer 3 will act like an ordinary transformer and the sum of the ampere turns of its two secondary circuits will differ very little from the sum of the ampere turns of its primary circuit. It follows that, under these conditions, if the high voltage net work supplies a current of constant intensity under a variable voltage, there will be fed to the distributing conductors 13 and 16 a current of constant intensity under a variable voltage. I need only remark, in conclusion, that I branch a condenser 18, or its equivalent, between the leads 13 and 16 of the local consumption circuit, which condenser acts to maintain constant the voltage, between these leads, during the half period of the alternating current which has been rectified by the electric valves.

I now turn to a brief description of the electric exploders which I employ.

In order that the arc may be suddenly extinguished, when the intensity of the current which traverses it becomes zero, it is advantageous to send a draft of air between the balls of the exploder, as is indicated in Fig. 4. The same result may be reached by using two horn shaped parts *a*, *b*, situated between the polar extremities of an electro magnet, in which case the arc will break spontaneously as soon as the intensity of the current which supports it sinks below a certain limit. This is shown in Fig. 5. Again this result may be attained by inclosing the balls *a*, *b*, in a vacuum, as is indicated in Fig. 6. Exploders, thus constituted, may be relied upon to extinguish their arc as soon as the current which traverses them sinks below a certain limit. An excellent type of such vacuum exploders is shown in Fig. 7, in which two mercury globules *a*, *b*, are contained in the ends of an inverted U tube in which a vacuum has been formed. The apparent resistance of such tubes, when the arc has been struck, is small; they go out of action very quickly; and the surface of their electrodes is not injuriously affected.

When exploders having their terminals in air are used, the voltage necessary to spring an arc between them is varied by changing the distance between the balls. But with the vacuum exploders, this result is best attained by placing several of them in series, as is indicated in Figs. 8 and 9.

I have now to describe the electric valves. As before indicated, such valves oppose a more or less negligible resistance to currents

which traverse them in a given direction and a practically infinite resistance to currents which traverse them in the opposite direction.

While I may use electric valves of various sorts, the electric valves which I have shown in the drawings are, in the form of vacuum tubes. Thus in Fig. 10, I have shown, inclosed in a vacuum, separated ball and point terminals, a much smaller voltage being necessary to make the current pass from the point to the ball than to make a current of the same intensity pass from the ball to the point. In Fig. 11, I have shown a vacuum tube containing, as one of its terminals, a globule of mercury and, as its other terminal, a bell of steel: When we are dealing with voltages as low as those usually found in the secondary circuits of the transformer 3, it so happens that an electric valve comprising a vacuum tube opposes a resistance to the passages of current in either direction which is too great to initially establish the arc. It is therefore necessary to cause this initial establishment of the arc by a current of higher voltage. Besides, if the current to be rectified by the electric valve is alternating in character, and at times has zero intensity, it will be seen that the arc in the electric valve will at times be disestablished and that the low voltage of the alternating current cannot thereafter, of its own accord, re-establish it. It is therefore necessary to employ a device for giving a current of high voltage, which initially establishes the arc, and it is furthermore necessary to superimpose upon the alternating current which is to be rectified, an auxiliary current, the intensity of which does not become zero when the intensity of the alternating current becomes zero. This auxiliary current may be of very small voltage, a voltage just sufficient to maintain the arc after it has once been established, and its purpose is to always keep an arc between the terminals of the electric exploder, so as at all times to permit the alternating current to pass through this arc when the current is in one direction but to bar its passage when it is in the other direction.

A means for producing an auxiliary current, to maintain the arc in the electric valve when the intensity of the alternating current to be rectified is zero, is shown in Fig. 12. The arrangement shown in Fig. 12, in fact, is one designed to produce an auxiliary current dephased by 90 degrees from the alternating current to be rectified. I use a small transformer having two primary circuits U_1 U_2 similar to each other but wound in contrary directions and I cause the positive part of the alternating current to be rectified to traverse one of these circuits and the negative part of the alternating current to be rectified to traverse the other circuit. I then choose the capacity of the condenser Z in the single secondary W of this transformer such that

the intensity of the current which traverses the secondary circuit will be a maximum when the intensity of the currents which traverse the primary circuits are zero. The two electrodes of the electric valve in the secondary circuit W are similar in form.

In Fig. 13 I have shown embodied not only the arrangement thus described for producing an auxiliary current when the intensity of the alternating current to be rectified is zero, but also a simple means for initially generating a high voltage in the electric valve in order to initially establish its arc. It is to be understood that the coils U_1 U_2 at the left of this figure are respectively connected with the terminals of the coils 8, 9, of the transformer 10, in Fig. 2, or to the terminals of the coils 6, 7, in Fig. 2, when the transformer 10 is suppressed. The lead 16 in the lower left hand corner of Fig. 13 is connected to one side of the translating devices, the other side of which is placed in electrical connection with the lead 13 of Fig. 2. In comparing the circuits of Fig. 13 with those of Fig. 2, we find the positive and negative terminals of the electric valves have been interchanged; but this is manifestly of no consequence. The primary circuit is caused to traverse the rheostat N_1 , tapped from which is an impedance coil N_2 . The circuit breakers N_3 , N_4 , N_5 , N_6 , are employed in the positions shown and the connections of the other parts will be plain without further description. I need only remark that the single terminal r connected with the lead 16 is employed instead of the two terminals, each of them connected with the lead 16, as shown in Fig. 2. In order to initially establish the arc in the electric valve, I send a current of high tension between the like shaped terminals q , r . This current I generate by opening the circuit closer N_5 and by closing the circuit closers N_3 , N_4 , and N_6 . A certain portion of the current from the high tension line A now traverses the self-induction coil N_2 . I quickly open the circuit breaker N_6 , whereupon the extra current from the self-induction coil N_2 traverses the terminals q , r , and establishes the arc in the electric valve. I immediately close the circuit closer N_5 whereupon, as is evident from what has been said in connection with Fig. 12, an alternating current of a voltage which, though low, is yet sufficiently high to maintain the arc once established passes between the terminals q , r . The circuit closers N_3 , N_4 , may now be opened and the rheostat thrown out of circuit. The electric valves will now be in full operation. One portion of the alternating current to be rectified will pass from the common terminal r to the terminal m and the other portion of the alternating current to be rectified will pass from the terminal r to the terminal p . The arc between the terminals r and q being always maintained at the times when the

arcs between the terminals r and m , or between the terminals r and p , is disestablished, it follows that the alternating current to be rectified is not required to establish an arc but merely to traverse, in a given direction, an arc already established, from a terminal of one shape to a terminal of another shape.

In Fig. 14 I have shown a modified form of four point electric valve in which the terminals are constituted as globules of mercury and bells of steel respectively.

I need hardly remark that while the means of generating auxiliary current to maintain an established arc and the means to generate an initially high voltage to establish the arc which I have referred to above are very useful, they are not only the only means for producing these results which I may use.

It has been proposed, in the prior art, to convert a continuous current into an alternating current of high frequency by charging a resonator with the continuous current and then discharging the resonator through an exploder. But such apparatus has never been perfected to a point at which it can be commercially used and certainly not for the purposes requiring transformation into continuous current by electric valves, for the reason that it was not known how to make the alternating currents of effective constant frequency, nor how to make them, practically speaking, sinusoidal in form. I have discovered how to do these two things. Without explaining, at length, how I have reached a knowledge of the requirements necessary to effect these two objects, I may say that if we designate by R the ohmic resistance of the resonator, by l the coefficient of its apparent self-induction, by c the capacity of its condenser, and by E the quantity of electrical energy stored in the resonator at any instant of time t , then the rules are these: In order that the frequency of the alternating current shall be constant, it is necessary that R^2 shall be small with respect to $\frac{4l}{c}$. In order that the alternating current wave shall be sinusoidal, it is necessary that the quantity of energy E stored in the resonator shall be large with respect to that which is used up in the system between two consecutive explosions. In this connection I may say that if E_0 and E_1 are the quantities of energy stored in the instant t in the condenser and self-induction coil, respectively, and if x denotes the frequency, we may write,

$$\begin{aligned} E_c &= E \sin^2 2\pi \times t \\ E_l &= E \cos^2 2\pi \times t \\ E &= E_c + E_l \end{aligned}$$

The conditions which prevail are diagrammatically indicated in Fig. 3 in which the

period is designated by $1/B$; the horizontal line S corresponds to the period of charge in the condenser and will be very short with respect to the length represented by the period $1/B$; the short inclined straight line T represents the variation of the charge in the condenser during the time the exploder arc is out of action; Q_0 represents the charge stored in the condenser at the moment of striking the arc in the exploder, and the variation of this charge Q is represented by a sinusoid. This sinusoid is dephased 90 degrees from the sinusoid representing the current J .

I claim,

1. A system for transforming unidirectional currents of one tension into unidirectional currents of another tension which comprises a line carrying unidirectional currents, a resonator having R^2 small with respect to $\frac{4l}{c}$, an electric exploder in shunt of the resonator, a transformer, and an electric valve or valves for rectifying the transformed alternating currents thus produced, substantially as described.

2. A system for transforming unidirectional currents into unidirectional currents of a different tension, which comprises a line carrying unidirectional currents, a resonator arranged to store an amount of energy which is large with respect to that consumed in an alternating period, an electric exploder in shunt of the resonator, a transformer, and an electric valve or valves to rectify the transformed alternating current thus produced, substantially as described.

3. A system for transforming unidirectional, high-tension into unidirectional, low-tension currents, comprising a line carrying continuous currents, a resonator having R^2 small with respect to $\frac{4l}{c}$ and arranged to store an amount of energy which is large with respect to that consumed in an alternating period, an electric exploder in shunt of the resonator, a step-down transformer, and an electric valve or valves for rectifying the low tension currents thus produced, substantially as described.

4. A system for transforming unidirectional high-tension currents of constant strength into unidirectional, low-tension currents of constant voltage, comprising a line carrying the continuous, high-tension currents, a resonator having R^2 small with respect to $\frac{4l}{c}$ and arranged to store an amount of energy which is large with respect to that consumed in an alternating period, an electric exploder in shunt of the resonator, a step-down transformer, a condenser in its secondary circuit to render zero its coefficient of apparent self-induction, and an electric valve or valves for

rectifying the low-tension alternating current thus produced, substantially as described.

5 5. The combination of a line carrying continuous currents, a resonator including a condenser connected therewith, an automatic circuit breaker in shunt of the condenser and an electric exploder in shunt of the resonator, the parts being electrically proportioned so that the circuit breaker will close its circuit to cause the extinction of the arc if the arc in the exploder is not disestablished at the proper time, substantially as described.

15 6. The combination of a line carrying continuous currents, a resonator including a condenser connected therewith, an automatic circuit breaker having its actuating coil in series with and its contact points in shunt of the condenser, and an electric exploder in shunt of the resonator, the parts being electrically proportioned so that the circuit breaker will close its circuit to cause the extinction of the arc in the exploder if this arc is not disestablished at the proper time, substantially as described.

25 7. An induction coil having a secondary circuit, a primary circuit of a second transformer connected therewith, and a condenser in the secondary circuit of the second transformer of a capacity to render zero the apparent self-induction of the combined secondary and primary circuits first specified, substantially as described.

30 8. An induction coil having a pair of oppositely wound secondaries, connected at one end to one side of the local circuit, a pair of oppositely wound primaries of a second induction coil connected respectively to the other ends of the secondaries, a pair of elec-

tric valves connected to these primaries and to the other side of the local circuit respectively, and a condenser in the secondary circuit of the second transformer of a capacity to render zero the apparent self-induction of the pair of secondary and the pair of primary circuits above specified, substantially as described.

9. An electric valve comprising a vacuum tube containing one terminal connected to one side of the circuit, a pair of terminals of opposite sign to the first connected to the other side of the circuit, these three terminals supporting alternating electromotive forces dephased by 180 degrees, and a fourth terminal similar to the first terminal, the first and fourth terminals supporting an electromotive force, dephased with reference to the electromotive forces first specified to always maintain an arc in the exploder, substantially as described.

10. The combination of an electric valve comprising a vacuum tube having terminals of opposite signs, a source of alternating electromotive force to be rectified connected with the terminals, a source of electromotive force of high tension to initially establish the arc in the valve, and a source of electromotive force dephased with reference to the electromotive force to be rectified, to always maintain an arc in the valve, substantially as described.

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

MAURICE LEBLANC.

Witnesses:

P. PELAPHY,
H. C. COXE.