J. L. WOODBRIDGE.

MEANS FOR INTERCONVERTING ALTERNATING AND DIRECT CURRENTS.

APPLICATION FILED JULY 16, 1915.

1,244,569.

Patented Oct. 30, 1917.

2 SHEETS—SHEET 1.

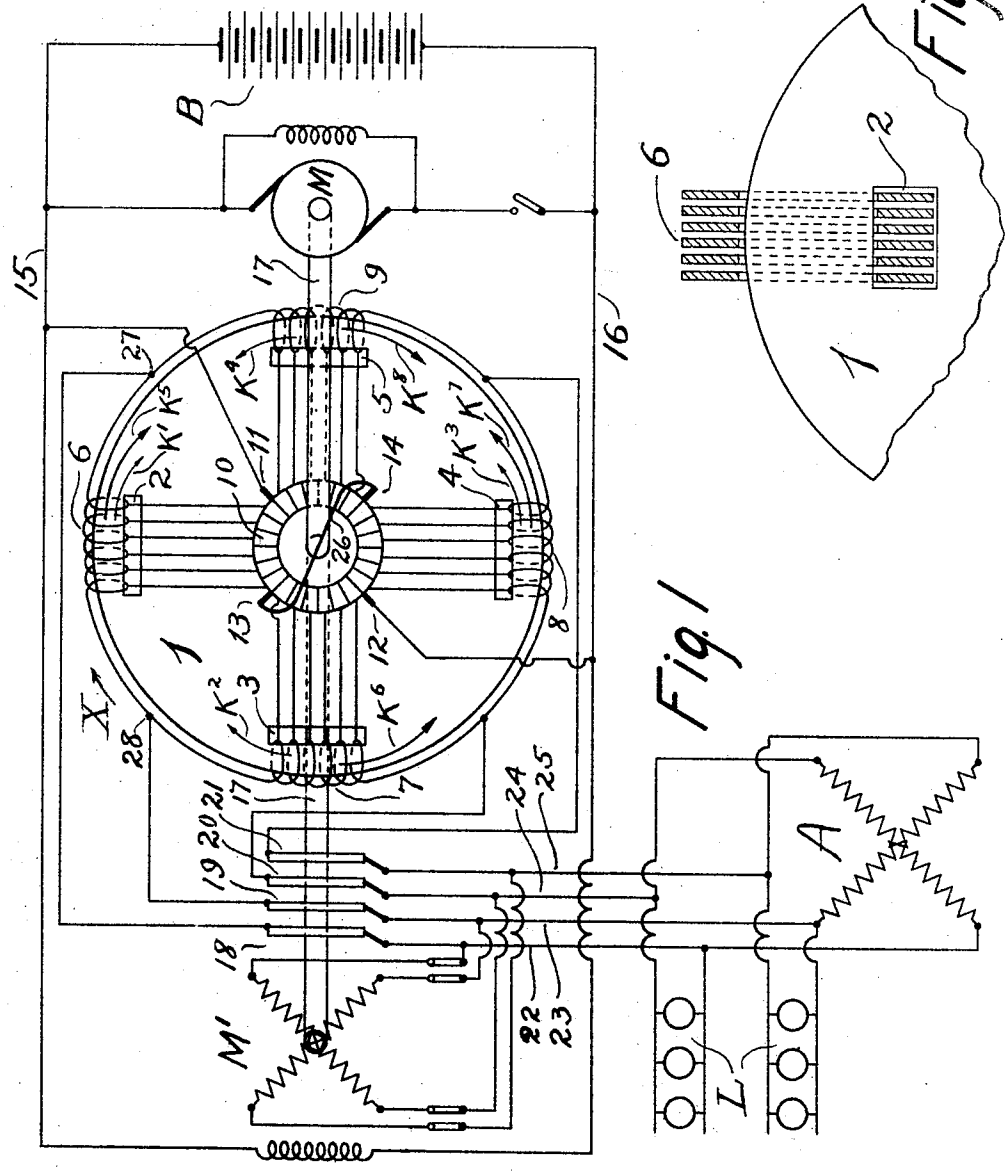


Fig. 1

Fig. 2

WITNESSES:

C. Armbruster.

J. H. Tracy

INVENTOR

Joseph Lester Woodbridge

BY

Augustus B Stoughton

ATTORNEY.

J. L. WOODBRIDGE.

MEANS FOR INTERCONVERTING ALTERNATING AND DIRECT CURRENTS.

APPLICATION FILED JULY 16, 1915.

1,244,569.

Patented Oct. 30, 1917.

2 SHEETS—SHEET 2.

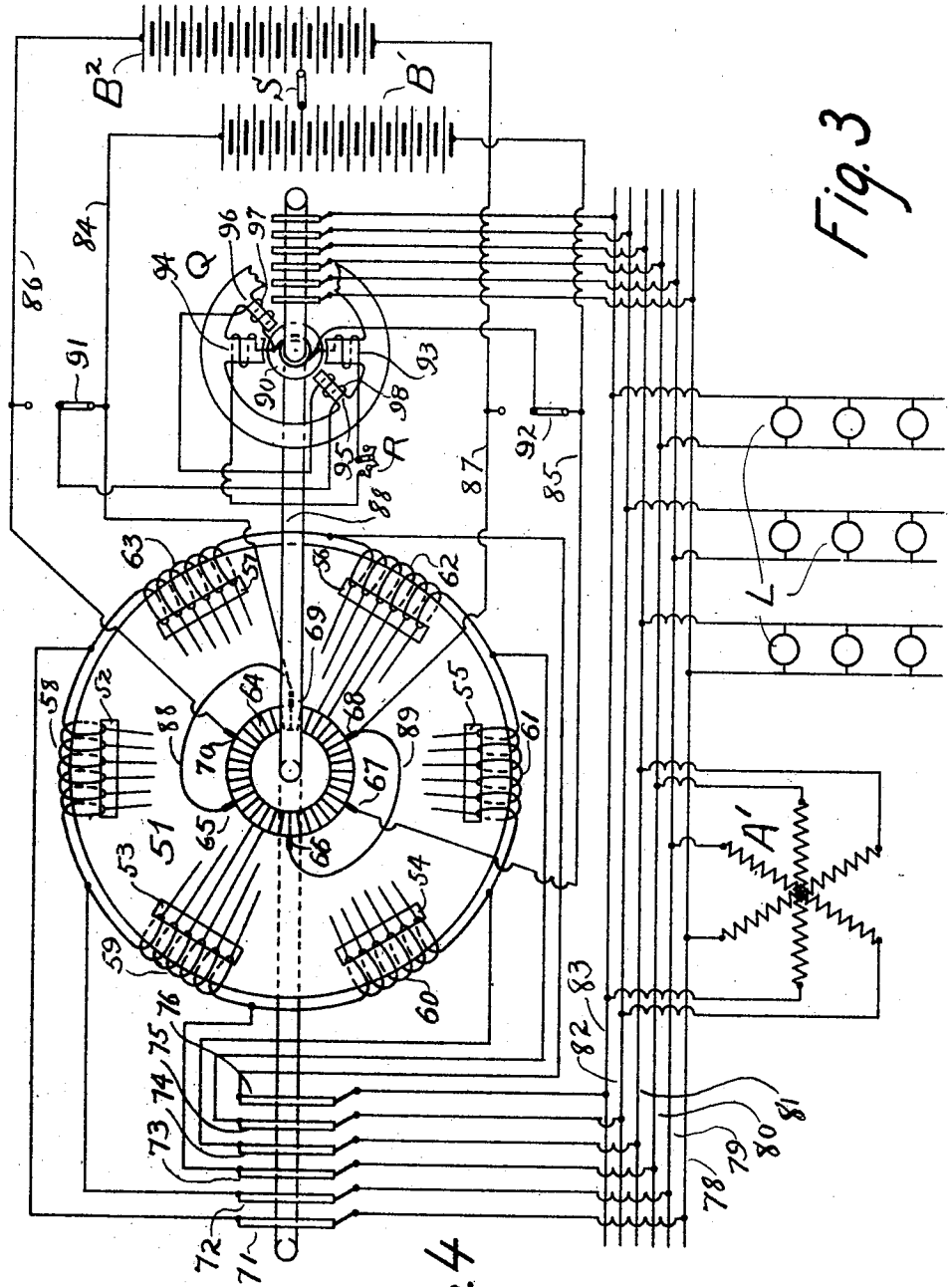


Fig. 3

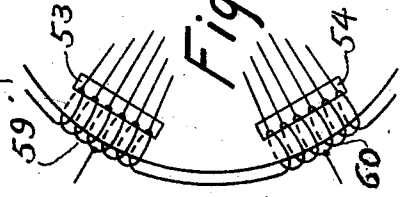


Fig. 4

WITNESSES:

C. Ambruster.

J. H. Tracey.

INVENTOR

Joseph Lester Woodbridge

BY

Augustus B. S. Coughlin

ATTORNEY.

UNITED STATES PATENT OFFICE.

JOSEPH LESTER WOODBRIDGE, OF PHILADELPHIA, PENNSYLVANIA.

MEANS FOR INTERCONVERTING ALTERNATING AND DIRECT CURRENTS.

1,244,569. Specification of Letters Patent. Patented Oct. 30, 1917.

Application filed July 16, 1915. Serial No. 40,190.

To all whom it may concern:

Be it known that I, JOSEPH LESTER WOODBRIDGE, a citizen of the United States, and a resident of the city of Philadelphia, in the State of Pennsylvania, have invented certain new and useful Improvements in Means for Interconverting Alternating and Direct Currents, of which the following is a specification.

My invention relates to apparatus for converting alternating current into direct current, or vice versa, and especially to such converting apparatus in which there is a magnetic structure, all parts of which are relatively fixed, upon which are wound suitable coils or windings connected to the AC and DC circuits; such apparatus, for example, as described in my Patent No. 880,705.

The object of my invention is to provide more efficient and less expensive means for effecting the interconversion of alternating and direct currents, to improve the commutation in apparatus designed for this purpose, and further to provide improved means for rotating such converting apparatus.

These and other objects of the invention will be more clearly understood by reference to the following description in connection with the accompanying drawings, in which,

Figure 1 is a diagrammatic view of apparatus involving features of the invention, and arranged for converting 2 phase alternating currents into direct current or vice versa.

Fig. 2 illustrates details of one section of the winding shown in Fig. 1.

Fig. 3 is a diagrammatic view of apparatus similar to that shown in Fig. 1, except that it is designed for connection to a 6 phase circuit, and a special split pole converter is used for driving, and

Fig. 4 shows an alternative method of connecting the alternating current circuit to the windings of Fig. 3.

Referring to Fig. 1, 1 is a magnetic structure similar to the iron core of a dynamo armature, preferably made up of laminations of iron, and provided with 4 openings, 2, 3, 4, and 5 near the periphery, through which openings pass the conductors of the windings 6, 7, 8 and 9. The winding is thus divided into four sections, all of the turns of each section passing through the corresponding opening in the iron core so that all of the turns in any one section embrace the same portion of the magnetic circuit. The object of this construction is to insure that any magnetic flux that passes through one turn of the winding shall pass through all the other turns in the same section. In order to secure this result more effectively and prevent leakage of flux between adjacent turns of the winding the conductors are preferably made of flat strip, as shown more in detail in Fig. 2, which shows the conductors of sections 6 of the winding to an enlarged scale and partly in section. This construction increases the reluctance of the leakage path for magnetic lines between adjacent conductors by increasing the length and reducing the cross sectional area of such paths.

The object of this construction will be explained later.

Referring to Fig. 1 a commutator 10 is shown connected in the usual manner to the windings 6, 7, 8 and 9. Upon this commutator bear four brushes, 11, 12, 13 and 14, of which one pair, 13, 14 is short-circuited by conductor 26, while the other pair, 11, 12, is connected to the direct current circuit 15, 16. The magnetic structure 1 with its commutator and windings is mounted on a shaft 17, which may be driven by a suitable direct current motor M connected across the circuit 15, 16. A suitable source of direct current, such as the battery B may be connected across the circuit 15, 16. On the shaft 17 are also mounted collector rings 18, 19, 20 and 21 connected to points in the winding intermediate between the sections 6, 7, 8 and 9. Suitable brushes bearing upon the collector rings are connected to the two phase alternating current circuit 22, 23, 24, 25. To the latter circuit a source of two phase alternating current A is connected, as well as translating devices L. A two phase synchronous motor M^1 is also shown mechanically connected to the shaft 17 and electrically connected to the two phase circuit 22, 23, 24, 25. Suitable switches are shown for connecting or disconnecting the motors M and M^1 to the corresponding cir-

cuits so that the shaft 17 may be driven either from the DC circuit or from the AC circuit as desired.

When the source A is connected to the AC circuit the synchronous motor M^1 should be used for driving the shaft 17 in order to produce synchronous rotation of the converter. If the source A is disconnected the direct current motor M may be used for driving the converter.

The method of operation of the apparatus shown in Fig. 1, is, in general, similar to that described in my Patent No. 880,705. Assuming first that the source of alternating current A is disconnected and the magnetic structure 1 with its windings and commutator is being rotated by means of the motor M, a small amount of direct current passing from the circuit 15, 16 through the windings 6, 7, 8, 9 by way of the brushes 11 and 12 will produce a primary component of magnetic flux in these windings in the direction of the arrows K^1, K^2, K^3 and K^4. In the position shown in the drawing, current from conductor 15 entering brush 11 divides into two parts, one part passing through sections 6 and 7, and the other through sections 9 and 8 to brush 12. As the rotation progresses in the direction of the arrow X, the current in some of the coils of sections 7 and 8 is reversed, thus reducing and finally reversing the magnetic flux in these two sections. This change of magnetic flux induces an electro-motive-force in the coils affected thereby, and this electro-motive-force develops a difference of potential between brushes 13 and 14. Since these two brushes are short-circuited by conductor 26, a small flow of current will take place between these brushes. This current passing through the windings 6, 7, 8, 9 produces a secondary component of magnetic flux represented by the arrows K^5, K^6, K^7, and K^8. The rotation of the converter causes a similar variation and reversal of this secondary component of magnetic flux in the sections of the windings, resulting in an electro-motive-force between brushes 11 and 12, which will be counter to that of the circuit 15, 16. If the apparatus is properly designed and operated at a suitable speed this counter-electro-motive-force will be nearly equal to that of the circuit 15, 16, but just enough less to permit the small flow of current into the brushes 11, 12, necessary to establish the primary magnetic flux described above.

The counter-electro-motive-force developed across the brushes 11, 12, as described above, will also appear as an alternating current electro-motive-force at the collector rings 18, 19, 20, 21, and alternating currents may, therefore, be taken from these collector rings for the translating devices L, or the alternating current source A, if operating at a suitable voltage and frequency may be connected to the alternating current circuit 22, 23, 24, 25. Obviously the rotation of the converter 1 must be maintained in synchronism with the source A, and to insure this the synchronous motor M^1 should be used for driving the converter whenever the source A is connected. Under these conditions the direct current motor M should preferably be disconnected. When alternating currents are taken from the collector rings 18, 19, 20, 21 in phase with the alternating electro-motive-force across these collector rings, these currents in the windings 6, 7, 8, 9 will, in general be opposed to the small direct current input at the brushes 11, 12 necessary to maintain the primary magnetic flux above described. The first effect, therefore, of any such alternating current output from the converter will be a tendency to reduce the counter-electro-motive force developed in its windings, and this reduction will permit an in-put of direct current at the brushes 11, 12 equal and opposite to the alternating currents taken from the collector rings. Similarly if the voltage of the source A is raised sufficiently, alternating currents will be supplied to the converter increasing the counter-electro-motive-force at the brushes 11 and 12 until this exceeds the voltage of the battery B and energy will be transferred from the source A to the battery. The apparatus, therefore, acts as a true inductive converter between the alternating and the direct current circuits.

When the direct current brushes are in the position shown in the diagram, direct current entering the brush 11 may pass directly to collector ring 18 by way of tap 27 without passing around the magnetic circuit of the converter. When, however, the rotation has proceeded until the brush 11 is in contact with one of the commutator bars connected to an intermediate point of section 6 of the winding, the current entering brush 11 will divide, a part of it passing to the tap 27 and the balance going to tap 28. This division of current will be such as to reduce the total ampere turns in section 6 practically to zero, except for the small exciting currents necessary to maintain the counter-electro-motive-force as described above. For example, if brush 11 is in contact with the next commutator bar to that shown so that there will be one turn between brush 11 and tap 27, and 5 turns between brush 11 and tap 28, then one-sixth of the total current entering brush 11 with pass to tap 28, and five-sixths to tap 27, thus the one-sixth of the current passing through five turns of section 6 will just balance the five-sixths of the current passing in the opposite direction through one turn. This division of current at any point in the rotation will be brought about owing to the fact that

any small departure from it will produce changes of flux in the sections of the winding and resultant induced electro-motive-force tending to restore the balance of ampere turns as described above.

In order to produce this result, it is necessary that in any position of the brushes on the commutator, intermediate of the windings of sections 6, 7, 8, 9, there shall be an alternating current tap on each side of each brush. In other words, there must be the same number of alternating current taps as there are direct current brushes. This construction very materially reduces the tendency to sparking at the brushes, and also avoids the tendency to magnetic saturation in sections of the magnetic circuit.

The short-circuit conductor 26 in addition to providing a path for the exciting current necessary to develop the counter-electro-motive-force required across the brushes 11, 12 has also another important function. If the alternating current on the two phases of the circuit is unbalanced, for example, if all of the load is taken from the two conductors 22, 24, or if the load on these two is greater than that taken from the conductors 23, 25, a part of this excess current will pass through conductor 26 in certain positions of the brushes on the commutator. This result also occurs if the converter is used for transforming single phase alternating current into direct current.

In Fig. 3 a modification of the invention is shown in which the converter is adapted for connection to a 6 phase alternating current circuit. The magnetic core 51 is provided with six openings 52, 53, 54, 55, 56 and 57 on which are wound, respectively, the groups of coils 58 to 63. These coils are connected to the commutator 64 in the usual manner, but in order to avoid confusion most of the conductors connecting the coils to the commutator bars have been interrupted on the drawing. Six brushes are shown bearing on the commutator numbered from 65 to 70, inclusive. Brushes 65 and 69 are short circuited as well as brushes 66 and 68. Brushes 64 and 67 are connected to the opposite terminals of a storage battery B^1 and brushes 70 and 68 are connected to the opposite terminals of a second storage battery B^2. Under usual conditions of operation the positive terminal of the battery B^1 will have a different potential from the corresponding terminal of the battery B^2. There will, however, be certain points in the two batteries which will have the same potential and may be connected together as by the switch S. This intermediate circuit between the two batteries will under some conditions of unbalanced AC load, and some positions of the brushes on the commutator carry a part of the unbalanced current. Under other conditions this circuit will carry no current and the switch S need not be closed. The converter 51 is mounted on a shaft 88 which carries 6 collector rings numbered from 71 to 76, inclusive, which are connected to corresponding taps between the adjacent sections of the converter winding, as shown. These collector rings by means of suitable brushes are connected to the six conductors of the 6 phase circuit, numbered from 78 to 83, inclusive. To this 6 phase circuit is connected a source of 6 phase alternating current A^1 and translating devices L.

The shaft 88 is driven by a split pole converter Q constructed in the usual manner with a bi-polar wound armature 90 provided with the usual commutator, and six collector rings. The latter are connected to the 6 phase circuit, while the commutator through suitable brushes is connected to the terminals of the battery B^1. Double throw switches 91 and 92 permit the direct current terminals of the converter Q to be disconnected from the battery B^1, and connected to the battery B^2 if desired. The converter Q is provided with main poles 93 and 94 and regulating poles 95 and 96. These latter have their usual function of varying the direct current electro-motive-force developed in the armature without changing the value of the alternating current electro-motive-force in any marked degree when their excitation is varied.

The converter Q is designed to act as a motor for driving the converter 51, either from the AC circuit or the DC circuit. It is, however, so designed as to prevent any considerable transfer of energy between these two circuits, such transfer being accomplished through the converter 51. This result is secured by a special winding on the regulating poles 95 and 96.

The main poles 93 and 94 are provided with an ordinary shunt field winding connected across the brushes of the machine so that the excitation of the main poles is substantially constant. The regulating poles 95 and 96 are provided with a series winding 97, 98 connected between one brush of the machine and the direct current circuit. This series winding is wound in the direction to increase the direct current voltage of the machine with any increase of direct current input to the DC brushes. If, therefore, there should occur any tendency to transfer energy between the AC and the DC circuits through the machine Q, a change in the direct current input or output of this machine will vary the counter-electro motive force developed in the machine in the direction to counteract such tendency.

Furthermore, the regulating poles 95 and 96 are located on the trailing side of the main poles. This produces a shift of the alternating current electro-motive-force of the machine with any change in the excita-

tion of these regulating poles in the direction to further counteract the transfer of energy between the AC and DC circuits. Thus if there is a small increase of direct current input to the machine Q the strength of the regulating poles is increased, thus shifting the mean position of the total field flux in the direction of armature rotation. This shift will retard the phase of the alternating current electro-motive-force developed in the armature of the machine Q causing it to take additional energy from the AC circuit in accordance with the usual law of synchronous machines of this type. This input of energy from the AC circuit will oppose any further increase of input from the DC circuit. The shunt field excitation of the machine Q may be adjusted by means of the rheostat R, so that when running at synchronous speed the energy required to drive the apparatus will be taken substantially all from the DC circuit. Any slight variation in the energy required will be supplied from the AC circuit on account of the action of the regulating poles as above described. If the supply of alternating current energy from the source A^1 is interrupted, the machine Q will still continue to drive the converter 51 and energy will be supplied to the translating devices L through this converter from the batteries B^1 and B^2.

While Figs. 1 and 3 show the AC taps taken from points intermediate between the various sections of the converter winding, this arrangement is not necessary, and these taps may be taken from intermediate points in each winding section instead of from points between adjacent sections, as shown in Fig. 4. In such case it is preferable to take these taps from the middle point of each section, in order to secure a symmetrical wave shape of alternating electro-motive-force. One of the advantages of the construction shown in Figs. 1 and 3, and especially that shown in Fig. 3 lies in the fact that when current is being transmitted between the AC and the DC circuit, the average current value in the windings of the converter 51 is comparatively small. It will be noted that there are 6 points in each revolution of the converter, at which the current passes directly from the AC to the DC circuit or vice versa without passing through the converter winding at all.

In other positions the current is divided in inverse ratio to the number of coils through which it is transmitted, so that the heaviest current is transmitted through the fewest number of coils. This reduces the total amount of heating in the winding and permits a small machine to carry comparatively large loads.

It will be noted that in some positions of the brushes, direct current flows in opposite directions to or from an intermediate point in each of the winding sections, the ampere turns on each side of this intermediate point being equal and opposite. In order to reduce to a minimum the leakage of magnetic flux across the openings 2, 3, 4, 5 under these conditions, the leakage path should be as long and of as small cross section as possible. This result is accomplished by making the conductors of thin strips as shown in Fig. 2.

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

1. In apparatus of the type described for interconverting alternating and direct currents, the combination of a plurality of closed magnetic circuits, a group of conducting coils embracing each of said circuits, said groups connected in series to form a continuous closed circuit winding, a commutator connected to said winding, brushes bearing upon and spaced apart around said commutator at contact points equal in number to the number of coil groups, short circuiting connections interconnecting some of said brushes, alternating current taps to said winding, one for each coil group, and means for producing relative rotation of commutator and brushes.

2. In apparatus of the type described for interconverting alternating and direct currents, the combination of winding sections, a closed magnetic circuit and an alternating current tap for each section, a commutator connected to the sections and direct current brushes equal in number to the taps and equally spaced around the commutator.

3. In apparatus of the type described for interconverting alternating and direct currents, the combination of winding sections, a closed magnetic circuit and an alternating current tap for each section, a commutator connected to the sections, direct current brushes equal in number to the taps and immovable in respect to each other, and means for short circuiting some of said brushes.

4. In apparatus for interconverting alternating and direct currents, the combination of a converter devoid of motor function and a motor devoid of converter function for driving the converter, said motor drivable from both the alternating and direct current source simultaneously.

5. In apparatus of the type described the combination of groups of coils, closed magnetic circuits one of which passes through all the coils of each of the respective groups, a commutator connected to the coils, and alternating current taps and direct current brushes equal in number to the number of groups and symmetrically spaced.

6. In apparatus of the type described the

combination of six winding sections, a closed magnetic circuit and an alternating current tap for each section, a commutator connected to the sections, six direct current brushes whereof two pair are short-circuited, two sources of direct current each of which is connected between one of the pairs of short circuited brushes and one of the single brushes, and connections from the taps to a six phase alternating current circuit.

In testimony whereof I have duly executed these presents this 13th day of July, 1915.

JOSEPH LESTER WOODBRIDGE.

Witnesses:
J. L. MACBURNEY,
W. G. ROGERS.

Copies of this patent may be obtained for five cents each, by addressing the "Commissioner of Patents, Washington, D. C."