No. 788,279. PATENTED APR. 25, 1905.

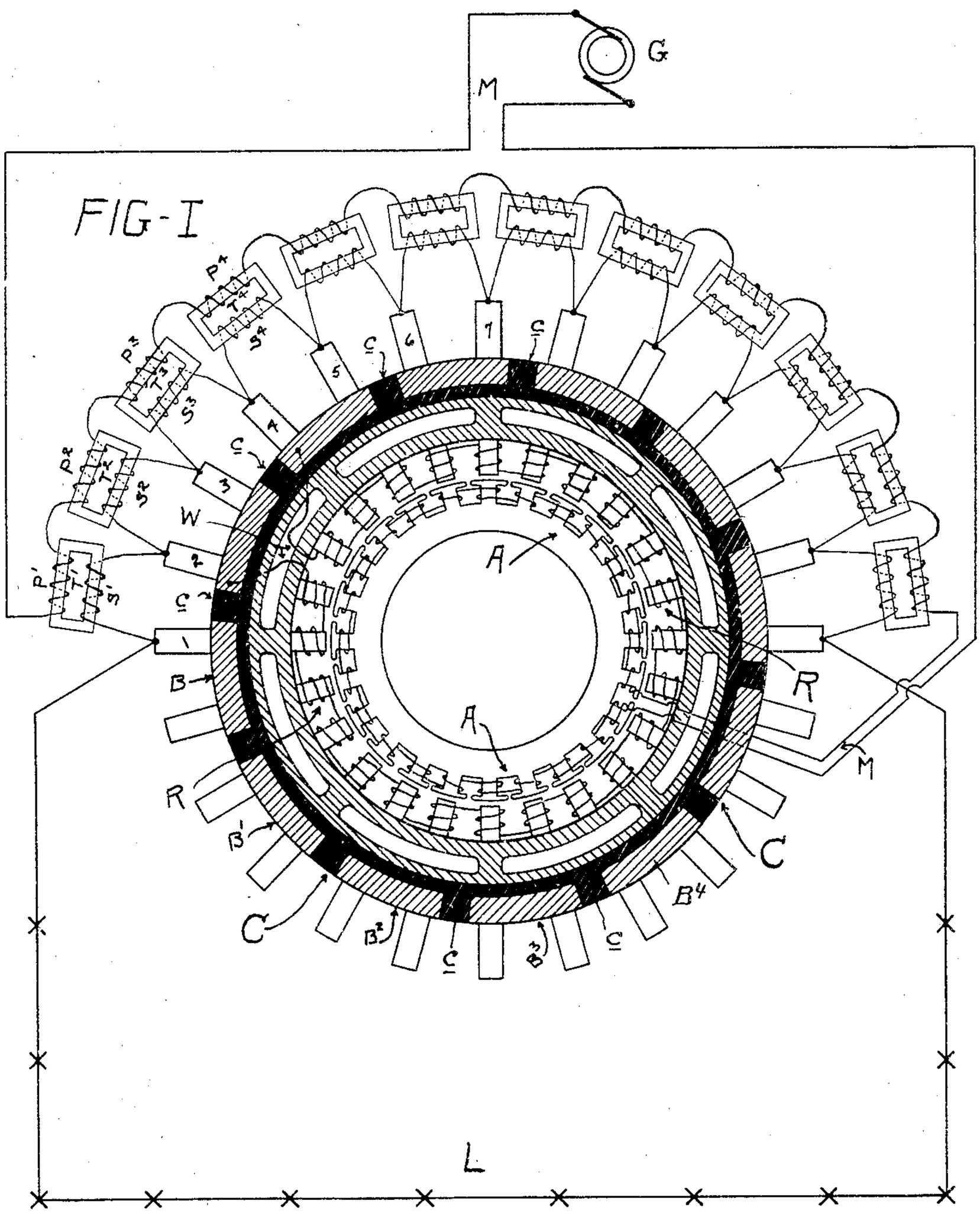
E. H. PORTER & B. CURRIER.

ALTERNATING CURRENT RECTIFIER.

APPLICATION FILED OCT. 7, 1904.

3 SHEETS—SHEET 1.

FIG-I



WITNESSES:

M. R. Cleland

H. Woodhead

INVENTORS:
Edwin H. Porter and
Burleigh Currier
BY
F. DeWitt Goodwin
ATTORNEY.

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3 SHEETS—SHEET 2.

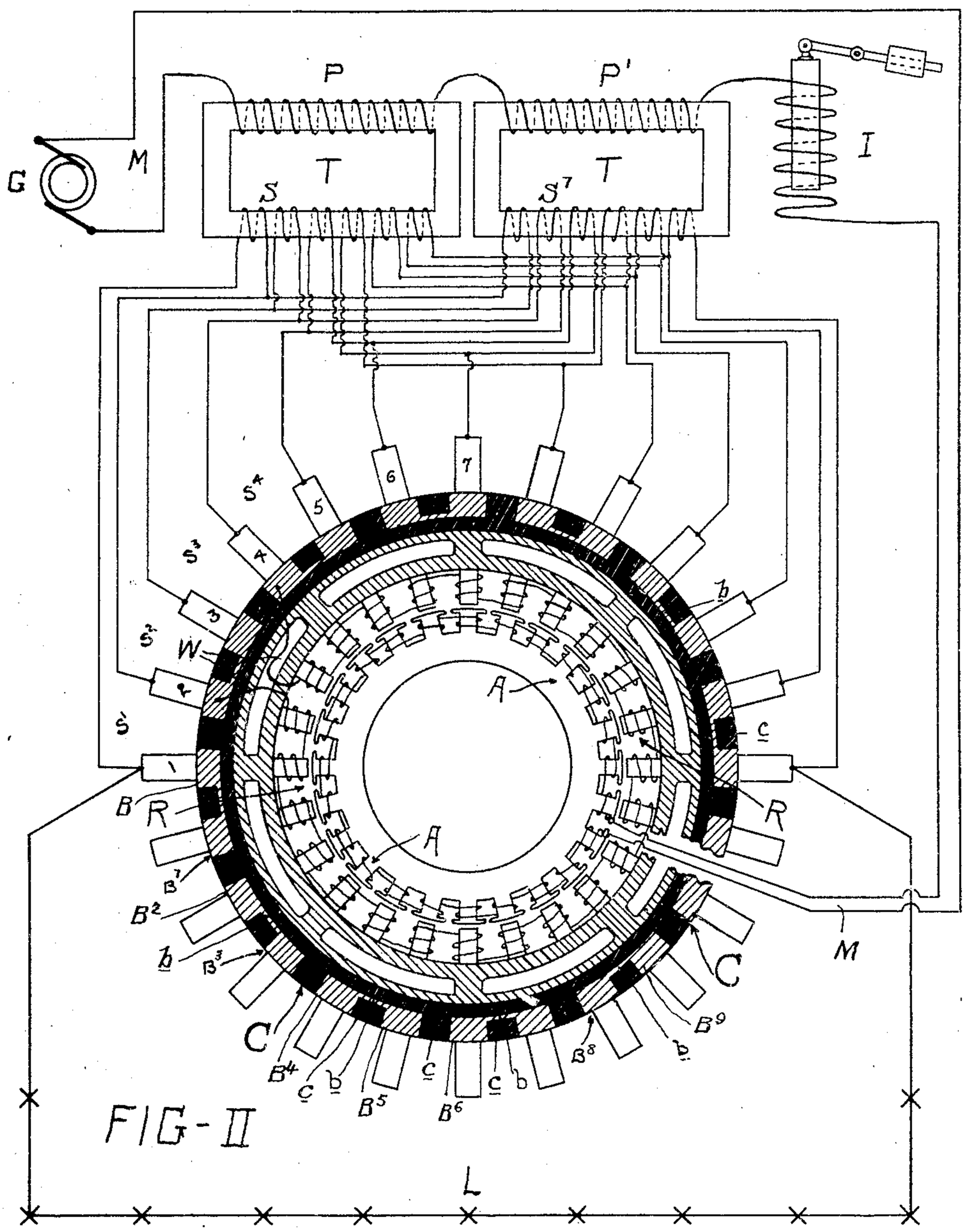

FIG-II

WITNESSES:

M. R. Cleland
F. N. Woodhead

INVENTORS:
Edwin H. Porter and
Burleigh Currier
BY
F. DeWitt Goodwin,
ATTORNEY.

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3 SHEETS—SHEET 3.

FIG-III

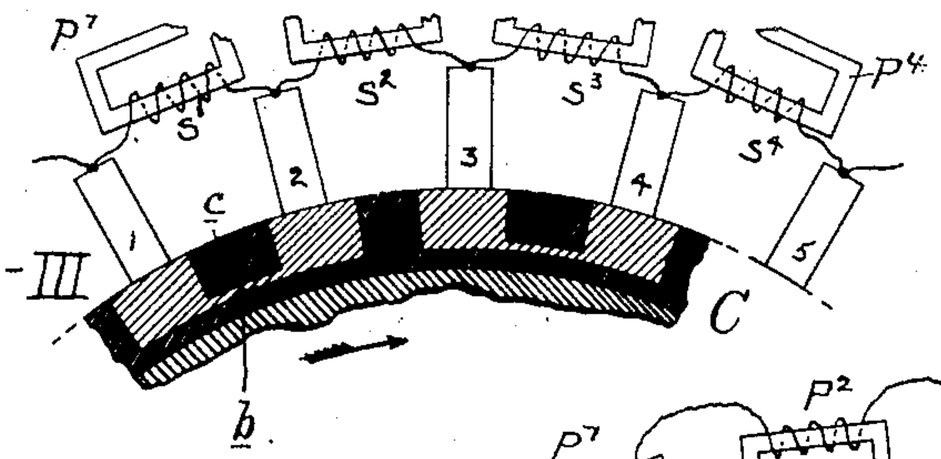


FIG-IV

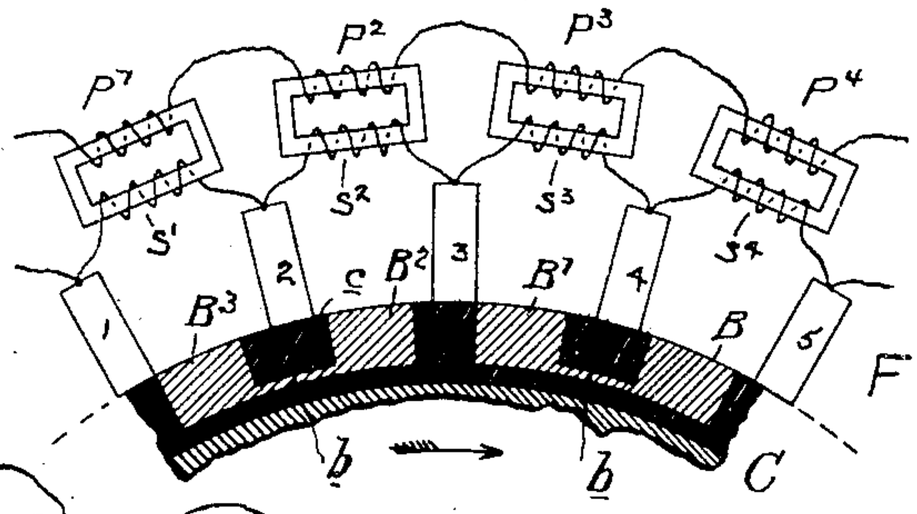


FIG-V

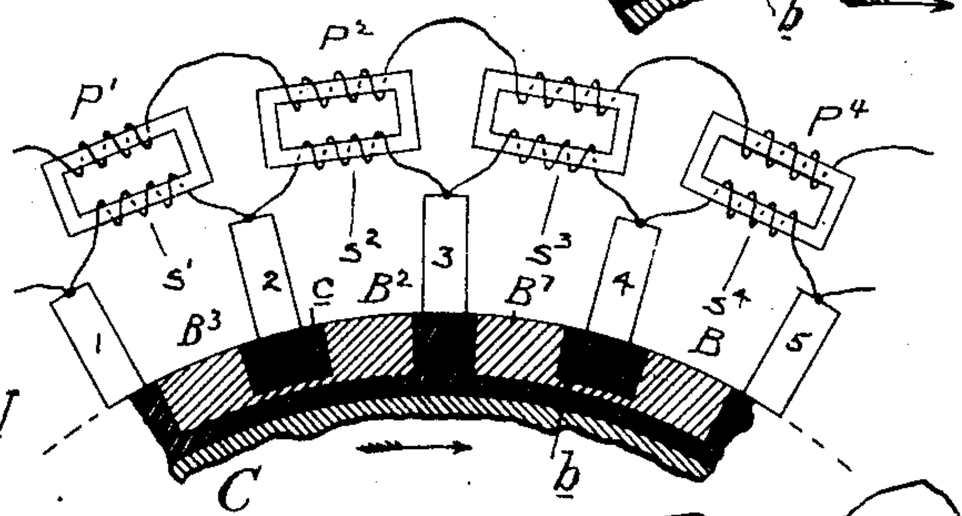


FIG-VI

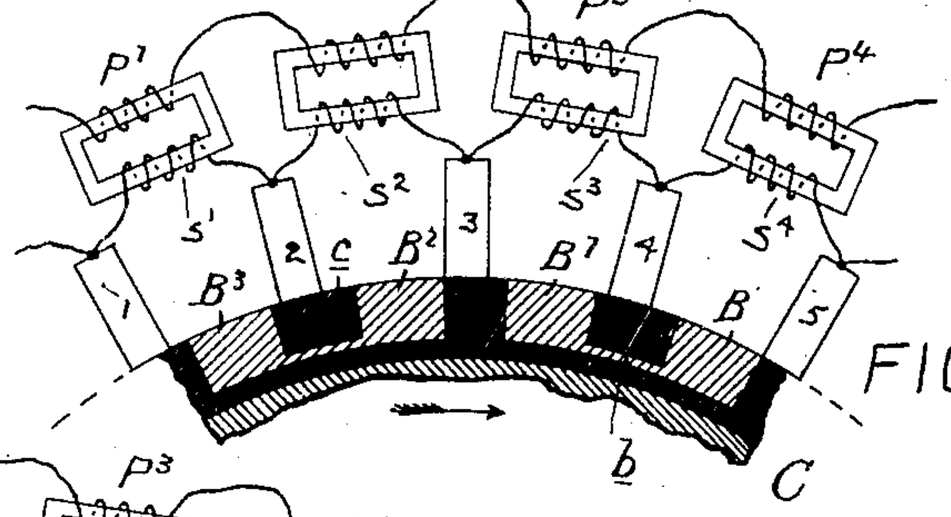
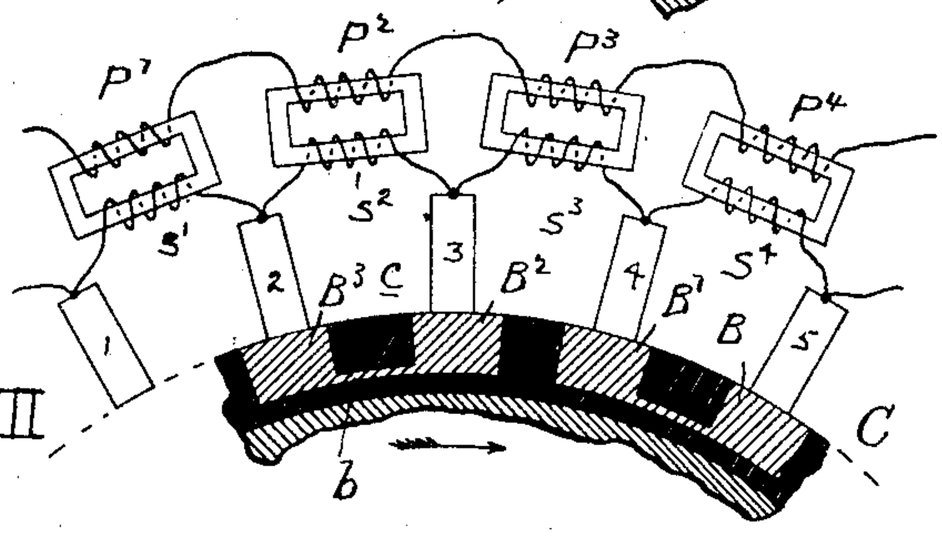


FIG-VII



WITNESSES:

N. R. Cleland

J. H. Goodhead

INVENTORS:
Edwin H. Porter and
Burleigh Currier
BY
F. DeWitt Goodwin
ATTORNEY.

No. 788,279. Patented April 25, 1905.

UNITED STATES PATENT OFFICE.

EDWIN H. PORTER AND BURLEIGH CURRIER, OF PHILADELPHIA, PENNSYLVANIA.

ALTERNATING-CURRENT RECTIFIER.

SPECIFICATION forming part of Letters Patent No. 788,279, dated April 25, 1905.

Application filed October 7, 1904. Serial No. 227,521.

To all whom it may concern:

Be it known that we, EDWIN H. PORTER and BURLEIGH CURRIER, citizens of the United States, residing at Philadelphia, in the county of Philadelphia and State of Pennsylvania, have invented certain new and useful Improvements in Alternating-Current Rectifiers, of which the following is a specification.

Our invention relates to alternating-current electrical apparatus, and particularly to a rectifier for translating an alternating current into a unidirectional or direct current.

The object of our invention is to produce a simple rectifier which will be free from the sparking and flashing and consequent rapid deterioration commonly found in this type of apparatus.

A further object of our invention is to construct the rectifier in a manner to accomplish the above results and to avoid disconnecting the work-circuit from the supply-circuit; also, to avoid short-circuiting the work or supply circuit at any time.

Our invention, generally speaking, consists of a commutator with means for driving the same, and brushes in conjunction with a generator, transformers arranged in the circuit from the generator, together with various novel features of construction and organization of parts, which will be hereinafter fully set forth.

Throughout the specification the words "electromotive force" are abbreviated to "E. M. F."

In the drawings, in which similar letters refer to similar parts throughout the several views, Figure 1 is a diagrammatic view showing a motor, commutator, brushes, and transformers, illustrating our invention. Fig. 2 is a view similar to Fig. 1, showing the parts more in detail, also a slightly-different arrangement of said parts. Figs. 3, 4, 5, 6, and 7 are diagrammatic views showing the brushes and the commutator-bars in successive positions in relation to said brushes.

Referring to the drawings, A represents the stationary armature of a synchronous motor having a revolving field R. The circuit M is supplied with an alternating current from any source, such as the generator G, which may be operated by any suitable mechanical means. The circuit M supplies the motor-armature A with an alternating current, which is the current to be rectified.

The commutator C is carried by the revolving field R of the motor and is composed of bars B B′ B^2 B^3 B^4, and so on, which are separated by insulating material *c*, which, if desired, may be provided with sheets of metal scattered between the layers of insulation to insure them wearing evenly.

Stationary brushes 1 2 3 4 5, and so on, are in working contact with the commutator C. The bars B′ B^2 B^3, and so on, of the commutator are of sufficient width to connect any adjacent two of said brushes and to short-circuit the same.

The transformers T′ T^2 T^3, and so on, have primary coils P′ P^2 P^3, and so on, connected in the circuit M. The transformers also have secondary coils S′ S^2 S^3, and so on, connected to the brushes. As shown in Fig. 1, there is one transformer to each space between the brushes.

It is clear that the number of bars in the commutator and the number of brushes can be anything desired consistent with a synchronous speed. It will be arranged to use a large number of bars at a low speed for high voltage, giving a low voltage per bar and coil.

In Fig. 2 the commutator-bars B B′, and so on, are arranged in pairs, having permanent connections *b* between them. Said bars are separated by insulating material, which, with the two bars exposed to contact with the brushes while the connecting-plate *b* is below the contact-surface of said insulation, will break the contact between the bars and the brushes and avoid sparking, as will be described hereinafter.

In Fig. 1 the transformers are shown each having only one secondary coil, one transformer to each space between the brushes. In Fig. 2 the same result is attained by the use of a less number of transformers—in this case two—each having a plurality of second-

aries and the two having their primaries in series.

In Fig. 2 a variable impedance I is shown in the alternating-current circuit. This is only for the regulation of the potential and current strength as applied to a constant-current circuit of variable resistance.

In both Fig. 1 and Fig. 2 only part of the allowable brushes are shown connected in circuit, other similar connections being omitted for clearness. The receiving-circuit is represented at L in Figs. 1 and 2.

In rectifying alternating currents the common practice to-day employs commutators of various designs to transpose the terminals of the supply-circuit relative to the work-circuit at the exact time of the reversal of the current in the supply-circuit. This transposition of circuits produces a unidirectional current in the receiving-circuit, while the current in the supply-circuit is alternating. This transposition is effected by disconnecting the receiving-circuit from the supply-circuit by the commutator, thus opening the circuit, or if the circuit is not opened the supply or work circuit must be short-circuited for a short period while the connection is being transposed, for the brushes overlapping the commutator-bars to keep the circuit closed necessarily short-circuit the supply or work circuit. Either of the above transposition methods would be successful if the E. M. F. and current both reached zero at the same instant and the rectifying-commutator were driven absolutely synchronous; but such conditions are never available in practice, so different degrees of sparking and flashing are experienced, which have made the use of rectifiers almost prohibitive.

In our present invention the sparking and flashing is avoided by not disconnecting the work-circuit from the supply-circuit nor short-circuiting the work or supply circuit at any time. In fact, the circuits are not disconnected or transposed in any way by the operation of the rectifier. Two equal alternating currents or E. M. F.'s of one hundred and eighty degrees difference in phase are taken from any alternating supply-circuit, preferably by means of transformers. We connect these alternating currents or E. M. F.'s in series with the receiving-circuit in such a manner that they oppose and neutralize each other, and their resultant is zero. We then arrange the bars B B′ B^2, and so on, of a synchronously-driven commutator to short-circuit successively the brushes or terminals of the E. M. F. or current that is not in the desired direction, leaving the remaining E. M. F. and current in the desired direction with relation to the receiving-circuit to do work in said circuit.

The act of short-circuiting the coil whose E. M. F. is in the wrong direction will not produce sparking, and suitable means are provided to prevent the current in the short-circuited coil from rising higher than that in the working coil. This could be accomplished by means of a constant-current transformer having sufficient magnetic leakage; but it is preferable to accomplish it by connecting the primaries of the two transformers in series whose secondaries supply the opposing currents. The short-circuiting of either secondary coil at the brushes eliminates the impedance of the primary of that transformer, leaving the full E. M. F. to apply to the primary of the transformer whose secondary is supplying the receiving-circuit.

The primary of each transformer is wound for the full E. M. F. that the two transformers are to receive in series, the current in the short-circuited coil being the same in strength as that of the coil doing the work.

On removing the short circuit from the inactive coil if the E. M. F. and current are both zero there would be no tendency to spark; but this would require absolute synchronism, so we have arranged that the coil when the short circuit is removed is already in the work-circuit. Any E. M. F. it may have at first is instantly met by an opposing E. M. F. of its mate till its mate is in turn short-circuited, leaving its own E. M. F. alone in the circuit throughout one alternation of E. M. F. in the supply-circuit.

The form of commutator-bars shown in Fig. 1 will accomplish the above result, in which the said bars are of sufficient width to short-circuit two brushes and their attached coils. This arrangement is satisfactory as long as the commutator is driven very close to synchronism. In Fig. 2 we have arranged insulation between the two halves of each bar of the commutator in such a manner as to break the contact between the bar and the brush that is connected at the juncture of the working coil and the inactive coil, so as to oppose the full E. M. F. of one coil to the E. M. F. of the coil as it is relieved from the short circuit and leave it doing work in the circuit after its opposing mate is short-circuited. By this arrangement if the reversal of the current is attempted at any part of the cycle the reversal will take place without sparking, equal E. M. F.'s being always opposed at the time of reversal.

In practice the commutator will be driven as near synchronously as possible; but an amount of leading or lagging less than the period of one alternation can be allowed without causing any difficulty.

The stationary brushes 1 2 3 4 5, and so on, as above stated, are in working contact with the commutator C, which is carried at a synchronous speed by the revolving field of the synchronous motor R A. The direct current for the field is supplied by the rectified cur-

rent at the commutator by the circuit W or supplied from any external source. The stationary armature is supplied with alternating current from the same source as that to be rectified.

Figs. 3 to 7 show the relation of the brushes to the commutator-bars throughout one half-cycle. The cycle of operations is as follows: Fig. 3 shows the secondary coils S′ and S^3 short-circuited, with coils S^2 and S^4 feeding the circuit. Fig. 4 shows the coils S′ in series with and opposing S^2, also coils S^3 in series with and opposing coil S^4 just at the instant of the removal of the short circuit or connection across coils S′ and S^3. Fig. 5 shows all the bars disconnected entirely from the brushes and the coils S′ with S^2 opposed, also coils S^3 and S^4 opposed in their E. M. F.'s. Fig. 6 shows coils S^2 and S^4 at the point of being short-circuited and coils S′ and S^3 introduced to feed the circuit. Fig. 7 shows coils S^2 and S^4 fully short-circuited and coils S′ and S^3 feeding the circuit at their maximum. This completes one half the cycle of operation. The other half of the cycle is a repetition of the first half with the succeeding bars.

As shown in Fig. 1, it is clear that one bar short-circuits through a pair of brushes, one alternation or one-half a cycle leaving one alternation or the other half-cycle active, so it is clear that one bar is required to each two brush-spaces or two alternations or one cycle, so the synchronous speed of the commutator-bars, Fig. 1, is the same as the cycles of the current to be rectified.

In Fig. 2, each bar being divided into two smaller bars joined together, it is evident that the number of half-bars or small bars per second is equal to twice the cycles per second of the current.

It is well known in the art that the synchronous motor of a rectifier can be displaced by connecting or gearing the commutator direct to the generator-shaft or other synchronously-revolving shaft. It is also well known in the art that rectifiers can be connected in series or multiple the same as batteries or other electrical generators, also that several rectifiers can be driven from one synchronous source of power and when so driven can be supplied with currents differing in phase from each other, providing the relative position of the commutator-bars and brushes is the same as the relative difference in phase between the currents applied. So, while we do not show different combinations of this rectifier in series and multiple or operating on different phased currents we would not want to confine ourselves to rectifiers of the above description operating singly. Also in our drawings for simplicity the primaries of all the transformers are all shown connected in series across the main. It is clear that the different pairs of transformers can be connected in multiple across the main, it being only necessary to have each active transformer with its primary in series with the primary of an inactive mate.

Having thus described our invention, we claim and desire to secure by Letters Patent—

1. In an alternating-current rectifier the combination of a source of alternating current and electromotive force supplying currents of opposing phase relation, a circuit embracing the opposing electromotive forces in series and means for synchronously short-circuiting the electromotive forces of undesired sign to produce a unidirectional pulsating electromotive force and current.

2. In an alternating-current rectifier the combination of a source of alternating electromotive forces of different phase relation whose algebraic sum is zero, a circuit embracing said electromotive forces in series with a work-circuit and means for successively synchronously short-circuiting all electromotive forces opposed to the flow of current in a desired direction in said work-circuit.

3. In an alternating-current rectifier the combination of a source of alternating electromotive forces whose algebraic sum is zero, a work-circuit embracing said electromotive forces in series and a synchronously-revolving commutator having insulated bars with brushes arranged to short-circuit all electromotive forces opposed to a desired flow of unidirectional current in the work-circuit.

4. The combination in an alternating-current rectifier of a source of alternating electromotive forces of a plurality of phases whose algebraic sum is zero, a work-circuit embracing said electromotive forces in series, brushes connecting to said electromotive forces and to said work-circuit, a commutator of insulated separate bars revolving synchronously and arranged so as to short-circuit all electromotive forces of a negative sign.

5. The combination in an alternating-current rectifier of a source of alternating electromotive forces of a plurality of phases whose algebraic sum is zero, a work-circuit embracing said electromotive forces in series, brushes connecting to said electromotive forces and to said work-circuit, a commutator of insulated separate bars revolving synchronously and arranged so as to short-circuit all electromotive forces of a positive sign.

6. The combination in a rectifier for alternating currents of a source of alternating currents, a transformer having its secondary joined to a pair of brushes, another transformer having its secondary coil joined to another pair of brushes, the brushes so connected with the secondaries that the secondaries are in series, each giving an electromotive force in a reverse direction, the primaries of the transformers also in series supplied from said source of alternating electromotive

force and a revolving commutator arranged to short-circuit each pair of brushes and connected secondaries in succession.

7. The combination in a rectifier for alternating currents, of a source of alternating currents, a set of transformers having their secondaries each joined to a pair of brushes, another set of transformers having their secondaries each joined to another pair of brushes, the brushes and secondaries so connected that each like set of secondaries is in series with the second set of secondaries giving an electromotive force in a reverse direction, the primaries of each set of transformers also in series with the primaries of the other set and supplied from said source of electromotive force and a revolving commutator arranged to short-circuit each set of brushes and connected secondaries in succession.

8. The combination of a source of alternating electromotive force, a synchronous motor operating from said electromotive force, the revolving element of said motor carrying a commutator of a plurality of insulated bars, brushes bearing on said commutator, opposing and equal electromotive forces of alternating direction applied between adjacent brushes in series with a work-circuit, the whole arranged to successively synchronously short-circuit all electromotive forces of one sign.

9. In an alternating-current rectifier the combination of two sources of alternating electromotive force of opposing phase relation, both electromotive forces being in series with a work-circuit, means for short-circuiting one electromotive force, and for opposing an opposite electromotive force at the time of removing the short-circuit, and for short-circuiting the opposing electromotive force as soon as the first short-circuit is removed.

10. A rectifying-commutator having a plurality of insulated bars, stationary brushes in contact with said bars, said bars being of such size and so arranged as to short-circuit successive adjacent brushes in pairs.

11. A rectifying-commutator having successive adjacent bars electrically short-circuited together in pairs, each pair insulated from all other pairs.

12. A synchronously-revolving commutator having a speed of bars per second equal to twice the cycles per second of the current to be rectified, adjacent bars being connected together in pairs by a low-resistance contact, each pair insulated from all other pairs.

13. A rectifier for alternating currents consisting of stationary brushes, transformers supplying alternating current of opposite phase relation to adjacent brushes, the algebraic sum of the electromotive forces of adjacent pairs of brushes being zero, a synchronously-revolving commutator having insulated bars arranged to short-circuit successively between all pairs of brushes bearing an electromotive force of like sign.

In testimony whereof we affix our signatures in presence of two witnesses.

EDWIN H. PORTER.
BURLEIGH CURRIER.

Witnesses:
WM. A. ALLISON,
WM. R. STACKHOUSE.