E. BLUM.

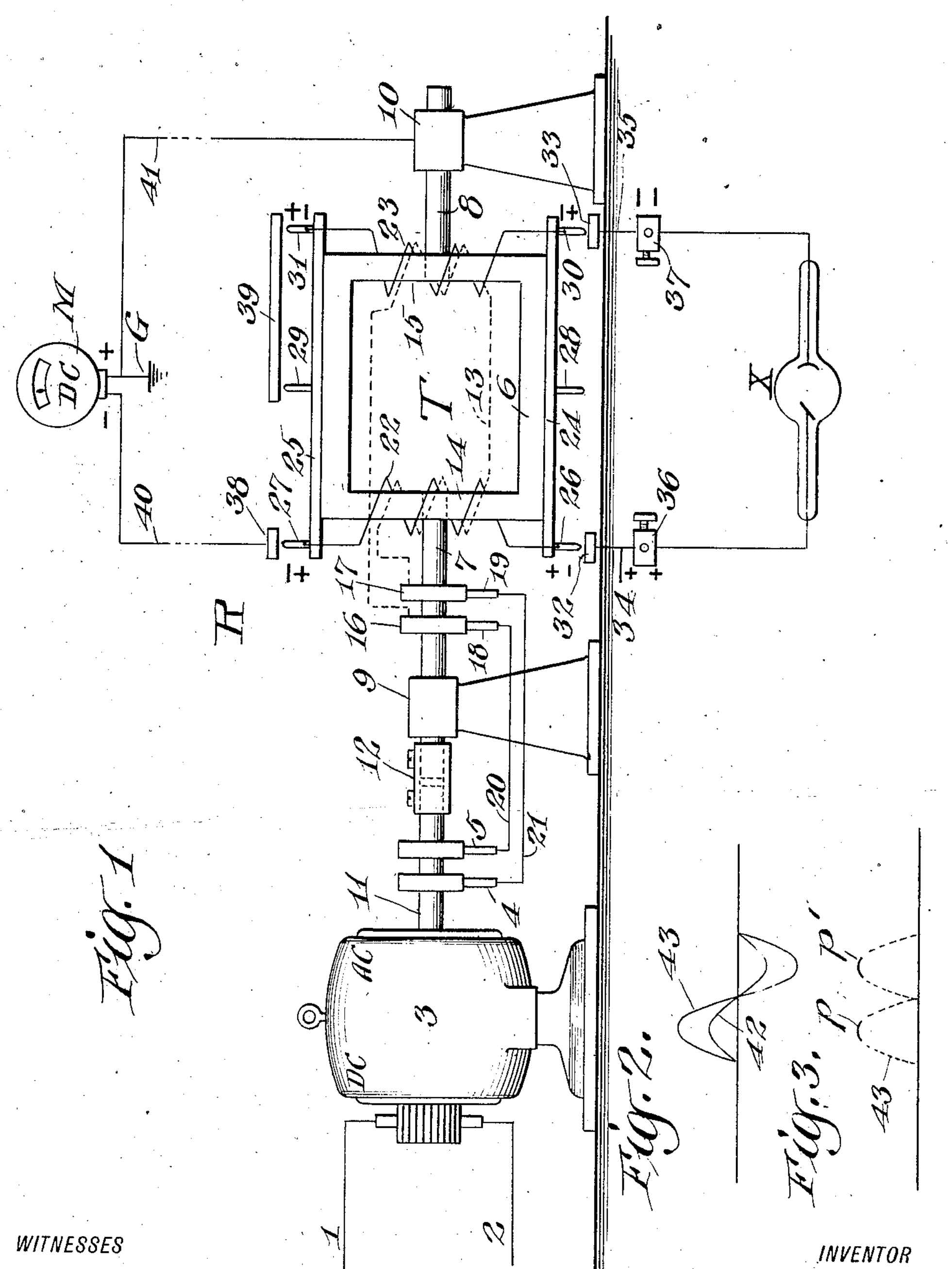
X-RAY SYSTEM.

APPLICATION FILED SEPT. 27, 1910.

1,003,325.

Patented Sept. 12, 1911.

2 SHEETS—SHEET 1.



WITNESSES

H. Crocheron

W. F. Allen.

INVENTOR

Eugen Blum

BY

Leonard Day

ATTORNEY

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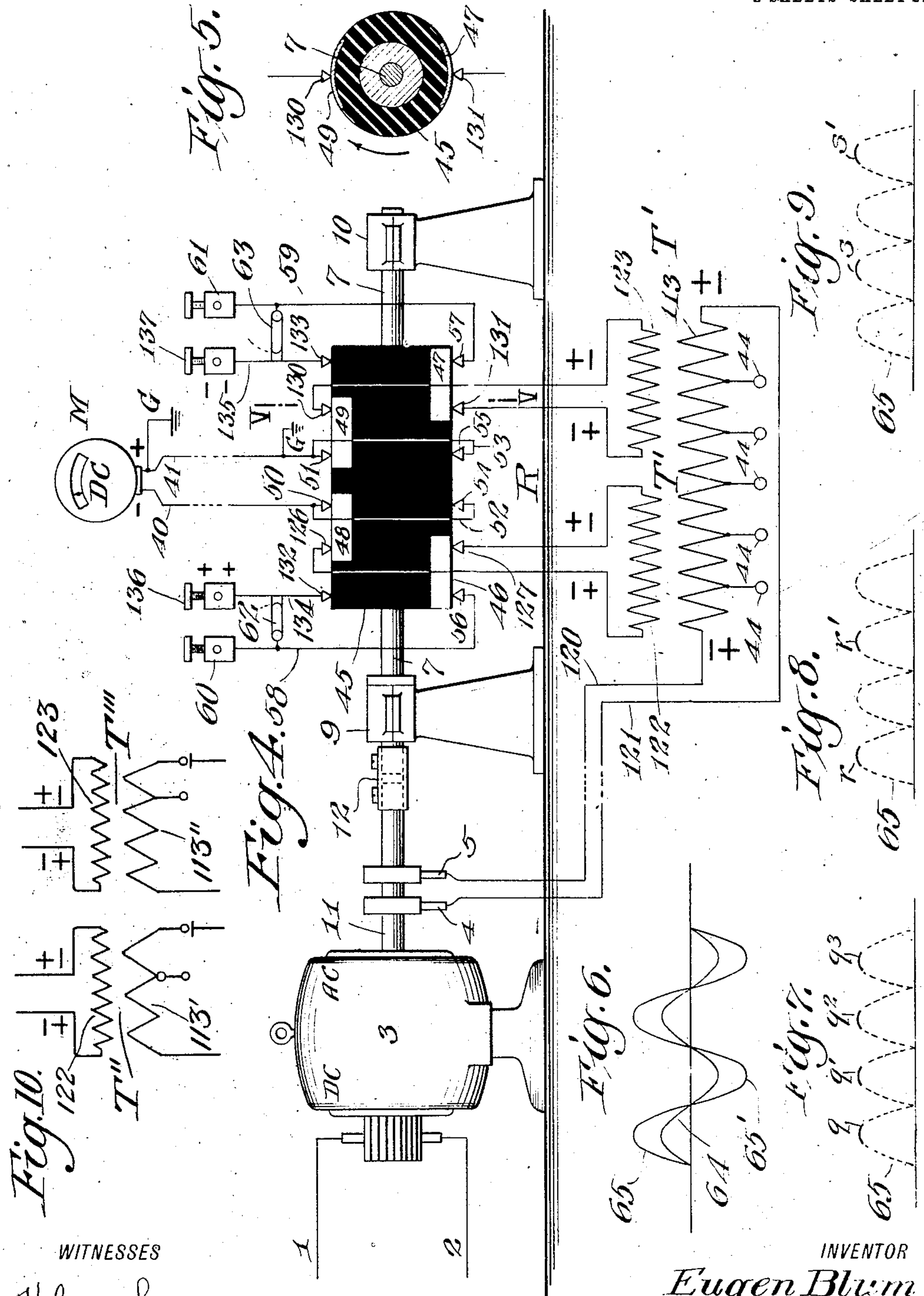

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UNITED STATES PATENT OFFICE.

EUGEN BLUM, OF UNION HILL, NEW JERSEY, ASSIGNOR TO THE KNY-SCHEERER COMPANY, A CORPORATION OF NEW YORK.

X-RAY SYSTEM.

1,003,325. Specification of Letters Patent. Patented Sept. 12, 1911.

Application filed September 27, 1910. Serial No. 584,037.

To all whom it may concern:

Be it known that I, EUGEN BLUM, a subject of the Emperor of Germany, and a resident of Union Hill, county of Union, and State of New Jersey, have invented certain new and useful Improvements in X-Ray Systems, as set forth in the following specification.

This invention relates to rectifying systems for high potential alternating-current and particularly to those adapted especially for X-ray work.

An object of the invention is to eliminate disadvantages present in rectifying systems previously known and at the same time to maintain the advantages of such systems. Previously known types of rectifying systems are exemplified in the patent to Lemp 774,138, November 1, 1904, and in the patent to Snook, 954,056, April 5, 1910. In a system such as that of the Lemp patent portions only of either the + or — waves are available in a working circuit.

In a system such as that of the Snook patent the rectification is such that corresponding portions of both the + and — waves are available. The disadvantages inherent in each of these systems will not be enumerated specifically but rather the advantages attained by the applicant's system.

On account of the disastrous effect upon the human body of too frequent exposure to the X-ray it has become customary to inclose the operator in a cage of material impervious to the X-ray. This cage is preferably located at some distance from the X-ray tube. It is expedient that the operator be able to control and make readings of the generating current for the X-ray without leaving his protecting cage. Consequently the various meters and controlling instruments should be located preferably within this cage.

Current of extremely high potential, preferably upward of 100 kilo-volts, is desirable for the working circuit in X-ray systems. It is also almost a necessity to be able to meter the current flowing in the working circuit in order that the operator may determine and regulate the operation of an X-ray tube. For his safety and convenience this necessitates the location of the amperemeter for the working circuit within his protecting cage.

The most practical method of attaining high potentials is by means of the transformer, although this has the defect of delivering from its secondary a potential of alternating sign, whereas a pulsating current is a necessity for the best operation of an X-ray tube. By rectifying the alternating current delivered by a high potential transformer it has heretofore been possible to operate X-ray tubes with a considerable degree of satisfaction. In systems employing transformers no difficulty has been experienced in controlling the primary low potential side of the transformer from the operator's protecting cage.

In addition to making possible the location of all controlling instruments for the low potential side of the transformer it is an object of the present invention to make possible the safe installation within the operator's protecting cage of an ampere-meter for the high potential working circuit. To this end a transformer having a two-coil secondary winding is employed, although in the broad aspect of the invention the two coils of this secondary winding should be understood as being two independent sources of alternating current of the same frequency. The expression alternating current is employed to designate generally both a true alternating current and also one in which the current cycle may have any form provided it regularly changes from + to — even though intermittent periods of no current be present.

In addition to rectifying the current supplied to the working circuit, the invention provides a rectifying interconnection of the two sources of alternating current whereby a direct current ampere-meter may be cut in series between the two said sources of alternating-current at what is in effect a neutral point which may be grounded at one of the terminals of the ampere-meter. By this method the entire current flow for the working circuit is caused to traverse the direct current ampere-meter always in the same direction and the difference in potential between the two ampere-meter leads is maintained practically zero with a positive ground for one of the leads. By reason of these circumstances the ampere-meter may be located with safety within the protecting cabinet for the operator.

It is a further object of the invention to minimize insulating troubles in a rectifying system of the type described. The employment of two sources of alternating current instead of the employment of a single source of double the potential of either contributes to this end and makes possible the employment in the applicant's rectifier construction of a simple cylindrical commutator, between adjacent brushes for which the full potential for the working circuit is never present. This does away with the necessity of extensive insulating partitions such as those described in the patent to Snook referred to above.

The above and further objects of the invention will be set forth more in detail in the following claims and will be more apparent from the following description which should be read in connection with the accompanying drawings, illustrating embodiments of the invention, in which like characters designate corresponding parts, and in which,

Figure 1 is a diagrammatic representation of one embodiment of the invention; Fig. 2 is a diagrammatic representation of unrectified potential-waves for the transformer of Fig. 1; Fig. 3 is a diagrammatic representation of the rectified waves for the transformer of Fig. 1; Fig. 4 is a diagrammatic representation of a preferred embodiment of the invention; Fig. 5 is a cross-section through line V—V of Fig. 4; Fig. 6 is a diagrammatic representation of the unrectified potential-waves for the transformer of Fig. 4; Fig. 7 is a diagrammatic representation of the rectified potential-waves for the system shown in Fig. 4; Fig. 8 is a diagrammatic representation of rectified waves delivered at one pair of terminals of the system of Fig. 4; Fig. 9 is a similar diagram showing the rectified waves delivered at the other pair of terminals of the system of Fig. 4; and Fig. 10 is a diagrammatic representation of a modification of the stationary transformer so as to comprise two independent transformers particulary adapted for energization from a polyphase circuit.

In the practical embodiment of the invention it is many times expedient to employ direct current as the original source of power, which in the embodiment of the invention shown is supplied by the mains 1 and 2 connected to the direct current end of the inverted rotary converter 3, which in the present embodiment is to be considered of a type to deliver single phase alternating current at the collecting brushes 4 and 5, one complete cycle corresponding to one rotation of the converter's rotor.

It is, of course, to be understood that single phase alternating current may be better available than direct current, in which event the alternating current mains should be connected to the terminals 4 and 5. In such case the electric unit 3 acts merely as a synchronous motor, as will be understood.

The second part of the system is denoted by R and comprises a transformer and rectifying means.

In Fig. 1, 6 indicates a magnetic core of the closed circuit type for the transformer T which should be built according to approved transformer-core construction. It is shown rectangular and mounted symmetrically to rotate with the attached shafts 7 and 8 journaled respectively in bearings 9 and 10, the shaft 7 being adjustably clutched to the shaft 11 of the unit 3 by means of the coupling 12. The core 6 has a primary winding 13 shown in dotted lines and disposed with an equal number of turns about each of the legs 14 and 15. The terminals of this primary winding 13 are connected respectively to the rings 16 and 17, coöperating with brushes 18 and 19, which in turn may be connected respectively with the brushes 5 and 4 by means of the wires 20 and 21 to complete the primary circuit.

The secondary for the core 6 comprises two equal coils 22 and 23 of an appropriate number of turns each greater than the number in each corresponding primary coil and preferably wound over the primary coils according to the most approved transformer construction to prevent magnetic leakage and to give a minimum shifting of phase for the secondary current with respect to secondary electro-motive force. Each of these secondary coils 22 and 23 constitutes a source of high potential alternating current and is so regarded in this specification. The attaching strips 24 and 25 are secured to the core 6 as shown to provide for the mounting of terminals 26 and 27; 28 and 29; and 30 and 31, which preferably terminate all equidistant from the axis of rotation of the transformer and in the same plane. 26 and 27 are respectively the ± and ∓ terminals for the secondary coil 22.

30 and 31 are respectively the ∓ and the ± terminals for the secondary coil 23.

28 and 29 are terminals electrically connected with the core 6, which in turn is connected to ground by the shaft 8 and journal 10.

32 and 33 are stationary contacts for coöperating with the terminals 26, 27, 30 and 31 and are respectively connected by leads

34 and 35 with the + terminal 36 and the — terminal 37 of the working circuit, which in this embodiment includes the X-ray tube X.

38 is a stationary contact coöperating with the terminals 26 and 27.

39 is a bridge contact for coöperating with the terminals 28, 29 and 30, 31. The contacts 38 and the journal 10 are connected through leads 40 and 41 to the terminals of direct current milli-ampere-meter M. The leads 40 and 41 are shown in part broken to denote that they may be of any desired extent permitting the location of the meter M at a distance, in which event it may be desired to provide the lead 41 with an additional ground G in the neighborhood of the meter itself.

In Fig. 2 the sine wave 42 diagrammatically illustrates one complete electro-motive force cycle for each of the secondary coils 22 and 23 while the sine wave 43 indicates on the same scale the electro-motive force cycle for the complete secondary winding comprising the two coils 22 and 23 in series. As is obvious these are the usual alternating current waves and involve a change in sign.

In Fig. 3 the portions p and p' indicate the portions of the electro-motive force wave 43 rectified and as they are applied to the terminals 36 and 37 of the working circuit, p being a portion of the + part of cycle 43 and p' being a corresponding portion of the — part of the cycle 43, but rectified to be a + wave part.

Operation for Fig. 1.—Any and all of the well known regulating and measuring devices for electric circuits may be employed in connection with the mains 1 and 2 to start the unit 3 and in connection with the wires 20 and 21 to regulate the current flow in the primary 13. The rotation of the shaft 11 causes a synchronous rotation of the transformer T and its attached secondary terminals. The angular position of transformer T may be adjusted as desired with respect to the motor shaft 11 according to the location desired for the wave parts p p' by a suitable adjustment of the coupling 12, and as will be obvious to those skilled in the art. The various terminals 26, 27, 28, 29, 30 and 31 make and break contact simultaneously with their coöperating stationary contacts. With the contacts in the relative positions illustrated, the first quarter of the cycle indicated in Fig. 2 has been completed; the ± terminal 26 of secondary coil 22 is in working connection with stationary contact 32, leading to the working circuit; and the ∓ terminal 30 of secondary coil 23 is in working connection with the stationary contact 33 leading to the other terminal of the working circuit. The secondary circuit for this position may be traced as follows:—secondary source 22, out what is now the + terminal 26, stationary contact 32, lead 34, + terminal 36 of the working circuit,—terminal 37 of the working circuit, lead 35, contact 33, terminal 30, secondary source 23, terminal 31, bridge 39, terminal 29, core 6, shaft 8, journal 10, lead 41, (connected with ground G), meter M, lead 40, contact 38, terminal 27, back to secondary source 22. Since the terminal 31 is now instantaneously +, the meter lead 41 is consequently positive, and the direction of current flow in the meter M is indicated by the plus and minus signs applied thereto.

With the parts in the positions shown, the terminal 26 is instantaneously + while the terminal 30 is instantaneously —. The wave part p is delivered to the working circuit terminals. The meter M is cut in in series between the secondary sources 22 and 23 and, therefore, at the neutral point of the transformer secondary which is grounded at G.

Upon a half rotation of shaft 7 the three-fourths point for cycle 43 is reached and terminals 27 and 31 are caused to contact respectively with brush contacts 32 and 33 while terminal 26 is caused to contact with brush contact 38 and terminals 28 and 30 are caused to be bridged by the brush contact 39. At this instant the terminals 27 and 30 have become + and the terminal 31 has become — so that a similar circuit to that previously traced is produced to cause a current flow through the working circuit and meter M in the same direction as the former current flow, the wave part p' being applied. This current flow is a pulsating one for X-ray work and its intervals of flow may correspond to any particular fraction of each secondary current wave corresponding to a commensurate fraction of each secondary electro-motive force wave as indicated in Fig. 3, in which p p' indicate the fractions being employed by the system of Fig. 1. The actual location of the fraction employed on its wave may be adjusted by the sleeve 12 and its extent or duration is regulated by the angular extent about the shafts 7 and 8 of relative contact between the terminals 26, etc. and their coöperating stationary contacts 32, etc. With the extremely high potentials employed, it is well known that actual contact between the terminals 26, etc. and the contacts 32, etc. is not actually a necessity, it being merely necessary to reduce the air gap therebetween to a small distance. For this reason the contacts 26, 27, 28, 29, 30 and 31 are not shown as actually physically contacting with their stationary coöperating contacts although such physical contact is not precluded by the nature of the invention.

Embodiments of Figs. 4 and 5.—In many instances it is preferred that the transformer of the installation R be stationary instead of rotated, as shown in Fig. 1. Such an embodiment is shown in Fig. 4. In this embodiment the stationary transformer is indicated by T′ and comprises the primary winding 113, the terminals of which are connected to a source of single phase alternating current by the leads 120 and 121; the secondary winding having two coils 122 and 123 of the same number of turns each and wound preferably in close relation to the primary winding 113; and a core having preferably a closed magnetic circuit, as shown in the embodiment of Fig. 1. It should be understood that this transformer T′ may be constructed according to well known approved transformer construction, insuring a minimum amount of magnetic leakage. Various leads 44 may be tapped out of the primary 113 to provide for varying the number of ampere turns in the primary circuit in a manner now well known in the art, while the dotted portion of the leads 120 and 121 indicate that the same may be of indefinite length to provide for the insertion of any of the well known controlling devices such as switches, rheostats, meters, etc. The two secondary coils 122 and 123 may each be regarded as a source of alternating current of the same frequency. 126 and 127 indicate respectively the and ± terminals of secondary coil 122 and are shown in the form of diametrically opposed brush contacts. 130 and 131 indicate respectively the ± and ∓ terminals of secondary coil 123 and are likewise shown in the form of diametrically opposed brush contacts. In this embodiment the shaft 7 is extended longitudinally through the journal 10 and has fixed thereto the rectifying commutator 45, carrying a pair of alined segments 46 and 47 located respectively at the opposite ends of the commutator; and a pair of laterally spaced inner commutator segments 48 and 49 diametrically opposed to the segments 46 and 47. In the preferred construction for X-ray work each segment encircles approximately 70° of the commutator 45 which should be constructed according to improved commutator construction of high quality insulating material. The cross section of Fig. 5 shows a satisfactory construction for this commutator.

Between the brush terminals 126 and 130 is a pair of brush contacts 50 and 51, cross connected respectively by wires 52 and 53 with a pair of diametrically opposed brush contacts 54 and 55. The leads 40 and 41 of the direct current milli-ampere-meter M are connected respectively as shown to the brush contacts 50, 54 and 51, 55, the lead 41 being grounded at one or more points G. The + terminal 136 for the working circuit is connected by lead 134 to brush contact 132 while the − terminal 137 of the working circuit is similarly connected by lead 135 with the brush contact 133. Contacts 132 and 133 are symmetrically positioned toward the outer edge of the commutator 45 and have diametrically opposing them the similar brush contacts 56 and 57 which are connected respectively by leads 58 and 59 to supplemental working circuit terminals 60 and 61 and are provided with switches 62 and 63 for cross connection to the leads 134 and 135 respectively.

Inasmuch as the electro-motive force cycle for each of the sources 122 and 123 may be represented by the line 64 of Fig. 6 indicating that they are both not only of the same frequency but in phase, the brush contacts 132, 126, 50, 51, 130 and 133 have been shown in the same plane with the diametrically opposed brush contacts 56, 127, 54, 55, 131 and 57; also the segments 48 and 49 have been shown occupying the same angular position diametrically opposite to the segments 46 and 47 of the commutator 45. However, as will be understood by those skilled in the art, should the current of source 122 be out of phase with that of the source 123, all that is necessary properly to add the electro-motive forces of these two sources to produce the combined wave 65 of Fig. 6, is to cause a relative angular shifting of the commutator parts for one of the sources 122 and 123 relatively to those of the other. For instance, the contacts and segments at the right of the central zone of the commutator 45 may be shifted angularly relatively to those at the left a suitable number of degrees to offset any shifting in phase between the two sources 122 and 123.

Operation for Figs. 4 and 5.—The wave diagram 64 of Fig. 6 shows the electro-motive force wave for each of the secondary coils 122 and 123 which, if combined by cross connecting unlike terminals such as 127 and 131, would produce the electro-motive force wave 65 of Fig. 6, it being understood, of course, that the diagrams of Figs. 6 indicate the unrectified electro-motive force waves. For some purposes, it is desirable to employ a part of each electro-motive force wave (both + and −) for the working circuit and in X-ray work these waves must be rectified so as to tend to cause the passage of current waves in the working circuit always in the same direction. For example, the parts q, q^1, q^2, and q^3, shown in Fig. 7, may be desired. With the connections as shown in Fig. 4, the working circuit terminals 136 and 137 are capable of delivering such electro-motive force pulsations. For the position of the parts indicated, the negative working circuit terminal 137 is connected by lead 135, through switch 63, lead 59, brush contact 57, segment 47, with what is now the negative terminal 131 of source 123. The path continues through coil 123 out what is now the + terminal 131, thence through segment 149, contact 51, lead 41, ampere-meter M, lead 40, contact 50, segment 48, to — terminal 126 of coil 122, thence through coil 122 to + terminal 127, segment 46, contact 56, lead 58, switch 62, lead 134 to the + terminal 136 of the working circuit, to give the electro-motive force impulse q. Thus, in effect, by the connection of terminal 126 of coil 122 with terminal 130 of coil 123 there is produced practically a transformer secondary of twice the number of turns of either of these coils 122 and 123 and this secondary is grounded at its neutral point to the ground G connected to lead 41. Also the ampere-meter M is connected in series or cut into this secondary winding at its neutral point so that the direction of flow is in accordance with the + and — signs applied to the ampere-meter M, that is from lead 41 to lead 40.

When the commutator 45 has been rotated 180° corresponding to the three-quarters point 65′ of the electro-motive force cycle of Fig. 6, segment 46 is bridging contacts 132 and 126; segment 47 is bridging contacts 130 and 133; segment 48 is bridging contacts 147 and 54; and segment 49 is bridging contacts 55 and 131. Under these conditions the secondary circuit from terminal 137 continues through lead 145, contact 133, segment 47, contact 130, which is now the — terminal of coil 123, through coil 123, contact 131, segment 49, contact 55, wire 53, lead 41, ampere-meter M, lead 40, wire 52, contact 54, segment 48, terminal 127 of coil 122, which is now negative, through coil 122, terminal 126 (now +) segment 46, contact 132, lead 134, to the + terminal 136 of the working circuit. Thus, under these conditions, the current flow through the ampere-meter M is also as indicated by the + and — signs, from lead 41 to lead 40. An electro-motive force impulse corresponding to q^1 of Fig. 7 is, therefore, applied. Upon each 180° rotation of the commutator 45 successive impulses such as q^2, q^3, etc. are applied to the terminals. It is well understood, of course, that there may be a displacement in phase between the secondary electro-motive force and the secondary current, although it may be minimum in this system. This, however, may be rectified merely by the proper angular adjustment of the commutator parts. The electro-motive force waves have been illustrated diagrammatically because, obviously, a current wave is dependent upon the creation of an electro-motive force wave and the latter is always present during the operation of the machine whether or not the working circuit is closed.

It is sometimes desirable that impulses of half frequency be delivered to a working circuit. It is also sometimes desirable to energize two separate working circuits with impulses identical in frequency and in strength. With the apparatus illustrated in Fig. 4 this may be accomplished through the medium of the switches 62 and 63. By opening these switches the working circuit terminals 60 and 61 will deliver waves corresponding to the wave parts r and r' of Fig. 8, while the terminals 136 and 137 will deliver waves corresponding to the wave parts s and s' of Fig. 9, the wave parts of both Figs. 8 and 9 being identical in sign, potential and frequency, although those of Fig. 8 alternate with those of Fig. 9 and are a half cycle out of phase therewith.

In connection with the commutator 45 of Fig. 4 and its associated parts particular attention is called to the fact that the maximum potential corresponding to the electromotive force wave 65 is carried only to the opposite ends of the commutator 45, by which arrangement many insulation difficulties are eliminated. Also middle contacts, such as 50, 54 and 51, 55 are always practically of the same potential neutral to the endmost contacts and substantially equal to the potential of the earth by reason of the ground G. The leads 40 and 41 are, therefore, safe to extend into the operator's protecting cage and require very little insulation notwithstanding the fact that the entire secondary current flows through them and the ampere-meter M, which may be a comparatively cheap instrument of the direct current type due to the fact that current impulses always flow therethrough in the same direction, as has previously been explained.

Since the electro-motive force waves of the two sources 122 and 123 may be out of phase and still be rectified and combined, it may be desirable to employ a two-phase power circuit with one phase energizing coil 122 and the other phase energizing coil 123 in any suitable manner as for example, through the medium of independent primary windings, such as the primary windings 113′ and 113″ for the transformers T″ and T‴, shown in Fig. 10. The out of phase relation between these two sources is compensated for or practically annulled by merely giving an angular displacement, lead or lag, as the case may be to the segments 47 and 49 and the diametrically opposed contacts 51, 130, 133, and 55, 131, 57 relatively to the similar segments and contacts shown at the left therefrom in Fig. 4. Such an angular displacement or shifting can be easily understood if the cylinder 45 is considered as consisting of two symmetrical adjacent parts along the shaft 7 and that one of these two parts together with its brush contacts is angularly rotated relatively to the other part so as to assume the necessary leading or lagging position to correspond with the difference in phase between the two sources 122 and 123.

The embodiments of the invention shown and described are in a large degree diagrammatical, as it is to be understood that the proper construction of the various parts illustrated is now well known in the art and is contemplated by the applicant. It is also well understood that other modifications than the two illustrated and described may embody the applicant's broad invention and that the same are fully contemplated by the applicant.

What is claimed and what is desired to be secured by United States Letters Patent is:—

1. In a rectifying high potential system, the combination with a source of alternating current, of a high potental transformer; a secondary working circuit; a synchronous rectifier for sending current waves all in the same direction through said secondary working circuit from the secondary of said transformer; a direct current ampere-meter; and means for cutting said ampere-meter in series at the neutral point of said secondary throughout each period that a current wave is sent through said secondary working circuit to measure the value of the current in said secondary working circuit.

2. In a rectifying high potential system, the combination with a source of alternating current, of a high potential transformer; a secondary working circuit; a synchronous rectifier for sending current waves all in the same direction through said secondary working circuit from the secondary of said transformer; a direct current ampere-meter; and means for grounding the neutral point of said secondary and for cutting said amperemeter in at the neutral point of said secondary, throughout each current pulsation of said secondary working circuit, to measure the value of the current in said secondary working circuit.

3. In an X-ray system, a source of single phase alternating current; a power shaft rotated synchronously with said current; a high potential transformer having a primary winding connected with said source and a secondary winding comprising two separate coils; the terminals for a power circuit; a direct current ampere meter; a rotating commutator-means driven by said power shaft; and terminal contacts for said two separate coils and said ampere meter and coöperating with said commutator-means for connecting and disconnecting alternate terminals of said two coils, one of each, with the respective terminals of said ampere meter and for simultaneously connecting and disconnecting the free terminals of said two coils respectively with the corresponding terminals for the working circuit so that the ampere meter is progressively connected at a neutral point in series between the two coils and will be traversed by the same rectified current as that delivered to the working circuit.

4. In an X-ray system, a source of single phase alternating current; a power shaft rotated synchronously with said current; a high potential transformer having a primary winding connected with said source and a secondary winding comprising two separate coils; terminals for a working circuit; a direct current ampere-meter; a rotating commutator means driven by said power shaft for connecting alternate terminals of one of said two coils to one terminal of said ampere-meter and alternate terminals of the other of said two coils to the other terminal of said ampere-meter, all throughout corresponding parts of the electro-motive force waves of the said coils and for connecting the free terminals of said coils to the terminals for the working circuit throughout the same periods, whereby current waves of the same direction only pass through said ampere-meter, the terminals for the working circuit are always of the same sign and one terminal of the ampere-meter may be grounded to constitute the neutral point for the transformer secondary.

5. In a rectifying high potential system, two sources of alternating current of the same frequency; terminals for a working circuit; a direct current ampere meter; commutator-means driven synchronously with the current alternations of said sources and operative to connect and disconnect alternate terminals of one of said sources with one terminal of said ampere meter and alternate terminals of the other of said sources to the other terminal of said ampere meter all throughout corresponding parts of the electro-motive force waves of the said sources and for connecting and disconnecting the free terminals of said sources with the terminals for the working circuit throughout the same periods, whereby current waves of the same direction only can pass through the said ampere meter, the terminals for the working circuit are always of the same sign and one terminal of the ampere meter may be grounded to constitute a neutral point for the system.

6. In an X-ray system, a rectifying commutator comprising a cylinder of insulating material; a pair of segments each spanning less than 180° of said commutator and axially spaced thereon; a second pair of commutator segments each of the same angular span as the first pair, and respectively diametrically opposed to the segments of the first pair, and each axially overlapping a part of the corresponding segment of the

first pair and a part of the axial space between the segments of the first pair; and two diametrically opposed sets of three brush contacts each for each two diametrically opposed segments.

7. In an X-ray system, a high potential transformer; a direct current amperemeter; current rectifying means for connecting said ampere-meter in series with the secondary of said transformer at a point intermediate its full potential poles.

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

EUGEN BLUM.

Witnesses:
SIDNEY NEWBORG,
W. G. ALLEN.