E. W. CALDWELL.

X-RAY APPARATUS.

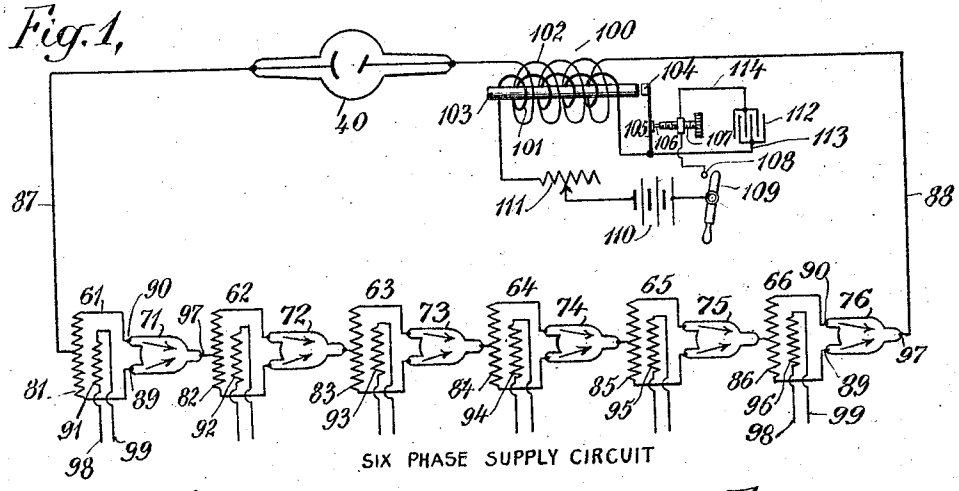
APPLICATION FILED MAY 18, 1914.

1,217,149.

Patented Feb. 27, 1917.

2 SHEETS—SHEET 1.

Fig. 1,



SIX PHASE SUPPLY CIRCUIT

Fig. 2

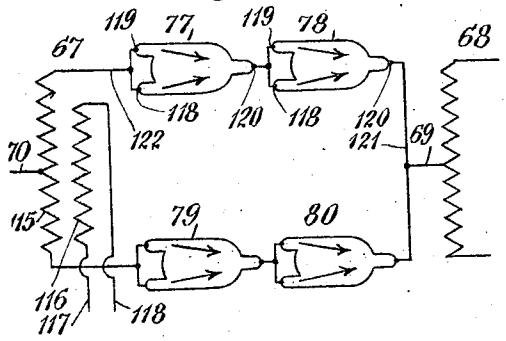


Fig. 7,

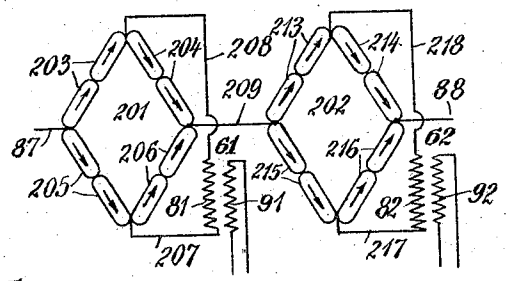
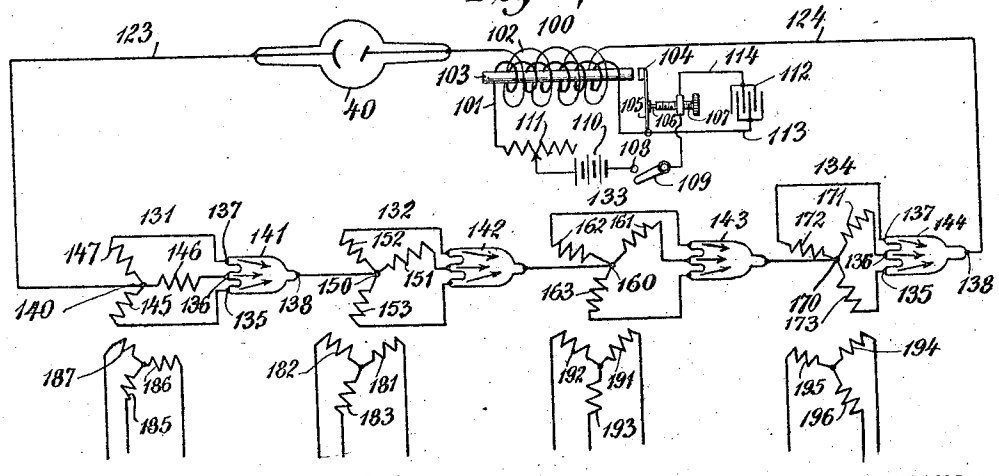


Fig. 3,



TWELVE PHASE SUPPLY CIRCUIT

WITNESSES

Charles Eberhart

Jesse B. Kay.

INVENTOR

Eugene W. Caldwell

BY

Harry L. Unwin ATTORNEY

E. W. CALDWELL.

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2 SHEETS—SHEET 2.

Fig. 4,

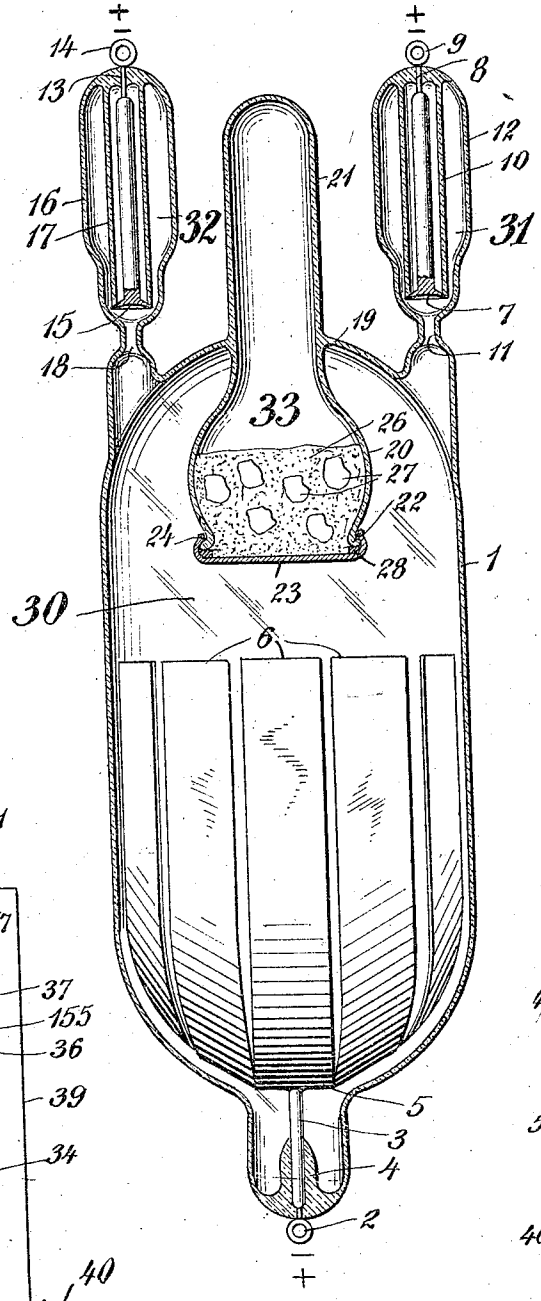


Fig. 5,

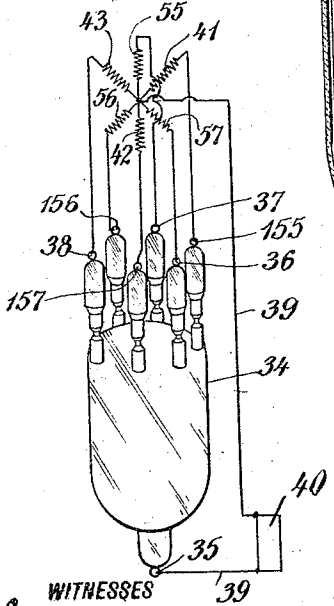
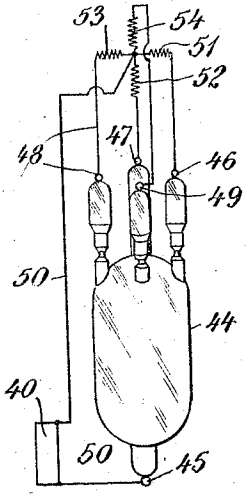


Fig. 6,



WITNESSES

Charles Eberhart

Jessie B. Kay.

Eugene W. Caldwell INVENTOR

BY

Harry L. Duncan ATTORNEY

UNITED STATES PATENT OFFICE.

EUGENE W. CALDWELL, OF NEW YORK, N. Y.

X-RAY APPARATUS.

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Application filed May 18, 1914. Serial No. 839,230.

To all whom it may concern:

Be it known that I, EUGENE W. CALDWELL, a citizen of the United States, and resident of the city, county, and State of New York, have made a certain new and useful Invention Relating Especially to X-Ray Apparatus, of which the following is a specification, taken in connection with the accompanying drawing, which forms part of the same.

This invention relates especially to X-ray apparatus and may comprise a working circuit in which an X-ray tube may be arranged in series with a suitable current equalizing inductance, such as the secondary winding of an induction coil which may be used as an auxiliary source of intermittent energizing impulses for the tube in connection with an interrupter and source of potential in the primary winding of the coil. The working circuit may also comprise a series of polyphase alternating high potential units or transformer windings connected in series in the circuit and having interposed between them suitable vacuum valve tubes which are preferably self-regulating and each of which may have its cathode connected to a mid or intermediate point in the succeeding unit while each of its multiple separated anodes may be connected to the ends of the preceding unit to superimpose in the working circuit the polyphase current impulses from said units.

In the accompanying drawings showing in a somewhat diagrammatic way illustrative embodiments of this invention

Figure 1 is a circuit diagram showing a six-phase arrangement.

Fig. 2 is a detail view on a larger scale showing a modified construction.

Fig. 3 is a circuit diagram showing a twelve-phase arrangement.

Fig. 4 is a sectional elevation showing one form of valve tube which may be used in this connection.

Fig. 5 is a diagram showing another form of tube connected in circuit; and

Fig. 6 shows still another form, and Fig. 7 is a circuit diagram showing a four-phase arrangement.

The polyphase alternating high potential current which may be used to supply substantially continuous high potential current in the working circuit may be derived from any suitable polyphase supply circuit at six to eighteen phases, for instance. It is desirable also to be able to regulate the potential in the working circuit and this may be done in a number of ways as by regulating the potential developed in the different polyphase alternating high potential units. For many reasons it is desirable for X-ray work and the like to have a series of separate interchangeable transformers to produce the polyphase impulses in the high potential units with which the valve tubes are connected so that insulation may be more effectively provided for and by making the transformer units interchangeable replacements and repairs are considerably facilitated.

In Fig. 1 a series of high potential polyphase transformers are indicated diagrammatically as 61, 62, 63, 64, 65 and 66 in a six-phase arrangement in which the terminals 98, 99 of the different primary windings of these transformers 91, 92 and so forth may be connected to any six-phase supply circuit of the desired power and potential. The secondary windings 81, 82 and so forth of these transformers constitute under working conditions a series of polyphase alternating high potential secondary units from which the current impulses may be conveniently derived by connecting them in series in a suitable way in connection with suitable vacuum valve tubes, preferably though not necessarily of a self-regulating character. It is desirable in this connection to use self-regulating vacuum valve tubes, such as are described and claimed in my co-pending application, Serial No. 838,449 filed May 14, 1914, and where a single valve tube is used between each of the high potential polyphase units connected in series, the valve tubes may with advantage have as many separated anodes as there are different phase ends of the high potential alternating current unit connected therewith. In this way one of these different phase ends of the high potential units can be connected to each of the separated anodes and a single tube can thus take care of the rectification of several different phase alternations. A series of vacuum valve tubes of this description 71, 72, 73, 74, 75 and 76 are shown as connected in series with the polyphase high potential units by having each of the different phase ends of the secondary winding 81, for instance, of the first unit or transformer 61 connected to each of the two separated anodes 89, 90 of this tube. The cathode 97 of this tube may with advantage be connected to the mid or neutral point of the succeeding unit in the

series so that when either end of the high potential unit 61 is energized the corresponding current and potential impulse in the direction of the arrow shown on this tube 71 is imparted to the circuit so that all of the polyphase units which are positively energized at any instant are adding their potential and current impulses to the working circuit in which an X-ray tube or any other lighting or other utilizing or transforming device may be arranged. As indicated in Fig. 1 an X-ray tube, such as 40, may be included in the working circuit comprising the connections 87, 88 with the series of high potential polyphase units and valve tubes and still further equalization of the current in this working circuit may be effected by connecting in series therewith a suitable inductance current equalizer, such for instance as the induction coil 100 whose secondary winding 102 is shown connected in series with the working circuit. The magnetic core 103 of this coil adds to the inductance equalizing action and by providing a primary winding, such as 101, on this coil coöperating with the core and secondary thereof an auxiliary energizing circuit may be secured which may be used with advantage in starting the tube and also when desired for energizing the same with interrupted current impulses for the desired periods as for fluoroscopic or other work for example, the induction coil's inverse or "make" impulses in the working circuit being cut off or suppressed by the action of the valve tubes. This auxiliary circuit may comprise any suitable source of current and coöperating interrupter to cause the desired current impulses in the primary of the induction coil and if desired the battery or other source of potential 110 may be arranged in series with this primary, and an interrupter, such as the armature 104 mounted on the spring 105 arranged in this circuit so as to allow current to flow therethrough when the spring in its normal position withdraws this armature 104 away from the core of the induction coil so as to engage the adjustable contact 106 on the end of a suitable adjusting screw mounted in the block or support 107. The potential developed in the working circuit in this way may be adjusted by any suitable regulating means such as the regulator or resistance 111 more or less of which may be included in this circuit so as to regulate the amount of current flowing when the starting switch 109 is thrown into contact with its switch point 108. It is also desirable to provide a suitable condenser, such as 112, connected in shunt as by the wires 113, 114 across the interrupter to minimize undesirable action thereof. In this arrangement it is possible to have the potential of the intermittent impulses in the working circuit substantially the same as the potential of the practically continuous working current supplied thereto by rectification of the polyphase impulses so that the same X-ray tube which has been utilized for fluoroscopic work, for instance, can by opening the starting switch 109 as shown in Fig. 1 be instantly used for radiographic work when the polyphase rectified current is sent through the working circuit. It is also possible when the regulator is adjusted to give a higher potential intermittent current through the tube to use this auxiliary circuit for starting impulses preferably in the same direction as the normal working current so as to break down the starting resistance of the tube or other device and thus initiate the passage of the normal working current therethrough which continuously energized the core of the inductance coil so as to attract the armature 104 and hold open the auxiliary circuit as long as the normal constant current is flowing through the working circuit.

For many purposes it is highly important in X-ray work to have a substantially continuous current of uniform value pass through the tube since any variations in the amount of tube current seem to be considerably exaggerated in some cases by the resulting variations in the luminosity or actinic power of the X-rays developed by the ordinary tubes. For many classes of radiographic work therefor it is correspondingly important to secure a working current which is very nearly constant and this may be done by increasing the number of phases of the polyphase units connected in series through such valve tubes. The differences between the maximum and minimum values of the potential and current when sine wave polyphase units are superimposed is as follows according to the theoretical considerations of the circuits. With a three-phase system between about 14 and 15 per cent. variation, with a six-phase system about 3½ per cent. variation, with a nine-phase system about 1½ per cent. variation and with a twelve-phase system about 1 per cent. variation. While with a three-phase arrangement the variations in luminosity are readily apparent when investigated by oscillograph or suitable photographic methods the twelve to eighteen phase arrangements especially when a suitable equalizing inductance is connected in series gives such constant current values as to be free from substantial objection for X-ray work. Since, practically speaking, the working current in an ordinary X-ray tube is limited by the amount of current which may be used without destructive or decidedly undesirable action on the tube, it is possible where the working current is substantially constant to keep the current value constantly at substantially such a safe maximum so that very much greater radio-

graphic effects can be secured than are possible by the use of ordinary induction coils or mechanically rectified single phase transformers. Another practical advantage of using a polyphase arrangement having a large number of phases is that the desired potential for any ordinary X-ray work, for instance, can be secured by interposing only a single valve tube of this character between the succeeding polyphase units which are connected together in series. With a nine or twelve phase arrangement of this character, for example, potentials of 100,000 volts or more can be secured, the reverse starting or break-down potentials of the tubes being ample to secure satisfactory rectifying efficiency under these conditions. When necessary, however, any desired number of vacuum valve tubes may be arranged in series between the succeeding polyphase units, as is shown for example, in Fig. 2 where two valve tubes such as 77, 78 are shown as connected between the end 122 of the secondary winding 115 of the polyphase transformer 67 and the connection 121 which may communicate with the mid or neutral point 69 of the succeeding unit 68. By connecting both anode terminals 118 and 119 of such a tube in parallel its current capacity is correspondingly increased without undesirable heating or other effects and the cathode terminal 120 of this tube 77 may as indicated be connected to both anode terminals 118 and 119 of the succeeding tube 78 in parallel where increased current capacity is desired, although it is of course understood that only a single anode terminal may be connected or provided in the tubes. The other end of the polyphase unit 115 is shown as similarly connected through the two vacuum tubes 79 and 80 in series so as to secure a polyphase rectification of these impulses when the primary winding 116 is energized through the connections 117, 118 with the supply circuit.

Another arrangement in which vacuum tubes of this general description such as are described in the Caldwell Patent No. 1,076,949 of October 28, 1913, may be connected in circuit so as to rectify the current impulses from the high potential polyphase units is shown diagrammatically in Fig. 7 in which only two of the interchangeable transformers 61, 62 are indicated, although it is of course understood that any desired number of polyphase units may be connected in series in this way. Both ends of each of these transformer secondaries may be connected with the bridge or parallelogram arrangement of rectifying tubes indicated so as to secure a substantially uniform working current in the working circuit 87—88. The side 87 of this working circuit may be connected with the two series of valve tubes 203, 205, the ends of which connect with the terminals 207, 208 of the transformer secondary 81 and also with the two coöperating series of valve tubes 204, 206 forming the bridge arrangement 201 as indicated and delivering the rectified current impulses along the working circuit connection 209 which leads to a succeeding similar bridge or parallelogram arrangement of tubes 202. This second valve tube bridge or parallelogram may comprise the series of tubes 213, 214, 215, 216, each of these valve tube units comprising one or more tubes as required to take care of the potential and current developed, and arranged so that their valve action allows current to pass in the direction of the arrows. This tube parallelogram 202 may as indicated have its opposite angles connected to the terminals 217, 218 of the secondary winding 82 of the second transformer 62 while its other two opposite angles are connected in the working circuit 87—88 in series with the rest of these valve tube bridges or parallelograms. In this way the continuous rectification of the different phase current impulses is secured without passing the entire rectified current through the transformer windings and affecting the magnetic and electrical conditions of the working circuit.

A twelve-phase arrangement is shown diagrammatically in Fig. 3 as comprising a series of polyphase high potential units which are all slightly out of phase with one another, so that the desired number of different phase impulses are secured. While it is apparent that the desired number of phases may be arranged in any suitable number of units with the corresponding number of phases in each unit the system shown in Fig. 3 comprises four three-phase units which are one-twelfth phase out of phase with each other, the high potential windings being shown above and the low potential windings of these separate interchangeable transformers being shown below as connected to any suitable twelve-phase supply circuit. These four polyphase alternating high potential units 131, 132, 133 and 134 may be connected in series and vacuum valve tubes interposed between the successive units and each connected with its cathode to a mid or intermediate point of one of these units, while the separated anodes of a single tube are each connected to the different phase ends of the preceding unit. As shown the three-phase coils or circuits 145, 146 and 147 of the unit 131 may radiate in about the indicated phase relation from their mid or neutral point 140 and may each be connected to the separated anodes 135, 136 and 137 respectively of the vacuum valve tube 141 whose cathode terminal 138 may be connected to the mid-point 150 of the succeeding unit 132. The three-phase coils or circuits 151, 152 and 153 of this unit may be in the usual three-phase re-

lation to each other and displaced by about a twelfth phase from the corresponding coils or circuits of the preceding unit. The free or live ends of these windings 151, 152 and 153 may be similarly connected to the three separated anode terminals of the multiple anode valve tube 142 whose cathode as indicated may be connected to the mid-point 160 of the succeeding polyphase unit 133. The connections of this unit with a succeeding valve tube 143 and the connection of the succeeding unit 134 therewith and with the final valve tube 144 are similar as indicated, the cathode terminal 138 of the final valve tube being joined to the working circuit 123, 124 in which an X-ray tube 40 or other lighting or transforming device is arranged in series if desired with a suitable current equalizing induction coil 100 and auxiliary devices as previously described. It is to be noted that the windings or circuits 161, 162 and 163 of the unit 133 while in three-phase relation with one another are about one-twelfth phase out of phase with those of the preceding unit 132 and about the same amount out of phase with the windings 171, 172 and 173 of the succeeding unit 134. In this way a twelve-phase rectification may be secured by the use of only four vacuum valve tubes of this special construction and ample current secured for many classes of X-ray work which greatly minimizes the installation and maintenance cost of such a system, the self-regulating action of the tubes considerably promoting their uniformity and reliable action in this relation. The primary windings of the high potential polyphase transformer 131 are shown below as 185, 186, 187, and as indicated may be in the same phase relation as the corresponding secondary windings 145, 146 and 147 above. The primary windings 181, 182 and 183 of the second transformer 132 may be similarly related to the corresponding secondary windings thereof and the same is true of the primary windings 191, 192 and 193 and 194, 195 and 196 of the other two transformers.

The valve tubes for this purpose may have a body of any suitable size, shape and material and as indicated in Fig. 4 the substantially cylindrical glass tube body 1 may have mounted therein adjacent one end a cathode terminal 2 connected to the cathode stem or support 3 which may be firmly supported by being more or less surrounded and supported by a glass reinforcement 4 extending up from the wall of the tube at this point. The cathode 5 is preferably given a large effective diameter or capacity which seems to materially increase the effectiveness and efficiency of the valve action of the tube. The cathode may be conveniently formed of a number of electrically connected strips 6 of aluminum or other suitable material which may be bent up into generally cylindrical or tumbler shaped form so as to be, for example, about two and one-half inches in diameter and three or three and a half inches long when the main cathode chamber 30 in the tube body is about two and three-quarters inches in diameter and about six inches long inside with the approximate contour indicated in Fig. 4.

It is desirable to have a separate regulating chamber to hold the gas generating material or salts, such as sodium formate or the like and for some purposes it is desirable to have this regulating chamber in part within the cathode chamber or subject to the heating or regulating action caused when the tube gets into regulating condition while part of the chamber is preferably so arranged as not to be substantially exposed to such heating or regulating effects. This may be conveniently effected by using a separate glass tube or extension such as 21, fused into the top 19 of the tube body, so that the lower or inner portion 20 of this regulating chamber 33 which may be suitably enlarged as indicated extends sufficiently near the cathode to be exposed to the heating effects caused when the tube gets into regulating condition. Any suitable regulating diaphragm may be arranged between this regulating chamber and the cathode chamber 30 and a suitable thin metallic regulating diaphragm 23 of aluminum, for instance, may be conveniently secured on the outwardly flaring end 22 of the regulating chamber by bending the securing clips or extensions 24 of this diaphragm around the same and securing them in position in any desired way. A suitable somewhat porous washer or packing is preferably used to close the joint around this diaphragm and an asbestos washer, such as 28, may be interposed between these parts so as to prevent all substantial leakage of the gas generating material or salt 26 within the chamber while allowing the gas generated under regulating conditions to pass into the cathode chamber. For some purposes it is desirable to break up the aggregations of the gas generating salt which is sometimes caused by the heat developed in the portions adjacent the regulating diaphragm and this may be readily effected by suitable loosening devices, such as lumps or particles of glass or other inert material or metal which may be mixed with the gas generating salt in the regulating chamber so as to break up lumps or aggregations by gently agitating the tube. By arranging the regulating chamber so that part of it such as the outer extension 21, for instance, is outside or removed from the action of the heating or regulating effects caused under regulating or high vacuum or resistance conditions of the valve tube, the initial pumping or exhaus-

tion of the tube may be considerably facilitated by transferring the gas regulating salt to such inoperative or inactive portion of the regulating chamber as by keeping the tube in an inverted position and preventing any substantial portions of the gas generating material from coming in contact with the regulating diaphragm until the tube is fully exhausted. This allows current to be run through the tube during the pumping or exhausting process which facilitates the elimination of the gases therefrom and enables any desirable degree of exhaustion to be readily secured after which the tube may be sealed in the usual way. The finished tube may then be turned into its normal operating position as shown in Fig. 4 and connected in circuit when the initial high vacuum and resistance which may be caused by the exhaustion will at once cause a regulating condition in the tube in which sufficient heating effects are caused on the regulating diaphragm 23 as by the concentration of the cathode stream in the tube to cause the generation of gas from the gas generating material in substantial contact with the regulating diaphragm. This quickly brings the tube into its normal critical condition where the vacuum and resistance conditions are such that no further regulating action takes place, although such effects are imminent and are again brought into play by a relatively slight increase in the vacuum, resistance and so forth. This is shown by the action of the electrical measuring instruments in circuit with the tube which show a gradual decrease in the tube resistance, the normal resistance being quickly attained after which the tube resistance remains practically constant under all normal working conditions.

Any suitable anode electrodes may be arranged in connection with the tube and either a single anode or any desired number of separated multiple anodes may be used for some purposes in a vacuum valve tube of this character. As indicated the anode 7 may be mounted on the stem 8 so as to be electrically connected with its terminal 9 outside the anode extension 12, the anode being mounted within a restricted glass shield, such as 10, and arranged in connection with a coöperating constricted anode passage 11 between the anode chamber 31 and the cathode chamber 30. If desired one or more additional anodes may be arranged in the tube each preferably separated from the other anodes so as to maintain the desired electric insulation under working conditions. The anode 15 may as indicated be mounted on a stem, such as 13, and connected with the terminal 14 outside of the tube or anode extension 16 fused thereon. This anode may be mounted within the usual restricted glass shield 17 and arranged so as to coöperate with the constricted anode passage 18 between the anode chamber 32 and the cathode chamber 30. Such valve tubes have given highly effective and efficient valve or rectifying action with high potential currents up to a few hundred milliamperes or more suitable for X-ray work, etc., and the tubes have maintained their high efficiency and run cool when operated in a number of instances continuously for hours at a time. With a vacuum tube of this character having a main cathode chamber about two and three-quarter inches in internal diameter and about six inches in length, the valve action was very pronounced and the direct resistance of the tube was found to be very low so as to give the tube a correspondingly high working efficiency. The potential required to break down the starting resistance in the direction of the normal operation of the tube was in the neighborhood of 1000 volts, while a potential of about 30,000 to 40,000 volts was required to overcome the starting resistance of the tube in the reverse direction.

By using multiple separated anodes in such valve tubes each anode may be connected to a separate source of polyphase high potential electricity so as to allow periodic current impulses to pass through the tube in the desired direction and superimpose through a single tube current impulses from a number of branches of a polyphase circuit. Fig. 5 shows diagrammatically such an arrangement, the tube 34 being provided with the cathode terminal 35 and with six separated anode terminals 36, 37, 38 and 136, 137 and 138 which are each shown as connected to one of the branches 41, 42, 43, 55, 56 and 57 of a six-phase high potential circuit, the neutral point of which may be connected to the working circuit 39 about which the working device 40, such as an X-ray apparatus for example, is connected to the X-ray cathode 35. Fig. 6 shows diagrammatically a four-phase arrangement in which the tube 44 is provided with the cathode terminal 45 and with the terminals 46, 47, 48 and 49 connected to the separated anodes within the tube which are not shown. A four-phase high potential circuit of any description may have its branches 51, 52, 53 and 54 each connected to one of the anode terminals, while the mid or neutral point of the four-phase circuit may be connected to the working circuit 50 including a similar utilizing device 40. Such a system of interchangeable high potential transformers and coöperating valve tubes, such as are illustrated in Figs. 1 and 3 form a relatively simple X-ray generating system which may be compactly arranged so as to secure a corresponding economy of space which is often important under operating conditions. The entire series of high potential trans-

formers and tubes may, for example, be mounted on the top of a suitable cabinet or shield such as is shown in the Caldwell Patent 931,034 of August 17, 1909. A suitable insulating support or upper extension or casing can be arranged on such a cabinet to mount all of these high potential devices where they will be out of the way and also to minimize danger from that source and at the same time maintain their proper connection with the coöperating control and measuring devices which may be located in the body of the cabinet as shown in that patent.

This invention has been described in connection with a number of illustrative embodiments, forms, proportions, sizes and materials, parts, arrangements and methods of preparation and operation, to the details of which disclosure the invention is not of course to be limited, since what is claimed as new and what is desired to be secured by Letters Patent is set forth in the appended claims.

1. In X-ray apparatus, a working circuit comprising an X-ray tube and four high potential polyphase alternating current units each having three-phase windings connected together at a mid point and having ends one-twelfth phase out of phase with the ends of the other units, self-regulating vacuum valve tubes interposed in the working circuit between each of said units and each having a cathode terminal connected to the mid-point of the succeeding point and having three separated anode terminals each connected to one of the ends of the preceding unit to superimpose in said working circuit the rectified polyphase impulses from each of said units connected in series and an equalizing inductance connected in series with said working circuit.

2. In X-ray apparatus, a working circuit comprising an X-ray tube and four high potential polyphase alternating current units each having three three-phase windings connected having ends one-twelfth phase out of phase with the ends of the other units, vacuum valve tubes interposed in the working circuit between each of said units and each having a cathode terminal connected to the mid-point of the succeeding unit and having three separated anode terminals each connected to one of the ends of the preceding unit to superimpose in said working circuit the rectified polyphase impulses from each of said units connected in series and an equalizing inductance connected in series with said working circuit.

3. In X-ray apparatus, a working circuit comprising an X-ray tube and a plurality of high potential polyphase alternating current units each having three-phase windings having ends out of phase with the ends of the other units, vacuum valve tubes interposed in the working circuit between each of said units to superimpose in said working circuit the rectified polyphase impulses from each of said units connected in series and an equalizing inductance connected in series with said working circuit.

4. In X-ray electrical apparatus, a working circuit comprising an X-ray tube and a plurality of high potential polyphase alternating current units each having a plurality of polyphase windings connected together at a mid point and having ends out of phase with the ends of the other units, self-regulating vacuum valve tubes interposed in the working circuit between each of said units and each having a cathode terminal connected to the mid-point of the succeeding unit and having separated anode terminals each connected to one of the ends of the preceding unit to superimpose in said working circuit the rectified polyphase impulses from each of said units connected in series and an equalizing inductance connected in series with said working circuit.

5. In X-ray apparatus, a working circuit comprising an X-ray tube and an inductance current equalizer and a series of more than three interchangeable polyphase alternating current high potential transformer units each having a plurality of polyphase secondary windings each of which are in different phase connected in series in said working circuit, a series of self-regulating vacuum valve tubes in circuit between each of said secondary windings and each having its cathode connection connected to an intermediate point of the succeeding winding and having its separated anode terminals connected to the ends of the preceding winding to superimpose the polyphase current impulses from each of said units.

6. In X-ray apparatus, a working circuit comprising an X-ray tube and an inductance current equalizer and a series of more than three interchangeable polyphase alternating current high potential transformer units each having a plurality of polyphase secondary windings each of which are in different phase connected in series in said working circuit, a series of vacuum valve tubes in circuit between each of said secondary windings to superimpose the polyphase current impulses from each of said units.

7. In X-ray apparatus, a working circuit comprising an X-ray tube and a series of more than three interchangeable polyphase alternating current high potential transformer units having secondary windings each of which are in different phase connected in series in said working circuit, a series of vacuum valve tubes in circuit between each of said secondary windings to superimpose the polyphase current impulses from each of said units.

8. In X-ray electrical apparatus, a working circuit comprising more than six different phase elements, an X-ray tube and an inductance current equalizer and a series of more than three interchangeable polyphase alternating current high potential transformer units having their secondary windings each of which are in different phase connected in series in said working circuit, a series of self-regulating vacuum valve tubes in circuit between each of said secondary windings and each having its cathode connection connected to the midpoint of the succeeding winding and having its separated anode terminals connected to the ends of the preceding winding to superimpose the polyphase current impulses from each of said units.

9. In X-ray apparatus, a working circuit comprising an X-ray tube and an inductance current equalizer and a series of more than five polyphase alternating high potential windings in different phase connected in series in said working circuit and self-regulating vacuum valve tubes interposed in said working circuit between each of said windings to superimpose the rectified polyphase current impulses therefrom.

10. In X-ray apparatus, a working circuit comprising an X-ray tube and a series of more than five polyphase alternating high potential windings in different phase connected in series in said working circuit and vacuum valve tubes interposed in said working circuit between said windings to superimpose the rectified polyphase current impulses therefrom.

11. In X-ray apparatus, a working circuit comprising an X-ray tube and a plurality of high potential polyphase alternating current units, coöperating rectifying vacuum valve tube devices in the working circuit between each of said units and an equalizing induction coil having its secondary winding connected in series with said working circuit, an interrupter and source of potential connected to the primary winding of said induction coil to cause intermittent unidirectional current impulses through said X-ray tube of substantially the same potential as the working current therethrough.

12. In X-ray apparatus, a working circuit comprising an X-ray tube and a plurality of high potential polyphase alternating current units, coöperating rectifying vacuum valve tube devices in the working circuit and an equalizing induction coil having its secondary winding connected in series with said working circuit, an interrupter and source of potential connected to the primary winding of said induction coil to cause intermittent unidirectional current impulses through said X-ray tube of substantially the same potential as the working current therethrough.

13. In X-ray apparatus, a working circuit comprising an X-ray tube and a high potential alternating current unit, coöperating rectifying devices in the working circuit and an induction coil having its secondary winding connected in series with said working circuit, an interrupter and source of potential connected to the primary winding of said induction coil to cause intermittent unidirectional current impulses through said X-ray tube of substantially the same potential as the working current therethrough.

14. In electrical apparatus, a working circuit comprising a vacuum tube and a high potential alternating current unit, coöperating rectifying devices in the working circuit and an induction coil having its secondary winding connected in series with said working circuit, an interrupter and source of potential connected to the primary winding of said induction coil to cause intermittent unidirectional current impulses through said tube in the same direction and of substantially the same potential as the working current therethrough.

15. In X-ray apparatus, a working circuit comprising an X-ray tube and a current equalizer and a series of three or more polyphase alternating high potential windings in different phase connected in series in said working circuit and vacuum valve tubes interposed in said working circuit between each of said windings to superimpose the rectified polyphase current impulses therefrom.

16. In X-ray apparatus, a working circuit comprising an X-ray tube and an inductance current equalizer and a series of polyphase alternating high potential windings in different phase connected in series in said working circuit and vacuum valve tubes interposed in said working circuit between said windings to superimpose the rectified current impulses therefrom.

17. In X-ray apparatus, a working circuit comprising an X-ray tube and a current equalizer and a series of two or more alternating high potential windings in different phase connected in series in said working circuit and vacuum valve tubes interposed in said working circuit between said windings to superimpose the rectified current impulses therefrom.

EUGENE W. CALDWELL.

Witnesses:
HARRY L. DUNCAN,
JESSIE B. KAY.

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