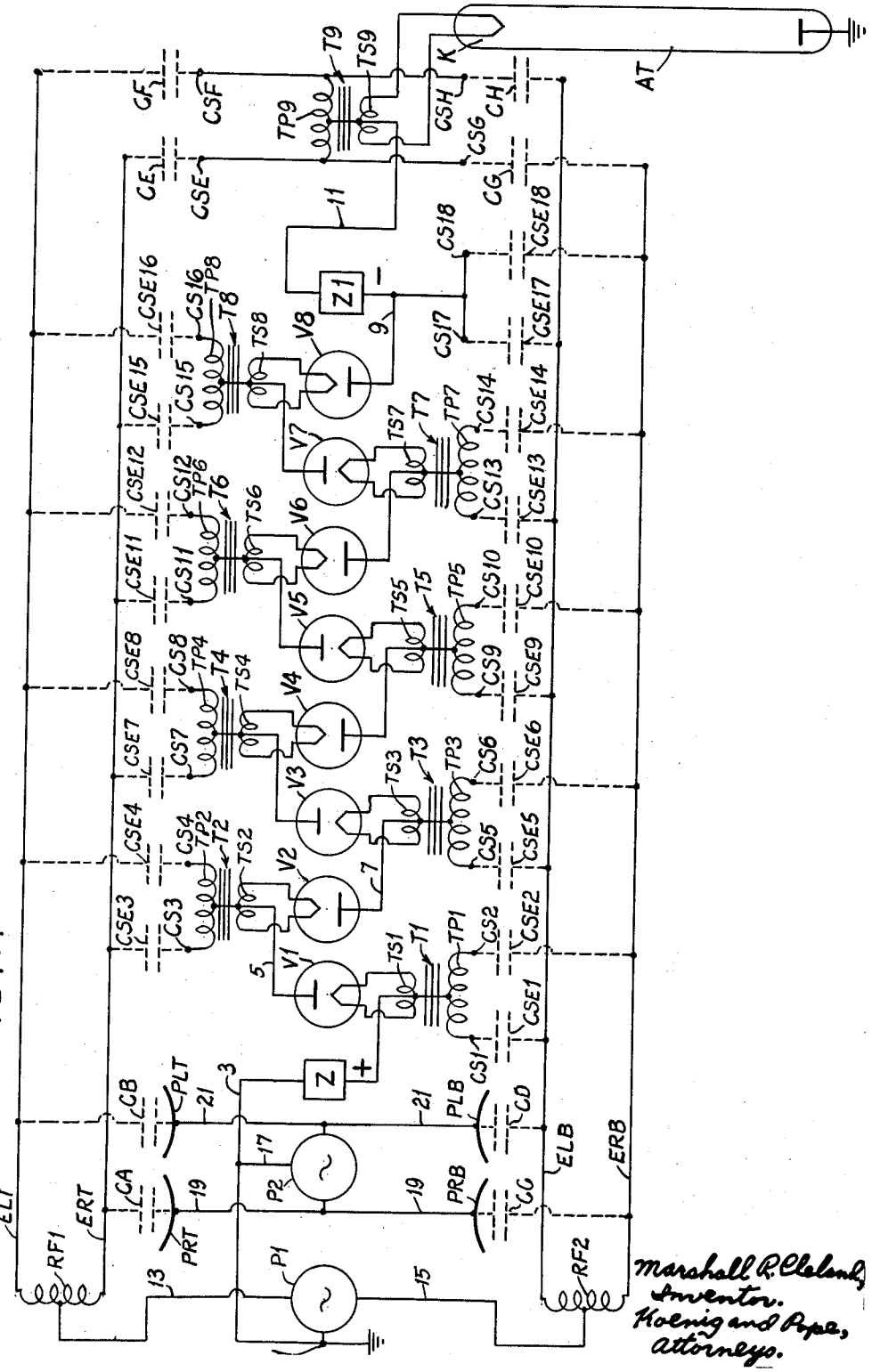
Nov. 6, 1962 M. R. CLELAND 3,063,000

VOLTAGE MULTIPLICATION APPARATUS

Filed May 27, 1959 8 Sheets-Sheet 1

FIG. 1.



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VOLTAGE MULTIPLICATION APPARATUS

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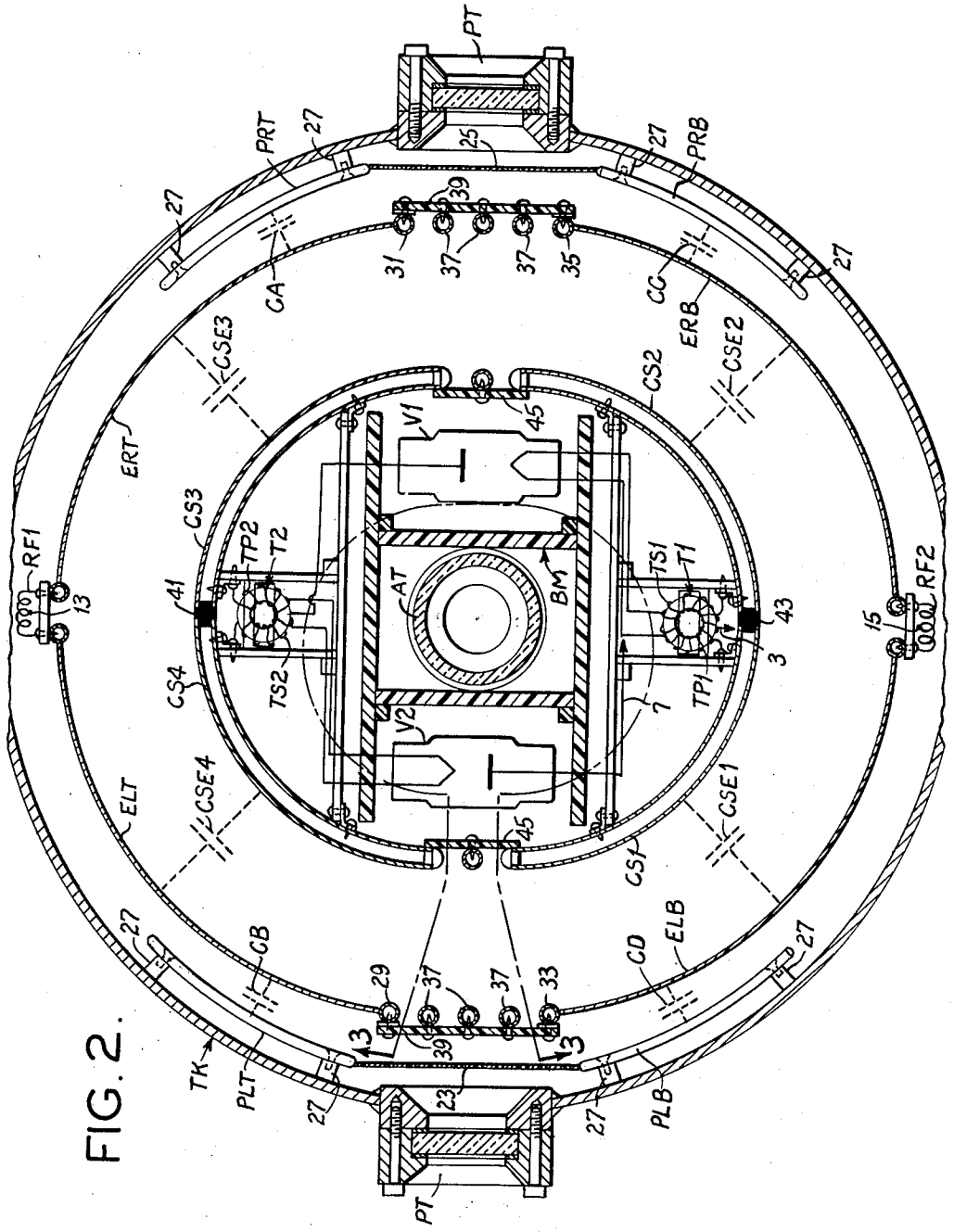


FIG. 2.

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VOLTAGE MULTIPLICATION APPARATUS

Filed May 27, 1959 8 Sheets-Sheet 3

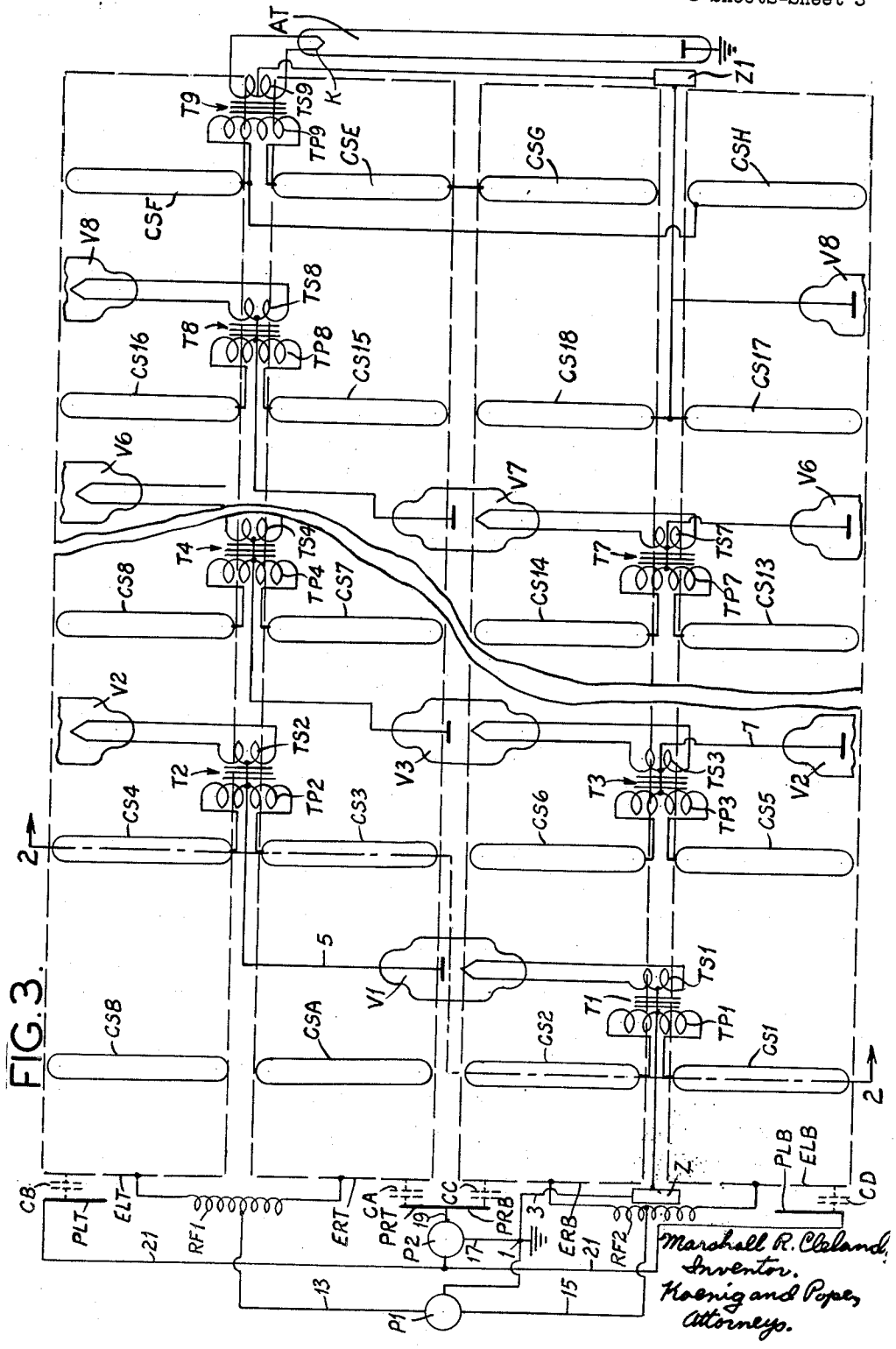


FIG. 3.

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VOLTAGE MULTIPLICATION APPARATUS

Filed May 27, 1959 8 Sheets-Sheet 4

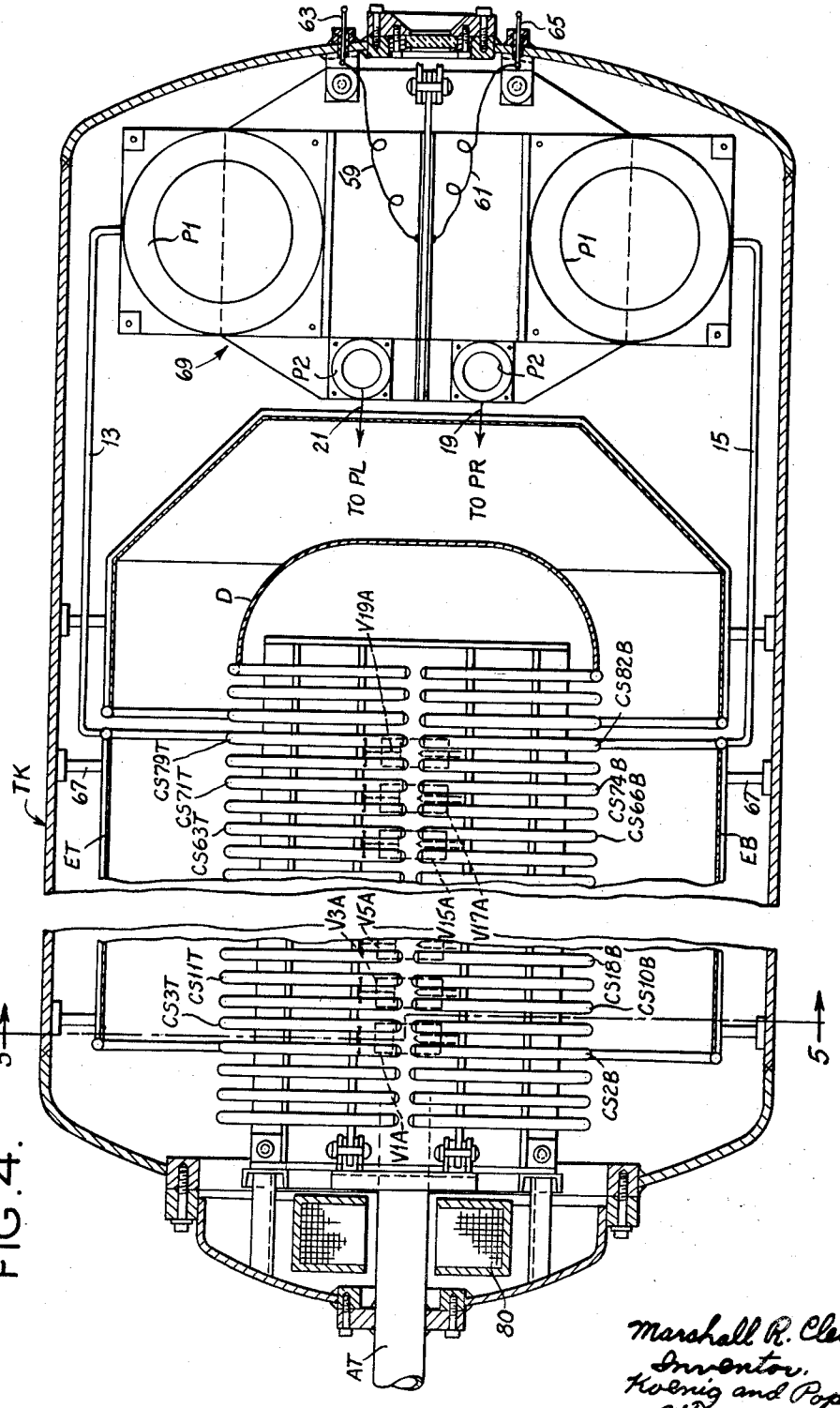


FIG. 4.

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VOLTAGE MULTIPLICATION APPARATUS

Filed May 27, 1959 8 Sheets-Sheet 5

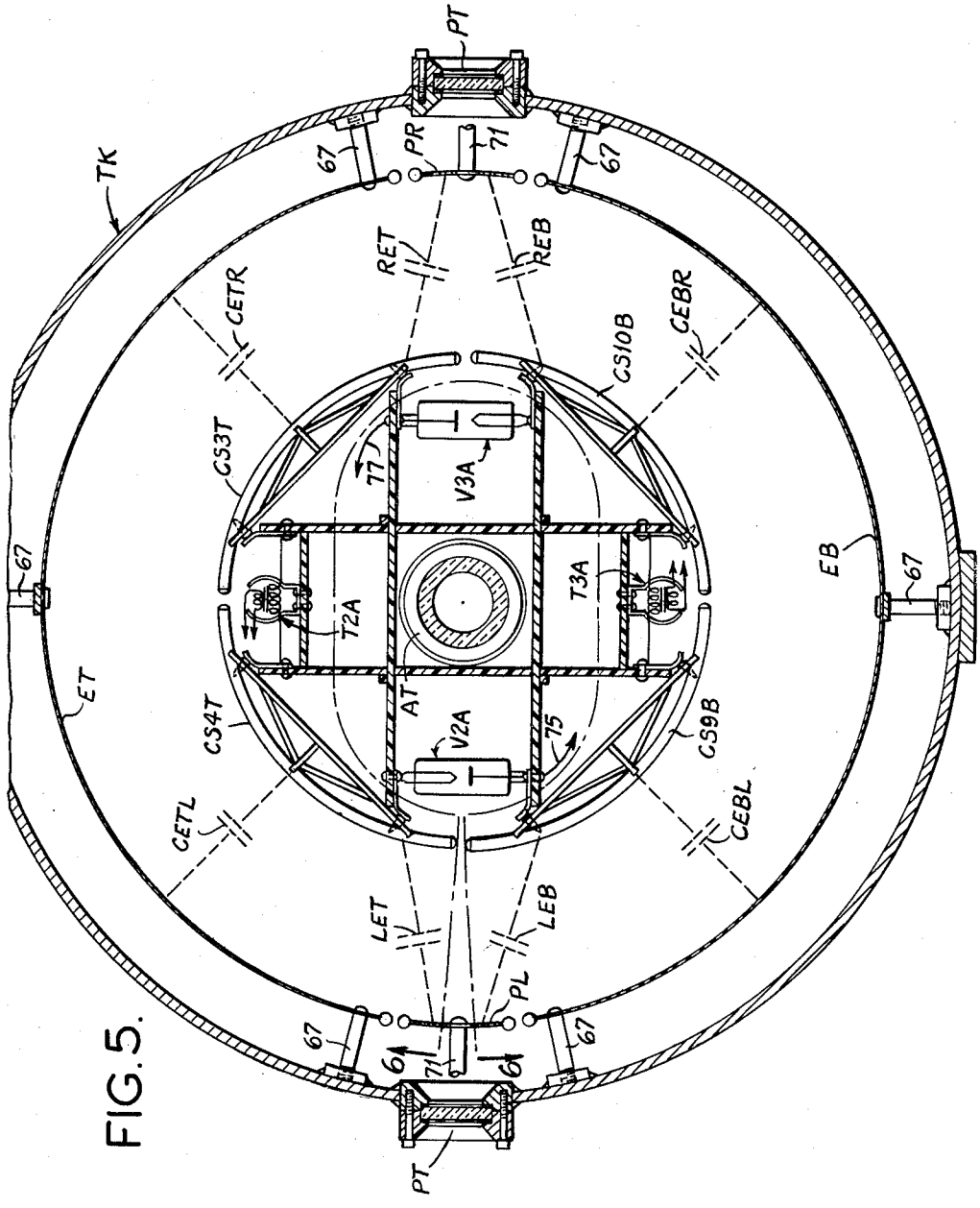


FIG. 5.

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VOLTAGE MULTIPLICATION APPARATUS

Filed May 27, 1959 8 Sheets-Sheet 6

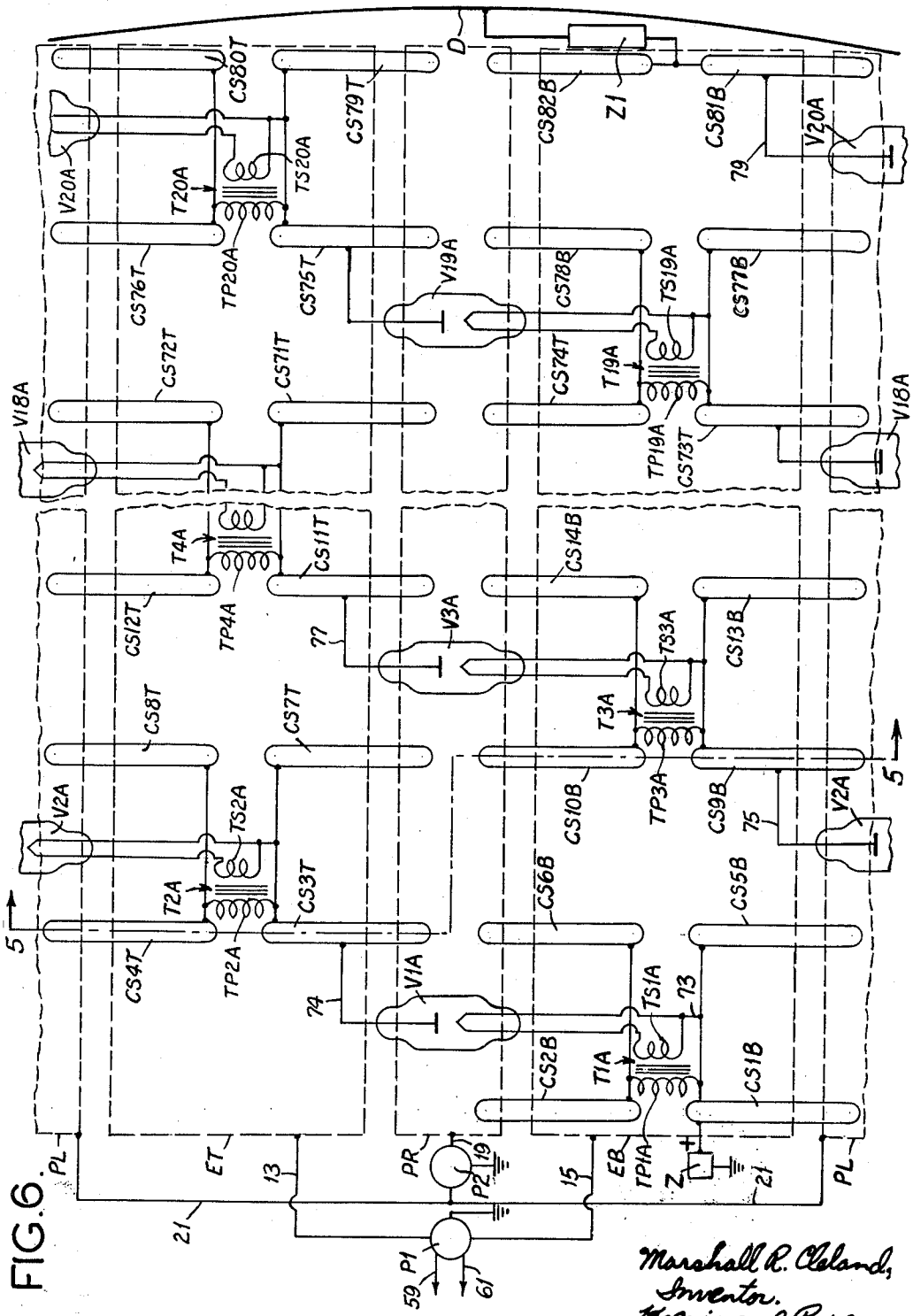


FIG. 6.

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VOLTAGE MULTIPLICATION APPARATUS

Filed May 27, 1959 8 Sheets-Sheet 7

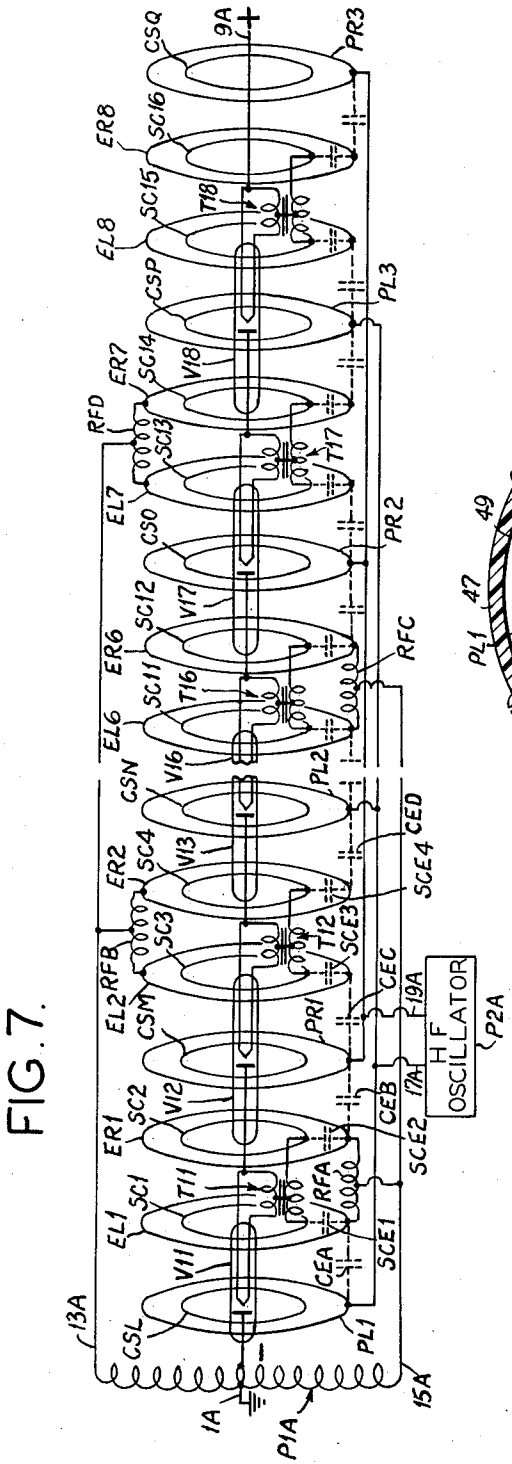


FIG. 7.

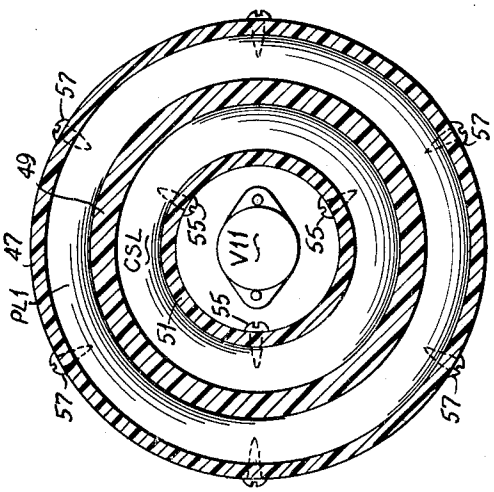


FIG. 9.

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VOLTAGE MULTIPLICATION APPARATUS

Filed May 27, 1959 8 Sheets-Sheet 8

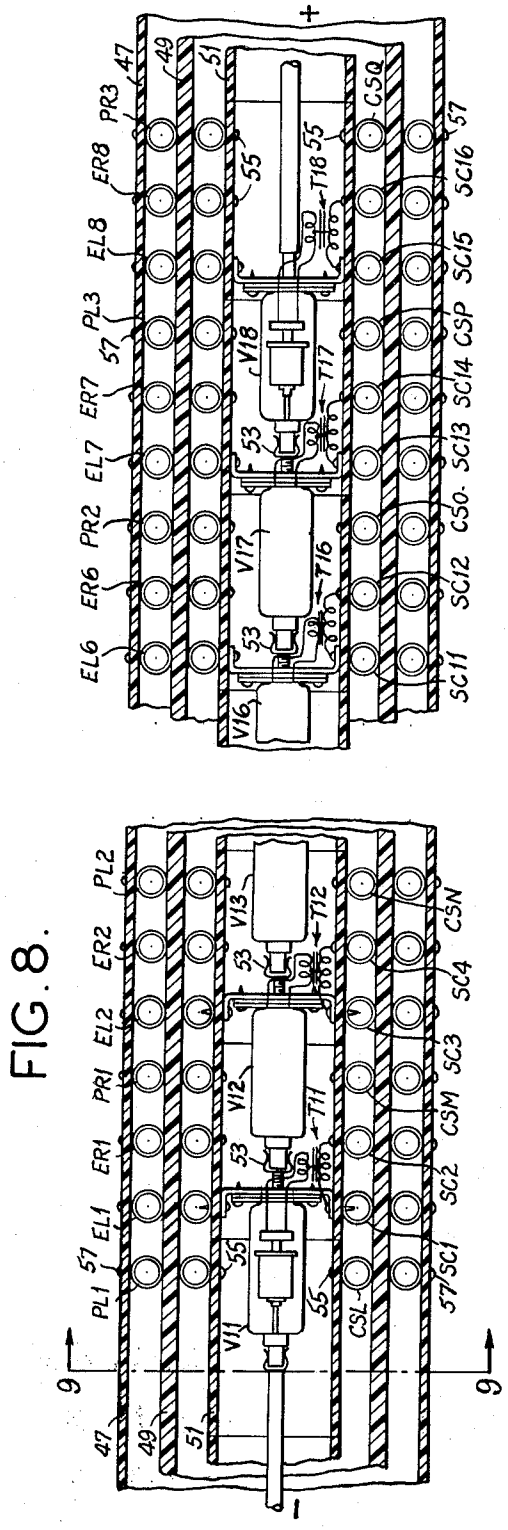


FIG. 8.

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United States Patent Office

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3,063,000

VOLTAGE MULTIPLICATION APPARATUS

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Filed May 27, 1959, Ser. No. 816,134
25 Claims. (Cl. 321—15)

This invention relates to voltage multiplication apparatus and more particularly to voltage multiplication apparatus employing rectifier units with heated cathodes.

Among the several objects of the invention may be noted the provision of voltage multiplication apparatus in which the cathodes of the rectifier units are energized by a power source independent of the A.C. power source supplying the anode-cathode circuits of each of the rectifier units; the provision of such apparatus in which the cathodes of said rectifier units may be preheated before application of A.C. potentials to the anode-cathode circuits of said rectifier units; the provision of apparatus of the class described in which the A.C. potential of the anode-cathode circuit of each of the rectifier units and therefore the rectified D.C. output potential of the apparatus may be adjusted without affecting the power supplied to heat the cathodes of said rectifier units; and the provision of voltage multiplication apparatus which is relatively simple in construction, economical in cost and reliable in operation. Other objects and features will be in part apparent and in part pointed out hereinafter.

In voltage multiplication apparatus of the cascaded rectifier type, it is desirable to have the cathodes of the rectifier units energized or heated by some means which is independent of the A.C. potentials applied to the cathode-anode circuits of each of the rectifier units. As there are high A.C. and D.C. potential differences between the various rectifier tubes or units, isolation transformers, built to withstand these high potential difference, and individual batteries for each rectifier unit cathode, and other means have been used to power the cathodes. Each of these arrangements, however, has certain disadvantages. Batteries must be replaced or recharged frequently, and isolation transformers or sufficient insulation capacity are expensive and bulky.

In accordance with the present invention, voltage multiplication apparatus has been developed in which a source of cathode or filament power is provided. This source is independent of the A.C. potentials applied to the individual anode-cathode circuits of the cascaded rectifier units and very simply and effectively heats these cathodes. Thus, the cathodes of the rectifier units may be preheated to avoid the possible damage to them attendant upon simultaneously applying power to the cathodes and a potential across the anode-cathode circuits. Also, these latter A.C. potentials, and therefore the D.C. output potentials of the voltage multiplication apparatus, may be varied without affecting the power levels supplied to the rectifier unit cathodes. In essence, my invention comprises voltage multiplication apparatus incorporating means for independently electrically energizing and heating the cathodes of the rectifier units including a pair of metallic electrodes connected to a first source of A.C. power and another A.C. supply source which powers or supplies an A.C. potential to each of a series of cascaded or series-connected rectifier units. Preferably, although not necessarily, the frequencies of the first and second A.C. power sources are different. The A.C. power from this first A.C. source is capacitively coupled to a pair of corona shields connected to each of the junctions formed by serially connecting the rectifier units anode-to-cathode. This transfer of power to these corona shields (which are preferably connected to a primary winding of a transformer which has its secondary connected to the rectifier cathode or filament) is either directly through or across the capacitance between each of the electrodes and its respective corona shield, or indirectly by a capacitive coupling to another set of metallic electrodes interposed between said corona shields and the former metallic electrodes. By certain novel structural features and electrical circuitry, the corona shields accomplish several functions, e.g., not only do they minimize corona discharge from various high potential points along the cascaded rectifier, but they also serve to pick up and transfer electrical energy from each of the two A.C. power sources to the different supply points (viz., the rectifier unit cathode and the cathode-anode circuits of the individual rectifier units).

The invention accordingly comprises the constructions hereinafter described, the scope of the invention being indicated in the following claims.

In the accompanying drawings, in which several of various possible embodiments of the invention are illustrated.

FIG. 1 is a circuit diagram of one embodiment of voltage multiplication apparatus of the present invention;

FIG. 2 is a cross section of a structural embodiment of voltage multiplication apparatus of FIG. 1 taken on line 2—2 of FIG. 3;

FIG. 3 is a developed diagrammatic view of the voltage multiplication apparatus of FIG. 1 taken on line 3—3 of FIG. 2;

FIG. 4 is a side elevation of a second embodiment of voltage multiplication apparatus of this invention, with various parts broken away;

FIG. 5 is an enlarged cross section taken on line 5—5 of FIG. 4;

FIG. 6 is a developed diagrammatic view of the voltage multiplication apparatus of FIGS. 4 and 5 taken on line 6—6 of FIG. 5;

FIG. 7 is a circuit diagram of a third embodiment of voltage multiplication apparatus of the present invention;

FIG. 8 is a longitudinal cross section of a structural embodiment of the voltage multiplication apparatus of FIG. 7; and

FIG. 9 is an enlarged section taken on line 9—9 of FIG. 8.

Corresponding reference characters indicate corresponding parts throughout the several views of the drawings.

Referring now more particularly to FIG. 1, voltage multiplication apparatus of the present invention is schematically depicted. A first source of A.C. power is generally indicated at reference character P1, which is preferably a balanced or three-wire A.C. power supply with its neutral point grounded. Any customary source of A.C. power that will provide a potential in the order of 50,000–300,000 v. at a frequency in the range of 20–300 kc. and of the necessary current capacity, may be employed at P1. For example, P1 may be a center-tapped inductor electrically connected or coupled to, or driven by, an oscillator or a power amplifier. It will be understood that a single-ended or unbalanced source of A.C. power could also be utilized conveniently at P1. The grounded neutral terminal of P1, indicated at 1, is connected by means of a wire or connector 3 and an R-F impedance Z, such as an R-F choke, to the cathode of a rectifier unit or diode vacuum tube V1. The interconnection of wire 3 may be through a secondary TS1 of a filament transformer T1, or if V1 is of the indirectly heated cathode type, directly to such a cathode. The anode or plate of V1 is interconnected in turn to a secondary TS2 of a filament or cathode with a transformer T2, which secondary is similarly connected across the filament of a second rectifier unit V2. The anode of V2 is connected to the cathode of a third rectifier tube

V3 by a wire 7, continuing in this fashion until a total of eight rectifier units V1–V8 are serially connected anode-to-cathode via the secondaries of the respective associated filament transformers T1–T8, thereby forming a cascaded rectifier connected between ground and a high voltage terminal 9. A conductor 11 via a second impedance (e.g., an R-F choke) Z1 interconnects high D.-C. voltage terminal 9 to a secondary TS9 of another transformer T9, which secondary is also connected across the cathode K of an elongate evacuated accelerator tube AT. A plate or anode at the opposite end of tube AT is at ground potential, thus completing the D.C. circuit of the cascaded rectifier.

In order to supply A.C. power of the proper potentials to the anode-cathode circuits of each of the tubes V1–V8, I interconnect two metallic electrode sections ELT and ERT to one terminal of P1 via a wire 13 at a center-tapped inductance of R-F choke RF1. The other terminal of P1 is interconnected by a wire 15 at a second center-tapped R-F choke RF2 to another pair of metallic electrode sections ELB and ERB. The A.C. potential developed by P1 and impressed across ELT—ERT and ELB—ERB is capacitively coupled as indicated at CSE1 through CSE4 to two pairs of corona shields CS1, CS2 and CS3, CS4. The former set or pair of corona shields is connected to opposite sides of transformer primary TP1 while the latter set of corona shields is connected to opposite ends of transformer primary TP2. Inasmuch as the transformer primaries TP1 and TP2 are respectively connected at their neutral points to the center taps on the secondaries TS1 and TS2, the A.C. potential of P1 is thereby impressed across the two successive electrical junctions formed at the cathode of V1 and the V1 anode-V2 cathode connection. Thus, this potential is impressed across the anode-cathode circuit of V1. Each of the other filament transformer primaries TP3—TP8 is similarly connected respectively to pairs of corona shields CS5—CS16, thereby establishing capacitances between the successive pairs of corona shields and the electrodes ELT—ERT and ELB—ERB as indicated at CSE5—CSE16. The A.C. potential across the electrodes ELT—ERT and ELB—ERB is thus impressed individually and in effect in parallel across the anode-cathode circuits of V1—V8 via the successive pairs of corona shields CS1—CS16 connected at successive junctions between the serially connected rectifier units. In order to capacitively couple the A.C. potential from ELB and ERT to the anode of V8, two additional corona shields CS17 and CS18 are provided, thus establishing capacitive coupling paths as indicated at CSE17 and CSE18.

A second A.C. power supply is indicated at reference character P2 and is constituted by an A.C. generator, such as an oscillator or power amplifier preferably having a balanced output, such as a center-tapped inductor which would constitute the circuit of such an oscillator or power amplifier. The neutral conductor or center tap of P2 is connected to ground by wire 17 and the output terminals of P2 are connected via wires 19 and 21 and to two pairs of electrode sections PRT—PLT and PRB—PLB. This A.C. energy from P2 is capacitively coupled to ERT—ELT and ERB—ELB through the interelectrode capacitance CA, CB, CC and CD established between the closely adjacent respective electrode sections. The frequency of the second power source is different and preferably higher (e.g., 200 kc. to 2 mc.) than that of P1, so that the impedances constituted by RF1 and RF2 are very high at the P2 frequency. Thus, ELT and ERT serve as conductors of instantaneously opposite polarity for the output A.C. potential of P2 and capacitively couple this potential through CSE3 and CSE4 to the primary TP2, thereby energizing it and heating the cathode or filament of V2. Similarly, the instantaneously opposite polarity A.C. potential of P2 is also impressed across ELB and ERT (via

CC and CD) and is capacitively coupled via CSE1 and CSE2 to TP1 so as to energize T1 and power the filament of V1. There is also a capacitive coupling effect between ERT—ERB and ELT—ELB and corona shields CSE, CSG, CSF and CSH through the respective interelectrode capacitances established between these electrode sections and their respectively closely adjacent corona shields. As CSE and CSG are connected to one side of a transformer primary winding TP9 of an accelerator tube cathode transformer T9 and CSF and CSH are commonly connected to the other side of TP9, A.C. power is thereby transferred from P2 to the cathode of accelerator tube AT, which constitutes the electron source for this tube.

A structural embodiment of the FIG. 1 voltage multiplication apparatus is illustrated in FIG. 2 in which the components thereof are enclosed in an electrically grounded, heavy steel, cylindric, gas-tight pressure container or tank TK having inspection ports PT in the sides thereof. The two electrodes constituted by electrode sections PLT—PLB and PRT—PRB are elongate metallic sheets or plates, curved in cross section, parallel and opposing each other. Sections PLT and PRT are interconnected respectively to PLB and PRB by conductive screens or conductors 23 and 25. These electrodes are mounted spaced from the inside surfaces along the length of the tank and on opposite sides thereof by stand-off insulators 27. These electrodes are coaxial with AT which is positioned along a longitudinal axis of tank TK. Electrodes ELT and ERT are also elongate, curved in cross section, metallic sections and are electrically connected at their adjacent ends by R-F choke RF1. These two electrode sections constitute the upper half of a metallic shell, the lower edges (as indicated at 29 and 31) of which are spaced from the opposing edges 33 and 35, respectively, of a second metallic shell electrode constituted by electrode sections ELB and ERB. These two shells or electrode sections ELB and ERB are interconnected together at their adjacent edges by RF2 which is in turn connected through its center tap and conductor 15 to A.C. power source P1. These two shells ELT—ERT and ELB—ERB are insulatedly supported interiorly of tank TK on opposite sides of a central longitudinal horizontal plane of the tank. The opposing edges 29, 31, 33 and 35 of the respective opposing pairs thereof have interposed therebetween a number of parallel lengths of round metallic tubing 37 mounted on insulating strips 39 by metal screws. These lengths of tubing 37 function as an R-F potential divider bridging the gap between the opposing shell electrodes, the middle tubing 37 preferably being grounded. The four sections of the pairs of metallic shell electrodes ELT—ERT and ELB—ERB are rigidly secured within the tank TK, preferably by an insulated cantilever beam construction to a removable end cover of the tank, so as to maintain their position as illustrated coaxial with a longitudinal axis of the tank and equidistantly spaced from the curved inner surfaces of electrodes PLT—PLB and PRT—PRB. Electrodes ELT—ERT and ELB—ERB are electrically connected to power source P2 by means of conductors 13 and 15 via the center taps of RF1 and RF2.

Also mounted within tank TK, preferably by means of a cantilever support including a hollow insulated beam, as shown at BM, are the corona shields CS1—CS18. These shields are constituted by short lengths of metallic tubing, each bent into an arcuate shape, and generally circular in cross section. Four of these shields, each of which is a quadrant, are arranged in a generally circular end-to-end configuration in a plane transverse to the longitudinal axis of the tank. Each set of four of these corona shields forms a layer and a number of these layers are coaxially positioned parallel each to the other and spaced apart along this longitudinal axis. It will be noted that the adjacent ends of the top two corona shields CS3 and CS4 (FIG. 2) are insulated from each other by a

separator or insulating plug 41 and that the bottom two quadrant corona shields CS1 and CS2 are similarly secured together at their adjacent ends, but insulated from each other, by plug 43. The ends of the top left corona shields, such as CS4, are spaced in a vertical web from the opposing ends of the lower left corona shields, such as CS2, by an insulating plate 45. An identical web, also shown at 45, holds the opposing ends of the upper and lower right quadrant corona shields (e.g., CS3 and CS1) in a spaced-apart insulating relationship.

The adjacent ends of the pair of corona shields CS1 and CS2 are connected to the cathode of V1 by means of transformer T1. More specifically, the ends of CS1 and CS2 are connected to the primary winding TP1 and the secondary winding TS1 is connected across the filament of V1. The center taps of these two windings are commonly connected as shown in FIG. 1. Tubes V1—V8 are arrayed in a generally helical fashion around the longitudinal axis of accelerator tube AT. The pair of corona shields CS3 and CS4 are similarly connected via TP2 and TS2 of transformer T2 to the next or successive junction (constituted by the interconnection of the anode of V1 to the center tap of TS2) of the cascaded rectifier tubes. The anode of V2 is connected to the cathode of V3 in a similar way, thus forming a junction for connection of corona shields CS5 and CS6, et seq.

It will be understood, as described in more detail hereinafter, that although a plurality of parallel layers of spaced-apart corona shields, four in each layer, are provided, CS1 and CS2 are not in the same plane as CS3 and CS4. The latter two shields are actually in the same planar layer as CS5 and CS6. This is due to the fact that each pair of corona shields is connected to a successive junction and that two such successive junctions of the tubes V1—V8 (except for the terminal units V1 and V8) will fall generally within each of the several parallel planes transverse the longitudinal axis. Thus, CS5 and CS6 are in the same layer as CS3 and CS4, and CS7 and CS8 are arranged end to end in a generally circular fashion with CS9 and CS10 to form the next adjacent parallel layer, etc.

Operation of the voltage multiplication apparatus of FIGS. 1–3 is initiated by energizing A.C. power source P2, thereby applying the A.C. potential of P2 across PLT—PLB and PRB—PLB. The interelectrode capacitances CB and CA capacitively couple the A.C. potential electrode sections ELT and ERT respectively. This potential of P2 is further capacitively coupled to each of the transformers T2, T4, T6 and T8 by means of the pairs of corona shields CS3—CS4, CS7—CS8, CS11—CS12, and CS15—CS16 which are respectively connected to the junctions between the anodes of V1, V3, V5 and V7 and the cathodes of V2, V4, V6 and V8. Similarly, the P2 potential is capacitively coupled first by electrodes PRB and PLB (through capacitances CC and CD) to electrodes ERB and ELB, and thence via capacitances CSE1—CSE2, CSE5—CSE6, CSE9—CSE10, and CSE13—CSE14 to their respective adjacent corona shields to energize transformers T1, T3, T5 and T7 to heat the cathodes of V1, V3, V5 and V7. As RF1 and RF2 are high impedances at the frequency of P2, there is no effective shunting effect across RF1 (between ELT and ERT) and RF2 (between ELB and ERB). T9 is also energized from P2 by means of the capacitances CE, CF, CG and CH so as to heat cathode K of AT. By varying the A.C. potential of P2 the cathode power supplied to each of tubes V1—V8 and AT is conveniently adjusted and preheating thereof can continue as long as desired.

The other power source P1 is then actuated and as RF1 and RF2 present only a low impedance to the flow of A.C. power at the frequency of P1, the A.C. potential of P1 is present across the thereby commonly connected electrode sections ELT—ERT and ELB—ERB. Again via the capacitive coupling through CSE1—CSE2 (connected to the first junction) and CSE3—CSE4 (connected to the second junction) of the cascaded rectifiers, the anode-cathode circuit of V1 is powered. The two corona shields (effectively commonly connected together through the transformer primaries TP1—TP8) at each of the successive junctions between the anodes and cathodes of V2—V8 serve to pick up this A.C. potential of P1 and similarly apply it to the respective anode-cathode circuits thereof. As the A.C. potential of P1 is connected in parallel across each of V1—V8 and the rectified D.C. outputs of each of V1—V8 are effectively serially connected, the D.C. potential impressed across the anode-cathode circuit of AT is approximately eight times the value of P1. The accelerated beam of electrons produced by AT may be used to produce X-rays by impinging the beam on a target of a metal of high molecular weight. Also, the beam can be used to irradiate various chemical materials, food products, pharmaceuticals, etc., to effect desirable chemical and physical property changes, sterilization, etc. It will be noted that charged particles other than electrons, such as ions and protons, may be accelerated. In such instances any of the customary sources of such other charged particles may be substituted for cathode K, and any necessary reversal of D.C. output polarity can conveniently be made.

It will be understood that the impedances Z and Z1 which provide conducting paths for the D.C. load current without shorting out the high voltage A.C. potentials may be resistors, parallel resonant circuits tuned to the P1 frequency, or rectifiers which would pass current intermittently. If, for example, it is desired to use a power supply P2 lower in frequency than P1, the capacitances indicated at CA, CB, CC and CD could be replaced by R-F chokes (which would pass current of a relatively low frequency, but not of a higher band of frequencies) and RF1 and RF2 could be replaced by two condensers series-connected between ELT—ERT and another two series-connected condensers interconnected between ELB—ERB with the junctions of the two sets of such condensers (instead of the center taps of RF1 and RF2) connected to the conductors 13 and 15.

Referring now to the second embodiment of the present invention as illustrated in FIGS. 4–6, it will be noted that there are several differences between this embodiment and that of FIGS. 1–3. For example, the means for coupling the output of power source P2 to the corona shields comprises two curved in cross section, elongate, metallic panels or electrodes PL and PR, instead of two pairs (PLT—PLB and PRT—PRB) of electrode sections as in FIGS. 1–3, spaced on opposite sides of the longitudinal axis of tank TK. Electrodes PL and PR are interposed between the opposing edges of two metallic shell electrodes ET and EB in this embodiment, rather than positioned outside of two pairs of electrode sections ELT—ERT and ELB—ERB. Thus, in the FIGS. 4–6 embodiment, the A.C. potential of P2 is capacitively coupled directly to the corona shields rather than indirectly through the shell electrodes and thence to the corona shields, as in FIGS. 1–3. Also, the physical arrangement of the corona shields of this FIGS. 4–6 embodiment differs somewhat from that described and shown in FIGS. 1–3.

The first source of A.C. power for the voltage multiplication apparatus of FIGS. 4–6 is more specifically illustrated as comprising a toroidal coil indicated generally at P1 and interconnected by conductors 59 and 61 through pressure-tight connectors 63 and 65, preferably to a transducer, such as an R-F oscillator or power amplifier. Thus, P1 in this embodiment comprises an inductor included in the tank circuit of the power amplifier or oscillator. The capacitance of the LC circuit of this oscillator, which establishes the resonant frequency of P1, includes the capacitance between the two metallic electrodes ET and EB respectively interconnected by con-

ductors 13 and 15 to toroidal coil P1. These upper and lower electrodes ET and EB are supported by insulated electrode supports 67 within the container TK. Toroidal coil P1 is supported by a frame or bracing of insulating material 69 so that its axis is substantially coincident with that of the central longitudinal axis of the tank TK. The second source of A.C. power, which energizes the cathodes of the rectifier units and which in this instance may operate at the same frequency as P1, is illustrated as a second toroidal coil P2, coaxially mounted and spaced from P1, and also supported by bracing 69. P2 is interconnected by conductors 19 and 21 to the curved elongate panels PL and PR, which are physically supported by stand-off insulators 71 so as to space them parallel to each other on opposite sides of tank TK and from the inside surface thereof substantially the same distance as ET and EB are spaced. The capacitance between PL and PR and the inductance of P2 comprise an LC tank circuit adapted to be driven by an A.C. generator outside container TK at the resonant frequency of this circuit. Preferably PL—PR and inductor P2 are major components of the LC tank circuit of a remote oscillator or R-F power amplifier. However, as noted hereinafter, P1 and P2 may be both included in a common tank circuit energized by a single remote oscillator or R-F power amplifier.

As shown perhaps more advantageously in FIG. 6, the cathode of a first rectifier unit of tube V1A is connected to ground through R-F impedance Z, a corona shield of quadrant shape CS1B and a filament transformer T1A. Primary winding TP1A of this transformer is connected between CS1B and a second similar quadrant corona shield CS2B, both located in the same vertical plane transverse the longitudinal axis of tank TK. CS1B and CS2B are respectively commonly connected to two similar parallel and spaced-apart corona shields CS5B and CS6B. Secondary winding TS1A of T1A is connected across the filament of V1A. One side of secondary TS1A is directly commonly connected as indicated at 73 to CS1B, CS5B to provide a direct D.C. path for the filament of V1A through the R-F choke or impedance Z to ground.

The anode of V1A is connected by a wire 74 to another corona shield CS3T which is in turn connected through primary winding TP2A to another corona shield CS4T. Secondary winding TS2A is connected across the filament of diode rectifier V2A to heat it. One side of TS2A is commonly connected to CS3T and another corona shield CS7T. Corona shield CS4T is cross connected to another parallel spaced-apart corona shield CS8T. This completes one "module" of the cascaded rectifier units comprising the voltage multiplication apparatus of this embodiment.

The next "module" is series-connected cathode to anode to the V1A, V2A rectifier units by connecting the V2A anode by a wire 75 to corona shield CS9B. Three additional corona shields CS10B, CS13B and CS14B are interconnected with each other, the primary and secnodary windings of a filament transformer T3A, and the filament of a third rectifier unit V3A in a fashion similar to that previously described in the interconnection of V1A and V2A and their respective transformer windings and corona shields. The anode of V3A is connected by wire 77 to two corona shields CS11T and (via primary TP4A) CS12T. This serial interconnection of the rectifier units so that each anode is connected to the cathode of the next succeeding rectifier unit continues in this fashion for any desired number of rectifier unit modules, twenty such cascaded rectifier units being utilized in this particular embodiment. The terminal unit, including V20A, has its anode connected by a conductor 79 to a final pair of corona shield quadrants CS81B and CS82B, the junction between these two shields being connected through R-F impedance Z1 to a smooth rounded metallic dome D which constitutes the negative high voltage D.C. terminal of this voltage multiplication apparatus. This dome D is connected to the cathode of accelerator tube AT which, as may be noted in FIGS. 4 and 5, lies along a central longitudinal axis of tank TK. The various layers, each made up of four quadrant corona shields CS1B—CS82B symmetrically positioned in a circular array around this axis, lie in parallel spaced-apart planes transverse to this axis.

The matching structural embodiments of FIGS. 4 and 5 are keyed in by corresponding reference numerals so that corresponding components can easily be located. The interelectrode or distributed capacitances between the corona shields in the several banks or layers and the pair of opposed metallic electrodes ET and EB are indicated generally at CETL, CETR, CEBL and CEBR. Similarly the capacitances existing between these various corona shields in the layers and the other pair of opposed metallic electrodes PL and PR are generally indicated at LET, LEB, RET and REB. The remaining structural details of mounting the various components in tank TK and insulating them one from the other are apparent from the drawings and the description of the first embodiment, which is generally similar in construction and details, and do not require further description. It will be noted that a beam focusing coil 89 is coaxially positioned around the left end of accelerator tube AT to provide a magnetic focusing field for the accelerated stream of charged particles passing through AT.

The operation of this FIGS. 4–6 voltage multiplication apparatus is quite similar in principal to that described above in regard to the first embodiment. The essential and significant differences will be apparent from the following description. To preheat the rectifier tube cathodes V1A—V20A, which again may be of the directly or indirectly heated type, toroidal coil P2, which constitutes an A.C. power source therefor, is energized. The potential developed by P2 is impressed across the opposed curved panel electrodes PL and PR by wires 19 and 21. By means of capacitances LET, LEB, RET and REB, A.C. power of instantaneously opposite polarity is capacitively coupled to the many pairs of corona shields on the left (e.g., CS4T, CS9B) and the pairs of corona shields on the right (e.g., CS3T, CS10B). Thus CS9B and CS10B are fed with opposite polarity A.C. power from P2 and will energize the primary winding T3A to heat the cathode of V3A. A similar operation takes place with regard to the upper pair of corona shields CS4T and CS3T, which energize the filament of V2A via transformer T2A. Heater power is thereby supplied to each of the rectifier units V1A and V20A from P2, and by varying the output potential of P2 the heater power may be adjusted conveniently.

After sufficient preheating, P1 can then be energized to apply a high A.C. potential across the other pair of electrodes ET and EB. By means of the interelectrode or distributed capacitances CETL, CETR, CEBL and CEBR, A.C. power is capacitively coupled to the upper and lower pairs of corona shields (e.g., CS4T, CS3T and CS9B, CS10B). Inasmuch as these respective pairs of corona shields are connected at succeeding junctions formed at each anode-cathode connection between rectifier units, a high A.C. potential of substantially equal magnitude is impressed across each of tubes V1A—V20A, the rectified D.C. output of each being additively impressed between ground and the high voltage terminal at dome D. The level of the D.C. voltage may be conveniently adjusted simply by varying the potential of P1.

It will be noted in this second embodiment that two pairs of corona shield quadrants are effectively interconnected at each junction rather than a single pair as in FIGS. 1–3. For example, CS4T and CS3T are cross connected to CS8T and CS7T, respectively. The additional pair of shields connected at each junction increases the capacitance between the various rectifier junctions and

the electrodes ET, EB, thereby increasing the coupling therebetween. The same increased pick-up or coupling results between electrodes PL, PR and the various filament transformers, the capacitive coupling between P2 and the various transformers being doubled because of the additional pairs of corona shields. In this modification, therefore, only one tube is positioned between adjacent layers of four corona shields instead of placing two tubes between each layer as in FIGS. 1–3. An additional important feature in the FIGS. 4–6 embodiment is the increased flexibility of using the same frequency A.C. power sources for P1 and P2. Because the axis of ET, EB is displaced 90° relative to the axis of PL, PR, the A.C. power fed by P1 to the top and bottom pairs of corona shields (e.g., CS4T, CS3T and CS9B, CS10B) will not interact or effect the transfer of A.C. power from P2 to these same corona shields, or vice versa. For example, CS4T and CS3T are at one and the same potential level relative to the P1 power source, and CS9B and SC10B are at another opposite polarity but the same potential level relative to the P1 power source. Thus, there is no flow to current induced in the primaries of transformers T2A or T3A due to any difference in potential (relative to P1) between CS4T and CS3T, or between CS9B and CS10B. These transformer windings are responsive solely to the difference in potentials between CS4T and CS3T applied respectively thereto from the P2 power source. Similarly there is no difference in potential relative to P2 power source impressed between successive rectifier junctions (e.g., across V2A). Thus, CS4T and CS9B are at the same potential level relative to P2, and also CS3T and CS10B are at a common potential level relative to P2. Therefore, only P2 power will energize the filament transformers and only P1 power will supply a potential to the anode-cathode circuits of the cascaded rectifier units. P1 and P2 could conveniently be supplied from a common A.C. source (usually exterior tank TK), P2 preferably being of a lower potential, and P1 being controlled by a switch at a relatively low potential point so that it may be cut in or out as desired.

It will also be understood that the polarity of the rectifier string V1A–V20A may be easily revised simply by connecting each of the anode conductors (e. g., 74, 75, 77 and 79) to the corona shield pairs on their left (FIGS. 4 and 6) instead of as shown to the ones on their right, with an appropriate change in connections at the cathode of V20A (thereby connecting it to dome D through Z1) and at the anode of V1A (connecting wire 74 to ground through Z). A filtered D.C. potential of several or more million volts can be conveniently produced by this apparatus at a high power level (e.g., in the order of 1–10 ma. or more), the D.C. potential value being approximately the product of the number of rectifier units and the A.C. potential applied from P1 to each of the units. Adding more or less tubes and increasing or decreasing the potential P1 provides any desired D.C. output potential.

Referring now to FIGS. 7–9, the third embodiment of the voltage multiplication apparatus of the present invention is shown to comprise a plurality of cascaded rectifier units or diode vacuum tubes V11—V18, each of V12—V18 having its respective anode connected to the cathode of the tube on its left, and the terminal tube V11 having its anode connected to ground potential as indicated at 1A. The cathode of V18 is connected to a high voltage D.C. terminal as indicated at 9A, thereby providing a source of substantially constant high voltage D.C. power adapted to energize an accelerator tube, etc. This embodiment differs somewhat in construction from those described previously (FIGS. 1–3 and FIGS. 4–6) in that the rectifier units are disposed end-to-end aligned a longitudinal axis of the apparatus instead of being arrayed around such an axis. Also, instead of employing elongate curved metallic panels for transfer of A.C. power from two different A.C. sources respectively to the rectifier tube anode-cathode circuits and to their filaments, a plurality of metal rings are used in this embodiment. Furthermore, the corona shields in FIGS. 7–9 are also metal rings instead of arcuately shaped tubing lengths or quadrants, as in the preceding embodiments. As illustrated in FIG. 7, a power source P2A, such as a high voltage oscillator is connected by conductors 17A and 19A to a number of spaced-apart pairs of rings PL1—PR1, PL2—PR2 and PL3—PR3. In regard to the V1 and V2 tubes, the instantaneously opposite polarity terminals of A.C. supply P2A are connected to PL1 and PR1 respectively. Due to the distributed or interelectrode capacitance (indicated at CEA) between PL1 and an adjacent similar ring electrode EL1, and the distributed capacitance (indicated at CEB) between PR1 and its closely spaced and parallel ring ER1, the A.C. potential of P2A is capacitively coupled to EL1 and ER1. Two additional, but smaller rings, which also serve as corona shields, SC1 and SC2, are coaxially aligned and positioned in the same parallel planes as EL1 and ER1. Because of the distributed capacity between EL1 and SC1 (as indicated at SCE1) and ER1 and SC2 (as indicated at SCE2) this A.C. potential is impressed across SC1 and SC2. The opposite ends of a primary winding of a transformer T11 are connected across SC1 and SC2 and the winding is thereby energized therefrom to provide a filament heating voltage for the cathode of V1 which is connected to the secondary of T11.

As there is a similar large ring electrode EL2 positioned parallel and closely adjacent PR1 on its right, there is also a coupling path through a capacitance CEC between PR1 and EL2. The other terminal of P2A is connected via 17A to still another large ring electrode PL2 which in turn is positioned parallel, coaxial with and closely adjacent another large ring electrode ER2. Thus, through the distributed capacity (as indicated at CED) between PL2 and ER2 A.C. power is transferred from P2A via 17A and PL2 to ER2. Two smaller coaxial corona shield rings SC3 and SC4 are positioned in the same parallel planes as EL2 and ER2, respectively. Due to the capacitances (as indicated at SCE3 and SCE4) thereby established between EL2 and ER2 and their respective inner shield rings SC3 and SC4, A.C. power from P2A is applied to SC3 and SC4. The primary winding of a filament transformer T12 is connected across SC3 and SC4 so as to be energized thereby and provide power via the secondary of transformer T12 to heat the cathode of V12 which is connected thereacross. Similarly, the filaments of the other cascaded rectifier units such as V13, V16, V17 and V18 are supplied with A.C. power from P2A by ring electrodes PL2, PR2, PL3 and PR3, the capacitive coupling paths between these electrode rings and EL6, ER6, EL7, ER7, EL8 and ER8 and the corona shield rings SC11—SC16, and the transformers, such as T16—T18, respectively. For brevity and clarity, not every such interelectrode capacitance is referenced nor is each of the rectifier units V1—V8 completely illustrated or shown. Inasmuch as each of the rectifier units is identical to those described in detail above, it is apparent that each of these units has its cathode energized in the same fashion from P2A.

A second A.C. power source, preferably of a lower frequency and higher potential is indicated at P1A, as an inductor to which A.C. energy is transferred or coupled from any conventional generator such as an oscillator or power amplifier. By means of conductors 13A and 15A the A.C. potential of P1A is impressed across successive spaced pairs of electrode rings EL1—ER1, EL2—ER2, EL6—ER6, EL7—ER7 and EL8—ER8. As EL1 and ER1 are interconnected through an R-F choke RFA which has a low impedance at the frequency of P1A, these two electrode rings are at the same potential relative to P1A. The capacitors SCE1 and SCE2 serve as parallel paths to impress this potential on the T11 primary (via rings SC1 and SC2 and the center-tap interconnected primary and

secondary windings of T11) and on the electrical junction established between the anode of V12 and the cathode of V11 by the interconnection of the anode of V12 to one side of the filament of V11. Similarly, RFB interconnects EL2 and ER2 and A.C. power is transferred to the anode-cathode junction of V12 and V13 via SCE3 and SCE4, SC3 and SC4, and transformer T12. Again as in the previous embodiments the high impedance of the R-F chokes RFA—RFD at the frequency of P2A avoids any shunting effect between the respective EL and ER pairs of electrode rings. Thus, there is always the full A.C. potential of P2A present across EL2—ER2, for example, while these two electrodes are at the same potential relative to P1A.

It will be noted that PL1 and PR1 electrode rings also have smaller rings CSL and CSM positioned coaxially therewith and in the same general parallel planes as PL1 and PR1. In addition to functioning to minimize corona, these rings also provide alternate parallel paths to capacitively couple A.C. power from P2A to the primary of T11. The distributed capacitance between PL1 and CSL, and between CSL and SC1, constitute an energy transfer path to one side of transformer primary of T11, while the capacitances between PR1 and CSM, and CSM and SC2 constitute a similar transfer circuit or path to the other side of the primary of T11. However, these additional parallel capacitive coupling paths to SC1 and SC2 are not necessary to the operation of this voltage multiplication apparatus and CSL and CSM may be omitted therefore if desired.

It will be noted that the apparatus schematically depicted in FIG. 7 lends itself to a very compact physical counterpart as shown structurally in FIGS. 8 and 9. Several telescoped tubes of plastic, such as polyethylene or rolled mylar film, are indicated at **47**, **49** and **51**, and constitute the mechanical support and principal insulating members of this embodiment. Tube sockets for V1—8 are mounted by brackets and metal screws within and spaced apart along the longitudinal axis of tube **51**. Transformers T11—T18 are secured on the bases of each of the tube sockets, and anode clips **53** are also provided to series-connect these rectifier units in cascaded configuration. Each of the smaller rings CSL—CSQ and SC1—SC16 is affixed along the outer surface of tube **51** by means of metal screws as shown at **55**. As tubes **V11—V18**, transformers T11—T18 and all of the small ring corona shields are mounted on **51**, they can be withdrawn or inserted with ease by sliding this assembly in or out of engagement with intermediate tube **49**. The remaining ring electrodes, PL1—PL3, PR1—PR3, EL1—EL8 are secured to the inner surfaces of tube **47** by means of metal screws **57**. The tube 49 may be eliminated, if desired, if the FIGS. 7–9 embodiment is to be submerged in oil or mounted in a sealed pressurized container charged with an insulating gas medium such as sulfur hexafluoride.

The operation of the voltage multiplication apparatus of this third embodiment is substantially indentical to that of the previously described embodiments in that the A.C. potential of one A.C. power source (P2A) is capacitively coupled to each of the transformer primaries via the distributed capacitance between two corona shields at each junction and closely adjacent electrodes (e.g., EL1 and EL2), while the relatively higher A.C. potential of another A.C. power source (P1A) is capacitively coupled to the anode-cathode circuit of each of the rectifier units V11—V18 by the distributed capacity between a pair of corona shields at each such junction (e.g., SC1—CS2 and SC3—SC4) and two closely adjacent respective pairs of electrodes (e.g., EL1—ER1 and EL2—ER2). Thus, the filaments are heated from a power source (P2A) independent from the power source (P1A) which energizes the anode-cathode circuits of the cascaded rectifiers V11—V18. It will be noted that no series impedances (such as Z and Z1) or isolation chokes are used in this embodiment. Therefore, because of the push-pull or balanced R-F signal applied from P1A to the rectifier junctions and the fact that no R-F signal is present at the input and output terminals 1A and 9A, the D.C. voltage impressed across the end rectifiers V11 and V18 is only one half that impressed across V12—V17. Thus, the D.C. voltage developed by this embodiment is $(n-1)V$ where V is the amplitude of the R-F potential applied across each rectifier anode-cathode circuit from P1A, and where n is the number of rectifier units.

It will be understood that the term "rectifier unit" as used herein refers not only to a single rectifier tube or diode, but to an assembly of two series- or parallel-connected rectifier tubes. Also, it will be noted that either end of the voltage multiplication apparatus may be grounded, and the polarity of the terminals reversed, if desired, merely by reversing the connections between or the direction of the rectifier units. The apparatus may also be enclosed in a gas-tight tank with an evacuated interior or a pressurized gas- or liquid-filled container.

In each of the embodiments of the present invention neither of the power sources contributes powerwise to the other in its respective function, so that filament heating is always independent of the power supplied to the anode-cathode circuits of each of the cascaded rectifier units. The shapes of the various pairs of electrodes energized by the two power sources may be varied considerably from the various forms specifically illustrated, but each member of a pair should be symmetrical with respect to its opposing member.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As various changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. Voltage multiplication apparatus comprising first and second pairs of metallic electrodes, first and second sources of A.C. power respectively connected to said first and second pairs of electrodes, a plurality of rectifier units each having an anode and a cathode and being series-connected anode-to-cathode between ground and a high voltage D.C. terminal, and first and second corona shields connected at each of the electrical junctions thereby formed between said rectifier units, each of said first and second corona shields at each junction being respectively closely adjacent said first pair of electrodes whereby A.C. power from said first A.C. source is capacitively coupled to said cathodes to heat them, said corona shields connected at successive junctions also being closely adjacent said second pair of electrodes whereby A.C. power from said second A.C. source is capacitively coupled to the anode and cathode of each of said rectifier units to apply an A.C. potential thereacross.

2. Voltage muultiplication apparatus as set forth in claim 1 in which said first and second sources of power have different frequencies.

3. Voltage multiplication apparatus as set forth in claim 1 in which said first source of A.C. power has a substantially higher frequency than that of said second source of A.C. power.

4. Voltage multiplication apparatus as set forth in claim 1 in which said first pair of metallic electrodes comprises two parallel elongate metallic members curved in cross section and spaced apart and opposing each other on opposite sides of a longitudinal axis of said apparatus.

5. Voltage multiplication apparatus as set forth in claim 4 in which said corona shields are arcuate in shape and circular in cross section, each set of said first and second corona shields commonly connected to any one of said junctions being coplanar and insulated from each other and lying in a plane transverse said longitudinal axis.

6. Voltage multiplication apparatus as set forth in claim 5 in which each planar set of corona shields comprises a layer, and said layers are respecitvely parallel and spaced from one another along said longitudinal axis.

7. Voltage multiplication apparatus comprising first and second pairs of metallic electrodes, first and second sources of A.C. power of different frequencies respectively connected to said first and second pairs of electrodes, a plurality of rectifier units each having an anode and a cathode and being series-connected anode-to-cathode between ground and a high voltage D.C. terminal, and first and second corona shields connected at each of the electrical junctions thereby formed between said rectifier units, said corona shields being arcuate in shape and each comprising a quadrant, the first and second shields connected at two successive junctions being arranged end-to-end to form a circle in a plane transverse a longitudinal axis of said apparatus, the respective ends of each of said quadrants being spaced apart and insulated from each other, each of said first and second corona shields at each junction being respectively closely adjacent said first pair of electrodes whereby A.C. power from said first A.C. source is capacitively coupled to said cathodes to heat them, said corona shields connected at successive junctions also being closely adjacent said second pair of electrodes whereby A.C. power from said second A.C. source is capacitively coupled to the anode and cathode of each of said rectifier units to apply an A.C. potential thereacross.

8. Voltage multiplication apparatus as set forth in claim 7 in which the adjacent ends of each set of first and second corona shields are connected to the primary of a transformer and the secondary of said transformer is connected to the cathode of a rectifier unit.

9. Voltage multiplication apparatus comprising first and second pairs of metallic electrodes, first and second sources of A.C. power of different frequencies respectively connected to said first and second pairs of electrodes, a plurality of rectifier units each having an anode and a cathode and being series-connected anode-to-cathode between ground and a high voltage D.C. terminal, first and second corona shields connected at each of the electrical junctions thereby formed between said rectifier units, and an additional corona shield respectivley electrically connected to each of said corona shields, said corona shields each being arcuate in shape and comprising a quadrant, the first and second shields connected at any one junction being arranged end-to-end with a pair of said additional corona shields connected to the first and second corona shields at a successive junction to form a circle in a plane transverse a longitudinal axis of said apparatus, the respective ends of each of said quadrants being spaced apart and insulated from each other, each of said first and second corona shields at each junction being respectively closely adjacent said first pair of electrodes whereby A.C. power from said first A.C. source is capacitively coupled to said cathodes to heat them, said corona shields connected at successive junctions also being closely adjacent said second pair of electrodes whereby A.C. power from said second A.C. source is capacitively coupled to the anode and cathode of each of said rectifier units to apply an A.C. potential thereacross.

10. Voltage multiplication apparatus as set forth in claim 9 in which the adjacent ends of each set of first and second corona shields are connected to the primary of a transformer and the secondary of said transformer is connected to the cathode of a rectifier unit.

11. Voltage multiplication apparatus comprising a plurality of first and second pairs of metallic electrodes, first and second sources of A.C. power of different frequencies respectively connected to said first and second pairs of electrodes, a plurality of rectifier units each having an anode and a cathode and being series-connected anode-to-cathode between ground and a high voltage D.C. terminal, and first and second corona shields connected at each of the electrical junctions thereby formed between said rectifier units, said corona shields being ring shaped and parallel and spaced apart along a longitudinal axis of said apparatus, each of said first and second corona shields at each junction being respectively closely adjacent one of said first pairs of electrodes whereby A.C. power from said first A.C. source is capacitively coupled to said cathodes to heat them, said corona shields connected at successive junctions also being closely adjacent one of said second pairs of electrodes whereby A.C. power from said second A.C. source is capacitively coupled to the anode and cathode of each of said rectifier units to apply an A.C. potential thereacross.

12. Voltage multiplication apparatus as set forth in claim 11 in which each set of first and second corona shields is connected to the primary of a transformer and the secondary of said transformer is connected to the cathode of a rectifier unit.

13. In voltage multiplication apparatus including a plurality of rectifier units each having an anode and a cathode and being series-connected anode-to-cathode between two high voltage D.C. terminals, and a first source of A.C. power adapted to apply an A.C. potential of a first frequency across each of said rectifier units; means for independently electrically energizing said cathodes to heat them comprising a pair of metallic electrodes, a second source of A.C. power of a frequency differing from said first frequency connected to said metallic electrodes, and first and second corona shields connected at each of the electrical junctions thereby formed between said series-connected rectifier units, each of said first and second corona shields at each junction being respectively closely adjacent said pair of electrodes whereby A.C. power from said second A.C. source is capacitively coupled to said cathodes to heat them.

14. In voltage multiplication apparatus as set forth in claim 13, said rectifier units being arrayed around a longitudinal axis of said apparatus, said corona shields being arcuate in shape and circular in cross section, each set of said first and second corona shields commonly connected to any one of said junctions being coplanar and insulated from each other and lying in a plane transverse said longitudinal axis.

15. In voltage multiplication apparatus as set forth in claim 13, said pair of metallic electrodes comprising two parallel elongate metallic members curved in cross section and spaced apart and opposing each other on opposite sides of said longitudinal axis.

16. In voltage multiplication apparatus as set forth in claim 13, said rectifier units being aligned end-to-end along said longitudinal axis, and said corona shields being rings coaxial with said axis and positioned side by side and spaced from one another.

17. In voltage multiplication apparatus as set forth in claim 16, said metallic electrodes being rings of larger diameter than said corona shield rings and positioned closely adjacent thereto and coaxial therewith.

18. Voltage multiplication apparatus comprising first and second pairs of metallic electrodes, first and second sources of A.C. power of different frequencies respectively connected to said first and second pairs of electrodes, said first pair of metallic electrodes comprising two parallel elongate metallic members curved in cross section and spaced apart and opposing each other on opposite sides of a longitudinal axis of said apparatus, a plurality of rectifier units each having an anode and a cathode and being series-connected anode-to-cathode between ground and a high voltage D.C. terminal, said units being positioned between said pairs of metallic electrodes and generally symmetrically arrayed around said longitudinal axis, and first and second corona shields connected at each of the electrical junctions thereby formed between said rectifier units, said corona shields being arcuate in shape and circular in cross section, each set of said first and second corona shields commonly connected to any one of said junctions

being coplanar and insulated from each other and lying in a plane transverse said longitudinal axis, each of said first and second corona shields at each junction being respectively interposed between said second pair of electrodes and said rectifier units whereby A.C. power from said second A.C. source is capacitively coupled to said cathodes to heat them, said corona shields connected at successive junctions being closely adjacent said first pair of electrodes whereby A.C. power from said first A.C. source is capacitively coupled to the anode and cathode of each of said rectifier units to apply an A.C. potential thereacross.

19. Voltage multiplication apparatus comprising a plurality of rectifier units each having an anode and a cathode and being series-connected anode-to-cathode between ground and a high voltage D.C. terminal, first and second corona shields connected at each of the electrical junctions thereby formed between said rectifier units, a pair of opposed elongate metallic shells having their respective edges spaced apart on opposite sides of a first plane, a pair of parallel elongate metallic electrodes curved in cross section and spaced apart and opposing each other on opposite sides of a second plane normal to said first plane, first and second sources of A.C. power of different frequencies respectively connected to said opposed metallic shells and said opposed metallic electrodes, said first and second corona shields at each junction being respectively closely adjacent said pair of electrodes whereby A.C. power from said second A.C. source is capacitively coupled to said cathodes to heat them, said corona shields connected at successive junctions also being closely adjacent said metallic shells whereby A.C. power from said first A.C. source is capacitively coupled to the anode and cathode of each of said rectifier units to apply an A.C. potential thereacross.

20. Voltage multiplication apparatus as set forth in claim 19 in which each of said metallic shells comprises two symmetrical longitudinal sections spaced apart on each side of said second plane, and said metallic shells are interposed between said corona shields and said metallic electrodes whereby A.C. power from said second source is capacitively coupled from said metallic electrodes to said cathodes via said metallic shell sections and said corona shields.

21. Voltage multiplication apparatus as set forth in claim 19 in which one of said metallic electrodes is positioned between one pair of said opposing edges of said metallic shells and the other said metallic electrode is positioned between the other pair of said opposing edges of said metallic shells, whereby A.C. power from said second source is capacitively coupled to said cathode via said corona shields.

22. Voltage multiplication apparatus comprising a plurality of rectifier units each having an anode and a cathode and being series-connected anode-to-cathode between ground and a high voltage D.C. terminal, said rectifier units being aligned end-to-end along a longitudinal axis of said apparatus, first and second corona shields connected at each of the electrical junctions thereby formed between said rectifier units, said shields being rings coaxial with said axis and spaced from one another, a plurality of ring-shaped metallic electrodes of larger diameter than said shields, each one of said electrodes positioned closely adjacent a respective shield and coaxial therewith, a first source of A.C. power capacitively coupled via said first and second corona shields and their respective electrodes to said cathodes to heat them, and a second source of A.C. power of a frequency different than said first source capacitively coupled via said corona shields connected at successive junctions and their respective electrodes to the anode and cathode of each of said rectifier units to apply an A.C. potential thereacross.

23. Voltage multiplication apparatus as set forth in claim 22 which further includes an additional ring-shaped metallic electrode interposed between each successive pair of the first metallic electrodes and coaxial therewith, successive ones of said additional electrodes being directly connected to said first A.C. power source whereby A.C. power is capacitively coupled to said cathodes from said additional electrodes via the first said metallic electrodes and said first and second corona shields at each junction.

24. Voltage multiplication apparatus as set forth in claim 23 in which one terminal of said second source of A.C. power is commonly connected to the first said electrodes adjacent the first and second corona shields at one junction and the other terminal of said second A.C. power source is commonly connected to the first said electrodes adjacent the first and second corona shields at a successive junction.

25. Voltage multiplication apparatus as set forth in claim 24 in which said first and second corona shields at any one junction are connected to a primary winding of a transformer and a secondary winding thereof is connected to the cathode of the respective rectifier unit.

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