March 28, 1961 H. T. BOEKER 2,977,500

PRODUCTION AND CONTROL OF ELECTRON BEAMS

Original Filed Dec. 4, 1956 2 Sheets-Sheet 1

FIG. 1

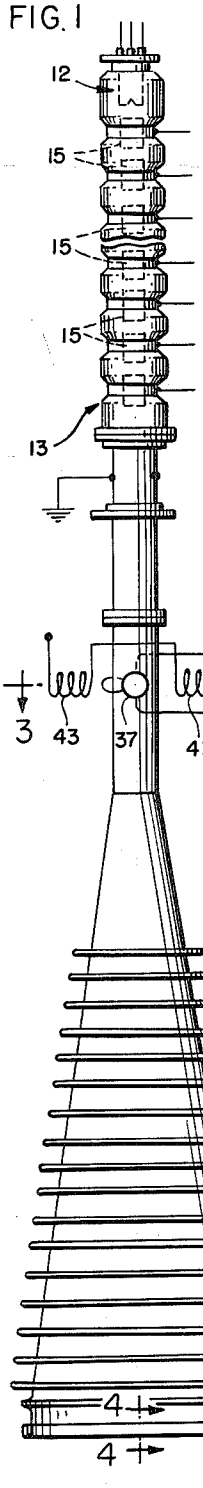
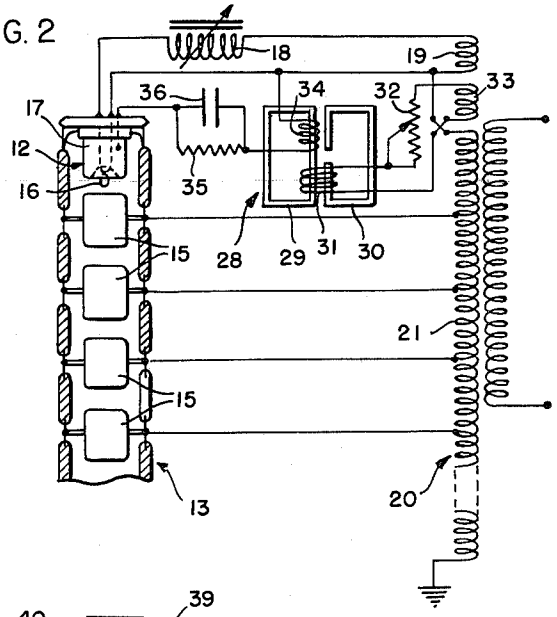



FIG. 2



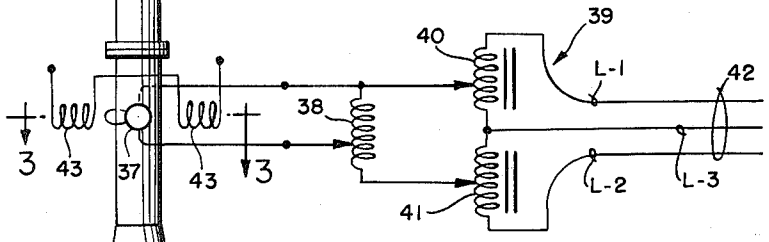




FIG. 3

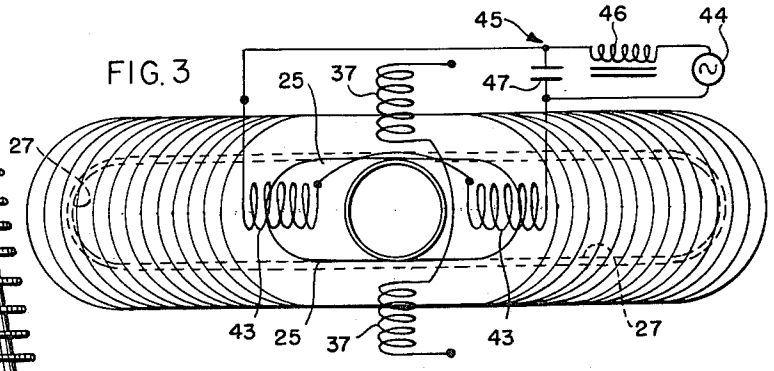
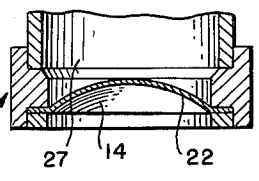



FIG. 4




*INVENTOR:—*

HAROLD T. BOEKER

*BY:—*

Junius F. Cook, Jr.

ATTORNEY

March 28, 1961 H. T. BOEKER 2,977,500

PRODUCTION AND CONTROL OF ELECTRON BEAMS

Original Filed Dec. 4, 1956 2 Sheets-Sheet 2

FIG. 5

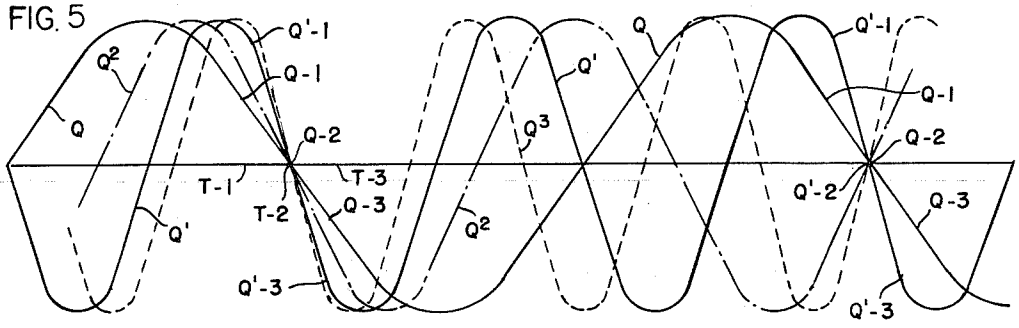
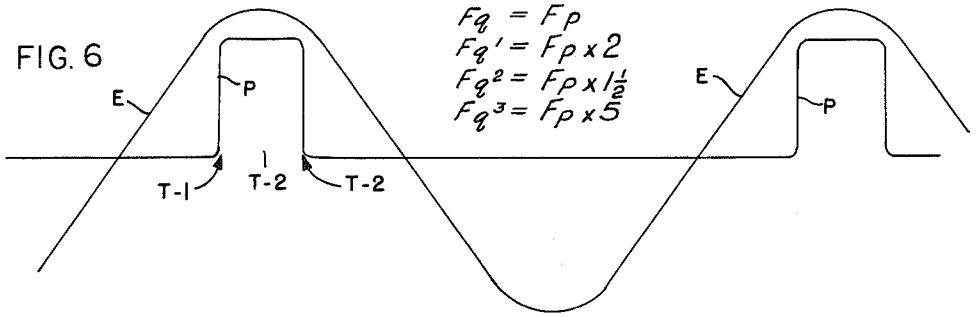



FIG. 6




$F_q = F_p$
$F_{q'} = F_p \times 2$
$F_{q^2} = F_p \times 1\frac{1}{2}$
$F_{q^3} = F_p \times 5$

FIG. 7

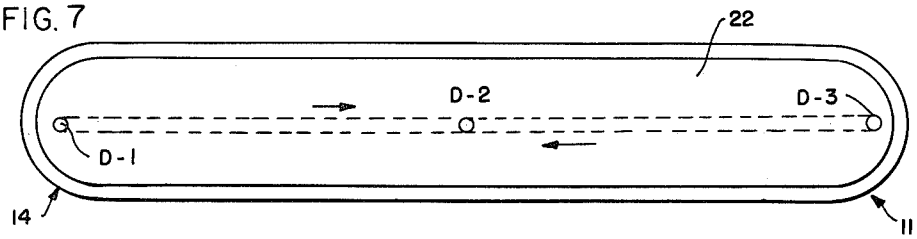
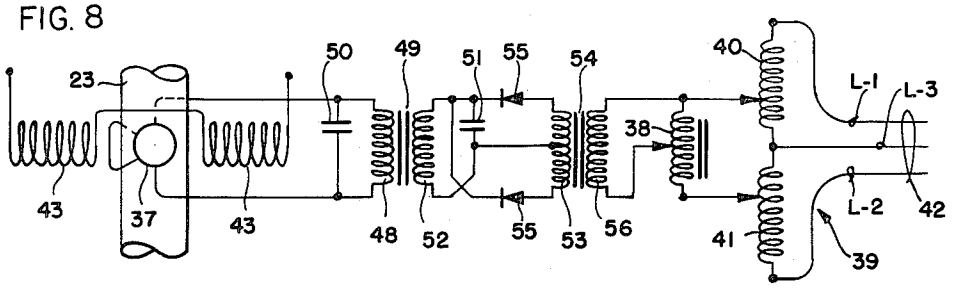



FIG. 8




*INVENTOR:—*

HAROLD T. BOEKER

*BY:—*

Junius T. Cook, Jr.

ATTORNEY

United States Patent Office 2,977,500 Patented Mar. 28, 1961



2,977,500

# PRODUCTION AND CONTROL OF ELECTRON BEAMS

Harold T. Boeker, Milwaukee, Wis., assignor to General Electric Company, a corporation of New York

Continuation of application Ser. No. 626,108, Dec. 4, 1956. This application June 16, 1959, Ser. No. 820,824

15 Claims. (Cl. 315—15)

The present invention relates to electron beam generation, and more specifically, to the generation and deflection of electron beams to provide improved electron beam control.

This application is a continuation of a copending application of Harold T. Boeker, Serial No. 626,108, filed December 4, 1956, now abandoned, assigned to the assignee of the present invention.

Electron flow devices of the character mentioned, as shown more especially in a copending application for U.S. Letters Patent, Serial No. 487,922, filed February 14, 1955, on the invention of Carl W. Hansen in Electron Discharge Apparatus, now Patent No. 2,853,622 issued September 23, 1958, may comprise an electron emitting cathode and a cooperating anode supported in spaced apart, electrically insulated alinement, as by means of a suitable tubular envelope of elongated configuration, commonly embodying glass as an insulating medium disposed between the cathode and anode. It should be understood that electron discharge devices may be caused to operate by exciting the cathode for electron emission while simultaneously applying an electrical potential, between the anode and cathode of the device, to drive cathode emitted electrons toward the anode, the envelope of the device being maintained under low pressure, substantially vacuum conditions to form a suitable electron flow path within the envelope between the anode and cathode.

In devices of the character mentioned the anode commonly comprises a tubular element mounted upon and at the cathode remote end of the envelope of the device, in coaxial alinement with the electron emitting cathode, said anode element forming an extension of the closing envelope. Where the device is constituted as an electron beam generator, the tubular anode element, as at its cathode remote end, may be closed by a panel of material that is substantially transparent to electrons and which, consequently, may function as an efficient electron transmitting window, permitting substantially unhampered delivery of cathode emitted electrons outwardly of the envelope for application to objects upon which it may be desired to apply the electrons as an irradiating beam. Such window panels, of course, may not be entirely transparent to the passage of electrons therethrough, and consequently are usually made as thin as possible to afford a minimum obstruction to the passage of electrons, window panels preferably being only thick enough to sustain required low pressure conditions within the envelope of the device.

As shown more particularly in the copending application for U.S. Letters Patent Serial No. 552,847, filed December 13, 1955, for the invention of Michael J. Zunick and Reimann L. Stroble in Electron Flow Apparatus and Method of Making the Same, now Patent No. 2,885,585 issued May 5, 1959, the formation of the electron emitting end of the anode of an electron generator as a hollow element having laterally flared and relatively flattened configuration, defining a narrow, elongated, electron transmitting window at the end thereof, has been proposed.

An important object of the present invention is the



provision of means for controlling the electrons delivered through the transmission window so that the electron transmission rate is substantially uniform throughout the entire area of the window.

Another important object is to provide for controlling the electrons in fashion to obtain a substantially uniform loading of the electrons on the thin transmission window, throughout its entire area; a further object being to provide an electron beam having a narrow velocity spectrum substantially free of electrons traveling at speeds low enough to allow absorption of electrons by the window and consequent heating thereof.

Another important object is to provide for the oscillation of the electron beam back and forth between the opposite ends of the narrow, elongated window, as well as transversely between the opposite sides thereof, in order to deliver the electrons outwardly of the window substantially uniformly within a relatively wide zone of shallow depth corresponding with the elongated configuration of the window.

Another important object of the invention is to provide for biasing the electron emitting cathode in fashion such that electrons are emitted at substantially the same energy level; a further object being to provide for the deflection of such substantially uniform energy beam with an alternating flux having the same frequency as the pulsations of electron emission at the cathode, in order to cyclically sweep the beam between the opposite ends of the transmission window at a controlled rate such that each portion of the window receives a substantially uniform electron transmitting load; a still further object being to provide for deflecting the beam laterally or transversely at relatively high frequency during longitudinal beam movement between the opposite ends of the elongated transmitting window.

Briefly stated, in accordance with one of its aspects, the present invention contemplates the provision of an improved electron beam generator embodying an electron emitting cathode enclosed at one end of an elongated insulating envelope having a hollow extension forming an anode at the cathode remote end of the envelope, said extension providing a narrow, elongated, electron transmitting window at its cathode remote end, suitable means being provided for biasing the cathode for the emission of electrons of desired velocity, preferably within a narrow velocity spectrum; the invention also including beam deflecting coils and means for energizing the same to cause the beam to traverse the elongated electron transmitting window rapidly from one end thereof to the other in synchronism with the emission of electrons at the cathode, thereby to apply a substantially uniform electron load on the window in longitudinal direction thereof, the invention additionally including lateral deflection coils operable to oscillate the beam transversely of the window at relatively high frequency of the order of 50 kilocycles per second during movement of the beam longitudinally of the window, in order to accomplish substantially uniform electron loading on the window throughout its width.

The foregoing and numerous other important objects, advantages, and inherent functions of the invention will become apparent as the same is more fully understood from the following description, which, taken in connection with the accompanying drawings, discloses preferred embodiments of the invention.

Referring to the drawings:

Fig. 1 is a side elevation view of an electron beam generator;

Fig. 2 is a diagrammatic showing of portions of the generator and associated control circuitry embodying the present invention;

Figs. 3 and 4 are enlarged sectional views respectively taken substantially along the lines 3—3 and 4—4 in Fig. 1

to illustrate additional circuitry embodying the invention;

Figs. 5 and 6 are graphical illustrations showing instantaneous energy values established in the generator of Fig. 1, when in operation in accordance with the teachings of the present invention;

Fig. 7 is a plan view of a beam transmitting window; and

Fig. 8 is a view showing modified circuitry embodying the invention.

To illustrate the invention the drawings show an electron beam generator comprising a hollow anode 11, Figs. 1 and 4, and a cathode 12, Figs. 1 and 2, supported in spaced apart, relatively insulated relation, as by means of an elongated insulating envelope portion 13 of generally tubular configuration, the same enclosing the cathode therein, at one end thereof. As shown, the envelope portion 13 may carry the anode, as an extension at the cathode remote end of the envelope portion, thereby providing a sealed and evacuated envelope forming an enclosed electron flow path between the cathode and the cathode remote end of the hollow anode.

The anode 11 may comprise a hollow, elongated element formed at its cathode remote end with an electron transmitting window structure 14 for the delivery of a useful electron beam therethrough and outwardly of the anode.

It should be understood that electron beam generators of the character mentioned may be operated by applying electron driving potential between the anode and cathode of the device, in order to cause cathode emitted electrons to travel through the envelope from the cathode toward the anode. Where the electron driving anode-cathode potential is of alternating character, as depicted by the sinusoidal curve E in Fig. 6 of the drawings, electrons will be driven from the cathode to the anode only during such portions of positive half cycle intervals of the electron driving potential when such potential is in excess of that required to drive cathode emitted electrons through the envelope 13. Accordingly, a generator operated with fluctuating potential E applied between its anode and cathode may produce an electron beam comprising successive electron pulses P generated at the fluctuating frequency of the electron driving potential only during the positive half cycle intervals thereof.

In order to guide and accelerate electrons, while traveling through the envelope, a series of electrodes 15, comprising metal sleeves forming electronic lenses, may be mounted in spaced apart alinement, within the envelope portion 13 and between the anode and cathode, as suggested in U.S. Letters Patent No. 2,144,518, which issued January 17, 1939, on the invention of W. F. Westendorp in High Voltage Apparatus, means being provided to electrically energize the electrodes at progressively increasing potential values away from and with respect to the cathode 12, whereby electron movement between cathode and anode may be guided and accelerated by the action of the energized electrodes 15.

The cathode 12 may be of any suitable, convenient or preferred character and may embody an electron emission filament 16 mounted in a conventional electron focusing structure 17, suitable conductor means being provided for exciting the filament for electron emission by electrically connecting the same with a source of filament energizing power disposed outwardly of the envelope. As shown in Fig. 2, the filament may be connected in series with an adjustable reactance 18 and the secondary winding 19 of a transformer 20 as a suitable source of cathode exciting energy.

The transformer 20 may also include a secondary winding 21, connected between the cathode filament and ground, in order to apply electron driving potential between the electron emission filament of the cathode and the anode 11, which is also preferably grounded. The secondary winding 21 of the transformer also may be connected at intervals with the electron guiding and accelerating electrodes 15 in order to deliver electrons, emitted by and at the cathode, through the envelope portion 13 and the hollow anode 11, at high speed. After traversing the anode, high speed electrons may be delivered thence, as a useful beam of electrons, through the window structure 14, at the cathode remote end of the anode element.



In order to provide for the application of electrons upon objects of large size, it is desirable to obtain electron emission from the generator within as wide an emission field or zone as possible. To this end, the window structure 14 may be of narrow, elongated configuration embodying an electron transmitting window pane 22 of thin, foil-like character sealed in the cathode remote end of the hollow anode element 11. The anode element 11 may conveniently be formed of sheet metal, such as stainless steel, and may comprise a preferably cylindrical sleeve portion 23, at one end, adapted for connection with the cathode remote end of the envelope portion 13. The anode element may also comprise a laterally flared portion 24 forming a flat funnel having an end secured to the sleeve portion 23, the portion 24 being flared outwardly, progressively away from the portion 23, and flattened so that said portion 24 comprises a pair of flat parallel walls 25, as indicated in Fig. 3, and integral wall portions 26 of semi-circular configuration interconnecting the opposite flared sides of the flat wall portions 25. Such flared and flattened configuration provides a relatively narrow, elongated window opening 27 at the end of the flared portion 24 remote from the sleeve portion 23.

The foregoing flared configuration of the anode permits a beam of electrons, delivered through the tubular portion 23 and thence into the flared portion, to be oscillated rapidly back and forth between the opposite curved sides 26 of the flared portion, as said beam passes therethrough and outwardly of the window structure 14, suitable means being provided for inducing such oscillation of the beam; and it will be obvious, of course, that the oscillating electron beam may be transmitted through the window structure 14 and caused to traverse a relatively wide zone of shallow depth outwardly of said window structure.

In order to obtain optimum generator performance through uniform electron loading upon the thin, foil-like window pane 22 and, to such end, to produce a beam of electrons in which the constituent electrons have as nearly the same velocity as possible, the present invention contemplates the provision of means for biasing the cathode with respect to the electron focusing structure 17, Fig. 2. In this connecton, relatively slow electrons are capable of being absorbed by the thin transmitting window pane element and, hence, of producing undesired heat therein, such absorbed electrons being also withheld from the performance of useful work outwardly of the envelope.

Accordingly, the present invention employs a peaking transformer 28, shown in Fig. 2, comprising core members 29 and 30 of magnetic material, in order appropriately to bias the filament with respect to the focusing structure 17. The transformer core 30 is provided with an air gap and may contain substantially more magnetic material than the core 29. As a consequence, the core 29 will become satuarated at a much lower value of magnetizing current than the core 30. A winding 31, inductively coupled with both of the cores 29 and 30, may be connected in series with an adjustable resistor 32 and a secondary winding 33 of the transformer 20, in order to cause magnetic flux to circulate in both of the cores 29 and 30.

The current thus permited to flow in the magnetizing coil 31 is determined by the size of the air gap in the core 30, while the phase of such energizing current, with respect to that in the transformer winding 33, may be regulated by adjusting the resistor 32. The peaking transformer 28 may also be provided with a secondary winding 34 inductively coupled with the core 29 only,

one end of said winding 34 being connected with the filament 16, while its other end is connected with the focusing structure 17 through a network comprising a resistor 35 and a condenser 36 interconnected in parallel.

The foregoing filament biasing system produces, as shown in Fig. 6, electron driving energy comprising successive energy pulsations P of substantially square wave form delivered during alternate half cycle intervals of A.C. power supplied through the transformer 20, whereby the beam comprises electrons of substantially equal velocity delivered during each electron emitting and driving energy pulsation. The resulting electron beam will thus consist of electron pulses comprising electrons falling within a relatively narrow velocity spectrum, the electrons having velocities such that substantially all of them may pass through the transmitting window without being absorbed thereby. Any other suitable, preferred or convenient filament biasing system may, of course, be employed to obtain energy pulsations of desired configuration.

The substantially uniform velocity electron beam thus produced may be subjected to the action of deflection means, such as the magnetic deflection coils 37 disposed on opposite sides of the anode portion 23, in position to oscillate the beam within the flared anode portion 24 between the opposite ends 26 thereof, means being provided to accomplish such beam oscillation in synchronism with the pulsations of electron emitting energy supplied through the transformer 20. To this end, the coils 37 may be adjustably connected with a coil or winding 38 of a three-phase autotransformer 39, the opposite ends of said winding 38 being adjustably connected respectively with the other two windings or coils 40 and 41 of the autotransformer. The coils 40 and 41 may be powered from a three-phase supply line 42 comprising the phase conductors L–1, L–2 and L–3, and operating at a frequency preferably identical to that of the electron driving energy supplied through the transformer 20.

Biasing and deflection of the electron beam is desirable in order to obtain a uniform loading of electrons upon the thin window 22, and also in order to produce a beam of electrons having a narrow velocity spectrum above a selected velocity value. Slow electrons are absorbed by the window element 22, thereby producing heat therein, and such absorbed electrons are useless in performing useful work outwardly of the window. In order to obtain the desired electron beam characteristics, the biasing system may be adjusted to produce energy pulsations between the filament 16 and the focusing structure 17, the form of such pulsations being substantially as shown in Fig. 6. The electron beam, accordingly, will comprise bursts of electrons emitted at successive intervals in conformity with the biasing pulse illustrated in Fig. 6.

The beam may also be deflected by an alternating magnetic flux applied by means of the deflection coils 37 at the frequency of the biasing pulsations shown in Fig. 6, such flux being applied at right angles to the electron beam and being phased with respect to the beam as shown in Fig. 5 and 6, Fig. 5 illustrating the sinusoidal flux Q applied through the path of the electron beam by the deflection coils 37.

At the instant of time T–1, the deflection flux has a value of Q–1 which will displace the electron beam to the position D–1 at one end of the window 22. At the instant T–2, the deflection flux Q–2 is equal to zero. As a consequence, no deflection force will be applied to the beam which, accordingly, will pass through the window midway between the opposite ends thereof. At the time instant T–3, the deflection flux will have a value Q–3 equal to flux value Q–1 but of opposite sign, so that the beam will be displaced on the window 22 to the position D–3 at the end of the window remote from position D–1. Since the variation of flux with respect to time is substantially linear throughout the portion of the sine wave between Q–1 and Q–3, the resultant deflection of the beam will be approximately linear so that the beam will load the window substantially uniformly in a direction longitudinally thereof.

The proper phasing and magnitude of flux for deflecting the electron beam is obtained by adjusting the sliding connection of the deflection coils 37 with the transformer winding 38, as well as the adjustable connection of the winding 38 with the associated transformer windings 40 and 41. If the adjustable connections of the coil 38 with the coils 40 and 41 are made at the ends thereof that are connected with the line conductors L–1 and L–2, the voltage applied across the coil 38 will be in phase with the energy vector applied through said conductors. If the coil 38 is connected to the opposite ends of the coil 40, the voltage across the coil 38 will be in phase with the energy vector applied through the conductors L–1 and L–3. If the coil 38 is connected to the opposite ends of the coil 41, the voltage across the coil 38 will be in phase with the energy vector applied through the conductors L–2 and L–3.

By connecting the ends of the coil 38 at various positions on the coils 40 and 41, the power applied to the coil 38 may be adjusted to any desired phase angle, so that the phase of the energy delivered to the deflection coils 37, as depicted in Fig. 5, may be adjusted to any desired extent with respect to the electron driving energy supplied through the transformer 20, as depicted in Fig. 6. The magnitude of the flux produced by the coils 37 may be controlled by the adjustable connection of the coils on the winding 38.

The foregoing arrangement will sweep the beam from one end of the window to the other end during each cycle of energy applied to the deflecting coils 37, such sweeping movement being accomplished along a linear path extending medially of the window pane 22.

In order to apply the beam throughout the entire width of the window and thereby increase the amount of permissible energy transmitted in the beam without overloading the window, another pair of deflecting coils 43 may be provided in position extending at right angles with respect to the deflection coils 37. The alternating flux applied by the coils 43 upon the electron beam may be delivered at a random frequency of the order of 200 kilocycles per second, although the frequency is preferably held at a convenient sub-multiple of the frequency at which the flux supplied by the coils 37 is delivered, the frequency of flux supplied through the coils 43 being of the order of one thousand times that supplied through the coils 37. As a consequence, the beam may be deflected transversely of the window 22 between the opposite sides thereof many hundreds of times during the interval while the beam is moved between the opposite ends of the window by action of the coils 37. The power required for energizing the transverse deflection coils 43 may comprise a suitable alternator 44, as shown in Fig. 3, interconnected to energize the coils 43 through a resonant oscillating circuit 45 embodying inductive and capacity reactance means 46 and 47.

It should be noted that the square wave pulsations have rounded corners, in Fig. 6, signifying that electron density is not a maximum, although nearly so, at the beginning and end of the interval between T–1 and T–3. Since window loading is a function of electron density, and the time interval during which electrons are delivered, it will be seen that electron loading is somewhat below normal at and adjacent the instants of time T–1 and T–3, that is to say, when the beam is near the positions D–1 and D–3. In order to obtain uniform electron loading at the opposite ends of the window as in the medial portions thereof, the deflection coils may be operated to decrease the flux applied thereby when the beam is in the vicinity of the ends of the window, in order that movement of the beam longitudinally of the window may be reduced sufficiently to maintain the

electron loading of the window at the opposite ends thereof substantially equal to the electron loading of the medial portions of the window.

This may be accomplished by applying a frequency doubler in the coil energizing circuit, between the coils 37 and the transformer winding 38, as shown more particularly in Fig. 8. To this end, the coils 37 may be connected in series with the secondary winding 48 of a transformer 49, a condenser 50 being connected across the transformer winding 48. A condenser 51 may be connected across the primary winding 52 of the transformer 49, one end of said primary winding being connected with a center tap on the secondary winding 53 of a transformer 54, the other end of the winding 52 being electrically connected through rectifiers 55 with the opposite ends of the winding 53. One end of the primary winding 56 of the transformer 54 may be connected with one end of the coil 38, the other end of said primary transformer winding 56 being adjustably connected with said coil. Enough capacity is provided by the condensers 50 and 51 to produce a tank circuit in conjunction with the windings of the transformer 49 to accomplish resonance at the desired frequency.

The foregoing arrangement may operate to produce flux in the coils 37 at a frequency substantially double that produced in said coils when energized directly by the three-phase autotransformer 39 when connected as shown in Fig. 1, such flux at double frequency being illustrated by the sinusoidal curve Q' in Fig. 5. It will be seen at and near the time instants T–1 and T–3, that the flux Q'–1 and Q'–3 supplied by the windings 37 will be non-linear in fashion to reduce the speed of sweeping movement of the beam longitudinally of the window, whereby the beam will traverse the window at reduced speed during the initial and terminal stages of electron pulse emission, thereby accomplishing substantially uniform electron loading throughout the area of the window 22, and, of course, upon any irradiation subject disposed outwardly of the window.

It will be noted that electron density curve P is sharper at time instant T–3 than it is at T–1, and it will be seen that during successive electron pulsations P, the beam will always be swept from one end of the window, such as the end D–1, toward the opposite end thereof, if the frequency of beam sweeping flux Q or Y' is an even multiple of the electron beam pulse frequency.

In order to compensate for the unlike density during the initial and terminal stages of the electron pulses P, i.e., greater density at one end than at the other, the present invention contemplates the adjustment of beam deflecting flux frequency to such an extent that the beam will be moved in opposite directions, longitudinally of the window, during successive electron pulses P, that is to say, if the frequency of the electron pulses P be F$p$, the frequency of beam deflecting flux should be adjusted to a value equal to an uneven number multiple of pulse frequency, such as the frequency 1½ F$p$, as shown by the curve $Q^2$ in Fig. 5. Alternately, the beam deflecting flux, applied through the frequency doubling system shown in Fig. 8, may be adjusted to a frequency equal to 5 F$p$, as shown at $Q^3$ in Fig. 5, in order to obtain the desired alternately reversing electron beam sweep between opposite ends of the window 22 during alternate pulsations P of the electron beam.

It is thought that the invention and its numerous attendant advantages will be fully understood from the foregoing description and it is obvious that numerous changes may be made in the form, construction and arrangement of the several parts without departing from the spirit or scope of the invention, or sacrificing any of its attendant advantages, the forms herein disclosed being preferred embodiments for the purpose of illustrating the invention.

What I claim as new and desired to secure by Letters Patent of the United States is:



1. The method of obtaining substantially uniform loading upon an electron transmission window, throughout its entire area, while delivering therethrough an electron beam comprising a succession of periodic pulses or bursts of electrons of substantially uniform high velocity during each pulse but having reduced electron densities toward the ends of the pulses, said pulses being emitted at a selected burst frequency, which consists in cyclically deflecting the beam longitudinally of the window, between the opposite ends thereof, at a frequency that is an odd numbered multiple of burst frequency, to thereby sweep the beam alternately from one end of the window to its opposite end during successive electron bursts, said cyclical deflections being so phased and related to said periodic pulses or bursts that successive traversals of said window by said beam occur in opposite directions, whereby each end of the window is impinged alternately by the greater density and lighter density ends of the pulses in succession thereby to increase the uniformity of electron loading of the window throughout the length of the deflection.

2. In an electron beam generator, an elongated envelope having an electron emitter in one end and an elongated window at the other, means to apply alternating voltage to said generator to produce emission of a pulse of electrons in a beam from said emitter to said window during each cycle of said voltage, said emission occurring in a short pulse of high velocity electrons at the peak of said alternating voltage, means to subject said apparatus to an alternating deflection field to deflect said beam longitudinally of said elongated window during each pulse, said deflection field having a frequency which is an odd number multiple of the frequency of said pulses of high velocity electrons and of phase to deflect the beam across said window in opposite directions during successive pulses to increase the uniformity of electron loading of said beam on said window throughout the length of the deflection of the beam across the window.

3. Electronic apparatus embodying an elongated electron emission window of length substantially greater than width, generating means for producing an electron beam of limited sectional area and comprising successive pulses or bursts of high velocity electrons delivered at a desired burst frequency, the pulses having undesired variations in intensity of electrons during the length thereof, guide means for applying said beam at an elongated zone having length substantially greater than width, and deflection means between the opposite ends of the beam to subject the beam to a deflection field having a frequency which is an odd numbered multiple of said burst frequency, and means to phase the deflection field to deflect said beam across said zone during each pulse of said high velocity electrons in opposite directions during successive pulses to produce more uniform electron distribution over the length of said elongated zone notwithstanding said undesired variation in electron density.

4. Electronic apparatus embodying an elongated electron emission window of length substantially greater than width, generating means for producing an electron beam of limited sectional area and comprising successive short pulses or bursts of high velocity electrons delivered at a desired periodic burst frequency, said pulses having undesired variations in density of electrons during the length thereof, guide means for applying said beam at an elongated zone having length substantially greater than width, and means to increase the uniformity of impingement of electrons over the length of said zone, said means comprising deflection means for cyclically sweeping the beam in said zone, between the opposite ends thereof, said deflection means comprising magnetic deflection coils disposed adjacent the path of said beam between said generating means and said zone, and phase adjustable transformer means for applying energizing power to said coils.

at the required frequency and phase relative to said periodic burst frequency such that successive pulses of said beam traverse said elongated zone longitudinally in opposite directions thereby to produce more uniform electron loading of said window throughout the length of the sweep.

5. In an electron beam generator, an elongated envelope having an emitter in one end and an elongated window in the other end, means to produce periodic emission of short pulses of high velocity electrons from said emitter and to guide said pulses in a beam to said window, beam deflection means spaced along the envelope between the ends thereof, means to supply alternating potential to said deflection means having a frequency which is an odd numbered multiple of the frequency of said pulses and having phase relation to occurrence of the periodic pulses such that the beam is deflected the length of said window during each pulse by said means and in opposite directions longitudinally of said window during successive pulses thereby to increase uniformity of electron loading of said window throughout the length of said sweep.

6. Electronic apparatus embodying an elongated electron emission window of length substantially greater than width, generating means for producing an electron beam of limited sectional area and comprising successive short pulses or bursts of high velocity electrons delivered at a desired burst frequency, guide means for applying said beam at an elongated zone having length substantially greater than width, and deflection means for cyclically sweeping the beam in said zone, between the opposite ends thereof, deflection means for simultaneously sweeping the beam transversely of said zone, between the opposite sides thereof, at a transverse sweep frequency substantially higher than longitudinal sweep frequency, whereby the beam may traverse a zigzag path in said zone between the opposite ends thereof, said first deflection means comprising magnetic deflection coils disposed adjacent the path of said beam between said generating means and said zone, and phase adjustable transformer means for applying alternating energizing power to said coils at a frequency which is an odd numbered multiple of the frequency of said burst whereby the alternating field produced by said coils may be of such frequency and phase that said beam is deflected the length of the window in opposite directions during successive pulses thereby to increase the uniformity of loading of said window throughout the length of the sweep.

7. The combination, in an electron beam generator, of an elongated envelope having an emitter in one end and an elongated window at the other, means to apply an alternating potential between said emitter and a point of said generator near said window, means to cause short pulses of high velocity electrons to flow from said emitter to said window, during the portion of said alternating potential when said point is at its peak positive potential with respect to said emitter whereby said electrons have high uniform velocity throughout each pulse, said pulses having some undesired diminution of intensity at the ends of the pulse, means to guide said pulses in a beam to said window, deflection means along the envelope to subject said beam to an alternating deflection field thereby to deflect the beam longitudinally of the window during each pulse whereby the electron loading of said elongated window is reduced near the ends by reason of said undesired diminution of intensity of electrons near the ends of the pulses, and means to increase said electron loading of said window near the ends of the sweep, comprising means to supply an alternating potential to said deflection means to produce a deflection field having a frequency which is an even numbered multiple of the frequency of said pulses and phased to reduce the rate of deflection of the beam near the ends of the sweep relative to the rate midway of the sweep thereby to produce more uniform electron loading of the window throughout the length thereof.

8. The combination, in an electron beam generator, of an elongated envelope having an emitter in one end and an elongated window at the other, means to apply an alternating potential between said emitter and a point of said generator near said window, means to cause pulses of high velocity electrons to flow from said emitter to said window when said point is at approximately its peak positive voltage relative to said emitter, means to guide said pulses in a beam to said window, deflection means along the envelope to subject said beam to an alternating deflection field thereby to deflect the beam longitudinally of the window during each pulse and means to supply an alternating potential to said deflection means to produce a deflection field having a frequency which is a whole numbered multiple of the frequency of said pulses and so related in phase and frequency to the frequency of the pulses as to increase the uniformity of electron loading of the window throughout the length thereof caused by impingement of the pulses thereon during their deflection.

9. The combination, in an irradiation apparatus, of an elongated evacuated envelope having an electron emitter near one end, an anode near the other end having an electron pervious window elongated in a direction transverse to the axis of said elongated envelope, means to supply an alternating voltage between said cathode and anode, and means to emit bursts of high velocity electrons from said emitter during a small peak portion of alternate half-cycles of said alternating voltage when said anode is at maximum positive potential relative to said emitter whereby said high velocity electrons traverse said window and said window is not impinged by low velocity electrons, and means to sweep said high velocity electrons across the length of said window during each burst thereof, said bursts having electron density varying undesirably during the burst, and means to vary the rate of sweep of each burst in direct relation to the instantaneous electron density thereby to increase the uniformity of electron loading of said window throughout the length thereof.

10. The combination, in an irradiation apparatus, of an elongated evacuated envelope having an electron emitter near one end, an anode near the other end having an electron pervious window elongated in a direction transverse to the axis of said elongated envelope, means to supply an alternating voltage between said cathode and anode, and means to emit bursts of high velocity electrons from said emitter during a small peak portion of alternate half-cycles of said alternating voltage when said anode is at maximum positive potential relative to said emitter whereby said high velocity electrons traverse said window and said window is not impinged by low velocity electrons, and means to sweep said high velocity electrons across the length of said window during each burst thereof, and to increase the uniformity of electron loading of said window throughout the length of the window notwithstanding undesired diminution in electron density of said bursts near each end of the burst, said means comprising means to effect said sweep at a rate varying in accord with a sine wave of an even harmonic of said alternating voltage, said sine wave harmonic being phased relative to said first alternating voltage, to vary between points adjacent successive peaks of said sine wave during each burst, said points being sufficiently close to said peaks substantially to reduce the rate of change of sweep voltage near the ends of the sweep relative to the rate at the middle of the sweep whereby the rate of sweep across the window is reduced near both ends of the window where the electron density of the burst reduces thereby producing more uniform electron loading of the window toward the ends thereof.

11. The combination, in an irradiation apparatus, of an elongated evacuated envelope having an electron emitter near one end, an anode near the other end having an

electron pervious window elongated in a direction transverse to the axis of said elongated envelope, means to supply an alternating voltage between said cathode and anode, and means to emit bursts of high velocity electrons from said emitter during a small peak portion of alternate half-cycles of said alternating voltage when said anode is at maximum positive potential relative to said emitter whereby said high velocity electrons traverse said window and said window is not impinged by low velocity electrons, and means to sweep said high velocity electrons across the length of said window during each burst thereof, said burst having greater electron density toward one end of the duration of the burst than toward the other, and means to sweep alternate bursts of said high velocity electrons across the length of said elongated window in opposite directions thereby to alternate the ends of the window traversed by the more dense portion of the bursts to render more uniform the electron loading of said window throughout the length thereof.

12. The combination, in an irradiation apparatus, of an elongated evacuated envelope having an electron emitter near one end, an anode near the other end having an electron pervious window elongated in a direction transverse to the axis of said elongated envelope, means to supply an alternating voltage between said cathode and anode, and means to emit bursts of high velocity electrons from said emitter during a small peak portion of alternate half-cycles of said alternating voltage when said anode is at maximum positive potential relative to said emitter whereby said high velocity electrons traverse said window and said window is not impinged by low velocity electrons, and means to sweep said high velocity electrons across the length of said window during each burst thereof, and to increase the uniformity of electron loading of said window throughout the length thereof notwithstanding unequal electron density at opposite ends of the bursts, said means comprising means to sweep said bursts across the length of said window in accord with portions of an odd harmonic of said alternating voltage varying through zero in opposite directions during alternate bursts thereby to sweep alternate bursts in opposite directions across the window to load more uniformly opposite ends of said window.

13. An electron beam generating device comprising: an electron beam generating tube having a window through which electrons exit said tube; means for generating an electron beam comprising bursts of electrons having a given repetition frequency and for directing said beam through said window; and means for cyclically deflecting said beam across said window in a given direction with a frequency equal to said burst repetition frequency multiplied by the factor

$$\frac{N}{2}$$

where N is an integer other than 2.

14. An electron beam generating device comprising: an electron beam generating tube having a window through which electrons exit said tube; means for generating an electron beam comprising bursts of electrons having a given repetition frequency and for directing said beam through said window; and means for cyclically deflecting said beam across said window in a given direction with a frequency equal to said burst repetition frequency multiplied by the factor

$$\frac{N}{2}$$

where N is an odd integer.

15. A device as recited in claim 14, including means for phasing said deflection frequency relative to said repetition frequency so as to deflect succeeding electron bursts in alternate directions across said window.

**References Cited** in the file of this patent

UNITED STATES PATENTS

| | | |
|---|---|---|
| 2,602,751 | Robinson | July 8, 1952 |
| 2,730,566 | Bartow et al. | Jan. 10, 1956 |
| 2,821,655 | Westendorp | Jan. 28, 1958 |

FOREIGN PATENTS

| | | |
|---|---|---|
| 334,193 | Germany | Mar. 11, 1921 |
| 145,084 | Great Britain | Sept. 19, 1921 |