

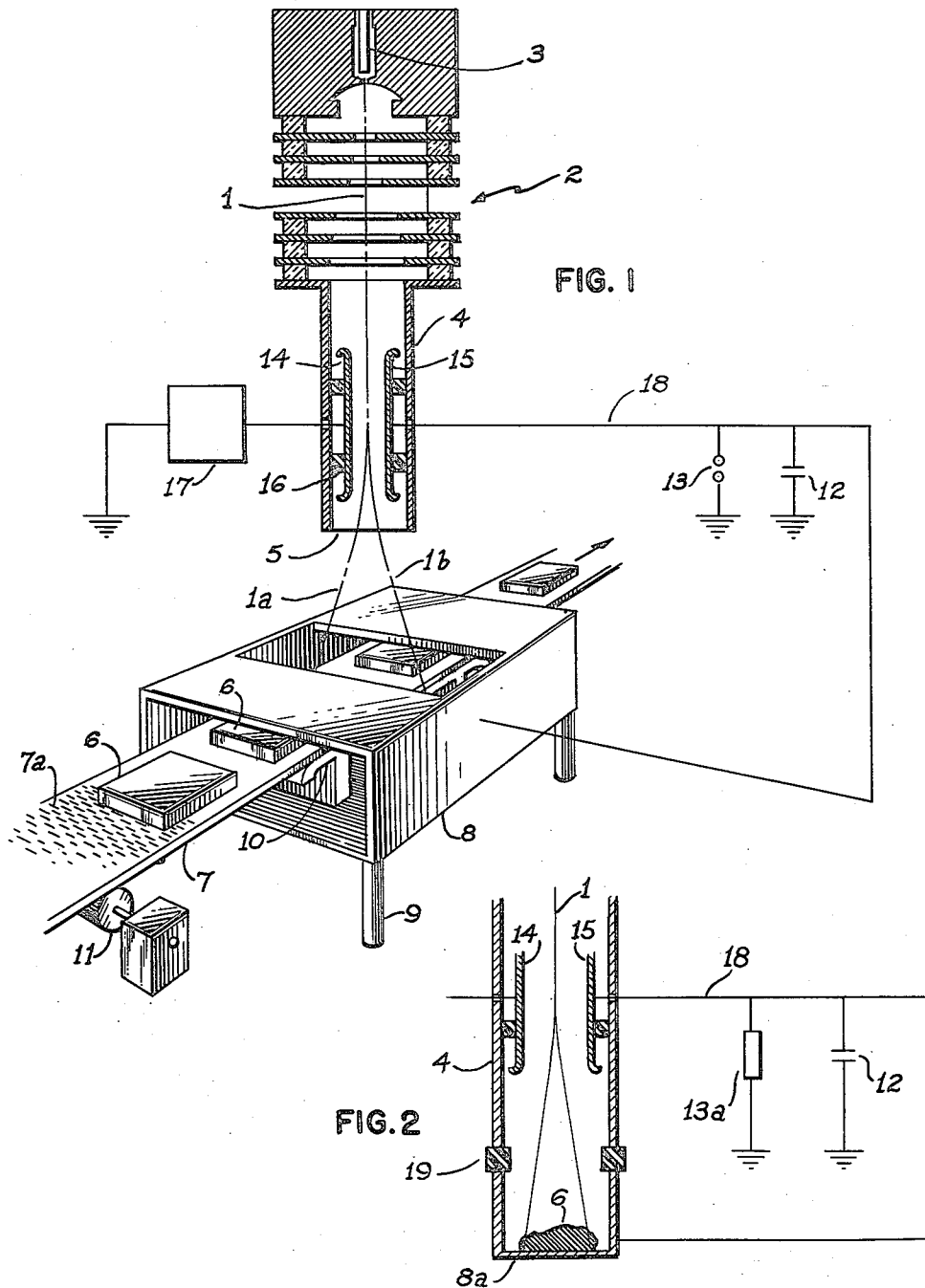
Dec. 10, 1957

J. C. NYGARD
METHOD AND APPARATUS FOR IMPARTING A SCANNING
MOVEMENT TO A BEAM OF CHARGED PARTICLES

2,816,231

Filed Sept. 29, 1953

3 Sheets-Sheet 1



INVENTOR *John C. Nygard*
BY *Henry C. Nichols* ATTY

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J. C. NYGARD

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3 Sheets-Sheet 2

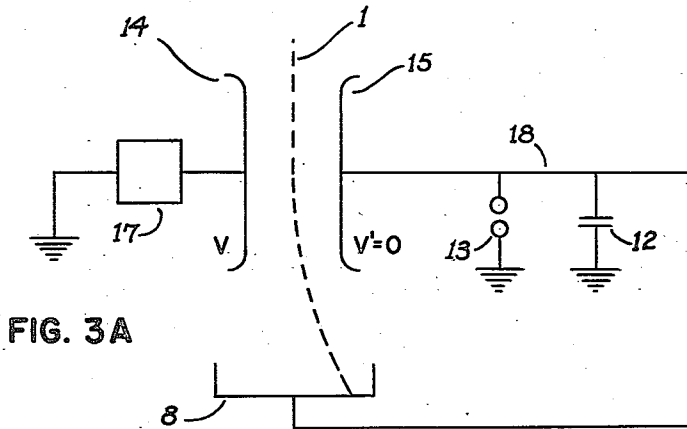


FIG. 3A

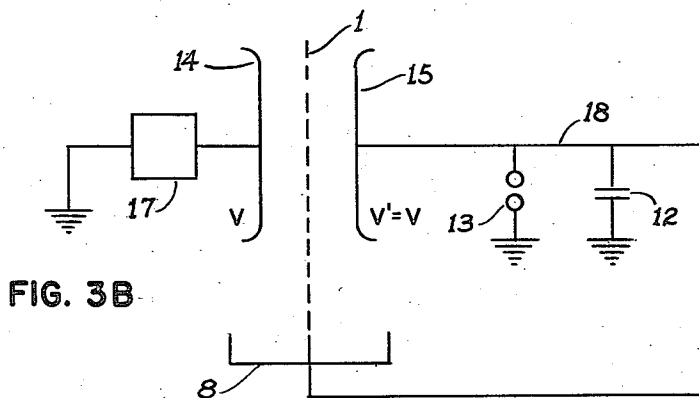


FIG. 3B

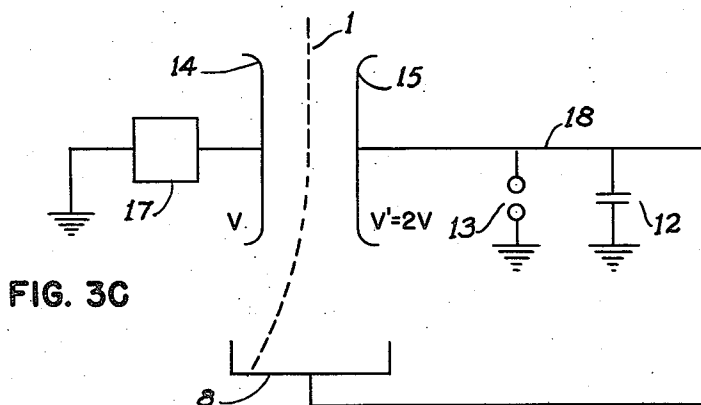


FIG. 3C

INVENTOR *John C. Nygard*
BY *Henry C. Nields* ATTY

Dec. 10, 1957

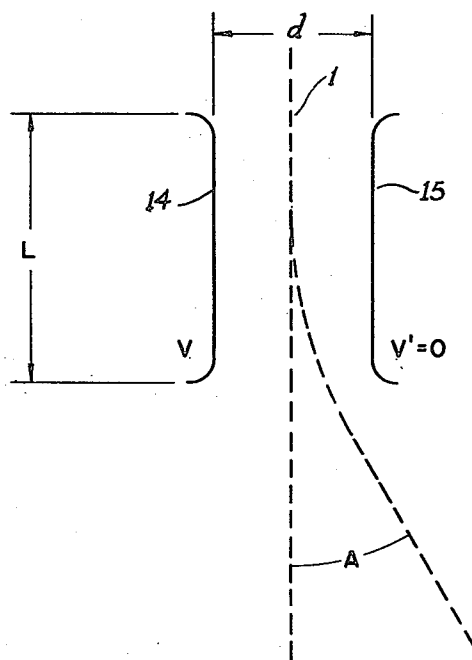
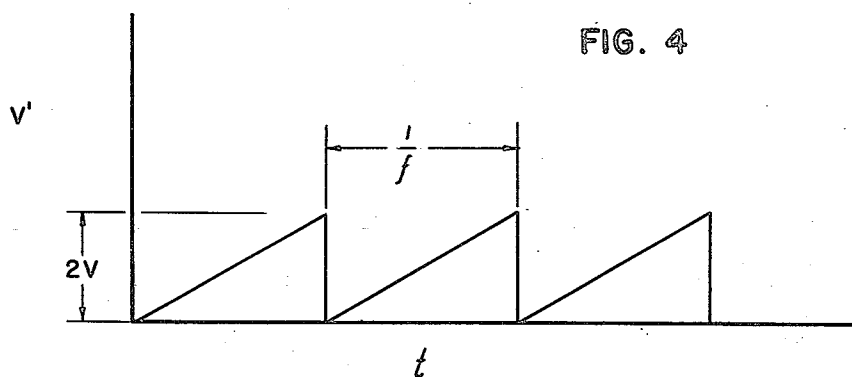
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3 Sheets-Sheet 3



INVENTOR *John C. Nygard*
BY *Henry C. Nields* ATTY

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METHOD AND APPARATUS FOR IMPARTING A SCANNING MOVEMENT TO A BEAM OF CHARGED PARTICLES

John C. Nygard, Waltham, Mass., assignor to High Voltage Engineering Corporation, Cambridge, Mass., a corporation of Massachusetts

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8 Claims. (Cl. 250—43)

This invention relates to a simple method and apparatus for imparting a scanning movement to a beam of charged particles, and in particular to a method and apparatus for imparting a substantially linear scanning movement to a beam of charged particles without the use of complicated electronic devices by allowing the utilized beam current to charge a capacitor and discharge periodically through a discharge device, and applying the resulting wave form to a suitable pair of electrostatic deflector electrodes.

In order to illustrate my invention, I have shown in the accompanying drawings apparatus for irradiating a product, material or substance with high-energy charged particles, because in such apparatus a substantially linear scanning movement of the beam of charged particles is particularly desirable in order that uniform irradiation may be achieved. However, my invention is not limited to the particular apparatus shown, but my invention may be used to advantage in many other cases where it is desired to impart a substantially linear scanning movement to a beam of charged particles; that is, where it is desired to cause a beam of charged particles to scan a target area with substantially constant linear velocity.

In the drawings:

Fig. 1 is a diagram, partly in longitudinal section and partly in perspective view, illustrating one embodiment of apparatus for practicing the method of my invention;

Fig. 2 is a diagram, mainly in longitudinal section, illustrating another embodiment of apparatus for practicing the method of my invention;

Figs. 3A, 3B and 3C are diagrams illustrating in detail the operation of the apparatus of Fig. 1;

Fig. 4 is a graph illustrating the variation of the deflecting voltage with time; and

Fig. 5 is a diagram illustrating certain dimensions of the deflecting electrodes.

Referring to the drawings and first to Fig. 1 thereof, therein is shown one embodiment of apparatus for irradiating a product, material or substance with a beam of electrons to which a substantially linear scanning movement is imparted in accordance with my invention. A beam 1 of electrons is created by any suitable means, such as an acceleration tube 2 of the type disclosed in U. S. Patent No. 2,517,260 to Van de Graaff and Buechner. Electrons emitted by a source 3 are accelerated down the tube 2 in a manner not necessary to set forth herein in detail, and enter a tube extension 4 as a concentrated beam. In accordance with my invention and by means of apparatus to be described in detail hereinafter, a scanning movement is imparted to the beam 1 as it travels through the tube extension 4, so that the beam is fanned out in the plane of the drawing as indicated by the lines 1a and 1b in Fig. 1. The tube extension 4 terminates in an electron window 5, comprising, for example, a thin aluminum foil, through which the fanned electron beam 1a, 1b issues.

A product, material or substance 6 which is to be irradiated is supported in the path of the fanned electron

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beam 1a, 1b a short distance below the electron window 5 by a support 7 which may be stationary or which, as shown in Fig. 1, may be a movable conveyor such as a belt which travels in a direction perpendicular to the plane in which the electron beam is fanned out.

Some of the electrons in the beam 1a, 1b will be reflected by or scattered out of the product 6. Other electrons in the beam may pass by the product. Most of the electrons in the beam will travel into the product, where their energy is expended in ionization and other processes. However, although most of the energy of the electrons in the beam is thus expended in the product, the entry of such electrons into the product results in an accumulation of free electric charge in the product. For all products except those which are nearly perfect insulators, this accumulated free electric charge will not remain in the product, but will leak off very rapidly to any materials with which the product is in contact.

By the term "nearly perfect insulator" I mean a material which will store electric charge within its volume with a very low rate of leakage. Lucite and certain glasses are nearly perfect insulators, but otherwise there are very few such materials.

By the term "utilized beam current" I mean the sum of the aforementioned flow of electric charge away from the product: that is, the reflected and scattered electrons; the electrons which pass by the product; and the free electric charge which is continuously leaking off from the product.

In accordance with my invention, I accumulate the utilized beam current in a capacitor and discharge the capacitor periodically to produce a voltage wave-form which is then applied to suitable deflecting electrodes. To that end, a charge-collector 8 of conductive material is supported on insulating supports 9 so as partially to surround the product 6 at the place where it travels through the electron beam 1a, 1b. Said charge-collector 8 must be adapted to collect at least a portion of the utilized beam current, and preferably said charge-collector is adapted to collect as much of the utilized beam current as possible.

In order that the charge-collector 8 may collect those electrons which are reflected by or scattered out of the product, or which pass by the product, the charge-collector preferably surrounds the product as much as is convenient without obstructing the path of the primary beam 1a, 1b.

In order that the free electric charge in the product may leak off to the charge-collector 8 and not to ground, the conveyor 7 is preferably so constructed that its cross-sectional resistivity is relatively low while its longitudinal resistivity is relatively high. For example, the conveyor 7 may be composed of insulating material (but not a nearly perfect insulator) in which strips 7a of conducting material, such as metallic staples, have been imbedded at appropriate intervals, in order to provide a plurality of low-resistance paths through the thickness of said conveyor. A conducting member 10 upon which the conveyor 7 slides as it travels through the beam 1a, 1b completes the electrical connection between the product 6 and the charge-collector 8.

In order further to assist in preventing electric charge from flowing from the product 6 along the conveyor 7 to ground, any grounded supports for the conveyor, such as that shown at 11 in Fig. 1, should be spaced a substantial distance from the charge-collector 8.

The charge-collector 8 is electrically connected to ground through a capacitor 12, which serves to store the utilized beam current collected by the charge-collector. As electric charge accumulates in the capacitor 12, the voltage drop across it rises, so that the potential of the charge-collector 8 is raised. A discharge device 13 con-

nected in parallel with the capacitor 12 discharges the latter whenever the voltage drop across it exceeds a predetermined value. Said discharge device 13 may comprise a simple spark-gap, as shown in Fig. 1, or, alternatively, a thyratron may be used, as shown at 13a in Fig. 2. The resultant variation of the voltage across the capacitor 12 is employed to energize a beam-deflecting electric field, as will now be described.

A scanning movement is imparted to the beam 1 within the tube extension 4 by a varying electric field between a pair of deflecting electrodes 14, 15 which are preferably supported within the tube extension 4 by insulators 16. One electrode 14 is maintained at constant potential, which may be ground or, as indicated in Fig. 1, a constant bias potential may be applied thereto by a bias supply 17. The other electrode 15 is electrically connected directly to the charge-collector 8 by a lead 18, so that the potential of the electrode 15, and hence the intensity of the electric field between the deflecting electrodes, is determined by the voltage drop across the capacitor 12.

In general, my invention will be most useful in the irradiation of substances by electrons. However, the principle of my invention is equally applicable to beams of positive ions. If the beam 1 consists of positive ions, the tube extension 4 may terminate in an unclosed exit opening of the type disclosed in U. S. Patent No. 2,640,948 to Burrill; or, alternatively, the modifications shown in Fig. 2 may be used. In said Fig. 2, the charge-collector comprises a chamber 8a which is hermetically sealed to the tube extension 4 but insulated therefrom by an insulating ring 19; and the chamber 8a itself may conveniently serve as the support for the product, material or substance 6 to be bombarded by positive ions.

The operation of the device is illustrated in Figs. 3A, 3B and 3C. In Fig. 3A, the spark gap 13 has just discharged, so that the electrode 15 is at ground potential and the condenser 12 is uncharged. The electrode 14 is maintained at a fixed potential of V volts by the bias supply 17, so that there is an electric field of V/d volts/cm. between the electrodes 14, 15; where d is the distance in cm. between the electrodes 14, 15. The polarity of V should be the same as that of the charged particles in the beam 1, so that the beam 1 is deflected away from the biased electrode 14, as shown in Fig. 3A. For example, if the beam 1 consists of high-energy electrons, V may be fixed at -50 kv.

The beam 1 delivers electric charge to the charge-collector 8 at a rate i amperes, where i is the utilized beam current; and this charge accumulates in the capacitor 12, thereby raising the potential V' of the electrode 15 at a rate

$$\frac{dV'}{dt} = \frac{i}{C}$$

where C is the capacitance in farads of the capacitor 12. If the utilized beam current i is constant, as is generally the case, $V' = it/C$, and the potential V' of the electrode 15 increases linearly in time. When the potential V' of the electrode 15 equals V , there is no electric field between the electrodes 14, 15, and the beam 1 is undeflected, as shown in Fig. 3B.

If the spark gap 13 is adjusted to discharge when the voltage drop across it is $2V$, then the voltage V' of the electrode 15 will continue to rise until it reaches $2V$. At this maximum value $2V$ the electric field between the electrodes 14, 15 is such as to deflect the beam 1 towards the biased electrode 14, as shown in Fig. 3C. Then the spark gap 13 discharges the capacitor 12 and the cycle is repeated.

The variation of the voltage V' of the electrode 15 with time is illustrated by the graph of Fig. 4. As the capacitor 12 is charged up, the voltage V' rises linearly with time t at a rate i/C . When the spark gap 13 discharges the capacitor 12, the voltage V' drops rapidly to zero.

The frequency of oscillation is the inverse of the time required for the voltage V' to rise to its maximum value of $2V$. Hence,

$$f = i/2VC \text{ C. P. S.}$$

Strictly speaking, the capacitance C is the total capacitance between the electrode 15 and ground. However, since the capacitance of the capacitor 12 will generally be much larger than that between the electrodes 14, 15, the latter may be neglected.

If the voltage V' of the electrode 15 varies between 0 and $2V$, then the maximum angular deflection of the beam 1 will be $2A$, where A is the maximum angular deviation of the beam 1 from its undeflected position. Referring now to Fig. 5, the angle A is related to the bias voltage V in accordance with the relation

$$\tan A = \frac{VL}{kdE}$$

where L is the length of the electrodes, d is the distance (measured in the same units as L) between the electrodes. E is the potential drop through which the particles have been accelerated by the acceleration tube (measured in the same units as V), and k is a number which varies slightly depending upon the velocity of the particles. k is never less than 1 nor more than 2, and is generally approximately 2, except for very light particles at high energy. Consequently, the maximum angular deflection is independent of the amount of charge on the particles in the beam, and is only slightly dependent upon the mass of the particles in the beam.

It may be noted that when the electrode 15 is at its maximum voltage of $2V$, the potential drop through which the particles are accelerated is reduced by $2V$, since the charge-collector 8 is directly connected to the electrode 15. Consequently, the potential drop through which the particles are accelerated varies between E and $E - 2V$, so that the energy of the particles varies by a fractional amount $2V/E$, which is proportional to $\tan A$.

For 2 MeV electrons and a total deflection of 16° , k is 1.21, A is 8° , and $\tan A$ is 0.1405. If d is 4 cm. and V is -50 kv., L is 27.2 cm. The percentage variation of the energy of the electrons in the beam is 5%.

Having thus described the method of my invention together with several illustrative embodiments of apparatus for practicing the method, it is to be understood that although specific terms are employed, they are used in a generic and descriptive sense and not for purposes of limitation, the scope of the invention being set forth in the following claims.

I claim:

1. That method of imparting a scanning movement to a beam of charged particles which method comprises creating and directing a beam of charged particles; collecting substantially all of the current of said beam; storing the electric charge thus collected; dissipating the stored electric charge periodically; and subjecting said beam to the deflecting action of the electric field associated with said stored charge.

2. Apparatus for imparting a scanning movement to a beam of charged particles comprising in combination means for creating a beam of charged particles; a pair of deflecting electrodes supported so that said beam passes therebetween; a charge-collector for collecting substantially all of the current of said beam; a capacitor electrically connected to said charge-collector, whereby the electric charge collected by said charge-collector is stored in said capacitor; a discharge device adapted to discharge said capacitor whenever the voltage drop across said capacitor reaches a predetermined value; and means for applying the variation in the voltage drop across said capacitor to one of said electrodes.

3. Apparatus for imparting a scanning movement to a beam of charged particles comprising in combination means for creating a beam of charged particles; a pair of deflecting electrodes supported so that said beam passes

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therebetween; a charge-collector for collecting substantially all of the current of said beam; a direct electrical connection between one of said electrodes and said charge-collector; a capacitor electrically connected between said charge-collector and ground; and a discharge device adapted to discharge said capacitor whenever the voltage drop across said capacitor reaches a predetermined value.

4. Apparatus for imparting a scanning movement to a beam of charged particles comprising in combination means for creating a beam of charged particles; a pair of deflecting electrodes supported so that said beam passes therebetween; a charge-collector for collecting substantially all of the current of said beam; a direct electrical connection between one of said electrodes and said charge-collector; means for maintaining the other of said electrodes at a fixed potential; a capacitor electrically connected between said charge-collector and ground; and a discharge device adapted to discharge said capacitor whenever the voltage drop across said capacitor reaches a predetermined value.

5. Apparatus in accordance with claim 4, wherein said discharge device comprises a spark gap.

6. Apparatus in accordance with claim 4, wherein said discharge device comprises a thyatron.

7. Apparatus for imparting a scanning movement to a beam of charged particles comprising in combination an evacuated acceleration tube having a source of charged particles at one extremity thereof and a tube extension at the opposite extremity thereof; a pair of electrostatic deflector electrodes supported within said tube extension; a capacitor electrically connected to one of said electrodes;

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means for delivering substantially all of the current of said beam to said capacitor for the purpose of charging said capacitor; and means for periodically discharging said capacitor.

8. Apparatus for imparting a scanning movement to a beam of charged particles comprising in combination means for creating a beam of charged particles; a pair of deflecting electrodes supported so that said beam passes therebetween; a charge-collector for collecting substantially all of the current of said beam; a direct electrical connection between one of said electrodes and said charge-collector; and an electrical connection between said electrodes including a capacitor and a discharge device adapted to discharge said capacitor whenever the voltage drop across said capacitor reaches a predetermined value, the total current in parallel with said capacitor being negligible except during discharge of said capacitor by said discharge device.

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