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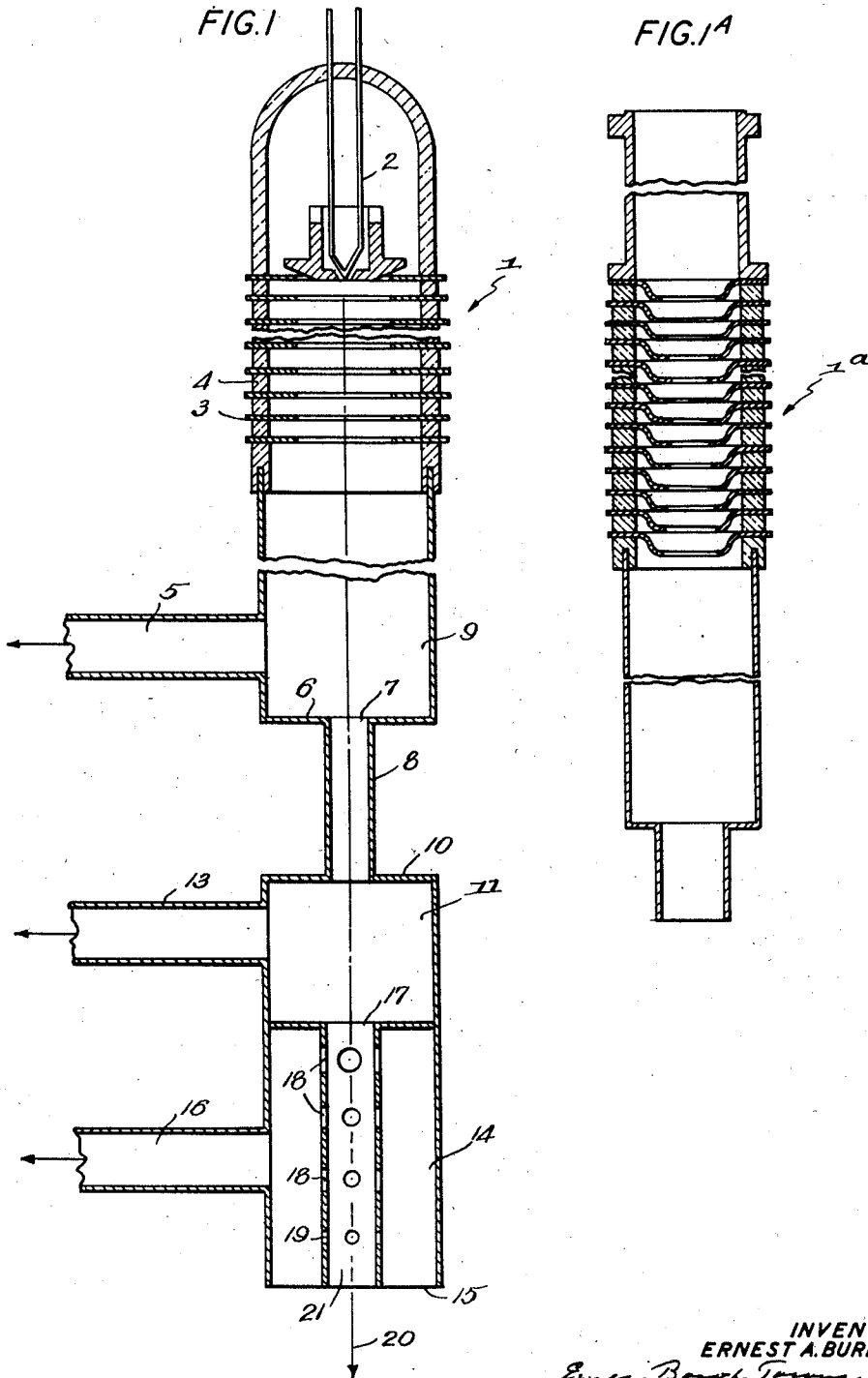
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APPARATUS FOR UTILIZING A BEAM OF HIGH ENERGY
ELECTRONS IN STERILIZATION AND IN THERAPY

Filed Sept. 21, 1950

2 Sheets-Sheet 1



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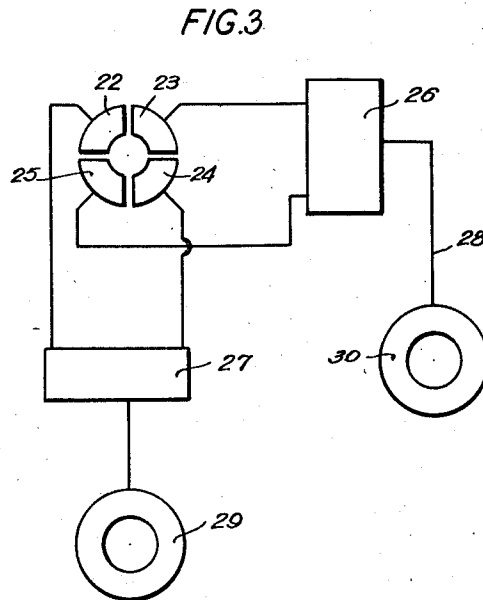
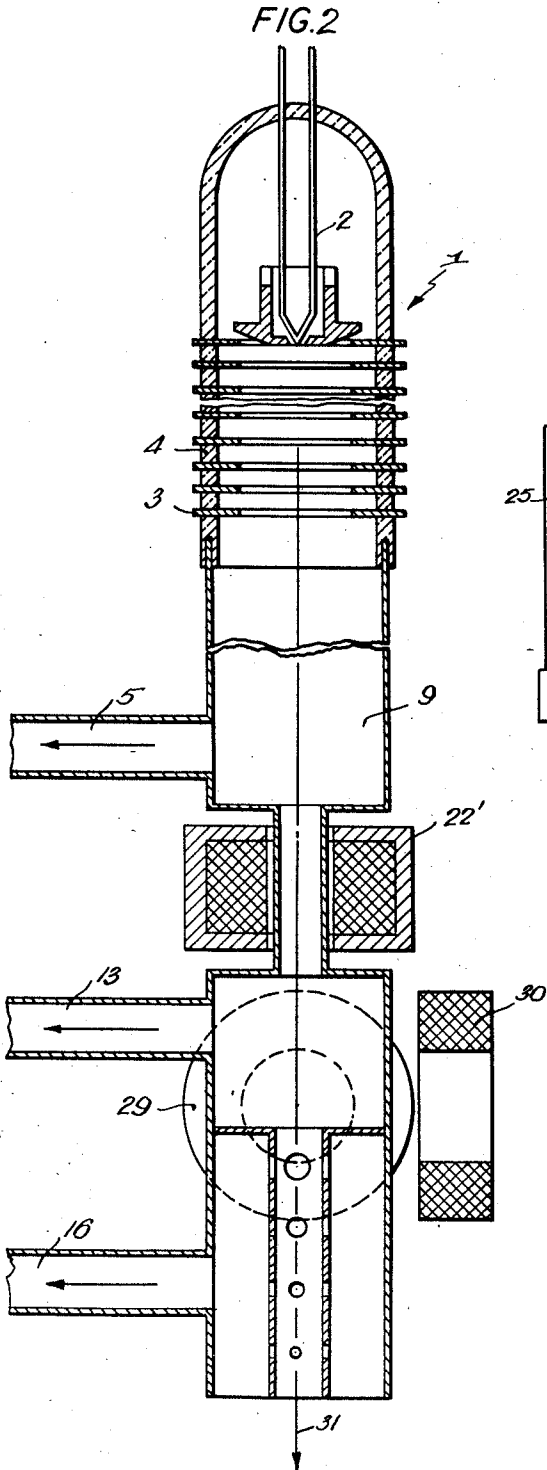
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2 Sheets-Sheet 2



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APPARATUS FOR UTILIZING A BEAM OF HIGH ENERGY ELECTRONS IN STERILIZATION AND IN THERAPY

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1

This invention comprises an apparatus which permits an intense beam of high-energy electrons to be removed or issue from the vacuum region of an electron acceleration or accelerating tube, and which interposes a barrier between the high-voltage region and the atmospheric region, such barrier consisting of a plurality of vacuum chambers and the total assembly forming a pressure gradient between atmospheric pressure and the high vacuum of the acceleration or accelerating tube, which apparatus permits the electron beam to emerge from the high-vacuum region of such tube without the necessity of permeating and losing energy through a solid barrier between atmospheric pressure exterior to said tube and the high vacuum region of said tube.

In order that the principle of my invention may be readily understood, I have in the accompanying drawings disclosed one type of apparatus embodying the structural features of my invention.

In said drawings:

Fig. 1 is a vertical or longitudinal sectional view of an acceleration tube that may be of any suitable type, it being shown, without limitation, as of the Van de Graaff type, and embodying the structural features of my invention, partly broken away because of space limitations, and indicating the cathode from which the beam of high-energy electrons is emitted, and a few of the alternating metallic electrode disks and the insulating disks of which the wall of the said tube is composed throughout at least the main vacuum chamber or portion thereof, and also representing two auxiliary vacuum chambers and the wholly open lower end of said acceleration tube;

Fig. 1A is a view similar to Fig. 1, but showing the latest form of acceleration tube of the Van de Graaff type, preferably employed by me, but broken away through the small diameter tube just below the main vacuum chamber, the auxiliary vacuum chambers being omitted because of space limitations;

Fig. 2 is a similar view but representing means for electronically controlling the electron beam so as to shrink or reduce the diameter thereof, so that it may be focused at the axial center of said tube throughout the longitudinal extent of the said tube and particularly at the small diameter tubes or orifices beyond or posterior to the main vacuum chamber of the said acceleration tube; and

Fig. 3 is a diagram indicating means that I preferably employ for electronically controlling the axis and diameter of the electron beam for the purpose stated.

2

In essence this invention comprises preferably an acceleration tube of any desired type having several vacuum systems and attendant vacuum chambers which are connected to each other by small orifices or tubes, the centers of the orifices or tubes being co-axial with the accelerated electron beam in the acceleration tube. The auxiliary vacuum system and chamber that is next to and directly connected to the main vacuum region of the acceleration tube is maintained at a pressure several times higher than that of the main vacuum region of said tube. That is, the degree of vacuum in the first auxiliary vacuum system is not as high or as near a complete vacuum as in the main chamber of the acceleration tube where the degree of vacuum is that normally maintained in an acceleration tube. The orifice or tube connecting the two systems is small enough so that the resultant leak from the high-pressure region into the low-pressure region or main chamber of the acceleration tube is small in comparison with the capabilities of the vacuum system of the main vacuum region. In the same sense, another auxiliary vacuum system and chamber may be and desirably are connected to the said system with a similar orifice or tube, with a maintained pressure several times higher than the system directly before it. That is, the nearness to a perfect vacuum of the second auxiliary chamber is not as close as in the just preceding auxiliary chamber. By means of this series of pressure differentials separated by small tubes or orifices, an open path can be and is made for the electrons emerging from the high vacuum region out to atmospheric pressure. Although I have herein shown in Figs. 1 and 2 the use of three vacuum systems, any number may be utilized, depending upon the type of pumping system and the quality of ultimate vacuum desired.

It is desirable for many purposes to bring a beam of accelerated electrons out of the accelerating vacuum system of the acceleration tube. In the field of cathode-ray sterilization of foods, drugs, medical supplies, packaging material and other products, and of cathode-ray therapy of malignant growths, the electron beams must be brought out from the acceleration tube for effective use. The usual cathode-ray window for an electron beam consists of a thin foil of material or membrane, usually metallic, which forms a vacuum-tight barrier between atmospheric pressure and the vacuum region inside of said acceleration tube. High-energy electrons have an energy great enough to penetrate such foil or

membrane without losing very much energy by reason of absorption in the said window. This thin cathode-ray window is easily damaged by one of several causes. The force due to atmospheric pressure on the window can cause a rupture; the electron energy absorbed by the window can cause local overheating and possibly melting; the effect of the high-energy electron stream permeating the window tends to cause a change in the crystalline structure of the window material, thereby weakening and eventually rupturing it; and because of its thin nature, it can be easily damaged through mechanical impact. When the window ruptures, atmospheric pressure is allowed to rush into the vacuum region, possibly damaging the performance of the vacuum pump and contaminating the interior surface of the accelerating tube with condensable vapors.

This invention herein disclosed eliminates the necessity for such a permeable foil or membrane and thus increases the reliability of the exit region of the electron beam. The fact that in this invention there is no foil, membrane or other closure at or constituting the window, results in all of the available electron energy accelerated in the vacuum region being used for sterilization, irradiation or therapy purposes. In some instances, the increase in available energy is considerable. For example, a foil of aluminum .003 of an inch thick absorbs 50 KeV of electron energy. In the case of a beam of one milliamperere intensity, the energy lost to the window amounts to fifty watts.

This invention is useful with any source of electrons whose energies are greater than 100,000 electron volts. The types of electron accelerators to which this invention applies or relates include the following, to which, however, the use of my invention is not limited: electrostatic or Van de Graaff generators, resonance transformers, transformer-rectifiers regardless of the type of circuit used, linear accelerators, betatrons and synchrotrons, and also the impulse or Marx-type generator or Capacitron.

Referring more particularly to the drawings, and first to Fig. 1, an acceleration tube is indicated generally at 1 in Figs. 1, 1A and 2. While it is herein shown as of the Van de Graaff type, and in Fig. 1A as of the latest Van de Graaff type, as built by the assignee (the High Voltage Engineering Corporation, of Cambridge, Massachusetts), it may be of any suitable type, and my invention is in no wise limited to any particular type of acceleration tube. The wall of the tube below the cathode 2, which may be of tungsten, is herein represented as composed of alternate metallic electrode disks 3 and insulating disks 4 or other material such as porcelain, suitably welded together. However, as already stated, any suitable type of acceleration tube may be employed. A high speed diffusion pumping system is indicated diagrammatically at 5. Thereby a vacuum is maintained at conditions required by the said acceleration tube (e. g. 10^{-6} mm. Hg).

Instead of the acceleration tube being of one diameter throughout its length, at some suitable distance below the pumping system 5, the said tube is closed as indicated at 6, except for the axially positioned, small orifice 7, which is in communication with a straight tube 8 of small diameter and which is axially positioned or coaxial with the longitudinal axis of the upper part of the acceleration tube. There is thus provided a main vacuum chamber 9 wherein the vacuum

is maintained as near a perfect or complete vacuum as is customary in the usual acceleration tube.

At its lower end the small diameter tube 8, which may be of any suitable length, is secured to or forms a part of a horizontal or transversely extending wall 10 of another or auxiliary vacuum chamber 11, the bottom wall whereof is indicated at 12. I have shown the vacuum chamber 11 as of the same diameter as the main vacuum chamber 9, but it may be of any other suitable diameter, and the wall thereof may be constructed in the same manner as is the wall of the main chamber 9. The vacuum chamber 11 is provided with a high speed pumping system 13, by which an intermediate vacuum is maintained (e. g. 10^{-4} mm. Hg).

Desirably, but not necessarily, below the auxiliary vacuum chamber 11 is another auxiliary vacuum chamber 14, the bottom of which is indicated at 15, and which is in communication with a mechanical pumping system indicated at 16, and by which a less complete vacuum is maintained (e. g. 10^{-2} mm. Hg). The diameter of the vacuum chamber 14 is represented as the same as the vacuum chambers 9 and 11, but this may be varied as desired, and the wall of the said second auxiliary vacuum chamber may be constructed in the same manner as that of the main vacuum chamber 9.

It will be noted that centrally or axially within the chamber 14 is provided a small diameter tube 17 that is itself provided with a graduated set of holes 18, 19. These holes are of greater diameter at the upper end of the tube 17, as indicated at 18, and gradually decrease in size to the smallest diameter holes 19 at the lower end (that is, at the end of the tube nearest atmospheric pressure). The purpose of this graduated size of openings is to establish a pressure gradient along the said tube 17. There may be any desired number of said gradient holes.

The center line of the axis at the emerging high-speed electron beam is indicated at 20.

It is to be understood that below the tube 17 (that is, at the point where the said tube 17 communicates with the outside) there is atmospheric pressure (e. g. 760 mm. Hg).

It will be understood that the lower end of the tube 17 is open to the atmosphere. That is, there is no foil or membrane or other closure, and yet there is no loss of electron energy. A high vacuum is maintained in the main portion or chamber 9 of the acceleration tube.

There are thus provided a plurality of vacuum-pumping evacuating chambers below or posterior to the main vacuum chamber 9. These several vacuum pumping-system evacuating chambers 11 and 14, which if desired may be of greater number and similarly connected, are separated from each other by a small diameter orifice or tube that is large enough in diameter to permit ready passage of the said beam of high energy electrons, but small enough in diameter to allow the vacuum pumping speed at the chambers 11 and 14 to be low. The said plurality of pumping systems below or posterior to the main vacuum chamber 9 act to maintain degrees of vacuum that are progressively higher from atmospheric pressure back to the most nearly complete vacuum of the main chamber 9.

Thus high vacuum is maintained in the main portion 9 of the acceleration tube 1 notwithstanding the fact that the lower end of the entire acceleration tube at 21 is in open communication with the external atmosphere.

5

Thus I have provided a so-called exit "window" which is completely permeable to electrons without any loss of electron energy, and which "window" permits a high vacuum to be maintained in the main portion 9 of the acceleration tube 1.

It will be understood that by my invention there is provided or secured an electron window that is obtained by differential pumping.

To make sure that the electron beam proceeds through the co-axial tubes or orifices 8 and 17 connecting the parts of the differential pumping system, an annular focusing magnet, such as indicated at 22' in Fig. 2, is desirably used at the first orifice or tube 8 to shrink or reduce the beam diameter down so as to focus at the center of the next tube or orifice such as 17. The annular focusing magnet minimizes the effect of stray electrons impinging on the sides of the interconnecting tubes, such as 7 and 17, of the auxiliary systems. To prevent the electron beam deviating from the axis of the acceleration tube, a set of insulated plates, here shown as quadrants or segments 22, 23, 24, 25 are placed directly before the second orifice or interconnecting tube such as 17. The focusing magnet arrangement, electron beam path, and quadrant or segment arrangement are indicated in Fig. 2 and in the diagram Fig. 3. If a portion of the electron beam falls on one of the said insulated quadrants, the resulting current is desirably amplified, as by amplifiers 26 and 27, and used as a signal in an electronic circuit, indicated at 28 in Fig. 3, to control the intensity of current through one of a pair of solenoid-type magnets 29 and 30, Figs. 2 and 3, whose axes are mutually perpendicular to themselves and to the electron beam, as shown in Fig. 2. The signal from the quadrants 22, 23, 24 and 25 results in a correction of the magnetic field to deflect the electron beam, indicated at 31, enough to reduce the signal on the quadrants 22, 23, 24 and 25 to zero, thus keeping the electron beam centralized.

Instead of employing the pair of solenoid-type magnets, I may employ only one, or a series of magnets, of suitable type for focusing the beam. For example, I may employ one annular magnet, or a series of magnets, placed about the path of the electron beam at a suitable position and preferably at substantially the position indicated.

I may, within the scope of the invention, employ any other suitable agency for centralizing the electron beam. Furthermore, electrostatic or mechanical centralization may be caused to take place either manually or automatically. By noting the amount of current falling on the insulated quadrants or segments, the operator may then vary the magnetic field or the electrostatic field, as the case may be, or he can effect a mechanical adjustment remotely.

Having thus described several types of apparatus for practicing the invention, 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. Apparatus for sterilizing (i. e. irradiating) by the action of high-energy electrons, respective masses of substances, such as foods, drugs, medical and surgical supplies, cosmetics, packaging materials, etc. containing organisms to be destroyed by the action of a beam of high-energy

6

electrons, and for use in cathode-ray therapy of malignant growths, comprising means for creating and directing a beam of high-energy electrons, said means including a high-vacuum acceleration tube-like envelope internally along which such beam of high-energy electrons is transmitted from its emanating source, and from which envelope said beam of high-energy electrons may be discharged into such respective substances for sterilizing (i. e. irradiating) the same, said high-vacuum envelope having a high-energy electron-beam exit "window" which is completely permeable to electrons without any loss of electron energy and which exit "window" for the electrons is in open communication with the outer atmosphere and means to prevent impairment of the degree of vacuum in said main chamber, and to maintain as near a perfect vacuum as is customary in usual acceleration tubes, notwithstanding said unclosed exit opening.

2. In an apparatus in accordance with claim 1 a high-voltage high-vacuum electron device, means to correct any occurrence of decentralization of the said beam of high-speed electrons within the acceleration tube-like envelope, such means including a series of insulated plates in an electric circuit, and positioned about said tube-like envelope and closely adjacent the normal path of the beam along the longitudinal axis of said envelope, so that onto some one of said plates, the beam, if decentralized, will fall or strike, and also including means whereby an electric signal is thereupon conveyed from such plate onto which the beam falls or strikes, which electric signal causes correction of the magnetic field about such decentralized beam, and consequently causes recentralization of said beam along the longitudinal axis of such envelope.

3. Apparatus for sterilizing (i. e. irradiating) by the action of high-energy electrons in accordance with claim 1 wherein there is means to correct any occurrence of decentralization of the said beam of high-speed electrons within said tube-like envelope, said means to correct decentralization of said beam of electrons including a series of insulated plates in an electric circuit and positioned about said tube-like envelope and closely adjacent the normal path of said beam lengthwise through said tube-like envelope along the longitudinal axis thereof, so that onto some one of said plates the beam, if decentralized, will fall or strike, and also including means whereby an electric signal is thereupon conveyed from the plate onto which the beam falls or strikes, and which electric signal causes correction of the magnetic field about said decentralized beam and consequently causes recentralization of said beam along the longitudinal axis of said tube-like envelope, and wherein the means to convey a signal from a plate of such series of plates onto which the beam falls or strikes is so positioned and arranged that the operator may thereupon vary the said field or effect a mechanical adjustment remotely.

4. A high-voltage, high-vacuum device in accordance with claim 1, wherein there is means to correct any occurrence of decentralization of the said beam of high-speed electrons within said tube-like envelope, said means to correct decentralization of said beam of electrons including a series of insulated plates in an electric circuit and positioned about said tube-like envelope and closely adjacent the normal path of said beam lengthwise through said tube-like

envelope along the longitudinal axis thereof, so that onto some one of said plates the beam, if decentralized, will fall or strike, and including means whereby an electric signal is thereupon conveyed from the plate onto which the beam falls or strikes, and which electric signal causes correction of the magnetic field about said decentralized beam and consequently causes recentralization of said beam along the longitudinal axis of said tube-like envelope, and wherein there are a pair of solenoid-type magnets adjacent the normal path of said beam whose axes are mutually perpendicular to themselves and to the path of said beam, and electric circuiting from said plates to said magnets and including amplifying means, whereby the current from the plate onto which the beam falls or strikes controls the intensity of current through said magnet or magnets, resulting in a correction of the magnetic field at said magnets, thereby reducing the signal on such plate to zero.

5. A high-voltage high-vacuum device in accordance with claim 1, wherein there is means to correct any occurrence of decentralization of the said beam of high-speed electrons within said tube-like envelope, said means to correct decentralization of said beam of electrons including a series of insulated plates in an electric circuit and positioned about said tube-like envelope and closely adjacent the normal path of said beam lengthwise through said tube-like envelope along the longitudinal axes thereof, so that onto some one of said plates the beam, if decentralized, will fall or strike, and including means whereby an electric signal is thereupon conveyed from the plate onto which the beam falls or strikes, and which electric signal causes correction of the magnetic field about said decentralized beam and consequently causes recentralization of said beam along the longitudinal axis of said tube-like envelope, and wherein a series of magnets are positioned about the normal axis of said beam, and wherein electric circuiting is provided between said insulated plates and said series of magnets.

6. Apparatus for sterilizing (i. e. irradiating) masses of substances by the action of high-energy electrons, in accordance with claim 1, wherein the means to prevent impairment of the degree of vacuum in the main vacuum chambers of said tube-like envelope includes at least one supplemental vacuum chamber in communication with the main vacuum chamber of the said tube-like envelope and vacuum-creating pumping means in operative connection and relation with said supplemental vacuum chamber.

7. A high-voltage, high-vacuum electron device in accordance with claim 1, wherein there is means to correct any occurrence of decentralization of the said beam of high-speed electrons within said tube-like envelope, said means to correct decentralization of said beam of electrons including a series of insulated plates in an electric circuit and positioned about said tube-like envelope and closely adjacent the normal path of said beam lengthwise through said tube-like envelope along the longitudinal axis thereof, so that onto some one of said plates the beam, if decentralized, will fall or strike, and including means whereby an electric signal is thereupon conveyed from the plate onto which the beam falls or strikes, and which electric signal causes correction of the magnetic field about said decentralized beam and consequently causes recentralization of said beam along the longi-

tudinal axis of said tube-like envelope, and wherein the means to correct decentralization of the beam of high speed electrons is under the manual control of the operator who for such purpose may note the amount of current falling on any one of said insulated plates and may then himself vary the field or effect mechanical adjustment remotely.

8. Apparatus for sterilizing (i. e. irradiating) the action of high-energy electrons, respective masses of substances, such as foods, drugs, medical and surgical supplies, cosmetics, packaging material, etc. containing organisms to be destroyed by the action of a beam of high-energy electrons, and for use in cathode-ray therapy of malignant growths, comprising means for creating and directing a beam of high-energy electrons, said means including a high-vacuum acceleration tube-like envelope interiorly along which such beam of high-energy electrons is transmitted from its emanating source, and from which envelope said beam of high-energy electrons is discharged into such respective substances, for sterilizing (i. e. irradiating) the same, said high-vacuum acceleration tube-like envelope having an unclosed exit opening through which such beam of high-energy electrons issues into such respective substances, and means to maintain substantially a high vacuum in said envelope notwithstanding the existence of said unclosed exit opening.

9. An apparatus for sterilizing (i. e. irradiating) substances by the action of high-energy electrons in accordance with claim 3, wherein the means to maintain substantially a high-vacuum in said envelope notwithstanding the existence of said unclosed exit opening, includes at least one supplemental vacuum pumping-system evacuating chamber at the electron beam exit portion of said envelope and which chamber is separated from the preceding interior portion of said envelope by a small, reduced-diameter orifice that is large enough in diameter to permit ready passage of the said beam of high-energy electrons, but is small enough in diameter to allow the vacuum pumping speed to said supplemental pumping system evacuating chamber to be low.

10. An apparatus in accordance with claim 9, wherein there is provided means anterior to and close to said small, reduced-diameter orifice, to correct any occurring decentralization of said beam of high-energy electrons.

11. An apparatus for sterilizing (i. e. irradiating) substances by the action of high-energy electrons in accordance with claim 8, wherein the means to maintain substantially a high-vacuum in said envelope notwithstanding the existence of said unclosed exit opening, includes a succession of pumping-system evacuating chambers at the said exit opening portion of the said envelope, each of said chambers being connected with any preceding and with succeeding evacuating chambers by relatively long, small-diameter tubing, each of said succession of evacuating chambers being provided with an auxiliary pumping system, and the first of said succession of evacuating chambers being in open communication with the preceding portion of the interior of said envelope, by means of an unclosed exit opening.

12. An apparatus for sterilizing (i. e. irradiating) substances by the action of high-energy electrons in accordance with claim 8, wherein the means to maintain substantially a high vacuum in said envelope notwithstanding the ex-

istence of said unclosed exit opening, includes at least one vacuum pumping-system evacuating chamber at the electron beam exit portion of said envelope and which chamber is separated from the preceding interior portion of said envelope by a small, reduced-diameter orifice that is large enough in diameter to permit ready passage of the said beam of high-energy electrons, but is small enough in diameter to allow the vacuum pumping speed to adjacent regions to be low, and means closely adjacent said reduced diameter orifice to correct decentralization of said beam of high-energy electrons.

13. An apparatus for sterilizing (i. e. irradiating) substances by the action of high-energy electrons in accordance with claim 8, wherein the means to maintain substantially a high-vacuum in said envelope notwithstanding the existence of said unclosed exit opening, includes at least one vacuum pumping-system evacuating chamber at the electron beam exit portion of said envelope and which chamber is separated from the preceding interior portion of said envelope by a small, reduced-diameter orifice that is large enough in diameter to permit ready passage of the said beam of high-energy electrons, but is small enough in diameter to allow the vacuum pumping speed to adjacent regions to be low, and four quadrant plates positioned about and closely adjacent the normal path of said beam and onto one of which the beam, if decentralized, would fall or strike, a pair of solenoid magnets adjacent the normal path of said beam and whose axes are mutually perpendicular to themselves and to the path of said beam, and electric circuiting between said plates and said magnets, thereby to vary transverse magnetic fields at said magnets with resulting correction of said decentralization.

14. An apparatus for sterilizing (i. e. irradiating) substances by the action of high-energy electrons in accordance with claim 8, wherein the means to maintain substantially a high-vacuum in said envelope notwithstanding the existence of said unclosed exit opening, includes at least one vacuum pumping-system evacuating chamber at the electron beam exit portion of said envelope and which chamber is separated from the preceding interior portion of said envelope by a small, reduced-diameter orifice that is large enough in diameter to permit ready passage of the said beam of high-energy electrons, but is small enough in diameter to allow the vacuum pumping speed to adjacent regions to be low, and electron beam focusing magnets about the path of said beam, anterior to and in substantial proximity to said small, reduced-diameter orifice.

15. An apparatus for sterilizing (i. e. irradiating) substances by the action of high-energy electrons in accordance with claim 8, wherein the means to maintain substantially a high-vacuum in said envelope notwithstanding the existence of said unclosed exit opening, includes at least one vacuum pumping-system evacuating chamber at the electron beam exit portion of said envelope and which chamber is separated from the preceding interior portion of said envelope by a small, reduced-diameter orifice that is large enough in diameter to permit ready passage of the said beam of high-energy electrons, but is small enough in diameter to allow the vacuum pumping speed to adjacent regions to be low, and electron beam focusing magnet means about the path of said beam, anterior to

and in substantial proximity to said small, reduced-diameter orifice, and means between said electron beam focusing magnet means and said small reduced-diameter orifice to correct any occurring decentralization of said beam of high energy electrons.

16. An apparatus for sterilizing (i. e. irradiating) substances by the action of high-energy electrons in accordance with claim 8, wherein the means to maintain substantially a high vacuum in said envelope notwithstanding the existence of said unclosed exit opening, includes at least one vacuum pumping-system evacuating chamber at the electron beam exit portion of said envelope and which chamber is separated from the preceding interior portion of said envelope by a relatively long, small-diameter tubing, and focusing magnet means surrounding the path of said beam, anterior to and adjacent the entrance end of said tubing to constrict the diameter of said beam within the said tubing.

17. An apparatus for sterilizing (i. e. irradiating) substances by the action of high-energy electrons in accordance with claim 8, wherein the means to maintain substantially a high-vacuum in said envelope notwithstanding the existence of said unclosed exit opening, includes a succession of pumping-system evacuating chambers at the said exit opening portion of the said envelope, each of said chambers being connected with any preceding and with succeeding evacuating chambers by relatively long, small-diameter tubing, each of said succession of evacuating chambers being provided with an auxiliary pumping system, and the first of said succession of evacuating chambers being in open communication with the preceding portion of the interior of said envelope, by means of said unclosed exit opening, the final one of said evacuating chambers having a small-diameter tubing axially extending therethrough for the passage of the electron beam, and at the outer end communicating with the external atmosphere, said tubing having a series of openings in the wall thereof communicating with said final evacuating chamber.

18. An apparatus for sterilizing (i. e. irradiating) substances by the action of high-energy electrons in accordance with claim 8, wherein the means to maintain substantially a high-vacuum in said envelope notwithstanding the existence of said unclosed exit opening, includes a succession of pumping-system evacuating chambers at the said exit opening portion of the said envelope, each of said chambers being connected with any preceding and with succeeding evacuating chambers by relatively long, small-diameter tubing, each of said succession of evacuating chambers being provided with an auxiliary pumping system, and the first of said succession of evacuating chambers being in open communication with the preceding portion of the interior of said envelope, by means of said unclosed exit opening, the final one of said evacuating chambers having a small-diameter tubing axially extending therethrough for the passage of the electron beam, and at the outer end communicating with the external atmosphere, said tubing having a series of openings in the wall thereof communicating with said final evacuating chamber, the said series of openings being increasingly smaller in size in the direction of the movement of the electron beam.

19. An apparatus for sterilizing (i. e. irradiating) substances by the action of high-energy

electrons in accordance with claim 8, wherein the means to maintain substantially a high-vacuum in said envelope notwithstanding the existence of said unclosed exit opening, includes at least one vacuum pumping-system evacuating chamber at the electron beam exit portion of said envelope and which chamber is separated from the preceding interior portion of said envelope by a small, reduced-diameter orifice that is large enough in diameter to permit ready passage of the said beam of high-energy electrons, but is small enough in diameter to allow the vacuum pumping speed to adjacent regions to be low, and annular electron-beam-focusing magnetic means about the path of said beam in substantial proximity to said small reduced-diameter orifice.

20. Apparatus for sterilizing (i. e. irradiating) by the action of high-energy electrons, respective masses of substances, such as foods, drugs, medical and surgical supplies, cosmetics, packaging material, etc. containing organisms to be destroyed by the action of a beam of high-energy electrons, and for use in cathode-ray therapy of malignant growths, comprising means for creating and directing a beam of high-energy electrons, said means including a high-vacuum tube-like envelope interiorly along which such beam of high-energy electrons is transmitted from its emanating source, and from which envelope said beam of high-energy electrons may be discharged into such respective substances, said high-vacuum envelope having an unclosed exit opening through which such beam of high-energy electrons issues into such respective substances, pumping means to create a high vacuum in said envelope and other vacuum creating pumping means in communication with the interior of said envelope at an area adjacent said unclosed exit opening to maintain substantially said high-vacuum in said envelope.

21. An apparatus for sterilizing (i. e. irradiating) substances by the action of high-energy electrons in accordance with claim 8, wherein the means to maintain substantially a high-vacuum in said envelope notwithstanding the existence of said unclosed exit opening, includes a plurality of vacuum pumping-system evacuating chambers at the electron beam exit portion of said envelope and which chambers are respectively separated from each other by a small reduced-diameter orifice that is large enough in diameter to permit ready passage of the said beam of high-energy electrons but is small enough in diameter to allow the vacuum pumping speed between respective chambers to be low.

22. Apparatus for sterilizing (i. e. irradiating) by the action of high-energy electrons, respective masses of substances, such as foods, drugs, medical and surgical supplies, cosmetics, packaging material, etc. containing organisms to be destroyed by the action of a beam of high-energy electrons, and for use in cathode-ray therapy of malignant growths, comprising means for creating and directing a beam of high-energy electrons, said means including a high-vacuum tube-like envelope interiorly along which such beam

of high-energy electrons is transmitted from its emanating source, and from which envelope said beam of high-energy electrons may be discharged into such respective substances, said high-vacuum envelope having an unclosed exit opening through which such beam of high-energy electrons issues into such respective substances, and means to establish a pressure gradient between exterior atmospheric pressure and the high vacuum of the acceleration tube.

23. Apparatus for sterilizing (i. e. irradiating) by the action of high-energy electrons, respective masses of substances, such as foods, drugs, medical and surgical supplies, cosmetics, packaging materials, etc., containing organisms to be destroyed by the action of a beam of high-energy electrons, and for use in cathode-ray therapy of malignant growths, comprising means for creating and directing a beam of high-energy electrons, said means including a high-vacuum acceleration tube-like envelope along which such beam of high-energy electrons may be discharged into such respective substances for sterilizing (i. e. irradiating) the same, said high-vacuum envelope having a high-energy electron-beam exit "window" which is completely permeable to electrons without any loss of electron energy, the said tube-like acceleration envelope at the end most remote from the emanating source of the high speed electrons having at the axial center, in open communication therewith, a tube of much smaller diameter than said envelope, for the passage of said electrons, said envelope being closed at its end opposite the emanating source of the beam of high energy electrons, excepting for the said smaller diameter tube, the said smaller diameter tube having an auxiliary vacuum chamber in communication therewith and means to maintain in said auxiliary vacuum chamber a lesser degree of vacuum than in said envelope, there being an open communication between said auxiliary vacuum chamber and the outer air, whereby a substantially high degree of vacuum is maintained in said tube-like acceleration envelope, notwithstanding the existence of the unclosed exit from the said auxiliary vacuum chamber.

ERNEST A. BURRILL.

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