

[54] **ELECTRON BEAM PRODUCING SYSTEM
FOR VERY HIGH ACCELERATION
VOLTAGES AND BEAM POWERS**

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313/452

[51] **Int. Cl.²** **H01J 29/46**

[58] **Field of Search**..... 313/63, 82 R, 82 BF, 336,
313/351, 446, 448, 449, 452, 454

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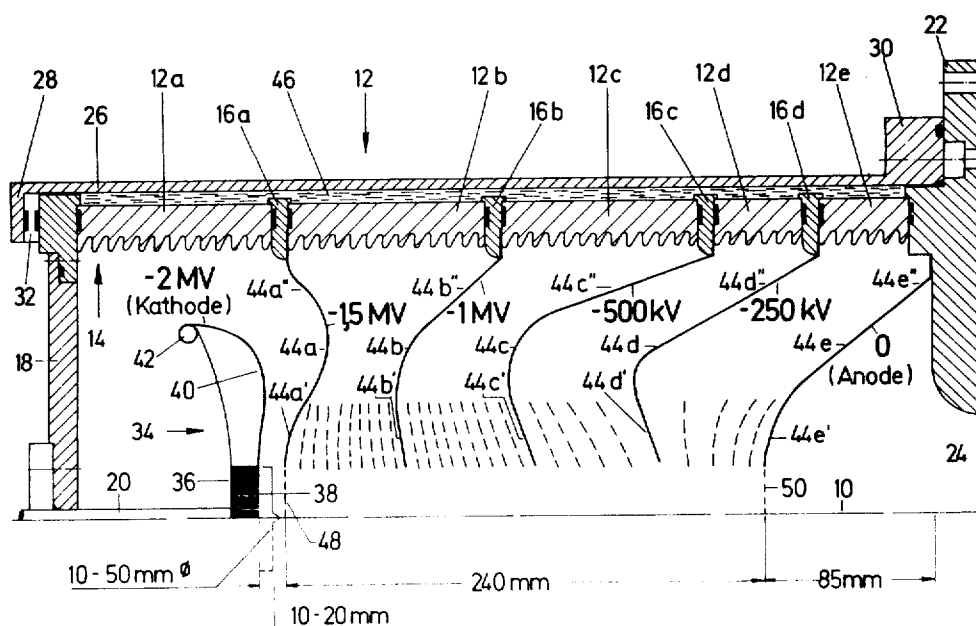
Attorney, Agent, or Firm—Spencer & Kaye

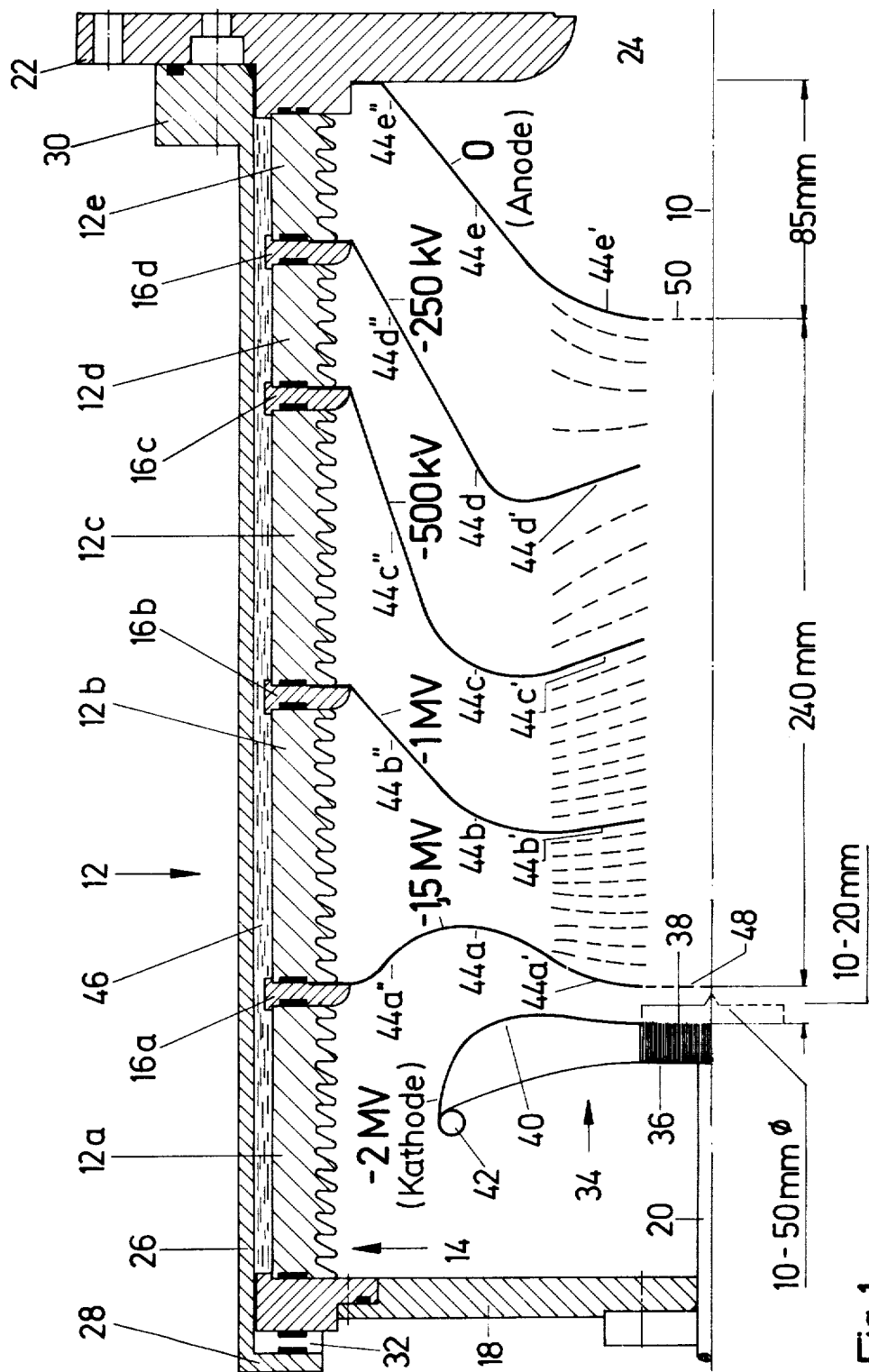
[57] **ABSTRACT**

An electron beam producing system for acceleration

voltages in the order of magnitude of megavolts and beam powers in the order of magnitude of gigawatts, comprises a tubular housing of insulating material, in which adjacent to its one closed end a field emission cathode with a large surface area is arranged while at its other end, from which the electron beam emerges, an annular anode is arranged. A device serves for collimating the electrons emitted by the cathode to form a collimated electron beam. The device for collimating the electron consists of annular electrodes, which respectively comprise a part adjacent to their center opening and an outer part which is held on the housing and has a radial electrical passage extending towards the outside of the housing. The inner part of the electrode lying closest to the cathode has at least approximately the shape of a frusto-conical surface which tapers towards the cathode; in that the inner part of the remaining electrodes is flat or at least approximately frusto-conical and respectively lies in an equipotential surface of an electric field, which collimates the electrons, emitted by the cathode, to form a parallel beam. The housing is surrounded by a coaxial insulating casing with a clearance. The intermediate space between the outer surface of the housing and the casing is surrounded with an electrically conducting liquid with a relatively high specific resistance and at the axial ends has a respective connection electrode, which makes contact with the liquid, for the operating voltage and that the outer parts of the electrodes are so shaped that the radial passages end at those sites of the liquid filled intermediate space at which the fraction, provided for the relevant electrode, of the operating voltage obtains when the operating voltage is applied to the connection electrodes.

13 Claims, 5 Drawing Figures





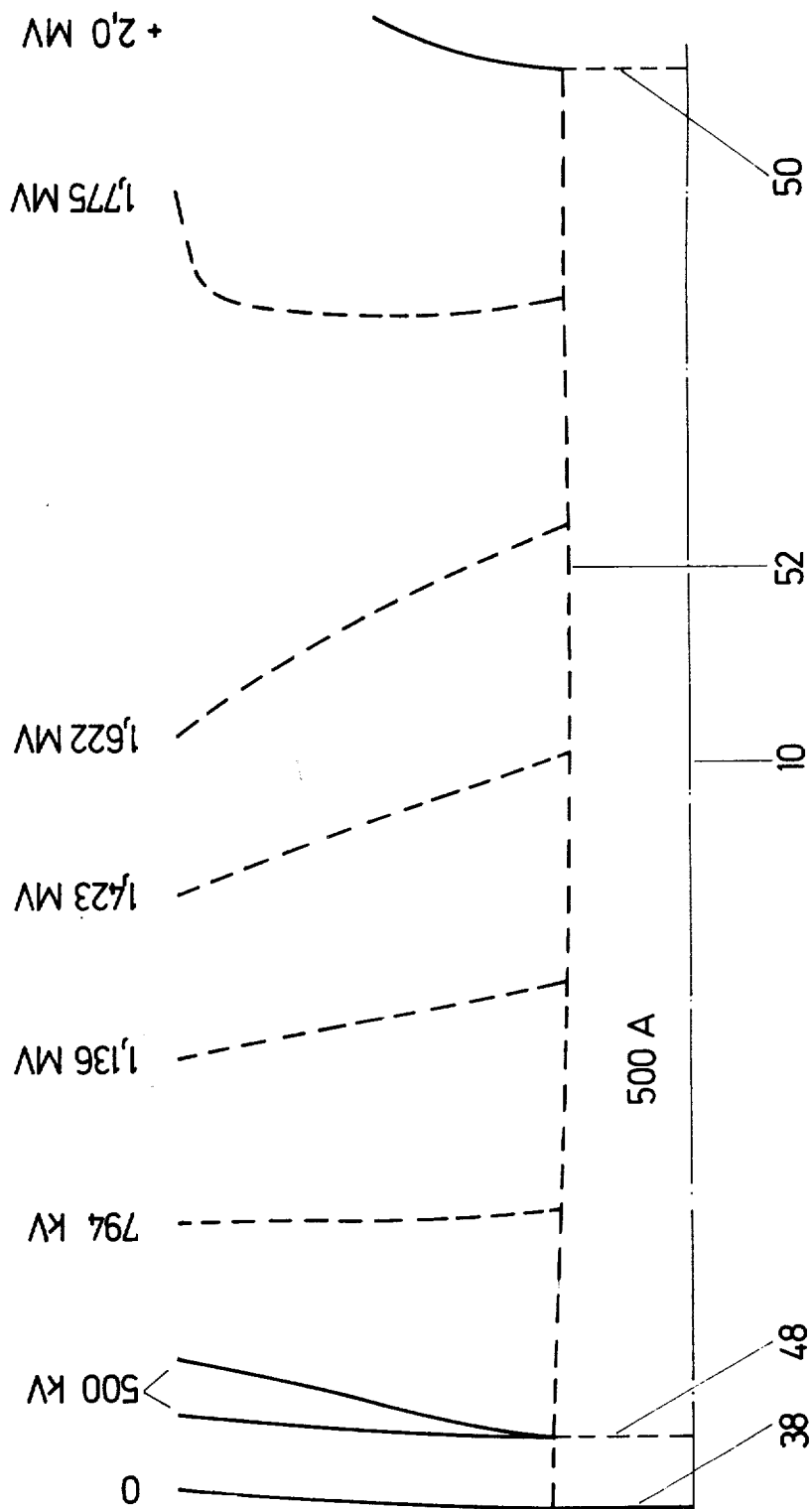


Fig. 2

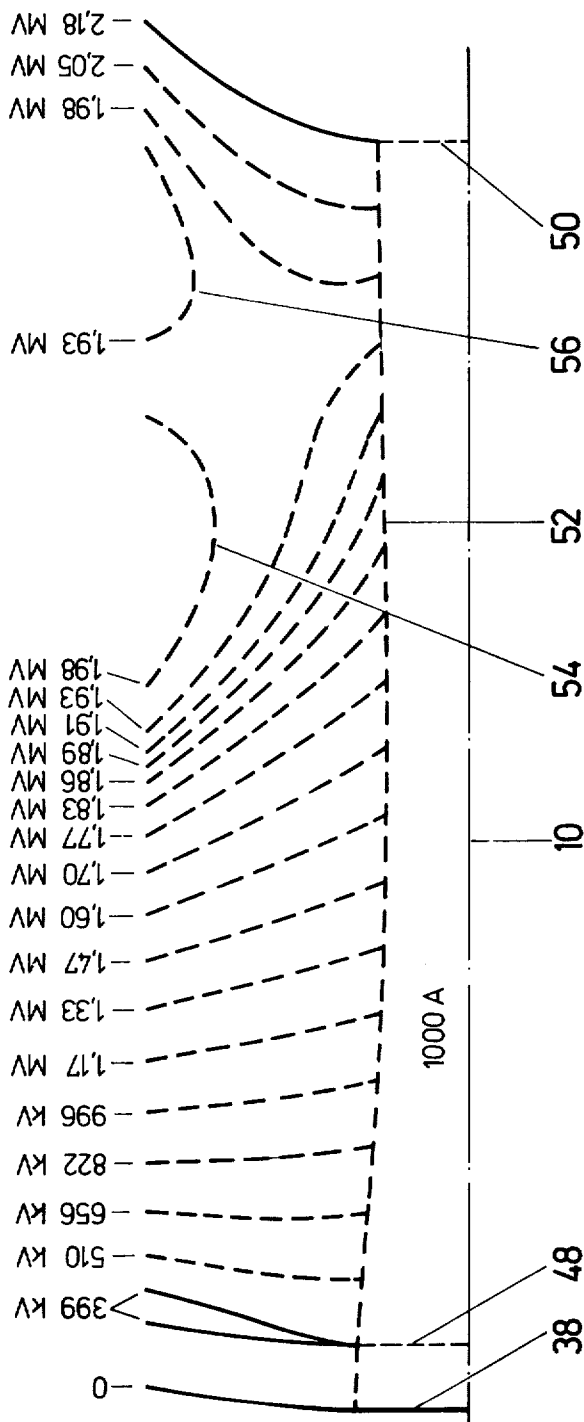


Fig. 3

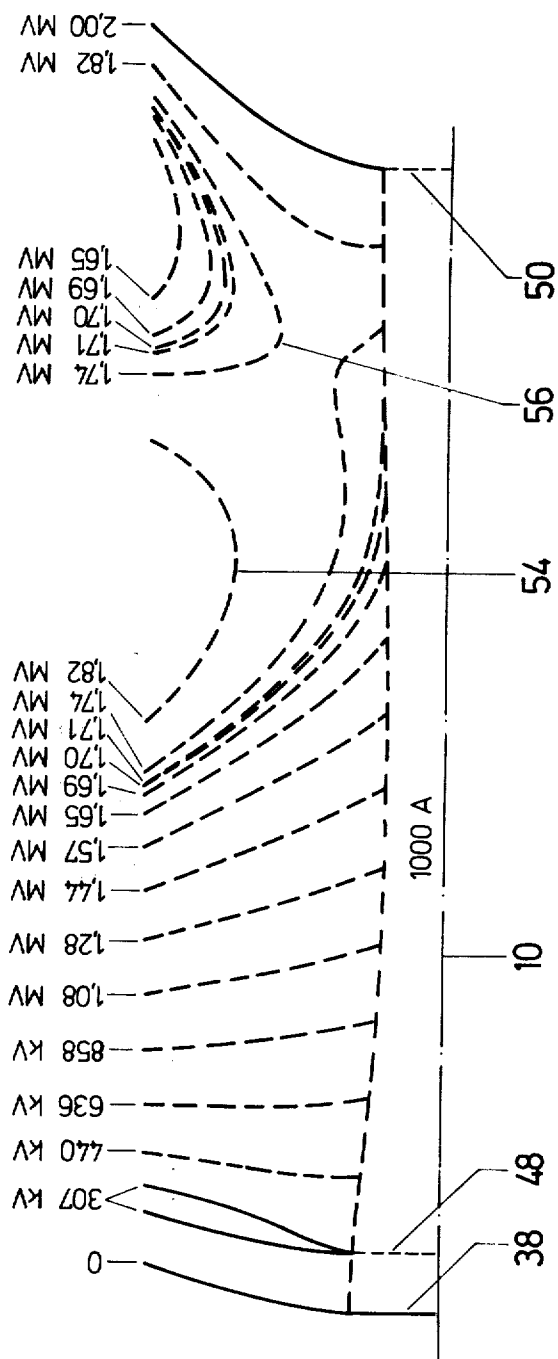


Fig. 4

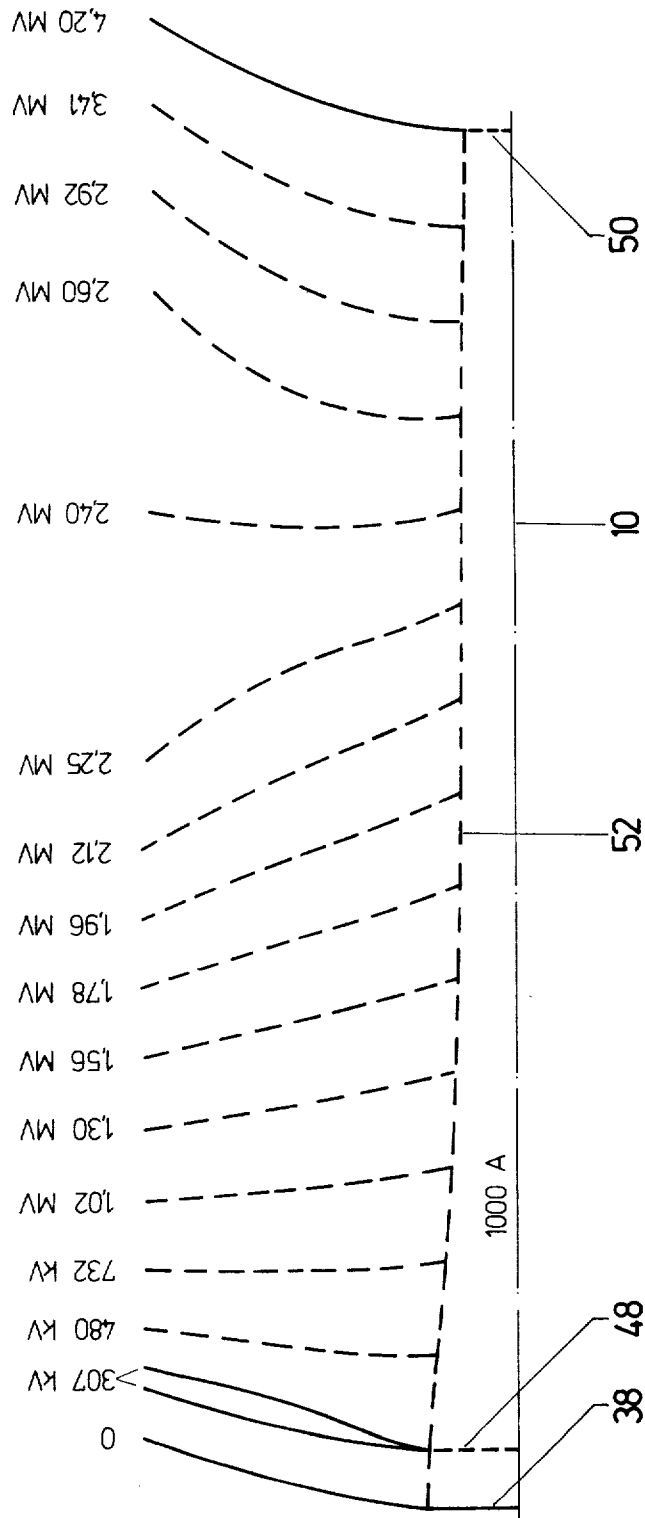


Fig. 5

ELECTRON BEAM PRODUCING SYSTEM FOR VERY HIGH ACCELERATION VOLTAGES AND BEAM POWERS

BACKGROUND OF INVENTION

1. Field to which Invention Relates

The present invention relates to an electron beam producing system for acceleration voltages in the order of magnitude of megavolts and beam powers in the order of magnitude of gigawatts, comprising a tubular housing of insulating material, in which adjacent to its one closed end a field emission cathode with a large surface area is arranged while at its other end, from which the electron beam emerges, an annular anode is arranged, and with a device for collimating the electrons emitted by the cathode to form a collimated electron beam.

2. The Prior Art

For a number of physical experiments and devices extremely energy-rich high current electron beams are required. For example, a prior art plasma ring accelerator requires a relative electron beam of some hundreds of amps with an emittance of approximately 1 rad mm.

Electron beam producing systems for very high acceleration voltages and beam powers have already been proposed. A prior art electron beam producing system of this type consists of a sealed by fusion tube, in which a vacuum of 10^{-9} torr obtains. The tube contains a relatively large surface area field emission cathode, that is to say a cold cathode. The ray emergence is through a Lenard window in the form of titanium foil with a thickness of 25 microns. However, such a window leads to an impairment in the ray quality to a substantial extent and furthermore limits the length of life of the tube to a few shots.

The above problems can be avoided with an open electron beam producing system, that is to say with an electron beam producing system, which at the beam outlet opening is not provided with a vacuum-tight window, and instead is connected with the vacuum space of the adjacent device or load for the electron beam. In this case the electron beam producing system must be operated with pressure in order of magnitude of 10^{-6} torr, something which in the prior art involved extraordinary difficulties as regards resistance to arcing. The required resistance to high voltages could admittedly be ensured with the known constructions in the condition free of current, that is to say without the electron beam, comparatively easily. However, as soon as the electron beam which has a very high current and is very rich in energy, is caused to flow arcing repeatedly occurs despite careful adjustment of the device for collimating, consisting of a magnet coil, the electrons emitted by the cathode.

SUMMARY OF INVENTION

One aim of the present invention is therefore that of creating an electron beam producing system of the above-mentioned type which can be reliably operated with an open electron beam outlet opening without arcing occurring and which produces a substantially mono-energetic electron beam which is highly collimated.

In order to achieve these and other aims the present invention consists in an electron beam producing system of the above-mentioned type which is characterized in that the device for collimating the electron con-

sists of annular electrodes, which respectively comprise a part adjacent to their center opening and an outer part which is held on the housing and has a radial electrical passage extending towards the outside of the housing; in that the inner part of the electrode lying closest to the cathode has at least approximately the shape of a frusto-conical surface which tapers towards the cathode (that is to say it is convex with respect to the cathode); in that the inner part of the remaining electrodes is flat or at least approximately frusto-conical and respectively lies in an equipotential surface of an electric field, which collimates the electrons, emitted by the cathode, to form a parallel beam; in that the housing is surrounded by a coaxial insulating casing with a clearance; in that the intermediate space between the outer surface of the housing and the casing is surrounded with an electrically conducting liquid with a relatively high specific resistance and at the axial ends has a respective connection electrode, which makes contact with the liquid, for the operating voltage and that the outer parts of the electrodes are so shaped that the radial passages end at those sites of the liquid filled intermediate space at which the fraction, provided for the relevant electrode, of the operating voltage obtains when the operating voltage is applied to the connection electrodes.

The present electron beam producing system thus operates with an electrostatic collimating of the electron beam and the annular electrodes producing the collimating field simultaneously ensure that the stray electrons do not reach the inner wall of the tubular housing and cannot at this position free adsorbed material, always present in the case of the relatively high working pressures, so as to lead to arcing.

In the case of one embodiment of the invention the electron current available was 300 A, that is to say approximately 4 to 4 times greater than in the case of prior art electron beam producing systems and could be focussed with an admittance of 1.3 rad mm. At the same time the total extraneous emission (X-ray emission) only amounted to approximately one fifth of that involved in the case of commercial prior art tubes.

The reproducibility of the electron energy amounted to 0.15 % in the case of series of shots occurring directly one after the other. Even in the case of shots made as intervals of several weeks the variations lay below 1 %. The present electron beam producing system can furthermore readily be matched to suit any desired initial resistance of the high voltage source by changing the specific resistance of the electrically conducting liquid (preferably water with small amounts of added salts, as for example copper sulfate).

The present electron beam producing system is furthermore capable of withstanding the voltage and resistant to arcing when a strong electron beam is flowing.

Further developments of the invention are defined in the subclaims.

LIST OF SEVERAL VIEWS OF DRAWINGS

The principle of the invention will now be explained in detail with reference to embodiments referring to the drawings.

FIG. 1 shows a sectional view of a half of an electron beam producing system in accordance with an embodiment of the invention.

FIGS. 2 to 5 show field line diagrams, from which the shape of the inner parts, bringing about the collimation

of the electron beam, of the annular electrodes of further embodiments of the invention is shown.

DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. 1 shows a half of an electron beam producing system in accordance with the invention in section. The electron beam producing system is substantially radially symmetrical with reference to a center axis 10. It is designed for an operating voltage of 2 megavolts.

The electron beam producing system which is shown comprises a tubular housing 12, which is mainly made of annular parts 12a-12e, which can be made of epoxy resin or ceramic material and in order to increase the voltage resistance have a ribbed inner wall 14 extending in the peripheral direction. Between the annular parts of the housing annular electrode holding means 16a-16d are arranged. The end surfaces of the annular pieces 12a-12e and of the annular electrode holding means 16a-16d have annular grooves in which the sealing rings are located. The sealing rings ensure that there is a vacuum-tight connection.

The one end of the housing 12 is closed by means of a disc-shaped end plate 18, which has an axial hole, through which a preferably axially sliding cathode connection and holding conductor 20 is passed in a vacuum-tight manner. On the other end of the annular housing there is an attachment flange 22, which consists of metal, and which forms a beam outlet opening 24.

The arrangement described is held together by means of a casing 26 consisting of acrylic resin and which at one end has a flange 28 which projects inwards and at the other end has a flange 30 which projects outwards. The flange 30 is connected by screw means with the attachment flange 22. Between the flange 28 and the end plate 18 there is a sealing and intermediate ring 32.

On the cathode connection conductor 20 a cathode 34 is attached, whose active part 36 consists of a razor blade stack or a stack of needles, whose cutting edges or tips form an emission surface 38, whose diameter can for example amount to 1 to 5 cm. To the outside a conductor part 40 is connected with the emission surface 38 of the cathode. The surface, adjacent to the beam exit opening 24, of the conductor part 40 adjacent to the emission surface 38 is firstly somewhat concave towards the outlet opening 24 and then forms an annular bead which is convex towards the surface. On the radially outer end of the conductor part 40 there is an anti-corona ring 42. On the electrode holding means 16a-16d there are respectively ring disc electrodes 44a-44d and a further electrode 44e is connected with the attachment flange 22. The electrodes each have a center opening, through which the collimated electron beam running along the axis 10 passes. Following the center opening they have an inner part 44a'-44e', which is respectively so shaped that it runs into an equipotential surface of an electric field, which collimates the electrons which are emitted by the emission surface 38 of the cathode and accelerated towards the outlet opening 24 to form a substantially parallel beam. The beam has in this case no so-called intersection point in contrast to beam producing systems as are used for example in television picture tubes.

Adjoining the inner part 44a'-44e' of the electrodes there is a respective outer part 44a''-44e'', which fulfills two functions. Firstly it serves to prevent the impingement of electrons which have been dispersed from the beam on the inner wall 14 of the tubular hous-

ing as far as this is possible, and secondly it constitutes a mechanical holding means and the electrical connection for the annular electrode holding means 16a-16d, consisting of metal, and, respectively, the attachment flange 24. The axial length of the annular pieces 12a-12e of the housing and thus the position of the annular electrode holding means 16 are so selected that the annular electrode holding means are located at a position, corresponding to the operating voltage provided of the relevant electrode, along the housing. The annular electrode holding means and the attachment flange 22 are thus connected electrically with a liquid 46 with a comparatively high specific resistance, for example a copper sulfate solution, which occupies the intermediate space between the outer wall of the tubular housing 12 and the casing 26 and provides a voltage divider for the operating voltage. The operating voltage is applied between the attachment flange 22 consisting of metal and the end plate 18, also consisting of metal, and also the cathode connection conductor 20.

Preferably the center opening of the first electrode 44a closest to the cathode is covered over by wire fabric 48. Also the center opening of the last electrode 44e at the other end of the housing, that is to say the anode, can be covered with wire fabric 50.

The various electrodes have the following shape in the case of the embodiment shown in FIG. 1.

The inner part 44a' of the first electrode 44a which as seen from the cathode is comparatively close (for example 10 to 20 mm with a distance of 24 cm between the electrodes 44a and 44e) is convex towards the cathode and can as a first approximation be denoted as frusto-conical with a taper towards the cathode. The part 44a'' adjacent to this is arranged to bulge outwards towards the last electrode (anode) 44e convexly.

The second electrode 44b has an inner part 44b' which is substantially frusto-conical and is concave towards the cathode, and an outer part 44b'' which is convex towards the cathode and is substantially frusto-conical. The two next electrodes 44c and 44d are apart from the angle, which the inner and the outer parts make with the axis 10, similarly shaped to the second electrode 44b. In the case of the last electrode (anode) 44e on the other hand both the inner and also the outer parts 44e' and 44e'' are convex towards the cathode, though they form different angles with respect to the axis, as will be gathered from FIG. 1.

The field which is produced by the electrode arrangements described, and of which the further equipotential surfaces lying between the electrodes are shown in broken lines, bringing about a satisfactory collimation of the electrons emitted from the cathode 34 and the shape of the outer parts of the electrodes ensures that practically no stray electrodes can strike the inner wall of the housing 12 and cause arcing on the wall.

By adjusting the distance between the emission surface 38 of the cathode 34 from the wire fabric 48 of the first electrode 44a ("take-up grid") it is possible to set an emission current resulting for a predetermined operating voltage.

Preferred dimensions and operational voltages are shown in FIG. 1. In this respect it was assumed that in operation the connection flange 22 lies at ground potential and the cathode lies at -2 MV. The internal diameter of the annular housing 12 amounts for example to approximately 28 cm and is therefore comparatively large having regard to prior art tubes. The diameter of

the electron beam which is collimated lies in the order of magnitude of 20 mm.

FIG. 2 shows in an extremely simplified form a further embodiment of the invention. In this case only the axis 10, the radial limit 52 of the electron beam, the inner parts of the various electrodes, the wire fabric 48 and 50 and then the inner parts of the electrodes are shown in broken lines while the further course of the ideal equipotential surfaces corresponding respectively to the electrodes are shown. The course of the electrodes can depart from this ideal course at a reasonable distance from the limit 52 of the electron beam in order to fulfill the above-mentioned conditions, which are to be set as regards the outer parts of the electrodes. Since the voltage drop at the liquid 46 operating as a voltage divider, is linear, the loci of the annular electrode holding means of the individual electrodes are fixed. In the case of FIG. 2 (and the following figures) the voltage values are with respect to the cathode.

In FIGS. 3 to 5 only the equipotential surfaces with the associated voltage values are shown, in which case it is assumed that the beam passage openings of the first electrode (draw-off electrode) and the last electrode (anode) are provided with wire fabric (like the wire fabric 48 and 50 in FIG. 1). The inner parts of the electrodes of the corresponding embodiments of the invention then have substantially the same shape as the relevant equipotential surfaces. Naturally it is not necessary for an electrode to be provided for each of the equipotential surfaces represented.

In the case of the field distributions in accordance with FIGS. 3 and 4 it is possible to provide, besides annular disc-shaped electrodes as explained with reference to FIG. 1, bead-shaped electrodes as well, which have, for example, the form of equipotential surfaces 54 and 56.

The saddle potential obtained in the field distribution in accordance with FIG. 3 can instead of the bead-shaped electrodes corresponding to the equipotential surfaces 54 and 56, also be produced by a single bead-shaped electrode 58 (which would then lie at approximately 1.95 MV) or an annular disc-shaped electrode 44f, or by an annular bead electrode 60 (potential 1.95 MV) shaped in cross-section like a pear which is flattened at the bottom.

In the absence of anything to the contrary the beam current I amounts respectively to 1000A.

We claim:

1. An electron beam producing system for acceleration voltages in the order of magnitude of megavolts and beam powers in the order of magnitude of gigawatts, comprising a tubular housing of insulating material, in which adjacent to its one closed end a field emission cathode with a large surface area is arranged while at its other end, from which the electron beam emerges, an annular anode is arranged, and with a device for collimating the electrons emitted by the cathode to form a collimated electron beam, characterized in that: the device for collimating the electron includes annular electrodes, which respectively comprise a part adjacent to their center opening and an outer part which is held on the housing and has a radial electrical passage extending towards the outside of the housing; the inner part of the electrode lying closest to the cathode has at least approximately the shape of a frusto-conical surface which tapers towards the cathode; the inner part of the remaining electrodes is flat and lies in

an equipotential surface of an electric field, which collimates the electrons, emitted by the cathode, to form a parallel beam; the housing is surrounded by a coaxial insulating casing with a clearance; in that the intermediate space between the outer surface of the housing and the casing is surrounded with an electrically conducting liquid with a relatively high specific resistance and at the axial ends has a respective connection electrode, which makes contact with the liquid, for the operating voltage and that the outer parts of the electrodes are so shaped that the radial passages end at those sites of the liquid filled intermediate space at which the fraction, provided for the relevant electrode, of the operating voltage obtains when the operating voltage is applied to the connection electrodes.

2. An electron beam producing system in accordance with claim 1, characterized in that the outer part of the annular electrodes is furthermore so curved that stray electrons are caught by the electrodes before reaching the inner wall of the housing.

3. An electron beam producing system in accordance with claim 1, characterized in that the housing includes tubular parts, between which annular electrode holding means of a conducting material are arranged, which form the passages.

4. An electron beam producing system in accordance with claim 3, characterized in that the inner wall of the housing has ribs extending in the peripheral direction.

5. An electron beam producing system in accordance with claim 1, characterized in that the opening of the electrode closest to the cathode is covered by a wire fabric.

6. An electron beam producing system in accordance with claim 1, characterized in that the opening of the electrode furthest removed from the cathode is covered with a wire fabric.

7. An electron beam producing system in accordance with claim 1, characterized in that the emission surface of the cathode is surrounded by an annular conductor part.

8. An electron beam producing system in accordance with claim 7, characterized in that the zone, adjacent to the emission surface, of the annular conductor part as seen from the adjacent annular electrode is concave.

9. An electron beam producing system in accordance with claim 7, characterized in that the radially outer part of the surface, adjacent to the emission surface, of the annular conductor part as seen from the adjacent annular electrode is convex.

10. An electron beam producing system in accordance with claim 1, characterized in that the cathode is axially adjustable with respect to the annular electrode adjacent to it.

11. An electron beam producing system in accordance with claim 1, characterized in that the emitting part of the cathode includes a stack of razor blades.

12. An electron beam producing system in accordance with claim 1, characterized in that the emitting part of the cathode consists of a stack of needles.

13. An electron beam producing system for acceleration voltages in the order of magnitude of megavolts and beam powers in the order of magnitude of gigawatts, comprising a tubular housing of insulating material, in which adjacent to its one closed end a field emission cathode with a large surface area is arranged while at its other end, from which the electron beam emerges, an annular anode is arranged, and with a de-

vice for collimating the electrons emitted by the cathode to form a collimated electron beam, characterized in that: the device for collimating the electron includes annular electrodes, which respectively comprise a part adjacent to their center opening and an outer part which is held on the housing and has a radial electrical passage extending towards the outside of the housing; the inner part of the electrode lying closest to the cathode has at least approximately the shape of a frusto-conical surface which tapers towards the cathode; the inner part of the remaining electrodes is at least approximately frusto-conical and lies in an equipotential surface of an electric field, which collimates the electrons, emitted by the cathode, to form a parallel beam;

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the housing is surrounded by a coaxial insulating casing with a clearance; the intermediate space between the outer surface of the housing and the casing is surrounded with an electrically conducting liquid with a relatively high specific resistance and at the axial ends has a respective connection electrode, which makes contact with the liquid, for the operating voltage and that the outer parts of the electrodes are so shaped that the radial passages end at those sites of the liquid filled intermediate space at which the fraction, provided for the relevant electrode, of the operating voltage obtains when the operating voltage is applied to the connection electrodes.

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