United States Patent

Kosmahl

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[54] **ELECTROSTATIC COLLECTOR FOR CHARGED PARTICLES**

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[73] Assignee: **The United States of America as represented by the Administrator of the National Aeronautics and Space Administration**

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[52] **U.S. Cl.**.....**315/5.38**, 315/3.5

[51] **Int. Cl.**.....**H01j 23/02**

[58] **Field of Search**.....315/5.38, 3.5

[56] **References Cited**

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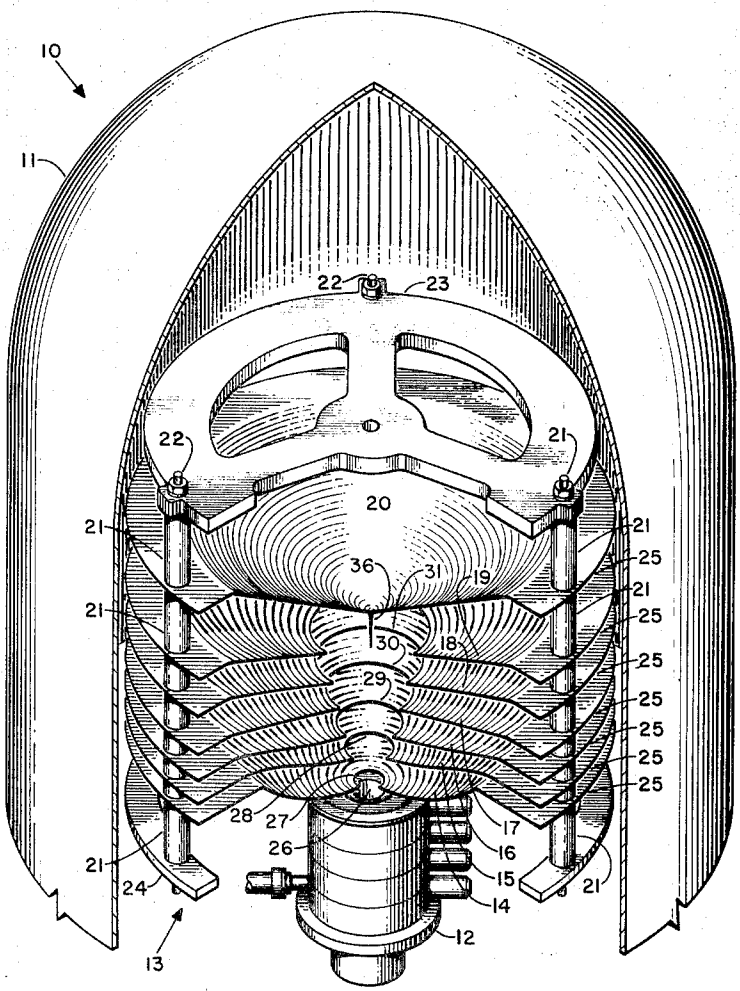
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[57] **ABSTRACT**

A charged particle collector comprising a stack of apertured electrode plates which lie within an imaginary sphere is provided. The plate closet to a charged particle emitter forms a portion of the imaginary sphere and is at zero volts potential with respect to the emitter. The plate farthest away from the charged particle emitter is of conical shape with the apex pointing toward the emitter and includes a spike extending toward the emitter. The conical plate has either a negative or positive potential with respect to the emitter, depending on whether the charged particles are negative or positive. A plurality of intermediate apertured electrode plates are positioned between the plate which forms a portion of the sphere and the conical plate, each of the plates being at a slightly lower potential than the preceding plate moving in a direction toward the emitter. These intermediate plates approximate the shape of an equipotential line which would be plotted for the particular voltage applied to the plate.

10 Claims, 2 Drawing Figures



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SHEET 1 OF 2

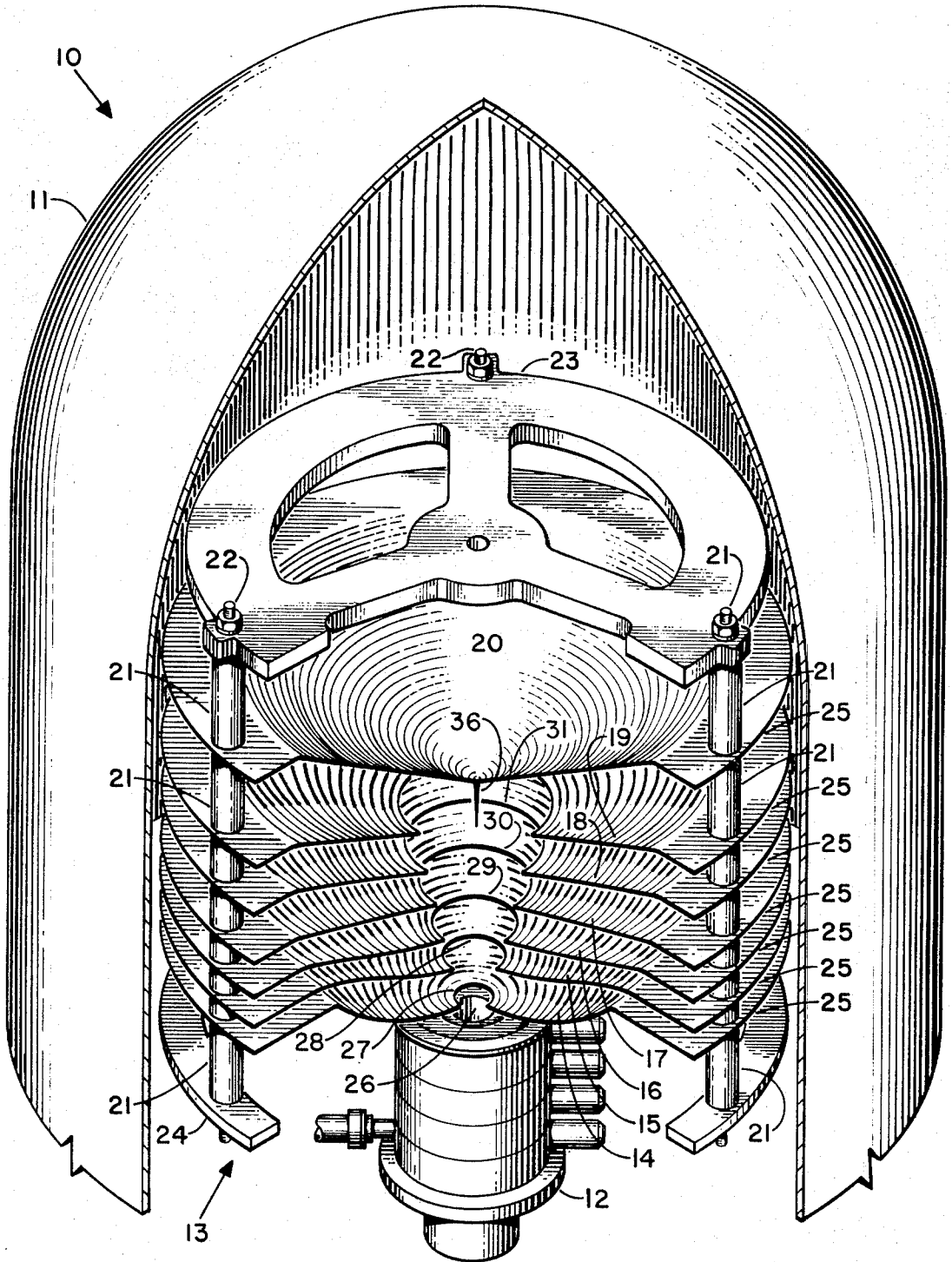


FIG. 1

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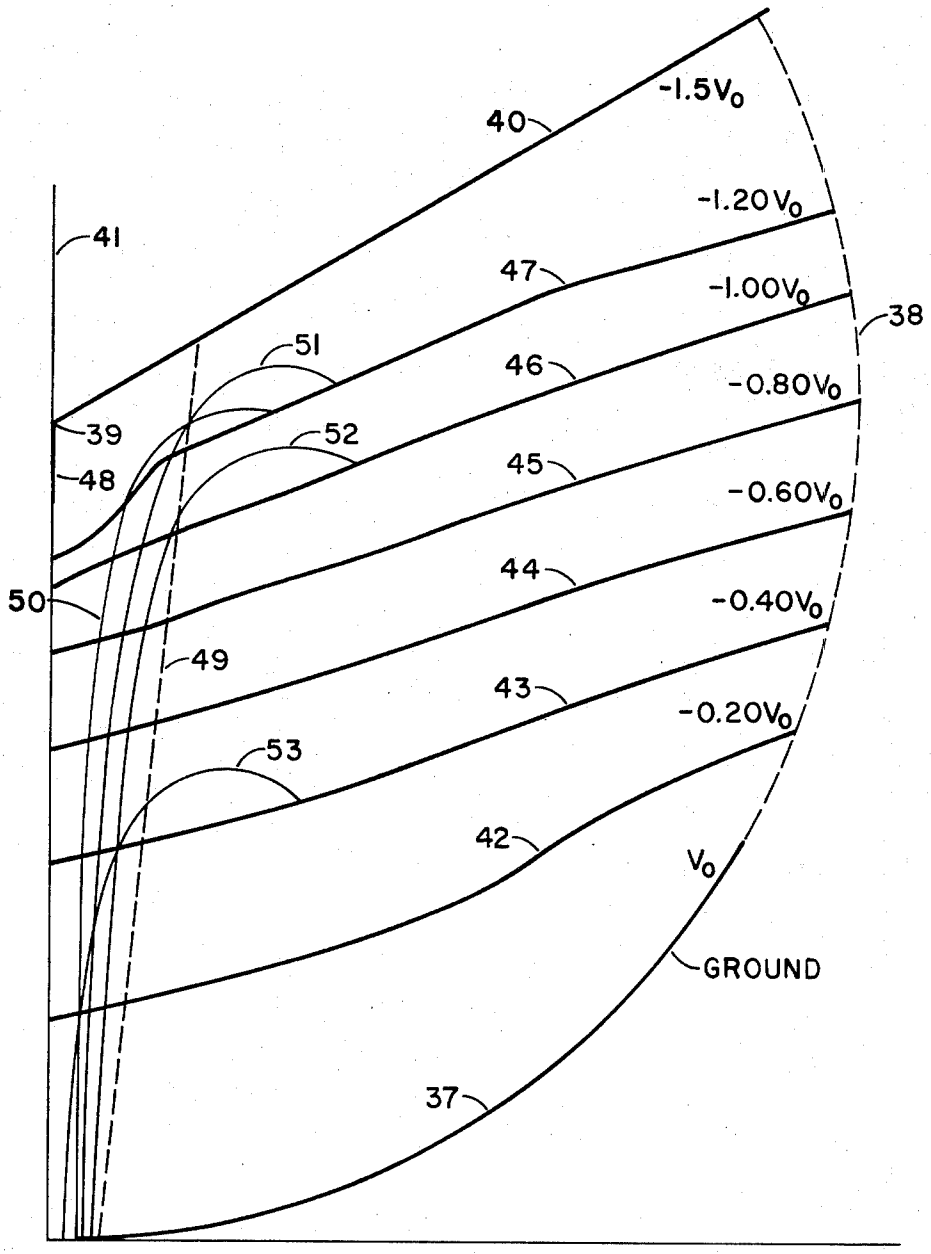


FIG. 2

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ELECTROSTATIC COLLECTOR FOR CHARGED PARTICLES

ORIGIN OF THE INVENTION

The invention described herein was made by an employee of the United States Government and may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

This invention relates to devices which produce charged particles as a consequence of their operation and is directed more particularly to a charged particle collector for such devices. Such devices include, but are not limited to for example, microwave tubes and fusion devices.

Microwave electron tubes are used to generate radio frequency electromagnetic waves in such devices as radar sets and television transmitters. With the advent of space communication systems using orbiting satellites there is a demand for maximum efficiency and for the elimination of cooling problems associated with microwave tubes. The relatively low efficiency and heating problems of prior art tubes result from spent electron beams emerging from the exits of microwave tubes and producing heat and energy losses in such tubes when they strike the walls of the tube shell or enclosure.

In the past, attempts have been made to reduce the velocity of spent electrons and collect them on surfaces at the lowest possible potentials by using depressed collectors, that is a collector comprising elements which are at low potential with respect to the electron emitter source.

Some prior art depressed collectors consisted of two or more cylindrical, axially aligned segments insulated from each other and shielded from a magnetic field established to focus the electron beam. Such arrangements provided a significant improvement in efficiency but caused strongly curving fringing fields which prevent collecting electrons at the lowest possible potential and which additionally caused undesirable backstreaming of many electrons.

Further improvements in depressed-type collectors have been made by providing the depressed collector with a spike pointed toward the electron emitting source and carrying a negative potential. Although the depressed collector utilizing a spike has further improved the efficiency of microwave tubes, much greater improvements in efficiency are required to minimize the weight and to reduce the heating and sputtering problems with respect to satellite communication systems.

Like microwave tubes fusion devices, as part of their operation, produce a beam of spent charged particles having a range of kinetic energies. The charged particles, in the case of a fusion device, are ions which carry a positive charge. As in the case of microwave tubes, it is desirable to collect the spent charged particles to increase efficiency and to reduce sputtering and heating.

OBJECTS AND SUMMARY OF THE INVENTION

In view of the foregoing, it is an object of the invention to provide a new and novel charged particle collector of the depressed type.

It is another object of the invention to provide for a microwave tube a collector which will minimize space charge effects and blocking which occur in the collector regions of microwave tubes.

Still another object of the invention is to provide a collector which will control electron trajectories with lens effects by providing parameters which result from exactly solving the boundary value problem.

Yet another object of the invention is to provide a collector which independently effects the sorting of low and high energy charged particle groups by utilizing sloped electrode plates and an axial spike, respectively.

An additional object of the invention is to provide a microwave tube wherein the electron source appears to the collector as a point source thereby making variations in the position of entry of electrons into the collector unimportant.

A further object of the invention is to provide a new and novel microwave collector which eliminates backstreaming of secondary and primary electrons into the collector entrance.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cutaway pictorial drawing of a microwave tube and collector embodying the invention.

FIG. **2** is a graph of the equipotential lines found in a collector arrangement embodying the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

While the following description is directed to a collector for a microwave tube, it will be understood that the same collector arrangement may be used for the ion beam of a fusion device by reversing the electrical potential on the collector. The same equations for equipotential lines apply to the electron collector and the ion collector.

Referring now to FIG. **1**, there is shown a microwave tube **10** comprising an evacuated shell **11** in which is disposed a microwave amplifier tube **12** which serves as the source of a beam comprised of spent electrons and an electron collector assembly **13**. The collector **13** is comprised of a stack of electrodes in the form of plates **14**, **15**, **16**, **17**, **18**, **19** and **20** which are retained in spaced apart positions by insulators **21** through which are threaded bolt **22**. As viewed in FIG. **1**, the bolts **22** also extend through an upper support plate **23** and through a lower support ring **24**. Each of the electrodes **14** through **20** includes an annular, radially extending flange **25** which is clamped between the insulators **21**.

The electrode **20** is conical in shape and disposed downstream of a beam of electrons emitted from an exit **26** of the microwave electron tube **12**. The apex of the conical electrode **20** lies on the axis of the electron beam emitted from exit **26** and is pointed toward the microwave tube **12**. A short spike **36** extends from the apex of electrode **20** toward the electron beam source **12** and is symmetrical about the axis of the electron beam.

The electrode **14** is of concave shape, as viewed from the electrode **20**, and is axisymmetric with respect to the electron beam. The curvature of electrode **14** is such that it forms a portion of an imaginary sphere whose center is at the apex of the conical electrode **20**.

To allow passage of the electron beam upwardly through the electrodes **14** through **19**, each is provided with respective central apertures **27, 28, 29, 30, 31** and **32**. Preferably, the apertures increase in size in a downstream direction from the electron exit **26** so that electrons of the electron beam will not strike the lower or upstream surface of the electrodes as electron beam spreads or increases in diameter in a downstream direction. On the other hand, the apertures must be small enough in size so that electrons falling back toward the microwave tube **12** will not fall past any electrode without being caught, that is, the electron will fall onto the surface of an electrode.

The microwave tube **12** is at ground potential (or positive) with respect to the collector **13**. The electrode **14** is also at ground potential while the electrode **20** is at a negative potential which, in the instant case, is about 1.5 V.

In the electrode **13** just described, the spike **36** serves to deflect high energy electrons. The relatively low energy electrons are collected by the sloped apertured electrode plates **14** through **19**.

Referring now to FIG. **2**, there is shown a graph of the equipotential points for various voltages which may be applied to the electrodes of a collector embodying the invention. Line **37** connects points which are at ground potential. As shown, line **37** forms part of the surface of a sphere which is further defined by the dashed line **38**. The radius of curvature of lines **37** and **38** emanates from a point **39** which is at the center of a sphere partially defined by lines **37** and **38**.

Line **40** connects points having the maximum negative potential on the collector. It will be understood by those skilled in the art that the shape of lines **37** and **40** are determined by the shape of electrodes **14** and **20**, respectively, of FIG. **1**. Thus, if lines **37** and **40** were rotated about the axis **41** they would generate a portion of a sphere and a cone, respectively, which have the same shape as electrodes **14** and **20**, respectively.

The lines **42, 43, 44, 45, 46** and **47** define equipotential levels which increase negatively in the direction toward the line **40**. To construct a collector in accordance with the invention, the intermediate electrodes between the conical electrode **20** and the concave electrode **14**, the intermediate electrodes would have shapes which would be approximately defined by rotating lines **42** through **47** about an axis defined by line **41**. The lines **42** through **47** would first be calculated in view of the desired difference in potential between electrodes **14, 20** and the desired equipotential levels between those electrodes. Of course, it will be understood that the number of intermediate electrodes will be determined by the degree of efficiency required in view of other considerations such as minimum weight. The line **48** in FIG. **2** represents the potential on spike **36** which, as will be seen from FIG. **2**, is the same as the potential along line **40** and which is present on electrode **20**.

It will be seen from the graph of FIG. **2** that electrodes which are formed in accordance with the equipotential lines **42, 43** and **44** are quasi-spherical in that the radius of curvature of each line is not uniform. It will also be noted that the radius of curvature of line **43** is greater than the radius of line **44** which, in turn, is greater than the radius of curvature of line **44**.

Lines **45, 46** and **47**, on the other hand, represent electrodes which are quasi-conical. It will also be seen that the included angle of an electrode determined by line **45** is greater than the included angle of an electrode determined by the line **46**. Likewise, an electrode formed by revolving line **46** about axis **41** has a greater included angle than one determined by line **47**.

As indicated previously, the apertures **27** through **31** preferably increase in diameter in a downstream direction in order to minimize the number of electrons which strike the lower surfaces of the electrodes as the electron beam spreads in a downstream direction. Dashed line **49** in FIG. **2** defines the apertures which would be provided in electrodes of a collector made in accordance with the voltages utilized in the graph of FIG. **2**. Thus, the distance between the axis **41** and the dashed line **49** would be the radius of the aperture for a particular equipotential electrode. The apertures thus defined increase linearly in size because line **49** is a straight line. However, the apertures may increase in size non-linearly depending on the kinetic energies in the electron beam and the voltages to be applied to the electrodes.

The lines **50, 51, 52** and **53** are illustrative of paths which may be taken by electrons of different kinetic energies and subject to different radial accelerations in a collector made in accordance with the equipotential surfaces represented by lines **37, 40** and **42** through **48** of FIG. **2**.

It will be understood that the foregoing invention may be changed or modified by those skilled in the art without departing from the spirit and scope of the invention, as set forth in the claims appended hereto.

What is claimed is:

1. A collector for a source which emits a beam of spent charged particles comprising

a first conical electrode disposed downstream of said source of charged particles symmetrical to the axis of the charged particle beam and having its apex pointing toward said source of charged particles,

a spike disposed on the apex of said conical electrode symmetric to the axis of the beam and pointing toward said source of charged particles, and

a concave electrode disposed between said conical electrode and said source of charged particles symmetric to the axis of the beam and including a central aperture, the concave side facing said conical electrode, said conical electrode being at a voltage potential of the same polarity as that of said charged particles with respect to said concave electrode.

2. The structure of claim **1** and including a plurality of centrally apertured intermediate electrodes disposed between said concave and conical electrodes symmetric to the axis of the beam and with the central area of each of said apertured electrodes depressed toward the source of spent charged particles, each of said apertured electrodes being a higher voltage potential than the electrode between it and the source of spent electrons.

3. The structure of claim 2 wherein the apertures increase in size in a downstream direction from the source of spent charged particles.

4. The structure of claim 2 wherein said spike extends through the aperture of the one of said apertured electrodes next below the negative potential of said conical electrode.

5. The structure of claim 2 wherein each electrode is shaped such that any point on it lies at approximately the same point as a corresponding equipotential point of a potential equal to the voltage potential applied to the electrode.

6. The structure of claim 1 wherein said conical electrode has an included angle of about 120°.

7. The structure of claim 1 wherein said concave electrode is a portion of a sphere whose center lies at the apex of said conical electrode.

8. The structure of claim 1 wherein the apertured electrodes nearest said conical electrode are quasi-conical and the apertured electrodes nearest said concave electrode are quasi-spherical portions.

9. The structure of claim 8 wherein the included angle of each of said quasi-conical electrodes is substantially greater than the next downstream quasi-conical electrode and wherein curvature of said quasi-spherical portions of each electrode is substantially less than the next upstream electrode.

10. The structure of claim 1 wherein said spike extends from the apex of said conical electrode approximately one-fourth of the distance to the source of the charged particle beam.

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