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3,371,204

MASS FILTER WITH ONE OR MORE ROD ELECTRODES SEPARATED
INTO A PLURALITY OF INSULATED SEGMENTS

Filed Sept. 7, 1966

2 Sheets-Sheet 1

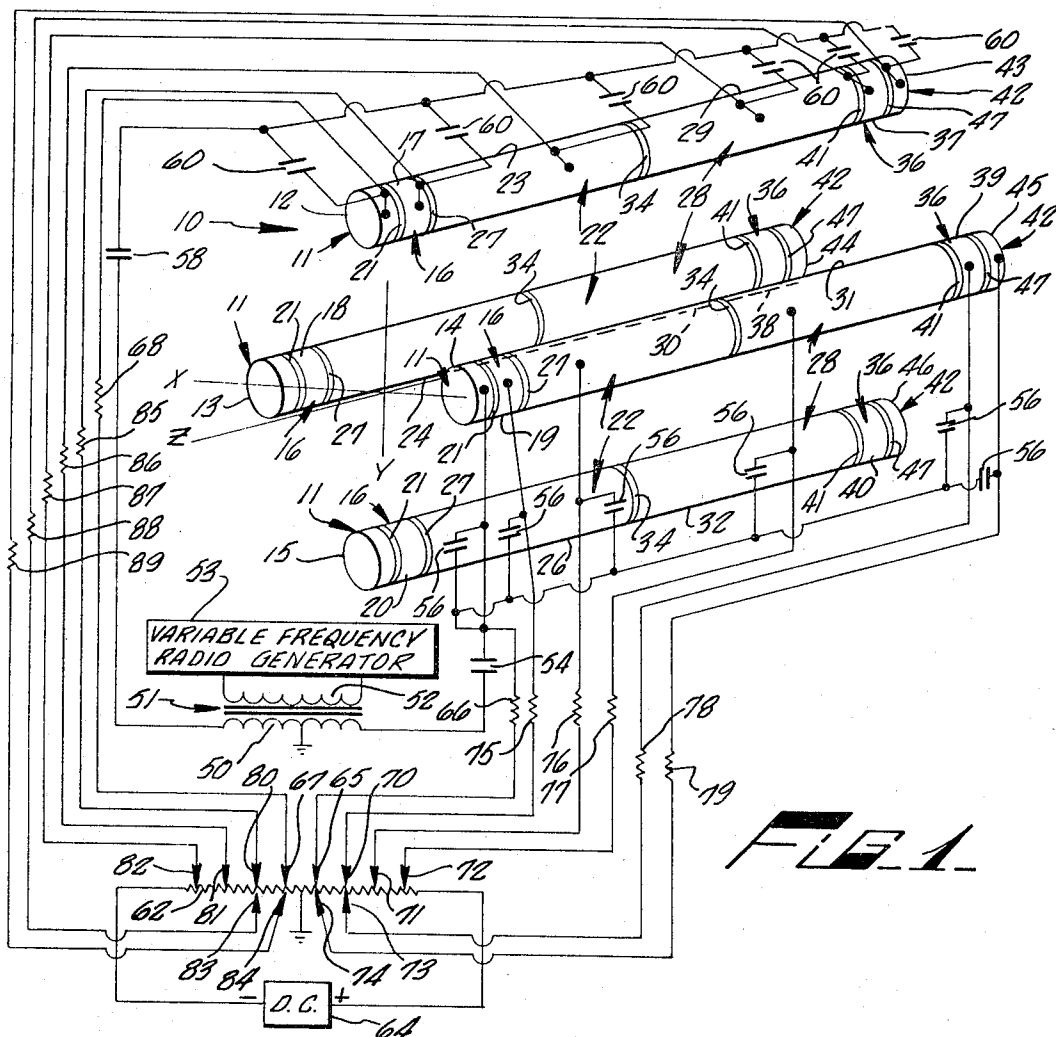


FIG. 1

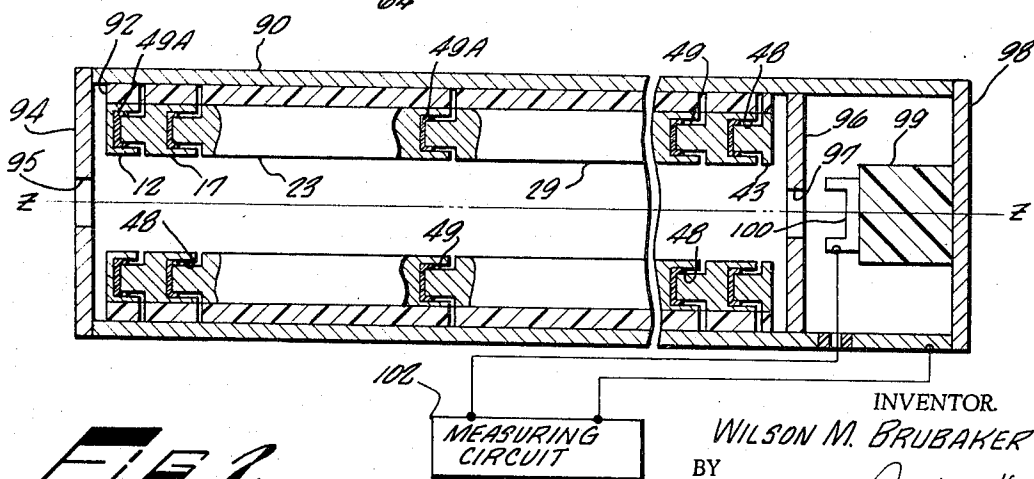


FIG. 2

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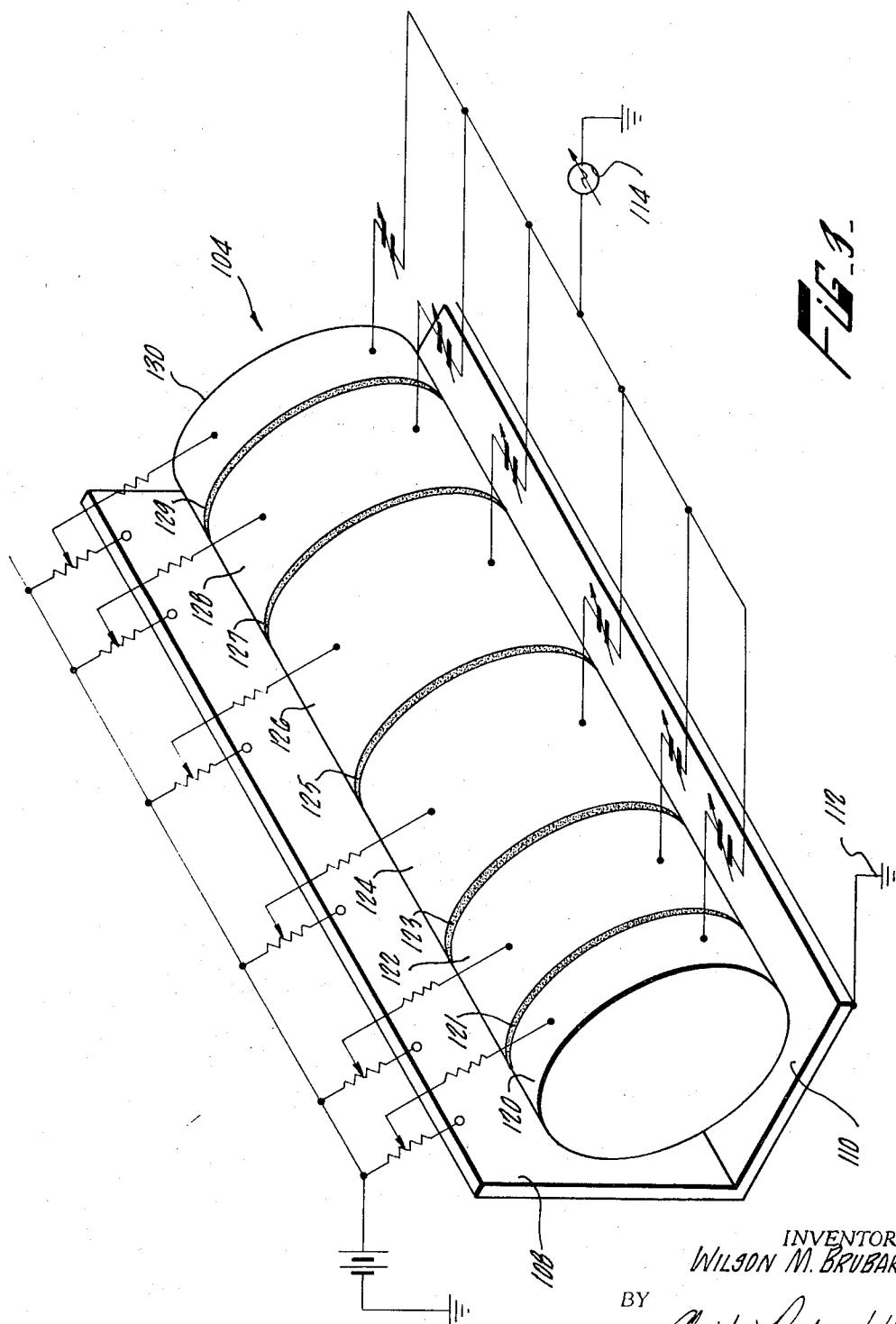
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MASS FILTER WITH ONE OR MORE ROD ELECTRODES SEPARATED INTO A PLURALITY OF INSULATED SEGMENTS

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Continuation-in-part of application Ser. No. 492,985, Sept. 20, 1965. This application Sept. 7, 1966, Ser. No. 593,231

12 Claims. (Cl. 250—41.9)

ABSTRACT OF THE DISCLOSURE

A non-magnetic mass filter utilizing one or more rod electrodes to create a mass analyzing electric field in the vicinity of the electrode. The rod electrode or electrodes are broken into two or more insulated segments with the voltages applied to the rod segment nearest the entrance end and/or the exit end of the filter having a magnitude less than the voltage applied to the segments located interiorly of the exit and entrance ends of the filter.

This is a continuation-in-part of application Ser. No. 492,985, filed Sept. 20, 1965 and now abandoned, which was a continuation-in-part of application Ser. No. 255,811, filed Feb. 4, 1963, and now abandoned.

This invention relates to mass filters, and provides an improved arrangement of electrodes in mass filters to enhance their operating characteristics and capabilities. The invention is adaptable for use in monopole as well as multipole mass filters, and is described in detail as embodied in a monopole and a quadrupole mass filter.

The basic function of any mass filter is to separate or selectively pass ions having different ratios of mass-to-charge (m/e). The multipole mass filter accomplishes this in a unique way, without a magnet, by utilizing the motion of charged particles in a multipole electric field having both alternating and static components.

A monopole mass filter such as that described in U. S. Patent 3,197,633 is similar in principle to multipole mass filters with the exception that the former is provided with one rod while the latter has two or more rods. In the monopole, a right angle electrode faces the rod and images the effect of the missing rods, causing charged particles introduced into the filter to experience electric fields similar to those of a multipole filter. Although the parameters of rod size and the amplitude and frequency of the energizing voltages are normally different for monopole as compared to multipole mass filters, the principle of operation and mass analysis results are similar as the following explanation will illustrate.

In a typical multipole mass filter, such as that described in U.S. Patent No. 2,939,952, four elongated continuous electrodes in the form of parallel cylindrical rods are arranged symmetrically about a central axis. The rods are electrically connected in pairs, opposing rods being connected together. If Z denotes the central axis of the rods, then one pair of rods lie with their centers on the X axis, and the other pair on the Y axis, the three axes being mutually perpendicular according to the convention of rectangular cartesian coordinate system. Both AC and DC voltages are applied to the rods. Ions or charged particles are introduced at one end of the filter and travel generally down the central axis of the filter. In traversing the filter, ions of different m/e ratios are separated so that only ions of a selected m/e ratio have stable trajectories and emerge from the outlet end of the filter to reach and charge an ion collector,

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which is connected to a current indicator. Those charged particles which are outside the selected m/e range have unstable trajectories and impinge on the field-generating electrodes and thus are removed. Ion selection is controlled by varying the voltage levels on the electrodes or by varying the frequency of the AC voltages.

The monopole and multipole mass filters are potentially very useful for upper atmosphere research, as analytical devices in a satellite vehicle or the like, where the ion source for the filter is the space surrounding the satellite. For such applications, the filter must have high sensitivity, high resolving power, and must consume as little electrical power as possible. Under these conditions, these filters suffer a serious loss in transmission efficiency, i.e., many of the ions entering the filter with the selected m/e ratio which should traverse the filter and emerge at the exit do not do so.

My copending application, Ser. No. 158,697, filed Dec. 12, 1961, now Patent No. 3,129,327, discloses and claims a system for improving the transmission efficiency of a multipole filter by the use of auxiliary electrodes at one or both ends of the filter. The auxiliary electrodes in my copending application are used to decrease the ratio of the static to the peak alternating component of the multipole electric field adjacent at least one end of the filter.

In accordance with the present invention, a mass filter is provided having a source of charged particles located at one end of the filter. The filter includes at least one rod comprising a plurality of electrically insulated electrodes and additional electrode means located adjacent the rod and coextending in a parallel relationship therewith substantially along the length of the rod, the rod and electrode means defining a filter axis therebetween. A source of AC voltage and means for applying the voltage from the source to the electrodes of the rod for creating a single alternating electric field component between the rod and the additional electrode means are provided as is a source of DC voltages of variable magnitudes and means for applying selected voltages from the DC source to the electrodes of the rod for producing different static electric field components between the rod and the additional electrode means. The DC voltage applied to an electrode at one end of the rod is different than the magnitude of the DC voltage applied to an electrode located interiorly of said end electrode. In addition charged particle collector means are located at the end of the filter opposite the charged particle source and means for adjusting the ratio of the static electric field to the alternating electric field is provided to select charged particles of a predetermined mass to charge ratio for transmission through the filter to the collector means and to deflect charged particles of other mass to charge ratios away from the filter axis.

With the mass filter of this invention, the ratio of the static (DC) to the peak alternating (AC) component of the monopole or multipole electric field in each electrode or array respectively, can be set to any desired value by variation of the applied DC voltages to achieve maximum transmission efficiency for charged particles of different m/e ratio.

In the preferred embodiment, the ratio of the DC component to the alternating component is lower at one end of the filter than intermediate the filter ends. In one form, the ratio of DC to AC voltage is substantially zero at the inlet end of the filter. In some instances, the ratio of the DC component to the alternating component is lower at each end than intermediate the ends of the filter. Preferably, the electrodes in the array at one end of the filter are shorter than the electrodes in one or more arrays located between the ends of the filter. The electrodes may be of equal length since it is not necessary

that the different parts of the field in the linear direction be of any particular relative length. Since, however, the gradient at the ends of the field need only be of relatively short length and the resolution of the filter is a function of the overall length of the field, in preferred practice the end electrodes are shorter than the intermediate electrodes. As will be shown in the following discussion of the illustrated unit, each rod may be composed of relatively short end electrodes, somewhat longer electrodes adjacent the ends, and still longer central electrodes. The preferred form of the invention also includes means for varying the value of the different DC voltages applied to the electrodes in each array.

The same technique of extending the entrance field by applying less than full AC potentials on the first short portion of the rod, and of reducing the ratio of the DC to the AC potentials on this first short portion, is equally applicable to the monopole mass filter as it is to the quadrupole mass filter.

These and other aspects of the invention will be more fully understood from the following detailed description in which:

FIG. 1 is a schematic perspective view showing one form of an electrode system in accordance with this invention, and a circuit for applying the voltages to the rods;

FIG. 2 is a schematic sectional elevation of the rods shown in FIG. 1 installed in a mass filter housing; and

FIG. 3 is a schematic perspective view of an embodiment of the invention as adapted for use in a monopole mass filter.

Referring to FIG. 1, an electrode system 10 includes a first array 11 of an upper electrode 12, a left electrode 13, a right electrode 14, and a lower electrode 15 (as viewed in FIG. 1). The four cylindrical electrodes in the first array are symmetrically disposed in a substantially coextensive parallel relationship about a central longitudinal axis Z. The axes of the upper and lower electrodes in the first array lie in the Y-Z plane, and the axis of the left and right electrodes in the first array lie in the X-Z plane. The X, Y, and Z axes are mutually perpendicular. A second array 16 includes upper, left, right, and bottom electrodes 17, 18, 19, and 20, respectively, which are each cylindrical and collinear with the upper, left, right, and lower electrodes, respectively, in the first array. Adjacent ends of collinear electrodes in the first and second arrays are separated by thin discs 21 of electrical insulating material. Alternatively, the insulating discs may be omitted, and the electrodes are merely spaced from each other so that they are not electrically connected. The electrodes in the second array are substantially coextensive and are substantially longer than the electrodes in the first array.

A third array 22 includes cylindrical and coextensive upper, left, right, and lower electrodes 23, 24, 25, and 26, respectively, each disposed to be collinear respectively with the upper, left, right, and lower electrodes in the first and second arrays. The electrodes in the third array are substantially longer than those in the second array, and adjacent ends of collinear electrodes in the second and third arrays are separated from each other by insulating discs 27.

A fourth array 28 includes cylindrical and coextensive upper, left, right, and lower electrodes 29, 30, 31, and 32, respectively, which are identical and collinear with corresponding upper, left, right, and lower electrodes in the third array. Adjacent ends of electrodes in the third and fourth arrays are separated by insulating discs 34.

A fifth array 36 includes cylindrical and coextensive upper, left, right, and lower electrodes 37, 38, 39, and 40, respectively, disposed coaxially with the upper, left, right, and lower electrodes, respectively, of the fourth array. Adjacent ends of the collinear electrodes in the fourth and fifth arrays are separated by electrically insulating discs 41.

A sixth array 42 includes cylindrical and coextensive upper, left, right, and lower electrodes 43, 44, 45, and 46, respectively, each collinear with the upper, left, right, and lower electrodes, respectively, in the fifth array. Electrically insulating discs 47 separate the adjacent ends of the collinear electrodes in the fifth and sixth arrays.

As shown best in FIG. 2, adjacent ends of collinear electrodes telescope together so that each insulating disc is not exposed to ion bombardment to avoid building up a charge on them. One end of an electrode includes a circular recess 48 into which fits a circular projection 49 on the adjacent end of the next electrode. An annular flange 49A on each disc fits over the end of the projection and keeps the electrodes out of contact.

An AC voltage is applied to the electrodes in the arrays from the secondary winding 50 of a transformer 51 which has its primary winding 52 connected to the output of a variable frequency radio generator 53. One end of the secondary winding is connected through a blocking capacitor 54 to the left and right electrodes of the arrays, i.e., to those electrodes lying in the plane determined by the X and Z axes. For clarity, the wiring for only the right electrodes in the arrays is shown. However, as indicated previously, the diametrically opposed electrodes in each array are electrically interconnected so that they are at the same potential. Thus, each series of collinear electrodes forms a separate segmented rod of uniform external diameter in which the segments are electrically insulated from each other. The electrodes in each rod or column are isolated by blocking capacitors 56.

The other end of the secondary winding is connected through a blocking capacitor 58 to the upper and lower rods, the axes of which lie in the plane defined by the Y and Z axes. For clarity, the electrical connection to the lower electrodes in each array is not shown, although, as indicated previously, the upper and lower electrodes in each array are electrically interconnected so they are at the same voltage. The upper and lower electrodes in the arrays are isolated against the DC voltage by blocking capacitors 60.

A potentiometer winding 62 is connected across a DC power source 64 and is grounded at its center. A first positive movable tap 65 set near the center of the winding on the positive side supplies a relatively low positive DC voltage through a resistor 66 to the left and right electrodes in the first array. A first negative adjustable tap 67 is set near the center of the winding on the negative side and supplies a relatively low negative DC voltage through a resistor 68 to the upper and lower electrodes in the first array. Positive second, third, fourth, fifth, and sixth adjustable taps 70, 71, 72, 73, and 74 are respectively connected through resistors 75, 76, 77, 78, and 79 to the left and right electrodes in the second, third, fourth, fifth, and sixth arrays, respectively. Similarly, negative second, third, fourth, fifth, and sixth adjustable taps 80, 81, 82, 83, and 84 on the negative side of the potentiometer winding supply negative DC voltage through resistances 85, 86, 87, 88, and 89 to the upper and lower electrodes in the second, third, fourth, fifth, and sixth arrays, respectively.

The distance of any negative tap from the grounded center point of the potentiometer is equal to the distance of the corresponding positive tap so that equal but opposite DC voltages are applied to adjacent electrodes in each array. Mathematically, this is expressed as

$$V_{DCxn} = -V_{DCyn}$$

where the subscript "n" indicates the array, and the letters x and y indicate the voltage applied to the electrodes lying on the X and Y axes, respectively.

Since the secondary winding of the transformer is center tapped to ground, then the AC voltage applied across adjacent electrodes in every array is equal but opposite. This is written mathematically as follows: $V_{ACx} = -V_{ACy}$.

Moreover, the DC voltage applied to the electrodes

in any array is some proportion of the peak alternating voltage and is expressed mathematically as follows:

$$[V_{DCxn}=0.168kV_{ACxn}]$$

and

$$[V_{DCyn}=0.168kV_{ACyn}]$$

where k is a constant with a value between 0 and 1 and the other subscripts are as designated above.

As shown in FIG. 2, the electrode assembly of FIG. 1 is disposed within an elongated cylindrical metal housing 90, with each of the electrodes mounted on a respective insulator 92 secured to the interior wall of the housing.

A conductive plate 94 is mounted across the inlet end of the housing, and has a centrally located circular aperture 95 which forms the ion entrance for the filter. A second conductive plate 96 is mounted at the outlet end of the electrodes within the housing, and it has a central circular aperture 97 which serves as the ion exit for the filter.

The outlet end of the housing is closed by a conductive rear wall 98. An electrical insulating support 99 is mounted on the interior of the rear wall and an ion collector electrode 100 is mounted on the support opposite the ion exit aperture. Ions of various mass-to-charge ratios enter the entrance aperture, but only ions of the selected mass-to-charge ratio traverse the filter, impinge on the collector, and electrically charge it. The remaining ions strike the electrodes and are neutralized. The ion current is measured by a conventional measuring circuit 102 connected between the ion collector and the ground. The conductive housing, aperture plates and the rear wall are all at ground potential.

When used in the laboratory, the housing is evacuated and an ion source is mounted over the entrance aperture. For upper atmosphere research, the ion entrance aperture is open and the vacuum inside the device is the vacuum of space.

Referring to FIG. 3, illustrating a monopole mass filter embodying the improvement of the present invention, one segmented field rod 104 is provided, the rod being made up of six electrodes 120, 122, 124, 126, 128, and 130 separated by electrically insulating discs 121, 123, 125, 127, and 129, respectively. The rod 104 is disposed and supported at a predetermined distance from the two planes 108 and 110 of the reference right angle electrode 106. The reference electrode 106 is connected to a source of reference voltage, such as ground potential 112, and the electrodes comprising the rod 104 are connected to a source of AC voltage 114 and DC voltage 116 such that an analyzing electric field is created in the space between the right angle electrode 106 and rod 104. These voltage sources are adapted to be varied by circuitry similar to that of FIG. 1 so that the different electrode segments of the rod 104 can be maintained at different potentials.

In operating the mass filter of this invention, voltages are applied to the rods as generally indicated in FIG. 1. The AC component of the voltage is the same for all electrodes lying on the Y axis, and is equal but opposite in polarity for all electrodes on the X axis. Preferably, a relatively low, or even zero, DC voltage is imposed on the electrodes in the first and sixth arrays. A larger DC voltage is applied to the electrodes in the second and fifth arrays, and a still larger DC voltage is applied to the electrodes in the third and fourth arrays.

In those instances where space charge is a problem, it is preferable that a larger DC voltage be applied to the electrodes in the fourth array than to those in the third array. The short electrode at the entrance end of the filter at the relatively low or zero DC potential and substantially full AC potential alternate the entrance field conditions to decrease the transient impulse which the ions received as they traverse the region where the DC field intensity varies from a low to larger values. The

advantage of this condition is increased resolution, increased sensitivity, or standard performance at lower power levels, or a combination of all three of these factors.

The increase in DC voltage in the region between the third and fourth arrays permits the operation of the front portion of the filter at a lower resolving power than the rear portion. The advantage is that the space charge of an intense ion beam does not alter the potentials so as to cause the loss of ions whose trajectories would otherwise be stable in the absence of the space charge. In a leak detector, for instance, a space charge of a large quantity of air ions can cause the loss of some of the ions of the detection gas, say helium, in the ordinary mass filter. However, with the resolution set lower on the forepart in accordance with this invention, the ions with trajectories that are very unstable in the latter part of the filter are still lost to the electrodes. But by energizing the forepart of the filter with a lower level of DC potentials, the stability of the detection gas ions is increased so that the distortion of the fields caused by space charge does not cause them to be lost.

When a portion of the rear end of the filter is energized with a relatively low value of DC potentials compared to the intermediate portion of the filter, the "spring constant" of the oscillating ions is effectively increased. By gradually decreasing the DC potentials toward the outlet end of the filter, the amplitude of the oscillations of the ions is decreased, so that they leave the filter at a smaller distance from the axis than if the DC potentials were uniform. In many cases, it is desirable to have the ions emerge from a smaller exit aperture. It permits the use of a smaller collector, which is of prime importance if a secondary emission multiplier is used in the measuring circuit. The smaller exit aperture also decreases the electrostatic coupling to the collector, which is important for shielding the collector from changes in electrode potentials, and thereby reduce spurious signals. If the geometrical and electrical symmetry is not perfect, the undesired zero shift occurs in the measuring circuit during voltage scans. This disadvantage is reduced or eliminated by the decreasing DC potentials at the outlet end of the filter.

In a modification of the operation of a mass filter of this invention, voltages are again applied to the rods; however, the AC voltage component can be varied in addition to the DC component. The electrodes of the rods in the X-Z axis then have different AC voltage components, but the corresponding electrodes of rods in the Y-Z axis have equal different AC voltage components of opposite polarity. The ability to vary the AC voltage component further enhances the resolution efficiency, sensitivity and low power level performance of the mass analyzing field.

While the invention has been illustrated and described with relation to the preferred embodiment in which the filter rods are segmented and connected in electrical circuit to provide a field gradient at both the entrance and exit ends of the filter, the invention is not so limited. It is useful to provide such a gradient at either end of the filter, the entrance end being the most important with respect to improvement of the transmission efficiency.

In short, the collinear electrodes insulated from each other permit a wide variety of electrical field conditions to be produced within a mass filter so that it can be adjusted to optimum operating characteristics and capabilities for different types of applications. Moreover, the DC potential gradient can be made to change as gradually or abruptly as desired by simply using more or less collinear electrodes of desired lengths. This advantage is obtained without interfering with the effective internal diameter of the filter.

What is claimed is:

1. A mass filter comprising:

a source of charged particles located at one end of the filter;

at least one rod, said rod comprising a plurality of electrically insulated electrodes;
 additional electrode means located adjacent said rod and co-extending in a parallel relationship therewith substantially along the length of the rod, the rod and electrode means defining a filter axis therebetween;
 a source of AC voltages;
 means for applying the voltage from the AC source to the electrodes of the rod for creating a single alternating electric field component between the rod and the additional electrode means;
 a source of DC voltages of variable magnitudes;
 means for applying selected voltages from the DC source to the electrodes of the rod for producing different static electric field components between the rod and the additional electrode means, the DC voltage applied to an electrode at one end of the rod having a magnitude less than the magnitude of the DC voltage applied to an electrode located interiorly of said end electrode;
 charged particle collector means located at the end of the filter opposite the charged particle source; and
 means for adjusting the ratio of the static electric field to the alternating electric field to select charged particles of a predetermined mass to charge ratio for transmission through the filter to the collector means and to deflect charged particles of other mass to charge ratios away from the filter axis.

2. The mass filter of claim 1 including means for applying selected voltages from the AC source to selected electrode-segments for producing different alternating multipole electric field components in selected portions of the filter.

3. The mass filter of claim 1 wherein the magnitude of the DC voltage applied to the electrode at each end of the filter is less than the magnitude of the DC voltage applied to the electrodes intermediate the ends of the filter.

4. A multipole mass filter comprising:

a source of charged particles located adjacent one end of the filter;

a plurality of rods symmetrically disposed in a substantially co-extensive parallel relationship about a central axis, each of said rods comprising a plurality of insulated electrode-segments, successive electrode-segments of each of said rods in combination with corresponding electrode-segments of the remaining rods forming multipole field arrays;

a source of AC voltages;

means for applying the voltage from the AC source to the electrode-segments in each array for producing an alternating multipole electric field component in the different arrays;

a source of DC voltages of variable magnitudes;

means for applying selected voltages from the DC source to the electrode-segments in each array for producing different static multipole electric field components in the different arrays, the magnitude of the DC voltage applied to the electrode-segments in an array at one end of the filter being less than the magnitude of the DC voltage applied to the electrode-segments in an array located interiorly of said end of the filter;

charged particle collector means located at the end of the filter opposite the charged particle source; and
 means for adjusting the ratio of the static electric field to the alternating electric field to select charged particles of a predetermined mass to charge ratio for transmission through the filter to the collector means and to deflect charged particles of other mass to charge ratios away from the central axis.

5. A multipole mass filter according to claim 4 wherein the ratio of the DC voltage to the AC voltage applied to the electrode segments in each array has the relationship

$$V_{DCxn}=0.168kV_{ACxn}$$

and

$$V_{DCyn}=0.168kV_{ACyn}$$

where

k has a value from 0 to 1,

n is the number corresponding to the number of the array in the filter,

x designates the segments lying on the X axis, and

y designates the segments lying on the Y axis.

6. A multipole mass filter comprising:

a source of ions located adjacent one end of the filter for directing ions into the filter in a direction generally along a central axis;

a plurality of rods symmetrically disposed in a substantially co-extensive parallel relationship about the central axis, each of said rods comprising a plurality of insulated, collinear, cylindrical electrode-segments, successive electrode-segments of each of said rods in combination with corresponding electrode-segments of the remaining rods forming multipole field arrays;

a source of AC voltages;

means for applying selected voltages from the AC source to the electrode-segments in each array for producing different alternating multipole electric field components in the different arrays;

a source of DC voltages of variable magnitudes;

means for applying selected voltages from the DC source to the electrode-segments in each array for producing different static multipole electric field components in the different arrays, the magnitude of the DC voltages applied to the arrays increasing away from each end of the filter;

an ion collector means located at the end of the filter opposite the ion source; and

means for adjusting the ratio of the static electric field to the alternating electric field to select ions of a predetermined mass to charge ratio for transmission through the filter to the collector means and to deflect ions of other mass to charge ratios away from the central axis.

7. A multipole mass filter according to claim 6 wherein the ratio of the DC voltage to the AC voltage applied to the electrode segments in each array has the relationship

$$V_{DCxn}=0.168kV_{ACxn}$$

and

$$V_{DCyn}=0.168kV_{ACyn}$$

where

k has a value from 0 to 1,

n is the number corresponding to the number of the array in the filter,

x designates the segments lying on the X axis, and

y designates the segments lying on the Y axis.

8. A monopole mass filter comprising:

a source of charged particles located adjacent one end of the filter;

a series of electrically insulated electrodes forming a segmented rod of uniform external diameter;

a right angle electrode located adjacent the rod and spaced a predetermined distance therefrom, said electrode co-extending in a parallel relationship with the segmented rod substantially along the length thereof the segmented rod and right angle electrode defining a filter axis therebetween;

a source of reference voltage connected to the right angle electrode;

a source of AC voltages;

means for applying the voltage from the AC source to the electrodes of the rod for producing an alternating electric field component between the rod and the right angle electrode;

a source of DC voltages of variable magnitudes;

means for applying selected voltages from the DC source to the electrodes of the rod for producing different static electric field components between the

- rod and right angle electrode, the DC voltage applied to an electrode at one end of the rod having a magnitude less than the magnitude of the DC voltage applied to an electrode located interiorly of said end electrode;
- charged particle collector means located at the end of the filter opposite the charged particle source; and means for adjusting the ratio of the static electric field to the alternating electric field to select charged particles of a predetermined mass to charge ratio for transmission through the filter to the collector means and to deflect charged particles of other mass to charge ratios away from the filter axis.
9. The monopole mass filter of claim 8 including means for applying selected voltages from the AC source to the electrodes of the rod for producing different alternating electric field components between the rod and the right angle electrode.
10. The monopole mass filter of claim 8 wherein the magnitude of the DC voltage applied to the electrode at each end of the rod is less than the magnitude of the DC voltage applied to the electrodes intermediate the ends of the rod.
11. A monopole mass filter comprising:
- a source of ions located adjacent one end of the filter for directing the ions into the filter in a direction generally along a central axis;
 - a series of collinear, cylindrical electrodes forming a segmented rod of uniform external diameter, adjacent electrodes of said rod being separated and spaced by means of insulating discs;
 - a right angle electrode located adjacent the rod and spaced a predetermined distance therefrom, said electrode co-extending in a parallel relationship with the segmented rod substantially along the length thereof;
 - a source of reference DC voltage connected to the right angle electrode;
 - a source of AC voltages;

- means for applying selected voltages from the AC source to the electrodes of the rod for producing different alternating electric field components between the rod and the right angle electrode;
 - a source of DC voltages of variable magnitudes;
 - means for applying selected voltages from the DC source to the electrodes of the rod for producing different static electric field components between the rod and the right angle electrode, the magnitude of the DC voltages applied to the electrodes increasing away from each end of the rod;
 - an ion collector means located at the end of the filter opposite the ion source; and
 - means for adjusting the ratio of the static electric field to the alternating electric field to select ions of a predetermined mass to charge ratio for transmission through the filter to the collector means and to deflect ions of other mass to charge ratios away from the central axis.
12. A monopole mass filter according to claim 11 wherein the ratio of the DC voltage to the AC voltage applied to each of the electrodes has the relationship
- $$V_{DCn} = 0.168kV_{ACn}$$
- where
- k has a value from 0 to 1, and
 - n is the number corresponding to the number of the electrode in the segmented rod.

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