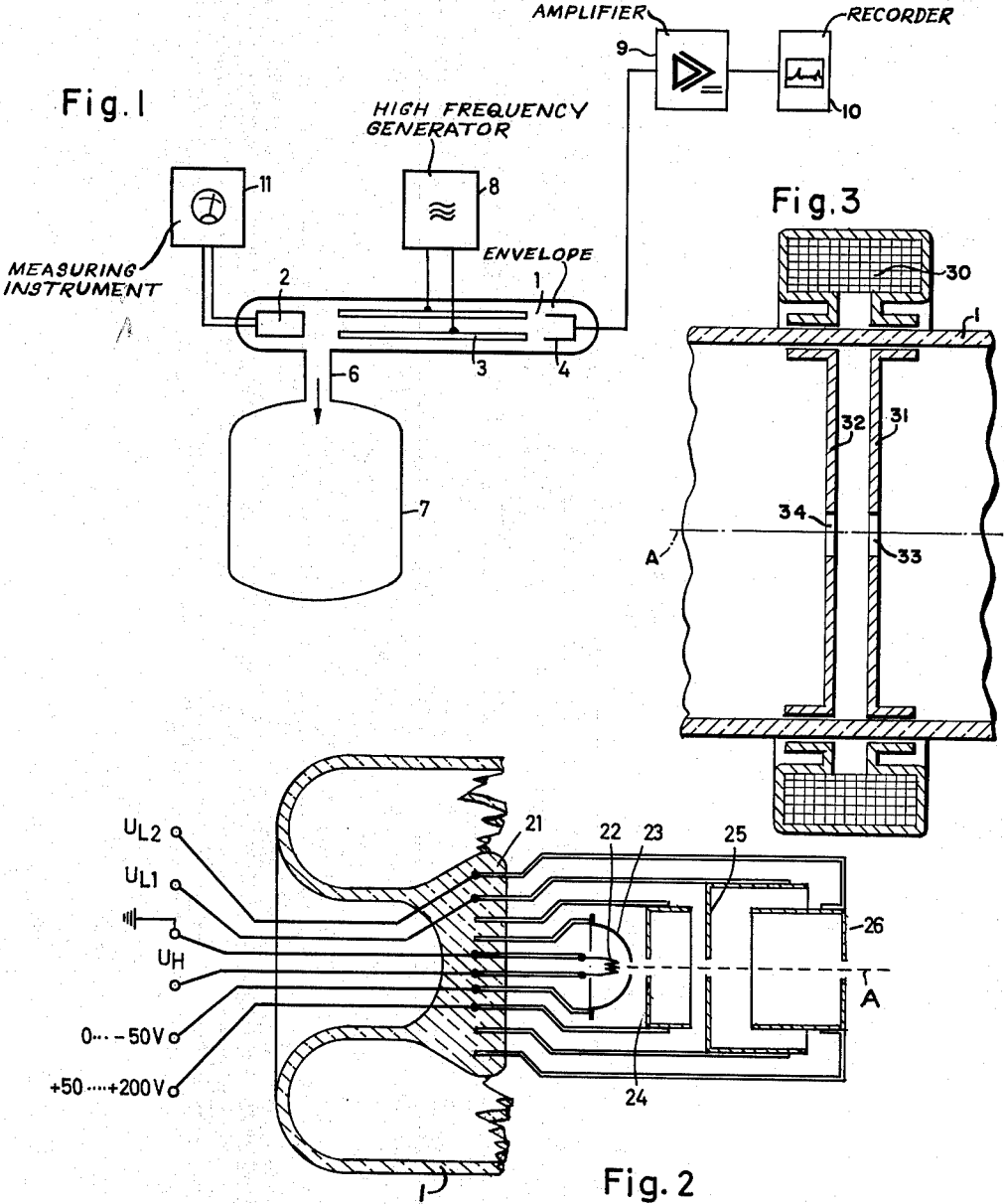


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ION SOURCE FOR MASS FILTER WHEREIN THE ELECTRON
AND ION BEAM AXES ARE THE SAME
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ION SOURCE FOR MASS FILTER WHEREIN THE ELECTRON AND ION BEAM AXES ARE THE SAME**Karl-Georg Günther, Nurnberg, Germany, assignor to Siemens-Schuckertwerke Aktiengesellschaft, Erlangen, Germany, a corporation of Germany**

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6 Claims. (Cl. 250—41.9)

My invention relates to mass filtering apparatus or isotope separators of the type known from U.S. Patent No. 2,939,952; U.S. Patent 2,950,389; and my copending application Serial No. 859,030, filed December 11, 1959, now U.S. Patent No. 3,075,076.

In such apparatus, ions of respectively different specific electric charges are separated by shooting a beam of differently charged ions into a periodically variable electric field between a group of elongated deflector electrodes that extend along the ion-beam axis and are distributed about that axis. These deflector electrodes are impressed with an electric high-frequency potential which, as explained in the above-mentioned copending application, is so chosen that the ions passing through the periodic field travel either on stable or on instable paths depending upon their specific electric charges. When the charges are such as to result in a stable path, the ions will pass through the variable field of the deflector electrodes onto a collector electrode at the end of the beam-path axis. When the ions travel on instable paths, they perform lateral pendulous motions and are caught on the deflector electrodes.

Such mass-analyzing or isotope-separating devices are applicable as partial-pressure vacuum meters, for detecting leaks in vacuum equipment, for the separation of gas mixtures, for trace analyses, or for measuring slight vapor pressures. The ion sources heretofore used in such apparatus included an incandescent cathode as part of a discharge path extending at a right angle to the beam axis of the ions to be extracted from the source. Such transverse direction of the electron flow in the source has heretofore been believed necessary for obtaining homogeneity of the energies of the generated ions.

It is an object of my invention to improve mass-filters of the above-mentioned type toward greatly increasing the flow of ions from the source toward the collector electrode, thus affording a simplification of the indicating or measuring components to be used with the filtering apparatus proper, or improving the sensitivity of the mass filter so that smaller amounts of mass quantities can be reliably observed.

To this end, and in accordance with my invention, I provide a mass filter of the above-described type with an electron-collision ion source having an electron discharge which is not self-sustaining, and whose electron-beam path has an axis coincident with the axis of the extracted ion beam, the latter axis being determined by the axial spacing between the ion source and the collector electrode and identical with the axis about which the above-mentioned elongated deflector electrodes are distributed.

Such an ion source is particularly advantageous at very low pressures of the gases to be investigated and results in a greatly increased quantity of ions passing from the source through the analyzing portion of the apparatus under otherwise comparable conditions. Such an ion source does not secure the above-mentioned degree of homogeneity with respect to the energy contents of the extracted ions, but is based upon the recognition and

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observation that such homogeneity is not necessary in mass filters of the present type.

It is preferable to design the electrodes of the ion source in such a manner and to impress them with suitable voltages to obtain a repeated pendulous travel of the ionizing electrons in the direction of the axis defined by the extracted ion beam.

According to another feature of my invention, I provide the ion source with focussing means which direct the extracted ions to the inlet opening of the analyzing portion of the electric mass filter. Preferably used for focussing is an electrostatic lens, although the same purpose may be served by a magnetic lens (as known, for example, from M. v. Ardenne, Tabellen der Elektronenphysik, Ionenphysik und Übermikroskopie, vol. 2, page 803, Berlin 1956, published by Deutscher Verlag der Wissenschaften).

In order that the present invention may be readily carried into effect, it will now be described with reference to the accompanying drawings, in which:

FIG. 1 is a schematic block diagram of a complete mass-filter apparatus corresponding to the one more fully illustrated and described in my above-mentioned copending application Serial No. 859,030;

FIG. 2 is a side view, partly in section, of an embodiment of an electron-collision ion source with which the apparatus is equipped in accordance with the present invention and

FIG. 3 is a view, partly in section, of an embodiment of a conventional electromagnetic lens which may be utilized with the apparatus of the present invention.

In FIG. 1, the mass filter is provided with an envelope structure 1 which contains an ion source 2, a group of elongated deflector electrodes 3 consisting of rods and having individually a hyperboloidal or circular cross section. Located at the end of the ion-beam path is a cup-shaped collector electrode 4. The ion source 2 and the collector electrode 4 are coaxially spaced from each other and thus define a center axis for the ion beam issuing from the source 2 toward the electrode 4. The electrode rods 3 are uniformly distributed about the ion-beam axis and extend parallel thereto. A total number of four such electrodes may be used.

The above-mentioned envelope 1 is vacuum-tight and has a neck portion 6 connected with a tank or other vessel 7 which contains the gaseous mixture to be investigated. The rod electrodes 3 are electrically connected with a high-frequency generator 8 which supplies the electrodes with electric energy of suitable voltage and frequency. The current due to the ions impinging upon the collector 4 is amplified by an amplifier 9 and supplied to a recorder 10 or other indicating or measuring device. Another measuring instrument 11 is provided for supervising the electron emission of the cathode in the ion source 2.

During operation, a beam of ions is continuously being extracted from the source 2 and is directed toward the collector 4. However, only the ions of a given specific electric charge, or within a given range of charges, can reach the collector 4. Those ions which have different specific charges travel on instable, pendulous paths and thus impinge upon the deflector electrodes, thus being filtered out of the mixture.

The electron-collision ion source with which the apparatus is provided in accordance with the present invention is shown in FIG. 2 to include a mounting 21 with six sealed lead-ins and four holder wires on which the other components of the source are mounted. These components comprise an incandescent cathode 22, a screen electrode 23, and an anode diaphragm 24. The electrode 23 resembles the electrode design also known as "Wehnelt cylinder"; that is, it is cup-shaped so as

to surround the incandescent cathode 22, and has a central aperture in its bottom portion facing toward the anode 24. The orientation of the electrode 23 is such that the electron beam, serving to effect ionization by collision, extends on the axis A of the ion beam to be extracted, this axis being identical with the above-mentioned axis defined by the source 2 and the collector 4 (FIG. 1).

In order to focus the extracted ions onto the inlet opening of the analyzing portion in the electric mass filter, the illustrated embodiment of the ion source is provided with an electrostatic lens along the beam axis A between the anode 24 and the deflector-electrode portion of the equipment. The electrostatic lens comprises a screen electrode 25 having an aperture on the axis A, and another screen or diaphragm member 26 which has a central aperture and forms the entrance diaphragm for the analyzing portion of the apparatus. The two components 25 and 26, jointly constituting the electrostatic lens, are being kept at respectively different electric potentials. The voltages for operating the source are indicated in FIG. 2 as: 0 (ground); 0 to -50 v.; +50 to +200 v.; U_H ; U_{L1} and U_{L2} .

FIG. 3 illustrates an electromagnetic lens which may be utilized in the apparatus of FIG. 2. The electromagnetic lens comprises a winding 30 positioned to coaxially surround the envelope 1 (FIG. 1) about the axis A of ion travel. A pair of apertures 33 and 34 are formed through core portions 31 and 32, respectively, of the winding and are coaxial with the axis A. The winding 30 is energized by means not shown in the drawing.

With respect to other details and electric operating data beyond the described features of the invention proper, reference may be had to the above-identified earlier disclosures, such as the data of structural dimensions, voltages and frequencies given in Patent 2,950,389. In comparison with the mass filters according to the earlier disclosures and under otherwise the same conditions, an apparatus according to the invention, in which the electron beam serving to effect ionization by collision extends in the axis of the extracted ion beam, yields a greatly increased ion current to pass into the ion separating portion of the apparatus, this increase being also due to the repeated pendulous motion of the ionizing electrons within the source and by the bunching effect of the electric focussing lens.

While the invention has been described by means of a specific example and in a specific embodiment, I do not wish to be limited thereto, for obvious modifications will occur to those skilled in the art without departing from the spirit and scope of the invention.

I claim:

1. In a mass filter having a negative-pressure envelope for receiving a gas to be analyzed, an ion source and a collector electrode spaced from each other in said envelope and defining together an ion beam axis from

said source to said collector electrode, a group of elongated ion-deflector electrodes extending parallel to and uniformly spaced about said axis between said source and said collector electrode, and high-frequency voltage supply means connected to said deflector electrodes for producing between them an electric field for ion separation, the combination wherein said ion source comprises an electron-emitting cathode, an anode spaced from said cathode along said axis toward said deflector electrodes and having a coaxial aperture traversed when in operation by an electron beam for electron-collision ionization of said gas, said cathode and said anode aperture defining an electron-beam axis coincident with said axis of the ion beam extracted from said source.

2. In a mass filter with an electron-collision ion source according to claim 1, said cathode of said ion source comprising an incandescent member, and a cup member coaxially surrounding said member, said cup member having a bottom facing said incandescent member, said bottom having an aperture at its center coaxial with said incandescent member, said bottom being axially spaced from said member and from said anode.

3. A mass filter with an electron-collision ion source according to claim 1, comprising a centrally apertured diaphragm mounted in said envelope transverse to said ion beam axis at a location between said ion source and said deflector electrodes, and focussing means disposed between said source and said diaphragm for directing the extracted ions through the aperture into the deflector-electrode space of the mass filter.

4. In a mass filter with an electron-collision ion source according to claim 3, said focussing means consisting essentially of electro-optical lens means coaxially surrounding said ion-beam axis.

5. In a mass filter with an electron-collision ion source according to claim 3, said focussing means comprising an electrostatic lens having two centrally apertured lens members insulated from each other and extending transverse to said axis in axially spaced relation to each other, one of said lens members being constituted by said diaphragm, and means for imposing respectively different electric potentials upon said two lens members.

6. In a mass filter with an electron-collision ion source according to claim 3, said focussing means consisting of an electromagnetic lens.

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