Aug. 4, 1964 KARL-GEORG GÜNTHER ETAL 3,143,647

DEMOUNTABLE MASS-FILTER CELL FOR USE IN HIGH VACUUM

Filed March 7, 1961 2 Sheets-Sheet 1

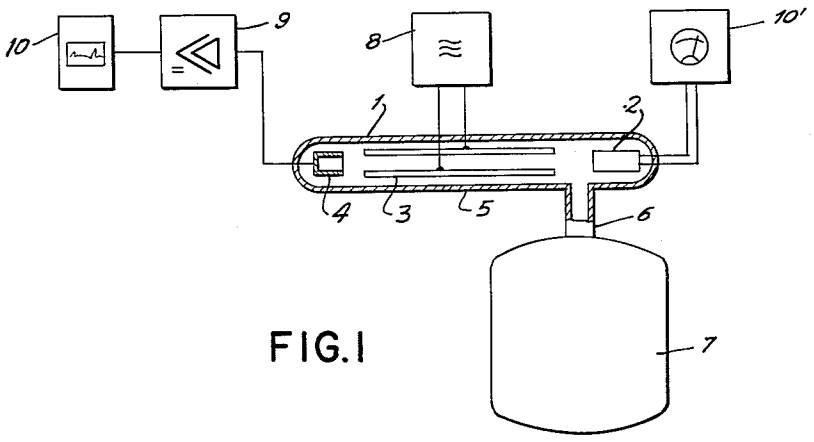


FIG.1

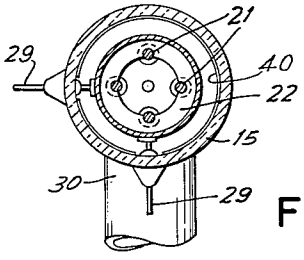


FIG.3

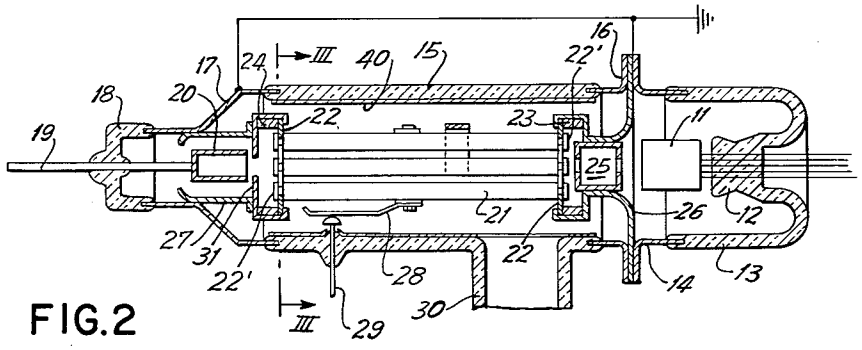


FIG.2

Aug. 4, 1964 KARL-GEORG GÜNTHER ETAL 3,143,647

DEMOUNTABLE MASS-FILTER CELL FOR USE IN HIGH VACUUM

Filed March 7, 1961 2 Sheets-Sheet 2

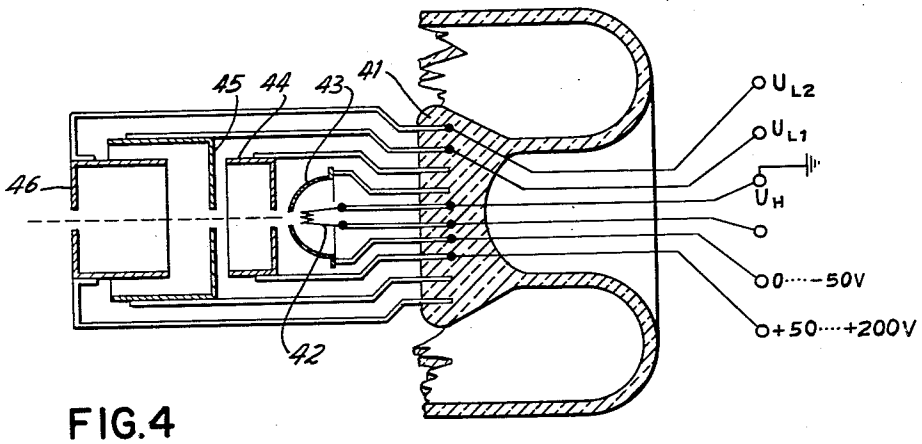


FIG.4

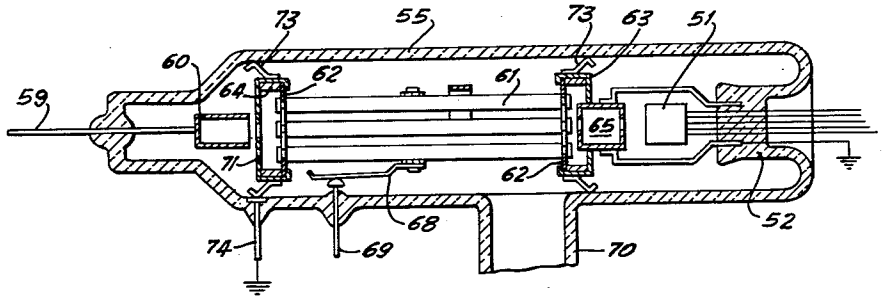


FIG.5

United States Patent Office 3,143,647 Patented Aug. 4, 1964

3,143,647

DEMOUNTABLE MASS-FILTER CELL FOR USE IN HIGH VACUUM

Karl-Georg Günther and Helmut Freller, Nurnberg, and Gunther Titze, Furth, Bavaria, Germany, assignors to Siemens-Schuckertwerke Aktiengesellschaft, Berlin-Siemensstadt, Germany, a corporation of Germany

Filed Mar. 7, 1961, Ser. No. 94,071
Claims priority, application Germany Mar. 9, 1960
13 Claims. (Cl. 250—41.9)

Our invention relates to mass filtering apparatus or isotope separators of the type known, U.S. Patent 2,939,-952 and U.S. Patent 2,950,389. Such apparatus are applicable as partial-pressure vacuum meters, for detecting leaks in vacuum equipment, for separation of gas mixtures, for trace analyses, or measuring slight vapor pressures.

In such apparatus, a beam of differently charged ions is directed into a periodically variable electric field between a group of elongated rod-shaped deflector electrodes which extend along the ion-beam axis and are distributed about that axis. The deflector electrodes are impressed with an electric high-frequency potential so chosen that the ions passing through the periodic field travel either on stable or instable paths, depending upon their specific electric charges, as is more fully explained in Patent No. 3,075,076, granted January 22, 1963. When the charges are such as to result in a stable path, the ions will pass through the variable field of the deflector rod electrodes onto a collector electrode. When the electrodes travel on instable paths, they perform lateral pendulous motions and are caught on the deflector electrodes.

It is an object of our invention to improve mass filter apparatus of the above-mentioned type so as to simplify the production of such apparatus and to ensure maximum accuracy of operation, particularly for operation of the mass filter at low gas pressures (below 10^{-4} mm. Hg) as partial pressure vacuum meter.

To this end, and in accordance with a feature of our invention, the components of the analyzer portion proper of the mass filter, namely the analyzer rod electrodes, the entrance diaphragm with the aperture for the incoming beam of ions, and the outlet diaphragm with an opening through which the undeflected ions travel to the collector anode, are mounted together so as to form an inherently complete unit that can be properly adjusted and calibrated independently of the other components of the equipment, such as the ion source and the collector anode structures.

According to another feature of the invention, the envelope of the mass filter, surrounding the axially aligned main components, namely the ion source, the analyzer portion, and the collector, is constituted by a tubular structure and posseses a tubular middle portion of glass, two end portions likewise of glass, and two intermediate ring pieces of metal which are vacuum-tightly joined with the glass components of the envelope and serve for holding the above-mentioned subassembly of the analyzer portion.

According to another feature of our invention, the analyzer portion, which comprises the analyzer rod, entrance diaphragm and exit diaphragm as a single inherently adjusted unit, is firmly connected at one end with the tubular envelope, whereas the other end of the analyzer portion is centered and held in position by means of a spring ring electrically and mechanically contacting one of the above-mentioned metallic ring portions of the envelope.

According to still another feature of our invention, the rod electrodes of the analyzer portion are held and properly adjusted at their respective ends by means of insulating rings. One of these insulating rings preferably also carries the entrance diaphragm and the connecting structure between the analyzer portion and the tubular envelope, whereas the other insulating ring carries the exit diaphragm of the analyzer portion. The supply of current to the respective pairs of analyzer rods may be effected by elastic contact members so as to readily permit inserting and removing the analyzer portion as a unit relative to the envelope structure.

According to another embodiment of the invention, the analyzer rods are held by means of bolts with the aid of which they are properly adjusted. These bolts are vacuum-tightly fused into the glass wall of the envelope and also serve as current supply means for the analyzer rod. In this case the final connection of the bolts with the glass envelope is effected subsequent to properly adjusting and calibrating the internal components.

According to further features of the invention, the individual components of the glass envelope are soldered or welded together by means of metal flanges fused to the glass components. However, the junction at these locations may also be effected by means of a releasable flange connection with the aid of inserted metal gasket rings. The inner sides of the glass envelope or of the glass components may also be provided, wholly or partially, with a conducting coating or a metal meshwork for the purpose of shielding the high-frequency field.

The nipple which connects the interior of the envelope with the tank or other vessel whose gas pressure is to be measured, is preferably given an internal width and a length approximately corresponding to the diameter of the group of rod electrodes.

The ion source is preferably of the electron-collision hot-cathode type in which the electrodes are so arranged that the ionizing electron beam extends in the axis of the discharge system. However, when using the measuring cell at relatively high pressures (above 10^{-4} mm. Hg) of the gas being investigated, the ion source may be of the cold-cathode type.

According to still another feature of the invention, the ion source, the entrance diaphragm, the analyzer rods, and the exit diaphragm are all mounted on a foot structure covered vacuum-tightly by a glass bell which contains the collector electrode as well as the nipple for connecting the measuring cell with a gas tank or vessel.

The foregoing and more specific objects and features of our invention, said features being set forth with particularity in the claims annexed hereto, will be apparent from, and will be described in, the following with reference to the embodiments of mass filters according to the invention illustrated by way of example on the accompanying drawings in which:

FIG. 1 is a schematic block diagram showing the entire equipment of a partial-pressure vacuum meter comprising the measuring cell proper as well as the appertaining voltage-supply and measuring equipment.

FIG. 2 is a longitudinal section through a measuring cell according to the invention.

FIG. 3 is a cross-sectional view, the section being along the line III—III in FIG. 2.

FIG. 4 is a longitudinal sectional view of an ion source with an incandescent cathode applicable in a measuring cell according to the invention.

FIG. 5 is a longitudinal section through another measuring cell according to the invention.

According to FIG. 1, the mass-filter cell 1 is provided with an envelope 5 which contains an ion source 2, a group of rod-shaped deflector electrodes having individually a 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 **5** of the cell **1** is vacuum-tightly sealed and has a nipple **6** connected with a tank **7** or other vessel which contains the gaseous mixture to be investigated. The rod electrodes **3** are electrically connected in pairs 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 **10'** 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 **4**, thus being filtered out of the mixture.

Details of the analyzer portion or measuring cell proper will now be described with reference to FIG. 2 in which the ion source shown at **11** is mounted on a foot structure **12** fused together with an end portion **13** of glass which forms part of the tubular envelope structure generally denoted by **5** in FIG. 1. Fused into the circular rim of the envelope end portion **13** is a ring-shaped flange member **14** of metal. By means of the metal flange and, if necessary, inserted metallic gasket rings, the individual parts of the envelope can be releasably connected, for example by fastening screw bolts (not illustrated) which pass through respective bores of the flange and are uniformly distributed along its periphery.

The middle cylindrical glass portion **15** of the envelope has its two circular ends likewise vacuum-tightly fused together with a metal flange **16** and a hollow conical member **17** respectively. The other end portion of the envelope is constituted by a cap **18** of glass vacuum-tightly traversed by a conductor wire **19** to which the cup-shaped collector electrode **20** (corresponding to electrode **4** in FIG. 1) is attached.

The analyzer portion of the apparatus is entirely accommodated within the the cylindrical middle portion **15** of the envelope. The four analyzer rods employed in this embodiment are denoted by **21** (corresponding to rods **3** in FIG. 1). They are mounted at both axial ends in respective mica discs **22** of circular shape (FIGS. 2, 3). For this purpose, the rods **21** are machined at their ends to have a small annular shoulder. The thin rod ends are stuck through matching openings in the mica discs. The rods are fastened to the discs by respective screws such as the one denoted in FIG. 2 by **22'**.

The mica discs **22** are rigidly mounted in respective rings **23** and **24**. The ring **23** close to the ion source **11** is rigidly seated on an annular socket piece **26** which carries in its midlle portion the ion-beam entrance diaphragm **25** comprising two centrally apertured diaphragm members located axially one behind the other. The annular piece **26** firmly joins the ring **23** and thus the mica disc with the flanges **16** and **14** of the envelope middle portion **15** and end portion **13** respectively.

The ring **24** close to the collector electrode **20** carries the exit diaphragm **31** of the analyzer portion, this diaphragm having likewise a central aperture. The ring **24** further carries a generally cylindrical, elastic sleeve **27** of spring material which supports and centers the analyzer portion of the apparatus in a cylindrical neck of the conical part **17**. The electric potentials are applied to the pairs of analyzer rods **21** by means of leaf springs

28 and contact pins **29**. The contact pins **29** extend vacuum-tightly through the wall of the middle envelope portion **15**. Joined with the middle portion **15** is a glass nipple **30** for connection of the analyzer cell with the tank or vessel containing the gas to be analyzed, this nipple corresponding to the one denoted by **6** in FIG. 1. The inner width and the length of the nipple portion **30** are approximately equal to the diameter of the analyzer system as defined by the circular arrangement of the four analyzer rods.

If desired, the metal flanges of the analyzer cell may be soldered or welded together instead of being fastened and tightened by bolts. For preventing the envelope walls from becoming charged electrically and also for shielding the environment from the high-frequency field produced by the analyzer rods, the inner or outer sides of the glass vessel or of the glass components may be wholly or partially covered with a thin coating in form of a metal deposition or a metal mesh. In FIG. 2 this coating is identified by the reference character **40**.

FIG. 4 illustrates an embodiment of a hot-cathode ion source particularly suitable for an analyzer cell according to the invention. This particular ion source corresponds to the one shown and claimed in the copending application Serial No. 57,851, filed September 22, 1960. The source possesses a squeeze foot **41** with six sealed inleads and four holder wires on which the other components of the source are mounted. These components comprise an incandescent cathode **42**, a screen electrode **43**, and an anode diaphragm **44**. The electrode **43** is cup-shaped so as to surround the incandescent cathode **42** and has a central aperture in its bottom portion facing toward the anode **44**. The orientation of the just-mentioned electrode is such that the electron beam, serving to effect ionization by collision, extends on the axis of the ion beam to be extracted. This axis, indicated by a broken line, is identical with the above-mentioned axis defined by the ion 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 measuring cell proper still to be described, the embodiment of the ion source shown in FIG. 1 is provided with an electrostatic lens along the beam axis between the anode **44** and the deflector electrodes of the analyzer portion. The electrostatic lens comprises a screen electrode **45** having an aperture on the axis of the beam, and another screen or diaphragm member **46** which has a central aperture and forms the entrance diaphragm for the analyzing portion of the apparatus. The two components **45** and **46** jointly constituting the electrostatic lens, are being kept at respectively different electric potentials. The voltages for operating the source are denoted in FIG. 4 by 0 (ground); 0 to -50 v.; $+50$ to $+200$ v.; U_H, U_{L1} and U_{L2}.

When using short analyzer rods, a correspondingly low ion velocity is required. In order to nevertheless obtain a high ion yield in such cases, the incandescent cathode is negatively biased by voltage between 0 and -50 v. In the described ion source, the electron beam which effects ionization extends on the axis determined by the ion beam to be extracted. This results in a considerably greater current flow to the collector electrode due, among other things, to the multiple pendulous travel of the ionizing electrons and also to the bunching effect of the electrostatic lens.

For operation at gas pressures above 10^{-4} mm. Hg, the use of a cold-cathode ion source is preferable. Such a source, suitable for the purposes of the invention, is illustrated and described in the copending application of K. G. Guenther, Serial No. 94,070, filed March 7, 1961.

In the event of any defect, as may occur in the ion source, the measuring cell according to the invention can readily be taken apart and reassembled. Furthermore, the entire analyzer system can be assembled, adjusted and calibrated outside of the tubular envelope, which

greatly facilitates the very sensitive total adjusted work required for the mass-filter cell. Furthermore, if needed, different analyzer systems of respectively different geometry can be inserted into the tubular envelope, thus affording a considerable increase of the total measuring range for which the apparatus is suitable.

In the embodiment according to FIG. 5, the envelope **55** of the measuring cell is illustrated as consisting entirely of glass, although it will be understood that it may also be composed of glass portions and metal portions as described above with reference to FIG. 2. The envelope **55** is provided with a connecting neck or nipple **70**. The ion source is denoted by **51**. The collector electrode **60** is attached to a supporting conductor **59**.

The analyzer rods **61** are mounted in mica discs **62** in the same manner as described above with reference to FIGS. 2 and 3. The mica discs are firmly held in ring-shaped structures **63** and **64** respectively. The ring structure **63** has an ion-entrance diaphragm structure **65**. The ring structure **64** carries an ion-exit diaphragm **71**. Voltage is supplied to the electrode rod **61** of the analyzer unit by means of a leaf spring **68** which contacts a contact member whose conductor **69** passes vacuum-tightly through the wall of the envelope **55**.

In this embodiment the entire analyzer unit of the measuring cell, comprising the analyzer rod **61**, the holder structures **62**, **63**, **64**, as well as the entrance diaphragm **65** and the exit diaphragm **71** constitute a single rigid subassembly, so that this subassembly can be completely assembled, adjusted and calibrated before inserting it into the envelope. The analyzer unit is held in proper position by means of leaf springs such as those denoted by **72** and **73**. These leaf springs are rigidly fastened to the respective ring structures **63** and **64** and are uniformly distributed along the periphery of each ring structure. The ends of the leaf springs enter into resilient contact with the cylindrical wall of the envelope **55** for securing the unit in proper position. One of the leaf springs **73** then contacts a conductor **74** which extends vacuum-tightly through the envelope wall and is shown grounded. The entrance diaphragm **65** comprises two diaphragm members located one behind the other along the beam axis. The diaphragm structure **65** may be resiliently contacted by respective holder arms on the squeeze foot **52**, or on one of the component diaphragm parts of the ion-source assembly.

It will be understood by those skilled in the art, upon studying this disclosure, that the number of analyzer rods in a measuring cell according to the invention may be changed. For example, six or more such rods can be provided. It will further be obvious that with respect to details in construction, the mass-filter apparatus can be modified in various respects and hence can be given embodiments other than particularly illustrated and described herein, without departing from the essential features of our invention and within the scope of the claims annexed hereto.

We claim:

1. In an electric mass filter having a tubular negative-pressure envelope for 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, the combination of an analyzer assembly comprising a group of elongated ion-deflector rods parallel to and mutually spaced about said axis between said source and said collector electrode, conductor means connected to said rods for impressing high-frequency voltage thereupon, a centrally apertured ion-beam entrance diaphragm coaxially located between said rods and said source, a centrally apertured ion exit diaphragm coaxially located between said rods and said collector electrode, and mounting structure means rigidly joining said rods with said two diaphragms in electrically insulating relation thereto and independently of said envelope for forming said analyzer assembly into a structural unit capable of being assembled and adjusted before joining it with said envelope and source and collector electrode, and holder means disposed in said envelope and forming a centering support of said unit relative to said envelope.

2. An electric mass filter comprising a tubular 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, an analyzer assembly having a group of ion-deflecting electrode rods parallel to and mutually spaced about said axis between said source and said axis, said tubular envelope having a middle portion of glass, two end portions of glass and two ring portions of metal fused together with said glass portions between said middle portion and said respective end portions, said analyzer assembly being mounted on and axially between said two ring portions.

3. An electric mass filter comprising a tubular 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, an analyzer assembly having a group of ion-deflecting electrode rods parallel to and mutually spaced about said axis between said source and said axis, said assembly having two centrally apertured electrically conductive diaphragms insulatingly joined with said rods whereby said assembly forms a rigid unit capable of being assembled and adjusted prior to being mounted in said envelope, said tubular envelope having a middle portion of glass, two end portions of glass and two ring portions of metal fused together with said glass portions between said middle portion and said respective end portions, said analyzer assembly when mounted in said envelope having one end rigidly connected to one of said ring portions, and elastic centering means joining the other end of said assembly with said other ring portion.

4. In a mass filter according to claim 2, said analyzer assembly comprising two insulating ring structures on which the respective axial ends of said rods are rigidly mounted, and two centrally-apertured electrically-conductive diaphragms for entrance and exit respectively of the ions, said diaphragms being coaxially mounted on said respective ring structures and electrically insulated from said rods.

5. In a mass filter according to claim 1, said ion-deflector rods being arranged in two pairs of mutually opposite rods, and said conductor means comprising resilient contact means electrically connected to said respective pairs.

6. In a mass filter according to claim 2, said collector electrode being mounted on one of said envelope end portions, and said ion source being mounted on the other end portion of said envelope and having an electron-collision discharge axis coincident with said ion-beam axis.

7. In a mass filter according to claim 2, and conductor means comprising holder structures of metal which secure said rods in position relative to said middle portion of said envelope.

8. In a mass filter according to claim 2, and conductor means comprising holder structures of metal which secure said rods in position relative to said middle portion of said envelope, said holder structures extending vacuum-tightly through said middle portion to the outside of said envelope.

9. In a mass filter according to claim 2, said two ring portions of said envelope comprising two metal flanges fusion-joined with the adjacent two glass portions of said envelope, said two flanges being coaxially and vacuum-tightly joined with each other.

10. In a mass filter according to claim 1, said envelope

having an electrically conductive coating for shielding the high-frequency field of said ion-deflector rods.

11. In a mass filter according to claim 1, said envelope having a connecting duct for connection to a gas supply, said duct having a length and a diameter which are both approximately equal to the diameter of said group of ion-deflector rods.

12. In a mass filter according to claim 1, said envelope having a foot structure at one axial end, and said analyzer assembly being mounted on said foot structure.

13. In a mass filter according to claim 1, said envelope

having a foot structure at one axial end, and said ion source and said analyzer assembly being mounted on said foot structure, said collector electrode being mounted on the opposite axial end of said envelope, and said envelope having a lateral connecting duct for supply of gas.

References Cited in the file of this patent

UNITED STATES PATENTS

2,570,158	Schissel	Oct. 2, 1951
2,939,952	Paul et al.	June 7, 1960
2,945,951	Bright	July 19, 1960