Oct. 1, 1963 KARL-GEORG GÜNTHER ETAL 3,105,899

ELECTRIC MASS FILTER

Filed March 21, 1961

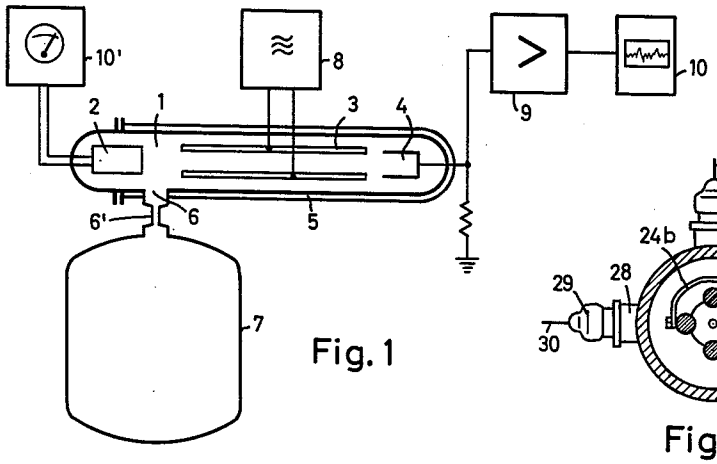

Fig. 1

Fig. 3

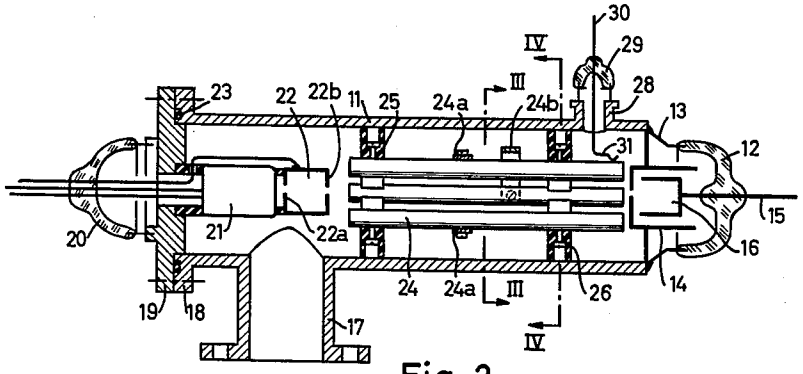

Fig. 2

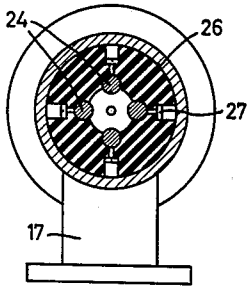

Fig. 4

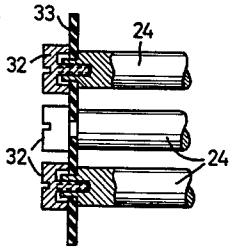

Fig. 5

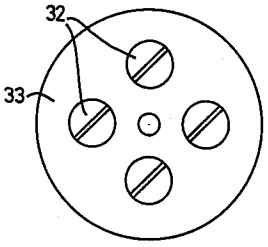

Fig. 6

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ELECTRIC MASS FILTER

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2 Claims. (Cl. 250—41.9)

Our invention relates to mass spectrometers or isotope separators of the type known from German Patent 944,900 and U.S. Patent 2,939,952. Such mass-filter devices are applicable for analyzing gaseous subtance, separating isotopes, measuring partial pressures, detecting leaks in vacuum plants, performing trace analyses, measuring vapor pressures, and related purposes. While the mass filters according to the above-mentioned patents are equipped with ion sources of the hot-cathode type, those of the cold-cathode type are also suitable for mass filters that are to operate at relatively high gas pressures.

It is an object of our invention to improve mass filters of the above-mentioned type, particularly for use at relatively high gas pressures, between 10^{-2} and 10^{-6} mm. Hg, toward a more rugged and structurally simplified construction that can be readily produced as an instrument for use in industries and utilities, and that, in the event of trouble, can be more readily checked or readjusted than the known devices of this type.

According to our invention the enclosure of the mass-filter cell proper consists essentially of metal and is composed of three subassemblies each forming a unit structurally different from the others, namely a first unit comprising a tubular envelope with a connecting nipple for the supply of gas to be investigated and with an ion collector electrode inserted into the envelope but insulated therefrom, a second unit comprising the mass analyzer system proper, and a third unit comprising the ion source with a connecting flange and, if desired, the ion-entrance diaphragms for the analyzer portion. These three units are mounted together in axial alignment with each other.

The invention will be further described with reference to the embodiments illustrated by way of example on the accompanying drawing in which:

FIG. 1 is a schematic block diagram showing the complete equipment of a partial-pressure vacuum meter on the principle of the above-mentioned electric mass filter, comprising a measuring cell, the appertaining electrical equipment, and a recipient for gas to be investigated.

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

FIG. 3 is a cross section taken along the line III—III indicated in FIG. 2.

FIG. 4 is a cross section along the line IV—IV indicated in FIG. 2.

FIG. 5 is a partly sectional view of a modified portion in a cell otherwise similar to that shown in FIG. 2; and

FIG. 6 is an axial view from the left of FIG. 5.

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 3 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 or neck 6 connected with a tank 7 containing the gaseous mixture to be investigated. The rod electrodes 3 are electrically connected in pairs to a high-frequency generator 8 which supplies 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 3, thus being filtered out of the mixture. This is more fully explained in the copending application Serial No. 859,030, filed December 11, 1959, now Patent Number 3,075,076, granted January 22, 1963 as well as in the above-mentioned patents.

Details of a measuring cell according to the invention will now be described with reference to the embodiments shown in FIGS. 2 and 3. The mass-filter cell comprises a tubular metal envelope 11, for example of cylindrical shape, in which the analyzer portion of the system is located. One end of the envelope is closed by a glass cap 12 which is vacuum-tightly joined with the metal tube 11 by a metal ring 13. Ring 13 is fused into the glass material of cap 12 and is welded or soldered to the rim of the tube 11. Mounted at the junction between ring 13 and tube 11 is an ion exit diaphragm 14 of metal. The conductor 15 for connection with the collector electrode 16 passes vacuum-tightly through the glass cap 12. The metal tube 11 is provided with a lateral neck 17 which has a flange for connection of the analyzer cell to a recipient or vacuum pump, or to the tank (7 in FIG. 1) containing the gas to be investigated.

The other end of the envelope tube 11 has a flange 18 to which a cover 19 is removably attached by means of fastening bolts and is sealed with the aid of a gasket 23. The cover 19 carries the ion source 21 and the ion entrance diaphragms 22. The electric conductors for supplying current to the ion source pass through the glass cap 20 to the outside, thus being sealed and insulated by the material of the cap. The seal between the flange 18 and the cover 19 may also be effected by means of readily melting solder materials. Aside from flat and planar sealing surfaces, cylindrical or conical sealing surfaces may be employed. The ion source may be designed in accordance with the one illustrated and described in the copending application Serial No. 94,070, filed March 7, 1961, by K. G. Günther, (F–2146, PA 60/1151).

The analyzer system, located within the tubular envelope portion 11, comprises four rod-shaped electrodes 24 of circular cross section which are electrically interconnected in pairs of mutually opposite rods. This connection is effected by conductors 24*a* and 24*b*. The rods are held in position by insulating rings 25 and 26 consisting of a material of high mechanical strength and low vapor pressure, such as mica, glass, or high-frequency ceramics. These substances are applicable when the measuring cell, during operation, becomes exposed to relatively high temperatures. If the operating temperature does not exceed a limit of approximately 150° C., such synthetic plastics as available in the trade under the name Teflon are likewise applicable.

Generally, the tubular envelope portion 11 with the neck 17 consists of stainless steel. However, if the meas-

uring cell is used at temperatures up to about 150° C., the envelope portion may also consist of copper or brass. As apparent from the cross section shown in FIG. 3, the insulating ring 26 has four holes merging with a central opening. The individual analyzer rods 24 are inserted into the respective holes so that an arcuate inner portion of each rod remains completely exposed to the gaseous atmosphere. This is also apparent from the cross section shown in FIG. 4 in which the insulating ring 26 is shown in section. The analyzer rods 24 are fastened in the insulating ring by means of radially extending set screws 27. By adjusting the screws 27, in conjunction with the elastic properties of the insulating material, a very fine adjustment and calibration of the electrode rods can be effected.

According to a modification, the analyzer rods may be supported by insulating rings of high mechanical strength and low vapor pressure which are joined with the analyzer rods at the respective axial ends thereof. In this case, the insulating rings consist preferably of mica, and a proper adjustment of the rods relative to the mica disc is effected by accurately adjusted screws in threaded engagement with the axial ends of the analyzer rods.

Such a modification is illustrated in FIGS. 5 and 6. The rods 24 are shown mounted on a mica ring 33. Each ring is securely fastened to the ring by a cap screw 32 whose threaded portion is in engagement with a threaded bore of the rod.

According to FIGS. 2 and 3, the envelope portion 11 is provided with two metal nipples 28 which are angularly displaced 90° from each other and are vacuum-tightly sealed by means of respective glass caps 29. Insulated conductors 30 pass centrally through the glass caps 29 and are connected to respective contact springs 31 for electrically connecting the analyzer rod with the high-frequency source (8 in FIG. 1) of the system.

At relatively high pressures (above 5.10^{-4} mm. Hg), the mass travel lines may become widened by collision and the stable ions may lose in intensity, also due to collision. To minimize such phenomena, a proper dimensioning of some of the filter components is important. Thus, the spacing between the two entrance diaphragms 22*a*, 22*b* of the part 22 located between the ion source and the analyzer, should be considerably smaller than the length of the analyzer rods. The mutual spacing of the diaphragms 22*a*, 22*b* is preferably 0.1 to 0.2 times the length of the analyzer rods. The diameter of the aperture in the entrance diaphragms is preferably 0.1 to $0.3r_0$, the term r_0 denoting one-half of the mutual spacing of the analyzer rods. When the measuring cell is assembled, the distance between the ion exit opening of the ion source 21 and the adjacent first entrance diaphragm 22*a* should be smaller than the value r_0 or at most equal thereto. A proper adjustment in radial direction must also be secured. The diameter of the connecting neck 17 is preferably approximately equal to the diameter of the analyzer system. The length of the neck portion 17 is likewise approximately equal to the diameter of the analyzer system.

Instead of using a hot-cathode type of ion source, a source of the cold-cathode type may also be employed in which the electron emission is excited by the discharge itself and a spacial and temporal fixing of the discharge plasma onto the ion exit opening is effected. Ion sources of this type, particularly well applicable for the purposes of the invention, are illustrated and described in the copending application of K. G. Günther, Serial No. 94,070, filed March 7, 1961, (F–2136, PA 60/1151).

The envelope, particularly the tubular portion 11 with the appertaining neck 17 and nipples 28, is preferably made of a non-magnetic material in order to prevent any disturbance of the ion motion within the measuring cell. Preferably the material should also be non-corrosive as is the case with non-magnetic alloy steel, copper and brass. At the highest operating temperatures, the material of the envelope should have an extremely small vapor pressure no longer ascertainable with the mass filter. That is, all of the components or constituents of the envelope material should have such a low vapor pressure in order to prevent varying and falsifying the results obtained with the mass filter. The above-mentioned materials satisfy these requirements.

The ion current passes through the collector electrode 4 (FIG. 1) into the high-ohmic input circuit of the direct-current measuring amplifier 9. In order to secure a high voltage sensitivity, it is preferable to give the collector electrode a small capacitance versus ground. This is attained by suspending the collector electrode in the illustrated manner within the measuring cell.

If the gas mixture to be investigated is available only at such a high pressure that a direct measuring with the mass filter cannot be performed, it is preferable to provide a fixed or controllable throttle in the connection between the gas supply and the measuring cell. Such a controllable throttle is schematically shown at 6′ in FIG. 1. As a result, the gas mixture enters into the measuring cell under reduced pressure in the vicinity of the ion source, and directly passes through the region of the ion source. The gaseous mixture can be pumped out of the analyzer system at any desired location, for example near the middle of the analyzer portion, by means of an auxiliary pump. A pressure stage between ion source and analyzer portion is not required.

For employment of the rugged measuring device according to the invention in practice, the measuring cell can be mounted on a mobile unit which also comprises the high-frequency generator with a high-voltage direct-current converter, a direct-current measuring amplifier with recorder, any auxiliary and supervisory devices and instruments required, and also an auxiliary pump and throttle if the gas to be measured is available only at pressure not matching the measuring range of the mass filter. By providing such a single mobile unit, the use of the invention in practice is greatly facilitated.

The measuring cell according to the invention has the advantage that the analyzer system can be assembled and adjusted outside of the envelope structure. This greatly facilitates the entire adjusting and calibrating work required.

If desired, a number of analyzer portions of respectively different geometry may be provided and can then readily be inserted selectively into the same envelope structure, depending upon the resolving power required and the types of gas to be analyzed. Consequently, the range of mass filtering operations can thus be varied. The entire measuring cell can be readily taken apart and reassembled for cleaning purposes or inspection and repair.

It will be obvious to those skilled in the art, upon study of this disclosure, that our invention affords of various modifications with respect to details and may be given embodiments other than 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. An electric mass-filter cell, particularly for measuring partial pressures in vacuum of 10^{-2} to 10^{-6} mm. Hg, comprising an envelope tube of metal and two envelope end portions sealing the respective ends of said tube, said tube having a lateral neck for connection to a supply of gas to be investigated; an ion source mounted on one of said end portions and forming a first structural unit together therewith; a collector electrode mounted on said other end portion and forming a second structural unit together therewith; and a group of analyzer electrodes consisting of elongated rods parallel to the axis of said tube and distributed about said axis, said rods being mounted on said tube in insulated relation to said source and collector electrode and tube, and said rods forming together with said tube a third structural unit; said three units being individually adjustable prior to being assem-

bled and being fastened and sealed together in coaxial alignment when assembled, said metal tube and said one end portion having respective metal flanges releasably and vacuum-tightly joined with each other, an ion entrance diaphragm mounted on said one end portion coaxially in front of the ion outlet of said source, said diaphragm being axially spaced from said outlet a distance at most equal to one-half of the mutual spacing of said analyzer rods.

2. An electric mass filter cell, particularly for measuring partial pressures in vacuum of 10^{-2} to 10^{-6} mm. Hg, comprising an envelope tube of metal and two envelope end portions sealing the respective ends of said tube, said tube having a lateral neck for connection to a supply of gas to be investigated; an ion source mounted on one of said end portions and forming a first structural unit together therewith; a collector electrode mounted on said other end portion and forming a second structural unit together therewith; and a group of analyzer electrodes consisting of elongated rods parallel to the axis of said tube and distributed about said axis, said rods being

mounted on said tube in insulated relation to said source and collector electrode and tube, and said rods forming together with said tube a third structural unit; said three units being individually adjustable prior to being assembled and being fastened and sealed together in coaxial alignment when assembled, said first unit comprising a plurality of ion entrance diaphragms mounted in coaxial relation to said source and axially spaced from each other between said source and said analyzer rods, the mutual spacing of said diaphragms being smaller than the length of said rods, said diaphragms having a central ion entrance opening whose diameter is 0.1 to $0.3r_0$, where r_0 is one-half of the spacing between the analyzer rods.

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