Aug. 21, 1956 J. T. DALTON ET AL 2,760,076

ARRANGEMENT FOR MINIMIZING NEGATIVE SIGNALS

Filed April 20, 1955 2 Sheets-Sheet 1

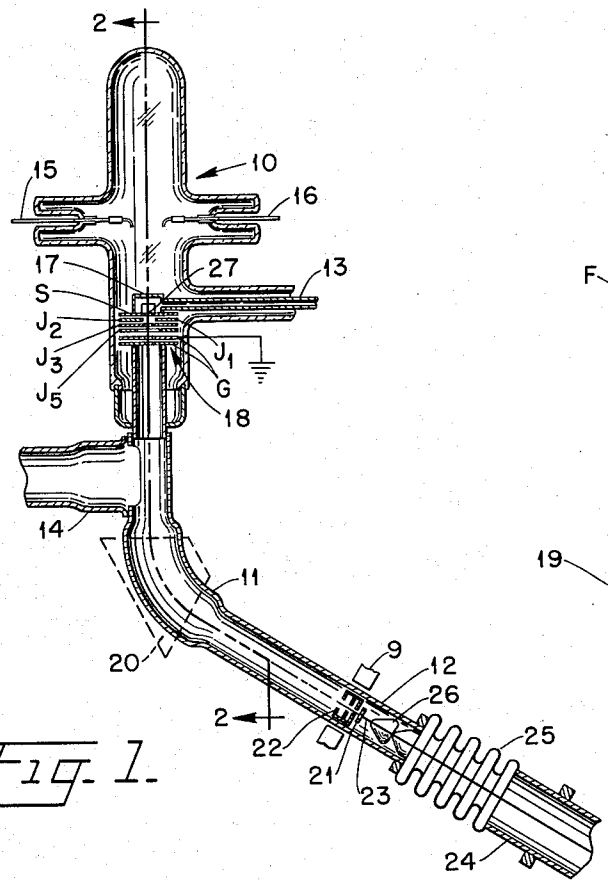


Fig. 1.

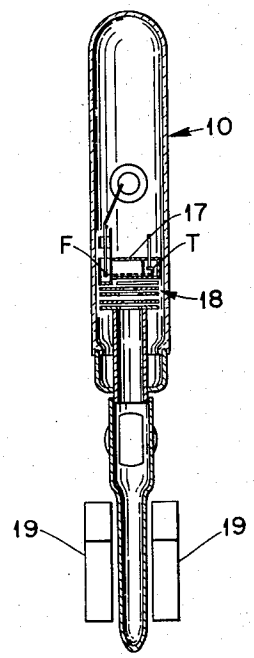


Fig. 2.

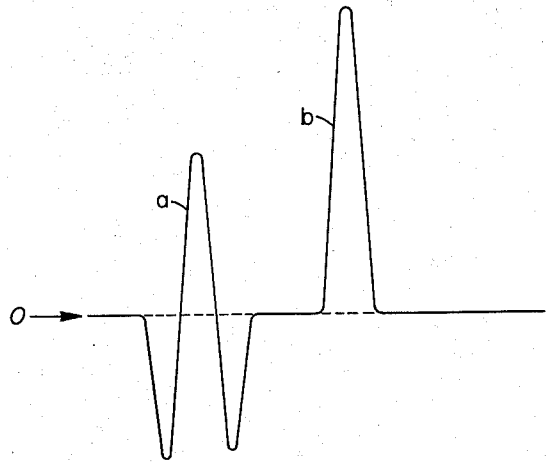


Fig. 3.

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ARRANGEMENT FOR MINIMIZING NEGATIVE SIGNALS

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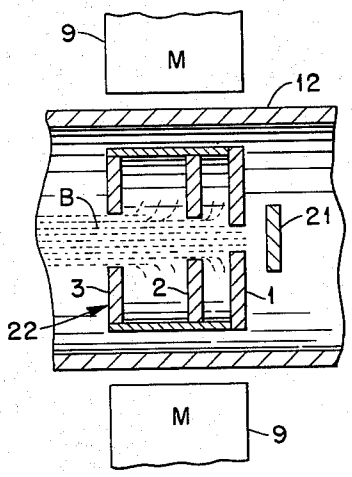


Fig. 4.

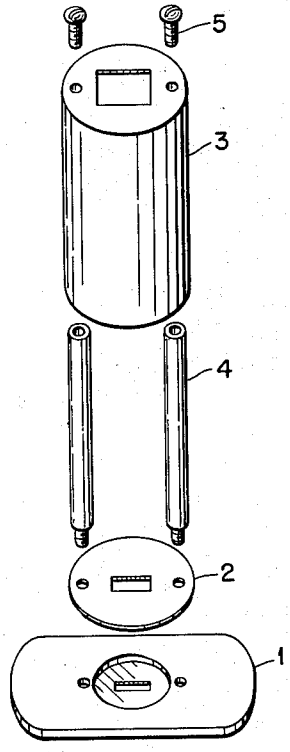


Fig. 5.

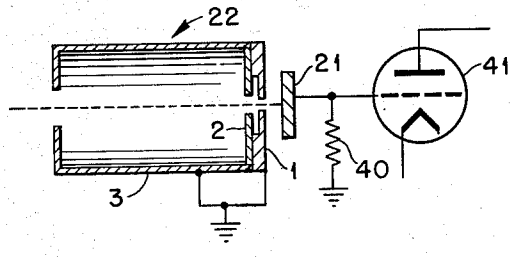


Fig. 6.

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ARRANGEMENT FOR MINIMIZING NEGATIVE SIGNALS

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8 Claims. (Cl. 250—41.9)

This invention relates to mass spectrometers and more particularly to a collector arrangement for mass spectrometers which overcomes the inaccuracies in analysis and/or calibration resulting from stray electrons, negative ions or other charged particles in the general region of the collector assembly.

In the operation of mass spectrometers, "negative signals," commonly called "negative peaks" or "base line depressions," often appear in the output signal from the collector. On a mass spectrum scan record, these appear as traces extending below the base line, that is, the line traced when the ion output from the source is zero. These signals are believed to be the result of secondary emission of electrons from metal surfaces bombarded by the ion beam and, to a degree, the production of negative ions. Signals of this character are objectionable, particularly in the case of highly-sensitive spectrometers, because they tend to make the positive peak height in the collector output indefinite and obscure the base line level. Consequently, negative peaks make calibration difficult and reduce accuracy.

Heretofore in the prior art, the problem of or the necessity for the elimination or disposition of undesired ions and other charged particles has been recognized. Nier, 2,660,677; Long, 2,543,859; and Washburn, 2,598,734. Magnets have been suggested for use at the collector end of the spectrometer tube to dispose of stray or undesired charged particles by positioning such magnets so that the magnetic field is generally parallel to the slit at the collector slit plate, thereby causing the paths of the undesired particles to bend or to be deflected. Nier, supra. The object is to have the field act on the charged particles to cause them to travel in paths which will bring them into contact with grounded conductive surfaces that will serve to neutralize and dispose of them . It has also been attempted to dispose of undesired charged particles at the collector end of the spectrometer through the use of charged suppressor or suppressor and grounded electrodes positioned either adjacent to or on either side of the collector plate. Long, supra; Washburn, supra. Further, it is known that during the operation of narrow range or multiple mass spectrum range mass spectrometers negative signals that appear in the mass range being used can be reduced by manipulation of the focusing potentials on the ion source of the instrument. By refocusing, these negative signals can be made to shift and appear in other mass ranges not being used at the particular time of operation. While these arrangements have had some effect in reducing spurious or interfering peaks which tend to mask the true signal and have resulted in reducing the shift in the base line, such arrangements and practices have proved to be inadequate for overcoming the effects of "negative peaks" and "base line depression" for spectrometers which are both highly sensitive and adapted for the continuous uninterrupted measurement of a wide range of masses e. g. from mass 12 to mass 600.

Applicants with a knowledge of these problems in the prior art have for an object of their invention the provision of an improved arrangement for eliminating negative peaks in the output signal from these mass spectrometers.

Applicants have as another object of their invention the provision of a "trap" and magnet assembly for a mass spectrometer to capture and dispose of undesired charged particles as they approach the collector.

Applicants have as a further object of their invention the provision of a collector assembly and magnet for disposing of stray or secondary electrons and the elimination of negative signals by altering the paths of travel of undesired charged particles and capturing them while permitting the desired ion beam to travel therethrough.

Applicants have as a still further object of their invention the provision of a collector arrangement for a mass spectrometer employing a plurality of electrodes associated to define adjacent electron capture chambers and an external magnet for disposing of electrons while permitting the passage of the ion beam therethrough.

Applicants have as a still further object of their invention the provision of an electrode and magnet assembly for disposing of undesirable charged particles in a mass spectrometer at the collector, employing a series of spaced plate electrodes having aligned slits of progressively narrower width and an external magnet.

Other objects and advantages of our invention will appear in the following specification and accompanying drawings, and the novel features thereof will be particularly pointed out in the annexed claims.

In the drawings, Figure 1 is a sectional elevation of a conventional mass spectrometer incorporating our improved electron trap and magnet assembly. Figure 2 is a cross-sectional view taken along the line 2—2 of Figure 1. Figure 3 is a comparative chart indicating generally the effect of wave shapes at the collector with and without applicants' improved assembly. Figure 4 is a schematic of our improved collector assembly indicating its action on undesired charged particles. Figure 5 is an exploded view of our improved collector assembly for a mass spectrometer. Figure 6 is a schematic of our improved collector assembly shown associated with a collector electrode.

While applicants' invention may have application to many special types of spectrometers, including process monitoring recorders, it also has general application to analyzers of the spectrometer type, and in Figure 1 a tube of a mass spectrometer of a conventional type is designated **10** and includes a glass envelope sealed to the copper analyzer tube **11**. The tube portion **12** housing the collector assembly **22** and collector plate **21** may be made of any appropriate material, while the collector assembly **22** and collector plate **21** is preferably made of Nichrome V and can be appropriately joined to the copper tubing portion of the spectrometer. The gas to be analyzed is fed into the instrument through the gas inlet or sample tube **13**, and vacuum is maintained in the spectrometer tube by pump down through outlet tube **14** which communicates with the usual arrangement of vacuum pumps (not shown). The sample tube **13** leads to the source **18** and enters the ionization chamber **17** thereof. This chamber is better illustrated in Figure 2 where the filament F is heated to give an electron beam which traverses chamber **17** and is received on anode or plate T. The electron beam passes over and is located immediately above the slit **27** in the shield plate S.

Ions formed by collision of the electrons with the gas molecules are drawn through the slit **27** in plate S and accelerated through a series of plates J_1, J_2, J_3, J_5, and G. Plates J_1 and J_2 are a split pair and permit one to bend the beam to one side or the other to compensate for imperfections in the alignment as well as for the slight bend-

ing of the beam produced by the magnetic field used for aligning the electron beam. The remainder of the plates form a lens which not only increases the intensity of the ion beam entering the magnetic analyzer, but also prevents a dropping off of ion intensity for all but the lowest energy ions. The upper plate marked G is grounded along with the magnetic analyzer housing to which it is tied.

The magnetic field associated with the tube for bending the ion beam, and that resulting in dispersion of the ions of various masses, is in trapezoidal form as indicated at **20**, the pole faces being indicated by numeral **19** on Figure 2. The collector plate is indicated at **21** and this is associated with our improved collector assembly **22** which is positioned in front of the collector plate. The lead **23** from the collector plate extends through the glass insulator **26** and passes outwardly from the tube through the shielding element **24**. The magnetic field is set up by any conventional type of magnet. The magnet **9**, however, is preferably a U-type permanent magnet assembly whole poles are positioned against the sides of the spectrometer tube and consists of two rod magnets in axial alignment connected by a yoke of soft iron, with field strength of approximately 200 to 350 gauss. The field is generally parallel to the major axis of the collector slit. In some instances, however, best operation is achieved when the field forms an angle of as much as 90° with the major axis of the slit and the exact setting is rather critical at the particular zone of location. To enable the magnet to set up the field in this manner, the poles of the magnet are made adjustable for movement in an arcuate path about the tube **12**, as well as longitudinally thereof.

In its operation, gas molecules which are fed to the source **18** through the sample tube **13** are ionized in the ionization chamber. The ions are ejected from the chamber **17** through the slit **27** and pass downwardly through the beam forming and focusing mechanisms J_1, J_2, J_3, J_5, and G. They are then projected into the portion **11** of the tube which is traversed by a magnetic field whose lines of force extend into the plane of the paper. This field is set up by the conventional spectrometer magnet indicated generally at **20**. This action has the effect of causing the ions to travel in arcuate paths whose radii correspond to the respective masses of the ions. By adjusting the focusing potentials of the source **18** any desired ion beam may be focused on the aligned slits of the collector assembly **22** and the selected beam may be made to fall or impinge upon the collector electrode **21**.

Referring to Figure 4, showing a schematic of our improved collector assembly with paths of travel of the ions generally indicated by the dotted lines, it will be seen that the field of the magnet **9** with pole faces designated M, M will traverse the spectrometer at the collector end but is not sufficiently strong to have very much effect on the relatively high energy ions that make up the beam, so that the main body of these ions pass on to the collector plate designated **21**. However, some of the ions of the beam, designated B, do not follow the others through the aligned slits to the collector assembly, but strike portions of the mass spectrometer including the baffle or collector arrangement **1**, **2** and **3** and knock out or otherwise produce secondary ions or electrons. These ions and electrons are of relatively low energy, so that they may be effectively acted upon by the magnetic field, set up by the magnet M, M, which tends to bend or deflect them. These and other low energy ions tend to follow paths which bring them into contact with the collector arrangement so that they may be neutralized and disposed of. This latter process is aided by the fact that the collector structure is arranged to define chambers which tend to trap these charged particles and increase their chances of engagement with the conductive metal walls.

Referring now to Figure 5, the aforementioned special baffle assembly comprises a grounded collector slit plate **1**, a baffle plate **2**, and a skirted baffle plate **3**. As shown, the baffle plates **2** and **3** are formed with central slits generally similar in shape to the collector slit. The three slits may be of the same length, but the slit in the baffle plate **2** is made somewhat wider than the slit **1**. The slit in the skirted baffle **3** is made still wider. All three of the slits are formed with very thin edges to minimize secondary election emission by ions grazing the slit edges. As shown, the baffles **2** and **3** are mounted to the collector slit plate **1** by means of suitable elongated spacer studs **4** and screws **5**. With this arrangement, the three slits are positioned one over another, in axial alignment.

As shown, the central part of the upper face of the collector slit plate **1** is cut away, or counterbored, so that the collector slit is recessed with respect to the upper face. Consequently, when the baffle plate **2** is mounted flush upon the plate **1**, a chamber is formed between the central portions of the plates. This chamber, in conjunction with the chamber between baffle plates **2** and **3** apparently functions as an electron trap. It will be noted that the skirt of the baffle **3** extends to the upper face of the plate **1**, so that the slits in the baffles **2** and **3** constitute the only openings through which positive ions, negative ions, and secondary electrons can enter the collector slit.

The combination of a collector magnet **9** and the assembly **22** of electrodes of Figures 1 and 5 are highly effective in minimizing negative peaks. For example, this combination is used with "line recorder" spectrometer systems for gaseous diffusion cascades. These systems are highly sensitive and are designed to record masses ranging from at least mass 12 to mass 400. When provided with the above arrangement, these system can be calibrated so that an ion signal as great as 20,000 millivolts will result in a negative signal extending less than 16 millivolts below the base line on the recorder chart (millivolts where preamplifier input resistor equals 10^{12} ohms). This magnitude of input resistor provides a signal sensitivity greater than is generally obtained in the art. This is a marked improvement over the prior art, and is obtained without significant reduction in the over-all sensitivity of the systems. Thus under comparable conditions the use of applicants' improved system results in the reduction of the magnitude of the negative peaks by a factor of about 1250.

Now referring to the schematic of Figure 6, it will be seen that the collector arrangement **22** which includes electrodes **3**, **2** and **1** are all maintained at ground potential while collector electrode **21** is coupled into the control grid of a D. C. amplifier **41**, and by virtue of the drop across grid resistor **40**, is maintained at a potential slightly above ground when a positive ion beam impinges upon it. It will be seen that some electrons or other stray ions which enter the chamber defined or enclosed by skirted electrode **3** may be deflected by the magnetic field at the collector assembly since it passes across the chamber substantially parallel with the major axis of the slits of the electrodes **3**, **2** and **1** and will have the tendency to deflect them to the grounded walls of the electrode **3** where they are neutralized. Most of the balance of these particles which enter the chamber defined by electrodes **1**, **2** are likewise deflected by the magnetic field and pass to ground.

Figure 3 is a chart indicating the effect of negative peaks on the shape of signal traces resulting from signals appearing at the collector plate **21**. It will be seen from chart *a* that negative peaks can serve to introduce inaccuracies into the measurements by reduction of the positive peak height. This is especially true where the negative signals are so large that the trace goes off of the recording tape. The wave shape of chart *b* indicates how the wave might have appeared except for the inaccuracies introduced by the presence of the negative peaks.

Experience has shown that: (*a*) Better elimination is obtained if the slit in plate **2** is wider than the collector slit, and if the slit in the plate **3** is wider than the slit in

plate 2. (*b*) The edges of the various slits are preferably approximate knife edges. (*c*) The spacing between plate 1 and plate 2 is of critical importance. Whereas the spacing between plates 2 and 3 is of somewhat lesser importance. (*d*) Improvement has been noted and negative signals reduced where the surfaces of the collector arrangement 22 exposed to positive ion bombardment is located perpendicular to the beam.

Having thus described our invention, we claim:

1. A mass spectrometer comprising an elongated envelope, an ion source positioned at one extremity of the envelope for producing ions, means for accelerating the ions alog the envelope, a magnetic field threading an intermediate portion of the envelope for separating the ions into beams, a collector toward the other extremity of the envelope for collecting ions of a desired beam, a grounded collector assembly including a plurality of spaced plates having aligned apertures positioned in the ion beam ahead of the collector for the passage of the beam, and an additional magnetic field threading the assembly normal to the beam for directing low energy ions and electrons toward the assembly for neutralizing them.

2. A mass spectrometer comprising an elongated tube, an ion source positioned at one extremity of the tube for producing ions, means for accelerating the ions along the tube, a magnetic field threading an intermediate portion of the tube for separating the ions into beams, a collector toward the other extremity of the tube for collecting ions of a desired beam, a grounded collector assembly including a plurality of spaced plates having apertures of substantially the same length positioned in the ion beam ahead of the collector for the passage of the beam, and an additional magnetic field threading the assembly normal to the beam for directing low energy ions and electrons toward the assembly for neutralizing them.

3. A mass spectrometer comprising an elongated envelope, an ion source positioned at one extremity of the envelope for producing ions, means for accelerating the ions along the envelope, a magnetic field threading an intermediate portion of the envelope for separating the ions into beams, a collector toward the other extremity of the envelope for collecting ions of a desired beam, a grounded collector assembly including a plurality of spaced plates having progressively wider apertures positioned in the ion beam ahead of the collector for the passage of the beam, and an additional magnetic field threading the assembly normal to the beam for directing low energy ions and electrons toward the assembly for neutralizing them.

4. A mass spectrometer comprising an elongated envelope, an ion source for ionizing neutral vapors positioned at one extremity of the envelope for producing ions, accelerating and collimating electrodes for accelerating the ions along the envelope, a magnetic fiield threading an intermediate portion of the envelope for separating the ions into beams, a collector toward the other extremity of the envelope for collecting ions of a desired beam, a grounded collector assembly including a plurality of spaced plates having aligned apertures positioned in the ion beam ahead of the collector for the passage of the beam, and a magnet having pole faces positioned on either side of said assembly for setting up a magnetic field substantially perpendicular to the ion beam for directing low energy ions and electrons toward the assembly for neutralizing them.

5. A mass spectrometer comprising an elongated envelope, an ion source positioned at one extremity of the envelope for producing ions, means for accelerating the ions along the envelope, a magnetic field threading an intermediate portion of the envelope for separating the ions into beams, a collector toward the other extremity of the envelope for collecting ions of a desired beam, a grounded collector assembly including a plurality of spaced slotted plates provided with conducting bridging enclosures positioned in the ion beam ahead of the collector, and an additional magnetic field threading the assembly normal to the beam for directing low energy ions and electrons toward the assembly for neutralizing them.

6. A mass spectrometer comprising an elongated tube, an ion source positioned at one extremity of the tube for producing ions, means for accelerating the ions along the tube, a magnetic field threading an intermediate portion of the tube for separating the ions into beams, a collector positioned adjacent the other extremity of the tube for collecting ions of a desired beam, a grounded collector assembly including a series of plates having aligned apertures for insertion in the ion beam ahead of the collector, said plates having a conducting enclosure, and an additional magnetic field threading the assembly normal to the beam for directing low energy ions and electrons toward the assembly for neutralizing them.

7. A mass spectrometer comprising an elongated envelope, an ion source positioned at one extremity of the envelope for producing ions, means for accelerating the ions along the envelope, a magnetic field threading an intermediate portion of the envelope for separating the ions into beams, a collector located adjacent to the other extremity of the envelope for collecting ions of a selected beam, a grounded collector assembly including a series of spaced plates having aligned apertures of substantially the same length and diminishing widths in the direction of the collector disposed in the beam ahead of the collector, and a conducting shell for enclosing the plates, and an additional magnetic field threading the assembly normal to the beam for directing low energy ions and electrons toward the assembly for neutralizing them.

8. A mass spectrometer comprising an elongated envelope, an ion source positoned at one extremity of the envelope for producing ions, means for accelerating the ions along the envelope, a magnetic field threading an intermediate portion of the envelope for separating the ions into beams, a collector positioned adjacent the opposite extremity of the envelope for collecting ions of a selected beam, a grounded collector assembly including a plurality of spaced plates having aligned apertures of substantially the same length for insertion in the beam ahead of the collector, one of said plates being spaced at a substantially greater distance than the others, and a conducting skirt on said one plate extending toward the others to enclose the space, and an additional magnetic field threading the assembly normal to the beam for directing low energy ions and electrons toward the assembly for neutralizing them.

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