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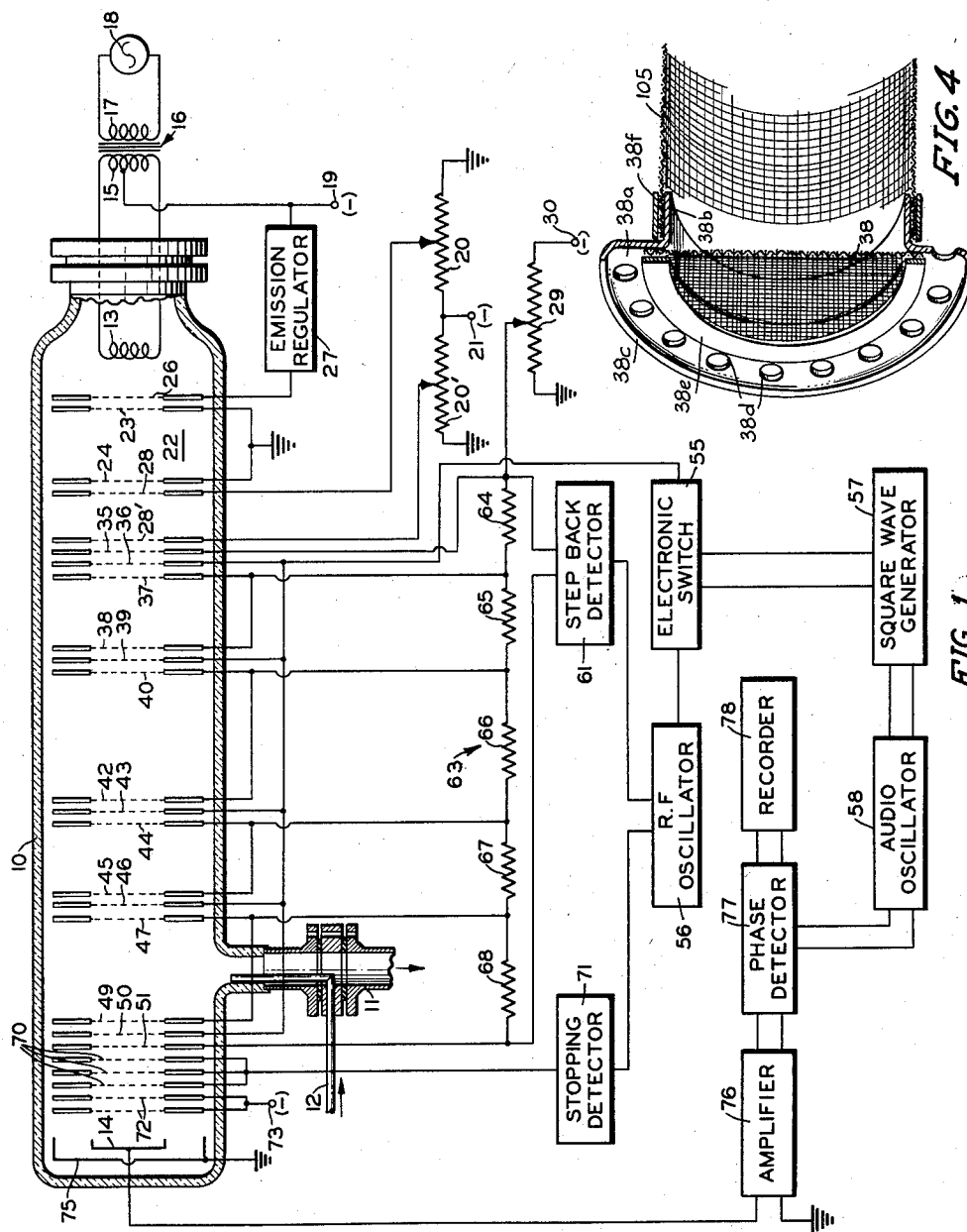
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MASS SPECTROMETER

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1

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MASS SPECTROMETER

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8 Claims. (Cl. 250—41.9)

This invention relates to mass spectrometers. In another aspect it relates to improved grid mounting structure for vacuum tubes.

In recent years mass spectrometers have been developed from highly specialized academic research instruments for measuring the relative abundance of isotopes into analytical tools of extreme sensitivity and accuracy. At the present time, applications are being found for the use of mass spectrometers in process monitoring and control. Mass spectrometry comprises, in general, ionizing a sample of material under investigation and separating the resulting ions according to their masses to determine the relative abundance of ions of selected masses. The material to be analyzed usually is provided as a gas which is bombarded by a stream of electrons to produce the desired ions. Although both positive and negative ions may be formed by such electrical bombardment, most mass spectrometers make use of only the positive ions. These positive ions are accelerated out of the region of the electron beam by means of negative potentials. Such potentials impart equal kinetic energies to ions having like charges such that ions of different masses have different velocities after passing through the electrical field and, consequently, have different momenta.

United States Patent 2,535,032 describes a mass spectrometer which is provided with two sets of three equally spaced accelerating grids. Direct potentials are applied to the outer two grids and a radio frequency potential is applied between the center grid and the outer two grids of each set. Ions which enter the space between the first two grids in proper phase receive maximum energy and are accelerated through the field between the first and second grids and the field between the second and third grids. The ions subsequently pass through a field-free drift space and enter the second group of three grids. The spacing between the grids, the frequency of the radio frequency voltage, and the magnitudes of the accelerating potentials are such that ions of predetermined mass receive sufficient energy to overcome a potential barrier and impinge upon a collector plate.

The mass spectrometer tube of the present invention is an improvement over the mass spectrometer disclosed in said Patent 2,535,032. The tube is provided a larger number of accelerating grids to define additional drift spaces. The grids are supported by annular plates having inner flanges integral therewith. The flanges support shield screens which extend between adjacent grids that define the drift spaces. The plates are provided with a plurality of holes. Support rods extend longitudinally of the tube through spaced holes in the plates to align the plates. Electrical leads extend through other holes in the plates to connect the grids to external operating circuits. Insulating spacers separate adjacent plates.

Accordingly, it is an object of this invention to provide an improved mass spectrometer which operates upon the principle of energy selection of ions of a predetermined mass.

2

Another object is to provide improved means to position grids in vacuum tubes.

Other objects, advantages, and features of this invention should become apparent from the following detailed description taken in conjunction with the accompanying drawing in which:

Figure 1 is a schematic representation of a mass spectrometer incorporating features of this invention;

Figure 2 is a detailed elevation view of the tube of Figure 1;

Figure 3 illustrates the grid support assembly; and Figure 4 is a detailed view of the grid support plate.

Referring now to the drawing in detail and to Figure 1 in particular, there is shown a mass spectrometer tube 10 comprising a gas impermeable envelope, the interior of which is maintained at a reduced pressure by a vacuum pump, not shown, which communicates with the interior of tube 10 through a conduit 11. A sample of gas to be analyzed is directed into tube 10 through a conduit 12. An electron emitting filament 13 is disposed in one end of tube 10 and an ion collector plate 14 is disposed in the second end of the tube. The end terminals of filament 13 are connected to the respective end terminals of the secondary winding 15 of a transformer 16. The end terminals of the primary winding 17 of transformer 16 are connected to an alternating current source 18. The center tap of the secondary winding 15 of transformer 16 is connected to a negative potential terminal 19.

The gas sample supplied through conduit 12 diffuses into an ionization chamber 22 in tube 10 which is defined by a pair of spaced grids 23 and 24 that are maintained at ground potential. Electrons emitted from filament 13 are accelerated into chamber 22 by the potential difference between filament 13 and grids 23 and 24. A grid 26 is positioned between filament 13 and grid 23. Grid 26 is connected to the output of an emission regulator circuit 27, which can be of the type disclosed in the copending application of M. C. Burk, Serial No. 412,790, filed February 26, 1954. The input of emission regulator 27 is connected to the center tap of transformer winding 15. This emission regulator is provided for the purpose of applying a potential to grid 26 of magnitude such as to maintain a constant flow of electrons into ionization chamber 22 irrespective of minor fluctuations in the electron emission from filament 13. In this manner the rate at which gas molecules are ionized in chamber 22 by electron bombardment is a function of only the gas pressure in the chamber.

A first collimating electrode 28 is positioned on the second side of ionization chamber 22 and is connected to the contactor of a potentiometer 20. One end terminal of potentiometer 20 is connected to a negative potential terminal 21, the second end terminal of potentiometer 20 being grounded. A second collimating electrode 28' is spaced from electrode 28. Electrode 28' is connected to the contactor of a potentiometer 20'. The end terminals of potentiometer 20' are connected to terminal 21 and ground, respectively.

The positive ions produced in ionization chamber 22 are accelerated by the negative potentials applied to electrodes 28 and 28' so as to travel through the tube toward collector plate 14. A first set of three equally spaced grids 35, 36 and 37 is positioned in tube 10 between grid 28 and collector plate 14; a second set of equally spaced grids 38, 39 and 40 is positioned in spaced relation with the first set of grids; a third set of equally spaced grids 42, 43, and 44 is positioned in spaced relation with the second set of grids; a fourth set of equally spaced grids 45, 46 and 47 is positioned in spaced relation with the third set of grids; and a fifth set of equally spaced grids 49, 50 and 51 is positioned in spaced re-

3

lation with the fourth set of grids. Grid 35 is connected to the contactor of a potentiometer 29. One end terminal of potentiometer 29 is connected to a negative potential terminal 30, the second end terminal of potentiometer 29 being connected to ground. The contactor of potentiometer 29 can be adjusted to apply selected negative accelerating potentials to grid 35. Grids 36, 39, 43, 46 and 50 are connected to one another and to the output terminal of an electronic switch 55. The input terminal of switch 55 is connected to one output terminal of a radio frequency oscillator 56. Switch 55 is controlled by the output of a square wave generator 57, which in turn is energized by the output of an audio oscillator 58. Switch 55 is thus turned on and off at the frequency of oscillator 58 to apply the output of oscillator 56 to grids 36, 39, 43, 46 and 50. Grid 35 is connected to one output terminal of a step back detector 61, which in turn is connected to an output terminal of oscillator 56. The second output terminal of detector 61 is connected to grid 51. Grids 35 and 51 are connected to one another by a voltage dividing network 63 which comprises five resistors 64, 65, 66, 67 and 68 that are connected in series relation. Grids 37 and 38 are connected to one another and to the junction between resistors 64 and 65; grids 40 and 42 are connected to one another and to the junction between resistors 65 and 66; grids 44 and 45 are connected to one another and to the junction between resistors 66 and 67; and grids 47 and 49 are connected to one another and to the junction between resistors 67 and 68.

A plurality of closely spaced stopping grids 70 is positioned between grid 51 and collector plate 14. Grids 70 are connected to one another and to the output of a stopping detector 71, which in turn is connected to an output of oscillator 56. A plurality of suppressor grids 72 is positioned between grids 70 and collector plate 14. Grids 72 are connected to a negative potential terminal 73 to suppress secondary electrons which may result from ions impinging upon metal parts of the tube. A grounded shield 75 is positioned adjacent collector plate 14.

Collector plate 14 is connected to one input terminal of an amplifier 76 which is tuned to pass signals of the same frequency as the frequency of oscillator 58. The second input terminal of amplifier 76 is connected to ground. The output terminals of amplifier 76 are connected to first input terminals of a phase detector 77. The second input terminals of phase detector 77 are connected to output terminals of oscillator 58. The output terminals of phase detector 77 are connected to a suitable indicating means such as a recorder 78.

The circuits illustrated schematically in Figure 1 are described in detail in the copending application of M. C. Burk and F. W. Karasek, Serial No. 480,696, filed January 10, 1955.

In the mass spectrometer tube of Figure 1, the spacings s between grids 35 and 36, 36 and 37, 38 and 39, 39 and 40, 42 and 43, 43 and 44, 45 and 46, 46 and 47, 49 and 50, and 50 and 51 are maintained equal. The spacings r between the centers of grids 37 and 38, 40 and 42, 44 and 45, and 47 and 49 can be represented by the expression:

$$r = 2s \left(\frac{n}{0.742} - 1 \right)$$

where n is an integral number, all dimensions being in inches. In one embodiment of this invention, s was 0.118 inch and the four n 's, proceeding from filament 13 to collector plate, were five, nine, four and seven, respectively. The values of n can be varied, they may be equal, and more or fewer drift spaces can be provided, if desired.

Tube 10 is illustrated in detail in Figures 2, 3 and 4. Each of the grids is formed of a circular screen which is supported by an annular plate, such as 38a shown in Figure 4 in conjunction with grid 38. Plate 38a is

4

provided with an inner flange 38b and an outer flange 38c, the latter providing rigidity. Plate 38a is also provided with a plurality of holes 38d through which support rods and electrical leads pass. Grid 38 is attached to plate 38a by means of a ring 38e which is welded to plate 38a. Grid 38 is thus "sandwiched" between ring 38e and plate 38a. Grid 38 preferably is formed of tungsten wire and plate 38a is formed of "Monel" metal. Each of the other grids in tube 10 is supported by a corresponding annular plate designated by an a reference numeral.

The several annular plates are positioned with respect to one another by support rod assemblies 85, 86, 87 and 88 which extend through corresponding holes in the plates. Assembly 85, for example, comprises a rigid metal rod 85a having an insulating sleeve 85b attached to one end thereof by a clamp 85c. Sleeve 85b extends nearly the entire length of rod 85a and the outer diameter thereof is approximately the same as the diameter of the holes in the annular screen mounting plates. An insulating spacer sleeve 85d extends between clamp 85c and plate 26a. Corresponding insulating spacer sleeves 85e, 85f, 85g, 85h, 85i, 85j, 85k, 85l, 85m, 85n, 85o, 85p, 85q, 85r, 85s, 85t, 85u and 85v, are mounted on sleeve 85b between respective pairs of plates 26a, 23a; 24a, 28a; 28a', 35a; 35a, 36a; 36a, 37a; 38a, 39a; 39a, 40a; 42a, 43a; 43a, 44a; 45a, 46a, 46a, 47a; 49a, 50a; 50a, 51a; 51a, 70a; 70a, 70a; 70a, 72a; and 72a, 72a. Metal spacer sleeves 90, 92, 93, 94 and 95 are mounted on sleeve 85b between respective pairs of plates 23a, 24a; 37a, 38a; 40a, 42a; 44a, 45a; and 47a, 49a. An insulating sleeve 96 extends between plate 72a and a guide plate 97. An insulating sleeve 91 extends between plates 28a and 28a'. An insulating sleeve 98 and a spring 99 extend between plate 97 and a clamp 101 on the second end of rod 85a. Spring 99 retains the plates tight against the spacers. Springs 102 and 103 are mounted on respective plates 26a and 97 to align the assembly in tube 10. The assembly is inserted in tube 10 and end 104 is fused to the tube.

Cylindrical screens 105, 106, 107 and 108 surround the four drift spaces. Considering Figure 4, for example, screen 105 is "sandwiched" between flange 38b and a cylindrical band 38f. Screens 105, 106, 107 and 108 serve to form uniform drift spaces down the center of tube 10.

The electrical leads extending to the several grids in tube 10 pass through corresponding holes in the annular plates, as illustrated in detail in Figure 3.

The collector plate assembly and the sample inlet tube evacuation system are illustrated in detail in the copending application of J. G. Skinner, Serial No. 546,221, filed November 10, 1955.

From the foregoing description of a preferred embodiment of this invention it should be apparent that there is provided an improved mass spectrometer tube. The individual grids which control the passage of ions to the collector plate are positioned by novel annular mounting plates which also support cylindrical guide grids. The several grid mounting plates are positioned by support rods which extend through the mounting plates.

While the invention has been described in conjunction with a present preferred embodiment, it should be evident that it is not limited thereto.

What is claimed is:

1. A mass spectrometer tube comprising a gas impermeable envelope enclosing means to produce ions of a sample to be analyzed; a collector plate spaced from said means to produce ions; and a plurality of grids positioned between said means to produce ions and said collector plate, said grids each comprising a flat annular metal plate having a first flange at the inner edge and a second flange at the outer edge, a metal screen extending across the opening in said plate on the side thereof opposite said first flange, and a second annular plate se-

5

cured to said flat plate, the periphery of said screen being positioned between said plates.

2. The combination in accordance with claim 1 wherein each of said flat plates has a plurality of openings therein, a plurality of insulating support rods extending through respective ones of the openings, and hollow spacers on said rods between said flat plates to separate said flat plates.

3. The combination in accordance with claim 2 wherein the first flanges of two adjacent ones of said flat plates oppose one another, and further comprising a cylindrical screen extending between said two plates, said screen engaging the opposing first flanges of said two plates, and annular bands securing the ends of said cylindrical screen to said first flanges.

4. Apparatus for controlling the passage of charged particles comprising a flat annular plate having a first flange at the inner edge and a second flange at the outer edge, a metal screen extending across the opening in said plate, the diameter of said screen being greater than the inner diameter of said plate, a second annular plate of inner diameter substantially equal the inner diameter of said flat plate, and means securing said second plate to said flat plate on the side thereof opposite said inner flange, the edge of said screen being positioned between said plates.

5. Apparatus for controlling the passage of charged particles comprising a pair of grid assemblies, each of said assemblies comprising a flat annular plate having a first flange at the inner edge and a second flange at the outer edge, a metal screen extending across the opening in said plate, the diameter of said screen being greater than the inner diameter of said plate, a second annular plate of inner diameter substantially equal the inner diameter of said flat plate, and means securing said second plate to said flat plate on the side thereof opposite said inner flange, the edge of said screen being positioned between said plates; means securing the two flat plates in spaced relationship so that the first flanges oppose one another; a cylindrical screen extending between said flat plates; and annular bands securing the ends of said cylindrical screen to said first flanges.

6. A mass spectrometer comprising a gas impermeable envelope enclosing means to ionize a sample of ma-

6

terial to be analyzed; a collector plate spaced from said means to ionize; a plurality of groups of grids spaced in a line between said means to ionize and said collector plate, each of said groups comprising three grids in spaced relationship with one another, the spacings between adjacent grids being equal, the spacings between adjacent groups of said grids being substantially

$$2s\left(\frac{n}{0.742} - 1\right)$$

where n is an integral number and s is the spacing between adjacent grids in each group, a second grid positioned between said collector plate and said groups of grids, said grids each comprising a flat annular metal plate having a first flange at the inner edge and a second flange at the outer edge, a metal screen extending across the opening in said plate on the side thereof opposite said first flange, and a second annular plate secured to said flat plate, the periphery of said screen being positioned between said plates; means applying steady potentials to the two end grids in each of said groups of grids; means applying a potential to said second grid of polarity opposite the polarity of the ions being detected; means applying an alternating potential to the center grid in each of said groups of grids; and detecting means connected to said collector plate.

7. The combination in accordance with claim 6 wherein each of said flat plates has a plurality of openings therein, a plurality of insulating support rods extending through respective ones of the openings, and hollow spacers on said rods between said flat plates to separate said flat plates.

8. The combination in accordance with claim 7 wherein the first flanges of the end flat plates in each of said groups extend toward an adjacent group, and further comprising a cylindrical screen extending between each of said groups, said screens engaging the first flanges of said flat plates, and annular bands securing the ends of said screens to the first flanges.

References Cited in the file of this patent

Bennett: Journal of Applied Physics, vol. 21, Feb. 1950, pp. 143-149 relied on. (Copy in Div. 44.)