

April 16, 1957

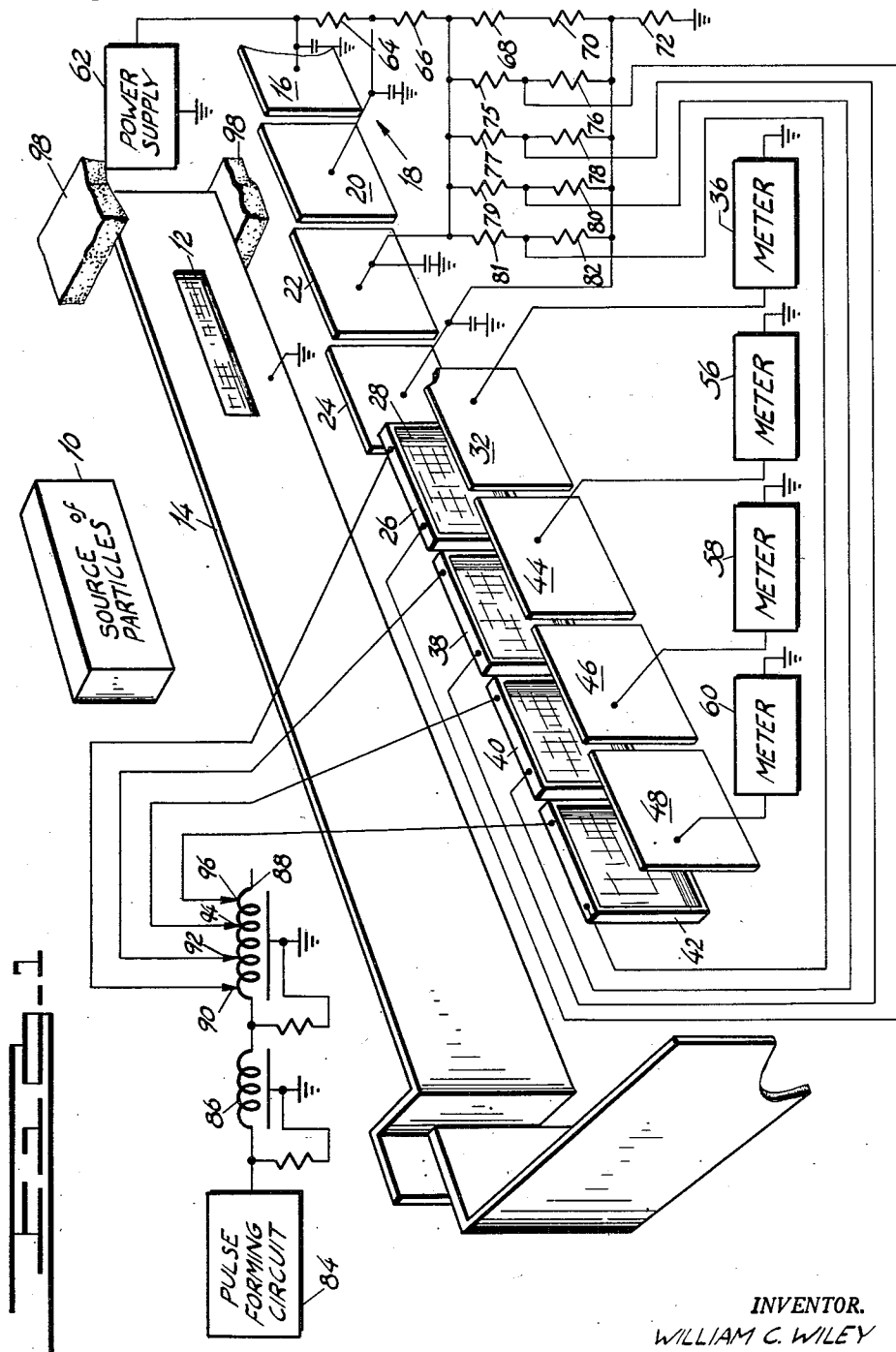
W. C. WILEY

2,789,228

ELECTRON MULTIPLIER

Filed Sept. 14, 1953

3 Sheets-Sheet 1



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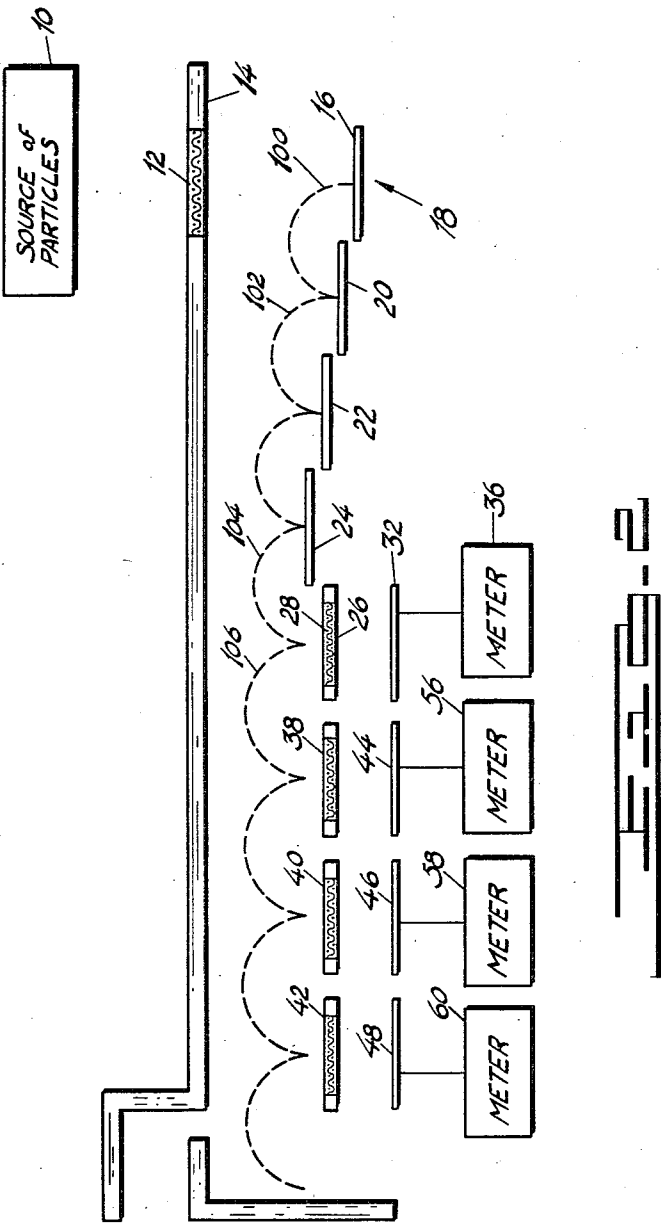
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3 Sheets-Sheet 2



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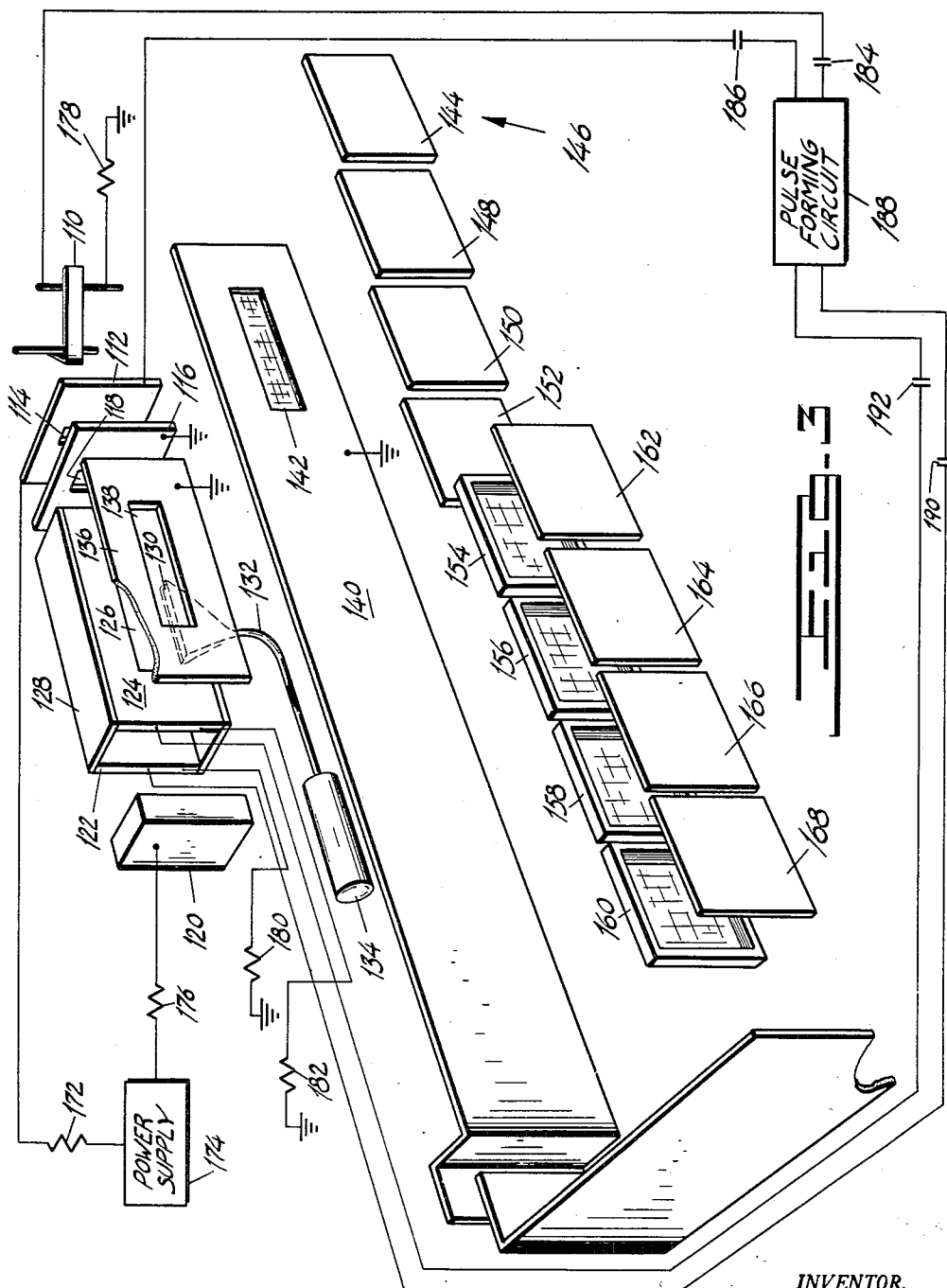
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ELECTRON MULTIPLIER

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Application September 14, 1953, Serial No. 380,009

13 Claims. (Cl. 250-41.9)

This invention relates to electron multipliers and more particularly to electron multipliers for amplifying a plurality of discrete pulses and for separating the pulses into separate channels after their amplification.

In certain types of mass spectrometers, a plurality of ions are produced from molecules of the different gases and vapors in an unknown mixture. After a considerable number of ions have been produced, the ions are withdrawn in a pulse from their place of retention by the imposition of a force upon the ions. This force causes the ions of light mass to attain a greater velocity than the ions of heavy mass and to reach a detector before the ions of heavy mass. By measuring the times at which signals are produced by the detector, the masses of the ions can be determined.

Since the signals produced by the operation of the mass spectrometer itself result from only a limited number of ions, they are relatively weak. In order to provide useful indications, these signals must be considerably amplified. Electron multipliers have been employed as a detector and amplifier to increase the strength of the signals produced by the ions. The multipliers include a plurality of plates so disposed relative to one another that each plate receives electrons from a preceding plate and produces an increased number of electrons. In this way, the multipliers have been able to provide gains of one million or more in the amplitudes of the signals produced by the ions. However, the electron multipliers now in use are not entirely advantageous in providing an instantaneous distinction between ions of different mass when the various ions are included in an unknown mixture.

This invention provides an electron multiplier having a plurality of separate collectors for producing signals indicative of the ions of different mass. A gate is associated with each collector and is normally biased to prevent electrons produced by intermediate plates in the multiplier from passing to its associated collector. By applying a voltage pulse to each of the gates at a different time, each collector receives the electrons resulting from the ions of different mass. In this way, the electron multiplier provides an instantaneous indication as to the presence or absence of ions of different mass in an unknown mixture.

An object of this invention is to provide an electron multiplier for providing an instantaneous distinction between groups of particles arriving at different times at the multiplier.

Another object is to provide an electron multiplier of the above character having a plurality of collectors so disposed and so operated that each provides an indication of the travel of a different group of particles to the multiplier.

A further object is to provide an electron multiplier of the above character for use in a mass spectrometer to provide an instantaneous indication as to the presence or absence of ions of different mass in an unknown mixture.

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Still another object is to provide an electron multiplier of the above character for use in a mass spectrometer to provide at different terminals signals indicative of the presence of the ions of particular masses in an unknown mixture.

In the drawings:

Figure 1 is a perspective view, partly in block form, illustrating an electron multiplier constituting one embodiment of this invention.

Figure 2 is a top plan view of the electron multiplier in Figure 1 illustrating the flow of electrons in the multiplier under a given set of conditions.

Figure 3 is a perspective view of the electron multiplier in Figure 1 positioned to receive ions from a mass spectrometer.

In the embodiment of the invention shown in Figures 1 and 2, a source 10 is adapted to emit groups of particles towards a window 12 in an electrode 14. For example, the source 10 may be in a mass spectrometer, such as is shown in Figure 3 and as will be disclosed in detail hereinafter. In addition to emitting positive particles such as ions, the source 10 may emit uncharged particles or negative particles such as electrons.

A plate 16 in an electron multiplier, generally indicated at 18, is disposed to receive particles passing through the window 12. Plates 20, 22, and 24 are also included in the multiplier and are disposed relative to one another and to the plate 16 such that the left extremity of each plate is very close to the right extremity of the next plate. Each of the plates 16, 20, 22 and 24 is made from a suitable material to emit a number of electrons proportionately greater than the number of particles which impinge upon it. For example, the plates may be made from a copper beryllium alloy having approximately 2% by weight of beryllium.

Each of the plates 16, 20, 22 and 24 is positioned at a different distance from the electrode 14. For example, the plate 16 may be positioned approximately .225 inch in front of the electrode 14 and the plates 20, 22 and 24 may be approximately .200, .175 and .150 inch away from the electrode 14.

A grid 26 is positioned adjacent to the left extremity of the plate 24 and at a slight distance from the plate 24. For example, the grid 26 may be positioned approximately .175 inch away from the electrode 14. The grid 26 may be made from a plurality of wires 28 spaced at regular intervals from one another. For example, adjacent wires 28 may be separated from one another by approximately 0.01 inch.

A collector 32 is positioned parallel to the grid 28 at a distance of approximately 0.250 inch away from the electrode 14. An indicator such as a meter 36 is connected to the collector 32.

Similarly, grids 38, 40 and 42 are disposed relative to one another such that the left extremity of each grid is adjacent to the right extremity of the next grid and the grids are approximately the same distance from the electrode 14 as the grid 26. The grids 38, 40 and 42 may be made from a plurality of spaced wires in a manner similar to that disclosed above for the grid 26. Collectors 44, 46 and 48 are associated with the grids 38, 40 and 42, respectively, in a relationship similar to that between the grid 26 and the collector 32. Meters 56, 58 and 60 are respectively connected to the collectors 44, 46 and 48 in a manner similar to that disclosed above.

Direct voltages are applied to the plates 16, 20, 22 and 24 to produce a substantially constant electric field between the plates and the electrode 14. Since the plates are positioned at different distances from the electrode, different voltages must be applied to the plates to produce such a substantially constant electric field. The voltages are applied to the plates 16, 20, 22 and 24 from a power

supply 62 through a resistance network including resistances 64, 66, 68, 70 and 72 connected in series between the power supply and ground. For example, voltages of approximately -1800, -1600, -1400 and -1200 volts may be applied to the plates 16, 20, 22 and 24, respectively.

Series resistances 75 and 76, 77 and 78, 79 and 80, and 81 and 82 are connected in parallel with the resistances 68 and 70.

Biasing voltages are respectively applied to the grids 26, 38, 40 and 42 from the common terminal between the resistances 75 and 76, 77 and 78, 79 and 80, and 81 and 82. The voltages applied to the grids 26, 38, 40 and 42 are of such value as to normally prevent the flow of electrons through the grids to the collectors associated with the grids. For example, a potential of approximately -1400 volts may be applied to the grids 26, 38, 40 and 42.

In addition to the direct voltages, the grids 26, 38, 40 and 42 also receive pulses of voltage from a pulse forming circuit 84. The voltage pulses from the source 84 are applied through a delay network 86 to a delay network 88. The networks 86 and 88 are provided with delay characteristics which will be disclosed in detail hereinafter. The network 88 has a plurality of movable contacts 90, 92, 94 and 96 which are shown as being respectively connected to the grids 26, 38, 40 and 42. Instead of being directly connected to the grids 26, 38, 40 and 42, the contacts 90, 92, 94 and 96 may be connected through suitable pulse shaping networks (not shown) to the grids.

A magnetic field as well as an electric field acts upon the electrons emitted by the plates 16, 20, 22 and 24. The magnetic field is applied in a vertical direction by a pair of pole pieces 98, one positioned above the plates and the other positioned below the plates. In the above example, the magnetic field may have a magnitude in the order of 350 gauss.

The source 10 is adapted to produce groups of particles, as will be disclosed in detail hereafter in connection with the mass spectrometer shown in Figure 3.

The particles in each group travel through the window 12 in the electrode 14 and impinge on the plate 16. Because of the particular material from which the plate 16 is made, the plate emits electrons when particles impinge upon it. The number of electrons emitted by the plate 16 is dependent upon the number of particles which impinge upon it.

The electrons emitted by the plate 16 are subjected to the combined action of the magnetic field between the pole pieces 98 and the electric field between the electrode 14 and the plates 16, 20, 22 and 24. This causes the electrons to travel through a curvilinear path towards the plate 20. The curvilinear movement of the electrons is indicated by broken lines at 100 in Figure 2 and can be mathematically defined as a cycloid.

When the electrons from the plate 16 impinge on the plate 20, they cause a proportionately increased number of electrons to be emitted by the plate. These electrons travel towards the plate 22 in a cycloidal movement indicated at 102 in Figure 2. The electrons from the plate 20 in turn cause an increased number of electrons to be emitted by the plate 22. In like manner, the plate 24 emits an increased number of electrons upon the impingement of electrons from the plate 22.

The electrons emitted by the plate 24 travel in a cycloidal movement indicated in broken lines at 104 in Figure 2. Since the grid 26 is positioned in front of the plate 24, the electrons emitted by the plate 24 complete their cycloidal movement before they reach the grid. Because of the negative potential on the grid 26 relative to the voltage on the plate 24, the grid 26 does not attract the electrons so as to produce a movement of the electrons through the grid. As a result, the electrons start a new cycloidal movement illustrated at 106 in Figure 2 after they have completed the movement 104.

When a positive pulse of voltage is applied to the grid

26, the grid attracts the electrons emitted by the plate 24 and causes the electrons to pass through the grid. The electrons then impinge on the collector 32 and produce an indication in the meter 36. In like manner, the grids 38, 40 and 42 pass electrons when pulses of positive voltage are applied to them. These electrons impinge on the collectors 44, 46 and 48, respectively, and produce indications in the meters 56, 58, and 60, respectively.

By utilizing the networks 86 and 88, positive pulses of voltage may be applied from the circuit 84 to the grids 26, 38, 40 and 42 at progressive intervals. These intervals may correspond substantially to the times at which different groups of particles are expected at the electron multiplier 18. For example, the grid 26 may be pulsed to pass to the collector 32 the electrons produced by a first group of particles, and the grids 38, 40 and 42 may be sequentially pulsed to pass successive groups of electrons to the collectors 44, 46 and 48.

The network 84 is provided with a time delay slightly shorter than the time required for the first group of particles to travel from the source 10 to the plate 16. In this way, the pulse produced by the circuit 84 reaches the network 88 just before the first group of particles reaches the plate 16. The contact 90 is then positioned along the network 88 to provide a slightly additional delay so that a pulse of voltage will be introduced to the grid 26 at substantially the instant that the electrons produced by the first group of particles reach the grid. The contacts 92, 94 and 96 are positioned further along the network 88 to impose sequential pulses of voltage on the grids 38, 40 and 42 for the passage of subsequent groups of electrons to the collectors 44, 46 and 48.

The electron multiplier disclosed above is adapted to be used in conjunction with different types of apparatus. For example, the multiplier may be used in conjunction with a mass spectrometer similar to that shown in Figure 3. The mass spectrometer includes a wedge-shaped filament 110 made from a suitable material such as tungsten to emit a plurality of electrons when heated. An electrode 112 is disposed at a relatively short distance such as ¼ millimeter away from the tip of the filament 110. The electrode 112 is provided with a vertical slot 114, the median position of which is substantially at the same horizontal level as the filament 110.

An electrode 116 is substantially parallel to and a relatively short distance such as one millimeter away from the electrode 112. The electrode 116 has a slot 118 corresponding substantially in shape and position to the slot 114. A collector 120 is positioned in substantially parallel relationship to the electrode 116 and a relatively great distance such as 4 centimeters away from the electrode.

A backing plate 122 is positioned between the electrode 116 and the collector 120 and in substantially perpendicular relationship to these members. The backing plate 122 is slightly to the rear of an imaginary line extending from the tip of the filament 110 through the slots 114 and 118 to the collector 120. An electrode 124 is disposed in substantially parallel relationship with the backing plate 122. The electrode 124 is a relatively short distance such as two millimeters in front of the backing plate 122 and slightly in front of the imaginary line disclosed above. The electrode 124 is provided with a horizontal slot 126.

Top and bottom slats 128 made from a suitable insulating material extend between the backing plate 122 and the electrode 124 to form a compartment with these members. The bottom slat 128 is provided with a horizontal slot 130 at a position directly below the imaginary line disclosed above. A conduit 132 communicates at one end with the slot 130 and at the other end with a receptacle 134 adapted to hold molecules of the different gases and vapors in an unknown mixture.

An electrode 136 is positioned a relatively short distance such as 2 millimeters in front of the electrode 124 and in substantially parallel relationship to the electrode. The electrode 136 has a horizontal slot 138 correspond-

ing substantially in shape and position to the slot 126 in the electrode 124. An electrode 140 corresponding to the electrode 14 in Figure 1 is positioned at a relatively great distance such as 40 centimeters in front of the electrode 136. The electrode 140 has a window 142 which corresponds in position to the slot 138 and which is slightly larger in dimension than the slot 138.

A plate 144 forming part of an electron multiplier generally indicated at 146 is positioned in front of the electrode 140. The plate 144 corresponds to the plate 16 shown in Figures 1 and 2. Plates 148, 150 and 152 are positioned in substantially the same relationship with respect to the plate 144 as the disposition of the plates 20, 22 and 24 with respect to the plate 16 shown in Figures 1 and 2. Grids 154, 156, 158 and 160 are constructed and disposed in a manner similar to the grids 26, 38, 40 and 42 disclosed above. Collectors 162, 164, 166 and 168 are associated with the grids 154, 156, 158 and 160 in a manner similar to that disclosed above.

In the steady state operation a positive voltage is applied to the electrode 112 through a resistance 172 from a suitable power supply 174. A slightly positive voltage is also applied to the collector 120 through a suitable resistance 176 from the power supply 174. A slightly positive voltage is applied to the collector 120 so that the collector will attract back to it electrons emitted from it upon the impingement of electrons from the filament 110. The filament 110, the backing plate 122 and the electrode 124 are connected to grounded resistances 178, 180 and 182, respectively, and the electrodes 116, 136 and 140 are directly grounded.

Negative pulses of voltage are applied to the filament 110 and the electrode 112 through coupling capacitances 134 and 186, respectively, from a suitable pulse forming circuit 188. Pulses of voltage are also respectively applied to the backing plate 122 and the electrode 124 through suitable coupling capacitances 190 and 192 from the pulse forming circuit 188. The pulse forming circuit 188 is set to apply the voltage pulses to the backing plate 122 and the electrode 124 a relatively short time after the imposition of the voltage pulses on the filament 110 and the electrode 112.

Although the pulse forming circuit 188 is shown in block form in Figure 3, its construction and operation are known to persons skilled in the art. For example, Model 902 of the Double Pulse Generator manufactured by the Berkeley Scientific Instrument Company, of Richmond, California, may be used to produce a plurality of pulses separated from one another by variable periods of time. This model generator is fully disclosed in a publication entitled "Instruction Manual, Berkeley Double Pulse Generator, Model 902" issued by the Berkeley Scientific Instrument Company in August, 1950. The pulse forming circuit disclosed in co-pending application Serial No. 288,104 filed May 16, 1952, by Macon H. Miller and William C. Wiley and now abandoned, can also be conveniently adapted for use.

The electrons emitted by the filament 110 are accelerated towards the electrode 112 because of the positive voltage on the electrode relative to the voltage on the filament. However, the electrons are decelerated in the region between the electrodes 112 and 116 since the electrode 116 is at substantially the same potential as the filament 110. This prevents the electrons from traveling into the region between the backing plate 122 and the electrode 124 with sufficient energy to ionize molecules of the different gases and vapors introduced into the region from the receptacle 134.

Upon the imposition of voltage pulses of negative polarity on the filament 110 and the electrode 112, the electrode 116 becomes positive with respect to the electrode 112. This causes the electrons traveling through the slot 114 to be attracted towards the electrode 116 so that the electrons travel into the region between the backing plate 122 and the electrode 124 with sufficient

energy to ionize molecules of the different gases and the vapors in the region. Most of the ions which are produced have a unitary positive charge.

The ions produced by the electron stream flowing from the filament 110 to the collector 120 are retained in the stream because of their opposite charge relative to the charge of the stream. The pulse forming circuit 188 is set to apply the pulses to the filament 110 and the collector 120 for a particular period of time to allow a considerable number of ions to be produced for retention in the stream. When the pulses are cut off, the ions are available for easy withdrawal upon the application of the voltage pulses on the vacuum plate 122 and the electrode 124.

The voltage pulses applied to the backing plate 122 and the electrode 124 have magnitudes to produce an electrical field of moderate intensity between the plate 122 and the electrode 124 and an electrical field of considerably increased intensity between the electrodes 124 and 136. For example, pulses of approximately +400 and +380 volts may be respectively applied to the backing plate 122 and the electrode 124. The electric fields produced by these voltage pulses cause the ions to be withdrawn in a pulse from their place of retention. The ions of light mass receive a greater amount of energy from the electric fields than the ions of heavy mass and travel to the plate 144 before the ions of heavy mass.

Because of the particular electric fields imposed on the ions between the backing plate 122 and the electrode 124 and between the electrodes 124 and 136, compensation is provided for differences in the positioning and random motion of individual ions. Differences in the positioning of individual ions result from the finite width of the slots 114 and 118. Differences in the random motion of individual ions result from thermal and other energy in the ions. The differences in the random motion of individual ions cause some of the ions to be moving towards the plate 122 and other ions to be moving towards the electrode 124 at the instant that the ions are withdrawn from their place of retention. The compensatory actions provided by the imposition of the particular voltage pulses on the plate 122 and the electrode 124 are fully disclosed in co-pending application Serial No. 249,318 filed October 2, 1951, by William C. Wiley, now Patent No. 2,685,035 issued July 27, 1954.

Since compensation is provided for differences in the positioning and random motion of the individual ions, the ions of each mass arrive at the plate 144 at substantially the same instant of time and at a time different from the arrival of the ions of other mass. When the ions in each group impinge on the plate 144, they cause electrons to be emitted by the plate. These electrons travel in a cycloidal movement towards the plate 148 and cause an increased amount of electrons to be emitted by the plate. In like manner, the plates 150 and 152 emit a number of electrons proportionately greater than the number of electrons which they receive.

Because of the voltage bias normally imposed on the grids 154, 156, 158 and 160, the electrons emitted by the plate 152 are not able to pass through the grids to any of the collectors 162, 164, 166 and 168. This prevents any signals from being produced by the collectors. At substantially the instant that the ions of lightest mass in an unknown mixture are expected at the plate 144, a positive pulse of voltage is applied to the grid 154. This causes the electrons produced by the ions to travel through the grid 154 to the collector 162 so that an output signal is produced by the collector.

Similarly, voltage pulses of positive polarity are applied to the grids 156, 158 and 160 at substantially the times that ions of progressively increasing mass in the unknown mixture are expected at the plate 144. The collectors 164, 166 and 168 produce signals indicative of the presence of these ions. For example, when molecules having masses

of 11, 32, 63 and 128 are present in an unknown mixture, the collectors 162, 164, 166 and 168 produce respective indications of the ions having masses 11, 32, 63 and 128.

Although this invention has been disclosed and illustrated with reference to particular applications, the principles involved are susceptible of numerous other applications which will be apparent to persons skilled in the art. The invention is, therefore, to be limited only as indicated by the scope of the appended claims.

I claim:

1. An electron multiplier, including, a plurality of plates arranged in staggered relationship with respect to one another, each plate being disposed to receive the electrons from a preceding plate and to produce a correspondingly increased number of electrons, means for introducing pluralities of particles to a first plate in the plurality to produce an emission of electrons from the plate in the plurality corresponding to the number of particles, a plurality of grids, each grid being disposed relative to the plates to receive electrons from the plates, means for biasing the grids to prevent the passage of electrons through the grids, and means for sequentially imposing pulses of voltage on different grids in the plurality to provide for the passage through the grids of electrons formed from the different pluralities of particles.

2. An electron multiplier, including, a plurality of plates, each plate being disposed to receive the electrons from a preceding plate and to produce a correspondingly increased number of electrons, means for introducing pluralities of particles to a first plate in the plurality to produce an emission of electrons from the plate corresponding to the number of particles, a plurality of grids disposed in laterally contiguous relationship to one another and to the last plate in the plurality, an electrical circuit for biasing the grids to prevent the movement of electrons from the last plate in the plurality through the grids, and an electrical circuit for sequentially imposing pulses of voltage on different grids in the plurality to provide for the movement through the grids of electrons formed from the different pluralities of particles.

3. An electron multiplier, including, a plurality of plates, each plate being disposed to receive the electrons emitted by a preceding plate in the plurality and to emit a correspondingly increased number of electrons, means for introducing discrete pluralities of particles to a first plate in the plurality to produce an emission of electrons by the plate corresponding to the number of particles, an electrode disposed in spaced relationship to the plates, means for producing an electric field between the electrode and the plates, means for producing a magnetic field for operating in conjunction with the electric field to produce a movement of the electrons from each plate to a successive plate in the plurality, a plurality of grids disposed in laterally contiguous relationship to one another and to the last plate in the plurality, means for biasing the grids to prevent a movement of the electrons from the last plate in the plurality through the grids, means for sequentially imposing pulses of voltage on the different grids to produce a movement of the electrons resulting from each discrete plurality of particles through a different grid, and means for indicating the electrons passing through the different grids.

4. An electron multiplier, including, a plurality of plates arranged in laterally contiguous relationship to one another to receive the electrons emitted by a preceding plate in the plurality and to emit a correspondingly increased number of electrons, means for introducing discrete pluralities of particles to a first plate in the plurality to produce an emission of electrons by the plate corresponding to the number of particles, a plurality of grids disposed in laterally contiguous relationship to one another and to the last plate in the plurality, the grids being constructed to provide for the passage of electrons through the grids, means for providing electrical and magnetic fields to produce a cycloidal movement of the electrons

emitted by each plate to the next plate in the plurality, an electrical circuit for biasing each grid to provide cycloidal movements along the grids of the electrons emitted by the last plate in the plurality, an electrical circuit for sequentially imposing voltages on different grids to produce a movement through a different grid of the electrons resulting from each discrete plurality of particles, and means for indicating the electrons passing through the different grids.

5. An electron multiplier, including, a plurality of plates arranged in laterally contiguous relationship with respect to one another, each plate being disposed to receive the electrons from a preceding plate and to produce a correspondingly increased number of electrons, means for introducing pluralities of particles to a first plate in the plurality to produce an emission of electrons from the plate corresponding to the number of particles, a plurality of grids disposed in laterally contiguous relationship with respect to one another and with respect to the last plate in the plurality, each grid being formed from a plurality of spaced wires to provide for the passage of electrons through the grid, a plurality of detectors each disposed relative to an associated grid to detect the electrons passing through the grid, an electrical circuit for biasing the grids to prevent the passage of electrons through the grids, an electrical circuit for imposing pulses of voltage on the different grids at substantially the instant that the different pluralities of particles are expected at the first plate to provide for the passage of the resultant electrons through the grids, and means for providing indications of the signals produced at the detectors.

6. An electron multiplier, including, a plurality of plates, each plate being disposed to receive the electrons from a preceding plate and to produce a correspondingly increased number of electrons, means for introducing discrete pluralities of particles to a first plate in the plurality to produce an emission of electrons from the plate corresponding to the number of particles, an electrode disposed in spaced relationship with respect to the plates, a plurality of grids disposed in laterally contiguous relationship with respect to one another and with respect to the last plate in the plurality, each grid being constructed to provide for the passage of electrons through the grid, means for producing a substantially constant electric field between the electrode and the plates and grids to prevent the movement of electrons through the grids, means for imposing a magnetic field on the electrons to provide in combination with the electrical field a movement of the electrons in a curvilinear path from each plate to the successive plate, means for varying the electrical field to produce a movement of the electrons resulting from each discrete plurality of particles through a different grid, and means for indicating the electrons passing through each grid.

7. In combination, means for producing a plurality of ions, means for accelerating the ions to produce a separation of the ions into groups on the basis of their mass, a plurality of plates, each plate being disposed to receive electrons emitted by a preceding plate and to emit an increased number of electrons, at least one plate in the plurality being disposed to receive the ions after their travel through a particular distance and to emit a number of electrons substantially proportionate to the number of ions reaching the plate, a plurality of grids disposed in lateral relationship to one another and to the plates for receiving electrons emitted by the plates, means for biasing the grids to prevent electrons from flowing through the grids, means for applying pulses of voltage on different grids at the instant that successive groups of ions are expected at the plates to provide for the passage through the grids of the electrons resulting from the ions, and means for indicating the electrons passing through the different grids.

8. In combination, means for producing a plurality of ions, means for accelerating the ions in a first direction

to produce a separation of the ions into groups on the basis of their mass, a plurality of plates, each plate being disposed to receive electrons emitted by a preceding plate and to emit a correspondingly increased number of electrons, at least one plate in the plurality being disposed to receive the ions after their travel through a particular distance and to emit a number of electrons substantially proportionate to the number of ions reaching the plate, a plurality of grids disposed in laterally contiguous relationship to one another and to the plates to receive electrons emitted by the last plate in the plurality, each grid being constructed to provide for the passage of electrons, an electrical circuit for applying voltages to different grids in the plurality at substantially the instants that the ions in successive groups are expected at the plates to provide for the passage through the grids of the electrons resulting from the ions, a plurality of detectors each associated with a different grid to detect the electrons passing through the grid, and means for indicating the signals produced by the detectors.

9. In combination, means for producing a plurality of ions, means for accelerating the ions in a first direction to produce a separation of the ions into groups on the basis of their mass, a plurality of plates disposed in staggered relationship transversely to the first direction, at least one of the plates in the plurality being disposed to receive the ions after their travel through a particular distance in the first direction and to produce a corresponding number of electrons, other plates in the plurality being disposed to receive the electrons emitted by a preceding plate in the plurality and to produce a proportionately increased number of electrons, a plurality of grids disposed in laterally contiguous relationship to one another and adjacent to the last plate in the plurality, means for providing voltages on each of the plates to produce a substantially constant electrical field, means for providing a magnetic field operative in conjunction with the electrical field to advance the electrons emitted by each plate towards a successive plate, a plurality of grids disposed in laterally contiguous and parallel relationship to one another and to the last plate in the plurality, means for biasing the grids with voltages relative to the voltages on the contiguous plate to prevent the flow of electrons through the grids, means for applying pulses of voltage to different grids in the plurality at substantially the instant that different groups of ions are expected at the plates to provide for the passage

through the grids of the electrons resulting from the ions, and means for indicating the passage of electrons through the different grids.

10. In combination with a magnetic electron multiplier having a plurality of plates, a plurality of gates disposed to receive electrons emitted by the plates in the multiplier, means for maintaining the gates normally closed to prevent the passage of electrons through the gates, and means for opening the gates in succession to provide for a successive passage of electrons through the gates.

11. In combination with a magnetic electron multiplier having a plurality of plates, a plurality of grids disposed to receive electrons emitted by the plates in the multiplier, means for biasing the grids to prevent the passage of electrons through the grids, and means for applying a voltage pulse to each grid to provide for the passage of electrons through the grid during application of the pulse.

12. In combination with a magnetic electron multiplier having a plurality of plates, a plurality of grids disposed to receive electrons emitted by the plates in the multiplier, means for biasing the grids to prevent the passage of electrons through the grids, and means for applying voltage pulses to the grids in succession to provide for a successive passage of electrons through the grids.

13. In combination with a magnetic electron multiplier having a plurality of plates, a plurality of grids disposed to receive electrons emitted by a last plate in the multiplier, a first electrical circuit for biasing the grids to prevent the passage of electrons through the grids, a second electrical circuit for applying voltage pulses to the grids in succession to provide for a successive passage of electrons through the grids, and means for indicating the electrons flowing through each grid.

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