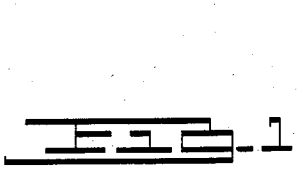
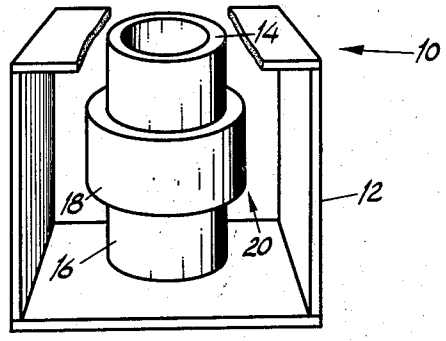
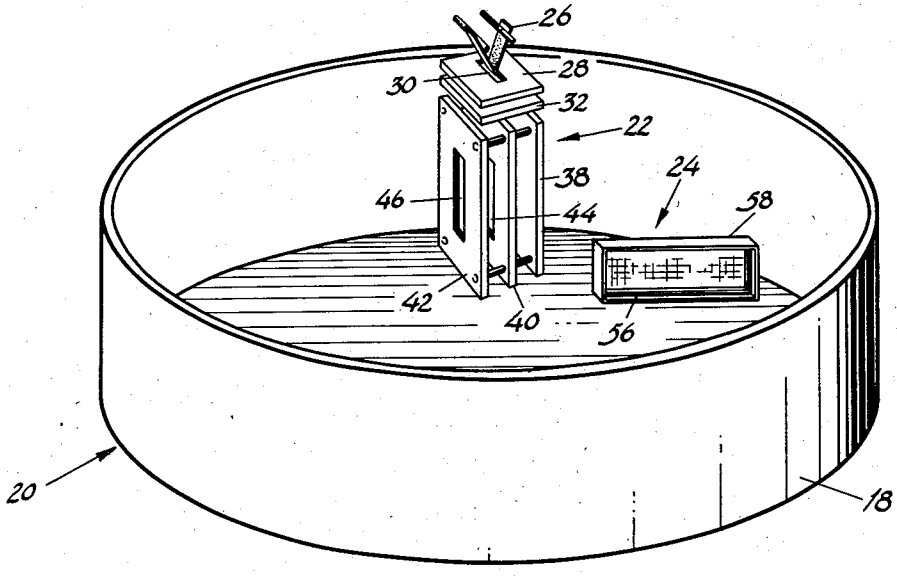
June 17, 1958 W. C. WILEY 2,839,687

MASS SPECTROMETER

Filed Oct. 29, 1953 3 Sheets-Sheet 1











INVENTOR.
WILLIAM C. WILEY
BY
Vett Parsigian
ATTORNEY

June 17, 1958 W. C. WILEY 2,839,687

MASS SPECTROMETER

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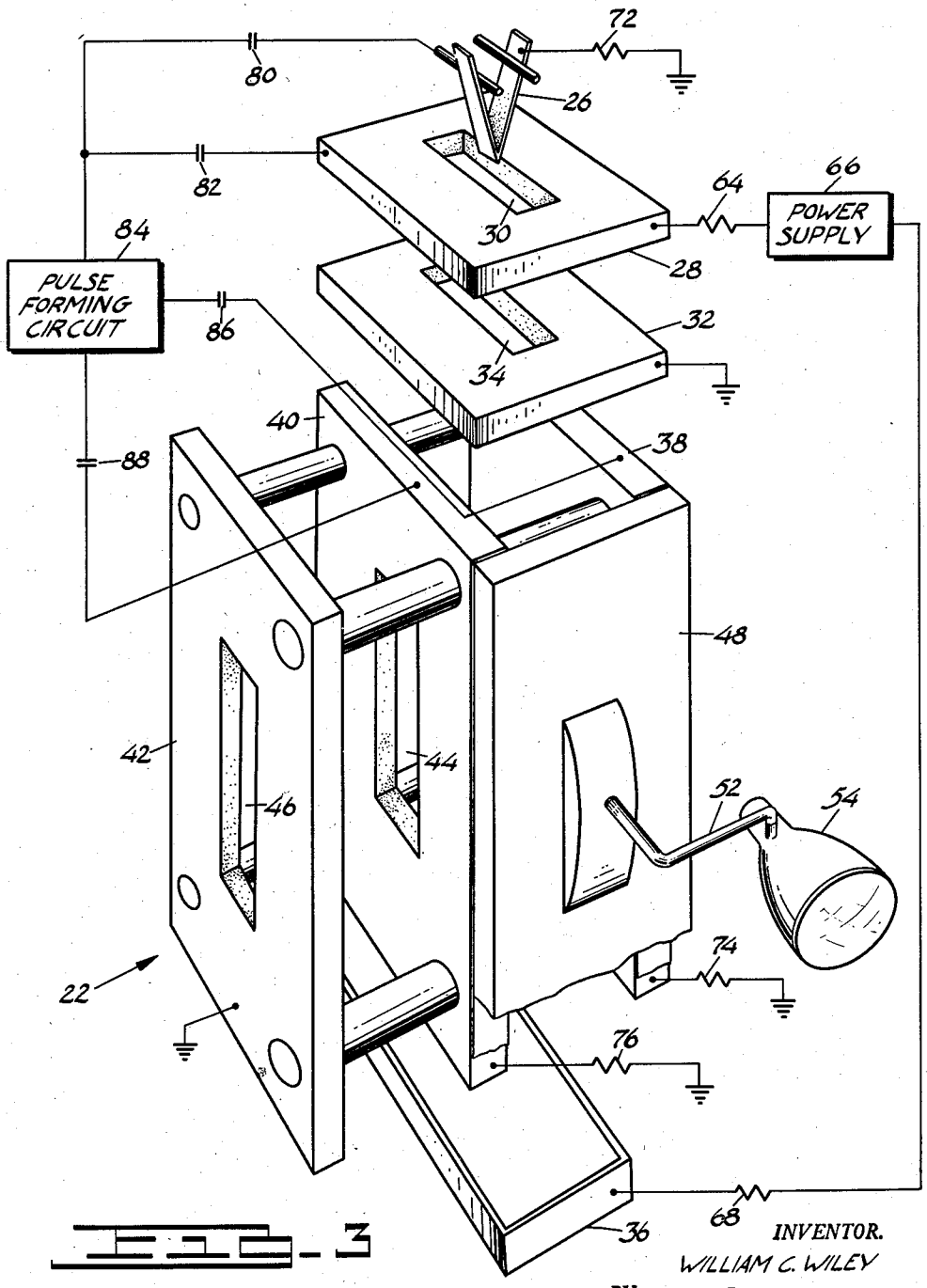


FIG. 3

INVENTOR.
WILLIAM C. WILEY
BY Vett Garsigian
ATTORNEY

June 17, 1958 W. C. WILEY 2,839,687

MASS SPECTROMETER

Filed Oct. 29, 1953 3 Sheets-Sheet 3

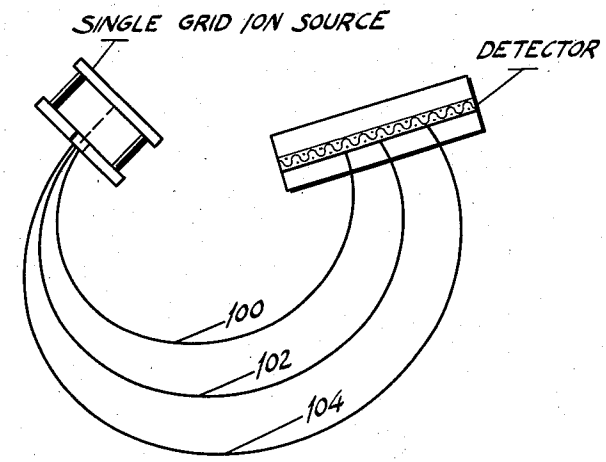


FIG. 5

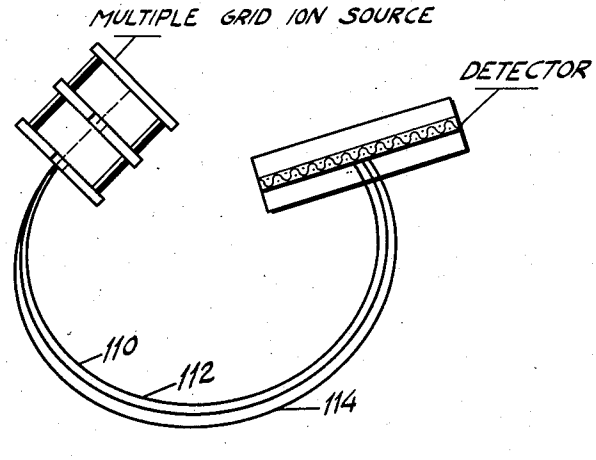


FIG. 6

INVENTOR.
WILLIAM C. WILEY
BY
Vett Parsigian
ATTORNEY

United States Patent Office 2,839,687 Patented June 17, 1958

2,839,687

MASS SPECTROMETER

William C. Wiley, Detroit, Mich., assignor to Bendix Aviation Corporation, Detroit, Mich., a corporation of Delaware

Application October 29, 1953, Serial No. 389,091

10 Claims. (Cl. 250—41.9)

This invention relates to mass spectrometers and more particularly to magnetic time-of-flight mass spectrometers for use in detecting the presence of a gas or vapor having a particular mass.

In many applications, mass spectrometers are used for indicating the presence of a known gas or vapor. For example, in testing television picture tubes for leaks, a known gas such as helium may be introduced over the outside surface of the tube. If there are any openings in the tube, the helium will leak into the tube and a detection of the helium ions formed by a mass spectrometer will indicate that the tube is defective.

Heretofore, mass spectrometers have not been entirely satisfactory for detecting the presence of a known gas or vapor because they are too expensive to manufacture. This is certainly true in mass spectrometers where the ions of different mass are subjected to a magnetic field to produce a rotational movement of the ions and to provide a detection of a particular gas such as helium on the basis of the time required for the ions to travel through the angular movement. All of the ions of a particular mass are detected at substantially the same time regardless of any differences in their energy since the travel time of the ions is dependent only on the mass of the ions and the intensity of the magnetic field. However, differences in the energy of individual ions cause them to travel through paths of different radii and require that a relatively large and accurate magnet be used. Since relatively large and accurate magnets are required, the cost of manufacturing such spectrometers results in large part from the magnet.

This invention provides a magnetic time-of-flight mass spectrometer for reducing the spread in the radii of ions of a given mass. The spectrometer reduces the radial spread of the ions by initially imparting substantially constant energies to the ions of each mass. These substantially constant energies are imparted to the ions in a plurality of electrical fields having intensities with a particular relationship to one another. Since the ions of a given mass will travel in circular paths having substantially the same radii, a magnetic field of relatively small area may be provided to act upon the ions. Therefore, a mass spectrometer may be constructed with relatively inexpensive magnets.

An object of this invention is to provide a mass spectrometer for subjecting a plurality of ions to a particular angular movement and for determining the masses of the ions on the basis of the time required for the ions of each mass to travel through the angular distance.

Another object is to provide a mass spectrometer of the above character for subjecting the ions to particular electrical fields before their angular movement to compensate for any differences in the initial positioning and movement of the ions before their angular movement.

A further object is to provide a mass spectrometer of the above character for imparting particular energies to the ions before their angular movement to provide all of

the ions of a given mass with an angular movement having a substantially uniform radius.

Still another object is to provide a mass spectrometer of the above character for use as a leak detector to determine the presence of a gas or vapor having a particular mass.

A still further object is to provide a mass spectrometer of the above character requiring only a relatively inexpensive magnet to accurately detect the presence of ions of a known gas or vapor.

Another object is to provide a method of subjecting the ions of a given mass to an angular movement having a substantially constant radius so as to provide a simple detection of the ions.

Other objects and advantages will be apparent from a detailed description of the invention and from the appended drawings and claims.

In the drawings:

Figure 1 is a perspective view schematically illustrating the disposition of a mass spectrometer relative to a permanent magnet for controlling the travel path of ions in the spectrometer;

Figure 2 is an enlarged perspective view of the mass spectrometer shown in Figure 1 and schematically illustrates the relative disposition of an ion source and a detector forming part of the spectrometer;

Figure 3 is an enlarged view, partly in perspective and partly in block form, illustrating in further detail the ion source shown in Figure 2;

Figure 4 is an enlarged perspective view illustrating in further detail the detector shown in Figure 2;

Figure 5 is a diagrammatic view illustrating the travel paths of different ions of a given mass in mass spectrometers now in use; and

Figure 6 is a diagrammatic view illustrating the travel paths of different ions of a given mass in a spectrometer having the ion source shown in Figure 3.

In one embodiment of the invention, a permanent magnet generally indicated at **10** (Figure 1) is adapted to supply a magnetic field of substantially uniform intensity across a suitable air gap. For this purpose, the magnet is provided with a yoke **12** and a pair of oppositely disposed annular pole pieces **14** and **16** separated from each other by the gap. A cylindrical cover **18** for a mass spectrometer, generally indicated at **20**, is positioned between the pole pieces **14** and **16**, with the faces of the cover contiguous to the annular faces of the pole pieces. An ion source, generally indicated at **22** (Figures 2 and 3), and a detector, generally indicated at **24** (Figures 2 and 4), are suitably disposed within the mass spectrometer **20**, which is evacuated to a relatively low pressure.

The ion source **22** includes a wedge-shaped cathode **26** (Figure 3) made from a suitable material, such as tungsten, for the emission of a large number of electrons when heated. The cathode **26** is disposed to direct the electrons vertically downwardly or, in other words, in the same direction as the magnetic field between the pole pieces **14** and **16**. An electrode **28** is disposed in a substantially horizontal plane at a relatively close distance such as ½ millimeter from the cathode **26**. The electrode is provided with a slot **30**, the median position of which is substantially vertically aligned with the cathode **26**. An electrode **32** having a slot **34** corresponding substantially in shape and position to the slot **30** is provided in substantial alignment with the electrode **28** at a relatively short distance such as 1 millimeter from the electrode. A collector **36** is disposed in substantial alignment with the electrodes **28** and **32** at a relatively great distance such as 2 centimeters from the electrodes.

A backing plate **38** is provided between the electrode **32** and the collector **36** in perpendicular relationship to

these members and slightly to the right of an imaginary line passing from the tip of the cathode **26** through the slots **30** and **34**. The plate **38** is in substantial alignment with a pair of electrodes **40** and **42** which respectively have slots **44** and **46** corresponding substantially in shape and position to each other. The electrode **40** is disposed between, and relatively close to, the plate **38** and the electrode **42** and is positioned slightly to the left of the imaginary line disclosed above. For example, the electrode **40** may be separated from the backing plate **38** and the electrode **42** by approximately 2 millimeters. The electrode **40** and plate **38** form an enclosure with laterally disposed insulated slats **48**, one of which has a vertical slot communicating with a conduit **52**. The conduit **52** is connected to apparatus, such as a television picture tube **54**, for introducing any gas present in the apparatus into the region between the plate **38** and the electrode **40**.

The detector **24** is positioned relatively near the ion source **22** so that the ions will travel through substantially an integral number of revolutions before being detected. The detector **24** includes a receptacle **56** (Figure 4) positioned within a grounded shield **58** in insulated relationship to the shield. The receptacle **56** and the shield **58** are open at the side facing the flow of ions. The open side of the receptacle **56** is slightly recessed within the shield **58** so as to be covered by a screen **60** extending across the open side of the shield **58**. An indicator, such as an oscilloscope **62**, is connected to the receptacle **56** to provide an indication of the relative times at which the ions reach the detector.

The electrode **28** normally has a positive voltage applied to it through a resistance **64** from a suitable direct power supply **66** (Figures 3 and 4). The collector **36** and the receptacle **56** are maintained at slightly positive potentials by suitable connections through resistances **68** (Figure 3) and **70** (Figure 4) to the power supply **66**. The collector **36** is maintained at a slightly positive potential to attract the electrons secondarily emitted from it upon the impingement of electrons from the cathode **26**, and the receptacle **56** is at a slightly positive potential to attract back to it electrons secondarily emitted from it by the impingement of ions. The cathode **26**, the plate **38** and the electrode **40** are respectively connected to grounded resistances **72**, **74** and **76**, and the electrodes **32** and **42** are directly grounded.

The cathode **26** and the electrode **28** are respectively connected through coupling capacitances **80** and **82** to a suitable pulse forming circuit **84**. Voltage pulses are also applied from the pulse forming circuit **84** through suitable coupling capacitances **86** and **88** to the backing plate **38** and the electrode **40**, respectively. These pulses may be applied a relatively short time after the imposition of the voltage pulses on the cathode **26** and the electrode **28**. A connection is also made from the pulse forming circuit **84** through a suitable coupling capacitance **90** to the oscilloscope **62** so that the oscilloscope sweep will be initiated at the same time as the imposition of the voltage pulses on the backing plate **38** and the electrode **40**.

Although the pulse forming circuit **84** is shown in block diagram in Figure 3, its construction and operation will be apparent 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 described 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, now abandoned, by Macon H. Miller and William C. Wiley may also be conveniently adopted for use.

The electrons emitted by the cathode **26** are attracted towards the electrode **28** because of the positive voltage on the electrode relative to the voltage on the cathode. In the steady state condition, the electrons are not further accelerated after they travel past the electrode **28**, since the electrode **32** has a lower potential than the electrode **28**. Therefore, any electrons that are able to reach the region between the backing plate **38** and the electrode **40** do not have sufficient energy to ionize molecules of gas introduced into the region.

Upon the application of negative pulses of voltage from the pulse forming circuit **84** to the cathode **26** and the electrode **28**, the electrode **32** becomes more positive than the electrode **28** and imparts an increased energy to the electrons in the region between it and the electrode **28**. This increased energy causes electrons to travel into the region between the backing plate **38** and the electrode **40** with a sufficient energy to ionize molecules of gas that they may strike in the region. The ions which are produced from the molecules of gas are retained in the electron stream, since they have an opposite charge relative to that of the electron stream.

Because of the large charge produced by the electron stream, a relatively large number of ions can be retained in the potential well created by the electron stream before the stream becomes saturated. These ions are retained to a large extent in a space having a relatively narrow width because of the collimating action which is provided on the electrons by the slots **30** and **34** and by the magnetic field produced by the magnet **10**. The operation of an ion source to store a large number of ions in an electron stream is disclosed in detail in co-pending application Serial No. 221,554, filed April 18, 1951, now Patent No. 2,732,500, by Ian H. McLaren and myself.

As the electron stream approaches saturation by the retention of ions, it is cut off by the removal of the voltage pulses on the cathode **26** and the electrode **28**. Upon the removal of the negative potential well created by the electron stream, the ions retained within the stream become available for easy withdrawal by the imposition of voltage pulses on the backing plate **38** and the electrode **40**. These pulses cause an electrical field of moderate intensity to be produced between the backing plate **38** and the electrode **40** and an electric field of considerably increased intensity to be produced between the electrodes **40** and **42**. For example, voltage pulses of approximately +300 and +250 volts may be respectively applied on the plate **38** and the electrode **40** from the pulse forming circuit **84**.

Upon the application of positive voltage pulses on the plate **38** and the electrode **40**, the ions are repelled from their position between the plate **38** and the electrode **40** and are accelerated through the slots **44** and **46** into the space between the ion source **22** and the detector **24**. Since the magnetic flux lines formed between the pole pieces **14** and **16** lie in substantially the same plane as the slots **44** and **46**, the ions will travel in a direction substantially perpendicular to the flux lines. This causes the magnetic field to exert a force upon the ions in a direction perpendicular to both the direction of the flux lines and the direction of ion travel, such that the ions adopt a circular path towards the collector **24**.

As previously disclosed, in mass spectrometers now in use, individual ions of a given mass may adopt circular paths having different radii because of differences in their energy. For example, individual ions of the same mass may travel in paths **100**, **102** and **104**, as illustrated in Figure 5. Because of the large spread in radii between the paths **100**, **102** and **104**, a magnetic field having a relatively large area must be provided to act upon the ions in each path. As a result, the magnets required in mass spectrometers now in use must be relatively large. This is undesirable because large magnets are expensive.

As disclosed above, differences in the radial paths traversed by individual ions of a particular mass result from

differences in the energy provided in the ions. Individual ions of a particular mass have different energies because of differences in their random motion and differences in the positioning of the ions in the electron stream. Differences in the random motion of individual ions result from thermal and other energies in the ions. These energies cause some of the ions to be travelling towards the backing plate **38** and other ions to be moving towards the electrode **40** at the instant that they are withdrawn from the electron stream. Differences in the positioning of individual ions result from the finite width of the electron stream. Such differences in positioning cause some of the ions to be positioned closer to the backing plate **38** and other ions to be positioned closer to the electrode **40** than the ions of intermediate position.

This invention provides a magnetic time-of-flight mass spectrometer which compensates for differences in the positioning and random motion of individual ions. Such compensation is provided by the particular electric fields imposed on the ions in the region between the backing plate **38** and the electrode **40** and in the region between the electrodes **40** and **42**. Since the electrical field is imposed on the ions in the region between the backing plate **38** and the electrode **40** until the movement of the ions past the electrode, individual ions positioned closer to the plate **38** receive a slightly greater amount of energy than ions of the same mass positioned closer to the electrode **40**. This causes a slightly greater velocity to be imparted to the ions positioned closer to the plate **38** than the ions positioned closer to the electrode **40**. Because of this the former ions catch up to the latter ions such that all the ions of a particular mass reach a collector at substantially the same time. Thus a compensation is provided for the initial differences in positioning of the ions.

Since all of the ions of a particular mass travel through the same distance in the region between the electrodes **40** and **42**, they receive substantially constant increments in energy. Because of the particular relationship of the voltage pulses on the backing plate **38** and the electrode **40**, the ions receive considerably greater increments in energy in the region between the electrodes **40** and **42** than in the region between the backing plate **38** and the electrode **40**. This causes any differences in velocity of individual ions resulting from the random motion of the ions to be dwarfed. For example, thermal and other energy in the ions may cause two ions of the same mass to have relative velocities of 5 and 8 as they move past the electrode **40**. By increasing their velocities to 55 and 58 in the region between the electrodes **40** and **42**, the relative differences in the velocity of the ions is considerably decreased. This causes the ions to have substantially the same velocities during their circular movement in the spectrometer.

Because of their substantially constant velocities, all of the ions of a particular mass travel through annular paths defined by a substantially constant radius. This radius can be expressed mathematically as follows:

$$R=KMv/H$$

where

K=a constant;
M=the mass of the ions;
v=the velocity of the ions; and
H=the magnetic field strength.

In the mass spectrometer disclosed above, the value of H is constant and the value of v is substantially constant for any given mass. Therefore, the radius of travel R will be substantially the same for all of the ions having a given mass M. For example, individual ions of a given mass may travel in paths **110**, **112** and **114** having substantially the same radius as illustrated in Figure 6. As a result, the area of the magnetic field required to act upon the ions can be relatively small. Such a magnetic field can be produced by a magnet having hollow annular pole pieces with a median radius corresponding substantially to that defining the movement of the ions of a particular mass. For example, in a leak detector the median radius of the pole pieces may correspond to the radius defining the travel path of helium ions. These magnets require much less material than the solid magnets heretofore required and are less expensive to manufacture. Since the ions all travel through substantially the same circular path, a relatively narrow collector having a width corresponding to the radial width of the hollow pole pieces may also be used.

The spectrometer provided is particularly suited for leak detection purposes. For example, the detection of a relatively light gas, such as helium, which may pass through apparatus such as a television picture tube would indicate that the apparatus is defective. Ions having a relatively light mass will travel in circular paths having relatively small radii since the radius of travel is dependent upon the mass of the ions. Therefore, the mass spectrometer may be constructed with very small and inexpensive magnets. Because of their small size, these magnets may be of solid or hollow construction without requiring the use of an excessive amount of material. Furthermore, the size of other components in the mass spectrometer may be correspondingly reduced. For example, the detector **24** may be relatively small because ions of a given mass will impinge upon the collector within a relatively small area. Because of the reduction in the size of the magnets and other components, the spectrometer will be compact in construction and relatively inexpensive to produce for commercial use.

It should be appreciated that the mass spectrometer can be utilized without any modifications in construction or applied voltages to determine the masses of different ions within a restricted range. For example, if the parameters in the mass spectrometer are such as to provide for the detection of ions having a mass of 200, the spectrometer will readily operate to separate ions having masses of 199, 200 and 201. It should be further appreciated that this range of detection can be considerably expanded by varying such parameters as the magnitudes of the voltage pulses applied to the backing plate **38** and the electrode **40**.

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.

What is claimed is:

1. A mass spectrometer, including, a backing plate, a first electrode disposed relatively close to the plate, a second electrode disposed relatively close to the first electrode, means for providing a plurality of ions in the region between the backing plate and the first electrode, means for applying a moderate accelerating force on the ions between the backing plate and the first electrode to produce a movement of the ions past the first electrode, means for applying a considerably increased accelerating force on the ions between the first and second electrodes to produce a movement of the ions past the second electrode and to impose substantially constant velocities on the ions of a given mass, means for providing a magnetic field in a direction substantially perpendicular to the direction of ion travel to produce an angular movement of the ions, means disposed at a particular angular distance from the second electrode to detect the ions, and means for indicating the times at which the ions are detected.

2. A mass spectrometer, including, a backing plate, a first electrode disposed a particular distance from the backing plate, means for providing a plurality of ions in the region between the backing plate and the first electrode, means for applying a voltage pulse on the back-

ing plate relative to the first electrode to produce a movement of the ions past the first electrode and to impart slightly greater velocities to the ions positioned closer to the backing plate than to the ions positioned closer to the electrodes, a second electrode disposed a particular distance from and in substantial alignment with the first electrode, means for applying a voltage pulse on the first electrode relative to the voltage on the second electrode to impart substantially constant increments in energy to the ions of each mass and greater energies than those imparted to the ions in the first region, means for producing a magnetic field in a direction substantially perpendicular to the direction of ion travel to produce a movement of the ions in circular paths dependent upon the mass of the ions, a detector disposed at a particular angular distance from the second electrode to detect the ions, and means for providing an indication of the ion detection.

3. A mass spectrometer, including, a backing plate, a first electrode disposed substantially in alignment with the backing plate at a particular distance from the plate, a second electrode disposed substantially in alignment with the first electrode at a particular distance from the electrode, means for providing a plurality of ions in the region between the backing plate and the first electrode, means for subjecting the ions to a pulsed electric field of moderate intensity between the backing plate and the first electrode until the movement of the ions past the first electrode, means for subjecting the ions to a pulsed electric field of considerably increased intensity between the first and second electrodes until the movement of the ions past the second electrode, means for subjecting the ions to a magnetic field in a direction having a component substantially perpendicular to the direction of ion travel to produce a movement of the ions in substantially circular paths defined by a substantially uniform radius for the ions of each particular mass, a detector disposed at a particular angular distance from the second electrode to detect the ions, and means for indicating the ion detection.

4. A mass spectrometer, including, a first electrode, a second electrode disposed at a particular distance from the first electrode and in substantial alignment with the electrode, a third electrode disposed at a particular distance from the second electrode and in substantial alignment with the electrode, means for providing between the first and second electrodes a plurality of ions having a particular mass, means for imparting a moderate amount of energy to the ions in the region between the first and second electrodes to produce a movement of the ions past the second electrode, means for imparting a relatively large amount of energy to the ions in the region between the second and third electrodes to produce a movement of the ions past the third electrode at substantially the same velocity, means for producing a magnetic field in a direction having a component substantially perpendicular to the direction of ion travel to produce an angular movement of the ions in a substantially uniform path, means disposed at a particular distance from the third electrode to collect the ions after the movement of the ions through a particular angular distance, and means for indicating the times at which the ions are collected.

5. A mass spectrometer, including, a first electrode, a second electrode disposed at a particular distance from the first electrode in substantially parallel relationship to the electrode, a third electrode disposed at a particular distance from the second electrode in substantially parallel relationship to the electrode, means for providing in the region between the first and second electrodes a pluraiity of ions having a particular mass, means for applying between the first and second electrodes an electric field of moderate intensity to move the ions past the second electrode and to impart slightly greater velocities to the ions positioned closer to the first electrode than to the ions positioned closer to the second electrode, means for applying between the second and third electrodes an electric field of increased intensity for imparting to the ions substantially constant increments of energy greater than those imparted to the ions in the first region to move the ions past the third electrode at substantially the same velocity, means for providing a magnetic field of substantially annular configuration and disposed in a direction having a component substantially perpendicular to the direction of ion travel to produce an angular movement of the ions within the magnetic field in a substantially uniform path, means disposed at a particular distance from the third electrode to collect the ions after they have travelled through a particular angular distance, and means for producing a signal upon the collection of the ions.

6. A mass spectrometer for detecting ions having a particular mass, including, a backing plate, a first electrode disposed at a particular distance from the backing plate, a second electrode disposed at a particular distance from the first electrode means for providing in the region between the backing plate and the first electrode a plurality of ions having the particular mass, means for imposing an electric field of moderate intensity between the backing plate and the first electrode and an electric field of considerably increased intensity between the first and second electrodes to produce a movement of the ions past the first electrode and a further movement of the ions past the second electrode at substantially the same velocity, means for providing a magnetic field having an annular configuration of restricted radial dimensions and having a component in a direction substantially perpendicular to the direction of ion movement to produce a movement of the ions in circular paths having substantially the same radii, a plate disposed at a particular distance from the second grid to intercept the ions after they have travelled through a particular distance in their circular paths, and means connected to the plate for producing a signal at the time the ions are intercepted by the plate.

7. A mass spectrometer for detecting ions having a particular mass, including, a first electrode, a second electrode disposed in substantial alignment with the first electrode at a particular distance from the electrode, a third electrode disposed in substantial alignment with the second electrode at a particular distance from the electrode, means for providing in the region between the first and second electrodes a plurality of ions of the particular mass, means for applying an accelerating force of moderate magnitude between the first and second electrodes to produce a movement of the ions past the second electrode, means for applying an accelerating force of substantially increased magnitude between the second and third electrodes to minimize any differences in the initial positioning and random motion of the ions in the region between the first and second electrodes and to produce a movement of the ions past the third electrode at substantially the same velocity, means for providing a magnetic field having a substantially annular configuration of relatively narrow width and disposed in a direction substantially perpendicular to the direction of ion movement to produce a movement of the ions in circular paths having substantially the same radii as the median radius of the magnetic field, a detector disposed at a particular distance from the third electrode to detect the ions after they have travelled in their circular paths through a predetermined distance, and means connected to the detector for producing a signal at the time the ions are detected.

8. A mass spectrometer, including, a backing plate, a first electrode disposed at a particular distance from the backing plate, a second electrode disposed at a particular distance from the first electrode, means for providing a plurality of ions in the region between the backing plate and the first electrode, a first electrical circuit for apply-

ing between the backing plate and the first electrode an electric field of moderate intensity to produce a movement of the ions past the first electrode, a second electrical circuit for applying between the first and second electrodes an electric field of considerably increased intensity to produce a movement of the ions past the second electrode and to impose substantially constant velocities on the ions of a given mass, means for providing a magnetic field in a direction substantially perpendicular to the direction of ion travel to produce a movement of the ions in substantially circular paths defined by a uniform radius for ions of each particular mass, a detector disposed at a particular angular distance from the second electrode to detect the ions, and means for indicating the detection of the ions.

9. A mass spectrometer, including, a first electrode, a second electrode disposed substantially in alignment with the first electrode at a particular distance from the electrode, a third electrode disposed substantialy in alignment with the second electrode at a particular distance from the electrode, means for providing in the region between the first and second electrodes a plurality of ions having a particular mass, a first electrical circuit for providing between the first and second electrodes an electric field of moderate intensity to move the ions past the second electrode and to impart slightly greater velocities to the ions positioned closer to the first electrode than to the ions positioned closer to the second electrode, a second electrical circuit for providing between the second and third electrodes an electric field of relatively great intensity to impart substantially constant increments of energy to the ions for the movement of the ions past the third electrode at substantially the same velocity,

means for providing a magnetic field of looped configuration and disposed in a direction substantially perpendicular to the direction of ion travel to produce an angular movement of the ions within the limits of the magnetic field, a detector disposed at a particular angular distance from the third electrode to detect the ions, and means associated wtih the detector for indicating the detection of the ions.

10. A mass spectrometer, including, a backing plate, a first electrode disposed to provide a first region between the electrode and the backing plate, a second electrode disposed to provide a second region between the electrode and the first electrode, means for providing a plurality of ions in the first region, means for applying a voltage pulse between the backing plate and the first electrode to produce an electric field of moderate magnitude in the first region for moving the ions past the first electrode, means for applying a voltage pulse between the first and second electrodes to produce an electric field of considerable magnitude in the second region for moving the ions past the second electrode and for imposing substantially constant velocities on the ions of a particular mass, means for providing a magnetic field in a direction substantially perpendicular to the direction of ion travel to produce an angular movement of the ions, and means disposed at a particular angular distance from the second electrode for detecting the ions.

References Cited in the file of this patent

UNITED STATES PATENTS

2,576,601	Hays	Nov. 27, 1951
2,582,216	Koppius	Jan. 15, 1952