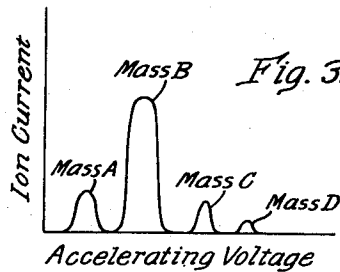
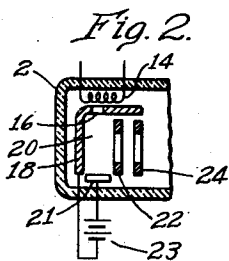
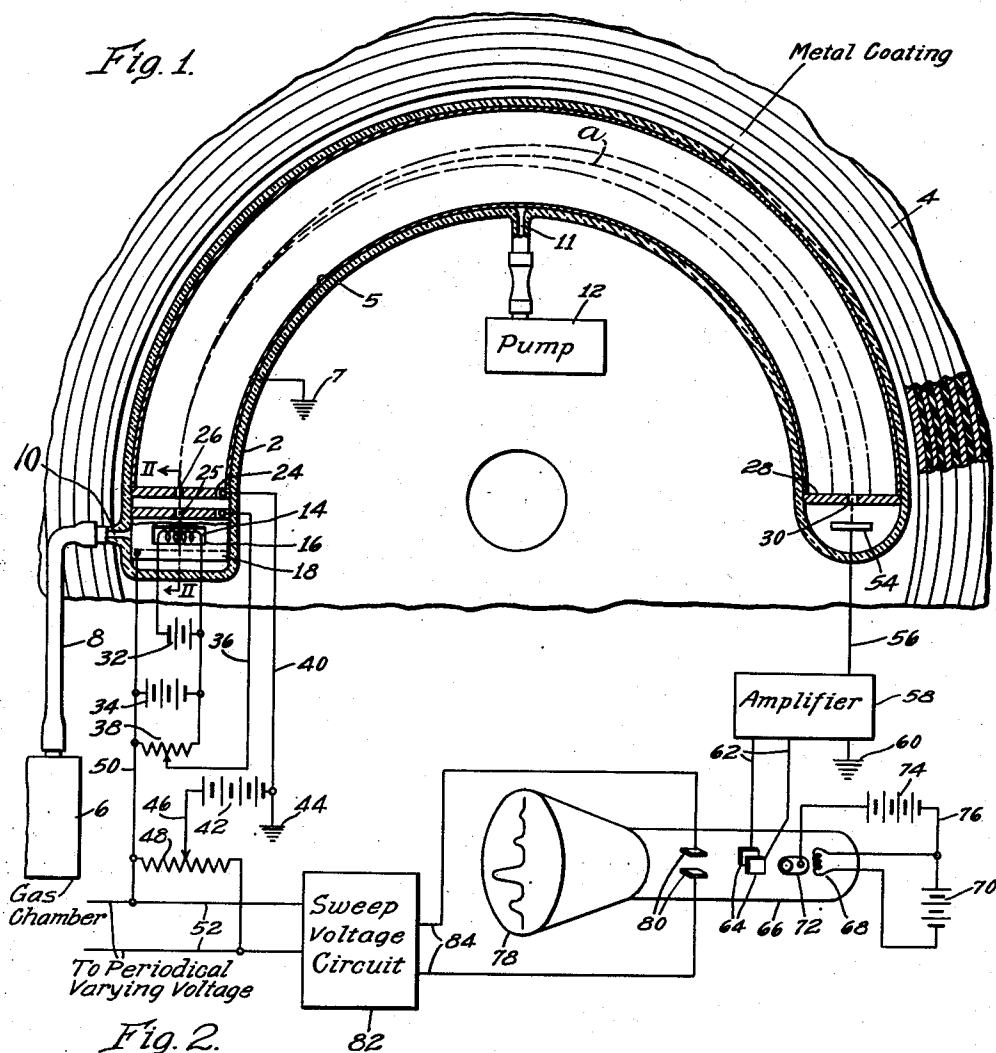


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MASS SPECTROMETER
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MASS SPECTROMETER

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The present invention relates to a device for analyzing the composition of matter, and it has particular relation to an arrangement which employs a mass spectrometer to continuously analyze a gas for a plurality of different constituents.

The mass spectrograph or mass spectrometer, as it is also known, is widely used for separating particles having a particular mass or atomic weight from a gaseous composition. There are many types of this instrument, a number of which are described along with the principles of operation in an article by Walker Bleakney, entitled the "Mass Spectrograph and Its Uses," published on pages 12 to 23, inclusive, of the February, 1936, issue of the American Physics Teacher. Briefly stated, the mass spectrometer ionizes the particles of material to be analyzed and subjects them to the action of a combination of electrostatic or electromagnetic fields, or both, to cause only those particles having a particular ratio of mass to electric charge to impinge a current collecting member. The current received by the collector may then be amplified and analyzed by various known methods. Since it is possible by adjusting the ionizing potential to a relatively low value to prevent any substantial number of particles from receiving a multiple charge, the device may be made to effectively segregate particles according to the mass alone instead of the ratio m/e , where m is the mass or atomic weight of the particle and e is its charge.

The mass spectrometer in many cases offers advantages over chemical methods of analysis. It is thus suitable for a number of applications such as the analysis of soil gas for petroleum prospecting or of annealing furnace gases. In these applications it is desirable to provide an arrangement which will furnish a substantially continuous analysis of a gas for a plurality of different constituents. As an example in the case of furnace gases, it may be required that the carbon, moisture, nickel and carbon monoxide content be kept within predetermined limits.

According to the present invention, a voltage which periodically oscillates between predetermined values is impressed on the accelerating plates of a usual type of mass spectrometer. This oscillating voltage causes the focusing characteristics of the instrument to vary in such a manner that particles having masses ranging between predetermined limits are periodically focused in sequence on a current collector. The accelerating voltage may thus be made up of a constant unidirectional voltage upon which is impressed

either an alternating voltage of smaller magnitude or a periodically varying unidirectional component. The amount of current received by the collector may be measured by means of a cathode ray oscillograph energized with a sweep voltage in synchronism with variations in the accelerating voltage. In this manner a single mass spectrometer of a usual type provides what is, in effect, a continuous measurement of the particles, having each of the masses falling within the predetermined range which are present in a sample of gas.

It is, accordingly, an object of the present invention to provide a novel and improved device for analyzing compositions of matter.

Another object of the invention is to provide a novel device for continuously analyzing a gas which is subject to change in composition for a plurality of different constituents.

More specifically stated, it is an object of the invention to provide an arrangement wherein the accelerating plates of a single mass spectrograph are energized with an oscillating voltage and a cathode ray oscillograph is operated in synchronism with the voltage variations to effect a continuous analysis of a gas for particles having masses falling within a predetermined range.

Other objects and advantages of the invention will appear from the following detailed description, taken in conjunction with the accompanying drawing, in which:

Figure 1 is a schematic diagram with parts in section of apparatus embodying the present invention;

Fig. 2 is a vertical sectional view of a portion of the apparatus taken along the line II—II of Fig. 1; and

Fig. 3 is a diagrammatic view of an indication such as might be obtained from the apparatus of Fig. 1.

Referring to the drawing, the apparatus includes a tube or vessel 2 which is approximately semi-circular in shape and may be of round cross section disposed within an electromagnet 4. The vessel 2 is preferably of glass, in which case it is provided with a grounded metallic lining or coating 5 in a usual manner. If desired, however, the vessel may be made entirely of metal in which case no separate lining is required. The particular structure of the electromagnet 4 forms no part of the present invention since any device suitable for providing a uniform magnetic field throughout the tube perpendicular to the plane of its curved portion might be used. By way of example, it may be of the type described in my

copending United States patent application Serial No. 296,607, filed September 26, 1939 which matured into Patent Number 2,265,041 on Dec. 2, 1941. A chamber 6, which may be an annealing furnace, communicates by means of a tube or pipe 8 with the interior of the vessel 2 through an opening 10 at an end thereof. The tube 8 may include a capillary for allowing a small continuous sample of the atmosphere in the chamber 6 to enter the tube. The tube is evacuated through an opening 11 at approximately the center thereof by means of a pump indicated at 12.

Within the tube 2 at the end which communicates with the vessel 6 is a filament or cathode 14 disposed immediately above a slot 16 in a right angle shield 18 which, in turn, defines an ionizing chamber indicated at 20. A collecting or conducting plate 21 is located at the bottom of the chamber 20 directly below the slot 16 for the purpose of collecting and neutralizing excess electrons. Disposed within the tube 2 immediately in front of the ionizing chamber are a pair of ion accelerating plates 22 and 24 having aligned narrow vertical slots at 25 and 26, respectively. Within the vessel at the other end is a baffle plate 28 having a narrow slot formed therein at 30. It will be noted that the center line *a* of a tube between the slot 26 in plate 24 and slot 30 in plate 28 is semi-circular and that particles passing through the slots in the accelerating plates are initially accelerated tangentially to this center line.

The filament or cathode 14 is connected for energization by a battery 32, while another battery 34 is connected to one of the filament terminals and to the shield 18 to maintain the latter member at a positive potential with respect to the filament. The accelerating plate 22 is maintained at a potential intermediate that of the filament and the shield 18 by means of a conductor 36 extending from an intermediate point on a resistor 38 which is connected in shunt with the battery 34. A conductor 40 electrically connects the plate 24 to the negative terminal of a relatively high voltage battery 42 which is grounded as indicated at 44. The other end of this battery 42 is connected to a contact 46 whose position is adjustable along a resistance 48, one end of which is connected to the shield 18 by means of a conductor 50. The resistor 48 is connected across lines 52 which are energized with an oscillating voltage which may be either alternating current or a direct current supply which periodically varies in magnitude.

The metallic coating 5 on the interior of the vessel 2 is connected to ground as is indicated at 7 so that any ions falling thereon are neutralized in a usual manner. This coating is also electrically connected to baffle plate 28 so that it is also effectively grounded.

Located within the vessel 2 in back of the slot 30 in the baffle plate 28 is a current collector 54 which is preferably a plate of conducting metal. This collector plate is connected by means of a conductor 56 to an amplifier 58 which may be of a usual construction. The amplifier is grounded at 60 and its output is connected by means of a pair of conductors 62 to energize deflecting plates 64 of a cathode ray oscillograph tube indicated at 66. The tube 66 may be of a usual type and includes a cathode 68 which is energized by means of a battery 70 to provide electrons within the tube. An anode member 72 is energized from a battery 74 by means of a conductor 76 connected

to the cathode circuit to accelerate the electrons formed within the tube toward a screen 78 at the other end thereof. A pair of sweep voltage plates 80 which are disposed perpendicularly to the plates 64 are energized from a sweep voltage source 82 by means of conductors 84. This voltage source 82 is connected to the conductor 52 as shown and may include an amplifier arrangement or any other suitable means for producing a voltage synchronized with that supplied by the conductor 52. It is, in fact, conceivable that the conductor 52 may be directly connected to the plates 80 to energize the sweep circuit of the oscillograph.

With the evacuating pump 12 in operation and a continuous sample of gas from the chamber 6 passing into the vessel through the opening 10, the operation of the device is as follows: Electrons from the filament or cathode 14, with the aid of the shield 18 which is at a positive potential with respect thereto, pass through the opening 16 and impinge on the gas sample in the chamber 20 to ionize the particles. These electrons which are ineffective in ionizing the gas pass directly to the plate 21 which is maintained at a relatively positive potential by means of battery 23 and are thus neutralized. The positive ions which are formed, however, are attracted toward the plate 22, and are accelerated by the electric field between that plate and plate 24 to a uniform energy. Ions of the same mass directed in the straight line through the slots 25 and 26 pass therethrough with equal velocities into the central portion of the tube 2, provided they are singly charged. These ions passing along this straight line will include particles having masses of all the different atomic weights constituting the gas sample and will then be deflected by the magnetic field from the magnet 4 in proportion to the ratio of their respective masses to their electric charges or m/e . Thus, for a particular accelerating voltage and assuming that the charges e of the different particles are equal, particles of a particular mass will follow the path indicated at *a* and pass through the opening 30 in the plate 28 to fall on the collector 54.

With the voltage which is impressed between the accelerating plates 22 and 24 varying because of the component furnished by the conductors 52, it will be evident that the acceleration, and consequently the energy collected by particles passing between these plates, will periodically vary between predetermined limits. Thus, particles having different masses within predetermined limits will periodically be focused along the line *a* in sequence. For example, when the accelerating voltage is at its highest value, particles of a certain mass will be focused to fall upon the plate 54. However, when this voltage is at its minimum value, the particles which are focused on the collecting plate 54 will be of a much greater mass or atomic weight. In a similar manner, particles having masses between these two extremes will impinge on the plate 54 when intermediate accelerating voltages are in operation.

Since the sweep voltage circuit of the oscillograph tube 66 is energized in synchronism with the variations in the accelerating voltage, it will be evident that the screen 78 will provide a trace indicative of the quantity of ion current carried to the plate 54 by particles having each of the masses within the limits designed for. This is so because the deflecting plates 64 continuously

deflect the beam of the cathode ray tube in a horizontal plane a distance proportional to the magnitude of the ion current in the mass spectrograph and at the same time, the sweep voltage plates 80 act to deflect the trace in a vertical plane dependent upon the mass being measured at each instant.

The graph of Fig. 3 shows somewhat more clearly the type of indication which will be obtained with this apparatus. With the device designed to analyze for masses within a range including masses A, B, C and D, the trace will show the quantitative relationship between them in the sequence of their atomic weights. Thus, with the ordinates in Fig. 3 representing ion current and the abscissa indicating accelerating voltage, the heights of the loops indicated by the letters A, B, C and D indicate the quantitative relationship of the respective masses. If desired, a permanent record of the results of the analysis may be made at any time by photographing the cathode ray tube screen in a known manner.

From the foregoing description it will appear that the present invention provides a convenient and efficient means for analyzing a continuous gas sample for a plurality of constituents. Although the analysis is not strictly continuous for each of the masses which it is desired to measure, it is, nevertheless, just as valuable as such an analysis would be because of the relatively rapid oscillations employed. The apparatus will be found of particular value for commercial analysis because no constant attention is required. In fact, it may be employed along with automatic controls for maintaining the gas composition constant, if desired.

While the invention has been described with reference to a particular embodiment thereof, it will be evident that various modifications may be made without departing from its spirit and scope. It is, therefore, intended that the invention be limited only by the appended claims.

I claim as my invention:

1. A device for analyzing a continuous supply of gaseous matter comprising means for ionizing particles of said matter, a current collector, means for periodically focusing ionized particles having mass to charge ratios within a predetermined range of values in a predetermined sequence on said current collector, and means including an oscillograph energized in accordance with the ion current received by said collector and having a sweep circuit synchronized with said focusing means for continuously indicating the value of said ion current.

2. A device for analyzing a continuous supply of gaseous matter comprising means for ionizing particles of said matter, a current collector, means for accelerating said ionized particles in a predetermined direction to a degree periodically varying between predetermined limits, means for deflecting the accelerated particles in accordance with their respective mass to charge ratios and acceleration so that particles having mass to charge ratios between predetermined values are periodically focused in sequence on said current collector, and means including an oscillograph having a sweep circuit synchronized with said accelerating means for continuously indicating the amount of ion current received by said current collector.

3. A device for analyzing a continuous supply of gaseous matter comprising means for ionizing particles of said matter, a current collector, means producing a periodically varying electric

field for accelerating the ionized particles in a predetermined direction, means for deflecting the accelerated particles in accordance with their respective mass to charge ratios and acceleration so that particles having mass to charge ratios between predetermined values are periodically focused in sequence on said current collector, and means including an oscillograph having a sweep circuit synchronized with said electric field producing means for continuously indicating the amount of ion current received by said current collector.

4. A device for analyzing a continuous supply of gaseous matter comprising means for ionizing particles of said matter, means producing an electric field for accelerating the ionized particles, a current collector displaced from said field producing means, means for deflecting the accelerated particles through paths determined by the strength of said accelerating field and the respective masses of the particles, means for periodically varying the strength of said accelerating field between predetermined values to focus particles having masses within a predetermined range of values in sequence on said current collector, and means including an oscillograph having a sweep circuit synchronized with the variations in strength of said accelerating field for continuously indicating the amount of ion current received by said current collector.

5. A device for analyzing a continuous supply of gaseous matter comprising means for ionizing particles of said matter, means for producing an electric field for accelerating the ionized particles, a current collector, means for deflecting the accelerated particles through paths determined by the strength of said accelerating field and the respective masses of the particles, said accelerating field producing means including a voltage supply having a variable component for periodically varying the strength of said accelerating field between predetermined values to focus particles having masses within a predetermined range of values in sequence on said current collector, and an oscillograph energized with a sweep voltage varying in synchronism with the variable component of said accelerating field voltage and connected to continuously indicate the amount of ion current being received by said current collector.

6. A device for analyzing a continuous supply of gaseous matter comprising a vessel and means for evacuating it, means for introducing said matter into said vessel, means for ionizing particles of said matter, a current collector in said vessel, means including a unidirectional voltage supply varying in magnitude between predetermined limits for accelerating the ionized particles in a predetermined direction, means for deflecting the accelerated particles in accordance with their respective mass to charge ratios and acceleration so that particles having mass to charge ratios between predetermined values are periodically focused in sequence on said current collector, and means including an oscillograph having a sweep circuit synchronized with the variations in said voltage supply to continuously indicate the amount of ion current being received by said current collector.

7. A device for analyzing a continuous supply of gaseous matter comprising a vessel and means for evacuating it, means for introducing said matter into said vessel, means for ionizing particles of said matter, a pair of spaced plates in said vessel, means for impressing a unidirectional

voltage between said plates for maintaining one of them at a negative potential with respect to the other to accelerate ionized particles toward it, the said plate at negative potential having an opening to permit only particles travelling in a predetermined direction to pass therethrough, a current collector in said vessel, means for deflecting the accelerated ions passing through said plate opening to an extent determined by their respective masses, said voltage impressing means including a periodically varying component to focus particles having masses within a predetermined range of values in sequence on said current collector, and an oscillograph energized with a sweep voltage in synchronism with said variable voltage component and connected to continuously indicate the amount of ion current being received by said current collector.

8. A device for analyzing a continuous supply of gaseous matter comprising means for ionizing particles of said matter, a current collector, means producing an electric field periodically varying between predetermined magnitudes of the same polarity for accelerating the ionized particles in a predetermined direction, means for deflecting the accelerated particles in accordance with their respective mass to charge ratios and the strength of the accelerating field so that particles having mass to charge ratios between predetermined values are periodically focused in sequence on said current collector, a cathode ray oscillograph including a set of sweep voltage plates and a set of main deflecting plates, means for impressing on said sweep voltage plates a periodic voltage synchronized with the variations in strength of said electric field, and means for impressing on said deflecting plates a quantity proportional to the current received by said current collector.

9. A device for analyzing a continuous supply of gaseous matter comprising means for ionizing particles of said matter, a current collector, means for focusing ionized particles on said current collector in accordance with their mass to charge ratios, said last-named means including a control portion responsive to variations in voltage impressed thereacross to focus particles having a corresponding mass to charge ratio on said current collector, a substantially constant unidirectional voltage supply, an alternating current voltage supply superimposed on said unidirectional voltage supply to produce a resultant voltage varying between predetermined limits of the same polarity, means connecting said voltage

supplies to energize said control portion of said focusing means with said resultant voltage to focus ionized particles having mass to charge ratios falling within predetermined limits on said current collector, and means including an oscillograph synchronized with said alternating voltage supply for continuously indicating the amount of ion current received by said current collector.

10. A device for analyzing a continuous supply of gaseous material comprising a vessel and means for evacuating it, means for introducing said material into said vessel, means for ionizing particles of said material, a current collector in said vessel, means producing an electric field proportional to a voltage impressed thereacross for accelerating the ionized particles in a predetermined direction, a substantially constant unidirectional voltage supply, an alternating current voltage supply superimposed on said unidirectional voltage supply to produce a resultant voltage varying between predetermined limits of the same polarity, means connecting said voltage supplies to impress said resultant voltage across said field producing means, means for deflecting the accelerated particles in accordance with their mass to charge ratios so that particles having mass to charge ratios between predetermined values are periodically focused in sequence on said current collector, and a cathode ray oscillograph synchronized with said alternating voltage supply and connected to said alternating voltage supply for continuously indicating the amount of ion current received by said current collector.

11. A device for analyzing a continuous supply of gaseous matter comprising means for ionizing particles of said matter, a current collector, means for focusing ionized particles on said current collector in accordance with their mass to charge ratios, said last-named means including control means responsive to variations in voltage impressed thereacross to focus particles having a corresponding mass to charge ratio on said current collector, a unidirectional voltage supply varying in magnitude between predetermined limits, means energizing said control means from said voltage supply, and means including an oscillograph having a sweep circuit synchronized with said voltage supply for continuously indicating the amount of ion current received by said current collector.

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