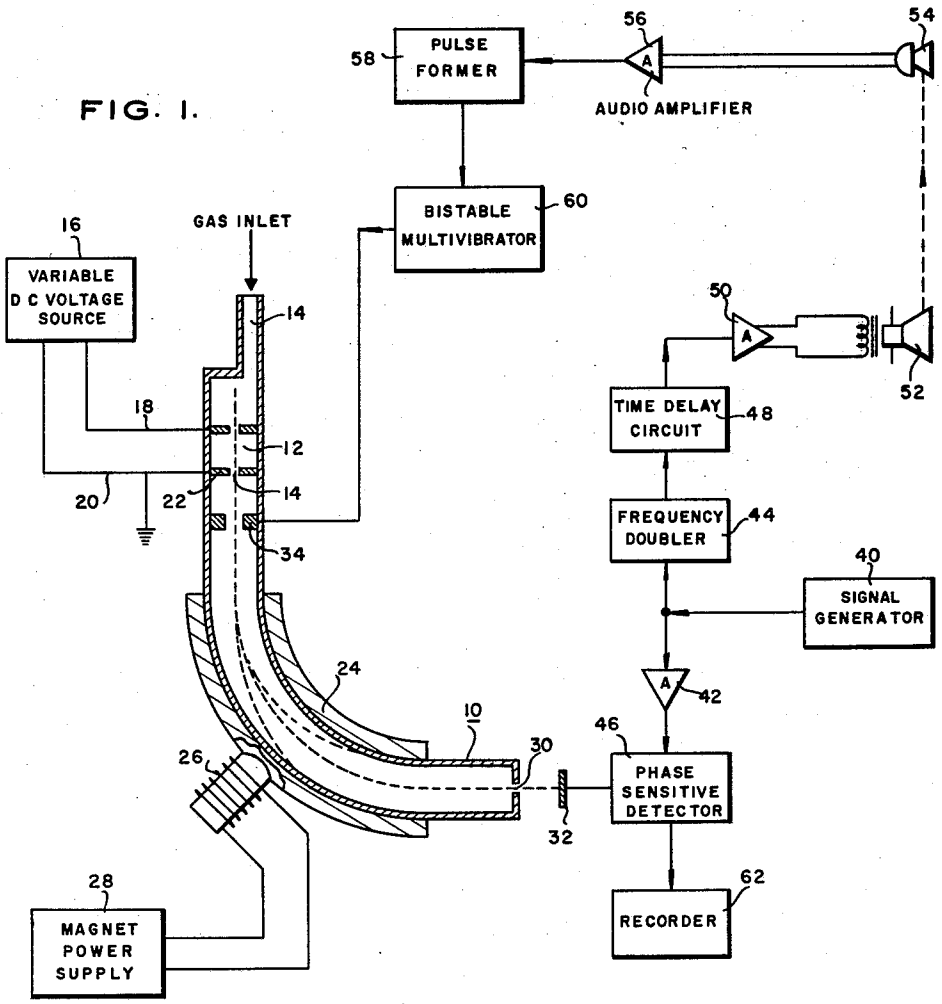
June 22, 1965 F. H. FIELD 3,191,027

MASS SPECTROMETER WITH MEANS TO IMPRESS A FLUCTUATING COMPONENT UPON THE ION STREAM AND MEANS TO DETECT THE SAME

Filed Aug. 24, 1962

FIG. 1.



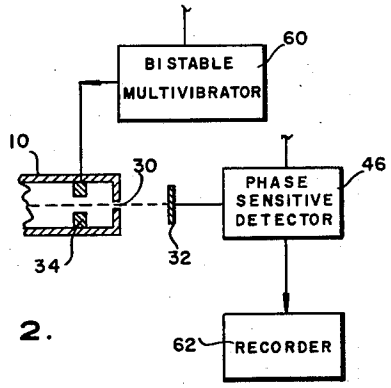


FIG. 2.

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MASS SPECTROMETER WITH MEANS TO IMPRESS A FLUCTUATING COMPONENT UPON THE ION STREAM AND MEANS TO DETECT THE SAME

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1 Claim. (Cl. 250—41.9)

This invention relates to mass spectrometers. More particularly, this invention is a new method and apparatus used in mass spectrometry which permits the attainment of higher resolution than formerly attainable.

One method of determining the chemical or elemental composition of a material as well as the relative abundances of the various materials in the sample is by means of a mass spectrometer. In a mass spectrometer, the material to be analyzed is ionized, accelerated by an electrostatic field, and resolved into homogeneous ion beams by means of a magnetic field. Each homogeneous beam contains ions having a single mass to charge ratio. By varying the strength of the electrostatic field used to accelerate the ionized particles, ion beams of various mass to charge ratios can be brought to focus on the ion collector and their relative intensities determined.

In conventional directional focusing mass spectrometers, the ions emerge from an ion source and are accelerated by a series of electrodes. The electrodes in the series have progressively decreasing potentials. The ions then enter the magnetic field and are deflected by amounts which depend upon their masses.

The invention to be described herein includes an additional electrode which is placed in the analyzer between the ion source and the collector. In general, the potential on this additional electrode is made slightly higher than the potential of the ion source. For example, the potential on the additional electrode may be made up to 10 volts higher than the potential on the ion source.

In carrying out my new process, the voltage on the additional electrode is varied periodically by an amount which can be chosen arbitrarily but will generally be on the order of 0.1 to 1.0 volts. Because the repelling voltage is periodically changing, the number of ions that can pass through the slit in this electrode changes in an inverse manner; that is, when the repelling voltage increases the number of ions passing decreases and conversely. Thus, the ion current passing through the analyzer consists of a constant component which may have a broad energy spread and a modulated fluctuating component, the energy spread of which, of necessity, is equal to the voltage variation applied to the ion retarder electrode.

The detecting portion of my new system is constructed to be sensitive only to the fluctuating component of the ion beam. Thus, the detecting system responds only to ions which have energy lying in a narrow and arbitrarily selected energy range.

A better understanding of the invention as well as its many advantages may be had by reference to the following detailed description and drawings in which:

FIG. 1 is a diagram of a simplified mass spectrometer showing one embodiment of my invention; and

FIG. 2 is a diagram of a simplified mass spectrometer showing a second embodiment of my invention.

Referring to the drawings, a mass spectrometer is shown including an analyzer **10**. The material to be analyzed, such as a gaseous hydrocarbon, is admitted into the ionization chamber **12** by means of an inlet such as gas inlet **14**. The gaseous molecules are ionized in the ionization chamber **12**.

An electrostatic field impressing electrical circuit is provided for accelerating the ionized particles through exit slit **14**. This circuit includes a D.C. voltage source **16** which feeds a voltage through lines **18** and **20** to apply a difference in potential v. between the chamber **12** and the accelerating electrode **22**.

After the ionized particles have accelerated, they are resolved into separate homogeneous beams according to their mass to charge ratio by means of a magnetic field produced between the poles of the electromagnet **24**. The strength of the magnetic field which exists between the poles of the electromagnet **24** is a function of the current flowing through the winding **26** from magnet power supply **28**. By maintaining the magnetic field constant and varying the accelerating potential v., the resolved ion beams are caused to move across the resolving slit **30**. Those ions which pass through the slit impinge on the collector electrode **32**.

The retarder electrode **34** is placed in the analyzer **10** between the ionization chamber **12** and the exit slit **30**. For example, the retarder electrode **34** may be placed in the analyzer immediately after the ionization chamber **12** as shown in FIG. 1 or it may be placed just before the exit slit **30** as shown in FIG. 2.

Any one of various circuits for applying a periodically varying voltage on the retarder electrode **34** may be used. Also, a detecting system is connected to electrode **32** which is sensitive only to the A.C. or fluctuating component of the ion beam. However, a particularly useful circuit is that described in patent application Serial No. 219,258 entitled "Remotely Controlled Modulating System," filed August 24, 1962 in the name of Walter A. Morgan. This circuit includes a signal generator **40** which produces a square wave output signal. The frequency of the square wave output signal may be varied over frequencies from 0 to 1,000 cycles per second with a frequency of about 20 cycles per second preferred.

The output singal from the signal generator **40** is fed to a power amplifier **42** and to a frequency doubler **44**. The power amplifier **42** amplifies the square wave signal to a level sufficient to energize a coil (not shown) in a phase sensitive detector **46**. A switching element of the phase sensitive detector **46** is thus synchronized with the output singal from the signal generator **40**.

A series of output pulses having a repetition rate equal to twice the input frequency is fed to a time delay circuit **48**. The time delay circuit **48** includes an adjustment potentiometer (not shown) for delaying the pulses from 0 to approximately 360° with respect to the output signal from the signal generator **40**.

The pulses from time delay circuit **48** are fed to the pulse amplifier **50** and then to an audio-transmitter **52**. The sound pulses from the audio-transmitter **52** travel to the remotely located microphone **54**. The microphone **54** converts the sound pulses to electrical pulses.

The output pulses from the microphone **54** are fed to an amplifier **56** where they are amplified. The amplified pulses are fed to a pulse former **58** where they are shaped. The shaped pulses are used to trigger a bistable multivibrator **60** causing the bistable multivibrator to flip from one stable state to the other stable state each time an acoustical pulse reaches the microphone **54**.

The output signal from the bistable multivibrator **60** is a square wave modulated voltage which has the same frequency as the output signal from the signal generator **40** and has a phase lag with respect to the signal from signal generator **40** equal to the time delay inserted by the time delay circuit **48** and the control link.

The output signal from the bistable multivibrator **60** is applied to the retarder electrode **34** in such a manner that a modulated output signal is obtained from the collector electrode **32**. By adjusting the amount of time

delay inserted by the time delay circuit 48, the input signal from the equipment can be brought into phase with the control signal from signal generator 40 to the phase sensitive detector 46. When the two signals are in phase, a D.C. output signal proportional to the A.C. component of the modulated input signal will be produced and recorded on recorder 62.

In operation, the gaseous ions are accelerated from ionization chamber 12. The ions are separated by the magnetic field applied by electromagnet 24 into homogeneous beams according to their mass to charge ratio. A periodically varying voltage is applied to retarder electrode 34 to cause an ion current consisting of a constant component and a fluctuating component. The fluctuating component of the ion current is recorded on recorder 62.

I claim:

In a mass spectrometer analyzer having an inlet end and an outlet end, the combination comprising

a gas inlet at said inlet end of said analyzer,

an ionization chamber within said analyzer adjacent said gas inlet,

an accelerating electrode adjacent said ionization chamber but remote from said gas inlet,

means for impressing a first voltage upon said ionization chamber and said accelerating electrode, said first voltage being a variable D.C. voltage,

an electromagnet juxtaposed on said analyzer intermediate said accelerating electrode and said outlet end,

a magnet voltage circuit for applying a constant magnetic field to the analyzer,

a resolving slit in the outlet end of said analyzer,

a retarder electrode positioned within said analyzer intermediate said accelerating electrode and said resolving slit,

means for impressing a second voltage on said retarder electrode and for varying said second voltage periodically within limits so that said second voltage is at all times greater than said first voltage, whereby a fluctuating component is impressed upon the ion stream,

and means for collecting ions emitted through said resolving slit, said means being operative to detect the fluctuating component of the ion current.

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