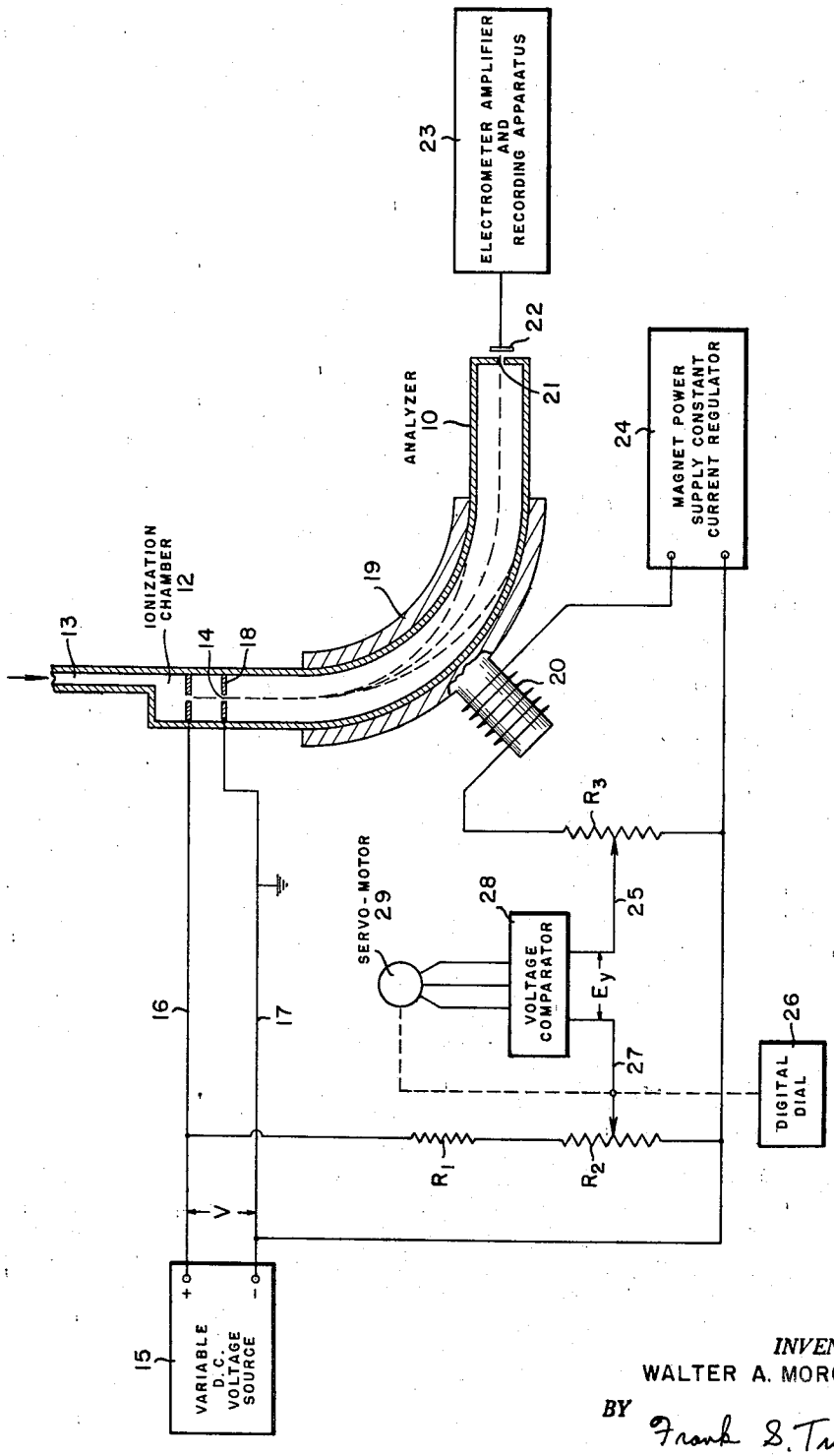
Jan. 24, 1961 W. A. MORGAN 2,969,462

MASS SPECTROMETRY

Filed Sept. 5, 1958



INVENTOR.
WALTER A. MORGAN,
BY Frank S. Troidl

ATTORNEY.

United States Patent Office

2,969,462

Patented Jan. 24, 1961

2,969,462

MASS SPECTROMETRY

Walter Avery Morgan, Baytown, Tex., assignor, by mesne assignments, to Esso Research and Engineering Company, Elizabeth, N.J., a corporation of Delaware

Filed Sept. 5, 1958, Ser. No. 759,245

1 Claim. (Cl. 250—41.9)

This invention relates to mass spectrometers. More particularly, this invention relates to an improved mass indicator for use with mass spectrometers.

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 ratio can be brought to focus on the ion collector and their relative intensities determined.

One major objective of mass spectrometry is to provide a visual form of mass to charge ratio identification at all times. The visual form should indicate directly the particular mass to charge ratio of the ionized particles brought to focus on the ion collector.

This invention provides the art of mass spectrometry with a new and relatively simple system for indicating visually the mass to charge ratio of the ionized particles being focused upon the collector at any particular time.

The mass indicator system to be described herein is particularly useful with a mass spectrometer including an ionization chamber, an analyzer, and a collector. Means are provided for accelerating and focusing the ionized particles by means of an electrostatic field. A field-applying electrical circuit is provided for applying a field through the analyzer to separate the ionized particles according to their mass to charge ratio.

The new mass indicator includes a means for obtaining a substantially fixed voltage from the field-applying circuit. Means are also provided for obtaining a voltage from the accelerating electrical circuit. These two voltages are continually compared by a voltage comparator such as a differential amplifier. An electrical circuit, including the voltage comparator, is provided, which is responsive to changes in the voltage from the accelerating electrical circuit to indicate the mass to charge ratio of ionized particles striking the collector at any particular time.

A better understanding of the invention, as well as its many advantages, may be had by reference to the following detailed description and drawing which is a diagram of a simplified mass spectrometer equipped with a mass indicator of my invention.

Referring to the drawing, 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 **13**. The gaseous molecules in ionization chamber **12** 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 variable D.C. voltage source **15** which feeds a voltage through lines **16** and **17**

to apply a difference in potential V between the chamber **12** and accelerating electrode **18**.

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 **19**. The strength of the magnetic field which exists between the poles of the electromagnet **19** is a function of the current flowing through the winding **20**. By maintaining the magnetic field constant and varying the accelerating potential V the resolved ion beam is caused to move across the resolving slit **21**. Those ions which pass through the slit impinge on the collector electrode **22**. The current produced by the ions impinging on the collector **22** is measured by an electrometer amplifier and recording apparatus **23**.

A resistor R_3 is connected in series with the electromagnet field windings **20**. Current from the magnet power supply constant current regulator **24** passes through the field windings **20** and resistor R_3 producing a voltage between tap **25** and ground which is proportional to the magnetizing current and which is a function of the magnetic field strength existing between the poles at the electromagnet. Since the magnetizing current is maintained constant by the current regulator **24**, the magnetic field strength and the voltage from the tap **25** to ground will also be constant. The position of the tap **25** on resistor R_3 is adjusted whenever the magnetizing current is changed to a new value so that the digital dial **26**, used to indicate the mass to charge ratio of the ions being brought to focus, will always read mass to charge ratio directly. Once adjusted for a particular magnetizing current the position of the tap **25** is fixed and the voltage between tap **25** and ground is a constant value.

A pair of resistors R_1 and R_2 are connected across the accelerating voltage V. R_2 is a linear potentiometer with movable wiper arm **27**. The voltages from wiper arm **27** and tap **25** are fed to a voltage comparator **28**. The output from the voltage comparator **28** is connected to a servo motor **29** which in turn is connected to wiper arm **27** and the digital dial **26**.

The voltage comparator **28** may suitably be a differential amplifier. Any slight difference in voltage between wiper arm **27** and ground and tap **25** and ground is amplified in the voltage comparator and causes the servo motor **29** to rotate the wiper arm **27** in such a direction that the magnitude of the differential voltage at the input to the comparator is reduced to zero. The digital dial **26**, attached to the potentiometer shaft, measures the mechanical position of the potentiometer wiper and expresses that position in terms of mass to charge ratio of the ions being brought to focus on the ion collector **22**.

That the mass is directly and visually indicated can be shown mathematically. In the mass indicating circuit shown,

$$E_y = V\left(\frac{R}{R_1+R_2}\right) - E_R$$

where:

E_y=the difference in voltage of wiper arm **27** to ground when compared with the voltage of tap **25** to ground
R=the resistance from wiper arm **27** to ground, in ohms.
R_1=resistance of R_1, in ohms
R_2=resistance of R_2, in ohms and
E_R=the voltage from tap **25** to ground

By the use of the comparator circuit **28** and servo motor **29**, the voltage E_y is kept substantially at zero. Therefore,

$$R = \frac{E_R(R_1+R_2)}{V}$$

From a study of ion optics it can be shown that

$$V=\frac{K}{M}$$

where:

K=a constant, and
M=the mass to charge ratio of the particles being brought to focus at the ion collector

Therefore,

$$R=E_R\left(\frac{M}{K}\right)(R_1+R_2)$$

where:

$$K=4.82\times10^{-5}\times B^2r^2$$

where:

B=the magnetic field in gauss, and
r=the radius of the analyzer in centimeters

For any particular application, B, r, E_R, R_1, and R_2 are constant. Therefore, R is proportional to M. Thus, the position of wiper arm **27** on resistor R_2 which is controlled by the servo-motor **29** is a direct indication of the mass to charge ratio of the ionized particles being detected at any particular time. This mass is indicated by the digital dial **26**.

In operation, if it is desired to scan the mass spectrum of the sample, voltage V is varied. As the voltage changes, the wiper arm **27** is continuously moved by the servo-motor **29** to maintain the voltage $E_y=0$. The movement of wiper arm **27** is calibrated to indicate on the digital dial **26** the mass to charge ratio of the ions being brought to focus at the ion collector **22**.

I claim:

A mass indicator system comprising: an analyzer; an ionization chamber; a collector; a voltage source for impressing a potential to accelerate the ions in the ionization chamber and to direct the ionized particles through the analyzer to the collector; a magnet juxtaposed on said analyzer; a magnet voltage circuit for applying a magnetic field to the analyzer to separate the ionized particles into homogeneous beams according to their mass to charge ratio; a resistor forming part of the magnet voltage circuit; at least one resistor connected across the voltage source for impressing a potential to accelerate the ions; and a mass indicator circuit including a tap for obtaining a substantially fixed voltage from the resistor in the magnet voltage circuit, a wiper arm for obtaining a voltage from the resistor connected across the voltage source, a comparator for receiving both voltages, a comparator controlled motor connected to the wiper arm responsive to any difference in the two voltages to move the wiper arm until the two voltages are again equal, and a dial indicator connected to the wiper arm for directly indicating the mass to charge ratio of ionized particles striking the collector.

References Cited in the file of this patent

UNITED STATES PATENTS

2,378,936 Langmuir ---------- June 26, 1945
2,676,264 Berry ---------- Apr. 20, 1954