Oct. 23, 1951 A. J. DEMPSTER 2,572,600

MASS SPECTROGRAPH

Filed Jan. 17, 1947 2 SHEETS—SHEET 1

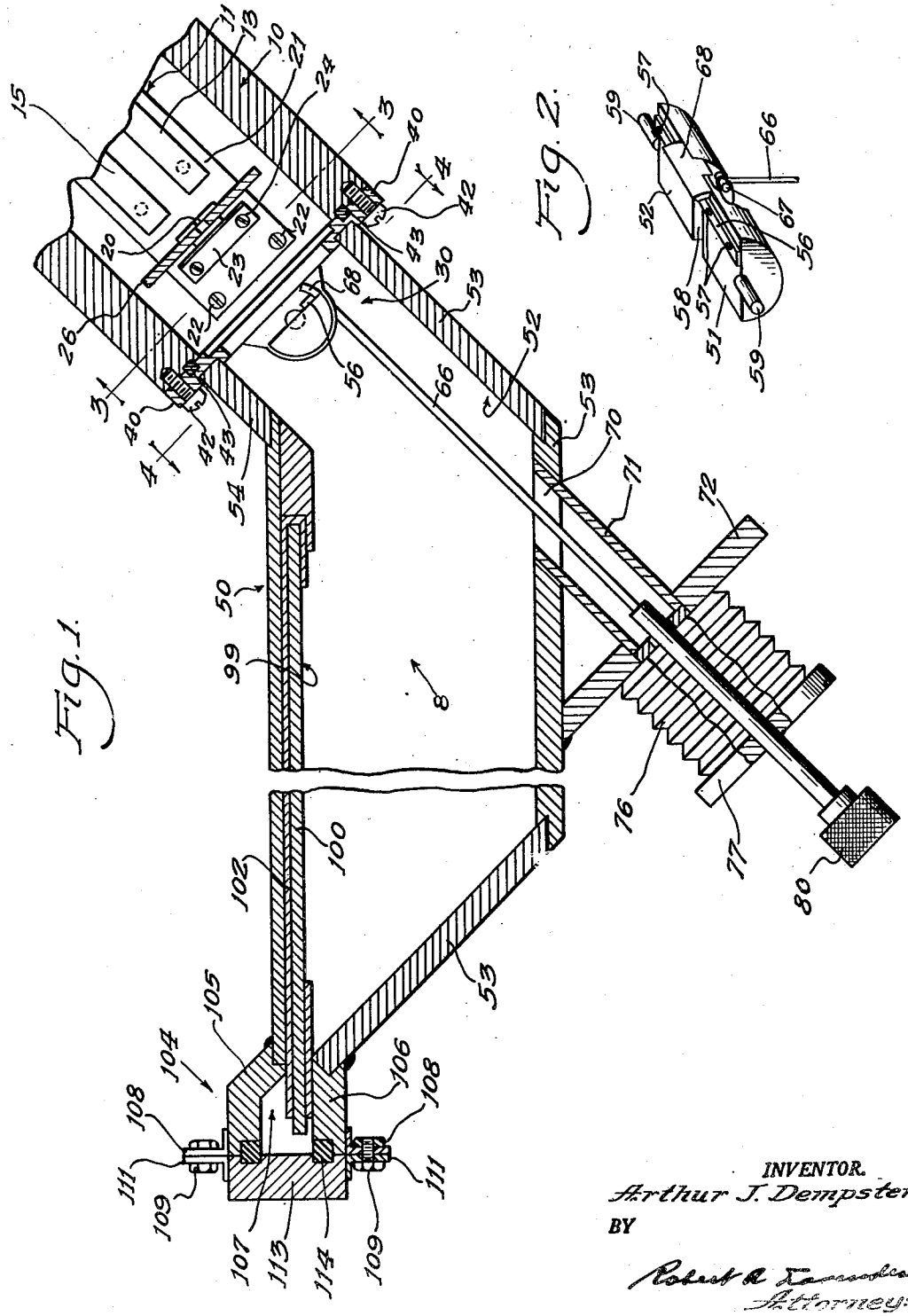


Fig. 1.

Fig. 2.

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Fig. 5.

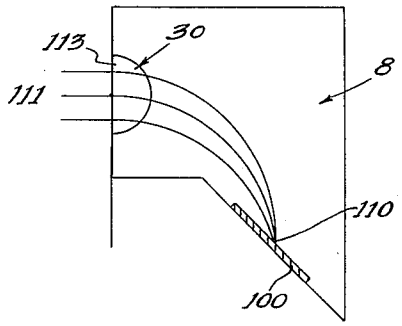


Fig. 6.

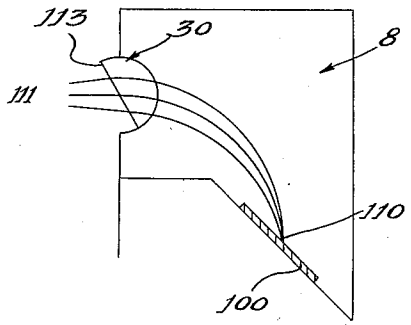


Fig. 7.

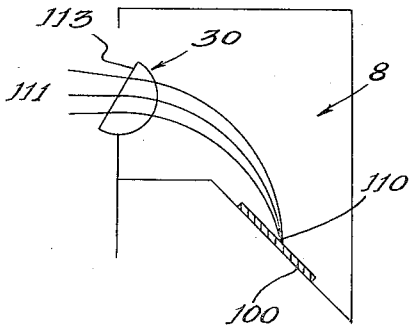


Fig. 3.

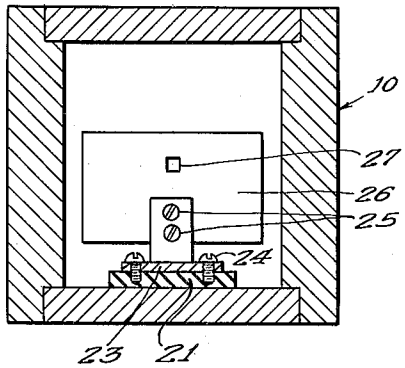
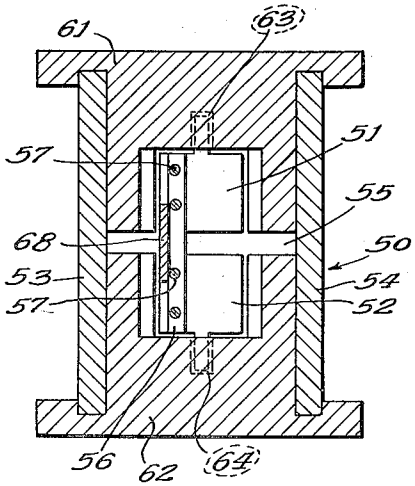


Fig. 4.



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Patented Oct. 23, 1951

2,572,600

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2,572,600

MASS SPECTROGRAPH

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Application January 17, 1947, Serial No. 722,640

7 Claims. (Cl. 250—41.9)

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The present invention relates to mass spectrographs and particularly to a mass spectrograph utilizing a variable magnetic lens so as to vary the angle of incidence of the ion beam upon entering a homogeneous magnetic field.

In a mass spectrograph, the focusing of the ions of different velocities is obtained as a result of a geometrical arrangement of the electric and magnetic fields, which are so positioned that the dispersion of the ions produced by one field is cancelled by the dispersion produced by the other field for a given velocity difference. In actual practice, the ion beam will not be substantially parallel upon entering the magnetic field, but will either be divergent or convergent due to the inherent design defects characteristic in the mechanical construction of the electrostatic deflecting condenser and collimating slit system accommodated in the mass spectrograph. These inherent defects will produce variation in the propagation so as to produce non-parallelism of the ion beam. In order to compensate for the deviation of the ion beam, the present invention comprehends an adjustable magnetic lens to vary the angle of incidence of the ion beam upon entering the magnetic field.

The principal object of the present invention is to provide an improved mass spectrograph, which will correct for the divergence or convergence of the associated ion beam.

As stated generally above, the object of the present invention is accomplished by providing an adjustable magnetic lens apparatus to afford a variable angle of incidence at the entrant boundary to the homogeneous magnetic field, in contrast with the prior known spectrographs employing fixed angles of incidence.

The improved apparatus of the present invention includes various novel structural features which contribute to its successful operation. These various structural features, and other objects and advantages of the invention, will be made more apparent by reference to the accompanying drawings and the following description of a preferred embodiment thereof. In the drawings:

Fig. 1 is a sectional plan view, partly in elevation, showing the magnetic deflecting assembly coupled to a posterior portion of the collimating and electrostatic deflecting unit of a mass spectrograph;

Fig. 2 is an enlarged perspective view of the variable magnetic lens structure, a portion thereof being broken away;

Fig. 3 is a vertical cross section, partly in elevation, taken on the line 3—3 of Fig. 1;

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Fig. 4 is a vertical sectional view, partly in elevation, taken along the line 4—4 of Fig. 1;

Fig. 5 is a schematic diagram showing a parallel incident ion beam being bent through an angle of 90° by means of a combined variable magnetic lens and a magnetic field so as to focus the beam at a defined focal point;

Fig. 6 is a schematic diagram showing a divergent incident ion beam which is deflected and focused at a defined focal point by means of a combined variable magnetic lens and a superimposed homogeneous magnetic field; and

Fig. 7 is a schematic diagram showing a convergent entrant ion beam which is deflected and focused at a defined focal point by means of a combined variable magnetic lens and a homogeneous magnetic field accommodated in a mass spectrograph.

Heretofore various combinations of magnetic fields have been employed in mass spectrographs to separate ion beams with similar, but not identical, charge to mass ratios, and to record the composite mass spectrum. Theoretical interpretations and calculations have been set forth wherein the design of the electrostatic condenser and the magnetic deflecting system have been compared with a corresponding optical lens and prism presentation. In the actual design and construction of the mass spectrograph, it was found that the variance in the mechanical construction of the mass spectrograph from the theoretical calculations produced a deviation of the associated ion beam from parallelism so that the incident ion beam was either divergent or convergent upon entering a homogeneous magnetic field. The present invention comprises novel means to compensate for the non-parallelism of the ion beam in order to facilitate simplicity in construction and operation. In addition, it has been found that an ion beam can be made to focus at a predetermined focal position on a recording means, such as a photographic plate by the varying of the electrostatic field developed across the electrostatic condenser or lens. In this manner, the ion beam can be slightly convergent or divergent prior to entering the magnetic field, and the focus of the beam can be adjusted by adjusting the angle of entrance into the magnetic field by means of a variable magnetic lens apparatus. This procedure is advantageous in operating a mass spectrograph so as to obtain good resolution of the spectrum over a well defined mass range.

The novel features embodied herein as shown in Fig. 1 include a device for varying the angle of incidence of an ion beam entering into a

deflecting magnetic field, generally designated by numeral 8. The mass spectrograph as fragmentarily shown in Fig. 1 comprises a non-magnetic metallic shell or housing 10 which contains the electrostatic deflecting condenser designated generally by numeral 11 and a collimating slit unit indicated by numeral 20. The collimating slit unit 20 is positioned within the housing 10 and is mounted on an electrical insulating base plate 21 formed, for example, of glass bonded mica sheet rigidly connected to the housing 10 by means of a plurality of screws 22. Attached to the base plate 21 is a non-magnetic metallic bracket 23, for example, brass, which is affixed to the base plate 21 by means of screws 24. Mounted perpendicularly to said base plate 21 and attached to said bracket 23 and mounted by means of screws 25, as shown in Fig. 3, is a slit holder 26 having the collimating slit 27 therein shown enlarged for the purpose of clarity in illustration. The slit is preferably rectangular with dimensions of approximately 0.9 mm. by 2.4 mm. Anterior to said collimating slit unit 20 and attached to the insulating base plate 21, is the conventional electrostatic deflecting condenser 11 comprising condenser plates 13 and 15 mounted in spaced relationship.

The shell or housing 10 is attached to a face plate 40 which is made of non-magnetic material such as brass, said face plate 40 being mechanically attached to said shell housing 10 by means of stud bolts 42. A resilient gasket insert 43, for example, rubber, is adapted to form a vacuum tight seal upon tightening the stud bolts 42.

The magnetic deflecting unit 50 comprises an upper magnetic pole piece 61, lower magnetic pole piece 62 and non-magnetic side walls 53 and 54, for example, brass, said side walls 53 and 54 comprising a housing wherein an aperture 55 (Fig. 4) is disposed between the pieces 61 and 62. Said side walls 53 and 54 are connected as by soldering, to said face plate 40, as shown in Fig. 1.

An adjustable magnetic lens unit 30 is recessed in the pieces 61 and 62 at the point of entrance of an ion beam to the aperture 55 of the magnetic deflecting unit 50. The lens 30 comprises spaced magnets 51 and 52, as shown in elevation in Fig. 2. The spaced magnets 51 and 52 are preferably of semi-circular cylindrical design, machined of magnetic materials, such as Armco iron, and inter-connected with a non-magnetic strip or member 56 by means of mounting screws 57.

The magnets 51 and 52 define a gap therebetween. Said air gap 58 corresponds approximately to the height of said aperture 55. At the opposite end surfaces of the spaced magnets 51 and 52 are mounting pivots 59 which are inserted into complementary sockets 63 and 64 in the upper and lower pole pieces 61 and 62 respectively, as shown in Figs. 2 and 3. Said recesses 63 and 64 afford a housing, or cavity, wherein the rotatable magnetic lens 30 is disposed. This manner of mounting allows for rotation of the variable magnetic lens 30 by the inward or outward motion of an actuating rod 66 which is pivotally connected to a pin 67 mounted on the upper surface of the lower magnet 52 near the outer periphery thereof, as shown in Fig. 1 and 2. A magnetic shutter 68, preferably made of non-magnetic metallic material, for example, brass, is mounted on an outer periphery of the magnetic lens 30 as shown in Figs. 1, 2, and 4; and upon rotating said lens 30 approximately 90° from its normal position where the flat surfaces of the lens 30 are approximately perpendicular to the incident ion beam as illustrated in Figs. 1 and 4, said shutter 68 will effectively cut off the incident ion beam.

The rod 66 extends through an opening 70 in the non-magnetic side wall 53 through a non-magnetic tubular member 71 which is rigidly attached to an annular base plate 72 as by means of solder. A flexible bellows 76 is connected at one end thereof to the plate 72 as by soldering, and the opposite end of said bellows 76 is soldered to an annular disc 77 which is soldered to the extended rod 66 so as to form a flexible, moveable vacuum tight seal with respect to the mass spectrographic device. The rod 66 is preferably provided with a knob 80 for convenient actuation thereof.

A photographic recording assembly 99 for recording the impinging ion beam comprises a photographic plate 100, and a photographic plate holder 102 which has an opening communicating with the aperture 55 in order that the impinging ion beam will strike photographic emulsified surfaces of said plate 100. At the posterior end of said magnetic deflecting unit 50, is a tail assembly indicated by numeral 104 comprising side walls 105 and 106 so as to form a vacuum chamber 107 wherein the posterior portion of said photographic plate 100 is disposed. Attached to the posterior ends of said side walls 105 and 106 are L-shaped brackets 108 connected to L-shaped brackets 111 on the end plate 113 by bolts 109. A resilient gasket 114 is disposed intermediate between said end plate 113 and said side walls 105 and 106 so as to afford a vacuum tight seal. Upon disassembling said stud bolts 109, the photographic plate 100 is easily accessible and can be inserted or removed through said chamber 107.

A number of focusing schemes have been utilized in mass spectrographs, some resulting in velocity focusing, some designed in the direction of focusing a non-collimated beam, and other constructions aimed more directly in achieving a linear mass range. These instruments providing double focusing of the ion beam, by using consecutive electrostatic and magnetic focusing of a well collimated ion beam, have provided results so as to record the ion spectrum on a photographic plate. Generally, the mass scale is not linear and must be determined from calculations on the geometry of the focusing conditions; also the resolution must be determined from the accuracy of collimation by the associated collimating slit 20 and of electrostatic deflection by the electrostatic condenser 11 deflecting the beam of ions from the source.

It may be noted that the theory and design of various spectrographs are subject to constructional variations and that this inherent variation will produce a non-parallel ion beam which may be either convergent or divergent. Since it is extremely difficult to adjust the critical interrelationship and alignment of the associated collimating slit 20 and the electrostatic deflecting condenser 11, it has been found that the ion beam is generally divergent or convergent upon entering the magnetic deflecting field. Considering the schematic illustration in Fig. 5 the drawing shows a parallel bundle of rays of an ion beam 111 being bent through an angle of 90° by the magnetic field at 8 and the magnetic lens 30, and brought to a focus on the photographic

plate 100 at a focal point 110. The propagation of a parallel ion beam 111 is generally considered desirable in operating a mass spectrograph. When an associated ion beam 111 is divergent, as shown in Fig. 6 after leaving the collimating and electrostatic deflecting assembly, a flat magnetic lens face 113 of the magnetic lens 30 is rotated so that the angle of incidence of the ion beam entering the magnetic field 8 is substantially varied in order to compensate for the divergency of the ion beam 111 so as to focus said beam 111 on the corresponding focal point 110. When an associated ion beam 111, is slightly convergent as shown in Fig. 7, the interface 113 of the magnetic lens 30 is rotated as shown, and the ion beam 111 is again focused on the focal point 110.

In addition, it has been demonstrated that by varying the electrostatic field developed across the electrostatic condenser 11, the ion beam 111 can be made slightly divergent or convergent so that the direction of said beam 111 prior to entering the homogeneous magnetic field 8, can be adjusted by the magnetic lens 30 to focus at a predetermined focal point 110. In this manner of operation, the ion beam 111 may be purposely made slightly convergent or divergent to accommodate a predetermined focal point of the ion beam 111 by adjusting the angle of entrance of said beam 111 into the magnetic field 8 by the variable magnetic lens 30.

It will be apparent that modifications will be readily suggested to others skilled in the art as the result of the teachings of my invention, hence, it should be understood that my invention is not limited by specific construction hereinbefore described, which is an exemplary embodiment, and should be restricted only insofar as set forth in the following claims.

What is claimed is:

1. A magnetic lens comprising spaced magnets arranged end-to-end defining an ion path therebetween, rigid non-magnetic means interconnecting said magnets, pivots on the remote sides of said magnets, disposed on a common axis, and means to rotate the magnets on the pivots attached to one of the magnets.

2. A magnetic lens comprising spaced magnets arranged end-to-end defining an ion path therebetween, rigid non-magnetic means interconnecting said magnets, pivots on the remote sides of said magnets disposed on a common axis extending through the magnets, a rod attached to one of the magnets at a point other than the axis, said rod being adapted to extend to an actuating means, and a shutter mounted on the magnets and extending between the magnets parallel to the axis.

3. A magnetic lens unit comprising spaced magnets in the form of semi-cylinders, arranged end to end, rigid means for interconnecting said magnets, pivots on the remote sides of the respective magnets disposed in a common axis coaxial to said cylinders, and means on the end of one of said magnets adjacent the other for connecting the unit to associated actuating means for rotating the same.

4. A magnetic lens unit comprising spaced magnets in the form of semi-cylinders, arranged end to end, rigid means for interconnecting said magnets, pivots on the remote sides of the respective magnets disposed in a common axis coaxial to said cylinders, and means on the end of one of said magnets adjacent the other for connecting the unit to associated actuating means for rotating the same, and a shutter extending across the space between said magnets at one side of said axis and secured to said unit.

5. A magnetic lens unit comprising spaced magnets in the form of semi-cylinders arranged end to end, rigid means for interconnecting said magnets, pivots on the remote sides of the respective magnets disposed in a common axis coaxial to said cylinders, and means on the end of one of said magnets adjacent the other for connecting the unit to associated actuating means for rotating the same, and a non-magnetic shutter having a portion extending between the magnets and secured to at least one thereof, said shutter extending across the space between said magnets at one side of said axis.

6. In a mass spectrograph, an aperture, a magnetic field therein for deflecting an associated ion beam, means communicating with said aperture for recording an ion spectrum, and magnetic lens means for compensating for the divergence or convergence of the paths of the ions in said beams, said lens means comprising spaced interconnected magnets defining a gap aligned with said aperture, means for rotating said magnets, and shutter means extending across the gap at one side thereof for closing said aperture against flow of ions therethrough in one rotatable position of said magnets.

7. In a mass spectrograph, an aperture, a magnetic field therein for deflecting an associated ion beam, means communicating with said aperture for recording an ion spectrum, and magnetic lens means for compensating for the divergence or convergence of the paths of the ions in said beam, said lens means comprising spaced interconnected rotatable magnets in the form of semi-cylinders arranged end to end.

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