June 7, 1955 M. G. INGHRAM ET AL 2,710,354

ION SOURCE

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FIG. 1

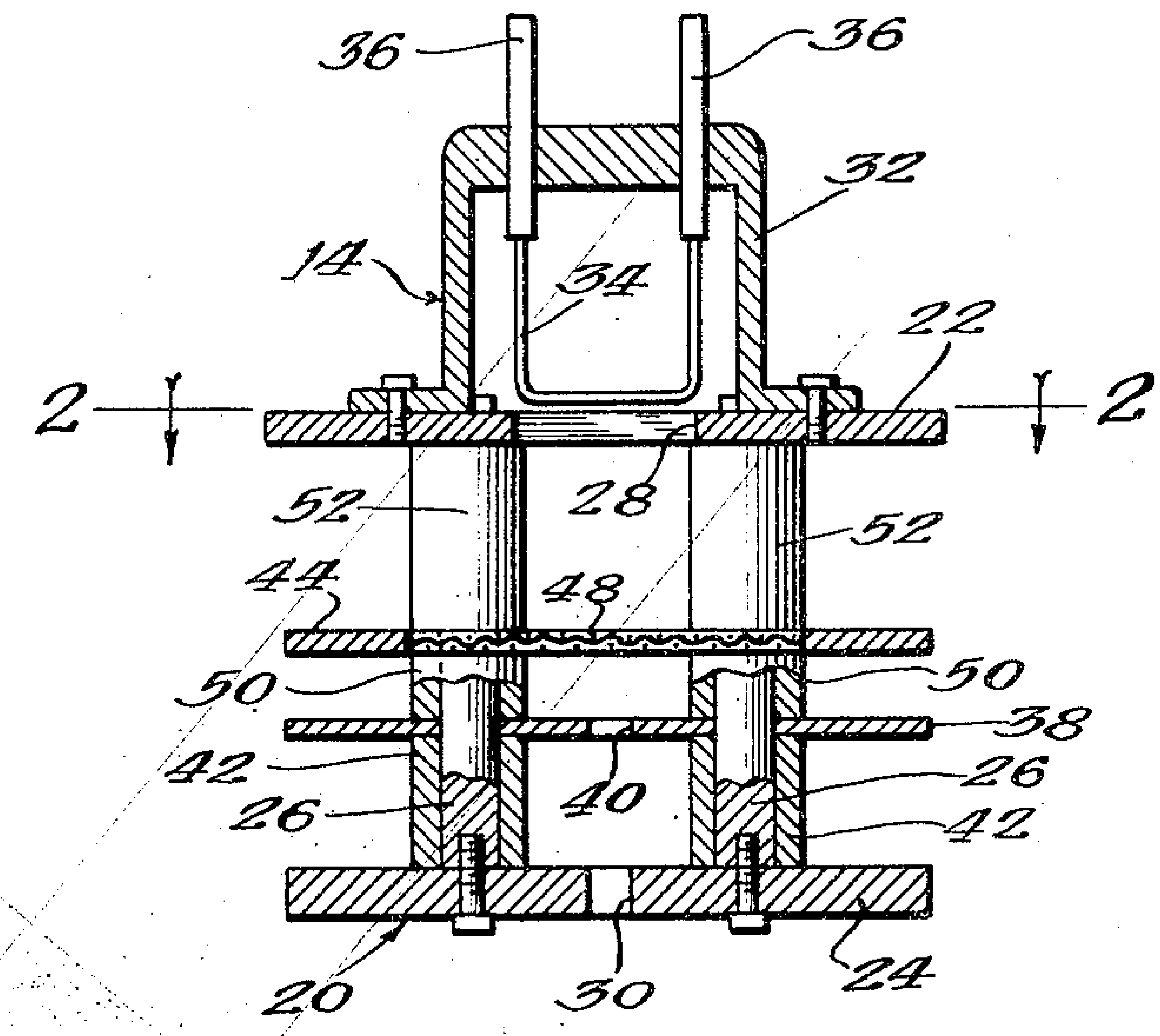


FIG. 2

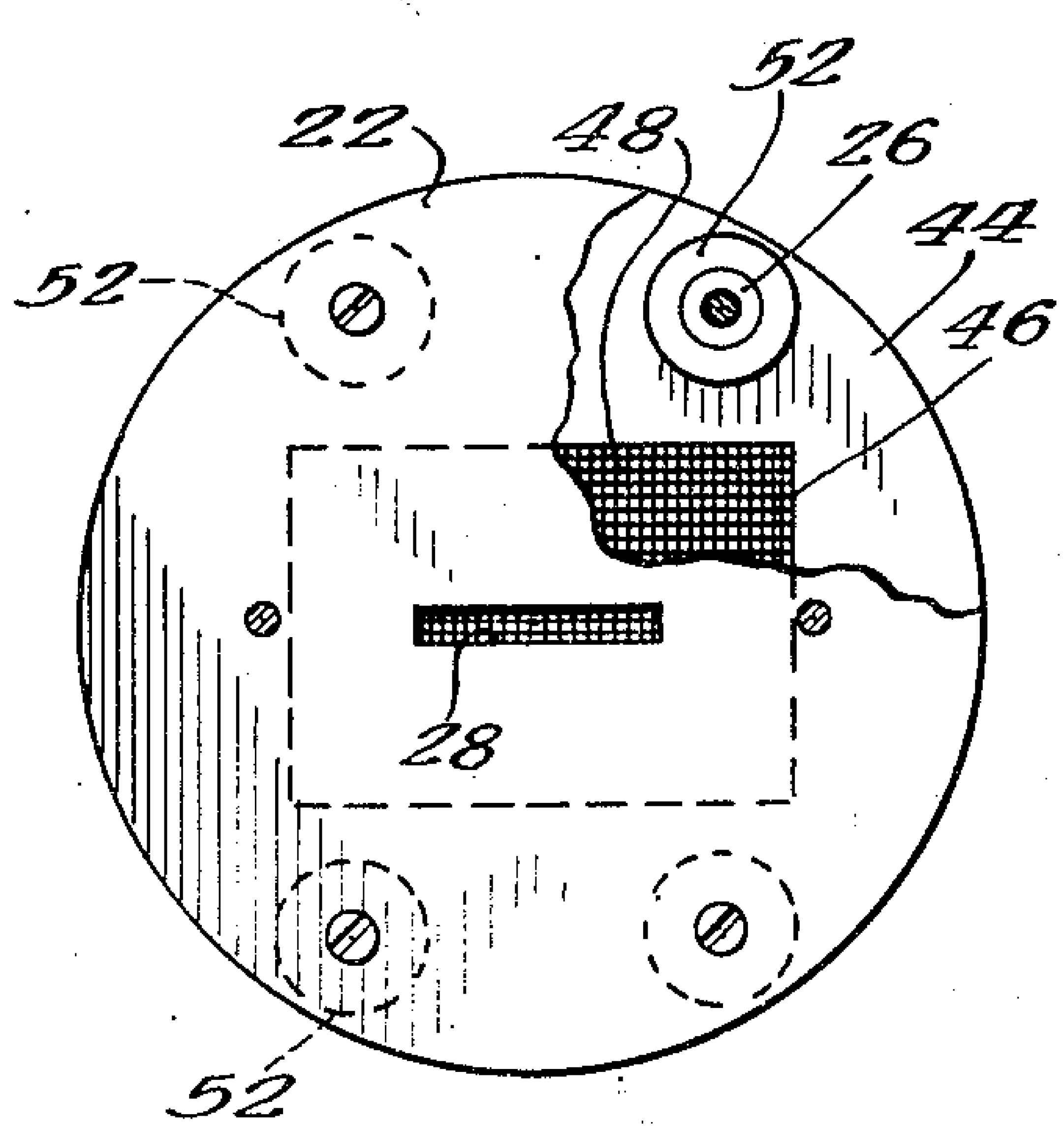
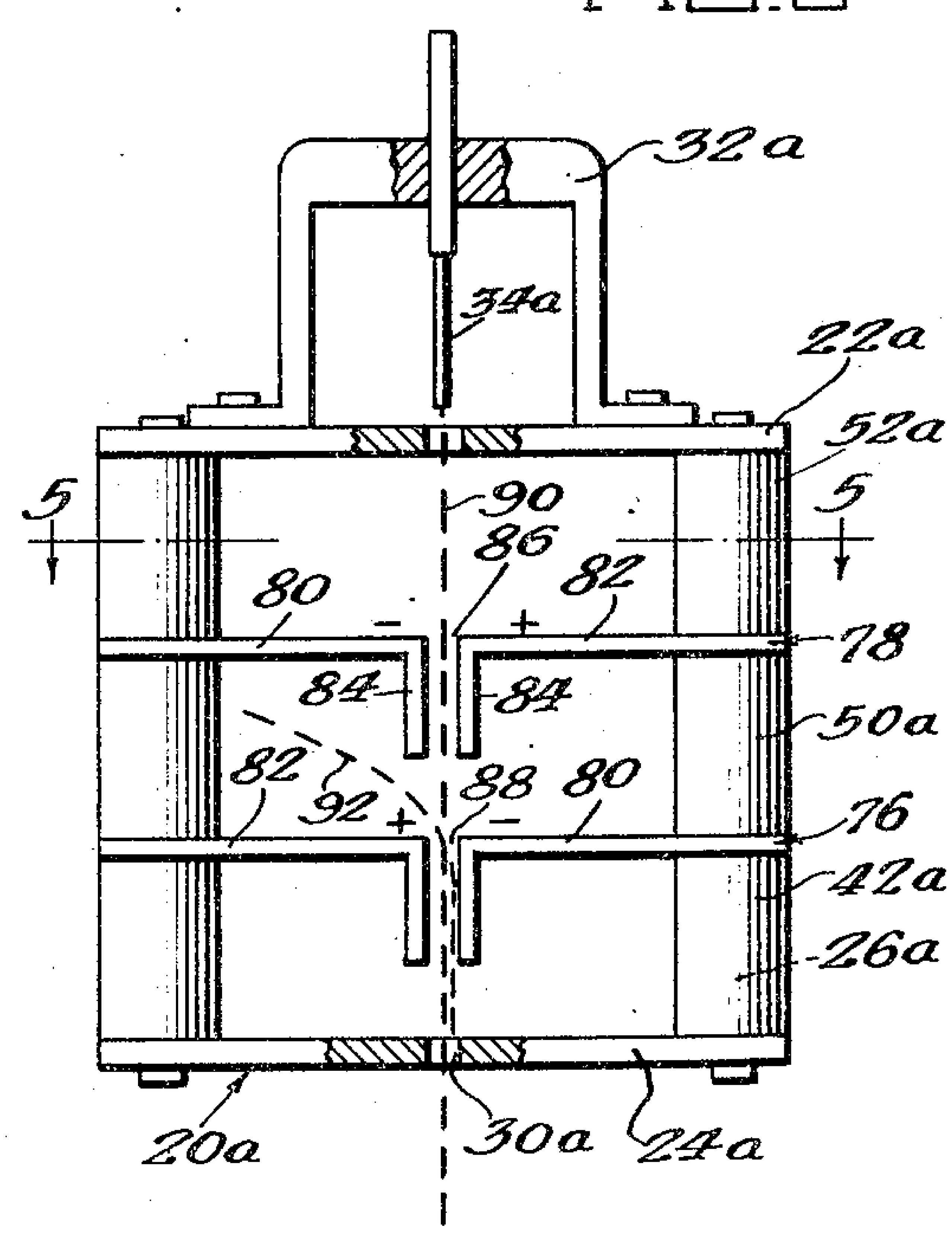


FIG. 3



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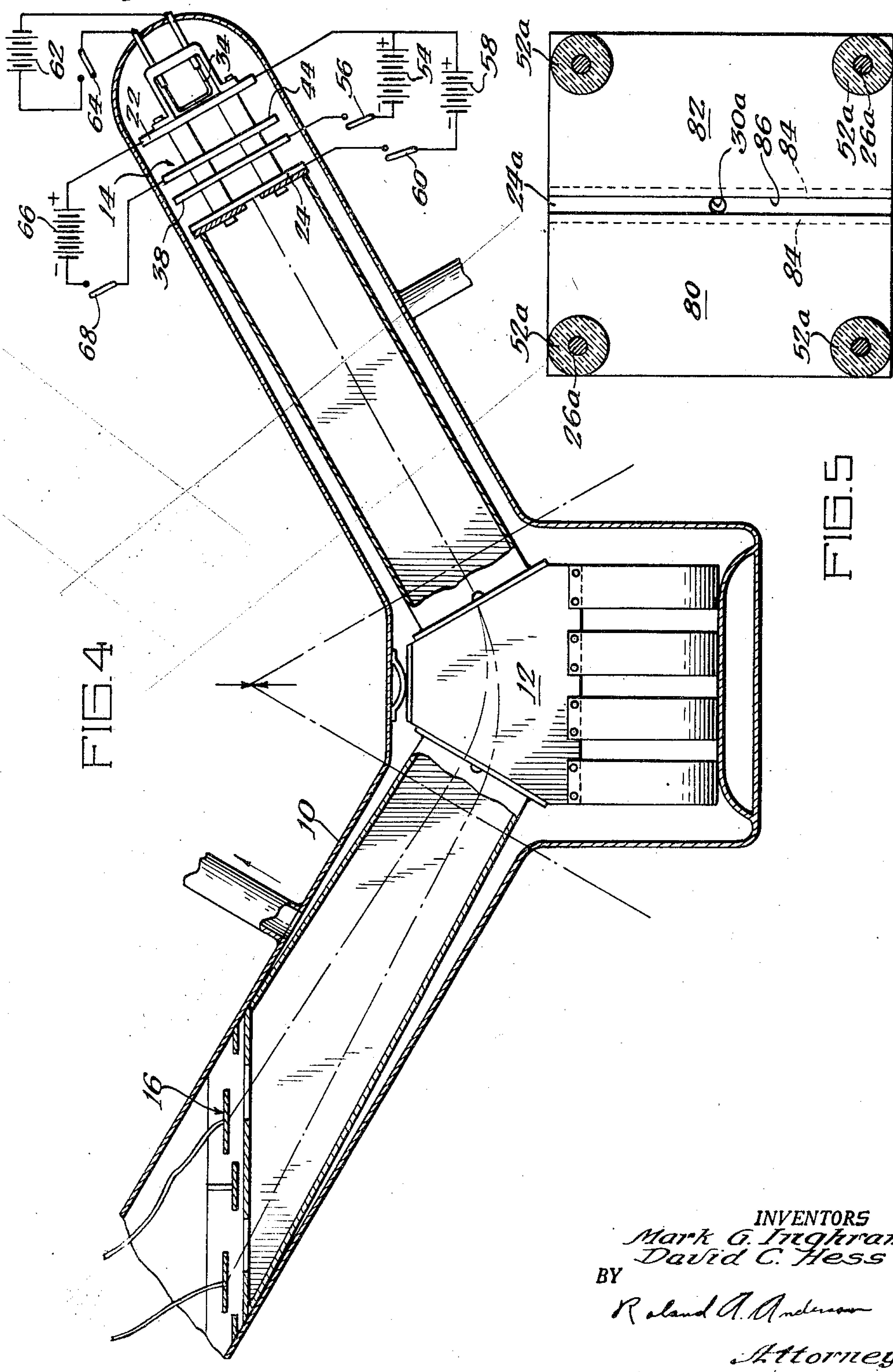

FIG. 4

FIG. 5

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ION SOURCE

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3 Claims. (Cl. 250—41.9)

The present invention relates to mass spectrometers, and particularly beam sources of positive ions suitable for use in mass spectrometers.

In recent years, the sensitivity of mass spectrometers has been greatly increased, largely as a result of the use of electron multipliers to measure the charge of ions separated and collected by the mass spectrometer. However, as the sensitivity of mass spectrometers is increased, the magnitude of background ion peaks becomes more important. It has been found that background ion peaks become objectionable with ion sources producing currents less than 10^{-12} amperes.

The present invention is directed to devices reducing the background ion peaks in mass spectrometers, and has been found to have particular advantages when incorporated with beam sources of ions depending upon surface ionization, since such sources normally produce small ion currents. However, the present invention is also of advantage in reducing the ion background peaks in electron bombardment beam ion sources or other beam sources when operated to produce small ion currents.

A more complete understanding of the present invention and its ramifications may be had from a reading of the present disclosure, particularly when viewed in the light of the drawings, in which:

Fig. 1 is a fragmentary view, partly in section, of a surface ionization beam source of positive ions constructed according to the teachings of the present invention;

Fig. 2 is a sectional view taken along line 2—2 of Fig. 1;

Fig. 3 is an elevational view, partly cut away in section, of an alternative embodiment of the beam ion source shown in Fig. 1;

Fig. 4 is a sectional view of a mass spectrometer incorporating the ion source shown in Fig. 1; and

Fig. 5 is a sectional view taken along line 5—5 of Fig. 3.

As shown in Fig. 4, the mass spectrometer is provided with a casing **10** in which a vacuum is maintained. The casing **10** is generally Y-shaped and is provided with a magnet **12** at the junction of the two legs of the Y. An ion source **14**, which will be described in detail later, is disposed within one of the legs of the casing **10** near one end thereof, and a collector **16** is disposed adjacent to the end of the other leg of the casing **10**. Mass spectrometers of the type here generally described are well known in the art. Patent No. 2,551,544 of Alfred O. C. Nier and Mark G. Inghram, filed September 20, 1944, entitled "Mass Spectrometer," discloses in detail a mass spectrometer of the type generally shown in Fig. 4.

The ion source **14**, as illustrated in Figs. 1, 2 and 4, has a supporting structure **20** with a pair of plates **22** and **24** affixed together by 4 posts **26** of electrically insulating material. One of the plates **22** is provided with a rectangular aperture **28** at its center, and the other plate **24** is provided with a collimating slit **30** at its center. A bracket **32** is attached to the plate **22**, and

supports a filament **34** adjacent to the rectangular aperture **28** in the plate **22**. The filament **34** is electrically insulated from the bracket **32** by insulators **36**.

A slit plate **38** is mounted upon the posts **26** between the plates **22** and **24**. The slit plate **38** is provided with a collimating slit **40** at its center, the collimating slit **40** being aligned with the collimating slit **30** and the rectangular aperture **28**. Electrically insulating sleeves **42** are disposed about the posts **26** and space the slit plate **38** from the plate **24**.

A grid plate **44** is mounted upon the posts **26** between the slit plate **38** and the plate **22**, and the grid plate **44** is provided with a large rectangular aperture **46** at its center. The aperture **46** is covered with a wire mesh grid **48** constructed of electrically conducting materials. The grid plate **44** is separated from the slit plate **38** by electrically insulating sleeves **50** disposed about the posts **26**, and the grid plate **44** is also separated from the plate **22** by sleeves **52** of electrically insulating material disposed about the posts **26**.

As shown in Fig. 4, a first accelerating voltage supply **54** is connected between the plate **22** and the slit plate **38** through a switch **56**, and a second accelerating voltage supply **58** is connected between the plate **22** and the plate **24**, through a switch **60**. Both of these voltage supplies **54** and **58** impress a positive potential upon the plate **22** relative to the slit plate **38** and the plate **24**. A current supply **62** is connected to the filament **34** through a switch **64**.

In order to place the mass spectrometer into operation, the filament switch **64** is closed heating the filament **34**. The filament will liberate ions, as is well known in the art, and the ions will be of the materials with which the filament **34** has been constructed. Materials which make good filaments, such as tungsten, are often coated with other elements in order to form a filament which will liberate the other more desirable ions. In this manner, the region immediately adjacent to the filament **34** becomes occupied with positive ions. However, since plate **22** is at a positive potential relative to slit plate **38** and plate **24**, the ions thus liberated from the filament **34** are accelerated toward the slit plate **38**. These ions readily pass through the grid **48**, since only a small percentage of the area is obstructed by the grid **48**, but only those ions directed toward the slit **40** and the slit **30** will be directed into the region of the magnetic field produced by the magnet **12** of the mass spectrometer. Many of the other ions which are not directed toward the slits **40** and **30** will strike the slit plates **38** or **24** and be deposited thereon.

However, a number of negatively charged particles, such as negative ions and electrons, are liberated from the slit plate **38** or plate **24** as a result of the bombardment of the plates **38** and **24** by the ions failing to pass through the slits **40** and **30**. These particles are repelled from the slit plate **38** and plate **24** and attracted by the plate **22**. Hence, these particles are accelerated in the direction of the filament **34**, and some bombard the filament **34**, thereby producing tertiary positive ions. It is believed that these tertiary ions produced by bombardment rather than by evaporation, as is the case of the positive ions originally produced by the filament **34**, are of a different character than those produced by evaporation, and often account for the background levels observable in mass spectrometers.

However, a source of grid voltage **66** is also connected between the plate **22** and the grid plate **44** through a switch **68**, and places the grid **48** at a negative potential relative to the plate **22**. As a result of the negative potential upon the grid **48**, negative particles ejected from the slit plate **38** or the plate **24** are no longer accelerated toward the plate **22**, and hence no longer bombard the filament 34. In this manner, tertiary ions ejected from the filament 34 by bombardment are substantially reduced, and the background intensities in the mass spectrometer are also reduced.

It has been found that the potential applied to the grid plate 44 should be about one tenth as negative as the potential applied to the slit plate 38 and plate 24 relative to plate 22. In a particular construction, the plates 38 and 24 are about 3,000 volts negative with respect to plate 22, and the grid 48 is about 300 volts negative. In this same construction, the grid 48 is spaced from plate 22 by 9 millimeters, and from slit plate 38 by 3 millimeters. Slit plate 38 is spaced from plate 24 by 12 millimeters.

Figures 3 and 5 show a second embodiment of a beam ion source constructed in accordance with the teachings of the present invention. This beam ion source has a supporting structure 20*a* with plates 22*a* and 24*a* and a mounting bracket 32*a* for a filament 34*a*, and is thus similar to the construction of the beam ion source shown in Fig. 1. A slit 30*a* is disposed centrally in the plate 24*a*. The plates 24*a* and 22*a* are separated by electrically insulating posts 26*a* which also support two pairs 76 and 78 of plates 80 and 82. The pairs of plates 76 and 78 are spaced between the plates 22*a* and 24*a* by spacers 42*a*, 50*a* and 52*a*. Each of the plates 80 and 82 are constructed with portions 84 normal to the rest of the plates 80 and 82, the portion 84 of each plate 80 being disposed adjacent to and parallel to the portion 84 of a plate 82, thereby providing gaps 86 and 88 between the plates 80 and 82 in both pairs of plates 76 and 78.

As illustrated in Fig. 3, plates 80 are on opposite sides of the ion path, as are plates 82. A positive potential is applied to plates 82, and a negative potential is applied to plates 80, thus the positive plates 82 are on opposite sides of the ion path in the two pairs of plates 76 and 78. Also, plate 24*a* is placed at a negative potential relative to plate 22*a*, as in the first embodiment.

The positive ions liberated by the filament 34*a* will follow a trajectory generally indicated by the dashed line 90, these positive ions being accelerated by the negative potential on plate 24*a* relative to plate 22*a*. The beam of positive ions is displaced in the direction of the negative plate 80 as it passes through the portion 84 of the first pair of plates 78, and is returned by displacement in the opposite direction when passing through the portion 84 of the following pair of plates 76. However, some of the positive ions will strike the plate 24*a* adjacent to the slit 30*a*, thereby ejecting negative particles and electrons. The negative particles and electrons are accelerated toward the filament 34*a*, but due to their relatively low velocity and the differences in the potentials of plates 80 and 82, the negative particles and electrons will follow a different trajectory than that of the positive ions, a possible trajectory being indicated by the dashed line 92. In this manner, the negative particles and electrons are blocked from bombarding the filament 34*a*, and background ion peaks in the mass spectrometer as a result of tertiary ions liberated by electron bombardment of the filament 34*a* are eliminated.

It is thus clear to the man skilled in the art, that the mass spectrometers provided as a result of the present invention have lower background ion peaks than those previously known to the art, and that the beam sources of ions here disclosed produce relatively few ions of undesired mass numbers. Many other modifications and advantages of the present invention will readily appear to the man skilled in the art, and hence it is intended that the scope of the present invention be limited only by the appended claims and not by the foregoing disclosure.

What is claimed is:

1. A beam source of positive ions comprising, in combination, an evacuated housing, a source of positive ions, a plate provided with a collimating slit disposed within the housing, means to maintain a potential gradient becoming more negative between the source and the slit, and an electrostatic deflection negative particle trap disposed between the ion source and the slit, said trap transmitting the beam of positive ions from the source through the collimating slit in a substantially straight path and trapping negative particles traveling toward the ion source.

2. A beam source of ions comprising, in combination, an evacuated housing, a source of positive ions disposed within the housing, a plate having a collimating slit disposed within the housing and spaced from the source of ions, means to maintain a potential gradient becoming increasingly negative from the source to the slit, a first pair of deflection plates mounted between the source and the slit, said plates being electrically insulated from each other and disposed upon opposite sides of the path between the source and the slit, a second pair of deflection plates disposed between the first pair of deflection plates and the plate, said plates being parallel to the first pair of plates, means to apply a potential gradient between the first pair of plates, and means to apply a potential gradient between the second pair of plates, said potential gradient being opposite to that applied across the first pair of plates.

3. A beam source of positive ions comprising, in combination, an evacuated housing, a surface evaporation ion source disposed within the housing, including a filament, a plate having a collimating slit disposed within the housing and spaced from the source, means to maintain an ever increasing negative potential gradient between the source and the slit, a first pair of deflection electrodes mounted between the source and the slit, said electrodes being disposed about opposite sides of the path between the source and the slit and electrically insulated from each other, a second set of deflection electrodes disposed between the first set of electrodes and the slit, said second set of electrodes being parallel to the first and electrically insulated from each other, means to apply a potential across the first pair of electrodes, and means to apply a potential across the second pair of electrodes, the electrodes in each pair on the same side of the path between the filament and the slit being of equal but opposite potential.

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