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(54) Title: APPARATUS FOR MEASURING TOTAL PRESSURE AND PARTIAL PRESSURE WITH COMMON ELECTRON BEAM
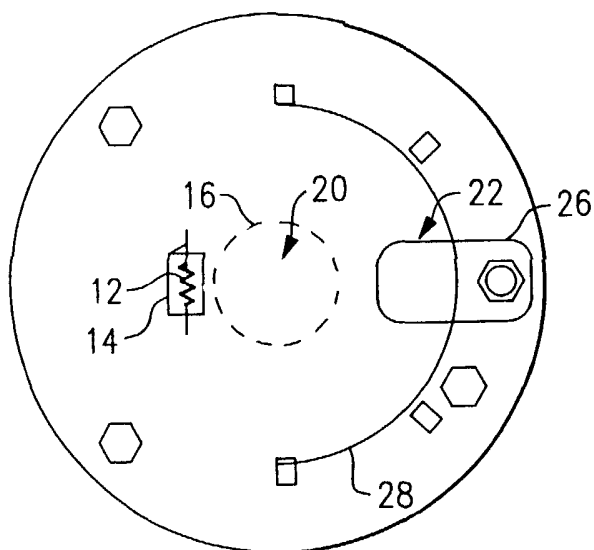
(57) Abstract: An apparatus for determining both total and partial pressures of a gas using one common electron beam includes a partial pressure ionization region and a total pressure ionization region separated by a grid or aperture. A filament produces a plurality of electrons which are focused into an electron beam by a repeller and an aperture or an anode. The interaction between the electron beam and molecules of said gas within the partial pressure and total pressure regions produces first and second ion streams. A focus plate is biased such that the first ion stream is directed to an analyzer which calculates the partial pressure of the gas. An ion collector collects the ions from the second ion stream, where the resulting reference current is used to determine the total pressure of the gas.

APPARATUS FOR MEASURING TOTAL PRESSURE AND PARTIAL PRESSURE WITH COMMON ELECTRON BEAM

FIELD OF THE INVENTION

This invention pertains to the field of ionizing gas samples for mass
spectrometers, and in particular to using one electron beam traversing two ionization
regions to provide separate streams of ions for independently measuring both total
pressure and partial pressure of the gas sample.

BACKGROUND OF THE INVENTION

Many scientific instruments, such as mass spectrometers, require generation of
ions so that the ions may be accelerated or otherwise input into the instrument for
sample identification, measurement, and other purposes. For a quadrupole residual
gas analyzer, it is desirable to indicate the ionization current as a total pressure
measurement, in addition to filtering the ion current to indicate specific ion species.

A conventional ion source includes a filament acting as an electron emitter, an
ion volume containing rarified gas, and an ion accelerator. Electrons from the
filament enter the ion volume through an opening in an ionization chamber
surrounding the ion volume to ionize gas molecules within the ion volume. The ion
accelerator draws the resulting ions out of the ion volume and focuses them into a
beam of ions suitable for injection into the quadrupole filter or other mass analysis
instrument.

When using such a device, it is usually desirable to have an accurate
measurement of the ion stream or ion current being supplied to the quadrupole mass
filter or other instrument. One conventional method for measuring ion current is
typically to measure an ion current at the ion accelerator, since a portion of the ion
stream impacts on the ion accelerator. However, this method has several drawbacks.
The principal drawback is a change in ion fraction impacting acceleration as the mass
range is scanned. For example, the ion accelerator often has electrical leakage. The
measurement may also be affected by stray currents from the ionization process.

Another conventional method is to place an ion collector in the path of the ion
stream. However, this method has the drawback of interfering with the ion stream.

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In addition, in both of the above methods, and in others where only a fraction of the ion stream is measured, it is difficult to judge the exact useable ion current by measuring the "test" fraction, because as the intensity of the total ion stream varies, the ratio between the "utilizable" portion of the ion stream and the "test" portion

5   striking the measurement collector may vary in unknown ways.

SUMMARY OF THE INVENTION

Briefly stated, an apparatus for determining both total and partial pressures of a gas using one common electron beam includes a partial pressure ionization region and a total pressure ionization region separated by a grid or aperture. A filament

10   produces a plurality of electrons which are focused into an electron beam by a repeller and an anode. The interaction between the electron beam and molecules of said gas within the partial pressure and total pressure regions produces first and second ion streams. A focus plate is biased such that the first ion stream is directed to an analyzer which calculates the partial pressure of the gas. An ion collector collects the

15   ions from the second ion stream, where the resulting reference current is used to determine the total pressure of the gas.

According to an embodiment of the invention, an apparatus for determining a total pressure of a gas includes an ionization chamber; the ionization chamber having first and second ionization regions, wherein a boundary between the regions is defined

20   by an anode grid or aperture; means for producing an electron beam passing through the first and second ionization regions, whereby an interaction between the electron beam and molecules of the gas within the ionization chamber produce first and second ion streams from a same gas density; means for directing the first ion stream to an analyzer; and means for directing the second ion stream to an ion collector.

25   According to an embodiment of the invention, an apparatus for determining a total pressure of a gas includes an ionization chamber; the ionization chamber having first and second ionization regions, wherein a boundary between the regions is defined by an anode grid or aperture; a filament for producing a plurality of electrons; a repeller; the repeller and anode operatively associated to focus the plurality of

30   electrons into an electron beam passing through the first and second ionization regions, whereby an interaction between the electron beam and molecules of the gas

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within the ionization chamber produce first and second ion streams from a same gas

density; a focus plate biased such that the first ion stream is directed to an analyzer,

wherein the analyzer includes means for calculating at least one partial pressure of the

gas within the ionization chamber; an ion collector biased such that the second ion

5   stream is directed to an ion collector; means for measuring a reference current

produced by the second ion stream at the ion collector; and means, using the reference

current, for calculating the total pressure of the gas within the ionization chamber.

According to an embodiment of the invention, a method for determining a

total pressure of a gas includes (a) providing an ionization chamber, the ionization

10   chamber having first and second ionization regions, wherein a boundary between the

regions is defined by an anode grid or aperture; (b) producing an electron beam

passing through the first and second ionization regions, whereby an interaction

between the electron beam and molecules of the gas within the ionization chamber

produce first and second ion streams from a same gas density; (c) directing the first

15   ion stream to an analyzer; and (d) directing the second ion stream to an ion collector.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a partial cross-sectional view of an embodiment of the present

invention.

Fig. 2 shows a side view of a portion of the embodiment of Fig. 1.

20   Fig. 3 shows a partial cross-sectional view of an embodiment of the present

invention.

Fig. 4 shows an ion optics plot of electron and ion trajectories according to the

embodiment of Fig. 3.

Fig. 5 shows a total pressure current and Ar-40 ion current as a function of Ar

25   pressure as measured by the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to Figs. 1-2, an electron beam 10 is emitted from a filament 12. The

electrons in electron beam 10 are focused by a three-sided repeller 14 which is

mounted such that a center of filament 12 is at the center of diagonals drawn from the

30   corners of repeller 14. Repeller 14 is connected to the negative side of filament 12,

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thus making repeller 14 more negative than the potential of emitted electrons by an amount equal to the filament voltage with respect to the negative lead at the point the electron is emitted. This is approximately one-half the voltage across the filament (~1.5 V).

5   The electrons in electron beam 10 are drawn to an anode 16 by a voltage that is positive with respect to filament 12. Anode 16 is preferably biased at 70 V. Anode 16 separates a first region 20 from a second region 22. Electron beam 10 forms ions in both the first and second regions 20, 22. A plurality of ions 30 from first region 20 are extracted by a focus plate 24 and directed to a mass analysis device, where they
10   form ion currents proportional to pressures of gas components in region 20. A plurality of ions 32 from second region 22 are collected by an ion collection device, such as a collector plate 26, to produce a current proportional to the total pressure of gas components in second region 22.

The electrons in electron beam 10 continue through first and second regions
15   20, 22 and impact on a beam stop 28. Anode 16 and beam stop 28 together function as an anode for electron beam 10, resulting in the acceleration of electrons in electron beam 10 being perpendicular to the equipotential lines established by the structure, thus resulting in a focused beam.

Referring to Fig. 3, an embodiment of the invention includes a square anode
20   16' that more efficiently draws electrons from filament 12 through a flat grid 18 on an entrance side of anode 16'. The higher efficiency for electrons in the anode 16' region results in increased ion formation in first and second regions 20, 22.

Referring to Fig. 4, an ion optics plot of electron and ion trajectories is shown. The accelerations of the electrons are perpendicular to the equipotential lines 34
25   established by the structure which results in a focused beam. Ions formed in the partial pressure ionization region (first region 20) by electron beam 10 are drawn toward focus plate 24 and form the stream of ions 30 for separation by a mass analyzer (not shown). Ions 32 formed in the total pressure ionization region (second region 22) by the continuation of electron beam 10 are collected by total pressure
30   collector plate 26.

Referring to Fig. 5, the total pressure ion current and mass analyzed ion current produced with 1000 uA of electron emission are shown for a wide range of Ar gas

pressure. The total pressure ion current responds linearly with pressure over the range. The Mass 40 ion current responds linearly to Ar pressure up to 2 E-5 Torr. At higher pressures the ion current is attenuated from the expected ion current due to gas scattering by a factor $\exp[-k\,P]$ where k is a constant and P is the process pressure.

5   While the present invention has been described with reference to a particular preferred embodiment and the accompanying drawings, it will be understood by those skilled in the art that the invention is not limited to the preferred embodiment and that various modifications and the like could be made thereto without departing from the scope of the invention as defined in the following claims.

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What is claimed is:

1   1. An apparatus for determining a total pressure of a gas, comprising:

2   an ionization chamber;

3   said ionization chamber having first and second ionization regions, wherein a

4   boundary between said regions is defined by one of an aperture and an anode grid;

5   means for producing an electron beam passing through said first and second

6   ionization regions, whereby an interaction between said electron beam and molecules

7   of said gas within said ionization chamber produce first and second ion streams from

8   a same gas density;

9   means for directing said first ion stream to an analyzer; and

10   means for directing said second ion stream to an ion collector.

1   2. An apparatus according to claim 1, further comprising:

2   means for collecting said second ion stream at said ion collector;

3   means for measuring a reference current produced by said second ion stream at

4   said ion collector; and

5   means, using said reference current, for calculating said total pressure of said

6   gas within said ionization chamber.

1   3. An apparatus according to claim 2, wherein said analyzer includes means for

2   calculating at least one partial pressure of said gas within said ionization chamber.

1   4. An apparatus according to claim 3, further comprising an electron beam stop

2   which collects substantially all electrons not interacting with said gas molecules.

1   5. An apparatus according to claim 4, wherein said means for producing an electron

2   beam comprises:

3   emission means for emitting a plurality of electrons; and

4   focusing means for focusing said plurality of electrons into said electron beam.

1   6. An apparatus according to claim 1, wherein said means for producing an electron

2   beam comprises:

3   emission means for emitting a plurality of electrons; and

4   focusing means for focusing said plurality of electrons into said electron beam.

1   7. An apparatus according to claim 6, wherein said focusing means includes a

2   repeller having three sides and an opening for said electron beam to pass through.

1   8. An apparatus according to claim 1, wherein said anode grid has a rectangular

2   cross-section.

        9. An apparatus according to claim 8, wherein said anode grid includes a flat portion

        that is oriented perpendicular to said electron beam.

1   10. An apparatus according to claim 1, wherein said electron beam passes through

2   said first ionization region before said electron beam passes through said second

3   ionization region.

1   11. An apparatus according to claim 1, wherein said electron beam passes through

2   said second ionization region before said electron beam passes through said first

3   ionization region.

1   12. An apparatus for determining a total pressure of a gas, comprising:

2   an ionization chamber;

3   said ionization chamber having first and second ionization regions, wherein a

4   boundary between said regions is defined by one of an aperture and an anode grid;

5   a filament for producing a plurality of electrons;

6   a repeller;

7   said repeller and anode operatively associated to focus said plurality of

8   electrons into an electron beam passing through said first and second ionization

9   regions, whereby an interaction between said electron beam and molecules of said gas

10   within said ionization chamber produce first and second ion streams from a same gas

11   density;

12   a focus plate biased such that said first ion stream is directed to an analyzer,

13   wherein said analyzer includes means for calculating at least one partial pressure of

14   said gas within said ionization chamber;

15   an ion collector biased such that said second ion stream is directed to an ion

16   collector;

17   means for measuring a reference current produced by said second ion stream at

18   said ion collector; and

19   means, using said reference current, for calculating said total pressure of said

20   gas within said ionization chamber.

1   13. An apparatus according to claim 12, wherein said anode grid has a rectangular

2   cross-section.

      14. An apparatus according to claim 13, wherein said anode grid includes a flat

      portion that is oriented perpendicular to said electron beam.

1   15. A method for determining a total pressure of a gas, comprising the steps of:

2   providing an ionization chamber, said ionization chamber having first and

3   second ionization regions, wherein a boundary between said regions is defined by one

4   of an aperture and an anode grid;

5   producing an electron beam passing through said first and second ionization

6   regions, whereby an interaction between said electron beam and molecules of said gas

7   within said ionization chamber produce first and second ion streams from a same gas

8   density;

9   directing said first ion stream to an analyzer; and

10   directing said second ion stream to an ion collector.

1   16. A method according to claim 15, further comprising the steps of:

2   collecting said second ion stream at said ion collector;

3   measuring a reference current produced by said second ion stream at said ion

4   collector; and

5   calculating, using said reference current, said total pressure of said gas within
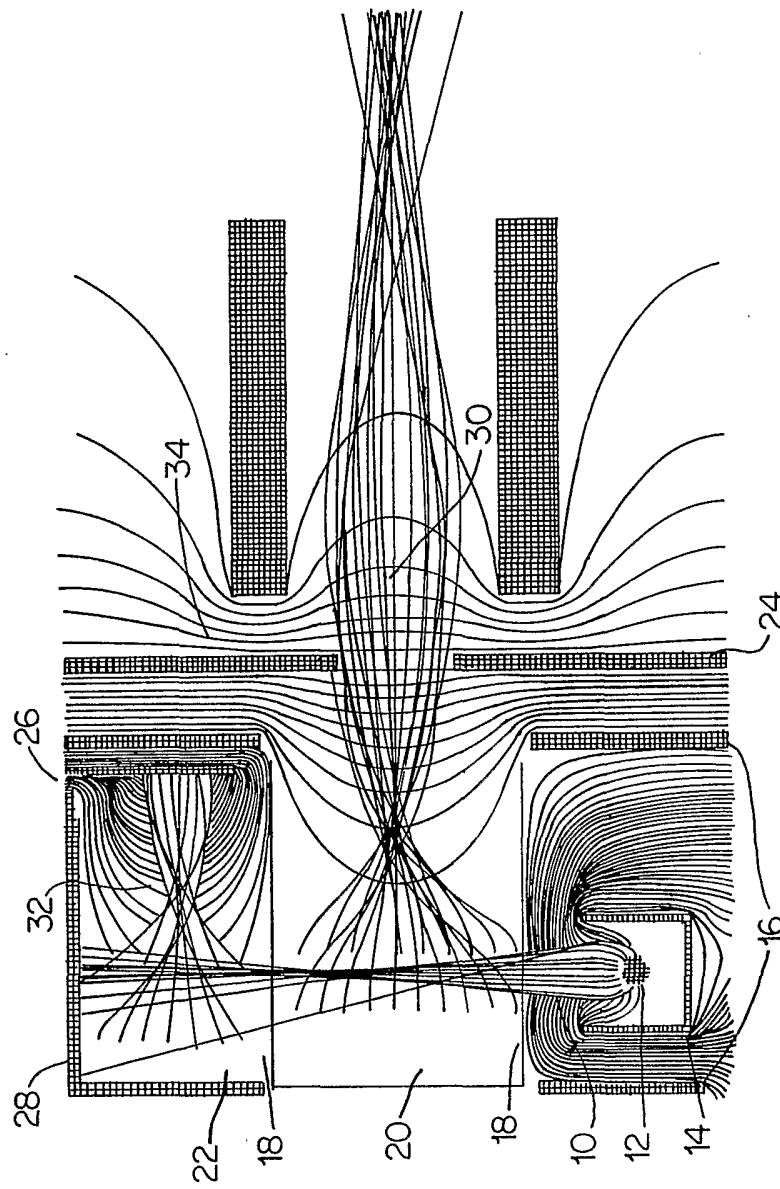
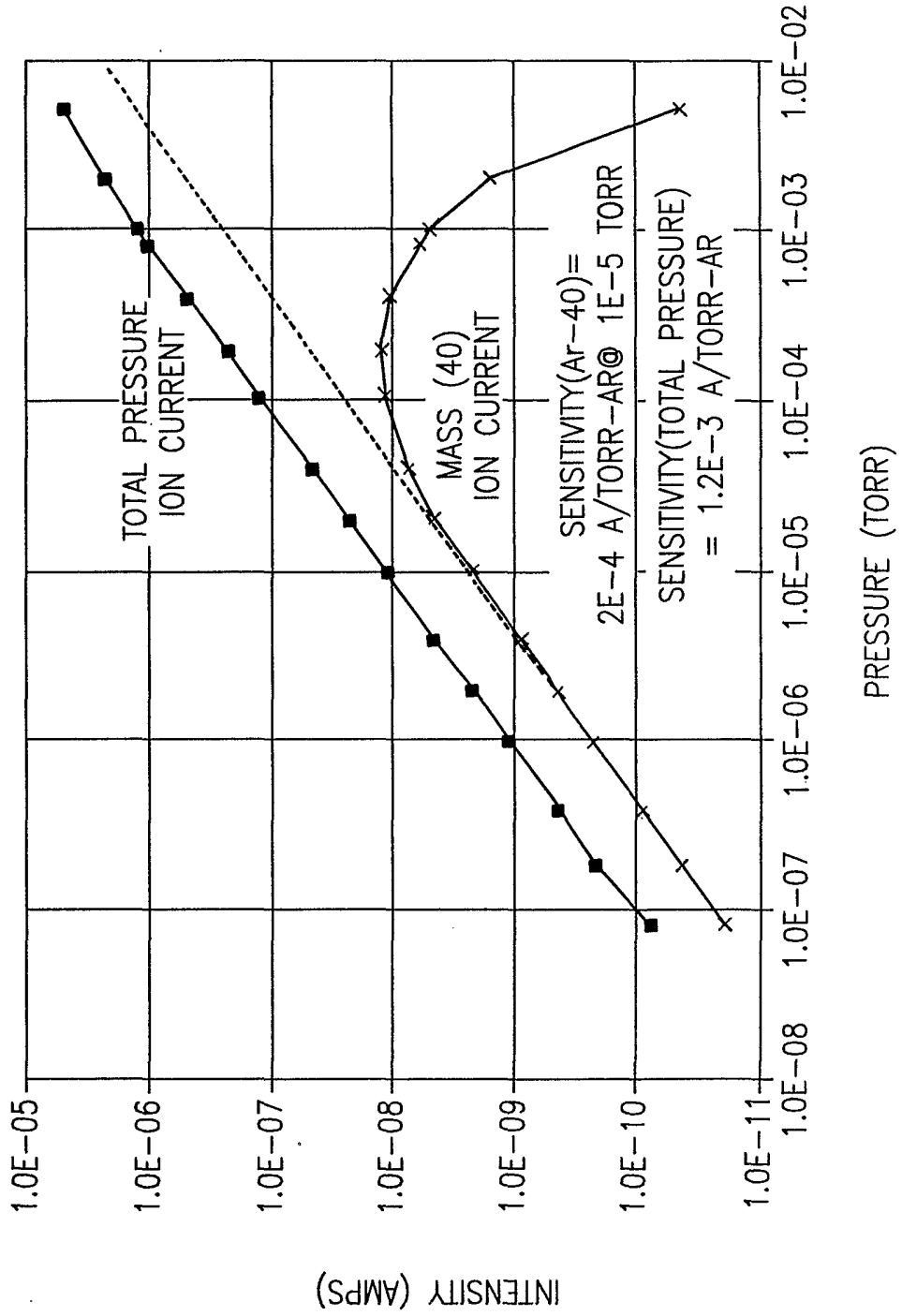6   said ionization chamber.

FIG.1

FIG.2

FIG.3
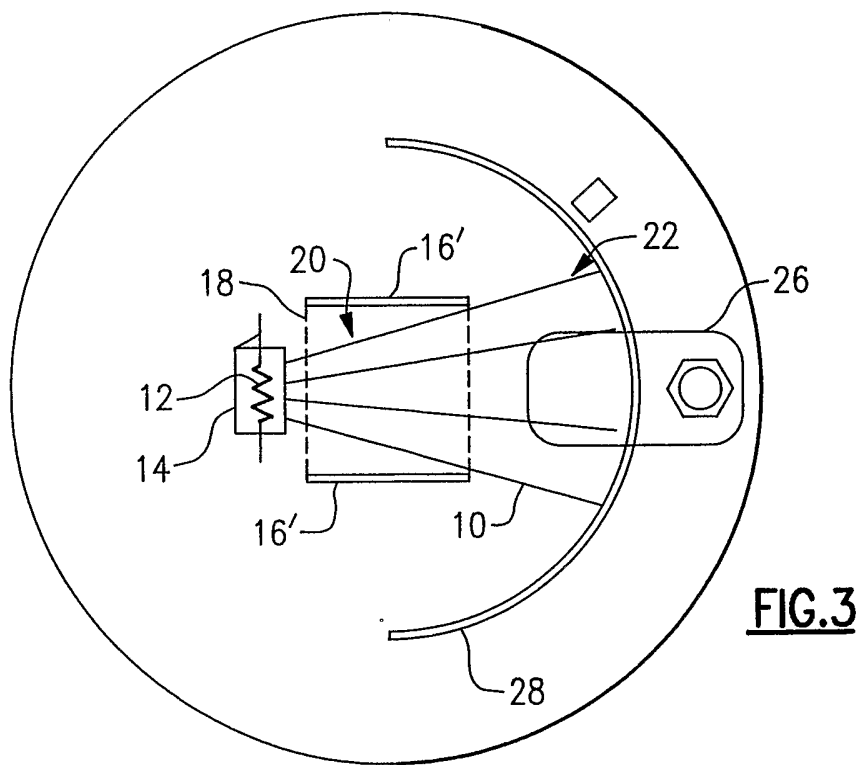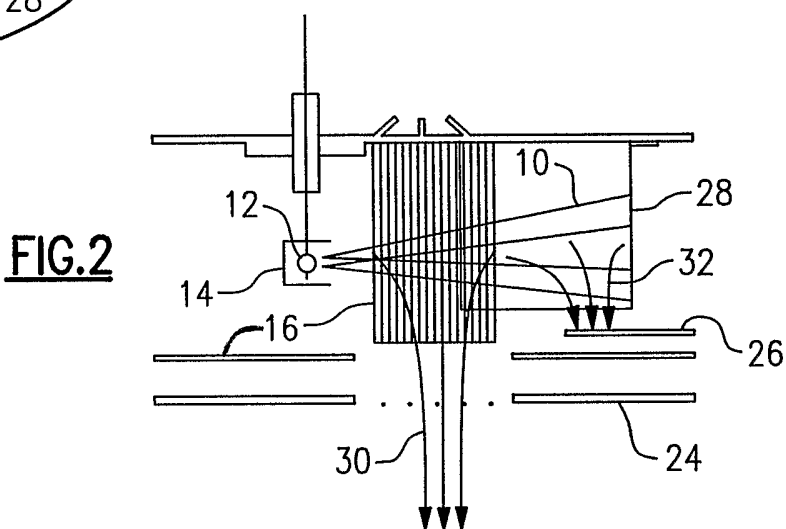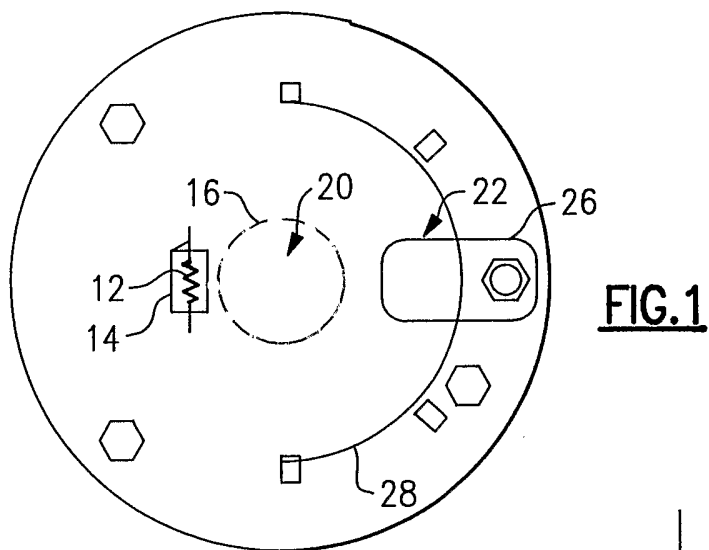
FIG.4

FIG.5

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   H01J41/04   H01J49/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7   H01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 889 281 A (ELLEFSON ROBERT E ET AL) 30 March 1999 (1999-03-30) claim 1	1

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
10 April 2003	23/04/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Hulne, S

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 5889281	A	30-03-1999	GB	2323469 A ,B	23-09-1998
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