Feb. 28, 1950 J. G. BACKUS 2,499,288

VACUUM ANALYZER

Filed July 2, 1947 2 Sheets-Sheet 1

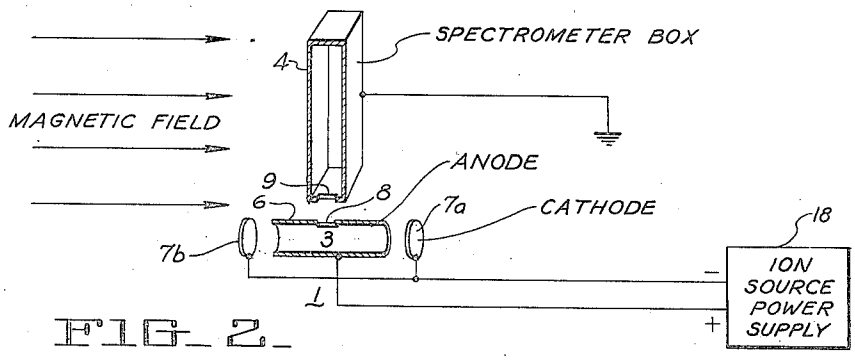

FIG. 2.

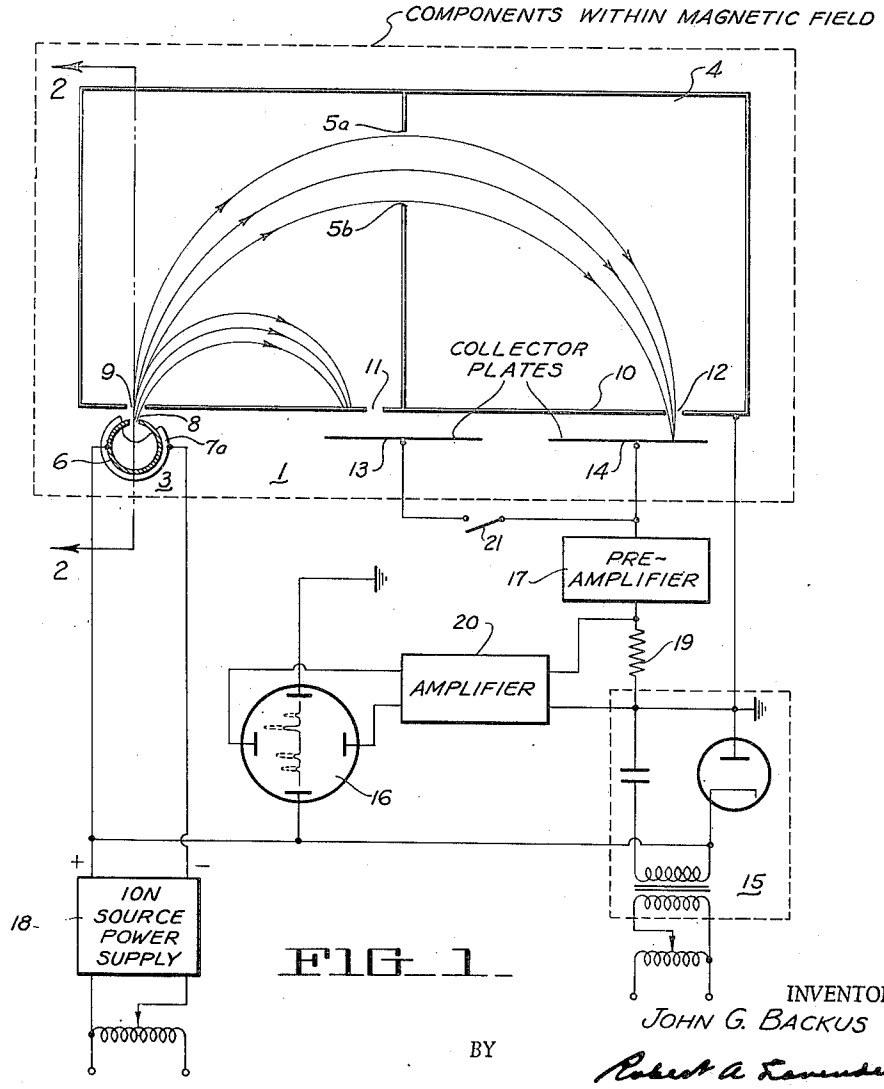

FIG. 1.

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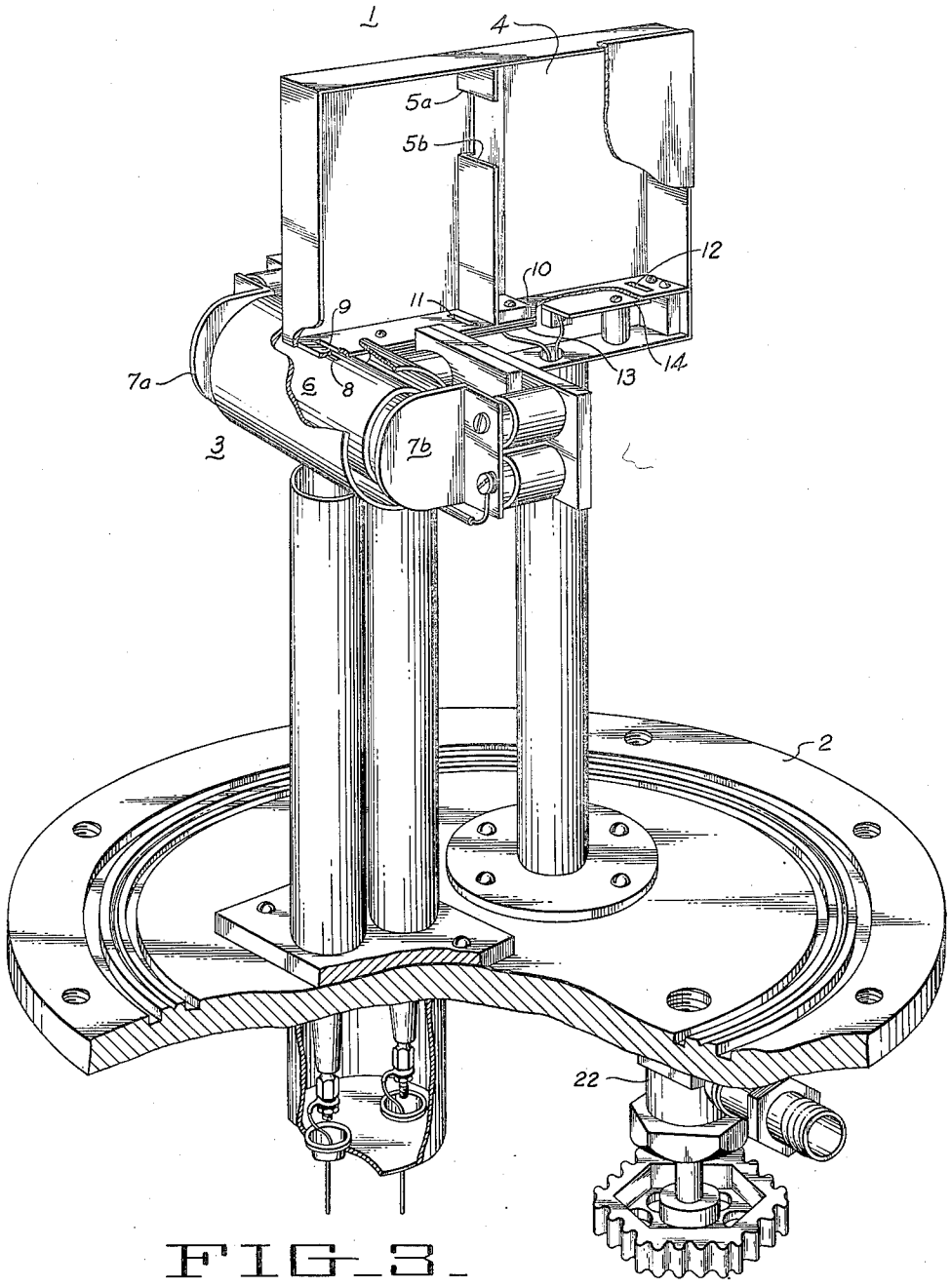

FIG. 3.

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VACUUM ANALYZER

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3 Claims. (Cl. 250—41.9)

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This invention relates to a vacuum analyzer adapted for detecting gas leaks in a highly evacuated vessel and for analyzing the gases present in said vessel as to their type and their relative concentrations within said vessel, and more particularly to a vacuum analyzer having an improved ion generating source.

In vacuum systems such as the tank portion of the calutron, information relative to the qualitative composition of the residual gases present is of great importance in order that ultimate vacuums can be quickly and efficiently obtained. By use of the vacuum analyzer progress of the bake-out processes and information on other outgassing phenomena can be simultaneously monitored.

In order to properly analyze the gases present in a vessel undergoing evacuation it is necessary for the analyzer ion source to be capable of operating over a wide range of gas pressures. Difficulty has been experienced with conventional ion sources in this respect, particularly at low pressures wherein they are incapable of producing a sufficient supply of ions and of providing an ion beam having sufficient homogeneity of energy to insure proper resolution of the beam. This invention includes an improved ion generating source which when used in a vacuum analyzer is capable of detecting one part of helium to 50 000 parts of air at pressures as low as 1×10^{-4} mm. of mercury contrasted to a sensitivity of one part of helium to 5,000 parts of air at the same pressure when using a conventional type of ion generating source.

A vacuum analyzer having an ion source slit together with a single slit positioned on the longitudinal baffle plate opposite an ion collector plate will portray for a given nominal ion accelerating voltage, indications of only such ions having comparable mass.

Let us now consider a vacuum analyzer having an ion source slit together with two slits in the longitudinal baffle plate spaced successively apart from the ion source slit. Then for a nominal ion accelerating voltage, ions of greater mass traverse longer arcuate paths than do ions of a lesser mass. Consequently in order to admit ions having the lesser mass to a collector plate, a slit in the longitudinal baffle plate must be located nearest the ion source slit. Conversely, in order to admit ions having the greater mass to a collector plate, a slit in the longitudinal baffle plate must be located further from the ion source slit than in the case for ions having lesser mass.

By incorporating a multiple slit baffle plate the

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usefulness of the device as a vacuum analyzer is extended to include for a given nominal accelerating voltage the indication of ions of a wide range of masses.

It is therefore an object of this invention to provide a vacuum analyzer whereby various gases present in a highly evacuated vessel can be detected and the relative concentrations of said gases indicated.

A further object of this invention is to provide an improved ion generating source capable of generating from the gas molecules present in a vessel evacuated to extremely low pressure, a sufficiently abundant supply of ions to produce satisfactory ion beams for use in the vacuum analyzer.

A further object of this invention is to provide means for portraying on the screen of a cathode ray oscilloscope evidences of the relative mass and concentrations of ions of gases present in a highly evacuated vessel, said ions varying widely in relative mass over a range of approximately 1 to 50.

A further object of this invention is to provide selective means of portraying on the screen of a cathode ray oscilloscope evidences of ions having relatively low mass, together concurrently with ions of relatively higher mass; or, of ions of relatively higher mass singularly.

A further object of the invention is to provide electrical circuits necessary to complete the overall operation of the device as a vacuum analyzer comprising an ion source voltage supply, an ion accelerator voltage supply, a pre-amplifier, an amplifier, and a cathode-ray tube.

Other objects and advantages of the invention will be apparent from the following description and claims considered together with the accompanying drawings in which:

Figure 1 is a block diagram of the functional elements comprising this invention.

Fig. 2 is a partial schematic representation of certain elements of the mass spectrometer as indicated by section line 2—2 of Fig. 1 showing the direction of the electromagnetic field, the ion source, and the spectrometer box.

Fig. 3 is a perspective view, partly in section of the mass spectrometer, together with an ion generator, mounted on a face plate.

Referring to Figs. 1 and 3, my improved vacuum analyzer generally indicated at 1 is suitably mounted on a face plate 2, the latter being positioned on the wall of a vessel whose vacuum analysis is desired such as a calutron tank and thereby projecting the vacuum analyzer 1 into the interior of the vessel, and hermetically seal-

ing the wall thereof. Further, face plate 2 has a gas valve 22 mounted thereon for test purposes. The vacuum analyzer 1 comprises essentially the following, all being within the vessel: an electron oscillator type of ion source 3, an ion beam chamber 4, and ion current collector plates 13 and 14.

Referring now to Fig. 2, the vacuum analyzer 1 is positioned in a substantially uniform magnetic field denoted by the arrows, which is parallel to the longitudinal axis of the ion source 3 and normal to the large face of the spectrometer box 4. The ion source 3 consists of an anode cylinder 6 having a pair of electrically connected cathode plates 7a and 7b spaced from the open ends of the anode cylinder 6.

Referring again to Figs. 1 and 3, a slit 8 is provided in the wall of anode cylinder 6 through which ions may be withdrawn and projected into the box 4 through an accelerating slit 9. There is also provided in the box 4 a longitudinal baffle 10 provided with slots 11 and 12 through which the ion beams may pass and be collected by collector plates 13 and 14 respectively. Moreover, a pair of beam-defining vanes 5a and 5b are positioned along the 90° radius of the ion beam of greater mass and are so spaced as to trim the beam to an angular divergence of ±10°.

Considering now the electrical connections, the cathode plates 7a and 7b, and the anode 6 are respectively connected to the negative and positive terminals of a high voltage ion source power supply 18 of the order of 2000 volts. Further, the anode 6 and the chamber 4 are respectively connected to the terminals of a sinusoidally varying high voltage accelerator supply 15 which varies from zero to a few thousand volts, the output of the voltage supply 15 being also applied to the horizontal plates of an oscilloscope 16. Considering the manner of operation of rectifier 15 it becomes apparent that after a few cycles the condenser becomes charged to a positive D. C. potential nominally equal to the secondary voltage of the transformer. The condenser once charged remains substantially at a D. C. potential due to the R. C. circuit having a comparatively long time constant by virtue of the large load resistance. Consequently, on negative peaks of secondary A. C. voltage, the voltage developed in the secondary winding of the transformer will be opposed by the equal voltage of the condenser, the resultant output voltage at such instants being zero: further, on positive peaks of secondary A. C. voltage, the voltage developed in the secondary winding of the transformer will be additive to the equal voltage of the condenser, the resultant voltage output at such instants being double the A. C. peak value and positive in polarity. Interpolation by this analysis indicates the output voltage to be sinusoidal and ranging from zero to a positive potential substantially twice the peak A. C. voltage of the secondary.

Collector plates 13 and 14 are connected as shown (Fig. 1) to a terminal strip in the preamplifier stage 17. Provision is made in said stage 17, whereby the input thereto can be electrically connected by means of a switch 21 to collector plate 13 in addition to its connection to collector plate 14. The output of the preamplifier stage 17 is connected to ground through a resistor 19, the voltage drop across resistor 19 being amplified by the amplifier 20 and applied to the vertical deflection plates of the oscilloscope 16.

In operation, the vacuum analyzer is mounted in the vessel to be tested and the gas in the anode cylinder 6 is of substantially the same composition and concentration as the gas in the vessel. When voltage from 18 is applied to the electrodes 7a, 7b and 6 of the ion source 3, electrons will oscillate between the cathodes 7a and 7b through the cavity in the anode cylinder 6 breaking up and ionizing the gases in the cavity, the kind of ion formed being dependent on the gases present, their quantity being dependent on the gas pressure. The ions are withdrawn through slit 9 into box 4 by the accelerating voltage impressed between the box 4 and the anode 6. The varying accelerating voltage results in the different ion beams sweeping across slots 11 and 12 and impinging on the respective collector plates 13 and 14 causing voltages to be impressed on the vertical plates of the oscilloscope 16 proportional to the current density of the particular ion beam. Moreover, the ions traverse circular paths, the radii depending on the impressed accelerating voltage, the mass and charge of the individual ions, and the magnetic field, in accordance with the formula:

$$\frac{m}{e}=\frac{r^2H^2}{2V} \quad \text{or} \quad r=\frac{1}{H}\sqrt{\frac{2mV}{e}}$$

Where:

H = strength of the magnetic field in gausses;
V = the accelerating voltage in practical volts to which the ions are subjected;
r = the radius of curvature in inches of the paths along which the ions are projected;

and

$\frac{m}{e}$ = the mass-to-charge ratio of the positive ions projected along arcuate paths and passing transversely through magnetic field H.

The ion egress slots 11 and 12 in the baffle surface 10 have been spaced from the ion source slot 9 so that for a given accelerating voltage V and a given magnetic field H, ions of mass two and ten on the scale of $O^+=16$ will pass through their respective ion egress slots, whereby the ration of their radii of curvature becomes

$$1/\sqrt{5}$$

This arrangement precludes ambiguity in differentiating between the H_2^+ ion and the H_2O^+ ion which otherwise would occur were the slots 11 and 12 positioned in accordance with ion masses two and eighteen. More particularly, slots 11 and 12 are so spaced from slot 9 that when an ion beam passes through slot 11 no ion beam passes through slot 12, thus avoiding overlapping peaks on the oscilloscope 16. Inasmuch as the oscilloscope sweep is controlled by the accelerating voltage, the oscilloscope trace is an indication of the various ion densities, the abscissa identifying the individual ion beam and the ordinate the density thereof, the former being an indication of the gases present and the latter the concentrations thereof.

Thus, after the system has been practically degassed, the presence of a high HO^+ peak is an indication of water vapor pointing to a water leak while a high N^+ peak would indicate an air leak. By directing a stream of hydrogen at a suspected surface region of the vessel a rise in the H^+ peak would indicate a leak in this region.

Although this invention has been described with reference to a particular embodiment thereof, it is not limited to this embodiment nor otherwise except by the terms of the following claims.

What is claimed is:

1. In a mass spectrometer an ion generating

source comprising a pair of spaced cathodes having a gaseous region therebetween, an apertured tubular anode axially aligned with, spaced from, and intermediate said cathodes, said anode being positioned within the magnetic field of said spectrometer and axially aligned therewith.

2. A vacuum analyzer comprising a mass spectrometer having an ion source, a spectrometer box, and a receiver, said ion source comprising a tubular apertured anode disposed in and parallel to the magnetic field of said mass spectrometer and a pair of cathodes disposed adjacent the ends of said anode, said spectrometer box being positioned adjacent said ion source and having an ion access slot formed therein, and being further provided with at least two ion egress slots, said receiver being disposed exterior to said spectrometer box and adjacent said ion egress slots, and electrical elements cooperatively associated with said mass spectrometer providing a visual indication of the kind and amount of ions formed at said ion source and received at said receiver.

3. A vacuum analyzer comprising a 180 degree mass spectrometer having an ion source, an ion

receiver, and an ion beam therebetween, means supplying a sweep voltage to said mass spectrometer whereby the trajectory of said ion beam is varied, and an ion baffle plate interposed between said receiver and said ion beam situated on the diameter of said ion beam path and having two ion egress apertures formed therein, the ratio of distances from said ion source to said apertures being substantially

$$1/\sqrt{5}$$

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