Nov. 27, 1956 C. E. BERRY 2,772,366

MASS SPECTROMETRY

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FIG. 1.

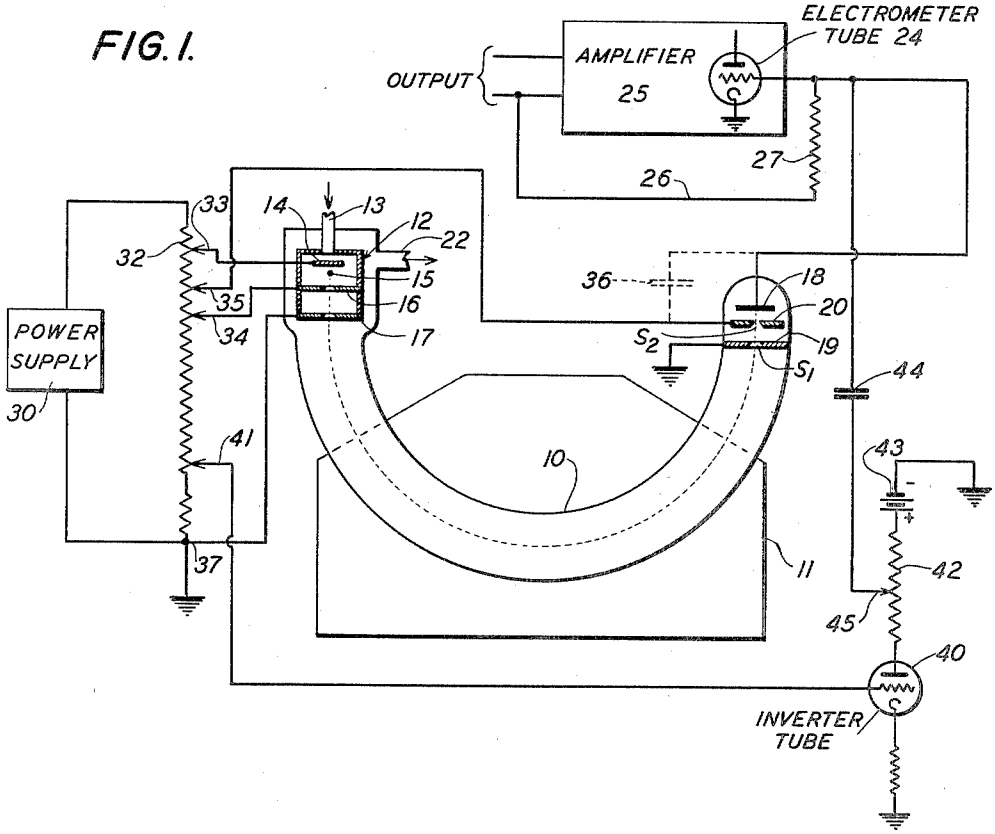
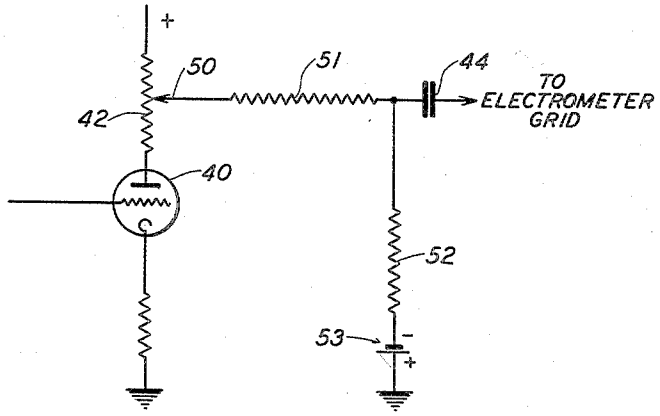


FIG. 2.



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MASS SPECTROMETRY

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6 Claims. (Cl. 250—41.9)

This invention relates to mass spectrometry and particularly to a neutralizing circuit for a mass spectrometer.

In recent years it has been the practice in mass spectrometry to employ a so-called metastable suppressor electrode intermediate the mass spectrometer resolving slit and collector electrode. Conventionally, such a metastable suppressor electrode has been maintained at a potential intermediate the potential of the ion source repeller electrode and the terminal accelerating electrode so as to prevent access to the collector electrode of metastable ions.

It has been known for some time that stray capacitance between such a metastable suppressor electrode and the ion collector couples variations in the ion accelerating voltage into the output amplifier of a mass spectrometer. Previous attempts to reduce the effect of this coupling have not met with any degree of success. With the present tendency toward higher scanning speeds, the effect has become much more significant and must be eliminated.

The invention comprises a neutralizing circuit for neutralizing stray capacitance between the collector electrode of a mass spectrometer and any electrode in capacitive relation with the collector electrode and on which the potential varies. The circuit in accordance with the invention comprises a capacitor connected between the collector electrode and the accelerating voltage supply network through phase inverting means whereby there is introduced into the collector electrode circuit a voltage which is equal and opposite to that induced by capacitive coupling between the collector electrode and the metastable suppressor. Since the injected voltage is derived from the same source as the potential supplied to the metastable suppressor, it will vary in magnitude proportionately to that potential as does the unwanted voltage induced through the coupling.

The invention will be clearly understood from the following detailed description thereof taken in conjunction with the accompanying drawing in which:

Fig. 1 is a schematic diagram of a mass spectrometer showing a neutralizing circuit in accordance with the invention associated therewith; and

Fig. 2 is a circuit diagram of a modification of the neutralizing circuit shown in Fig. 1.

The mass spectrometer shown in Fig. 1 comprises an analyzer tube 10 immersed in a magnetic field produced by a magnet pole 11 and an oppositely disposed magnet pole (not shown). An ion source 12 is housed within one end of the analyzer tube 10 and includes a sample inlet conduit 13, a repeller electrode 14, an ionizing electron beam 15 developed by an electron gun (not shown), and first and second accelerating electrodes 16, 17. A collector electrode 18 is disposed in the opposite end of the analyzer tube 10 and on which ions passing through the analyzer tube are focused through a resolving slit S_1 in a barrier electrode 19. A metastable suppressor electrode 20 having an ion slit S_2 is disposed intermediate the barrier electrode 19 and the collector electrode 18.

An exhaust conduit 22 connects the analyzer tube with an evacuating system (not shown).

The collector electrode 18 is connected to the grid of an electrometer tube 24 forming the first stage of an amplification system 25 which conventionally includes a feedback loop 26 connected through grid leak resistor 27 of the electrometer tube 24.

A power supply 30 is connected across a voltage divider 32 to which the repeller electrode 14 and accelerating electrodes 16, 17 of the ion source are connected at 33, 34, 37 respectively. The metastable suppressor electrode 20 is connected to the voltage divider 32 at 35, and in the particular embodiment illustrated is maintained at a potential intermediate that of the ion source repeller electrode 14 and the first accelerating electrode 16.

To this extent the illustrated mass spectrometer is conventional. It is immediately apparent that the potential on the metastable suppressor electrode 20 varies with any variation in the ion accelerating voltage, and the effect of this variation is evidenced schematically by the capacitor 36 coupled between the metastable suppressor electrode 20 and the collector electrode 18. Any variation in potential on the metastable suppressor produces a spurious transient signal in the output of the collector electrode 18 as a consequence of the capacitive coupling represented by the capacitor 36.

The illustrated neutralizing circuit in accordance with the invention comprises an inverter tube 40, the grid of which is connected at 41 to the voltage divider 32 so that the potential on the grid varies in proportion to any potential change across the divider 32. The plate of the inverter tube 40 is connected through a plate load resistor 42 and a battery 43 to ground. A capacitor 44 is connected between the plate load resistor 42 of the inverter tube at adjustable tap 45 and the grid of the electrometer tube 24.

The apparatus of Fig. 1 operates as follows: A sample entering the ion chamber 12 through the inlet conduit 13 is ionized under the influence of electron beam 14 and the resultant ions are accelerated into the analyzer chamber 10 under the influence of the potentials established between electrodes 14, 16 and 17 of the ion source. As is well known, ions of a particular mass may be focused on the resolving slit S_1 of the barrier electrode 19 by adjustment of the potentials applied to the accelerating electrodes to strike and discharge at the collector electrode 18. The potential on the metastable electrode is such as to prevent metastable ions from gaining access to the collector electrode in a manner familiar in the art.

The adjustable tap 45 on the plate load resistor 42 of the inverter tube 40 allows complete compensation to be obtained for the capacitive coupling between the metastable suppressor electrode and the collector electrode 18, as exemplified by the capacitor 36. This is accomplished simply by switching the accelerating voltage back and forth between two values and adjusting the tap 45 until a minimum transient appears on the output of the amplifier 25.

Although the required phase inversion means in the illustrated circuit constitutes a triode, any other phase inversion circuiting may be employed. For example, transistors find use in such application.

Tests of the neutralizing circuit show that it performs satisfactorily. Without this circuit, and at a given scanning speed, the amplifier zero was depressed about 7% of full scale for the particular recording system used immediately following the start of the scan. With the neutralizing circiut as illustrated adjusted properly, no discernible depression in the amplifier zero was observed. Likewise, when searching for peaks without the use of this circuit, a peak monitor meter fluctuated every time

the accelerating voltage was changed even slowly, making it extremely difficult to locate small peaks. With the neutralizing circuit in use, normal rates of change of the accelerating voltage produced no noticeable deflection of a peak monitor meter.

The circuit of Fig. 1 places approximately 200 volts across the coupling capacitor 44, which capacitor normally has a value of approximately 1 μf. Accordingly, the leakage requirements of this capacitor must be extremely stringent to prevent leakage of any appreciable voltage to the grid of the electrometer tube 24. Fig. 2 is a circuit diagram of a modification of a portion of the neutralizer circuit illustrated in Fig. 1 including the inverter tube 40, plate load resistor 42 and coupling capacitor 44. In this modified arrangement the plate load resistor 42 is tapped at 50 and is connected through a voltage divider network including resistors 51, 52 and a battery 53 to the coupling capacitor 44. The coupling capacitor is connected to the divider network at a point which is approximately ground potential, the battery 53 in effect balancing the potential of the plate load resistor 42 at the point at which it is tapped. This, in effect, reduces the static D. C. potential on the coupling capacitor 44 to effective zero with the only consequence of attenuating the signal developed by the inverter tube 40. However, since only a very small fraction of the signal available at the plate of the inverter tube is employed, the attenuation consequent upon the circuitry of Fig. 2 is of little importance.

The neutralizing circuit illustrated in Fig. 1 and as modified in Fig. 2 provides a system for reducing unavoidable coupling between a metastable suppressor electrode or any electrode on which the potential varies and the electrometer amplifier of a mass spectrometer provided the source of potential variation is available to the neutralizing circuit. Such coupling is of increasing importance because of the present trend toward higher scanning speeds.

I claim:

1. In a mass spectrometer including an accelerating voltage circuit, an ion collector, and an electrode disposed adjacent the ion collector and electrically connected to the accelerating voltage circuit, the combination comprising a capacitor connected to the ion collector, a phase inverter tube having an anode cathode and grid, means connecting the accelerating voltage circuit to the grid of the tube and means connecting the anode of the tube to the capacitor.

2. In a mass spectrometer including an accelerating voltage circuit, an ion collector, and an electrode disposed adjacent the ion collector and electrically connected to the accelerating voltage circuit, the combination comprising a capacitor means connecting the ion collector to one side of the capacitor, a phase inverter tube having an anode cathode and grid, means connecting the grid of the tube to the accelerating voltage circuit, an anode circuit including a resistor and a voltage source, and means connected to the other side of the capacitor and tapping the anode resistor.

3. In a mass spectrometer including an accelerating voltage circuit, an ion collector, and an electrode disposed adjacent the ion collector and electrically connected to the accelerating voltage circuit, a neutralizer circuit comprising a capacitor, means connecting the ion collector to one side of the capacitor, a phase inverter tube having an anode cathode and grid, means connecting the grid of the tube to the accelerating voltage circuit, an adjustable tap resistor connected to the anode of the tube, a voltage divider and a voltage source connected to the tap of the adjustable tap resistor and means connecting the other side of the capacitor to the voltage divider at a point thereon which is at approximately ground potential.

4. In a mass spectrometer including an accelerating voltage circuit, an ion collector, and an electrode disposed adjacent the ion collector and electrically connected to the accelerating voltage circuit, the combination comprising phase inverter means, means connecting the input of the phase inverter means to the accelerating voltage circuit, and a capacitor coupled between the output of the phase inverter means and the ion collector.

5. In a mass spectrometer including an accelerating voltage circuit, an ion collector, and an electrode disposed adjacent the ion collector and electrically connected to the accelerating voltage circuit, the combination comprising phase inverter means, means connecting the input of the phase inverter means to the accelerating voltage circuit, a capacitor connected to the ion collector, and means for applying a fraction of the output of the phase inverter means to the capacitor.

6. In a mass spectrometer including an accelerating voltage circuit, an ion collector, and an electrode disposed adjacent the ion collector and electrically connected to the accelerating voltage circuit, the combination comprising phase inverter means, means connecting the input of the phase inverter means to the accelerating voltage circuit, a capacitor couple between the output of the phase inverter means and the ion collector, and means for maintaining the output of the phase inverter means at substantially ground potential.

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