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APPARATUS FOR MEASURING GAS PRESSURES

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FIG. 1

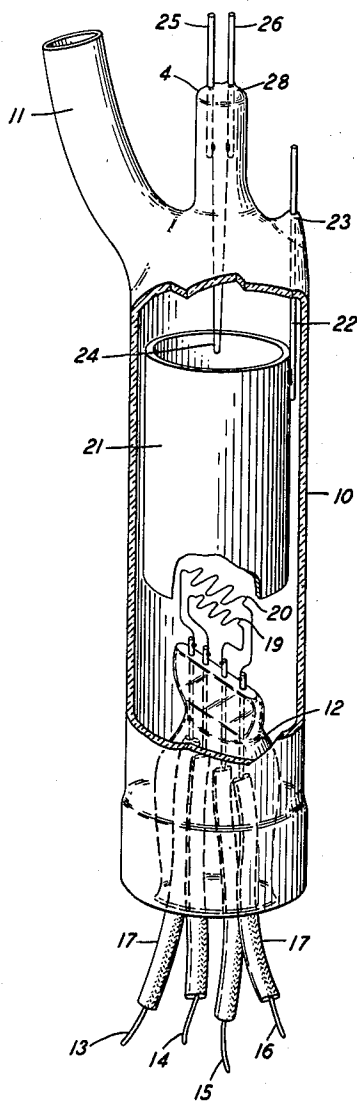


FIG. 2

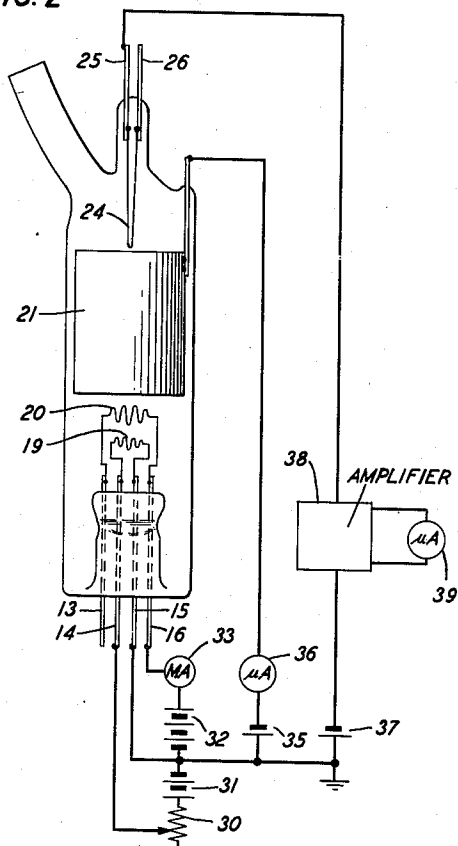
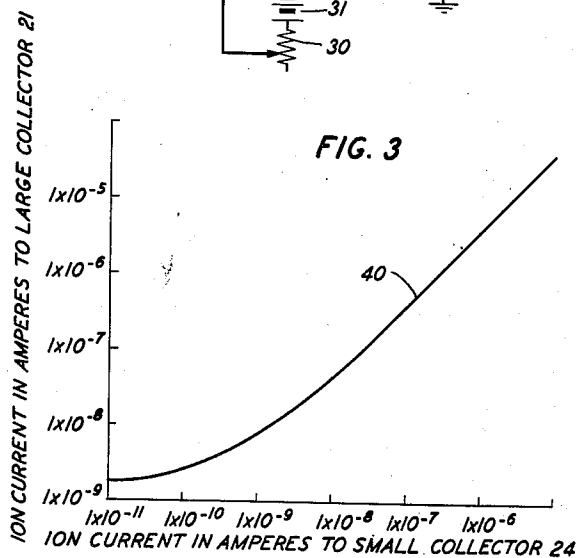


FIG. 3



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APPARATUS FOR MEASURING GAS PRESSURES

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11 Claims. (Cl. 175-183)

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This invention relates to apparatus for measuring gas pressures and, more particularly, to such apparatus comprising an ionization manometer.

Manometers of this type, which were generally described in Patent 1,372,798, issued March 29, 1921, to O. E. Buckley, indicate the pressure of the gas by determining the amount of ionization that takes place in a closed vessel when an electron current is passed through the vessel. Thus, the patent above referred to describes a manometer which comprises two electrodes, one of which is a cathode and a source of electrons to the other which acts as an anode or electron receiver. A third cold electrode is placed in the vessel adjacent the other electrodes and is maintained at a lower potential than either of these two electrodes so that no electron current will flow to or from it. However, positive ions will travel to this negatively charged electrode, and the amount of this ionic current will therefore be an indication of the gas pressure in the vessel, as the ionization, or the number of ionizing collisions, is dependent on the pressure of the gas for a given electron current.

This third electrode or positive ion collector has, in certain prior designs, such as shown in Patent 1,334,143, issued March 16, 1920, to S. Dushman, comprises a cylinder enclosing the electron emitter and electron receiver electrodes, the collector being positioned in the vicinity of the anode. While these prior manometers have been found to give reasonably accurate indications of gas pressure, they have a lower limit of gas pressure below which they cannot be used. This lower limit of pressure indications of prior ionization manometers is caused by the bombardment of the ion collector by soft X-rays which are generated by the electron bombardment of the positive anode or electron receiver, the soft X-rays probably having a wavelength of about 600 Å. This X-ray bombardment of the ion collector causes photoelectron emission from the collector, the emitted electrons also being collected by the anode. The current to the collector should at all times be proportional to the number of ions collected by the ion collector so that changes in the number of ions collected will cause a similar change in the current and thus in the indication of gas pressure, as read by a current sensitive instrument. The device, however, fails when, with decreasing pressure, the number of photoelectrons emitted from the ion collector by this X-ray bombardment becomes large in proportion to the number of ions collected so that changes

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in the number of ions collected are no longer directly observable by a change in the ion current, as the current indicated in the detector circuit is the sum of the positive ions collected and the electrons emitted. At pressures below that, the current levels off to approximately the photoelectron current from the collector.

It is, therefore, one object of this invention to obtain indications of very low gas pressures.

Another object of this invention is to provide an improved ionization manometer which is capable of indicating lower gas pressures than prior ionization manometers.

A still further object of this invention is to prevent the limitation of pressure indications of an ionization manometer by X-ray bombardment of the ion collector.

A still further object of this invention is to obtain indications of gas pressures of the order of 10^{-11} millimeters of mercury.

In one specific embodiment of this invention, an electron emitter is placed at one end of an enclosing vessel and an electron receiver is placed directly above the electron emitter but provided with sufficient spacings to allow the passage of electrons through it into the main body of the vessel. A first ion collector, which may be a cylinder, is placed medially in the vessel and will give accurate indications of gas pressure down to such pressure that the bombardment of the collector by X-rays introduces erroneous indications and thereby sets a limit on the readings that can be obtained from this collector. However, in accordance with a feature of this invention, a second small area ion collector is placed at the end of the vessel removed from the electron emitter and receiver electrodes.

As this second ion collector is of a small area, removed from the source of X-rays, which is the electron receiver or anode, it receives a substantially smaller amount of X-ray radiation than the main ion collector and is therefore subjected to a substantially smaller variation in indications due to electron or photo-electron emission.

It is, therefore, a feature of this invention that an ion collector of a small area be positioned in a device for measuring gas pressures removed from the generator of X-ray radiation.

It is a further feature of this invention that the electron emitter be at one end of a vessel with the electron receiver adjacent to it, a small area ion collector be positioned at the other end of the vessel, and a large ion collector may be positioned intermediate them.

It is a still further feature of this invention

that the small area ion collector be a hairpin wire sealed in the upper end of the vessel.

It is a still further feature of this invention that the intermediate ion collector may be a cylinder and that a slightly positive voltage may be applied to it to cause a focusing of the ions on the small area collector to increase its sensitivity and efficiency.

A more complete understanding of the invention and of the various features thereof may be gained from consideration of the following detailed description and the accompanying drawing, in which:

Fig. 1 is a perspective view of a device for measuring gas pressures illustrative of one embodiment of this invention, a portion of the envelope of the vessel and of one electrode being broken away to show the internal elements of the device;

Fig. 2 is a schematic of the device of Fig. 1 and of one illustrative circuit that may be employed therewith; and

Fig. 3 is a graph of the ion current indicated as flowing to the main ion collector plotted against the ion current indicated as flowing to the small area ion collector as the pressure in the device is reduced illustrating indication of pressure by the small area collector below the lower limit of pressure indication of the large ion collector.

Referring now to the drawing, the device for measuring gas pressures shown in Fig. 1 comprises an enclosing vessel 10, as of glass, which has an open tubulation 11 for connection to the gas flow system for which indications of low pressure are desired. The vessel may advantageously have a reentrant stem 12 through which extend four lead wires 13, 14, 15 and 16 which may each advantageously have an insulating sleeve 17 thereon. A filamentary cathode or electron emitter 19, which may be of tungsten or of other filamentary cathodic material known in the art, is positioned by the two inner leads 14 and 15 at the base of the vessel 10 adjacent the stem 12. A filamentary anode or electron receiver 20, which may advantageously also be of tungsten, tantalum, or other material known in the art, is positioned by the two outer leads 13 and 16 adjacent the cathode 19 and just above it. The anode 20 is wound with larger spacings to allow passage of electrons from the emitter 19 through it into the main portion of the vessel 10.

A first main ion collector 21 is provided medially in the vessel, the collector advantageously being a cylinder which may be of molybdenum, tungsten, tantalum, or other material known in the art. The ion collector 21 is supported and positioned in the vessel 10 by a lead wire 22 extending through the top of the vessel 10, as at 23, removed from the tubulation 11.

A second small area ion collector 24, which may be in the form of a single wire or hairpin wire having two leads 25 and 26, as shown, is positioned at the top of the vessel 10 between the tubulation 11 and the lead 22 and opposite the electron emitter 19 and collector 20 at the base of the vessel. The wire ion collector 24 is supported by the leads 25 and 26, which may be integral with it and which are sealed into the vessel as at 27 and 28.

Referring now to Fig. 2, there is shown one illustrative circuit that may be employed with the embodiment of this invention illustrated in Fig. 1. The electron emitter 19 is connected

through lead wire 14 and a resistance 30 to the negative terminal of a voltage supply 31, lead wire 15 being connected to ground. The electron receiver 20 is connected through the lead wire 16 to the positive side of a voltage supply 32, a milliammeter 33 being inserted to enable observation and maintenance of a constant electron current during the operation of the device. The other lead wire 13 is not connected in the indicating circuit. The first or main ion collector 21 is connected to the negative side of a voltage supply 35, a current detector such as a microammeter 36 being provided to allow readings of the ion current to give indications of the gas pressure. The second or small area ion collector 24 is also connected to the negative side of a voltage supply 37 through lead wire 25, an amplifier 38 being provided in the circuit to amplify the ion current so that it may be read on a galvanometer or microammeter 39 to give indications of the gas pressure. A very sensitive galvanometer may be employed which would not require the amplifier 38, as is known in the art, to provide direct readings of the ion current from the second or small area ion collector 24.

The lead wires 13 and 26 may be left unconnected, as shown in Fig. 2, or they may be connected to the lead wires 16 and 25, respectively, so that both sides of the electron receiver 20 and the small area ion collector 24 are connected to the appropriate voltage supplies. It has been found advantageous to provide the lead wires 13 and 26, though, so that current may be passed directly through the electron receiver 20 and the wire ion collector 24 to cleanse them during processing and so that all the electrodes may be degassed to enable attainment of the extremely low pressures.

In one illustrative circuit employed with this invention, the voltage supply 31 maintained the electron emitter 19 at +8 volts, the voltage supply 32 maintained the electron receiver 20 at +150 volts, and the voltage supplies 35 and 37 maintained the ion collectors 21 and 24 at -24 volts each. It is not essential, though, that the small area ion collector 24 be at the same potential as the main ion collector 21. In fact, maintaining the small area ion collector 24 slightly more negative than the main ion collector will increase its sensitivity. Thus, it is one feature of this invention that the sensitivity and efficiency of the small area ion collector 24 may be increased by applying a slightly positive voltage, such as +15 volts, to the large electrode 21, which will then not act to collect ions but will instead focus them by the electric field configuration thus set up, towards the ion collector 24.

In employing the embodiment of this invention illustrated in Fig. 1, accurate indications of gas pressure have been obtained down to a pressure of 10^{-11} millimeters of mercury. Referring now to Fig. 3, there is shown a graph of the current to the large ion collector which is indicative of ionization manometers of the prior type, where the ion collector is adjacent the anode, plotted against the current to the small area wire ion collector. The circuit employed was that shown in Fig. 2, and the circuit parameters were such that the anode was at +180 volts, both ion collectors at -24 volts, and the electron current was 5.0 milliamperes. The device was filled with air, the results with other gases varying proportionately, depending on the ionization efficiency of the gas. The coordinates of the graph are in amperes, but they approximate a gas pressure

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ten times as large, i. e., an ordinate of 10^{-7} amperes is indicative of a gas pressure of 10^{-6} millimeters of mercury.

As seen in Fig. 3 by curve 40 of ion current to the large collector 21 plotted against ion current to the small collector 24 for one specific illustrative embodiment of this invention, both collectors give accurate indications of pressure down to pressures of the order of 10^{-7} , at which pressure the current in the large collector circuit no longer properly indicates the decreased ion current, because of the increased effect of the photo-electron emission from soft X-ray bombardment. At a point between 10^{-7} and 10^{-8} millimeters of mercury the current to the main ion collector remains constant despite reduction in the gas pressure, which current is then only a measure of the photo-electron emission. The current indicated in the small area or wire collector circuit, however, continues to decrease proportionately with reduced gas pressures down to approximately 10^{-11} millimeters of mercury, which is off the lower end of the graph shown in Fig. 3. These lower pressure indications may be checked against extrapolated computations from the larger pressures. It is to be realized that in order to employ the ion currents flowing in the detector circuit under these low pressure conditions, exceedingly delicate amplifiers and detectors should be employed as the currents are of the order of 10^{-12} to 10^{-13} amperes.

In another illustrative embodiment of this invention, the large area ion collector may be entirely omitted and all readings indicating the gas pressure taken in the detector circuit for the ion current from the small area or hairpin wire ion collector so that only a small amount of X-ray emission bombards the collector. Where the device is intended to be employed both for gas pressures above 10^{-8} millimeters of mercury, which is approximately the lower limit or cut-off value of the large ion collector in the vicinity of the anode or X-ray emitter, and for pressures below that, it may be advantageous to employ both collectors as the large ion collector because of its larger area is slightly more efficient at those pressures where X-ray emission and bombardment of the collector are not of significance. It is further advantageous to employ the large area ion collector if it is desired to alter the electron current in the device, as the large area collector has been found not to be affected by space charge limitations, that is, the ion current to the collector has been found to vary directly with the electron current in the device, whereas the ion current to the small area or wire ion collector at the opposite end of the vessel from the electron system has been found not to be a linear function of the electron current. Therefore, where it is expected to vary the electron current for various applications, it is advantageous to employ both electrodes so that the effect of space charge on the ion current to the wire collector may be rapidly and facily ascertained.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and the scope of the invention.

What is claimed is:

1. A device for measuring gas pressures comprising a vessel, electron emitting means posi-

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tioned in said vessel adjacent one end, electron receiving means positioned adjacent said electron emitting means, and a small area ion collector positioned adjacent the other end of said vessel removed from said electron receiving means whereby soft X-rays generated by said electron receiving means do not sufficiently impinge on said ion collecting means to limit readings of pressures down to approximately 10^{-11} millimeters of mercury.

2. A device for measuring gas pressures in accordance with claim 1, in which said small area ion collector is a wire positioned by a lead extending through the other end of said vessel.

3. Apparatus for measuring gas pressure comprising a vessel, a thermionic filament at one end of said vessel, a foraminous anode positioned adjacent said filament and between it and the remainder of said vessel, said anode allowing passage of electrons through said anode into the remainder of said vessel, a wire ion collector positioned at the other end of said vessel removed from said anode, means applying a voltage to said anode positive with respect to said filament, means applying a voltage to said wire ion collector rendering it negative with respect to said filament and anode, and means for detecting the flow of current to said ion collector.

4. A device for measuring gas pressure comprising a vessel, electron emitting means positioned in said vessel, electron receiving means positioned adjacent said electron emitting means, a first ion collecting means adjacent said other mentioned means, and a second ion collecting means removed from said first two mentioned means, said second ion collecting means comprising a small area.

5. A device for measuring gas pressure comprising a vessel, electron emitting means positioned at one end of one of said vessel, electron receiving means positioned adjacent said electron emitting means at said one end, a first ion collecting means positioned centrally in said vessel and comprising a large area, and a second electron collecting means positioned at the other end of said vessel and comprising a small area, whereby soft X-rays generated by said electron emitting means do not sufficiently impinge on said second ion collecting means to limit readings of pressures down to approximately 10^{-11} millimeters of mercury.

6. A device for measuring gas pressure comprising a vessel, a cathode at one end of said vessel, an anode adjacent said cathode at said one end, said anode allowing passage of electrons through said anode into the upper regions of said vessel, a hollow ion collector centrally located in said vessel, and a small area ion collector positioned at the other end of said vessel removed from said anode.

7. A device for measuring gas pressure comprising a vessel, a wire filament at one end of said vessel, a wire anode positioned adjacent said filament and between it and the remainder of said vessel, said anode allowing passage of electrons through said anode into the remainder of said vessel, a hollow ion collector centrally located in said vessel, and a wire ion collector positioned at the other end of said vessel removed from said anode, whereby soft X-rays generated by electron bombardment of said anode impinge mainly on said hollow ion collector.

8. Apparatus for measuring gas pressures comprising a vessel, electron emitting means positioned in said vessel, electron receiving means

positioned adjacent said emitting means and between said emitting means and the remainder of said vessel, said electron receiving means allowing passage of electrons therethrough into the remainder of said vessel, first ion collecting means medially positioned in said vessel, second ion collecting means positioned in said vessel remote from said electron receiving means, said second ion collecting means having a small area, means applying voltages to both said ion collecting means rendering said ion collecting means more negative than said electron emitting and receiving means, and means for detecting the flow of currents to said ion collecting means.

9. Apparatus for measuring gas pressures comprising a vessel, electron emitting means positioned in said vessel, electron receiving means positioned adjacent said emitting means in said vessel, small area ion collecting means positioned at the other end of said vessel removed from said electron receiving means, electrode means positioned medially in said vessel between said electron emitting and receiving means and said ion collecting means, means applying a voltage to said ion collecting means rendering said ion collecting means more negative than said electron emitting and receiving means, means applying a voltage to said electrode means rendering said electrode means more positive than said ion collecting means to cause ions in said vessel to migrate to said ion collecting means, and means for detecting the flow of current to said ion collecting means.

10. A device for measuring gas pressures comprising a vessel having therein an opening for connection to the gas system in which the pressure is to be measured, said vessel housing electron emitting means, electron receiving means adjacent said emitting means, a large area ion collector relatively close to said emitting means and a small area ion collector relatively remote from said emitting means.

11. A device for measuring gas pressures comprising a vessel having therein an opening for connection to the gas system in which the pressure is to be measured, said vessel housing electron emitting means, a filamentary ion collector opposite and relatively remote from said emitting means, and an open-work anode between said emitting means and said ion collector and in proximity to said emitting means.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,334,143	Dushman	Mar. 16, 1920
2,081,429	Gaede	May 25, 1937
2,454,564	Nelson	Nov. 23, 1948
2,516,704	Kohl	July 25, 1950