Aug. 7, 1956 R. B. NELSON 2,758,233

ELECTRIC DISCHARGE DEVICE FOR GAS PRESSURE DETERMINATION

Filed Sept. 12, 1951

Fig. 1.

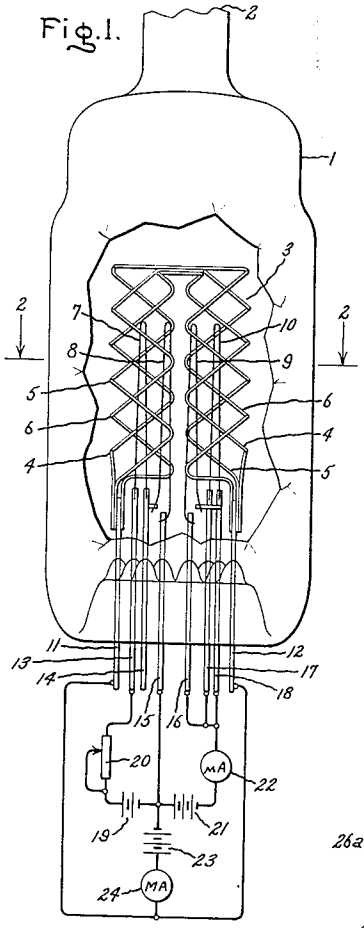


Fig. 4.

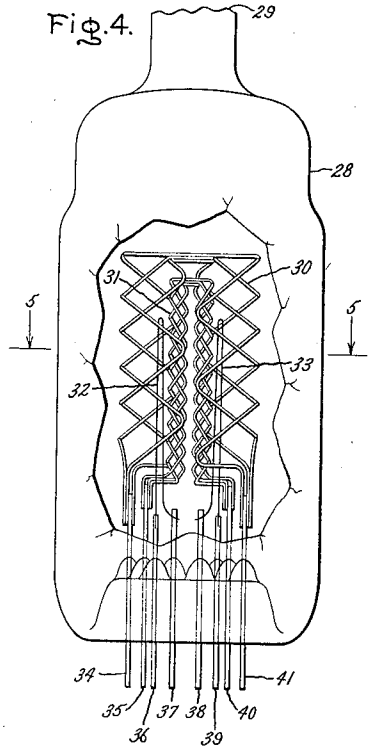


Fig. 3.

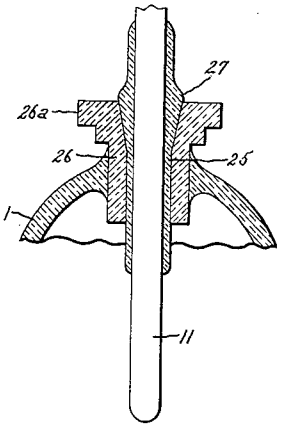


Fig. 2.

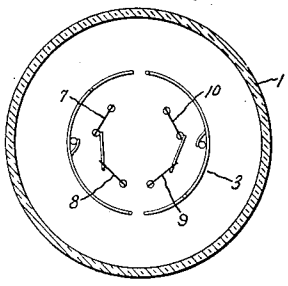
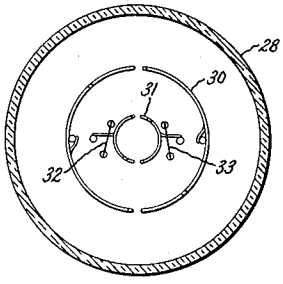


Fig. 5.



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ELECTRIC DISCHARGE DEVICE FOR GAS PRESSURE DETERMINATION

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2 Claims. (Cl. 313—7)

My invention relates to electric discharge devices for gas pressure determination and, more particularly, to electric discharge devices of the type in which ionization, measurable as electric current, of a gaseous medium is produced as an indication of the pressure of the gaseous medium. Such discharge devices are sometimes called ionization-type vacuum gauges since they are effective mainly in the determination of relatively low absolute pressures.

My invention is further related to and is an improvement in ionization-type vacuum gauges of the type shown and described in my U. S. Patent 2,454,564 issued November 23, 1949 and assigned to the assignee of the present application.

It is a general object of my present invention to provide a new and improved electric discharge device for use as an ionization-type vacuum gauge.

More specific objects of the invention are the provision of such an electric discharge device which may have a useful life considerably increased over that of prior art type devices; and the provision of an increased-life ionization-type vacuum gauge electric discharge device which has high ionization sensitivity for the measurement of extremely low pressures, as well as advantageous features permitting convenience of degassing the electrodes therein.

According to one embodied form of my invention, an electric discharge device for use in determining low pressures of a gaseous medium comprises an anode which is formed in basket configuration, i. e., a generally hollow configuration enclosing a central space therein. Within this central space a plurality of substantially identical thermionically electron emissive filamentary electrodes are located, preferably in symmetrical arrangement. The anode and the filamentary electrodes are housed within an envelope having provisions, such as an opening or passageway, therein for receiving within the envelope a gaseous medium under the pressure to be determined; and a plurality of lead-in connectors may extend in mutually insulated relation through the envelope to support and provide external electrical terminals for the anode and the filamentary electrodes.

In the operation of the device, heating current is passed through at least one of the filamentary electrodes to constitute it as an electron emitting cathode, while the remaining filamentary electrodes are placed at an electric potential negative with respect to the cathode-constituted electrode so that the remaining filamentary electrodes constitute ion collectors. The anode, of course, is placed at an electric potential considerably positive with respect to the cathode-constituted electrode so that emitted electrons are attracted with substantial velocity toward the anode and, in colliding with gas molecules cause ionization of the gas by impact. The positive ions thus formed are proportional in number to the pressure of the gaseous medium and are attracted to the negative ion collector-constituted electrodes. For given gaseous mediums, operating potentials, electron currents, and electrode spacing

and geometry, the measurable electric current of the positive ions is related in a known manner to the pressure of the gaseous medium. Since the anode at a positive potential surrounds the interaction or ionization space, positive ions are repelled from the anode as well as attracted by the ion collector electrodes so that substantially all ions formed become a part of the measured current and the pressure determination is accurate and sensitive. Further, the anode may be made of an open wire structure through which electric current may be passed to heat the same, whereby degassing or driving off occluded gases before the pressure determination is undertaken in order that unwanted and unknown gases are not present in the envelope to invalidate the results. The positive electric field between the anode wires successfully retains positive ions within the anode basket until picked up by the ion collectors. All of the filamentary electrodes may also be degassed by passing heating current therethrough.

The filamentary electrodes are not coated with a special electron emitting material, such as barium oxide, as is commonly employed in cathodes, since, such materials when heated may liberate gases which render the pressure determination inaccurate or degassing to a satisfactory degree futile. During the operation described briefly above, therefore, the cathode-constituted filamentary electrode or electrodes, which may for example be tungsten, are maintained at extremely high temperatures at which electron emission occurs directly from the filament metal and sooner or later, as in the case of all heated filaments, will rupture or "burn out" so that they will no longer conduct heating current. In keeping with an important aspect of my invention, however, the burned out filamentary electrodes may then be employed as ion collectors, and one or more of the previously ion collector-constituted electrodes employed as a cathode so that the useful life of the device is made much longer over that of devices limited to the life of a single filamentary electrode carrying heating current.

The features of the present invention which I believe to be novel are pointed out with particularity in the appended claims. For a more complete understanding of the invention, however, together with further objects and advantages thereof, reference should be had to the following description taken in conjunction with the accompanying drawing, wherein:

Fig. 1 is an elevational view, partially broken away, of an electric discharge device illustrating a first embodiment of my invention together with a schematic operating circuit diagram therefor; Fig. 2 is a sectional view taken along the line 2—2 of Fig. 1; Fig. 3 is an enlarged view, in section, of a preferred lead-in connector-to-envelope seal construction for the device of Fig. 1; Fig. 4 is an elevational view, partially broken away, of an electric discharge device illustrating a second embodiment of my invention; and Fig. 5 is a sectional view taken along the line 5—5 in Fig. 4.

Referring now to Figs. 1 and 2, I have shown an electric discharge device for use in determining pressures of a gaseous medium, particularly extremely low pressures, which comprises an envelope 1, conveniently but not necessarily made of glass, which is hermetically sealed except for an opening 2 therein through which the gaseous medium under the pressure to be determined is introduced. Within envelope 1 there is a conductive structure which is generally hollow, defining a central space therein, and providing an anode 3 which is preferably formed in basket configuration. While anode 3 may be made of solid sheet metal and of a cross section other than circular, the preferred structure for anode 3 is of wire conductors in open form easily heatable by the passage of current serially therethrough, such as three bights of wire 4, 5 and 6 which are fastened together at the re-

spective ends thereof. Each bight of wire is lapped back and forth around an approximate semi-circumference of the anode basket as it extends upward from one end, crosses over at the top of the anode basket, and is lapped back and forth around the opposite semi-circumference of the anode basket to its other end. The three wire bights are staggered in lapping so that a net-like basket structure is provided, and are resistance welded together at the side cross-over points and the top cross-over point. This provides a structurally rigid basket which may be heated to extremely high temperatures for good degassing without being weakened or deformed. The resulting circular cross section of anode 3, besides being easy to fabricate, provides a better symmetry of electric fields therewithin and eliminates sharp corners with attendant non-uniform potential gradients. This also allows convenient degassing of anode 3 as will be explained hereinafter and, notwithstanding the open wire structure, keeps ions within the central space.

Within the central space enclosed by anode 3 there is located a plurality of filamentary electrodes 7, 8, 9, and 10, which are preferably tungsten, substantially identical, and symmetrically spaced with respect to anode 3. The filamentary electrodes 7—10 by virtue of their fine cross section and resistance are heatable to electron emissive temperatures by relatively small currents passing therethrough. The filamentary electrodes 7—10 may be made in a complex helical or double helical winding form although the straight U-shaped form illustrated has been found to be satisfactory for most purposes.

In order to mount anode 3 and filamentary electrodes 7—10 within envelope 1 and provide external terminals therefor, a plurality of lead-in connectors 11—18 are extended in mutually insulated relation and sealed relation through the lower portion of envelope 1. Anode 3 is supported from connectors 11 and 12, the opposite ends of wire bights 4, 5, and 6 being bonded to connectors 11 and 12, respectively, as shown. Electrode 7 is bonded at the ends thereof to connectors 13 and 14; electrode 8 to connectors 14 and 15; electrode 9 to connectors 16 and 17; and electrode 10 to connectors 17 and 18. While each of the filamentary electrodes 7—10 may be mounted and connected by a separate pair of lead-in connectors, the mounting arrangement shown effectively connects electrodes 7 and 8 in series through connectors 13 and 15, and effectively connects electrodes 9 and 10 in series through electrodes 16 and 18, thereby eliminating the need for two additional lead-in connectors.

Disregarding for the moment the schematic diagram of a typical operating circuit shown in the lower portion of Fig. 1, the degassing of electrodes prior to a gas pressure measurement to drive occluded gases from the electrodes may be accomplished by heating anode 3 and filamentary electrodes 7—10 to a high temperature and drawing off the released gases through opening 2 by connecting opening 2 to a vacuum system. The heating may be accomplished by connecting connectors 11 and 12 to a source of current so that heating current flows through wires 4, 5, and 6 in parallel. By jumpering connectors 15 and 16 and connecting connectors 13 and 18 to the source of current, heating current flows through filamentary electrodes 7—10 in series.

The accurate determination of the pressure of a gaseous medium may then be made as follows: The gaseous medium under the pressure to be determined is introduced into envelope 1 through opening 2 and the connectors 11—18 connected to a circuit such as the one illustrated. A source of heating current, such as a battery 19, is connected through a variable resistor 20 to connectors 13 and 15 to supply heating current through electrodes 7 and 8 in series, thereby to constitute these electrodes 7 and 8 as an electron emitting cathode. The remaining filamentary electrodes 9 and 10 are preferably jumpered together at the connectors 16, 17, and 18 thereof and placed at a negative potential with respect to the cathode-constituted electrodes by means, such as a battery 21, to constitute electrodes 9 and 10 as an ion collector, a microammeter 22 being connected in series therewith to indicate current flow through the ion collector. The connectors 11 and 12 for anode 3 are preferably jumpered together and placed at a positive potential with respect to the cathode-constituted electrodes by means, such as a battery 23, connected through a milliammeter 24. It has been found, for example, that satisfactory operation may be obtained when the voltages of batteries 21 and 23 are in the order of 20 and 150 volts, respectively. Now, electrons emitted by the cathode-constituted electrodes 7 and 8 are attracted by anode 3 and repelled by the ion-collector-constituted electrodes 9 and 10 and the total electron anode current, as read on milliammeter 24, may be adjusted to a predetermined value by setting the tap on variable resistor 20. The electrons in traveling from the cathode to the anode strike gas molecules, which are present in a concentration dependent upon the pressure of the gaseous medium, and produce by collision positively charged gas ions, in numbers dependent upon the concentration of the gas molecules. The positively charged ions are repelled by anode 3 and attracted by the ion collector-constituted electrodes 9 and 10, forming an electric current through battery 21, readable on microammeter 22, which is related in a manner known to those skilled in the art to the pressure of the gaseous medium.

A specific advantage of this electric discharge device for use in determining the pressure of a gaseous medium is that its useful life may be twice that of prior devices employing filamentary electrodes, in that when the originally cathode-constituted electrodes rupture or "burn out," the connections between connectors 13, 14, and 15 and connectors 16, 17, and 18 may be switched for the operating circuit, the electrodes 9 and 10 then being employed as a cathode while the electrodes 7 and 8 are employed as an ion collector. If, as previously mentioned, each of the filamentary electrodes are mounted on a separate pair of connectors, the useful life of the device may be further increased by switching connections, since only one of the two filamentary electrodes connected externally in series will, as a rule, rupture at one time. Further, it is possible to provide a relatively great number of the filamentary electrodes, as many as eight or ten, each of which is sufficient in itself to constitute the cathode for the device so that each of the filamentary electrodes may, in turn, be used as the cathode while the remaining ones are connected together as the ion collector. In essence, then, each of the plurality of filamentary electrodes may be used either as a cathode or a part of a cathode or as an ion collector or a part of an ion collector, the ruptured filamentary electrodes being useful as parts of an ion collector.

In precise measurements of gaseous medium pressures, it is essential that the reading of microammeter 22 be an accurate indication of the ion current flow. In some instances, leakage current may flow directly between connectors through the glass envelope 1 or across the internal surface of the glass envelope 1, considerably invalidating the pressure determination, especially when such leakage current passes through microammeter 22. In Fig. 3 there is shown a seal construction which may be advantageously employed in sealing the connectors 11—18 through envelope 1 to increase the volume and surface resistance of envelope 1 between connectors and eliminate or successfully reduce such leakage currents. The connector 11, shown by way of example, is surrounded by a glass sleeve 25 bonded directly to the metal connector. A funnel-shaped ceramic tube 26 is pressed over sleeve 25 while the sleeve is softened by heat in such a way that the funnel portion of tube 26 gathers the glass of sleeve 25 slightly forming a flared portion 27 which makes for a stronger glass-

ceramic bond between sleeve 25 and tube 26. Ceramic tubes 26, which inherently have a higher volume resistance characteristic than glass, are thus interposed to reduce or eliminate volume leakage currents. A step portion 26a on tube 26, the underside of which cannot receive deposits of small amounts of conductive material, sputtered from the electrodes during operation, further shields the portion of the glass envelope 1 thereunder from receiving such sputtered materials. Thus, these surfaces present an increased length surface leakage path which remains free of conductive material so that the surface leakage resistance between connectors is very high and surface leakage currents are successfully reduced. The purpose of the intermediate glass sleeve is to obviate the necessity of employing a metal solder seal between the metal connector and the ceramic tube. The device is elevated to fairly high temperature, especially during degassing. Thus, a soft solder between the connector 11 and ceramic tube 27 would afford the possibility of metal vaporizing into the envelope to contaminate the gaseous medium or preclude good degassing results, while a hard solder would not sufficiently match the thermal expansion characteristics of the metal connector 11 and the ceramic tube 27.

Turning now to Figs. 4 and 5, I have shown a modification of the device illustrated by Figs. 1 and 2 which, by the addition of a second anode may be made to provide even greater sensitivity in determining extremely low pressures of gaseous mediums. This modified electric discharge device comprises an envelope 28 having an opening 29 therein and a first anode 30, similar to anode 3, mounted within envelope 28. Located centrally within anode 30 there is provided a second anode 31 which in the preferred illustrated form is made in the same open basket form as anode 30, except smaller in size. Intermediate the first and second anodes 30 and 31, a plurality of preferably identical filamentary electrodes are located, two such filamentary electrodes 32 and 33 being illustrated although any number greater than one may be used. A plurality of lead-in connectors 34—41 extend in sealed and mutually insulated relation through the lower end of envelope 28, preferably sealed and insulated as illustrated by Fig. 3, to support and provide external terminals for anodes 30 and 31 and filamentary electrodes 32 and 33. Anode 30 is supported from connectors 34 and 41; anode 31 from connectors 35 and 40; electrode 32 from connectors 36 and 37; and electrode 33 from connectors 38 and 39. Anodes 30 and 31 may also be connected together at the upper end thereof to add structural rigidity to the open wire spiral baskets of which they are formed and to electrically unite them, although as shown in the drawing this is not necessary.

The device of Figs. 4 and 5 may be degassed in the same manner as that described for the device of Figs. 1 and 2, the additional anode 31 being heated and degassed by connecting its external connectors 35 and 40 to a source of heating current. In operation, the device of Figs. 4 and 5 is similar to that of Figs. 1 and 2 and a circuit such as that illustrated in Fig. 1 may be employed. The anodes 30 and 31 are connected together by an external jumper to form a composite anode placed at a positive potential with respect to the filamentary electrode, say electrode 32, constituted as a cathode. The remaining filamentary electrode 33 is constituted as an ion collector by placing it at a negative potential with respect to cathode-constituted electrode 32. The electrons emitted by the cathode may be attracted either to the first or second anode 30 or 31, causing ionization of gas molecules enroute, which in turn are more effectively repelled toward the negative ion collector by the influence of positive potentials at both the center and the exterior of the interaction or ionization space. The second anode 31 also shields the cathode from the negative potential of the ion collector and confronts the cathode with a high positive potential on each side. A greater positive potential gradient is thus present on both sides of the cathode, permitting a more copious supply of electrons to be emitted for a given cathode heating current. And finally, when filamentary electrode 32 "burns out," it may then be employed as an ion collector while filamentary electrode 33 is employed as a cathode, so that the useful life of the device is considerably increased.

While the present invention has been described by reference to particular embodiments thereof, it will be understood that numerous modifications may be made by those skilled in the art without actually departing from the invention. I, therefore, aim in the appended claims to cover all such equivalent variations as come within the true spirit and scope of the foregoing disclosure.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An electric discharge device for use in determining the pressure of a gaseous medium, said discharge device comprising an envelope having an opening therein through which a gaseous medium under the pressure to be determined is introduced, a first anode formed of open wire in basket configuration around a central axis, a second anode formed of open wire in basket configuration located in coaxial spaced relation within said first anode, a plurality of substantially identical filamentary electrodes substantially parallel to said axis spaced between said first and said second anodes, and a plurality of lead-in connectors extending in mutually insulated relation through said envelope, each pair of said connectors supporting one of said anodes and said filamentary electrodes within said envelope.

2. An electric discharge device for producing measurable ionization indicative of the pressure of a gaseous medium supplied thereto, said discharge device comprising a cylindrical envelope having an opening concentric with said envelope through which said gaseous medium is introduced, two identical elongated filamentary electrodes in symmetrical lateral spaced relationship with respect to the central axis of said envelope and a coaxial conductive apertured structure surrounding said filamentary electrodes providing an anode, each of said filamentary electrodes having electrically independent externally accessible terminals independent of the terminals of the other whereby heating current may be supplied to either of said filamentary electrodes to provide an electron emitting cathode and a negative potential may be supplied to the other of said filamentary electrodes to provide a collector electrode.

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