ORBITRON ELECTRONIC VACUUM GAUGE HAVING SECOND ANODE FOR COLLECTING SCATTERED ELECTRONS

Raymond G. Herb, Madison, Wis., assignor to Wisconsin Alumni Research Foundation, Madison, Wis., a corporation of Wisconsin

Filed Aug. 10, 1966, Ser. No. 571,560

Int. Cl. G01N 27/62

U.S. Cl. 324—33

22 Claims

ABSTRACT OF THE DISCLOSURE

A first central anode is disposed axially within a boundary electrode, mounted within an enclosure connected to a vacuum system. A positive voltage is impressed between the central anode and the boundary electrode to produce a cylindrical electric field therebetween. Electrons are introduced into said field with initial angular momentum so that the electrons will travel in spiral orbits around the central anode. A second central anode is aligned axially with the first anode and is also charged with a positive voltage. The current to the second anode is measured separately to provide an indication of the vacuum in the enclosure. Such current increases with pressure, because of the increased scattering of the orbiting electrons by the gas molecules in said enclosure. The electrons may be introduced by a U-shaped ribbon filament having a highly emissive zone on at least one side thereof. The zoned filament causes a larger proportion of the emitted electrons to go into orbits around the central anodes. The highly emissive zone may be produced by thorating a portion of the filament. The highly emissive zone may be recessed into the surface of the filament. Either or both legs of the U-shaped filament may be formed with highly emissive zones.

This invention relates to electronic vacuum gauges, and particularly to such gauges which employ the basic principles of the orbitron, as disclosed and claimed in the Herb and Pauly U.S. Patent 3,244,969, patented Apr. 5, 1966, and also the co-pending application of Raymond G. Herb and Theodore E. Pauly, Ser. No. 447,678, filed Apr. 13, 1965, now Patent No. 3,388,290 issued June 11, 1968.

In the orbitron, electrons are caused to travel in a cylindrical electric field, without the aid of a magnetic field. The cylindrical electric field is produced between a central electrode or anode, usually in the form of a cylindrical wire, rod or other member, and an outer or boundary electrode, generally in the form of a cylindrical wall on which a positive voltage is employed between the central electrode and the boundary electrode. The electrons are introduced into the space between the central and boundary electrodes in such a manner that the electrons are given an initial angular momentum about the central electrode. Preferably, the electrons are introduced by means of thermionic cathode or filament structures of the types disclosed and claimed in the above-mentioned Herb and Pauly patent and co-pending application.

In the orbitron vacuum gauges as previously disclosed, the orbiting electrons are effective to cause ionization of gas molecules in the vacuum space between the central and boundary electrodes. The resulting positive gas ions are propelled outwardly by the electric field. An ion current is thus produced to the boundary electrode which is indicative of the residual pressure in the vacuum space. A more accurate indication of the pressure is obtained by providing a separate ion collecting electrode, remote from the filament, to avoid the masking effects due to such factors as photo-electric emission of electrons from the boundary electrode.

One object of the present invention is to provide a new and improved orbitron-type vacuum gauge in which scattered electrons are collected, rather than gas ions, so that the gauge may be operated at a low, non-ionizing voltage, or at a voltage such that only a small amount of ionization is produced. Ion pumping by the gauge is thus substantially eliminated or reduced to an extremely low level. When the gauge is operated on an ionizing basis, a slight amount of ion pumping is produced, because some of the positive ions which are propelled to the boundary electrode will stick to the boundary electrode and thus will be removed from the vacuum system, at least temporarily. The ion pumping produced by the prior orbitron vacuum gauges is very small, but the ion pumping produced by the gauges of the present invention is even smaller. The operation of the orbitron vacuum gauge at extremely low voltages has the additional advantage of minimizing the production of X-rays, which tend to produce photoelectric emission of electrons from the various electrodes of the gauge.

A further object of the present invention is to provide a new and improved orbitron vacuum gauge in which the current due to electrons scattering, which decreases with decreasing pressure, is effectively separated from the background current, which is substantially independent of pressure variations, so that an accurate and dependable indication of the pressure may be obtained.

The electron-scattering current is due to the impact or collision of the orbiting electrons with gas molecules. As the pressure is decreased, the scattering effect is decreased. It is a further object to provide a new and improved orbitron vacuum gauge having a first anode or central electrode to carry most of the background current, and a second anode or collector for collecting scattered electrons which are displaced from their orbits by impact with gas molecules.

Further objects and advantages of the present invention will appear from the following description, taken with the accompanying drawings, in which:

FIG. 1 is a diagrammatic longitudinal section of an orbitron vacuum gauge, to be described as an illustrative embodiment of the present invention.

FIG. 2 is an enlarged fragmentary elevation showing the filament construction for the gauge of FIG. 1.

FIG. 3 is a fragmentary side elevation, taken generally as indicated by the line 3—3 in FIG. 2.

FIG. 4 is an enlarged cross-section taken through the filament, generally along the line 4—4 in FIG. 2.

FIGS. 5 and 6 are fragment cross-sections showing additional modified constructions.

FIG. 7 is a fragmentary longitudinal section, similar to a portion of FIG. 1 but showing a modified filament construction.

FIG. 8 is a fragmentary longitudinal section, similar to a portion of FIG. 1, but of a modified construction.

As already indicated, FIG. 1 illustrates an orbitron vacuum gauge which preferably is operated on a non-ionizing basis, but may also be operated with a certain amount of ionization.

It will be recognized that the orbitron gauge employs the basic principles of the orbitron, as disclosed and claimed in the previously-mentioned Herb and Pauly patent and co-pending application.

As shown, the gauge 10 comprises a central or inner electrode 12 which is normally cylindrical in shape. As shown, the central electrode 12 comprises a hollow metal tube of relatively large diameter. The central electrode 12 is disposed axially within an outer or boundary electrode 14, which is normally cylindrical in shape and is
3,449,660

In this case, the boundary electrode 14 is in the form of a thin cylindrical coating or layer on the inside of a casing or a housing made of a glass or the like. The conductive coating may be made of various materials, but tin oxide has been found to be highly advantageous. The tin oxide may be fused to the inner surface of the glass casing 14 so as to form a transparent glaze which is electrically conductive. The electrical conductivity of the coating is restricted to the desired portion of the cylindrical wall of the casing 16, so that the conductive coating will be insulated from ground by the glass casing.

Means are provided to establish an electrical connection to the coating 14. As shown, the glass casing 16 has an end wall 18 into which a lead or wire 20 is sealed. The wire 20 extends through the end wall 18 and is connected at its inner end to the cylindrical coating 14 by a strip of metal foil 22 or the like. Any other suitable means may be employed to establish a connection to the conductive coating 14.

Another wire or rod 24 is sealed into the glass wall 18 to support the central electrode 12, while also establishing an electrical connection thereto. The support rod 24 extends axially into the cylindrical casing 16. As shown, the tubular central electrode 12 has an end portion 26 of reduced diameter which is slotted over and welded or otherwise secured to the support rod 24. The tubular central electrode 12 preferably has a smoothly rounded transitional portion 28 between the reduced end portion 26 and the large diameter main portion of the central electrode. The illustrated transitional portion 28 flares smoothly between the two diameters without any sharp edge or abrupt shoulder. However, an abrupt transition may also be employed, if desired.

Means are provided to apply a positive voltage to the central electrode or anode 12 relative to the cylindrical boundary electrode 14. In this case, the operating voltage is provided by a direct current power supply 30 having negative and positive output terminals 32 and 34 which are connected to the leads 20 and 24, respectively. It is preferred to ground the positive terminal 34 so that the central electrode 12 is grounded. Thus, the boundary electrode 14 is operated at a negative voltage relative to ground.

The operating voltage is very low, preferably so low as to avoid ionization of the gas molecules in the vacuum space within the gauge. However, in some cases, the voltage may be high enough to produce a certain amount of ionization. While the voltage may be varied, a typical range would be from 15 to 50 volts.

The casing 16 forms an enclosure which is adapted to be connected to a vacuum system 36. In this case, the glass casing 16 has an open lower end 38 to which an annular metal flange 40 is sealed. The flange 40 is adapted to be bolted, welded or otherwise secured to the vacuum system 36 so that the interior of the casing 16 will be connected to the interior of the vacuum system 36.

Means are provided for introducing electrons into the space between the central and boundary electrodes 12 and 14, with initial angular momentum so that the electrons will travel in spiral orbits around the central electrode. In the illustrated gauge 10, the electrons are introduced by a thermionic cathode or filament 42, which is of the general type disclosed and claimed in the co-pending Herb and Pauly patent application Ser. No. 447,678 now Patent No. 3,385,290. If desired, any of the filament constructions described in the Herb and Pauly Patent No. 3,244,969 may be employed.

The illustrated filament 42 is in the form of a substantially flat ribbon or strip of thin metal foil or sheet material, which is disposed edgewise toward the axis of the central electrode 12. The filament 42 is generally parallel to the central electrode 12 and is disposed to ward one end thereof. As shown in FIGS. 2 and 3, the filament 42 is preferably folded or bent into a U shape. Thus, the filament 42 preferably has two closely spaced longitudinal legs 44 and 46 with a semi-cylindrical bent portion 48 connected integrally therebetween. Most of the electrons are emitted from the flat outer sides of the legs 44 and 46, and these electrons are given a substantial amount of initial angular momentum about the central electrode 12 so that a high percentage of the electrons will go into spiral orbits around the central electrode.

The free ends of the ribbon filament 42 are connected to and supported by a pair of leads or wires 50 and 52 which are sealed into the glass end wall 18. The ribbon filament 42 may be welded or otherwise secured to the wires 50 and 52.

Means are provided to supply electrical current to the filament 42 so as to heat the filament to a temperature at which electrons will be emitted. In this case, the filament 42 is energized by a power transformer 54 having primary and secondary windings 56 and 58. The secondary winding 58 is connected to the filament leads 50 and 52 through an ammeter 55. To provide for regulation of the filament current, the primary winding 56 is connected to a variable transformer 57, which in turn is connected across power lines 60 and 62 adapted to supply alternating current at 117 volts, or some other suitable voltage. The primary winding 56 is connected to the variable transformer 57 and an adjustable tap 59 on the transformer. In some cases, it will be advantageous to employ a battery, rather than a transformer, to energize the filament 42. In that case, a variable resistor or some other regulating device may be employed in connection with the battery to control the current through the filament 42.

The filament 42 is normally biased to a low voltage relative to the boundary electrode 14. It is preferred to provide means for adjusting the biasing voltage to either a positive or a negative value to obtain the best operation of the ion gauge under various conditions. As shown, the biasing voltage is provided by two batteries 61 which are connected in series across a potentiometer 63. The junction of the two batteries 61 is connected to the negative terminal 32 of the power supply 30. It will be recalled that the negative terminal 32 is connected to the boundary electrode 14. The potentiometer 63 has a slider 65 which is connected to a center tap 66 on the secondary winding 58 of the transformer 54. By adjusting the slider 65 of the potentiometer 63, the biasing voltage on the filament 42 may be varied between positive and negative values corresponding to the voltage of each of the batteries 61. Normally, the biasing voltage is only a fraction of the voltage which is applied between the central electrode 12 and the boundary electrode 14.

To improve the orbiting of the electrons, an annular terminating electrode or sleeve 70 is preferably provided around the end of the central electrode 12, adjacent the filament 42. In this case, the terminating sleeve 70 is received around the reduced end portion 26 of the central electrode 12. The filament 42 is approximately opposite the lower end of the terminating sleeve 70. At its upper end, the sleeve 70 is mounted on an end plate or disc 72. Normally, the terminating sleeve 70 is at the same potential as the boundary electrode 14, although it may be at a somewhat different potential. As shown, the mounting disc 72 is connected to and supported by one or more rods or wires 74 which are sealed into the glass end wall 18. The disc 72 and the sleeve 70 are connected directly to the connecting lead 20 for the boundary electrode 14.

The central electrode 12 provides an anode around which the electrons are caused to travel in spiral orbits. In accordance with the present invention, the orbitron gauge 10 is provided with a second anode or collector 112 which may be regarded as an isolated extension of the first anode 12, in that the second anode 112 also participates in the orbiting of the electrons.
However, the second anode 112 has the additional purpose of providing an accurate measurement of the pressure in the vacuum space within the gauge. Thus, a highly sensitive current measuring instrument or meter 114 is connected between the second anode 112 and ground. If desired, a meter 115 may be connected in series with the first anode 12.

The illustrated second anode 112 is mechanically an extension of the first anode 12. Thus, the second anode 112 takes the form of a metal tube having a main portion 116 of large diameter, corresponding to the diameter of the first anode 12. At its opposite end, the second anode 112 has a portion 117 of reduced diameter. A smoothly flaring transitional portion 118 is preferably provided between the reduced portion 117 and the large diameter portion 116. However, an abrupt transition may also be employed, if desired.

It is preferred to provide a suitable support for the lower end of the second anode or collector 112. As shown, the lower end of the reduced portion 117 is supported by one or more wires or rods 120 which are preferably made of metal and are sealed into the wall of the glass casing of enclosure 16. The meter 114 is connected between one of the wires 120 and ground. The glass casing 16 provides effective insulation for the lead-in wires 120.

In the illustrated construction, the first and second anode 12 and 112 are connected mechanically by an insulating bushing or coupling 123 of glass, ceramic or other suitable material. The bushing 123 is received within the adjacent ends of the tubular electrodes 12 and 112.

To improve the orbiting of the electrons, the second anode or collector 112 is preferably provided with a terminating electrode 122, which may be similar to the terminating electrode 70. Thus, the illustrated electrode 122 is in the form of a sleeve which is received around and spaced outwardly from the reduced lower end portion 117 of the second anode 112. The sleeve 122 is preferably cylindrical in shape and concentric with the reduced portion 117. The sleeve 122 is insulated from the second anode 112. Suitable supports are provided for the terminating sleeve 122. As shown, the sleeve 122 is mounted on a disc or flange 124. One or more supporting wires or rods 126 are welded or otherwise secured to the disc 124. The illustrated wires 126 are sealed into the wall of the glass casing 16. It is preferred to operate the terminating electrode 122 as approximately the same potential as the boundary electrode 14. For convenience, one or more spring clips 127, made of thin sheet metal, may be welded or otherwise secured to the disc 126 and may be arranged to contact the boundary electrode 14. The clips 127 may be welded or otherwise secured to the wires 126. Strips of metal foil may also be employed between the boundary electrode 14 and the wires 126.

In the operation of the orbitron vacuum gauge of FIG. 1, the filament 42 is effective to emit electrons with initial angular momentum about the central electrode or anode 12. Due to the initial angular momentum, in conjunction with the cylindrical electric field between the central electrode 12 and the boundary electrode 14, a high percentage of the electrons are caused to travel in spiral orbits around the central electrode or anode 12. The biasing voltage on the filament 42 may be adjusted for the best orbiting of the electrons. Because of the orbiting of the electrons, the mean free path of the electrons may be much greater than the maximum size of the gauge. Thus, there will be an increased probability that any particular electron will collide with a gas molecule in the vacuum space between the central anode 12 and the boundary electrode 14.

The orbiting electrons with sufficiently good orbits travel in spiral paths along the entire length of the first anode 12, and then continue to spiral along the entire length of the second anode or collector 112. At the far end of the second anode 12, the orbiting electrons are reflected, without any substantial loss of angular momentum, so that they spiral back along the second anode, toward the filament 42. The configuration of the electric field at the far end of the second anode 112 causes the reflection of the spiralling electrons. The terminating sleeve 122 produces a field configuration which is especially favorable for efficient reflection of the spiralling electrons.

Some of the orbiting electrons collide with gas molecules. Such collisions normally deflect or scatter the electrons from their orbits so that they almost immediately travel to the first anode 12 or the second anode 112, whichever they happen to be opposite at the time. The scattered electrons which travel to the second anode or collector 112 produce a current which is indicated by the meter 114. Scattering of the orbiting electrons by impact with gas molecules decreases with decreasing pressure, so that the current registered by the meter 114 provides a direct indication of the pressure in the gas.

Normally, it is preferred to operate the orbitron vacuum gas with an anode voltage which is so low that the electrons do not produce ionization when they collide with the gas molecules. Under such non-ionizing conditions, the collisions between the electrons and the gas molecules are substantially elastic, so that the electrons are deflected or scattered from their orbits without any substantial loss of energy. Nevertheless, the orbiting electrons are normally scattered almost immediately to the adjacent anode 12 or 112. Inasmuch as no gas ions are produced by the orbiting electrons, there is no appreciable ion pumping.

However, the orbitron vacuum gauge may be operated with a somewhat higher anode voltage so that at least some of the orbiting electrons will produce ionization when they collide with the gas molecules. When ionization is produced, the impacts between the electrons and the gas molecules are noelastic, so that the electrons lose energy, as well as being deflected or scattered from their orbits. The scattered electrons travel almost immediately to the adjacent anode 12 or 112. The ionizing collisions between the orbiting electrons and the gas molecules produce additional free electrons which do not generally travel in orbits, but rather travel directly to the adjacent anode 12 or 112.

The large diameter of the first anode 12 causes it to act as a filter to prevent non-orbiting electrons and electrons with relatively poor orbits from traveling to or around the second anode or collector 112. Some of the electrons emitted by the filament 42 travel directly to the first anode 12. Very few of these non-orbiting electrons are able to travel to the second anode 12, due to the large diameter and length of the first anode 12.

Some of the electrons from the filament 42 are initially introduced into poor orbits which are quite elliptical, rather than being circular or nearly so. Most of these electrons with poor orbits do not travel through a sufficient number of revolutions around the first anode 12 to reach the second anode 112, but rather are captured by the first anode 12. Thus, nearly all of the orbiting electrons which spiral around the second anode or collector 112 have good orbits which are circular or nearly so. Very few of these orbiting electrons are captured by the second anode 112 unless they collide with gas molecules. There is nothing around the second anode 112, other than the gas molecules, to disturb the orbits of the electrons. Thus, the current to the second anode 112 is almost entirely indicative of the scattering of the orbiting electrons by the gas molecules. Thus, the current to the second anode 112 varies as a direct function of the pressure in space within the gauge.

The large diameter of the second anode 112 insures that substantially all of the scattered electrons will be captured by the second anode, rather than continuing to travel in modified orbits around the second anode. Due to the large size of the second anode 112, only electrons with
good orbits can continue to travel around the second anode. Normally, the collisions between the orbiting electrons and the gas molecules disturb the orbits of the electrons sufficiently so that the electrons travel almost immediately to the second anode 112.

In the present gauge, the radius of each of the anodes 12 and 112 is so large as to be of the same general order of magnitude as the radial distance between the filament 42 and the axis of the first anode 12. As illustrated, the radius of the anodes is approximately one-half the radial distance between the axis and the filament 42. This is in contrast with prior orbitron gauges, in which it was the practice to make the anode of small diameter, usually in the form of a fine wire. Such small anodes permit even poorly orbiting electrons to travel through a large number of revolutions. The large diameter anodes of the present vacuum gauge have the effect of causing such poorly orbiting electrons to be captured almost immediately by the anodes.

The current to the first anode 12 is largely background current which is substantially independent of the pressure in the gauge. Such background current is due to the non-orbiting electrons and the poorly orbiting electrons which are captured by the first anode. The first anode 12 should be long enough and large enough in diameter to prevent any substantial number of these non-orbiting electrons and poorly orbiting electrons from traveling to the second anode 112.

The current to the second anode 112 involves very little background current, but represents almost entirely the current due to the scattering of the orbiting electrons by the gas molecules around the second anode. Thus, the second anode current is substantially a direct function of the pressure within the gauge. It will be evident that the construction of the gauge is such as to bring about a high degree of separation between the background current and the second anode.

Some additional factors produce background current to the first anode 12, but these factors produce very little background current to the second anode 112. The light emitted by the filament 42 produces some photo-electric emission of secondary electrons by the boundary electrode 14, but most of the secondary electrons travel directly to the first anode 12, because the emission of the secondary electrons is largely concentrated in the region near the filament 42, where the light is most intense. Very few of these secondary electrons are attracted to the second anode 112, due to the remoteness of the second anode from the filament 42. To reduce the amount of light, the filament is preferably oxide coated so that it will emit electrons at a low temperature. The filament may be coated with thorium oxide and various other oxides.

Some X-rays are produced by the impact of the electrons against the anodes 12 and 112. However, the production of X-rays is very low due to the low anode voltage. Moreover, most of the X-rays are emitted from the portion of the first anode 12 close to the filament 42. These X-rays also tend to produce photo-electric emission of the secondary electrons from the boundary electrode 14, but most of the secondary electrons are attracted directly to the first anode 12. The scattered electrons which are attracted to the second anode 112 produce some X-rays, which in turn cause the photo-electric emission of some secondary electrons from the boundary electrode 14, but these secondary electrons merely augment the scattered electron current to the second anode 112, so that the secondary electron current is proportional to pressure, rather than being a background current.

The length of the second anode 112 is important, because the scattered electron current to the second anode is directly proportional to the length of the second anode. Thus, it is preferred to make the vacuum gauge long enough to provide for a relatively long second anode.

Some of the orbiting electrons spiral back along the second anode 112 and the first anode 12 with undisturbed orbits. Many of these electrons are again reflected at the upper end of the first anode 12 by the configuration of the electric field between the anode 12 and the terminating sleeve 70. These reflected electrons may again travel downwardly along the first anode 12 and the second anode 112.

The orbits of some of the electrons may be disturbed by the presence of the filament 42. If the orbits are disturbed to any great extent, the electrons will be attracted to the first anode 12, so that only electrons with good orbits will again be able to spiral downwardly around the second anode or collector 112.

FIGS. 2–4 illustrate further details of the ribbon filament 42, whereby the electrons are introduced into orbits with improved efficiency. In accordance with this improved construction, a highly emissive zone 130 is provided on the outer side of each of the longitudinal legs 44 and 46. As shown, the zones 130 are rectangular in shape and are somewhat smaller in cross-section than the surrounding legs 44 and 46. Thus, the edges of the zones 130 are spaced inwardly from the edges of the corresponding legs. Preferably, the zones 130 are thoriated, which has the effect of rendering them highly emissive at a lower temperature than would be the case for the unthoriated metal of the filament. It will be understood that the filament 42 is made of a material which will withstand extremely high temperatures, so that the filament may be heated to an electron-emitting temperature by the electric current which is caused to pass through the filament. Thus, the filament may be made of iridium, tungsten, platinum or other metals or alloys having high melting points.

The zones 130 may be thoriated by applying a thin coating of thorium oxide to the filament over the desired areas. When the filament is heated in the vacuum space within the gauge, some or all of the thorium oxide is reduced to produce a highly emissive coating of thorium. It will be understood that other highly emissive oxides or other materials may be employed in the zones 130. For clarity of illustration, the thickness of the thoriated coating is greatly exaggerated in FIGS. 3 and 4.

The thoriated filament is operated at a much lower temperature than would be the case for an unthoriated filament. The operating temperature of the thoriated filament is such that electrons are copiously emitted from the thoriated zones 130 but not from the unthoriated portions of the filament. Thus, most of the electrons emitted by the filament 42 are emitted from the thoriated zones 130. The location of the thoriated zones 130 is such as to produce the maximum efficiency in the introduction of the electrons into orbits around the central anode 12. Thus, virtually all of the electrons emitted from the thoriated zones 130 are given initial directions of movement transverse to the outer surfaces of the legs 44 and 46. A high percentage of these electrons are given sufficient initial angular momentum to go into good orbits around the central anode 12. Because the emitted coatings in the thoriated zones are extremely thin, only a small percentage of electrons are emitted radially toward the central anode 12. Thus, the inward movement of electrons, directly to the anode 12, is minimized. While the improved filament construction of FIGS. 2–4 is illustrated in connection with the present orbitron vacuum gauge, it will be understood that such filament construction is applicable to orbitron devices generally.

The provision of the thoriated zones 130 virtually eliminates the emission of electrons from the bare metal portions of the filament 42. Thus, the emitted electrons are largely eliminated from the edges and inner surfaces of the legs 44 and 46, and also from the curved portion 48. By confining the emission of electrons to the zones 130, which represent the most favorable areas of the filament, a much higher percentage of the emitted electrons are introduced into good orbits around the central anode.
FIG. 5 illustrates a modified filament construction, in which the thoriated zones or coatings 130 are recessed into shallow channels 134 formed in the corresponding legs 44 and 46. The channels 134 may be embossed or otherwise formed on the outer sides of the legs 44 and 46.

The modified construction of FIG. 5 has the advantage that the edges of the thoriated zones 130 are recessed into the legs 44 and 46, rather than being exposed, so that the emission of electrons from the edges is eliminated. A further improvement in the orbiting efficiency of the filament is thus achieved, inasmuch as the electrons emitted by the edges of the emissive zones tend to travel directly to the central anode 12 without going into orbits.

FIG. 6 illustrates another modified construction in which the highly emissive zone 130 is provided on only one of the legs 44 and 46 of the ribbon filament 42. As shown, the highly emissive zone 130 is provided on the leg 46. Thus, virtually all of the electrons emitted by the ribbon filament 42 are emitted from the leg 46. This construction has the advantage that virtually all of the orbiting electrons will travel in the same direction of rotation around the anodes 12 and 112. Collisions or impacts between different electrons are thereby minimized. Such electron-electron collisions will occur more frequently when the electrons are orbiting in both directions of rotation. Collisions or impacts between the orbiting electrons cause scattering of the electrons, so that the orbits of the electrons are disturbed. The scattered electrons tend to be attracted to the anodes 12 and 112. Such scattering of the electrons due to impacts with other electrons tends to produce a small background current to the second anode or collector 112. This background current is virtually eliminated by causing all of the orbiting electrons to travel in the same direction of rotation.

FIG. 7 illustrates still another modified construction in which the ribbon filament 42 is replaced with a filament construction as disclosed and claimed in the above-mentioned Herb and Pauly Patent No. 3,244,969. Thus, the construction of FIG. 7 employs a thermionic filament in the form of a fine wire 142 which preferably is parallel to the axis of the central anode 12. The illustrated filament 142 is opposite the lower end of the terminating electrode 70. The opposite ends of the filament 142 are connected to the lead-in wires 50 and 52. To increase the efficiency with which the electrons are introduced into orbits around the central anode 12, the lead-in wire 50 is arranged so that it has a portion 44 disposed between the filament 142 and the central anode 12. The portion 144 acts as a shield or deflector to minimize the direct movement of the non-orbiting electrons between the filament and the central anode 12. Moreover, the provision of the shield portion or member 144 modifies the electric field around the filament 142 so that a higher percentage of the electrons are introduced into good orbits around the central anode 12.

FIG. 7 also illustrates an abrupt transition between the central anode 12 and the reduced end portion 26. Thus, an end disc or wall 150 is provided between the tubular anode 12 and the tubular end portion 26.

FIG. 8 illustrates another modified construction, utilizing a second anode or collector 212 which is smaller in diameter than the first anode or filter 12. A stepped insulating bushing 228 is employed to provide mechanical support between the anodes 12 and 212. The smaller second anode or collector 212 tends to increase the filtering action of the first anode 12, so as to reduce the background current to the second anode 212 to an even lower level than is obtained with the construction of FIG. 1. Only those electrons with good orbits of circular or nearly circular shape can spiral downwardly to the end of the first anode or filter 12 without being captured by the first anode. These spiraling electrons continue to spiral downwardly around the second anode or collector 212. The orbits of these electrons, being good enough to avoid capture by the first anode 12, are better than good enough to avoid capture by the second anode or collector 212. Thus, virtually none of the orbiting electrons will be captured by the collector 212, unless the orbits of electrons are spoiled by collision with gas molecules. Although the diameter of the second anode or collector 212 is smaller than that of the first anode 12, to improve the filtering action, the diameter of the collector 212 is still large enough to insure that virtually all of the electrons which are scattered by collisions with gas molecules, opposite the collector, will be captured by the collector.

Various other modifications, alternative constructions, and equivalents may be employed without departing from the true spirit and scope of the invention, as exemplified in the foregoing description and defined in the following claims.

I claim:
1. In an electronic vacuum gauge, the combination comprising a central generally cylindrical electrode, a boundary electrode spaced outwardly from said central electrode, means forming an enclosure for connecting the interior of said boundary electrode to a vacuum system, means for impressing a positive voltage between said central electrode and said boundary electrode to produce a generally cylindrical electric field therebetween, means for introducing electrons into said field with initial angular momentum so that the electrons will travel in spiral orbits around said central electrode, a second central electrode aligned axially with said first mentioned central electrode, means for impressing a positive voltage between said second electrode and said boundary electrode, and means for measuring the electron current from said second central electrode, said current affording an indication of the subatmospheric pressure in said enclosure.
2. A combination according to claim 1, in which said means for introducing electrons are disposed toward one end of said first central electrode, and in which said second central electrode is disposed adjacent the opposite end of said first central electrode and remote from said last mentioned means.
3. A combination according to claim 1, in which said means for impressing a positive voltage are constructed and arranged to supply a low voltage less than the ionization voltage of the gas molecules in said enclosure so that the orbiting electrons do not ionize the gas molecules when they collide therewith but are disturbed from their orbits so as to travel to said central electrodes.
4. A combination according to claim 1, in which said means for introducing electrons comprise a thermionic filament.
5. A combination according to claim 1, in which said means for introducing electrons comprise a thermionic filament in the form of a flat ribbon disposed edgewise toward said first central electrode.
6. A combination according to claim 1, in which said means for introducing electrons comprise a thermionic filament in the form of a U-shaped ribbon disposed edgewise toward said first central electrode, said U-shaped ribbon having outer surfaces with zones of high emission thereon.
7. A combination according to claim 1, in which said first central electrode is formed with a main portion of relatively large diameter and a reduced end portion adjacent said means for introducing electrons.
8. A combination according to claim 7, in which said first central electrode has a smoothly
11. A combination according to claim 1, in which said second central electrode has a principal portion of relatively large diameter and a reduced terminal portion remote from said first central electrode.

10. A combination according to claim 9, in which said second central electrode has a smoothly flaring portion between said reduced terminal portion and said principal portion.

11. A combination according to claim 1, in which said first and second electrodes have main portions of relatively large diameter and reduced end portions, said reduced end portion of said second central electrode being remote from said reduced end portion of said first central electrode.

12. A combination according to claim 11, in which said first and second central electrodes have flaring portions between said reduced end portions and said main portions.

13. In an electronic device, the combination comprising a first generally cylindrical central electrode, a boundary electrode spaced outwardly from said first central electrode means forming an enclosure for connecting the interior of said boundary electrode to a vacuum system to be tested, said first central electrode being adapted to be charged with a positive voltage relative to said boundary electrode to produce a generally cylindrical electric field therebetween, electron source means disposed between said first central electrode and said boundary electrode for introducing electrons therebetween with initial angular momentum about said central electrode so that the electrons will travel in spiral orbits around said central electrode, a second generally cylindrical central electrode disposed within said boundary electrode and in axially aligned relation to said first central electrode, said second central electrode being adapted to be charged with a positive voltage so that the orbiting electrons will travel around said second central electrode, means for insulating said second central electrode from said first central electrode, and means for establishing an external connection to said second central electrode separately from said first central electrode whereby the electron current to said second electrode may be measured separately as an indication of the remaining pressure in said enclosure.

14. A combination according to claim 13, in which said second central electrode is disposed remotely from said electron source means.

15. A combination according to claim 13, in which said electron source means comprise a thermionic filament disposed toward one end of said first central electrode, said second central electrode being adjacent the opposite end of said first central electrode and remote from said thermionic filament.

16. A combination according to claim 13, in which said first and second central electrodes have main portions of relatively large diameter and reduced end portions at the remote ends of said electrodes.

17. A combination according to claim 16, in which said electron source means comprise a thermionic filament disposed adjacent said reduced end portion of said first central electrode.

18. A combination according to claim 13, in which said first generally cylindrical central electrode has a large radius such that the radius thereof is of the same general order of magnitude as the radial distance between the axis of said first central electrode and said electron source means.

19. A combination according to claim 13, in which said second generally cylindrical central electrode has a large radius such that the radius thereof is comparable to the radial distance between the axis of said first central electrode and said electron source means.

20. A combination according to claim 13, in which said first and second generally cylindrical central electrodes are of large diameter such that the radius thereof are comparable to the radial distance between said electron source means and the axis of said first central electrode.

21. A combination according to claim 13, in which said electron source means comprise an elongated thermionic filament disposed generally parallel to said first central electrode and toward the end thereof remote from said second central electrode, and an elongated shield member generally parallel to said filament and disposed between said filament and said first central electrode.

22. A combination according to claim 13, in which said second generally cylindrical central electrode is of reduced diameter relative to said first central electrode.

References Cited

UNITED STATES PATENTS

3,244,969 5/1966 Herb et al. 324—33
3,588,290 6/1971 Herb et al. 315—108

RUDOLPH V. ROLINEC, Primary Examiner.
C. F. ROBERTS, Assistant Examiner.

U.S. Cl. X.R.

313—7