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GAS DISCHARGE PROTECTOR FOR VACUUM SYSTEMS

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FIG. 1

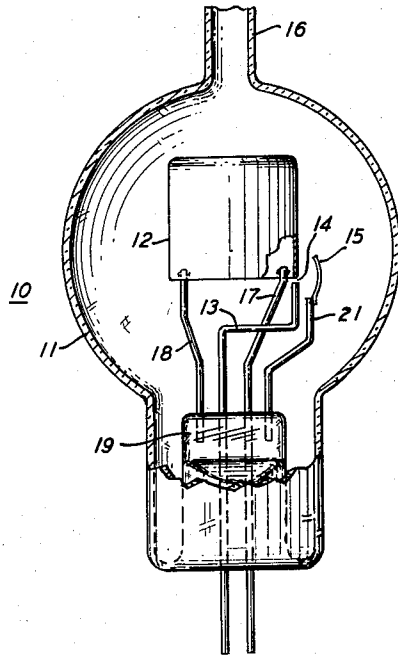
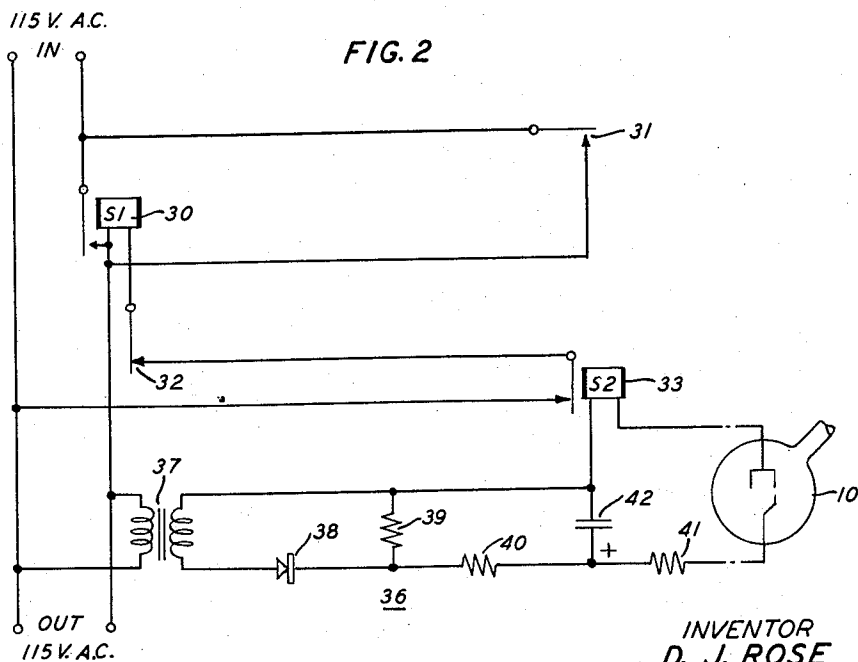


FIG. 2



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1

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GAS DISCHARGE PROTECTOR FOR VACUUM SYSTEMS

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This invention relates to gaseous discharge devices and more particularly to such devices for vacuum system protection and to the associated circuitry therefor.

Vacuum protector devices have been employed in the past and have, in general, consisted primarily of a pressure sensitive device, such as an ionization manometer, which supplies current to a meter which indicates the pressure. Generally, the meter has various scales to set the upper limit of loss of vacuum or pressure through the use of a contact at the upper limit of the meter scale. If the meter runs off scale, the circuit is cut off through this contact. Such a device has three inherent disadvantages. First, the manometer and ion current amplifier generally used in such arrangements must be left on continuously which may not be desirable. Second, the meter has many scales which often necessitates turning off the power of the circuit while switching scales. Third, the time lag may be a considerable fraction of a second which is too long to prevent excessive damage to the filament of the ionization manometer or to other sensitive equipment in the vacuum system. This time lag is of considerable consequence especially in such devices as ionization manometers inasmuch as a loss of vacuum sufficient to initiate a sudden arc discharge will damage the cathode of the manometer through sputtering or burn-out of the filament or both, before the meter swings off scale to actuate the control circuit.

Accordingly, it is an object of this invention to eliminate the necessity of operating current amplifiers continuously or switching the power off to change pressure scales by the use of a vacuum pressure device which operates independently of the other components in the vacuum system, and which is not itself damaged by loss of vacuum.

It is another object of this invention to materially decrease the time lag between loss of vacuum and actuation of a control circuit in a vacuum system through the use of a fast acting vacuum protector device.

It is still another object of this invention to protect vacuum systems and associated equipment from damage resulting from loss of vacuum by a single device which is sensitive to changes in vacuum pressure over a very wide range.

It is a still further object of this invention to provide a new and improved gaseous discharge device which can break down at the same voltage for a wide range of gas pressures and which can provide an adequate discharge current over this wide range of pressures.

In accordance with one specific illustrative embodiment of my invention, there is provided a gas discharge tube comprising within an envelope a cathode and an anode defining a discharge gap of varying length. The interior of the envelope communicates directly with the vacuum

2

system to be protected, so that a change in pressure within the system produces a corresponding change in pressure within the tube envelope.

In accordance with aspects of my invention, I provide a novel gas tube structure to obtain breakdown between the cathode and the anode over an exceedingly wide range of pressures for a substantially constant applied voltage and also to obtain sufficient current even at low pressures to operate the associated circuitry. Specifically, I arrange my anode and cathode so that the discharge can break down at different distances dependent on the pressure as the discharge, for a given voltage, will break down such that the pressure-distance product remains approximately constant.

Accordingly, in one specific illustrative embodiment I provide a wire anode and a cup-shaped hollow cathode. If we consider the anode characteristics alone first, a discussion of the cathode following below, the anode has its free end directly adjacent the edge of the cathode rim at one point, being either directly opposite the cathode rim or slightly within the cathode hollow. At very high pressures, as of atmospheric pressure which might be present if, by mistake, the operator turned on the equipment and ionization manometer without first evacuating the system, breakdown occurs in this very small gap. Further, because of the pressure the breakdown will result in a large current from a restricted discharge between the cathode rim and the anode wire end.

When the pressure at which breakdown occurs is less, the breakdown will occur progressively farther away from the end of the anode wire. Accordingly, I arrange the anode wire so that the end is directly adjacent the edge of the hollow cathode but that the end portion of the wire itself extends away from the cathode and, specifically in this one embodiment, is perpendicular to the rim of the cathode.

I have found that the anode wire preferably should have a portion directly opposite the cathode in order to take full advantage of the hollow cathode effect of the cathode structure. At relatively high pressures sufficient current is present in the discharge to actuate external circuitry even though the discharge is limited to a small cathode area. At very low pressures, however, for a flat or normal cathode the current would be exceedingly small; in fact, as is known, the current for a flat cathode is proportional to the square of the pressure. Accordingly, in a specific embodiment of my invention I employ a hollow cathode which, as is known in the art, can provide a large current even at low pressures. For optimum employment of the hollow cathode effect, in accordance with an aspect of my invention, I position a portion of the anode wire across the mouth of the hollow or cup-shaped cathode and at a distance from the cathode determined by the desired characteristics of the hollow cathode discharge.

The other end of the anode wire then extends away from the cathode and from the portion of the anode wire directly opposite the cathode. In operation, breakdown will occur at any portion of the wire as determined by the pressure increase in the tube. If the breakdown is at a high pressure, the discharge will sustain between the end of the anode and isolated points on the cathode; however, if the discharge is at a low pressure, the glow will spread along the anode wire from the point of breakdown so that the discharge is between the middle section of the anode directly opposite the mouth of the cathode and the hollow portion of the cathode itself.

In this manner, in accordance with my invention, breakdown can be effected for a very wide range of pressures and the discharge can be maintained sufficient to operate external circuitry. Accordingly, only a single gas tube in accordance with my invention need be employed to protect against any deleterious increase in pressure from a very low value to atmospheric.

It is one feature of my invention that a cup shaped or hollow cathode and an anode wire together define a discharge gap of varying size. A radioactive material is advantageously placed in close proximity to a portion of the gap so that the discharge across the gap is substantially instantaneous.

It is another feature of this invention that the anode have one end portion adjacent the rim of the hollow cathode, an intermediate portion removed from the cathode and extending across the mouth of the hollow cathode, and a third portion extending both from the intermediate portion and farther away from the cathode, the shape of the anode and cathode thereby allowing the resulting discharge to take place over a wide range of pressure variations.

Another feature of this invention relates to the incorporation of this device in a control circuit which, upon receiving the discharge current from the protector device, actuates suitable switching circuitry that turns the power off to both the protector device and the protected vacuum system within the first succeeding half cycle of an applied alternating voltage to the control circuit.

A complete understanding of this invention and of these and other features thereof may be gained by the following detailed description with reference to the accompanying drawing, in which:

Fig. 1 is a side view of a gas discharge protector tube illustrative of one specific embodiment of my invention, portions of the envelope being broken away; and

Fig. 2 is a schematic representation of a control circuit of the type in which a gas discharge protector tube in accordance with my invention is used.

Referring now more particularly to the drawing, a specific embodiment of the vacuum protector device of my invention is depicted in Fig. 1 and comprises a gas discharge protector tube 10 having an evacuated or partially evacuated envelope 11 of glass or other suitable material, a hollow cup-shaped cathode 12 of Kovar or other suitable conducting material, a wire anode 13, a radioactive foil 15 with the active side facing the cathode and anode, and an elongated hollow stem 16. The wire anode 13 may be considered to be substantially L-shaped and to be so positioned that its free end defines a very small discharge gap 14 with the edge or rim of the cathode cylinder 12; the radioactive foil is positioned so that the active side faces this gap 14. Because of the shape of the anode wire 13 and the cathode 12, different breakdown gaps are defined between the two electrodes, depending on the pressure within the envelope causing the device to break down.

While the cathode 12 is illustrated as being cup-shaped, other hollow or cylindrically-shaped cathodes can be utilized in practice. The purpose of the substantially hollow-shaped cathode is to provide what is commonly referred to in the art as a hollow type of glow discharge. In this mode, the discharge current can be much higher than is obtainable with flat or wire cathodes and assures that sufficient current will be obtained at even low pressures, to operate a sensitive control relay. The cathode 12 is supported at two points on the rim, at one point by the cathode potential lead 17 and at the other point by a support member 18 extending from a nonconductive mounting base 19. A support member 21 attached to the mounting base 19 effectively supports and isolates the radioactive foil 15 from the cathode circuit.

In accordance with a feature of this invention, the anode wire 13 extends toward a spot on the rim of the cup-shaped cathode 12. More specifically, the anode

wire in this specific illustrative embodiment resembles two inverted L-shaped members with one leg of each member attached in a collinear fashion, though other wire anode shapes can be employed to afford the same operation. The varying distance between the cathode and different points on the anode provides a discharge path suitable for breakdown of the gas over a wide range of vacuum pressures.

Advantageously, as is known in the art, the thinner the anode wire, the lower will be the breakdown pressure; thus, fragility of the anode wire is the primary factor which determines the lower limit of breakdown pressure for a cathode-anode structure designed in accordance with the principles of this invention.

The minimum breakdown voltage and effective range for reliable and uniform voltage versus pressure-distance (p.d.) characteristics will depend primarily upon such factors as the physical size of the various tube elements, the spacing of the elements and in particular the discharge gap, the voltages applied between the cathode and anode, and the type of radioactive foil used. For purposes of illustration, and by way of example only, the minimum breakdown potential can be 320 volts at a pressure of 0.5 mm. Hg if the gas is air. This, of course, can vary somewhat depending upon the condition of the cathode in a given tube. As is well known in the art, and as exemplified by a typical voltage versus p.d. curve for such an electrode arrangement, the voltage rises rapidly below a limiting lower pressure and very gradually for higher pressures. In practice, I have found that a typical but by no means critical potential of 900 volts applied between the cathode and anode is advantageously above the breakdown potential for any pressure between 0.05 mm. Hg and one atmosphere. Accordingly, a direct-current voltage of substantially 900 volts may advantageously be applied across the anode and cathode from the alternating-current line and associated rectifier when the line is closed, as discussed below with reference to Fig. 2.

The hollow cathode design insures that there will be sufficient current at the low pressure to operate a sensitive relay. At the higher pressure, current is no problem, and the discharge operates between spots on the cathode and wire anode. As previously mentioned by the anode wire extending toward the hollow cathode in a manner which provides a variable distance between anode and cathode, reliable and uniform pressure-distance characteristics are assured over a wide range of pressure. I have found that a radioactive foil 0.05 inch wide having a strength of 2.5 microcuries is sufficient to substantially eliminate the breakdown delay for all practical purposes except at very high pressure near one atmosphere. In that case, only the very small gap can break down and there is correspondingly lower probability of finding an ion there at the right instant. However, in the normal application this is no problem, because if air or other gas is admitted, the large volume of gas breaks down practically instantaneously as the pressure starts to rise above 0.06 mm. Hg.

Advantageously, the tube may be constructed as a separate entity to protect any vacuum system or it may be attached to either the high vacuum or fore-vacuum side of a vacuum system. The fore-vacuum side refers to the region between the mechanical pump and a high vacuum diffusion pump.

Fig. 2 illustrates schematically a control circuit for use with my vacuum protector device. This circuit comprises a 115 volt alternating-current supply line with the input and output of this line as designated, a normally open relay 30 energized by push button 31 is connected across the supply line through a normally closed push button 32, and the normally closed relay 33. A vacuum protector tube 10, in accordance with this invention, is placed across a half-wave rectifier circuit 36 including a step-up transformer 37, rectifier 38, resistors 39, 40 and

41, and a condenser 42. As readily seen from the circuit diagram, relay 33 is in series with the protector tube and when energized upon receiving a discharge current opens the circuit which energizes relay 30.

In operation, the field coil of relay 30 is energized with push button 31, and thus is closed. If the discharge tube fires, relay 33 opens, thus opening relay 30, turning off all power. The direct-current circuit may be grounded at some point if desired. In a preferred embodiment, and by way of example, relay 33 was chosen to operate at 2 milliamperes or more in a time of a few milliseconds. The current requirements of the relay are small. The resistors 39, 40 and 41 were chosen to give an initial discharge current of about 8 milliamperes and a steady current of approximately 4 milliamperes. The condenser 42 was chosen such that it would store sufficient energy itself to operate the relay and to maintain the anode-cathode voltage substantially constant. The turn-off time is determined in such a circuit principally by the alternating-current relay 30. With the choice of suitable components, in accordance with the principles of this invention, relay 30 will open in the first half-cycle following initiation of the discharge.

In order to better understand the advantages and protective features which are characteristic of the composite protective system described above, I shall briefly illustrate, by way of example, a typical application wherein my vacuum protector system is particularly well suited.

Envisage a vacuum system wherein my gas discharge protector tube is coupled to the high vacuum side of a vacuum pump together with a sensitive ionization manometer. Also, consider that the protector tube has illustrative operating characteristics similar to those described above for this particular embodiment. If the vacuum pump is turned on and working properly, a vacuum considerably below 0.06 mm. Hg, assumed to be the lower pressure limit defined by a breakdown potential of 900 volts, will exist. Accordingly, since the protector tube will not discharge at a pressure below 0.06 mm. Hg, by pressing the "on" button of the control circuit a voltage source will be established at the output terminals for the circuitry associated with the ionization manometer.

If the external vacuum system, namely, the ionization manometer, should experience a gradual loss in vacuum for any reason after initially being turned on, the protector tube having the operating characteristics described above, would detect the loss of vacuum and would discharge practically instantaneously as the pressure rose above 0.06 mm. Hg. The discharge would take place between outer portions of the anode wire and the hollow portion of the cathode at a distance which satisfies the requirement that the pressure-distance product remains substantially constant. At the lowest pressures of operation the discharge would break down to a portion of the anode wire 13 directly adjacent the base 19. The discharge current established by the utilization of a hollow cathode would be sufficient to energize the two control relays 30 and 33 depicted in Fig. 2, which would turn the power off to both the external circuit and the protector tube.

Lastly, we shall consider what would happen if the external vacuum system should be subjected to a very high pressure, say near one atmosphere, if, by mistake, the operator attempted to turn on the control circuit so as to apply power to the external ionization manometer without first having turned on the vacuum pump to evacuate the system. By pushing the "on" button of the control circuit under this condition, a breakdown potential would immediately exist across the shortest path between the anode and cathode, since it would be near the maximum pressure limit for a breakdown potential of 900 volts assumed herein, and a discharge would develop almost instantaneously between spots on or near the rim of the cathode and the end of the anode wire. Sufficient current would be developed by the discharge to energize

the control relays for turning off the power in the same manner as described above.

Advantageously, with the protector tube operating in the pressure range from approximately 0.06 mm. Hg to one atmosphere, it may also be attached to the fore-vacuum side of the vacuum pump with equal effectiveness, as this side of the vacuum system is usually well under the minimum breakdown pressure of 0.06 mm. Hg when the pump is in operation.

It is to be understood that the specific embodiments described are merely illustrative of the general principles of the present invention. Various other arrangements may be devised in the light of this disclosure by one skilled in the art without departing from the spirit and scope of this invention.

What is claimed is:

1. A gaseous discharge device comprising an envelope, a gaseous atmosphere within said envelope, an open-ended hollow cathode, a wire anode having one end directly adjacent a point at the rim of said cathode, said anode wire extending away from said rim and having a portion extending across the open hollow of said cathode whereby breakdown may occur between said anode and cathode at various points along said anode wire dependent on the pressure of the gaseous atmosphere in said envelope and the discharge may sustain between distinct points on said cathode and said anode wire end for high pressures and between the hollow of said cathode and said anode portion extending across said hollow for low pressures, and means within said envelope for eliminating breakdown delay on breakdown of a discharge between said anode and cathode.

2. A gaseous discharge device in accordance with claim 1 wherein said last-mentioned means comprises a foil of a radioactive material positioned directly adjacent the breakdown gap between said anode wire end and said point at the rim of said cathode, the active side of said foil facing said gap.

3. A gas discharge device comprising an envelope and a cup-shaped cathode and an anode within said envelope, said anode having a first wire portion extending towards said cathode with its free end in close proximity to the rim of said cathode at one point, a second middle section extending across the mount of said cup-shaped cathode at least a distance equal to the radius of said cathode, and a third section extending from said middle section away from said cathode, whereby distinct breakdown discharge paths exist between said cathode and said anode dependent on the pressure in said device.

4. A gas discharge device, in accordance with claim 3, wherein said anode is an integral wire.

5. A gas discharge device, in accordance with claim 4, wherein said second anode wire section extends normal to the axis of said cup-shaped cathode and said first and second wire anode sections are perpendicular to and extend in opposite directions from said middle section.

6. A gas discharge protector device comprising an envelope, a gaseous atmosphere within said envelope, a cup-shaped cathode, an anode having its terminus positioned in close proximity to the rim of said cathode at one point, the point on said rim and said anode terminus defining a high pressure discharge gap therebetween, said anode including at least three distinct segments providing discharge gaps of varying length between said anode and said cathode at various points along the segments of said anode dependent on the pressure of the gaseous atmosphere within said envelope, a first one of said segments extending toward the open end of said cathode with its terminus in close proximity to the rim of said cathode at said one point, a second segment extending from said first segment in a direction normal with respect to the axis of said cathode and parallel to a plane defined by the opened circular rim of said cathode, and a third segment extending away from said cathode, a radioactive material posi-

tioned directly adjacent the high pressure discharge gap between said anode terminus and said adjacent point at the rim of said cathode, the active side of said material facing said gap for eliminating breakdown delay on breakdown discharge between said anode and said cathode, and means for applying a vacuum pressure to said discharge device, said means including a hollow stem protruding outward from the envelope wall.

7. A gas discharge protector device, in accordance with claim 6, wherein said anode is an integral wire.

5

10

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