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(54) A METHOD AND APPARATUS FOR INSPECTING CONTAINERS OF INSULATING MATERIAL FOR DEFECTS

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The present invention relates to a method of and apparatus for inspecting for defects and more particularly, to a method of and apparatus for electrically detecting the presence of faulty sealed spots such as pin-holes and cracks in sealed containers of insulating material containing electrically conductive electrolyte or nonelectrolyte fluid, for example, ampoules or phials containing medicinal fluid therein.

In general, inspection for defects in sealed containers, for example ampoules of glass material containing therein sterilized medicinal fluids to preserve such fluids for a long period of time, constitutes an important process in the manufacturing of such sealed containers, since, if defects such as pin holes, cracks and the like be present is such sealed containers, various germs or bacteria may enter the interior of the containers together with atmospheric air through such pin holes or cracks, or the medicinal fluids contained in the sealed containers may exude or ooze out of the containers therethrough, thus making it impossible to use the medicinal fluids with safety.

Conventionally, there has been proposed one method of electrically inspecting for the presence of flaws in sealed glass containers such as ampoules of the above described kind containing therein electricallv conductive fluids, for example, by Japanese Patent laid-open publication Tokukaisho No. 45250/48, in which the glass container is passed between electrodes applied with AC high voltage, with the voltage being selected to be of such a value as will not develop sparking-over when the glass container is free from defects, but will produce sparking-over in the presence of pin holes or cracks in such a glass container. The sparking-over current is detected for testing the glass container for the above described defects.

In the prior art inspecting method as described above, one of the electrodes of the high voltage AC source is made to contact the glass container, while a spark gap is provided between the other of the electrodes and the portion of the glass container to be inspected so as to detect faulty sealed spots of the glass container whereat fluid contained therein has exuded onto the outer surface of the glass container by the presence of an abnormally high spark discharge current developed at the spark gap. The above described conventional inspecting method, however, has a disadvantage that, the spark discharge current developed at the spark gap on which the fault detection is based is very unstable and considerable time is required before the predetermined spark discharge takes place especially at an initial stage of the inspection, while, in some cases, spark discharge is not developed even when pin holes of the size of the order of several tens of microns are present in the glass container, thus resulting in failure to detect such faults, and thus it is difficult to effect fault detection with high accuracy. In order to improve the testing accuracy to overcome the above described inconveniences, it may be considered to raise the AC high voltage to such an extent that the spark discharge current is positively generated at the spark gap, in which case, however, since the energy of the spark discharge current is abnormally increased even if the spark discharge is produced without fail, there is a possibility that the glass container itself is destroyed thereby. Furthermore, when the spark discharge current is increased as a whole, the magnitude of the spark discharge current developed according to the presence of the pin holes in the glass container tends to be erroneously detected. Moreover, in the conventional method as described above, the flaws cannot be detected if nonelectrolyte fluids are contained in the glass container due to the insufficient testing accuracy.

Accordingly, an object of the present invention is to provide a method of electrically inspecting for the presence of defects in sealed containers and an apparatus employed therefor which are capable of accurately detecting faulty sealed spots in containers, such as ampoules, phials, milk bottles, paper containers or bottles, made of insulating material, such as glass, plastics or rubber containing therein electrically conductive electrolyte or nonelectrolyte fluids, for example water, water solution or distilled water having an electrical resistivity under 10 MΩ-cm, with alleviation of the disadvantages inherent in the conventional methods and apparatuses.

Another object of the present invention is to provide a method of electrically inspecting for the presence of defects in sealed containers as described above in which a container to be inspected is charged by DC high voltage from a high voltage DC source and the charging current developed thereby and/or the discharging current to neutralize the container is detected and the presence of flaws in the container is determined by way of the magnitudes and shapes of these currents or the difference therebetween, without employing a spark developed in a spark gap between an electrode connected to an high voltage AC source and portions of the container to be tested, as in the conventional methods.

According to one aspect of the present invention there is provided a method of inspecting for defects of flaws and emptiness in containers of insulating material filled with liquid, which comprises the steps of:

positioning a said container between first and second electrode members electrically connected to first and second terminals of a high voltage DC source, said DC source applying a voltage of first polarity to said first electrode member and a voltage of second polarity, opposite to the first polarity, to said second electrode member, said first electrode member being held in contact with a first portion of the container while said second electrode member is disposed adjacent and spaced a predetermined distance from a second portion to be tested of the container;

electrically charging the container by means of said DC source of discharging the container after charging thereof;

detecting the charging or discharging current; and

discriminating whether or not the detected current is approximately equal to a value detected for a container having no defects.

According to a further aspect of the present invention there is provided an apparatus for inspecting for defects of flaws and emptiness in containers of insulating material filled with liquid, said apparatus comprising;

a high voltage DC source having first and second terminals;

a first electrode member electrically connected to the first terminal of the DC source to be held in contact with a first outer surface portion of said container;

a second electrode member connected to the second terminal of the DC source and being disposed to confront a second outer surface portion to be tested of the container at a position spaced a predetermined distance therefrom to electrically charge and discharge the container;

means for detecting the charging or discharging current; and

means for discriminating whether or not the detected current is approximately equal to a value detected for a container having no defects.

An embodiment and modifications thereto of the present invention will now be described by way of example, reference being made to the accompanying drawings, in which:

Figure 1 is a schematic electrical diagram showing the construction of an apparatus for inspecting for defects according to one preferred embodiment of the present invention,

Figure 2 is an electrical diagram showing an equivalent circuit for the apparatus of Figure 1,

Figures 3(a) to 3(f) are similar views to Figure 1, but particularly illustrate functioning of the apparatus of Figure 1,

Figures 4(a) to 4(e) are wave forms of electric currents measured in the apparatus of Figure 1,

Figures 5 and 6 are views of respective modified versions of the apparatus of Figure 1,

Figure 7 is a view of a further modified version of the apparatus of Figure 1,

Figure 8 is a diagram showing characteristics of a vacuum tube employed in the apparatus of Figure 7, and

Figures 9 and 10 are similar views to Figure 1, but particularly show a further modification thereof.

Before the description of the present invention proceeds, it is to be noted that like parts are designated by like reference numerals throughout the several views of the accompanying drawings.

Referring now to the drawings, there is schematically shown in Figure 1 an electrical diagram of an apparatus for inspecting for defects, in which a body portion 1a of a container, for example an ampoule 1, to be inspected is placed on a cathode plate 2, while a head or neck portion 1b of the ampoule 1 is charged or discharged through an anode rod 3 and an auxiliary electrode rod 4 disposed adjacent to the neck portion 1b. The ampoule 1 is a sealed container of insulating material such as glass containing therein electrically conductive electrolyte or nonelectrolyte liquid, for example, medicinal fluid 5. The body portion 1a has a larger internal diameter than the neck portion 1b, and both portions 1a and 1b having approximately the same predetermined thickness. In Figure 1, the distal end of the neck portion 1b is assumed to be the portion to be inspected for flaws such a pin holes, cracks and the like. The anode rod 3 is connected to the plus or positive side of a high voltage DC source 6 having an output in the range from 0.1 to 10 and preferably in the range from 1 to 5 kilovolts (kV) per mm between the tip of the anode rod 3 and the tip of the auxiliary electrode rod 4, while the cathode plate 2 and the auxiliary rod 4 are connected to the minus or negative side of the same high voltage DC source 6 respectively through a measuring resistance 7 and a switch 8 as shown. The cathode plate 2 is a flat plate electrode, for example, of circular configuration which contacts the body portion la of the ampoule 1 through a large area, and is adapted to be held in contact with the ampoule 1 over substantially the entire surface of the plate 2 during testing in order to charge the ampoule 1 sufficiently. The anode rod 3 has a pointed tip, which is disposed a predetermined distance from the distal end of the neck portion 1b of the ampoule 1, for example a distance of 2 mm therefrom on the assumption that output of the DC high voltage source 6 is, for example, in the region from 20 to 24 KV, so that the neck portion 1b is charged through the electric field of the DC high voltage at the anode rod 3, but so that a spark is not normally produced between the anode rod 3 and the neck portion 1b. The auxiliary electrode rod 4 also has a pointed tip is disposed a predetermined distance, for example 1mm, from said neck portion 1b, and a predetermined distance, for example 10 mm, from the tip of the anode rod 3. When the switch 8 is off, the potential of the auxiliary electrode rod 4 is floating. However, when the switch 8 is on, connecting the auxiliary electrode rod 4 to the minus side of the high voltage DC source 6, a spark occurs between the auxiliary electrode 4 and the anode rod 3 simultaneously causing the neck portion 1b of the ampoule 1 to be discharged. The switch 8 should have sufficient capacity to withstand the high voltage of the DC source 6. A discriminator 9 is connected to opposite ends of the resistor 7, which is inserted between the cathode plate 2 and the minus side of the DC source 6 or ground, for detecting potential developed across the resistor 7 so as to detect the current flowing to and from the cathode plate 2. Although not shown in the drawings, the discriminator 9 may comprise a reference value setting circuit and emits an output depending on the values obtained by comparison of the input with a predetermined reference value set by the setting circuit.

It should be noted that if the shortest distances between the tip of the anode rod 3 and a detectable fault at the neck portion 1b, between the tip of the anode rod 3 and the tip of the auxiliary electrode rod 4 and between the tip of the auxiliary electrode rod 4 and a detectable fault at the neck portion 1b are represented by l1, l2 and l3 respectively, each of such distances l1, l2 and l3 should be 200 mm and under or preferably in the range from 0.1 to 30mm or most preferably in the range from 1 to 10mm.

It should also be noted here that the above mentioned detectable fault at the neck portion 1b means such a fault which is farthest from the tips of the anode rod 3 and the auxiliary electrode rod 4 and still within the range of detection by the apparatus.

The apparatus of the present invention as described above with reference to Figure 1 may be represented by an equivalent circuit as shown in Figure 2. In Figure 2, the ampoule 1 can be regarded as including a first capacitor C1 formed between the outer surface and the inner surface of the neck portion 1b, a resistance R1 formed by the fluid contained in the ampoule 1, and a second capacitor C2 formed between the outer surface and the inner surface of the body portion 1a of the ampoule 1, while the charging phenomenon by the anode rod 3 may be regarded as forming a third capacitor C3, the sparking phenomenon as forming a resistance R2, and the discharging phenomenon by the auxiliary electrode rod 4 as forming a resistance R3 connected in parallel to the third capacitor C3. Furthermore, in the case where the fluid contained in the ampoule 1 is leaking out of the same ampoule through defects therein as mentioned later, a leak resistance R4 connected in parallel to the first capacitor C1 may be regarded as present. The sparking resistance R2, third capacitor C3, first capacitor C1, fluid resistance R1 and second capacitor C2 as described above are sequentially connected in series between the high voltage DC source 6 and the detecting resistance 7.

Referring now to Figures 3(a) to 4(e), methods of inspecting for defects of an ampoule 1 by employing the apparatus of Figures 1 and 2 are described hereinbelow with reference to the cases where the ampoule 1 is free from defects, where a pin hole of 2μ and over is present in the ampoule, where the fluid contained in the ampoule is leaking out through a defect present in the ampoule, and where no fluid is contained in the ampoule.

In Figure 3(a), the ampoule 1 is first placed in the inspecting position, with the body portion 1a thereof being disposed on the cathode plate 2, and with the neck portion 1b to be tested being spaced apart from the anode rod 3 and the auxiliary electrode rod 4 by the distances mentioned above. With the above arrangement, when the voltage from the DC source 6 is applied between the anode rod 3 and the cathode plate 2 with the switch 8 turned off, charge, for example, positive charge is formed at the portion to be tested of the neck portion 1b of the ampoule 1 due to the electric field arising from the voltage on the anode rod 3 which voltage is not so great as to cause, intermittent sparking, as illustrated in Figure 4(a) between the anode rod 3 and the ampoule 1. The charging of the ampoule 1 is dependent on the contact area of the cathode plate 2 with the body portion 1a. At this time, the potential of the auxiliary electrode rod 4 is floating, since the switch 8 is off. After the ampoule 1 has been charged in the above described manner, the auxiliary electrode rod 4 is connected to the minus side of the DC source 6 by turning the switch 8 on whereby a spark discharge is developed between the anode rod 3 and the auxiliary electrode rod 4. Simultaneously, some of the electrons ejected from the auxiliary electrode rod 4 by the spark are attracted onto the outer surface of the portion to be tested of the ampoule 1 which was previously charged, and the ampoule 1 is discharged with consequent restoration of the ampoule 1 to the original state before the charging. At this time, a discharging current i_1 is caused to flow around the loop containing the auxiliary electrode rod 4, the resistor 7 the cathode plate 2 and the ampoule 1 and liquid therein, which current is detected by the discriminator 9. The discharging current i_1 normally reaches its maximum value immediately after initiation of the discharge by the auxiliary electrode 4, and subsequently decreases rapidly. In the state as described above, if the ampoule 1 is free from any defects, such as pin holes, and contains a predetermined amount of fluid, suppose that a discharging current i_1 of one Unit is caused to flow as shown in Figure 4(b). In the case where the ampoule 1 is empty without containing the predetermined amount of fluid therein, a discharging current i_5 of approximately half a Unit, half as shown in Figure 4(e) is caused to flow, due to an increased resistance R_1. Figure 3(f) illustrates the charge distribution in an empty ampoule. In the case where the fluid contained in the ampoule 1 is not leaking out onto the outer surface of the ampoule 1 despite the presence of a defect such as a pin hole of 2μ or over in the ampoule 1, a discharging current i_3 of approximately two Units or more is caused to flow, as shown in Figure 4(c), but if the fluid has been leaking out onto the outer surface of the ampoule 1, a spark is continuously developed between the anode rod 3 and the auxiliary electrode rod 4 through the leaking fluid 5, as seen from Figure 3(e), and a discharging current i_4 of approximately less than 0.9 units flows, as shown in Figure 4(d). Accordingly, it is possible to find out from the discriminator 9 whether the ampoule 1 is normal, or has a defect.

Subsequently, when the switch 8 is turned off and the auxiliary electrode rod 4 is disconnected from the DC source 6 so that the potential of the auxiliary electrode rod is floating, the same charge as described with reference to Figure 3(a) is again built up at the portion to be tested of the neck portion 1b of the ampoule 1 by the electric field arising from the voltage of the anode rod 3, in which case, a charging current i_2 as shown in Figure 4(b) is caused to flow from the cathode plate 2 to the DC source 6 and is processed by the discriminator 9. The charging current i_2 reaches the maximum value immediately after initiation of charging of the ampoule 1 and subsequently decreases rapidly. In the normal case where the ampoule 1 is free from such defects as pin holes and contains the predetermined amount of fluid 5, a charging current i_2 of one Unit approximately equal to the previous discharging current i_1 is caused to flow as shown in Figure 4(b). However when the ampoule 1 is empty, a charging current i_6 of approximately half a Unit, approximately equal to the previous discharging current i_5 flows, as shown in Figure 4(e). Accordingly, the discriminator 9 can determine on the basis of the set reference value and the size of the discharging current i_5 and/or the charging current i_6 as described above, whether the ampoule 1 is empty. Further, in the case where the fluid contained in the ampoule 1 has not leaked out onto the outer surface of the ampoule 1 despite the presence of a defect such as a pin-hole of 2μ and over in the ampoule, the amount of charge of the ampoule 1 is increased due to permeation of the fluid 5 into the defect as is seen from Figure 3(d) so as to cause a charging current i_3 of approximately more than 2 Units to flow. Therefore, the discriminator 9 can determine by comparing the amount of the above charging current with the set reference value, which may correspond to the charging current i_2 of a normal ampoule 1, whether the ampoule 1 is normal or has a pin-hole or the like of such an extent as will not allow conspicuous leakage of the fluid 5 therefrom. Furthermore, in the case where the ampoule 1 has a large fault which permits the leakage of fluid 5 onto the outer surface of the ampoule 1, even if the potential of the auxiliary electrode rod 4 is floating the sparking continuously takes place for some time thereafter in a similar manner as previously between the anode rod 3 and the neck portion 1b of the ampoule 1 through the fluid 5 leaking out onto the outer surface of the ampoule, thus causing a discharge current i_4 approximately less than 0.9 Units to flow continuously as shown in Figure 4(d). Accordingly, by comparing the amplitude or wave form of the charging or discharging current of an abnormal ampoule with that of a normal ampoule 1, the discriminator 9 can determine on the basis of the set reference values or set reference wave forms whether an ampoule 1 is normal or has such a defect through which fluid 5 has leaked out of the ampoule 1.

It should be noted here that it is possible to electrically inspect whether the ampoule 1 is normal or not through the inputs to the discriminator 9 developed by turning on and off of the switch 8. More specifically, predetermined reference values for discriminating the inputs to the discriminator 9 may be pre-set so that an output is developed therefrom when the ampoule 1 being tested is normal. For example, when the input value is higher than a reference value corresponding to an ampoule which is empty, and is simultaneously lower than a reference value corresponding to an ampoule having a pin-hole but no leakage, and when the integral of the value over a predetermined period of time is lower than a reference value corresponding to an ampoule having its fluid 5 leaking out, it is indicative that the ampoule is acceptable. Ampoules can therefore be automatically selected in an efficient manner.

In the inspecting methods of the present invention in the foregoing description, since the charging of the ampoule 1 and discharging of the auxiliary electrode rod 4 take place readily and positively under stable conditions, as compared with the conventional spark discharge method as mentioned earlier, ampoules can be inspected with improved accuracy, while since the current flowing through the ampoule 1 may be of such a small value as to be sufficient to cause the ampoule to be charged, the disadvantage in the conventional arrangements that the ampoules may be broken by the current flowing therethrough is advantageously eliminated, with simplification in construction or reduction in size of the inspecting apparatus on the whole.

The following Example is inserted for the purpose of illustrating the present invention, without any intention of limiting the scope thereof.

EXAMPLE

Container employed for inspection
Ampoule of glass material

Entire length:	55 mm
Length at neck portion:	23.5 mm
Diameter at neck portion :	5.1 mm
Thickness at neck portion:	0.3 mm
Length at body portion:	31.5 mm
Diameter at body portion:	12.5 mm
Thickness at body portion:	0.48 mm

Fluid contained: aqueous glucose solution having electrical resistivity of 1.50 KΩ-mm.

Anode rod: The anode rod was disposed at a space of 1 mm from the neck portion of the ampoule.

Auxiliary electrode rod: The auxiliary electrode rod was disposed at a distance of 10 mm from the anode rod.

Cathode plate: The cathode plate 23 mm × 20 mm in dimensions was disposed in close contact with the body portion of the ampoule to be inspected.

DC high voltage source; 24 kV

Results of measurements: A pin hole of 2μ located within 10 mm from tip of the neck portion of the ampoule was detected by an oscillograph. At each spark a voltage approximately three times as great as that for a normal ampoule was developed across resistor 7. For confirmation, the pin hole had preliminarily been measured with an optical microscope.

Referring to Figure 5 showing a modification of the apparatus of Figure 1 for inspecting for defects, the switch 8 described as connected in series with the auxiliary electrode rod 4 for selectively connecting and disconnecting the electrode rod 4 to and from the minus side of the DC source 6 in Figure 1 is dispensed with. The auxiliary electrode rod 4 described as disposed at a position adjacent to the neck portion 1b of the ampoule 1 in Figure 1 is replaced by a similar auxiliary electrode rod 4a which is secured, at one end thereof, to a rotatable shaft M1 of driving means, for example, a motor M for pivotal movement of the distal end of the rod 4a in directions shown by the arrow, between a position adjacent to the neck portion 1b and a position spaced away from said neck portion 1b. The cathode plate 2 in Figure 1 is also replaced by a pair of cathode plates 2a and 2b which hold the side of the ampoule 1 remote from the neck portion 1b therebetween through an increased contact area. By the arrangement as described above, since the distal end of the auxiliary electrode rod 4a is selectively brought into a position confronting the neck portion 1b and into a position spaced from the same neck portion 1b, a similar effect as using the switch 8 in the apparatus of Figure 1 can be expected.

Referring also to Figure 6, there is shown a further modification of the apparatus of Figure 1 for inspecting for defects. In the modified apparatus of Figure 6, which is arranged to inspect simultaneously a plurality of portions of the ampoule 1, the anode rod 3 having a pointed tip described as employed in the apparatus of Figure 1 is replaced by an anode plate 3′ of flat plate-like configuration, while the auxiliary electrode rod 4 and the switch 8 of Figure 1 are also replaced by auxiliary electrode rods 4′-1, 4′-2 and 4′-3, and respective switches 8′-1, 8′-2 and 8′-3. In addition the cathode plate 2 of Figure 1 is replaced by a cathode plate 2′ of flat plate-like shape which is held in contact with a bottom surface of the ampoule 1. The anode plate 3′ is formed, at its edge portion confronting the axial outer surface of the ampoule 1, into a configuration to conform with the external outline of the ampoule 1, with a minimum distance, for example, of 2 mm being provided between the outer surface of the ampoule 1 and the corresponding edge portion of the anode plate 3′. The extreme forward edge of the edge portion of the plate 3′ is made thin to be pointed toward the outer surface of the ampoule 1 so as to form an apparent needle-shaped electrode with respect to the corresponding auxiliary electrode rods 4′-1 to 4′-3. Each of the auxiliary electrodes 4′-1, 4′-2 and 4′-3 has its extreme end pointed, with the pointed ends thereof being spaced a distance, for example, of 1 mm from the ampoule 1, while the same pointed ends of the auxiliary electrode rods 4′-1 to 4′-3 are respectively spaced a distance, for example, of 10 mm from the anode plate 3′ and positioned to confront the plurality of portions to be tested of the ampoule 1. The switches 8′-1, 8′-2 and 8′-3 of the on-off type are respectively connected in series with the auxiliary electrode rods 4′-1, 4′-2 and 4′-3 for selectively connecting and disconnecting the latter to and from the minus side of the DC source 6. The cathode plate 2′ should preferably be spaced as far as posible from the anode plate 3′ and auxiliary electrode rods 4′-1 to 4′-3, while contacting the ampoule 1 over a large area, for example, approximately the entire bottom surface of the ampoule 1.

By the above arrangement, in the state where the switches 8′-1 to 8′-3 are all turned off, if either one of the switches 8′-1, 8′-2 and 8′-3 is turned on and off to obtain outputs from the discriminator 9, presence of a defect in the ampoule 1 at the portion thereof to be tested confronting the auxiliary electrode 4′ which is connected to the switch 8′ thus turned on and off can be detected in a similar manner as in the apparatus of Figure 1.

Other construction and functions of the apparatus of Figures 5 and 6 are similar to those in the apparatus of Figure 1, and therefore, detailed description thereof is abbreviated for brevity.

Referring to Figure 7, there is shown another modification of the apparatus of Figure 1 for inspecting for defects. In this modification, the switch 8 described as employed in the apparatus of Figure 1 is replaced by a small sized switch 8a and triode 10 capable of withstanding high voltage in a manner as described hereinbelow, with the anode rod 3 connected to the positive side of the DC source 6 through a resistor 3a. The high voltage resistant triode 10, for example, a GT tube of 6B54 type has its plate P connected to the auxiliary electrode rod 4 and its grid g to the negative side of a low voltage DC source 12 through the small sized switch 8a, while its cathode K is connected to the negative side of the high voltage DC source 6, and its heater h is coupled to a DC power source 11. It is to be noted here that since the triode 10 is capable of withstanding high voltage, for example over 30,000 volts, with its plate current Ip and grid to cathode voltage Eg being related as illustrated in the curve shown in Figure 8, the plate current Ip is reduced to zero and is not caused to flow, if the grid is coupled, for example, to −20 volts at the minus side of the low voltage DC source 12, while sufficient plate current Ip is allowed to flow when the grid to cathode voltage Eg is reduced to zero. The change-over of the grid to cathode voltage Eg between −20 volts and zero is effected by the small sized switch 8a. More specifically, since the low voltage DC source 12 is connected to the grid of the triode 10, upon turning on of the small sized switch 8a with consequent interruption of the plate current Ip of the triode 10, the triode 10 is apparently in an off state, and, accordingly, the potential of the auxiliary electrode rod 4 floats with respect to the negative side of the high voltage DC source 6. On the other hand, upon turning off of the small sized switch 8a, the grid to cathode voltage Eg is reduced to zero with the triode 10 seemingly being brought into an on state, and the auxiliary electrode rod 4 is therefore coupled to the negative side of the high voltage DC source 6 through the triode 10. Accordingly, by rendering the triode 10 operative or inoperative through turning off or on of the switch 8a, the auxiliary electrode rod 4 can selectively be connected to and disconnected from the negative side of the high voltage DC source 6. The small sized switch 8a may be a low voltage type, since it is only intended to withstand the maximum grid to cathode voltage Eg of, for example, 20 volts. As is seen from the foregoing description, by employing high voltage type triode 10, the switch 8a may be a low voltage type and of small size.

Other constructions and functions of the modified apparatus of Figure 7 are similar to those of the apparatus of Figure 1, and therefore, detailed description thereof is abbreviated for brevity.

Reference is now had to Figure 9 showing a circuit diagram of an apparatus according to a further modification of the apparatus of Figure 1, and also to Figure 10 showing one example of an actual circuit arrangement of the modified apparatus shown in Figure 9. In this modification, the apparatus of Figure 1 is so modified that an ampoule 1 to be inspected is automatically transported to a predetermined inspecting position and subsequently to an unloading position by a conveyor 13 for intermittently forwarding the ampoules 1, and means 14 for driving the conveyor 13 being further provided. A plurality of auxiliary electrode rods 4″ are radially mounted on a rotary wheel 15, with a motor 16 for driving the rotary wheel 15 being adapted to be turned on or off through a switch 8b. The conveyor 13, for example, of an endless belt type has its surface formed with a series of recesses 13a (Figure 10) spaced at predetermined intervals for receiving one ampoule in each of the recesses 13a, while one portion of the conveyor 13 is connected to ground so that the conveyor itself constitutes the cathode plate 2″. The anode rod 3 and the auxiliary electrode rods 4″ are normally connected to the plus side and minus side of the high voltage DC source 6 through the switch 8b, with the discriminator 9 being coupled between the switch 8b and the cathode plate 2″. The ampoules 1, for example ampoules 1-1, 1-2 and 1-3 in Figure 10, are placed one by one into the recesses 13a of the conveyor 13 at one side thereof either automatically or manually, while the conveyor 13 is intermittently moved to the other side by driving means 14 including, for example, a pair of sprocket wheels 14a supporting the conveyor 13 and suitable drive source (not shown) coupled to one of the shafts 14b of the wheels 14a. When either one of the ampoules 1 thus fed has reached the inspecting position confronting the anode rod 3, the particular ampoule 1 is charged by the action of the anode rod 3 in a similar manner as described with reference to Figure 1, and inspected for defects upon actuation of the switch 86. The ampoule 1 is then transported to the other side of the conveyor 13 to be sequentially unloaded from the conveyor 13 thereat. The auxiliary electrode rods 4″ are so arranged that a particular one thereof is located at a position which is spaced from the ampoule 1 and at which no spark discharge takes place between the rod 4″ and the anode rod 3 at the initial stage when the particular ampoule 1 to be tested has reached the inspecting position, but when the rotary wheel 15 is rotated by the motor 16 upon turning on of the switch 8b, the particular auxiliary electrode rod 4″ is brought to a position closest to the portion to be tested of the ampoule 1 to develop a spark between the rod 4″ and the anode rod 3, and is subsequently moved to a position spaced from the ampoule 1 to interrupt the spark between the rod 4″ and the anode rod 3, this causing the ampoule 1 to be charged again by the action of the anode rod 3. Accordingly, if the charging current and/or the discharging current at this time are detected and processed by the discriminator 9 in a similar manner as in the apparatus of Figure 1, the ampoules 1 can be automatically inspected successively while the ampoules 1 are transported in the advancing direction according to a series of operations programmed in advance.

As is clear from the foregoing description, according to the method of inspecting for defects apparatus employed therefor of the invention, containers of insulating material, for example, sealed ampoules containing therein medicinal fluids can be readily inspected for various defects such as pinholes with the use of an apparatus of simple construction and operation.

It should be noted here that, although the present invention is mainly described with reference to inspection of ampoules of glass material containing therein medicinal fluids, the defect inspection method and apparatus employed therefor according to the present invention are not limited in their applications to such ampoules alone, but may be readily applicable to inspection of faulty spots of any containers of insulating material containing therein electrically conductive electrolyte or nonelectrolyte fluids, such as water, water solution, or distilled water.

Although the present invention has been fully described by way of example with reference to the attached drawings, it is to be noted that various changes and modifications falling within the scope of the appended claims will be apparent to those skilled in the art. For example, a cathode rod may be used instead of the anode rod and an anode plate may be used instead of the cathode plate.

WHAT WE CLAIM IS:

1. A method of inspecting for defects of flaws and emptiness in containers of insulating material filled with liquid, which comprises the steps of:

positioning a said container between first and second electrode members electrically connected to first and second terminals of a high voltage DC source, said DC source applying a voltage of first polarity to said first electrode member and a voltage of second polarity, opposite to the first polarity, to said second electrode member, said first electrode member being held in contact with a first portion of the container while said second electrode member is disposed adjacent and spaced a predetermined distance from a second portion to be tested of the container;

electrically charging the container by means of said DC source or discharging the container after charging thereof;

detecting the charging or discharging current; and

discriminating whether or not the detected current is approximately equal to a value detected for a container having no defects.

2. A method of inspecting for defects as claimed in Claim 1, wherein said detected current, when it exceeds a predetermined value, indicates the presence of flaws in the container and, when it falls below a predetermined value, indicates emptiness of the container.

3. A method of inspecting for defects as claimed in Claim 1 or Claim 2, wherein the discharging current is detected, and comprising the steps of:

causing an auxiliary electrode member applied with a voltage of the first polarity from said DC source and disposed at a predetermined position in the vicinity of said portion to be tested and also in the vicinity of said second electrode member to establish a spark between said second electrode member and said auxiliary electrode member;

establishing a discharge, caused by said spark, between said portion to be tested of the container and said auxiliary electrode member through a network formed between said auxiliary electrode member and said first electrode member, to discharge the container; and

detecting electric current flowing through said network, said current being indicative of the discharging current.

4. A method of inspecting for defects as claimed in Claim 3, wherein the spark is established by closing a switch which is electrically connected between the first terminal of said DC source and the auxiliary electrode member.

5. A method of inspecting for defects as claimed in Claim 3, wherein the spark is established by moving said auxiliary electrode member towards said predetermined position.

6. A method of inspecting for defects as claimed in Claim 5, wherein said movement is a rotation.

7. A method of inspecting for defects as claimed in Claim 1 or Claim 2, wherein the charging current is detected, and comprising the step of detecting electric current flowing through the first electrode member upon charging of the container.

8. A method of inspecting for defects as claimed in Claim 7, comprising the steps of:

causing an auxiliary electrode member applied with a voltage of the first polarity from said DC source and disposed at a predetermined position in the vicinity of said portion to be tested and also in the vicinity of said second electrode member to establish a spark between said second electrode member and said auxiliary electrode member;

establishing a discharge, caused by said spark, between said portion to be tested of the container and said auxiliary electrode member through a network formed between said auxiliary electrode member and said first electrode member, to discharge the container;

interrupting the spark between said second electrode member and said auxiliary electrode member; and

charging the container, in response to the interruption of the spark.

9. A method of inspecting for defects as claimed in Claim 8, wherein the spark is established and interrupted by closing and opening respectively a switching means which is connected between the first terminal of the DC source and the auxiliary electrode member.

10. A method of inspecting for defects as

claimed in Claim 8, wherein the spark is established and interrupted by moving the auxiliary electrode member towards and away from respectively, said predetermined position.

11. A method of inspecting for defects as claimed in Claim 10, wherein said movement is a rotation.

12. A method of inspecting for defects as claimed in Claim 3, wherein each of the distances between a tip of said second electrode member and said portion to be tested of the container, between the tip of said second electrode member and a tip of said auxiliary electrode member and between the tip of said auxiliary electrode member and said portion to be tested of the container, is not more than 200 mm.

13. A method of inspecting for defects as claimed in Claim 12, wherein each of said distances is within a range from 0.1 to 30 mm.

14. A method of inspecting for defects as claimed in Claim 13, wherein each of said distances is within a range from 1 to 10 mm.

15. A method of inspecting for defects as claimed in Claim 14, wherein the distance between the tip of said auxiliary electrode member and said portion to be tested of the container is 1 mm, and the distance between the tip of said second electrode member and the tip of said auxiliary electrode member is 10 mm.

16. A method of inspecting for defects as claimed in any preceding claim, wherein said DC source has an output in the range from 0.1 to 10 kilovolts per mm as measured between said second electrode member and said auxiliary electrode member.

17. A method of inspecting for defects as claimed in Claim 16, wherein said DC source has an output in the range from 1 to 5 kilovolts per mm as measured between said second electrode member and said auxiliary electrode member.

18. An apparatus for inspecting for defects of flaws and emptiness in containers of insulating material filled with liquid, said apparatus comprising;

a high voltage DC source having first and second terminals;

a first electrode member electrically connected to the first terminal of the DC source to be held in contact with a first outer surface portion of said container;

a second electrode member connected to the second terminal of the DC source and being disposed to confront a second outer surface portion to be tested of the container at a position spaced a predetermined distance therefrom to electrically charge and discharge the container;

means for detecting the charging or discharging current; and

means for discriminating whether or not the detected current is approximately equal to a value detected for a container having no defects.

19. An apparatus for inspecting for defects as claimed in Claim 18, wherein said discriminating means indicates the presence of flaws in the container when the detected current exceeds a predetermined value, and indicates emptiness of the container when the detected current falls below a predetermined value.

20. An apparatus for inspecting for defects as claimed in Claim 18 or Claim 19, further comprising:

an auxiliary electrode member for connection to the first terminal of the DC source; and

means to establish and interrupt selectively a spark between said second electrode member and said auxiliary electrode member to cause a discharge to be developed between said portion to be tested of the container and said auxiliary electrode member through an electrical network formed between said auxiliary electrode member and said first electrode member to discharge the container;

said detecting means detecting electric current flowing through said network, which current is indicative of the discharging current.

21. An apparatus for inspecting for defects as claimed in Claim 20, wherein said network comprises a resistor and said detecting means comprises a meter connected in parallel with the resistor.

22. An apparatus for inspecting for defects as claimed in Claim 20 or claim 21, wherein said spark establishing and interrupting means comprises switching means capable of selectively connecting and disconnecting said auxiliary electrode member to and from said DC source, said auxiliary electrode member being disposed at a predetermined position in the vicinity of said portion to be tested of the container and also in the vicinity of said second electrode member.

23. An apparatus for inspecting for defects as claimed in Claim 22, wherein said switching means comprises a vacuum tube in combination with a switch element.

24. An apparatus for inspecting for defects as claimed in Claim 23, wherein said vacuum tube is a triode capable of withstanding high voltage, whose plate is connected to said auxiliary electrode member and whose grid is connected to a negative terminal of the high voltage DC source through the switch element and a low voltage DC source, the cathode of said triode being connected to the negative terminal of the high voltage DC source and with the heater thereof being coupled with a further electricity source.

25. An apparatus for inspecting defects as claimed in Claim 20 or Claim 21, wherein said spark establishing and interrupting means comprises a motor, said auxiliary electrode member being secured, at one end thereof, to a rotatable driving shaft of the motor to rotate said auxiliary electrode member selectively to and away from a predetermined position in the vicinity of said portion to be tested of the container and also in the vicinity of said second electrode.

26. An apparatus for inspecting for defects as claimed in any one of claims 22 to 24, wherein said auxiliary electrode member is one of a plurality of auxiliary electrode rod members and said switching means is one of a plurality of switching means each of which is associated with a respective one of the auxiliary electrode rod members.

27 An apparatus for inspecting for defects as claimed in Claim 20 or Claim 21, wherein said auxiliary electrode member is one of a plurality of auxiliary electrode rod members radially extending from a wheel member which is coupled for rotation with driving means so that upon rotation of said wheel member said auxiliary electrode rod members can be sequentially brought into said predetermined positions thereof.

28. An apparatus for inspecting for defects as claimed in any one of claims 18 to 27, wherein said second terminals of said DC source is positive with respect to the first terminal thereof.

29. An apparatus for inspecting for defects as claimed in Claim 28, wherein said first electrode member comprises a cathode plate member to be held in contact with said first surface portion of said container through large contact area therebetween.

30. An apparatus for inspecting for defects as claimed in Claim 28, wherein said first electrode member comprises a pair of cathode plates for holding said first portion of said container.

31. An apparatus for inspecting for defects as claimed in any one of claims 20 to 27, wherein said first electrode member comprises a movable conveyor belt member serving as a cathode and having recesses formed therein for receiving a plurality of the containers for sequentially bringing each of the containers into a testing position facing said second electrode member and the auxiliary electrode member, said movable conveyor belt member being connected to ground.

32. An apparatus for inspecting for defects as claimed in any one of claims 18 to 31, wherein the second electrode member is an anode plate member having one edge thereof formed to conform with outer configuration of the portion to be tested, said anode plate member being connected to the second terminal of the high voltage DC source.

33. An apparatus for inspecting for defects as claimed in any one claims 18 to 31, wherein said second electrode member comprises an anode rod member connected to the second terminal of the high voltage DC source.

34. An apparatus for inspecting for defects as claimed in Claim 20 or any one of claims 21 to 33 as dependent on Claim 20, wherein the auxiliary electrode member comprises an auxiliary electrode rod member connected to the first terminal of the high voltage DC source.

35. A method of inspecting for defects in containers of insulating material substantially as hereinbefore described with reference to Figures 1 to 4(e) of the accompanying drawings.

36. A method of inspecting for defects in containers of insulating material substantially as hereinbefore described with reference to Figure 5 of the accompanying drawings.

37. A method of inspecting for defects in containers of insulating material substantially as hereinbefore described with reference to Figure 6 of the accompanying drawings.

38. A method of inspecting for defects in containers of insulating material substantially as hereinbefore described with reference to Figures 7 and 8 of the accompanying drawings.

39. A method of inspecting for defects in containers of insulating material substantially as hereinbefore described with reference to Figures 9 and 10 of the accompanying drawings.

40. An apparatus for inspecting for defects in containers of insulating material substantially as hereinbefore desribed with reference to and as illustrated in Figures 1 to 4(e) of the accompanying drawings.

41. An apparatus for inspecting for defects in containers of insulating material substantially as hereinbefore described with reference to and as illustrated in Figure 5 of the accompanying drawings.

42. An apparatus for inspecting for defects in containers of insulating material substantially as hereinbefore described with reference to and as illustrated in Figure 6 of the accompanying drawings.

43. An apparatus for inspecting for

defects in containers of insulating material substantially as hereinbefore described with reference to and as illustrated in Figures 7 and 8 of the accompanying drawings.

44. An apparatus for inspecting for defects in containers of insulating material substantially as hereinbefore described with reference to and as illustrated in Figures 9 and 10 of the accompanying drawings.

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FIG. 1

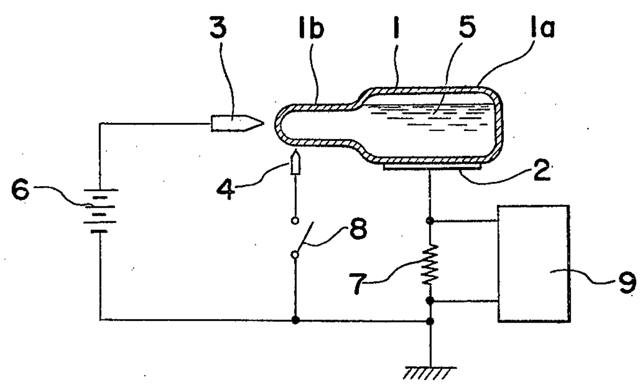
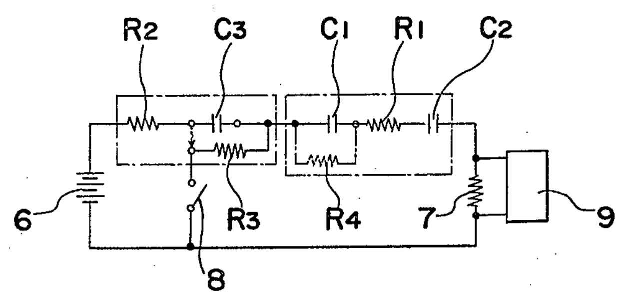


FIG. 2



1575100 COMPLETE SPECIFICATION

8 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

FIG. 3 (a)

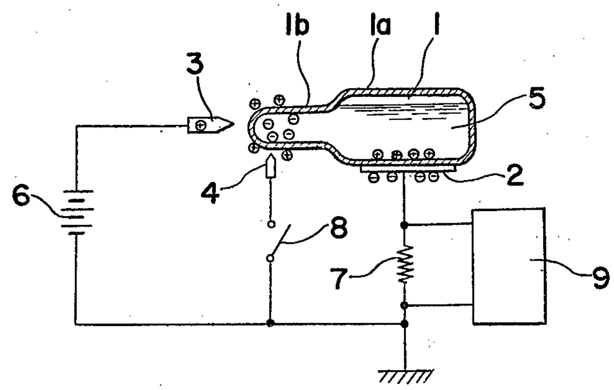
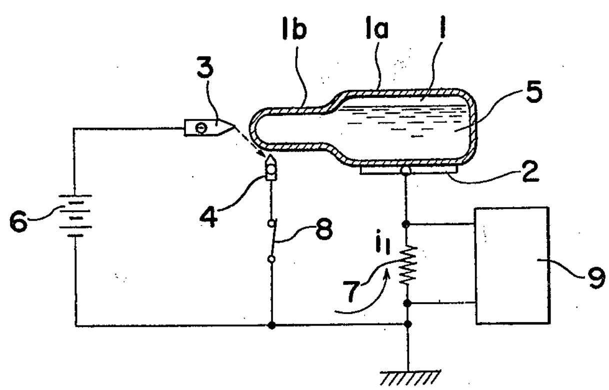


FIG. 3 (b)



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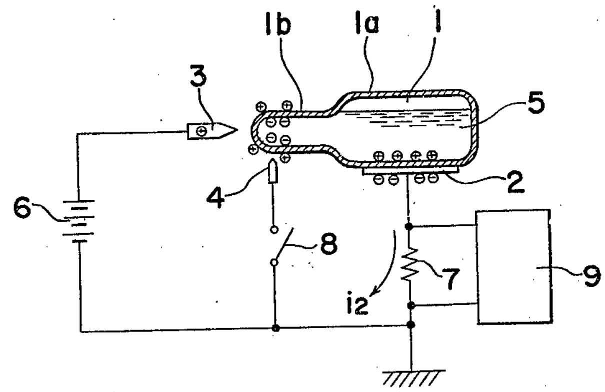
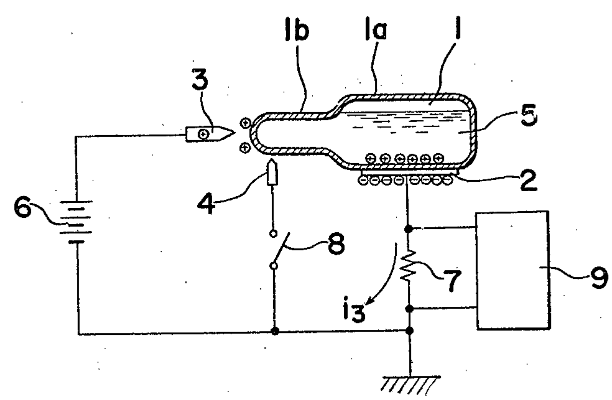


FIG. 3 (d)



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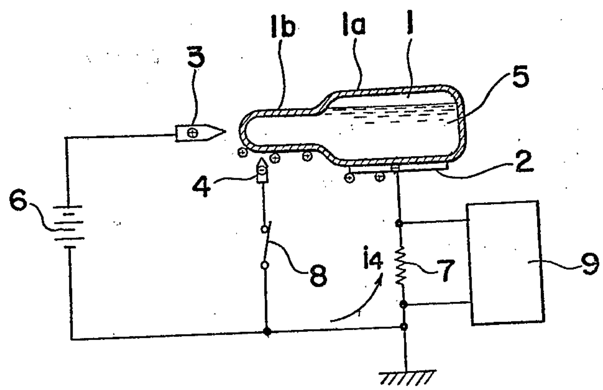
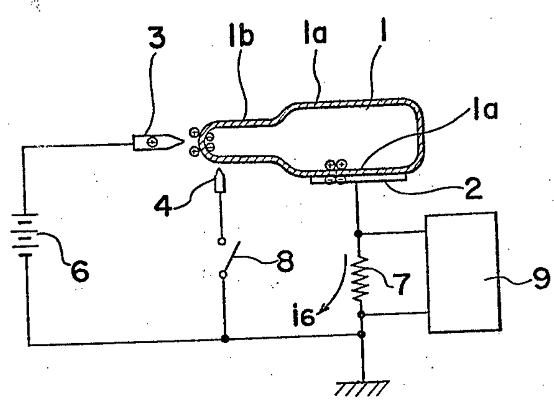


FIG. 3 (f)



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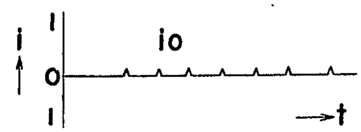
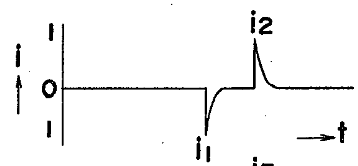


FIG. 4 (b)



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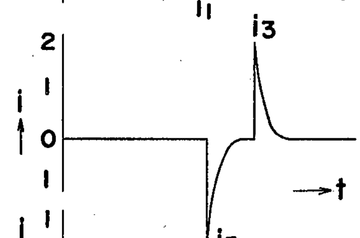

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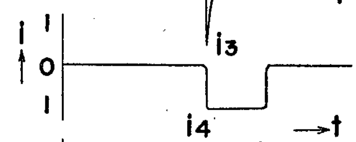

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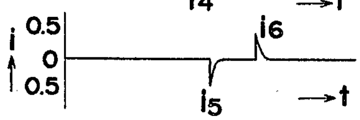

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FIG. 5

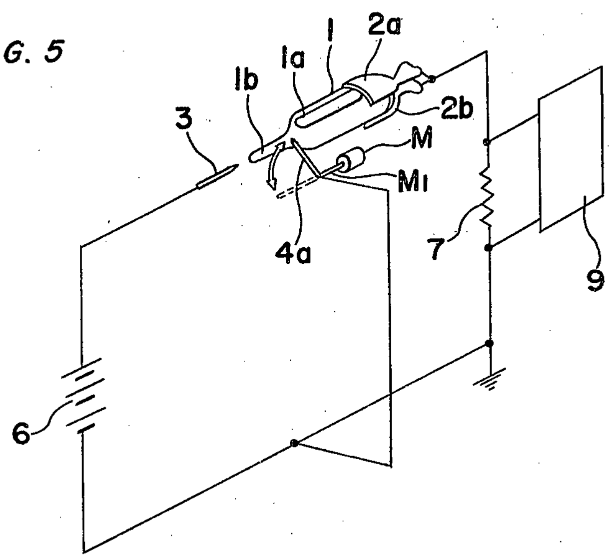

FIG. 6

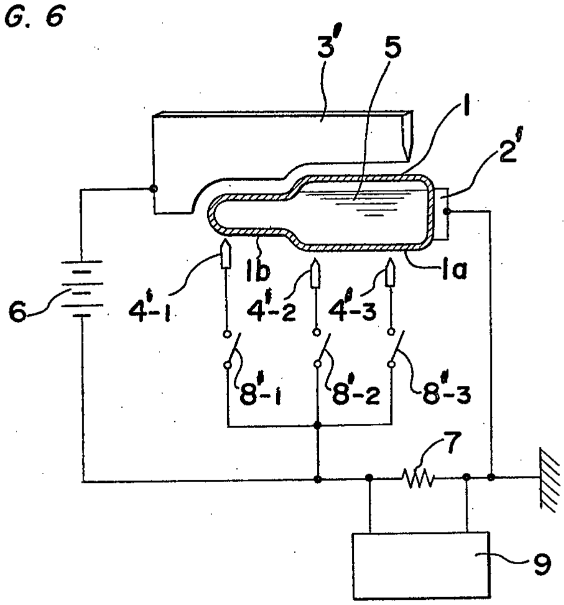

FIG. 7

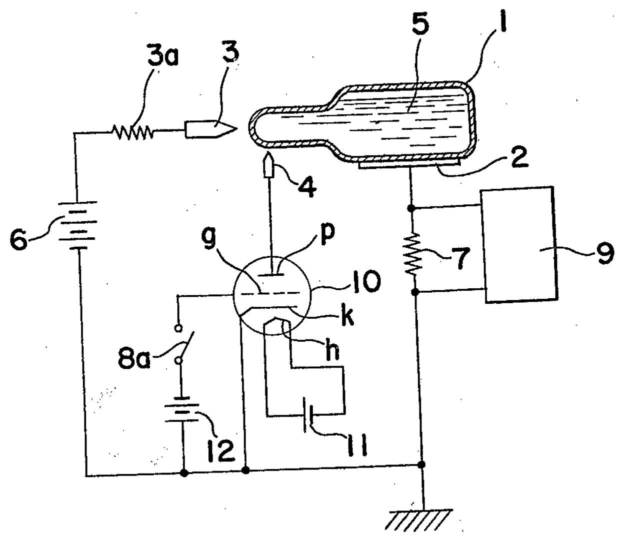

FIG. 8

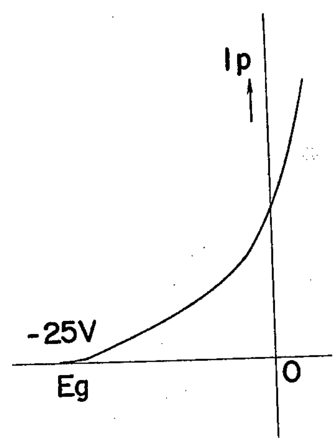

FIG. 9

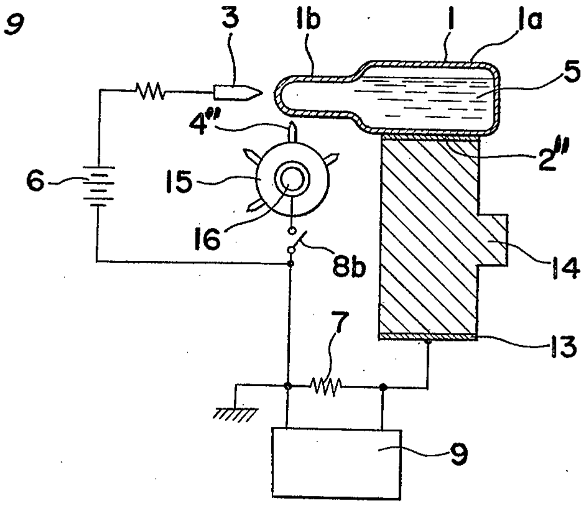
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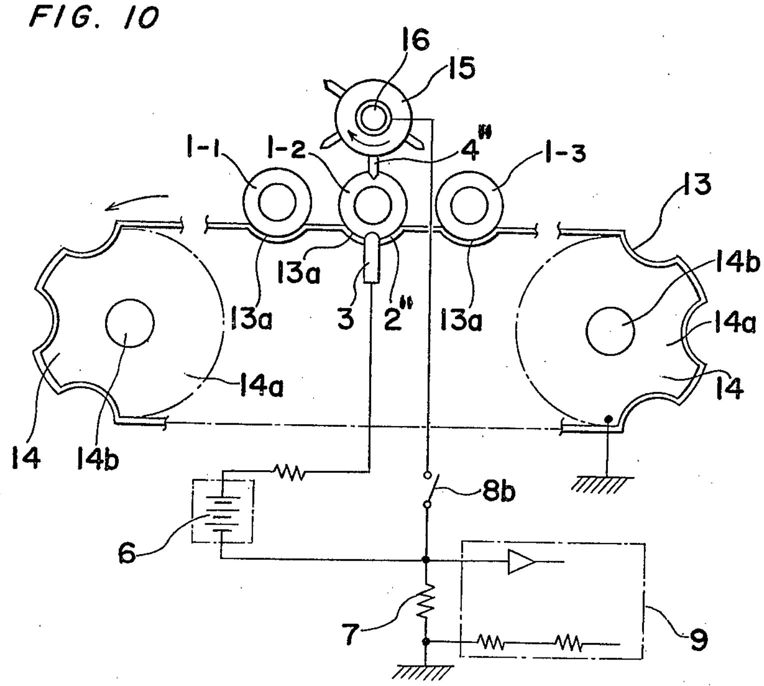
FIG. 10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