Dec. 19, 1944. W. E. BERKEY 2,365,517

ELECTRIC DISCHARGE DEVICE

Filed Nov. 13, 1941

Fig. 1.

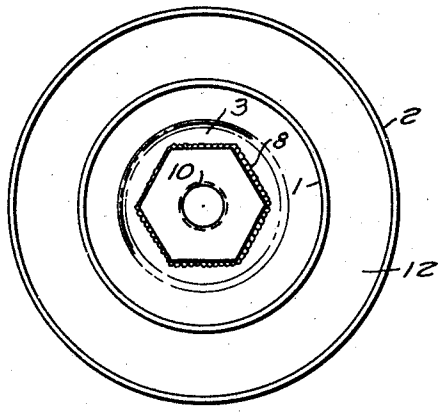


Fig. 2.

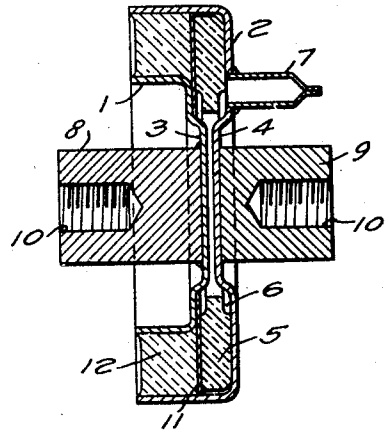


Fig. 4.

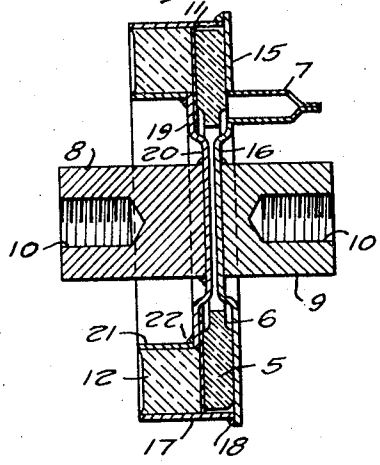


Fig. 3.

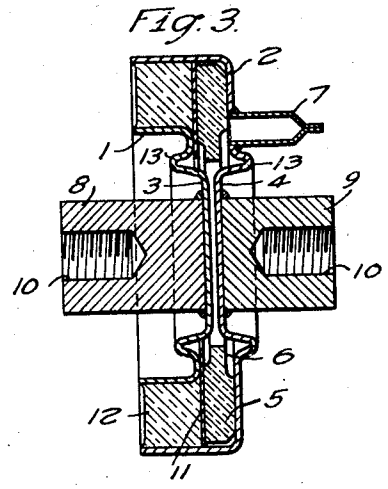
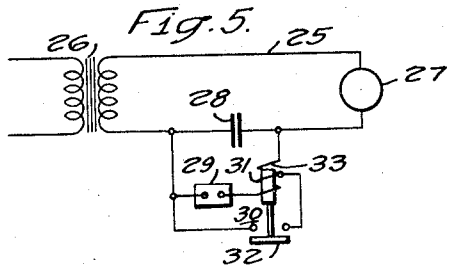


Fig. 5.



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ELECTRIC DISCHARGE DEVICE

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Application November 13, 1941, Serial No. 418,938

4 Claims. (Cl. 250—27.5)

The present invention relates to electric discharge devices, and more particularly to a low-pressure spark gap device which is especially suitable for voltage-limiting protective applications.

The spark gap device of the present invention is of the low-pressure type described and claimed in a copending application of J. Slepian and W. E. Berkey, Serial No. 358,634, filed September 27, 1940, and assigned to the Westinghouse Electric & Manufacturing Company. As more fully set forth in that application, spark gap devices of this general type consist of spaced electrodes with the air or other gas in the enclosed space between them maintained at a low pressure, which is less than 15 centimeters of mercury, and preferably in the range between 0.1 and 10 centimeters of mercury. It has been found that the current density at the terminals of an arc in air, or other gas, at this low pressure is of the order of 1,000 amperes per square centimeter or less, which is only about $\frac{1}{10}$ the current density at the terminals of an arc in air at atmospheric pressure. Because of this low current density, if the electrodes are made large enough to permit the discharge to spread between them, the temperature of the electrode surface at the arc terminal does not exceed the melting point of the metal, and as a result, there is substantially no burning or erosion of the electrode. The low pressure reduces the breakdown voltage of the gap, and this effect, together with the absence of burning of the electrodes, makes it possible to space the electrodes quite close together and obtain very low breakdown voltages, of the order of a few hundred volts, which can not be done, practically, with spark gaps operating at atmospheric pressure because the burning and melting of the electrodes, changes the effective spacing between them, and thus the calibration of the gap is altered after a few operations. The low-pressure type of gap, however, can be calibrated for low breakdown voltages, with closely spaced electrodes, and will maintain its calibration unchanged after repeated operation.

The low pressure used in these gaps reduces the breakdown voltage of the gap but has little or no effect on the extinction or cutoff voltage, so that a very low ratio of breakdown voltage to cutoff voltage is obtained, and such a gap is inherently a self-extinguishing device, in that the arc will be extinguished when the voltage across the gap falls to a value only a little less than the breakdown voltage. Because of the low current density, the temperature rise of the electrodes is relatively low if their sparking surfaces are made sufficiently large to permit the discharge to spread between them, and for this reason, such a gap has very high discharge current capacity. These characteristics make the low-pressure type of gap very suitable for voltage-limiting protective applications, especially in cases where the breakdown voltage must be relatively low, and where high currents may have to be discharged for appreciable periods of time.

Since the breakdown voltage of gaps of this type is a function of the gas pressure between the electrodes, and since the calibration must be maintained accurate in order for the gap to have any value as a protective device, it is essential in the practical construction of such gaps that a strong and permanent vacuum seal be provided, which has good mechanical strength and which will not permit leakage of air into the gap even over a long period of time. It is also necessary that the cost of producing these gaps shall not be too great, since the cost of protective equipment must not be too high as compared with the cost of the apparatus to be protected.

The principal object of the present invention, therefore, is to provide a vacuum-tight spark gap structure having a strong and permanent vacuum seal which can be readily produced.

A further object of the invention is to provide a vacuum-tight spark gap structure in which the electrodes are made at least in part of a metal which is capable of forming a strong vacuum seal with an insulating material, such as glass, and in which the electrodes are arranged so that they can be directly sealed together with an insulating vacuum seal of such material.

A more specific object of the invention is to provide a vacuum-tight spark gap structure in which the electrodes are arranged so that they can be sealed directly together with an insulating material which is capable of forming a permanent vacuum-tight seal with the electrode material, and in which the electrodes are so designed that expansion of the electrodes due to the heat of a discharge through the gap does not impose undue stresses on the seal.

Further objects and advantages of the invention will be apparent from the following detailed description, taken in connection with the accompanying drawing, in which:

Figure 1 is a plan view of a spark gap device embodying the invention;

Fig. 2 is a transverse sectional view of the spark gap of Fig. 1;

Fig. 3 is a transverse sectional view of a spark

gap showing a slight modification of the invention;

Fig. 4 is a transverse sectional view of a spark gap showing a further modification of the invention; and

Fig. 5 is a wiring diagram showing one typical application of the spark gap device of the present invention.

The spark gap device shown in Figs. 1 and 2 consists essentially of a pair of metallic electrodes 1 and 2. These electrodes are generally cup-shaped, and, as shown in Fig. 2, the electrode 1 is of smaller diameter than the electrode 2 and is disposed in nested relation within it. The cup-shaped electrode 1 has a depressed portion 3 in its flat bottom surface, which provides a plane sparking surface of relatively large area. Similarly, the electrode 2 has a raised portion 4 in its flat bottom surface which is positioned opposite the depressed portion 3 of the electrode 1, and which has a plane surface of approximately the same area. The electrodes are separated, and their sparking surfaces 3 and 4 spaced apart the desired distance, by an annular spacer member 5, which is preferably made of an insulating ceramic body, such as porcelain, and which is preferably of a type having good resistance to thermal shock, so as to avoid damage to the spacer by the sudden rise in temperature caused when a discharge occurs across the gap. The spacer member 5 fits in the outer cup-shaped electrode 2 and has an annular rib 6 about its inner periphery which serves to confine the discharge to the sparking surfaces 3 and 4, and to prevent it from spreading to a point where it might cause damage to the seal between the electrodes. The outer electrode 2 also has a short piece of metal tubing 7 soldered or otherwise secured in an opening in its bottom surface to permit evacuation of the gap. Terminal members or lugs 8 and 9 are soldered or otherwise rigidly attached to the electrodes 1 and 2, respectively. Since the electrodes are made of relatively thin sheet metal, their thermal capacity is rather low, and in case of a heavy discharge, the temperature of the electrodes might become high enough to damage the vacuum seal. For this reason, the terminal lugs 8 and 9 are made relatively heavy and massive so as to have high thermal capacity, as compared to that of the electrodes themselves, and thus the temperature rise of the electrodes in case of a continued heavy discharge is prevented from becoming too great. Holes 10 may be formed in the terminal lugs and internally threaded for reception of terminal studs of any suitable type.

The electrodes 1 and 2 are preferably made of the cobalt-nickel-iron alloy, known under the trade name of Kovar. This material has a thermal expansion curve which closely matches the thermal expansion curve of certain borosilicate glasses, and for this reason, it is capable of forming a permanent vacuum-tight seal with such glass. In the preferred embodiment of the invention, as described herein, the electrodes are made of Kovar and are sealed together with an insulating seal of borosilicate glass. It is to be understood, however, that if desired, other metals might be used in combination with other insulating sealing materials with which they are capable of forming permanent vacuum seals.

The specific seal arrangement, and method of forming the seal, which are preferably used in the gap of the present invention are described and claimed in a copending application of P. R. Kalischer and M. J. Kofoid, Serial No. 342,932, filed June 28, 1940, now Patent No. 2,300,931, issued November 3, 1942, and assigned to the Westinghouse Electric & Manufacturing Company. As set forth in that application, if the glass which is used for the insulating vacuum seal between the electrodes were permitted to come in direct contact with the thermal shock resistant porcelain spacer 5, the glass would fuse to the porcelain, when melted to form the seal, and upon cooling, the glass would be cracked because of the difference in the thermal expansion curves of the glass and porcelain. In order to prevent this, a thin mica washer 11 is placed on top of the spacer 5 to prevent contact between the glass and the spacer. The annular space between the cylindrical rim portions of the electrodes 1 and 2 is then filled with a suitable borosilicate glass 12, which may be either in powdered form or in the form of a curved rod. The assembly is then heated above the melting point of the glass, which thereupon melts and fills the annular space above referred to. When the gap device is slowly cooled, the glass fuses to the Kovar electrodes 1 and 2 and forms a strong, permanent vacuum-tight seal. The gap device may then be evacuated to the desired internal pressure through the metal tube 7, which is afterwards sealed off. This may conveniently be done by initially coating the inside of the tube 7 with solder, so that it may be sealed off merely by pinching it together and heating sufficiently to melt the solder and permit it to fuse together.

The gap structure described above, having cup-shaped electrodes assembled in nested relation, offers several advantages. This arrangement facilitates the formation of the seal between the electrodes since the assembled gap may be placed with the electrodes in a horizontal position, and the glass for the seal may then be placed in the annular space between the electrodes and will remain therein during melting without requiring any manipulation or special means for placing it or retaining it in position. This greatly facilitates the operation of sealing the gap, since it can be carried out easily and without the use of any special equipment.

A further important advantage also results from the shape of the electrodes. When a discharge occurs across the gap, a rather large amount of heat energy is dissipated, which raises the temperature of the electrodes and causes them to expand. The inner electrode 1 contains a smaller volume of metal than the outer electrode 2, and its temperature will become somewhat higher, so that its expansion will be correspondingly greater. Since the actual dimensions of the outer electrode 2, however, are considerably greater than those of the inner electrode 1, the total expansion of the outer electrode will be greater for a given temperature change than that of the inner electrode. These two effects, therefore, i. e., the higher temperature of the inner electrode 1 and the greater total expansion for a given temperature of the outer electrode 2, tend to compensate each other, so that the net result is that the compressive stress on the seal resulting from expansion of the electrodes is minimized, and even under heavy discharge currents, the stresses on the seal are not unduly great. For this reason, there is no danger of the glass being cracked, or broken away from the metal, or otherwise damaged, which would permit leakage of air into the gap and destroy its usefulness. Thus, the structure described provides a spark gap which is capable of discharging very large cur-

rents, because of the low current density and large area of the electrodes, and in which a strong and permanent vacuum seal is provided which is not subjected to undue stresses when the electrodes are heated by a discharge. The large thermal capacity of the terminal lugs 8 and 9 also tends to hold down the temperature of the electrodes, and thus prevents them from reaching a temperature at which the glass would begin to soften.

Fig. 3 shows a slight modification of the invention in which provision is made for non-uniform expansion of the electrodes. Such expansion may sometimes occur if a discharge is not centered between the sparking surfaces 3 and 4 but occurs at one side of the sparking area. In such a case, the temperature of the electrodes may be greater on one side of the gap device than on the other, and non-uniform expansion of the electrodes may result, which would cause undesirably high compressive or shearing stresses on the glass of the seal. If it is desired to provide for this condition, the electrodes 1 and 2 may have annular ridges 13 formed in them between the central sparking surfaces and the peripheral rim portions. These ridges 13 will provide sufficient resilience in the electrodes to take up any non-uniform expansion that may occur without causing serious stresses in the seal itself.

The electrodes 1 and 2 have been described as being made of Kovar, which is a special alloy of rather high cost. In order to reduce the cost of the gap by reducing the amount of this material which it is necessary to use, the construction shown in Fig. 4 may be employed. In this construction, the outer electrode consists of a generally disc-shaped bottom portion 15 which has a raised portion 16 formed therein to provide a large plane sparking surface. The disc-shaped portion 15 may be made of copper, brass or other suitable metal. A cylindrical rim portion 17 of Kovar is brazed, or otherwise rigidly secured, to the member 15 adjacent its periphery, as indicated at 18, to form a composite cup-shaped electrode. Similarly, the inner electrode consists of a disc-shaped bottom portion 19 of copper or brass with a central depressed portion 20 to provide a large plane sparking surface, and with a cylindrical rim portion 21 of Kovar brazed, or otherwise rigidly secured, as indicated at 22, to the periphery of the disc-shaped portion 19. Terminal lugs 8 and 9 are provided on the electrodes as before, and they are separated by an annular porcelain spacer 5, as previously described. The glass seal 12 is similar to that described in connection with Fig. 1, and the gap device is constructed and operates in the same manner as the embodiments of the invention described above. This form of the invention permits a considerable reduction in cost over those illustrated in Figs. 2 and 3, since it requires less of the relatively expensive Kovar.

Because of the characteristics of the low-pressure type of spark gap device, as described above, the new gap is particularly well adapted for use as a voltage-limiting protective device, and especially in applications where relatively low breakdown voltage is required and large currents must be discharged for an appreciable length of time, such as several cycles. One such application is for the protection of series capacitors. Fig. 5 shows an alternating-current line 25 which is supplied from a transformer 26 and connected to a load, indicated diagrammatically at 27. A capacitor 28 is connected in series with the line 25 to neutralize the inductive reactance of the line and improve its voltage regulation. Since the capacitor 28 is connected in series with the line and carries the line current, the voltage across the capacitor may rise to dangerous values in case of a short-circuit or continued heavy overload on the line, and in order to protect the capacitor against such overvoltage, a spark gap device 29, which may be of any of the constructions described above, is connected across the capacitor. In case the voltage across the capacitor exceeds the safe limit, the gap 29 is calibrated to break down at this voltage and short-circuit the capacitor to protect it from the overvoltage.

In some cases, where the short-circuit currents are relatively low and are definitely known, the gap may be connected directly across the capacitor without any other equipment, since it will extinguish the arc and restore the capacitor to service as soon as the overvoltage ceases, because of the inherent self-extinguishing characteristics of the low-pressure gap. In most cases, however, in order to prevent dangerous overheating of the gap by a long continued discharge, it is preferable to provide a contactor 30, having its operating coil 31 connected in series with the gap 29, and its contacts 32 connected to complete a shunt circuit around both the gap and the capacitor. With this arrangement, as soon as the gap has broken down, the contactor 30 is energized and closes its contacts, thus completing a shunt circuit and relieving the gap from carrying the heavy discharge current for longer than the one or two cycles required for the contactor to close. A portion 33 of the coil 31 is preferably included in the shunt circuit to function as a holding coil to maintain the contactor closed until the line current has fallen to its normal value. Thus, by using the new gap device, a simple and inexpensive protective system is provided for series capacitors, as compared with the complicated and expensive apparatus previously used. It is to be understood that although this particular application of the new gap device has been described as an example of the type of service for which it is especially adapted, its usefulness is not restricted to this particular arrangement, but it is of general application wherever a voltage-limiting protective gap device may be required.

It should now be apparent that a spark gap device has been provided in which the electrodes are so designed that a simple and easily produced vacuum seal may be used which has good mechanical strength and which will maintain the desired low pressure within the gap over a long period of time under service conditions. It will be obvious that this gap device is capable of various modifications and embodiments without departing from the spirit of the invention, and it is to be understood that the invention is not limited to the particular structural embodiments illustrated and described, but in its broadest aspects, it includes all equivalent modifications and embodiments which come within the scope of the appended claims.

I claim as my invention:

1. An electric discharge device comprising a pair of generally cup-shaped electrodes, one of said electrodes being of smaller diameter than the other, and the electrodes being disposed in nested relation, an insulating spacer member disposed between the electrodes spacing them

apart, insulating sealing-means in the annular space between the side walls of the electrodes sealing them with a vacuum-tight seal, and terminal means secured to each of the electrodes, said terminal means having high thermal capacity relative to the thermal capacity of the electrodes.

2. An electric discharge device comprising a pair of generally cup-shaped metal electrodes, each of said electrodes having a central portion providing a plane sparking surface of relatively large area and a generally cylindrical peripheral rim portion, the rim portion of one of the electrodes being of greater diameter than that of the other electrode, and the electrode of smaller diameter being nested within the electrode of greater diameter, an annular insulating spacer member disposed within the electrode of greater diameter spacing the sparking surfaces of the electrodes apart, insulating sealing-means in the annular space between the rim portions of the electrodes sealing them with a vacuum-tight seal, and terminal means secured to each of the electrodes, said terminal means having high thermal capacity compared to that of the electrodes.

3. An electric discharge device comprising a pair of generally cup-shaped metal electrodes, each of said electrodes having a cylindrical rim portion and a central portion which includes a substantially plane sparking surface of relatively large area, one of said electrodes being of smaller diameter than the other but the sparking surfaces of both electrodes being of substantially the same area, said electrodes being disposed in nested relation with the electrode of smaller diameter inside the other electrode, the sparking surfaces of the electrodes being opposed to each other and an annular space being provided between the rim portions of the two electrodes, insulating spacing means separating the electrodes and spacing the sparking surfaces a predetermined distance apart, said spacing means including means for restricting a discharge between the electrodes to the sparking surfaces, and sealing means in the annular space between the rim portions of the electrodes sealing the electrodes together with an insulating, vacuum-tight seal.

4. An electric discharge device comprising a pair of generally cup-shaped metal electrodes, each of said electrodes having a cylindrical rim portion and a central portion which includes a substantially plane sparking surface of relatively large area, one of said electrodes being of smaller diameter than the other but the sparking surfaces of both electrodes being of substantially the same area, said electrodes being disposed in nested relation with the electrode of smaller diameter inside the other electrode, the sparking surfaces of the electrodes being opposed to each other and an annular space being provided between the rim portions of the two electrodes, an annular insulating spacer member disposed between the electrodes to space the sparking surfaces a predetermined distance apart, said spacer member having an internal rib extending toward the sparking surfaces to restrict a discharge between the electrodes to the sparking surfaces, and sealing means in the annular space between the rim portions of the electrodes sealing the electrodes together with an insulating, vacuum-tight seal.

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