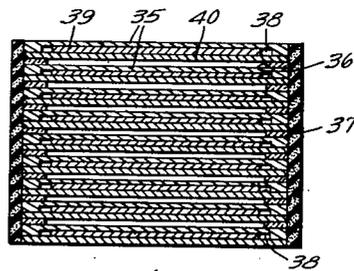
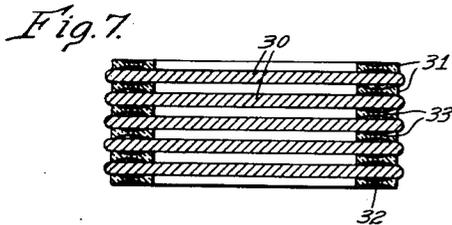
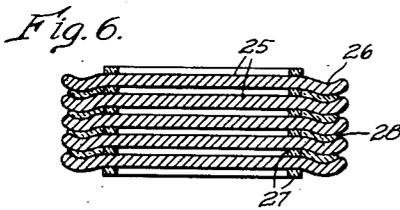
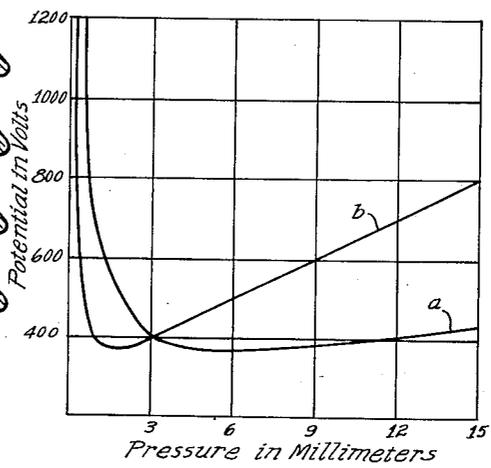
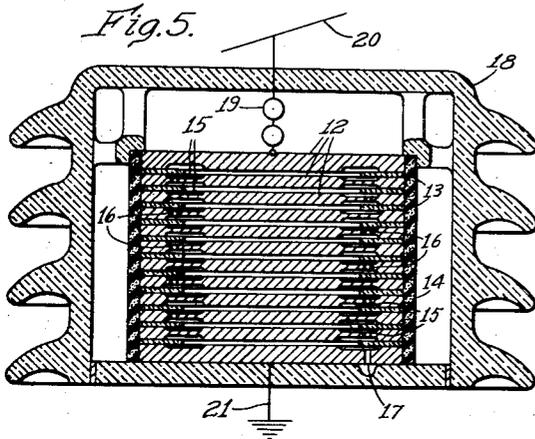
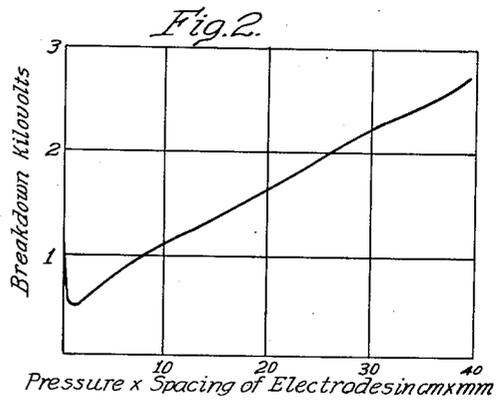
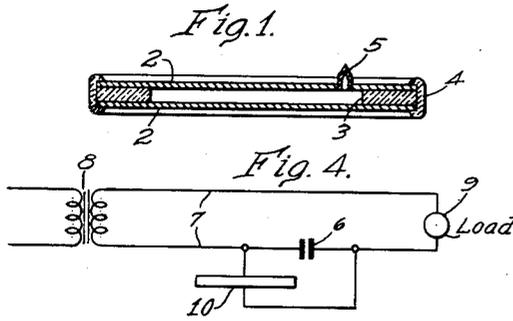


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ELECTRIC DISCHARGE DEVICE

2,370,082

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2,370,082

ELECTRIC DISCHARGE DEVICE

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3 Claims. (Cl. 175—30)

The present invention relates to electric discharge devices of the type in which an arc is formed between metal electrodes, and it relates, more particularly, to a discharge device which is adapted for use as a protective device for electrical apparatus or as a lightning arrester.

Simple arc discharge devices or spark gaps consisting of spaced metal electrodes between which an arc or spark discharge occurs at atmospheric pressures have been used for over-voltage protection, but such devices have been subject to serious disadvantages which greatly limited their usefulness. In such devices the high current density at the terminals of an arc in air at atmospheric pressure causes intense heating of the electrodes at the arc terminals and results in burning or erosion of the electrodes. This burning causes the electrode surfaces to become pitted and uneven, and, therefore, changes the effective spacing between the electrodes, so that it has not been possible to use closely spaced electrodes to obtain moderate or low breakdown voltages, since the burning of the electrodes resulted in erratic operation and changes in calibration. For this reason the practical usefulness of spark gap devices of this type has been restricted to relatively high breakdown voltages where the spacing between the electrodes is large enough so that it is relatively only slightly changed by the erosion of the electrode surface caused by burning and to applications where the discharge currents are limited to a value which will not objectionably distort the electrode surface by arc burning.

Another disadvantage of spark gap devices operating at atmospheric pressure is the fact that the reignition voltage, or voltage at which the arc will restrike after passing through a current zero of the alternating current wave, is very much lower than the breakdown voltage. After such a gap has broken down, therefore, the arc is not extinguished until the voltage across the gap has fallen to a much lower value than the breakdown voltage, since the air in the gap space remains ionized, and the arc restrikes after each current zero as long as the voltage remains above the reignition or extinction voltage, unless some external means are provided to extinguish it or to interrupt or greatly reduce the discharge current. For this reason, gap devices of this type, operating at atmospheric pressure, cannot successfully be used by themselves as lightning arresters, and their usefulness for other protective applications is greatly restricted.

Our invention provides an arc discharge de-

vice or spark gap operating at a reduced pressure considerably less than atmospheric, and preferably at a pressure less than 10 cm. of mercury.

We have found that an arc in air at low pressures has an effective current density at its terminals of the order of only about 1,000 amperes per sq. cm. or less, as compared to current densities of the order of 10,000 amperes per sq. cm. at the terminals of arcs in air at atmospheric pressure. Because of this low current density, the temperature rise of the electrode is low, and very little or no burning or erosion of the electrode occurs. Closely spaced electrodes can, therefore, be used and the calibration of the gap remains unchanged after repeated operation, since there is no burning to cause pitting or unevenness of the electrode surface.

The new gap can therefore be accurately calibrated for low or moderate breakdown voltages, and will retain its calibration unchanged after repeated operation.

The breakdown voltage of a spark gap is reduced by reducing the air pressure between the electrodes, but we have discovered that the reignition voltage is not reduced by reduction in gas pressure. Moreover, our tests have indicated a higher time rate of recovery of dielectric strength immediately after a current zero with our new low pressure gaps than with identical gaps tested at atmospheric pressure. For these reasons the ratio of breakdown voltage to reignition voltage of the new gap is very low, and it is, therefore, a self-extinguishing discharge device in that the arc fails to restrike after passing through a current zero even when the maximum recovery voltage across the gap is only slightly lower than the breakdown voltage.

These characteristics of the new gap make it very well suited for use as a voltage limiting protective device for electrical apparatus. Thus, as explained above, it may be accurately calibrated for relatively low voltages, and because of the absence of any burning of the electrodes, it will retain its calibration indefinitely, and is not subject to the erratic operation which was encountered with previous types of gap devices operating at atmospheric pressure when it was attempted to use them for low voltages. The self-extinguishing characteristics of the new gap resulting from the low ratio of breakdown voltage to reignition voltage make it possible to use the new gap by itself without the use of any external arc extinguishing or current limiting devices, since it will interrupt the discharge as soon as the voltage has fallen below a predetermined

value, which is not much less than the breakdown voltage. The new gap also has very large discharge current capacity because of the low current density and low discharge voltage, so that excessive heating of the electrodes is prevented, and it is, therefore, suitable for the most severe conditions of service.

Our low pressure discharge device is also very well adapted for use as a lightning arrester. Two general types of lightning arresters have been used. One of these consists, in general, of a spark gap operating in air at atmospheric pressure in series with a resistance or valve element, the resistance of which decreases under a high surge voltage to permit the discharge to pass to ground and increases when the voltage drops so that the discharge current is decreased to a point where the series gap can interrupt it. In this type of lightning arrester, when discharging a surge there is a potential drop through the arrester which is comparable in magnitude to the crest value of the line voltage, so that when the overvoltage has passed, only a small current remains. This type of arrester is required to dissipate large amounts of heat in very short periods of time, and failures occur because of the thermal effects.

The second type of lightning arrester commonly used is characterized by a high breakdown voltage and an initially low discharge voltage so that high surge currents can be discharged through it with relatively low dissipation of energy. The arc extinguishing properties of this type of arrester are obtained by gas evolution from walls of organic material which are heated by the discharge. The so-called protector tube is an example of this type of arrester and depends for its operation on gas evolution from the fiber walls of a confined discharge space. In this type of arrester, high discharge currents develop high internal gas pressures, and failures occur as a result of these high pressures. The high breakdown voltage of these types of lightning arresters in relation to their arc extinguishing voltage greatly restrict their application as overvoltage protectors.

The low pressure gap device of the present invention may be used advantageously as a lightning arrester which avoids the disadvantages of both of the general types described above since it will discharge large currents with a low discharge voltage and without excessive heating, and also inherently has a low breakdown voltage coupled with good arc extinguishing ability so that the power current is readily interrupted after the passage of a voltage surge. A very desirable type of lightning arrester is obtained, therefore, merely by placing a sufficient number of the new gaps in series to give the desired voltage rating.

A principal object of the invention is to provide an electric arc discharge device in which there is substantially no burning of the electrodes at the arc terminals.

Another object of the invention is to provide an arc discharge device which has a relatively low breakdown voltage and a reignition voltage which is not much lower than the breakdown voltage.

A further object of the invention is to provide an electric discharge device in which an arc is formed in air or other gas at low pressure between metal electrodes which may be closely spaced to obtain a low breakdown voltage, and in which there is no danger of change in calibration

or erratic operation because of burning of the electrodes.

Still another object of the invention is to provide an electric discharge device in which the current density at the arc terminals is very low so that it is capable of discharging large currents without burning or excessive heating of the electrodes or the gap itself.

A further object of the invention is to provide an electric discharge gap suitable for use as a protective device or lightning arrester which has an arc extinction voltage on high alternating current which is only slightly less than the breakdown voltage.

A further object of the invention is to provide an electric discharge gap suitable for use as a protective device or lightning arrester which has a higher rate of recovery of dielectric strength after conducting a high alternating current than conventional spark gaps operating at atmospheric pressure.

A still further object of the invention is to provide a lightning arrester having a low discharge voltage for both surge currents and normal frequency power current so that there is a relatively small input of heat energy to be dissipated in the arrester.

Other 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 sectional view of a simple embodiment of the invention;

Figs. 2 and 3 are explanatory curves;

Fig. 4 is a wiring diagram showing one application of the new gap as a protective device;

Fig. 5 is a sectional view of a preferred embodiment of the invention as a lightning arrester; and

Figs. 6, 7 and 8 are sectional views showing further embodiments of the invention.

As previously stated, the new gap consists essentially of a pair of metal electrodes between which an arc discharge occurs in air or other gaseous medium at a reduced pressure which is preferably in the range between 10 cm. and 0.1 cm. of mercury. One embodiment of the invention is shown in Fig. 1 and consists of two flat disc-shaped metal electrodes 2 of relatively large area which are spaced apart by an annular spacer 3 of porcelain, or other suitable insulating material. The spacing between the electrodes 2 may be quite small and is preferably of the order of one or two millimeters. The electrodes 2 and spacer 3 are held together by an insulating or slightly conducting seal 4 of glass, or any other suitable sealing material such as a vitreous enamel, or wax or other organic seals, which secures them rigidly together and forms an airtight joint. The glass or other sealing material 4 is fused in place while the electrodes and spacer are held together under pressure so that an airtight seal is formed. A pump connection, indicated at 5, is provided in one of the electrodes 2, and after the gap is sealed up, the air pressure in the space between the electrodes is reduced to less than 10 cm. of mercury, and preferably to a pressure of the order of 1 cm. of mercury, after which the pump connection 5 is sealed off. If desired, any other inert gas, such as nitrogen or argon may be used in the gap instead of air.

The effect of the reduced gas pressure is illustrated in Figs. 2 and 3. The breakdown voltage between closely spaced plane electrodes at reduced pressure is a function of the product of the

spacing of the electrodes and the density of the gas between them. Since the density of a gas is proportional to the pressure at a given temperature, the breakdown voltage may also be expressed as a function of the product of the electrode spacing and the gas pressure. Fig. 2 is a curve for air showing the relation between the breakdown voltage between flat electrodes and the product of gas pressure and spacing of the electrodes expressed in cm. of mercury and mm., respectively. It will be seen from this curve that as the product of gas pressure and spacing of electrodes decreases, the breakdown voltage also decreases until a minimum breakdown voltage is reached at a relatively low value of this product, after which further decrease in pressure or spacing results in a rapid rise in the breakdown voltage. The minimum breakdown voltage obtained in this way is a constant for any given gas and cathode material, and the corresponding value of the product of pressure and spacing between the electrodes is also a constant at the minimum breakdown voltage. This is illustrated in Fig. 3 which shows the relation between pressure and breakdown voltage in air for gaps having different electrode spacings. Curve *a* in this figure shows the relation for a spacing of 1 mm., and curve *b* shows the relation for a spacing of 3 mm. It will be seen that the same minimum breakdown voltage is obtained for both spacings, but at different pressures such that the product of pressure and spacing is the same for both cases.

It will be apparent from the foregoing, therefore, that the breakdown voltage of the new gap depends upon the relation of the spacing of the electrodes and the pressure in the space between them, and it is intended that the gap shall be operated in the range in which the breakdown voltage is close to the minimum. For practical purposes, this critical range may be taken as being less than 10 cm. of mercury, and down to pressures as low as 0.1 cm. of mercury. The pressures mentioned herein are to be understood as meaning the pressure at ordinary room temperatures. When the temperature is increased in our new gap, the pressure will, of course, be increased but the density of the gas will remain the same, and the breakdown characteristics of the gap will not be affected, since the breakdown characteristics depend upon the density rather than the pressure of the gas. We have discovered that although the breakdown voltage is reduced by reducing the pressure, the reignition voltage or extinction voltage is not affected, or is affected only to a slight extent by the reduction in pressure, and is substantially the same as at atmospheric pressures. For this reason, the ratio of breakdown voltage to reignition or extinction voltage is very low when the pressure in the gap is kept in the range close to the minimum breakdown voltage, and the gap is self-extinguishing when the voltage is only a little less than the breakdown voltage, since the arc will not restrike after passing through a current zero.

When an arc is formed between metal electrodes in air or other gas at atmospheric pressure, the current density at the arc terminal is very high, being of the order of 10,000 amperes per sq. cm. We have discovered that when an arc is formed in air or other gas at low pressures in the range less than 10 cm. of mercury, the effective current density at the arc terminal is relatively very low, being only about 1,000 amperes per sq. cm. or less. For this reason the temperature rise of the elec-

trode is quite low, and no substantial amount of burning or erosion of the electrode takes place.

The temperature rise T° C. of a plane electrode at the arc terminal is given by the equation

$$T = \frac{2W\sqrt{t}}{4.18\sqrt{\pi k c \delta}} = \frac{26EI\sqrt{t}}{\sqrt{k c \delta}}$$

where

10 W =energy input in watts per square centimeter.

E =arc voltage

I =current density at cathode

k =thermal conductivity of electrode

c =specific heat of electrode

15 δ =density of electrode

t =time of arcing.

For copper electrodes with $k=0.98$, $c=0.13$ and $\delta=8.9$, the temperature rise as calculated from this equation is only 600° C. for an arcing time of 0.01 second, with a current density of 1,000 amperes per square centimeter, and arc terminal voltage drop of 25 volts. This temperature is well below the melting point of copper, and there is, therefore, no burning or erosion of the electrodes. In the case of an arc in air at atmospheric pressure, the temperature of the electrode as calculated by this equation rises well above the boiling point of copper in an arcing time of only one-half cycle of a 60 cycle current source, because of the very much higher current density.

It will be seen from the above equation that the temperature rise is dependent on the thermal characteristics of the electrode material as well as on the current density, and it is desirable to use a metal having high thermal capacity and high thermal conductivity. A comparison of the available metals indicates that copper will have the lowest temperature rise because of its high heat capacity and high thermal conductivity. Another factor to be considered, however, is the total rise in temperature caused by a given amount of heat, which is determined by the volume heat capacity. A comparison of various metals on a basis of the product of thermal capacity and density shows that iron has the highest value of this product, being about 10% greater than that of copper. From these theoretical considerations, therefore, it appears that the most desirable type of electrode for the new gap would be an iron disc coated with copper. From a practical standpoint, however, it has been found that other materials are equally well adapted from the standpoint of temperature rise and have other properties which make them desirable. Thus, in the gap structure shown in Fig. 1, it has been found that the iron-nickel-cobalt alloy known as Kovar is the most desirable electrode material because of its ability to form an air-tight seal with glass. Other materials, such as brass or copper may also be used with suitable sealing material to form an air-tight seal.

From the foregoing discussion it will be apparent that a gap device consisting of closely spaced metal electrodes separated by a gaseous medium at a pressure within the range between 10 cm. and 0.1 cm. of mercury will have a low breakdown voltage and relatively high reignition voltage, and that there will be no substantial amount of electrode burning because of the low current density and the resulting low temperature rise of the electrode. Actual tests on a gap similar to Fig. 1 consisting of copper discs 3 mm. thick and 25 sq. cm. in area with a gap spacing of 1 mm., and a pressure in the gap of 1 cm. of mercury showed that the gap had an impulse breakdown voltage

of 350 volts and a 60 cycle crest breakdown voltage of 300 volts. The reignition voltage after arcing for a half cycle was approximately equal to the 60 cycle breakdown voltage, and the temperature rise after conducting 5,000 amperes for a half cycle was only about 50° C. The marking of the electrodes after the test was so slight that no appreciable burning could be detected.

By using electrodes of large area, such as 25 square centimeters or more, very high current capacity is obtained since the discharge is free to spread between the electrodes, and the low current density prevents excessive heating or burning of the electrodes. The use of large area electrodes also provides a minimum time lag of breakdown under surge voltages, and thus provides a low impulse ratio, or ratio of surge breakdown voltage to normal frequency breakdown voltage. It will be apparent, therefore, that the new gap has very desirable characteristics which make it particularly well suited for voltage limiting protective applications.

One typical application of the new gap as a protective device is shown in Fig. 4, which is a wiring diagram showing the use of the new gap for the protection of a series capacitor. Series capacitors are used to neutralize the inductive reactance of a transmission or distribution line, and thus improve the voltage regulation and increase the stability limits. Such capacitors are connected directly in series with the line and since they carry the line current, they may be subjected to dangerous overvoltages in case of heavy overloads or short circuits on the line. For this reason it is necessary to provide some means for by-passing the capacitor when the voltage across it exceeds a predetermined value. The new gap is particularly well suited for this purpose, since it can be accurately adjusted to a relatively low breakdown voltage and will maintain its calibration unchanged after repeated operation, because of the absence of burning of the electrodes. Its self-extinguishing characteristics also make it well adapted for this application since no external equipment is needed to interrupt the discharge after the overvoltage has passed.

Fig. 4 shows a typical circuit arrangement for a series capacitor. The capacitor 6 is connected in series with one of the conductors of a transmission or distribution line 7, which is shown as a single-phase line supplied from a transformer 8 and connected to a load indicated diagrammatically at 9. The low pressure gap, which may be similar in structure to that shown in Fig. 1, is indicated at 10 and is connected directly across the terminals of the capacitor 6. It will be apparent that if the voltage across the capacitor 6 rises above the breakdown voltage for which the gap 10 is calibrated, the gap will break down and bypass the capacitor to protect it from the overvoltage. When the voltage falls to its normal value, the gap 10 will interrupt the discharge because of its self-extinguishing characteristics and restore the capacitor 6 to service. It may be desirable in some cases where very heavy short-circuit currents may be encountered to provide additional means for short-circuiting the gap after it has broken down in order to relieve it from carrying very heavy currents for a relatively long period. Any of the arrangements known in the prior art for this purpose may be used in connection with the gap 10.

The low ratio of breakdown voltage to reignition voltage of the new gap and its ability to discharge large currents at a low discharge volt-

age also make it very well suited for use as a lightning arrester. Since the breakdown voltage of a single gap is relatively low, it is usually necessary to use a plurality of gaps in series in order to obtain the desired voltage rating for a lightning arrester. A preferred embodiment of a lightning arrester utilizing a plurality of the new gaps in series is shown in Fig. 5. The discharge element of this arrester consists of a plurality of plane disc-shaped electrodes 12 of brass, copper, or other suitable material. The electrodes 12 are arranged in a stack and are separated by annular spacers 13 which may be of insulating material such as porcelain or other low expansion ceramic insulating material. The spacers 13 space the electrodes apart a small distance of the order of one or two millimeters, and the stack of electrodes and spacers are sealed together in an air-tight assembly by means of a suitable cement or other sealing material 14. Each of the electrodes 12 has an annular groove indicated at 15 adjacent its outer periphery in order to confine the discharge to the central portion of the electrode and to provide adequate insulation after high current discharges. A small hole 16 is drilled through each of the electrodes to permit ready evacuation of the assembly. A pumping connection 17 is provided in the bottom electrode for connection to a vacuum pump by means of which the pressure between the electrodes is reduced to less than 10 cm. of mercury, and preferably to about 1 cm. of mercury, the exact value depending, of course, on the spacing of the electrodes and the desired breakdown voltage, after which the pumping connection is sealed off. The complete gap assembly is preferably supported in a suitable porcelain housing 18, and a spark gap of any suitable type, indicated diagrammatically at 19, may be connected in series with the gap assembly if desired or necessary. The arrester is connected in series between a line conductor 20 or other device to be protected and ground 21 in the usual manner.

The series gap 19, if used, serves to insulate the low pressure gap assembly from the line voltage under normal conditions, but breaks down when a lightning surge occurs to connect the arrester to the line, and the surge is discharged through the assembly of low pressure gaps. The line is short circuited to ground through the arrester but because of the high reignition voltage of the low pressure gaps the discharge will be interrupted at the first current zero after the surge has passed, since the reignition voltage is greater than the normal line voltage. The low current density of the discharge, together with the large area electrodes which are preferably used, permits the discharge to spread between the electrodes and thus very large surge currents may be discharged without excessive heating of the arrester and with substantially no burning of the electrodes. In actual tests surge currents as high as 120,000 amperes have been repeatedly discharged through gaps of this type without objectionable burning of the electrodes.

When a plurality of gaps are used in series as shown in Fig. 5, it is usually preferable to provide a high resistance shunt across the multiple gap structure in order to provide better distribution of voltage across the individual gaps during the period of voltage reestablishment. The use of a resistance shunt permits the normal frequency charging current to pass to the series gap 19 so that the line voltage under normal conditions is completely across the series gap. This gap in-

interrupts the small leakage current through the resistance shunt after a surge has been discharged. Such a shunting resistance may conveniently be provided by making the annular spacers 13 of a high resistance or semi-conducting ceramic material. It may also be provided by using a high resistance cement for the sealing means 14, or it might even be provided by the use of an external resistor connected across the individual gaps. Any other suitable construction may be utilized, if desired, for providing a resistance shunt across the multiple gap structure to insure proper distribution of the voltage across the individual gaps.

Figs. 6 and 7 show alternative embodiments of the invention which are particularly suitable for multiple gap structures, and which may be used either in a lightning arrester, as shown in Fig. 5, or for overvoltage protective devices where it is desired to have a higher breakdown voltage than can be obtained with a single gap. In the construction shown in Fig. 6, disc electrodes 25 of Kovar or brass are used having an annular ridge formed in the periphery as indicated at 26. The electrodes 25 are disposed in a stack and separated by annular spacers 27 of porcelain, or other suitable insulating material. After stacking the electrodes, the spaces between the ridged edges are filled with powdered glass 28 or other suitable fusible sealing material, which is then fused to form an air-tight seal between the electrodes.

In the alternative construction shown in Fig. 7, plane disc electrodes 30 are used, arranged in a stack and separated by annular spacers 31 of porcelain or other insulating material. As indicated at 32, the spacers are hollowed out on their upper and lower surfaces, and the spaces thus formed are filled with powdered glass or solder or other fusible material capable of adhering to the electrodes 30, the surfaces of the spacers 31 being platinized if solder is used. The electrodes and spacers are then assembled in a stack and the fusible material 33 is heated while the stack is held under pressure so that an air-tight seal is formed. It will be apparent that other types of construction could be used to form either a single gap or a multiple gap structure consisting of closely spaced electrodes with the space between them enclosed and sealed up and maintained at a pressure less than 10 centimeters of mercury. The gas in the enclosed spaces between the electrodes may be air but any other inert gas such as nitrogen or argon may be used.

When a short arc is formed between closely spaced electrodes, the magnetic forces acting upon the arc may be such as to drive it outwardly against the insulating spacers which separate the electrodes. Since the thermal conductivity of the spacers is usually small, the arc will rapidly heat the spacer surface to a temperature which will cause it to decompose and might result in the destruction of the spacers. For this reason it is desirable to provide means to prevent the arc from moving against the spacers. One such means is shown in Fig. 5, consisting of the annular groove 15 near the periphery of each electrode which prevents the arc from spreading against the spacer. Fig. 8 shows another means by which this may be accomplished. The discharge device shown in this figure consists of a plurality of plane disc-shaped electrodes 35 separated by insulating spacers 36, the whole assembly being secured together and sealed by a suit-

able cement 37. In this embodiment of the invention, the electrodes 35 are made up of a shallow cup-shaped element 38 and a flat plate 40, forming a hollow electrode, within which is placed a magnetic disc 39 of steel or other magnetic material. The disc 39 should be insulated from the electrode to prevent current from flowing directly across the electrode in the axial direction. The effect of the disc 39 is to provide magnetic forces acting on the arc which oppose the magnetic forces tending to move it outwardly, and since the discs are made of smaller diameter than the arc spaces, the effect on the arcs will be to pull them toward the center and prevent them from coming in contact with the surface of the spacers. The use of the hollow electrodes also tends to keep the arc away from the spacers, since if the discs 39 are insulated, the direction of current flow to the arc terminal is necessarily such that the magnetic forces exerted by it on the arc are in a direction to move it towards the center of the electrode. In some cases it may be possible to omit the magnetic discs and rely solely on the use of the hollow electrodes to prevent the arc from coming in contact with the spacers.

It will be understood that various modifications and embodiments of the invention are possible. Thus, as has been mentioned above, the use of electrodes of large area results in a low impulse ratio for the gap. If it is not possible or desirable to use sufficiently large electrodes, the impulse ratio may become undesirably high, and in this case other means may be employed to reduce it. Thus, it is within the scope of the invention to provide ionizing means for ionizing the air in the gap space in order to reduce the surge breakdown voltage. This may be done by placing a small amount of radioactive material in the gap space to provide an ionizing radiation. A similar result may be secured by using spacers of high dielectric constant, such as rutile ceramic, or spacers which are specially designed to concentrate the voltage stress, either of which produces an ionizing radiation in the gap space as more fully set forth in a copending application of W. E. Berkey, Serial No. 244,419, filed December 7, 1938, and assigned to the Westinghouse Electric & Manufacturing Company. Other suitable means might also be used to improve the impulse ratio if necessary.

It should now be apparent that an electric arc discharge device or spark gap has been provided which has very desirable characteristics. Although various embodiments of the invention have been described, the essential characteristics of the new gap are that it consists of closely spaced electrodes, preferably of relatively large area, with the space between them maintained at a low pressure in the critical range between 10 centimeters and 0.1 centimeter of mercury in which the breakdown voltage is near the minimum. The desirable characteristics of this new gap may be summarized as follows: low current density at the arc terminals with resultant absence of burning or erosion of the electrodes; low breakdown voltage and high reignition voltage as compared to the breakdown voltage; and low discharge voltage for large currents. These characteristics make the new gap very well suited for use either as a lightning arrester or for other overvoltage protective applications, since the gap is self-extinguishing and has large current capacity without burning or excessive heating of the electrodes so that the calibration of the gap

is not changed by repeated operation even when the electrodes are closely spaced.

Various types of low pressure discharge devices have, of course, been used for special purposes but all such prior devices have been suitable only for very low currents and have usually had long discharge paths between relatively small electrodes. The new gap device differs from all previous low pressure discharge devices in using closely spaced electrodes of large area operating in a critical range of pressure to obtain the desirable characteristics described above. The large flat electrodes provide a short discharge path of the same length throughout the arcing space, which permits the discharge to spread between the electrodes so that very high currents of the order of thousands of amperes can be safely discharged, while the highest discharge currents that could be obtained without damage or lowering of the reignition voltage in prior types of low pressure discharge devices were of the order of only a few amperes.

It is to be understood that although certain specific embodiments of the invention have been illustrated and described for purposes of illustration, it is not limited to the exact arrangement shown, but in its broadest aspect, it includes all equivalent embodiments and modifications which come within the scope of the appended claims.

We claim as our invention:

1. A low-pressure protective discharge device for discharging heavy currents, said discharge device comprising metal electrodes of high thermal capacity having substantially plane, parallel gap surfaces of large area disposed to form a discharge gap between them, and enclosing means forming an air-tight enclosure for said gap surfaces, said enclosure being evacuated to a sufficiently low pressure to cause a discharge between the gap surfaces to spread over the surfaces so as to have relatively low current density,

the area of said gap surfaces being large enough to permit such spreading of the discharge, whereby currents of the order of thousands of amperes can be discharged without excessive heating.

2. A low-pressure protective discharge device for discharging heavy currents, said discharge device comprising metal electrodes of high thermal capacity having substantially plane, parallel gap surfaces of large area disposed to form a discharge gap between them, and enclosing means forming an air-tight enclosure for said gap surfaces, said enclosure being evacuated to a sufficiently low pressure to cause a discharge between the gap surfaces to spread over the surfaces so as to have a current density of the order of 1000 amperes per square centimeter, the area of said gap surfaces being large enough to permit such spreading of heavy-current discharges, whereby currents of the order of thousands of amperes can be discharged without excessive heating.

3. A low-pressure protective discharge device for discharging heavy currents, said discharge device comprising metal electrodes of high thermal capacity having substantially plane, parallel gap surfaces of large area disposed to form a discharge gap between them, and enclosing means forming an air-tight enclosure for said gap surfaces, said enclosure being evacuated to a pressure at which the arc-interrupting voltage is not greatly different from the breakdown voltage, and at which a discharge between the gap surfaces is caused to spread over the surfaces so as to have a current density of the order of 1,000 amperes per square centimeter, the area of said gap surfaces being large enough to permit such spreading of heavy-current discharges, whereby currents of the order of thousands of amperes can be discharged without excessive heating.

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