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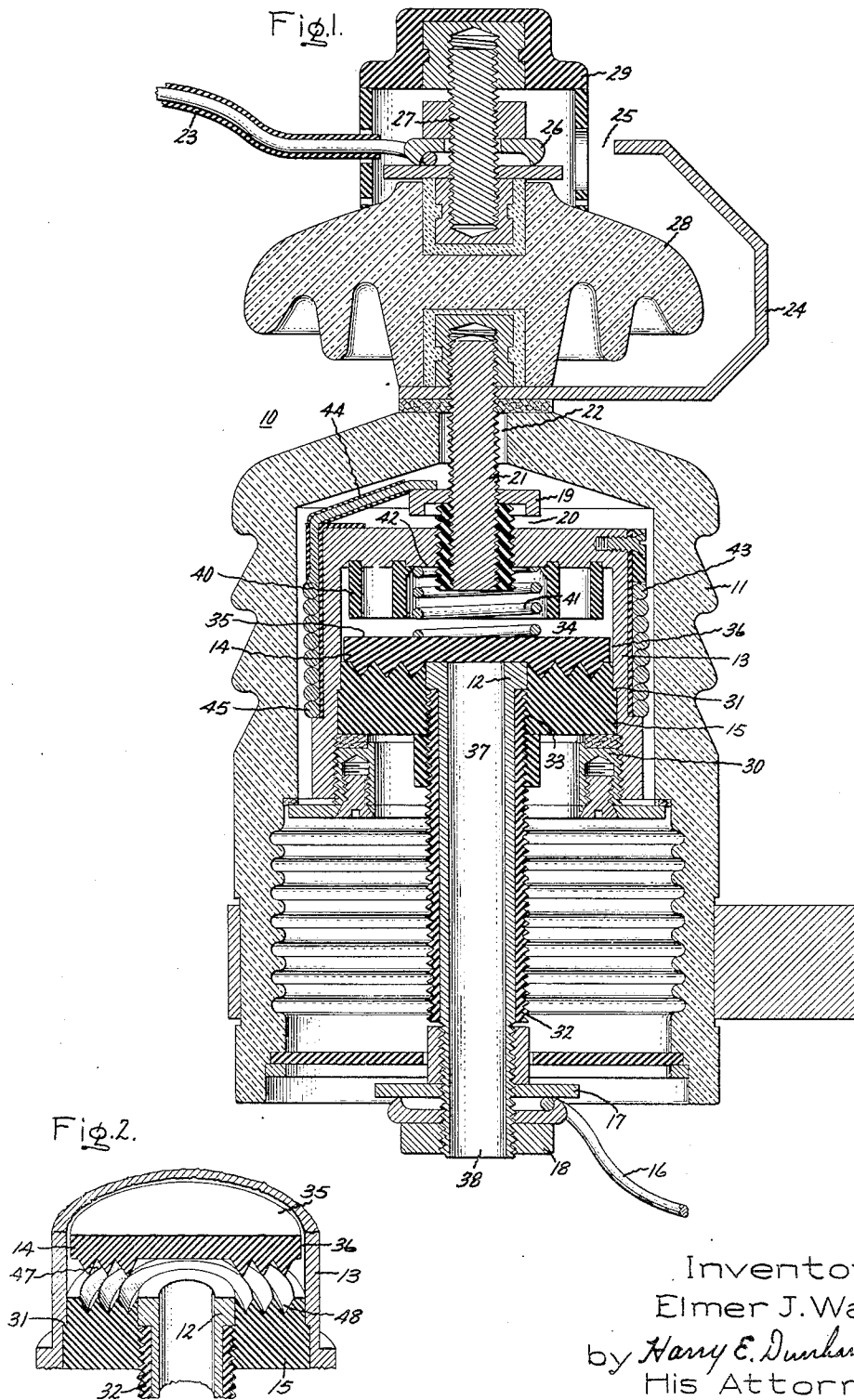
E. J. WADE

2,385,663

PROTECTIVE DEVICE

Filed May 9, 1942

2 Sheets-Sheet 1



Inventor:
Elmer J. Wade,
by *Harry E. Dunham*
His Attorney.

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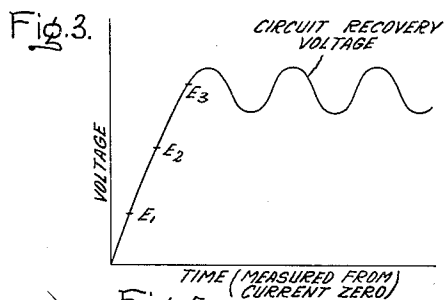
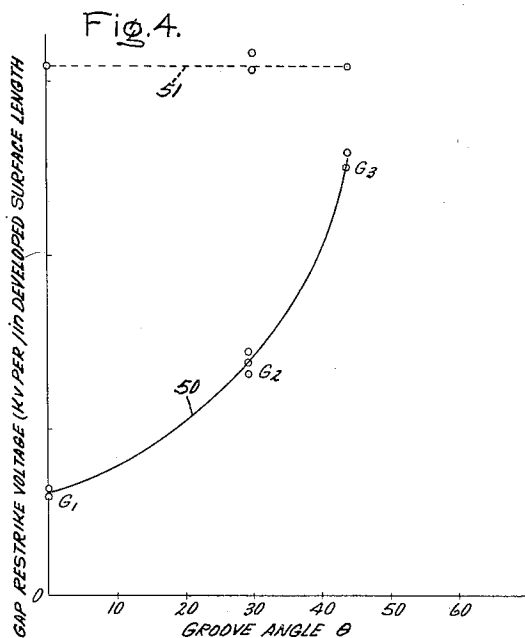
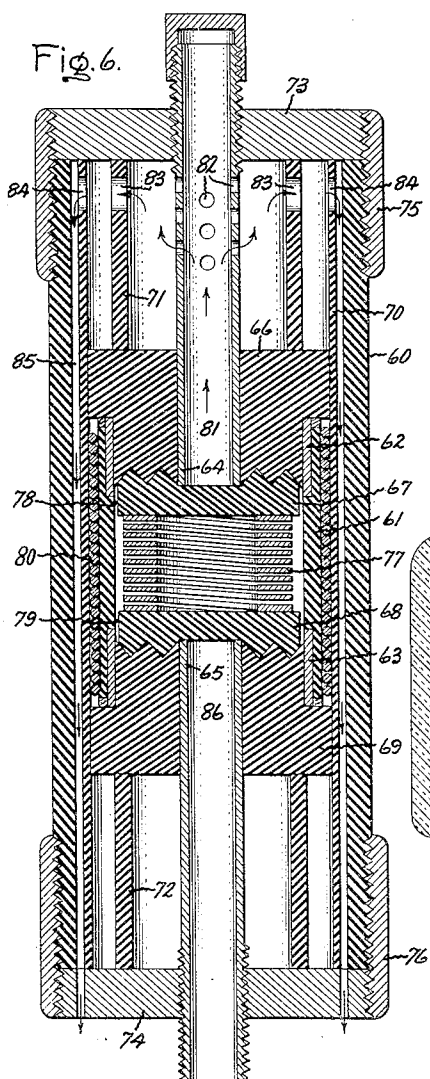
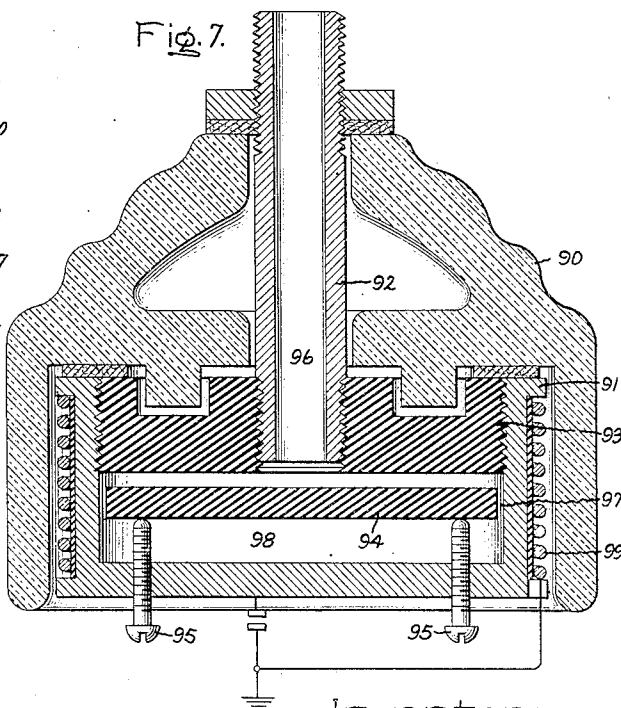
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2 Sheets-Sheet 2



Inventor:
Elmer J. Wade,
by *Harry E. Dunham*
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UNITED STATES PATENT OFFICE

2,385,663

PROTECTIVE DEVICE

Elmer J. Wade, Pittsfield, Mass., assignor to General Electric Company, a corporation of New York

Application May 9, 1942, Serial No. 442,337

14 Claims. (Cl. 175—30)

My invention relates to protective and circuit interrupting devices, and has application to overvoltage protective devices such as lightning arresters, and to fuse devices and electric circuit interrupters.

Various types of overvoltage protective devices for providing a circuit between an electrical device or line and ground for the passage of high voltage impulses have been suggested. One type, referred to as the arc expulsion tube, is provided with spaced electrodes with a surrounding tube of gas-evolving material so that when an arc occurs between the electrodes within the tube gas will be evolved from the tube walls to extinguish the arc caused by the power follow current. Such devices usually have a relatively high impulse discharge capacity, and when carrying impulse current have an arc-voltage drop low as compared to the voltage necessary to break down the gap and start a discharge. Such devices also, when discharging, usually pass one or more half-cycles of short circuit power current following the impulse discharge. Also, the gas emitting material is subject to erosion and in order to extinguish the arc such devices are made with relatively long gaps so as to provide an arrangement for extinguishing the power follow current. However, the larger the gap the higher the impulse breakdown. Furthermore, tubes of such construction which have a relatively large bore have a high impulse current discharge capacity, a high 60 cycle current discharge capacity, and a large value of minimum current which can be interrupted. Also, such tubes with a relatively small bore have a low impulse discharge capacity, a low 60 cycle current discharge capacity, and a low value of minimum current which can be interrupted. However, even with tubes of relatively small bores, a sufficient number of operations will erode the tube into a relatively large bore with a corresponding increase in minimum current sealing ability.

Also, overvoltage protective devices have been suggested having a pair of relatively movable coaxial disks of insulating material, a ground electrode positioned adjacent the center point of one of the disks, and a relatively narrow flat line electrode positioned adjacent a part of the periphery of the disks so as to provide an arcing path along a radius of the disks.

It is, therefore, an object of my invention to provide an improved protective device which has a much greater range of operation than the prior art devices, and which is efficient and reliable in operation and has a relatively long life.

Another object of my invention is to provide an improved overvoltage protective device which has a relatively low ratio of impulse breakdown voltage to rated voltage of the device.

5 A further object of my invention is to provide an improved protective device of the gas-evolving type which is highly efficient and reliable in gas liberation for putting out power follow-current arcs under a wide range of follow currents and voltages.

10 A further object of my invention is to provide a structure of the above-mentioned type with an improved arrangement for compensating for the erosion caused by arcing.

15 A still further object of my invention is to provide an improved overvoltage protective arrangement which has a relatively rapid insulation recovery characteristic.

20 A still further object of my invention is to provide an improved circuit interrupting device which is efficient and reliable in operation, and which has a relatively long life.

Further objects and advantages of my invention will become apparent from the following description referring to the accompanying drawings, and the features of novelty which characterize my invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

30 In the drawings Fig. 1 is a sectional side elevation of an overvoltage protective device which is provided with an embodiment of my invention; Fig. 2 is a perspective view of a portion of the protective device illustrated in Fig. 1, showing the position of parts thereof during a stage in its operation after the device has passed a high voltage impulse. Figs. 3 and 4 illustrate curves which will be employed in describing my invention; Fig. 5 is a fragmentary view of grooved disks employed in the device of Figs. 1 and 2, showing the groove angle; and Figs. 6 and 7 illustrate modifications of the device shown in Figs. 1 and 2.

45 In the arrangements illustrated in the drawings, I have shown my invention as applied to an overvoltage protective device such as one which will pass high current impulses such as those caused by switching impulses or lightning discharges, but it is to be understood that my invention has application to any other suitable protective device or circuit interrupting device which may provide a path for surges of short duration, or such devices as may be called upon to interrupt a power follow current, or interrupt
55 an electric circuit. The illustrated embodiment

of my invention includes a pair of electrodes with a suitable arrangement, such as insulating members defining an arc path through which an arc may strike between the electrodes. A vent opening is provided communicating with the arc path and a gas reservoir is provided which communicates with the arc path at a point removed from the vent opening communicating passage. Gas formed during arcing may flow into the reservoir during increasing current values and then this gas may flow from the reservoir over the arc path during decreasing current values. In order to increase the amount of gas given off during arcing the insulating members may be formed of any suitable material, such as gas evolving material. In order to provide an arc path the cross section of which will vary for different values of discharge current, the insulating members are made relatively movable and a biasing force is provided which force, during operation of the device, is a function of the value of current being interrupted. In addition, a relatively light force may be provided in any suitable manner, such as by a spring, so as to assist in interrupting power currents of relatively small magnitude. Any suitable arrangement may be provided for producing a force whose value is a function of the current being cleared, and in the arrangement illustrated in the drawings a reservoir is provided which communicates with a surface of one of the insulating members which is movable. In this manner the force developed by the gas in the reservoir will be communicated to the movable insulating member. The adjacent surfaces of the insulating members may be provided with cooperating grooves or corrugations, so as to provide a zig zag arc path when the disks are relatively close together, and it has been found that a device having my improved combination has a very high restrike voltage or dielectric recovery strength. In order to assist in distributing the erosion evenly around the insulating members a magnetic field may be provided for moving or rotating the arc. Also any erosion which does obtain will be compensated for since the disks are movable.

Referring more particularly to the drawings, I have illustrated in Fig. 1 an overvoltage protective device 10 which may be placed in any suitable housing such as a cup-shaped insulator 11. The protective device includes a pair of cooperating electrodes 12 and 13 between which an arc may strike. An arc path is provided between the electrodes 12 and 13 by adjacent surfaces of a pair of insulating members or disks 14 and 15. When a voltage of sufficient value is, therefore, impressed between the electrodes 12 and 13 an arc may strike between these electrodes and through the path defined by the adjacent and cooperating surfaces of the insulating members 14 and 15 and move them apart, as is shown in Fig. 2. The electrodes 12 and 13 may be connected in any suitable circuit and in the arrangement illustrated in the drawings the electrode 12 is adapted to be connected to ground through a conductor 16 which is attached to the lower end of the electrode 12 between a collar 17 and a nut 18. The electrode 13 may be connected to any suitable electric device such as a high voltage transmission line in any suitable manner, such as through a conducting member 19 which is spaced from the electrode 13 to form a gap 20. The member 19 is connected to a stud 21 which extends through an opening 22 in the insulator 11. This stud 21 is in turn connected to a cable

23 which is adapted to be connected to the transmission line. This connection is made through a conducting strap 24 which provides one electrode of the conventional series gap 25. The other electrode of the series gap is provided by a clamp 26 which is connected to the line connector 23, the clamp being carried by a stud 27 on a suitable insulator 28. A cap 29 is provided of any suitable material such as a molded plastic for enclosing the stud 27 and electrode 26.

In order to be able to vary the cross sectional area of the arc path between the electrodes 12 and 13 the insulating members 14 and 15 are mounted for relative movement. The members 14 and 15 may be mounted in any other suitable manner, however, if desired. In this manner the pressure between the disks due to an impulse or power frequency discharge will be limited, and thus the forces which the disks of insulating material must withstand may be limited to any suitable value. When this disk movement is combined with other features of my invention which will be described, various other desirable results obtain. This relative movement may be obtained in any suitable manner, such as by mounting one of the insulating members, such as the disk 14 for relative movement and by relatively fixedly mounting the disk 15 on the electrode 13. As the electrode 13 has a cup-shaped construction in the arrangement illustrated in the drawings, a convenient way of mounting the disk 15 is to provide a ring 30 which is threaded into the open end of the cup-shaped member 13 so as to force a shoulder of the insulating disk 15 against a suitable cooperating shoulder 31 on the inside periphery of the electrode. Also it is to be understood that the electrode 13 may have any other suitable shape. The center electrode 12 may be mounted with respect to the electrode 13 in any suitable relationship, such as by making them relatively fixed by providing a cylinder of insulating material 32 tightly around the electrode 12 which cylinder is supported within a central bore 33 of the insulating member 15.

In order to provide an arrangement for actuating or biasing the relatively movable insulating disks 14 and 15 during operation of the device with a force which is a function of the value of the current being interrupted, I provide a suitable reservoir 34 which communicates with a surface 35 of the relatively movable disk 14, see Fig. 2. By making the electrode 13 cup-shaped and extending the electrode 12 only part way into the electrode 13, a chamber or gas reservoir 34 is, therefore, provided by the end and side walls of the electrode 13 and the surface 35 of the disk 14. The gas reservoir is also provided with a suitable passage which communicates with the arc path so that gases formed by the arc may flow through this passageway into the gas reservoir. Such a passage is provided by making the outer dimension of the disk 14 less than the inner dimension of the electrode 13 so that a peripheral space 36 will be provided which communicates between the gas reservoir and the arc passage. A suitable venting arrangement is also provided which communicates with the arc passage at a point which is spaced or removed from the point at which the gas reservoir passage 36 communicates with the arc path. Any suitable arrangement may be provided for the vent, and in the arrangement illustrated in the drawings the vent passage is provided by a tubular passage 37 within the electrode 12 which passage

communicates with the arc path between the disks 14 and 15. The vent passage is provided with an opening 38 which communicates with the outside atmosphere. Thus, by providing a relatively tight connection between the outside periphery of the relatively stationary disk 15 and the inside surface of the electrode 13 the arc path has only a vent passage 37 and a passage 36 communicating with the gas chamber 34. It will be seen that a compact and efficient structure obtains when the tube forming the electrode 12 is substantially centrally disposed with respect to the electrode 13 and when the vent passage is provided by the central opening in the tube.

When a voltage of sufficient magnitude causes an arc to strike between the electrodes 12 and 13 in the arc path between the adjacent surfaces of the disks 14 and 15 gases will be formed which will separate the disks 14 and 15 and increase the cross sectional area of the arc path as is shown in Fig. 2. The amount of movement of the disk 14 away from the disk 15 will be dependent upon the amount of pressure produced between the surfaces which is in turn dependent upon the strength of the arc or the strength of the current flowing between the electrodes. Thus for larger currents the disk 14 will move away from the disk 15 until it touches suitable stops 40 which may be composed of any suitable resilient material. In order to enhance further the amount of gases evolved during the passage of the arc the disks 14 and 15 may be made of any suitable gas evolvable material, such as hard fibre. Thus, as the current is increasing gases will be evolved, some of which will flow out through the vent opening 37 and some of which will flow through the passage 36 into the gas reservoir 34. This will occur during that part of the cycle when the current is increasing so that pressure which will be developed in the reservoir will exert a force on the movable disk tending to move it toward the fixed disk. The higher the current the higher the pressure in the reservoir so that the movable disk will be acted upon by a force which is a function of the current being interrupted. When the current begins to decrease or when it approaches zero the gas pressure between the disk surfaces will decrease so that gas will flow from the reservoir through the passageway 36 across the surfaces of the arc path and out through the vent openings 37 and 38. Thus the surfaces of the arc path will be bathed with a relatively cool deionizing or un-ionized gas. It will also be apparent that during this period when the gas is flowing from the reservoir 34 out through the vent 37, the pressure back of the disk will exceed the pressure between the disks so that the movable disk 14 will be forced toward the stationary disk 15. This causes the disks to be moved relatively close together which increases the length of the arc path and improves the current interrupting ability of the protective device. Also, it will be seen that the movable disk acts as a check valve because as the movable disk approaches contact with the fixed disk, the flow of gas from the reservoir into the central venting tube is restricted. As a result, the pressure in the reservoir decreases relatively slowly when the disks are in contact and thus the disks are held firmly together for a longer period of time than would be the case if there were no gas pressure acting on the movable disk. It will also be appreciated that as the gas enters the reservoir during increasing current values or during

the rising portion of the current cycle, the gas will be cooled and deionized as it passes through the relatively narrow passage 36. Further cooling and deionization of the gas will proceed during the time the gas is in the reservoir. Thus, this cooled and deionized gas passes over the faces of the disks as it flows to the vent and the arc path between the faces of the disks is flushed with gas having a relatively high dielectric strength. Also by varying the size of the reservoir passage in its relation to the size of the vent passage, the area of the movable disk adjacent the reservoir, and the area of the arc path, the pressure developed in the reservoir may be controlled.

In order to provide a force for biasing the disks when only a relatively small amount of gas pressure is available in the reservoir 34, I may provide a biasing spring 41 which may be placed between the back surface 42 of the electrode 13 and the surface 35 of the disk 14. At very low currents the evolution of gas from the surfaces of the disks may be inadequate in itself to develop sufficient pressure in the reservoir so as to bias the disks together sufficiently for efficient low current interrupting ability, and so a biasing spring of a proper force will supply just enough force for low current interruption so as to assist the back pressure in keeping the movable disk in contact with the arc. However, the spring should have a relatively weak or light force characteristic since a strong spring would push the disks too tightly together as to prevent efficient interruption of the arc at low current.

If desired, the arc moving principle may be employed, with my improved structure, for moving or rotating the arc which strikes between the electrodes 12 and 13. In the arrangement illustrated in the drawings a magnetic field is provided by a coil 43, which is connected in series with the electrode 13. This connection is made by connecting one end of the coil 43 to the stud 19 through a conductor 44 and by connecting the other end of the coil to the electrode 13, as at 45. Thus, the power follow current will flow through the coil 43 and produce an axial field which will act on the radial arc so as to rotate it between the disks 14 and 15. The gap 20 provided between the stud 21 and the electrode 13 limits the voltage, during discharge, appearing between the turns of the coil and between the coil and the electrode 13 to safe values. Also, by properly proportioning the gap characteristics and the impedance of the coil 43, the high current impulses will pass to the electrode 13 through the gap 20 while the power frequency currents will flow through the coil and not across the gap 20. Thus, the series coil 43 provides an axial magnetic field during the flow of the power frequency current. By rotating the arc the erosion of the disks is not only more evenly distributed but the erosion of the metallic electrodes is also minimized. Furthermore, the axial flux will lag the current because the metallic shell electrode 13 provides a closed circuit electromagnetically coupled with the coil which acts as a short circuited secondary turn, and due to the lagging phase angle the value of the flux will be greater as the current is approaching zero, than would be the case were the flux in phase with the primary current. Thus, for these values of low currents the force available to rotate the arc will be relatively larger and the rotation, cooling and deionization of the arc consequently greater as the arc approaches zero which assists in interrupting the arc. Strange though it may sound, devices of the prior

art to which my improved device relates which are adapted to interrupt large currents are not usually expected to interrupt relatively small currents. However, the magnetic field feature of my device cooperates with the spring bias feature so that values of power current that are too low in magnitude to evolve gas in sufficient quantity may be efficiently interrupted.

As will be seen in Figs. 1 and 2 the cooperating insulating members which provide the surface for the arc path are provided with cooperating grooves. Thus, a plurality of grooves 47 on the disks 14 cooperate with a plurality of grooves 48 on the disks 15, so that when the power follow current is decreasing or approaching zero and the disks are relatively close together a zig zag path will be provided for the arc. The ends of the hills and valleys of the grooves may be pointed as shown or they may have any other suitable contour or construction. It has been determined that with grooved arc path surfaces the restriking voltage or insulation recovery characteristics of my improved device is greatly increased over the voltage or recovery characteristic obtaining with relatively flat arc path surfaces. In an overvoltage protective device or circuit interrupting device of this type in which an arc occurs during discharge, the arc will continue until the power follow current passes through zero at which time the arc will be momentarily extinguished. At this instance when the arc is extinguished the device will begin to build up its dielectric strength and this value of recovered dielectric strength, at any instant after the current passes through zero and for a given circuit recovery voltage characteristic, can be expressed as a voltage. A typical circuit recovery voltage characteristic is shown in Fig. 3 in which voltage is plotted as ordinate and time as abscissa. In order that the power follow current will not restrike the arc as the circuit recovery voltage begins to build up after current zero, this recovered dielectric strength of the device must at all times be greater than the circuit recovery voltage. When the circuit recovery voltage exceeds the recovered dielectric strength of the gap, the gap restrikes and the voltage at which this occurs is called the restrike voltage. The restrike voltage may then be considered a measure of the recovered dielectric strength of the gap for the instant at which restriking occurs and for the conditions of operation. It is, of course, desirable that this restrike voltage be as high as possible.

In Fig. 4, is illustrated a comparison between the recovered dielectric strength or gap restrike voltage of devices having gaps with grooved surfaces of various angles with devices having gaps formed between flat surfaces. Groove angles are plotted on the abscissa axis, and gap restrike voltage per inch of developed dielectric surface length is plotted as ordinate (the left-hand axis of the curve). What is meant by groove angle is illustrated in Fig. 5, and the groove angle, θ , is that angle between the tangent to a surface of the groove or a tangent to the surface between the ends of a corrugation and a plane perpendicular to the disk axis. Thus, curve 50 in Fig. 4 illustrates the change in gap restrike voltage for zero groove angle, which is, of course, a flat surface to groove angles up to about 45 degrees. It will be noted that the restrike voltage, and hence the recovered dielectric strength, increases at an unexpected rate as the groove angles increase from a flat surface. Thus, the recovered dielectric strength or voltage, G_2 , for a 30° groove is

about twice that voltage, G_1 , for a flat surface, groove angle zero, and the voltage, G_3 , for a device with a gap whose surfaces have a 45 degree groove is about four times that value obtaining with a device having relatively flat arcing surfaces. The particular values on the circuit recovery voltage curve which correspond to the values G_1 , G_2 , and G_3 are marked as E_1 , E_2 , and E_3 , respectively, on Fig. 3. These three values were found with three devices in which the developed surface length including the length of the hills and valleys between the electrodes was the same. The circuit recovery voltage, as will be seen in Fig. 3, was also the same, and this recovery voltage was made sufficiently severe so as to cause the arc to restrike in each case.

It will be seen that by employing corrugated arcing surfaces instead of an equivalent length of arc path with flat surfaces, I have obtained an unexpected and substantial increase in recovered dielectric strength. This, it is believed, is due to the reason that the disks are allowed to move apart at the initial time of the discharge to provide a relatively short arc path distance, as is shown in Fig. 2, the disks with their cooperating grooves being biased together to provide a much longer path, as the follow current approaches zero, by a force which is a function of the magnitude of the current being interrupted. Thus, an arrangement is provided for substantially increasing the length of the arc path when the current cycle is approaching zero. Another reason for this unexpected increase in restriking characteristics with grooved gap surfaces over flat gap surfaces, it is believed, is due to the fact that only a component of the radial field due to the restrike voltage acts in a direction of the arc path. The dielectric field due to the recovery voltage is, of course, predominantly radial in the illustrated construction while the arc path is zig zag due to the cooperating grooves. Thus, only a component of the field can act at any one time to restrike the arc. This grooved construction also apparently increases the contact between the arc and the disk surfaces because of the circuitous path through which the arc must follow. A further reason for the increase in the restrike voltage with grooved surfaces may also be that the constantly changing direction of the arc path will cause reflection of the gases and arc at the bottom of the grooves when the disks are relatively close together which will increase the turbulence of gas flow.

The dotted line curve in Fig. 4 illustrates that the increase in dielectric strength in devices with the grooved surfaces is not accomplished at the expense of an increase in the impulse breakdown potential of the device. On the contrary, the impulse breakdown voltage of the devices with various groove angles is constant as will be seen in the dotted line curve 51 of Fig. 4. For this curve the abscissa are groove angles while the ordinates read on the right-hand axis of the curve are breakdown values when tested at wave fronts rising at approximately 100 kv. per microsecond. Therefore, this result of a lowering of the ratio of impulse breakdown to restrike voltage which determines the circuit interrupting device rating is unexpected, since usually changes in protective device designs of this type, which increase the interrupting ability of the device, are accomplished only by a resulting increase in the impulse breakdown characteristics of the device, which result impairs the protective ability of the device.

In order to increase the interrupting capacity of the device described above, the dimensions thereof may be increased, or a plurality of such devices may be employed together. In Fig. 6 is illustrated an arrangement in which two protective devices are employed together as an integral structure. A housing 60 of suitable insulating material is provided with a pair of protective devices connected in series. A single insulating tube 61 is provided at the center of the housing 60 which has metal rings or inserts 62 and 63 at the top and bottom thereof, respectively, to provide electrodes for the devices. A center electrode 64 is provided which cooperates with the electrode 62 and a center electrode 65 axially spaced from the electrode 64 is provided for cooperating with the electrode 63. The electrode 64 may be connected to the apparatus which is being protected. An arcing surface is provided between the electrodes 62 and 64 by the adjacent surfaces of disks 66 and 67 while the arcing surface between the electrodes 63 and 65 is provided between disks 68 and 69. A cylindrical insulating member 70 may be spaced from the inside periphery of the housing 60 to provide a passage for the gases. The assembly including the electrodes and disks may be stationarily supported within the housing 60 by suitable insulating spacers 71 and 72 at the top and bottom, respectively, which spacers cooperate with covers 73 and 74 which are tightly attached to the top and bottom, respectively, of the housing 60 in any suitable manner such as by collars 75 and 76. The covers 73 and 74 are provided with suitable openings to accommodate the tubular electrodes 64 and 65, these electrodes being sufficiently long so that the ends thereof extend outside the covers 73 and 74.

In order to obtain the relative movement between the disks 66, 67 and 68, 69 the disks 67 and 69 are movably mounted. The movable disks may be guided within the bore formed by the insulating cylinder 61 in any suitable member such as by providing a spring 77 of suitable force characteristics with ends abutting against the adjacent surfaces of the movable disks. The space between the movable disks also provides a common reservoir for the gases, which reservoir communicates with the arcing space between the disks 66 and 67 through a peripheral passage 78 between the outer periphery of the disk 67 and the inner surface of the insulating cylinder 61. A similar passage 79 is provided between the disk 69 and the adjacent surface of the cylinder 61. A coil 80 with ends connected to the electrodes 62 and 63 may also be provided. This coil 80 is spaced wound, that is, each turn is spaced from the adjacent turn so as to provide a gap across which the high voltage impulse may pass instead of traversing the path around each turn. The electrode means including the coil and its gaps, therefore, connect the electrode portions 62 and 63 together.

When a high voltage is impressed on the electrode 64 an arc will be formed between the electrodes 64 and 62 and the electrodes 63 and 65 in the same manner as in the structure illustrated in Fig. 1. While gas is being developed between the arc path surfaces some of the gases will flow through the passages 78 and 79 into the chamber formed between the adjacent surfaces of the movable disks and the inside periphery of the cylinder 61. When the pressure in the chamber exceeds that obtaining between the cooperating disks 66 and 67 the gases will flow over the gap

surfaces and out a vent passage 81 which is provided by the opening in the central electrode 64, as is shown by the arrows. Suitable openings 82 are provided near the upper end of the electrode 64 and openings 83 and 84 are provided in the tubular members 71 and 70, respectively, so as to provide a passage for the escaping gases. In order to vent the escaping gases at the ground end of the device which is at a different potential than the electrode 64 a long peripheral passage 85 may be provided between the outer surface of the tubes 70 and the inner surface of the housing 60 to cool and deionize the gases before they reach the grounded end vent and prevent flash-over between the electrode 64 and ground. The gases will then flow out through this passage as is shown by the arrows. The gases which flow out between the disks 68 and 69 may pass through the vent passage 86 formed by the center electrode 65.

Another modification of my improved protective and circuit interrupting device is illustrated in Fig. 7, and this structure includes a housing 90 having a cup-shaped portion which contains a tubular electrode 91. A center electrode 92 may be provided and an insulating member 93 placed between the electrodes 91 and 92 to provide a portion of the arc path between the electrodes. The remainder of the arc gap is defined by an insulating member 94 of suitable material which member is relatively movable with respect to the disk 93. When the device is placed in a vertical position as shown, the disk 94 will be biased away from the disk 93 by the force of gravity, suitable stops in the form of screws 95 being provided for controlling the maximum cross-sectional area of the arc path. This construction has the advantage of providing an initial sparkover path of large cross-section which will minimize damage from high impulse currents. The outer electrode 91 may be connected to any suitable apparatus in the same manner as that of the structure illustrated in Fig. 1 is connected to a transmission line. In this construction when the arc strikes between the electrodes 91 and 92 the movable disk 94 is already in its position to provide maximum cross-sectional area for the arc space. Gases will be formed which will flow out a vent passage 96 which is formed through a central opening in the tube electrode 92 and gases will also flow through a passage 97 which communicates with a gas reservoir 98. When the pressure in the reservoir 98 exceeds that obtaining between the adjacent surfaces of the disks 93 and 94 the disks will be forced together at the same time gases flow out through the passageway 97 and through the arc path thus checking the movement of the disk 94 and cooling and deionizing the arc gap. A coil 99 may be provided for rotating the arc in the same manner that the coil is provided in the construction described above.

In view of the foregoing it will be seen that I have provided an improved protective or circuit interrupting device with advantages and improved operating characteristics which have been pointed out in the description of the various features of my invention, and these advantages and characteristics may be obtained over a relatively wide range of circuit conditions.

Modifications of the particular arrangements which I have disclosed embodying my invention will occur to those skilled in the art, so that I do not desire my invention to be limited to the particular arrangements set forth and I intend in

the appended claims to cover all modifications which do not depart from the spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A protective device including a pair of electrodes, relatively movable members defining an arc path through which an arc may strike between said electrodes, means defining a vent opening communicating with said arc path, and means defining a gas reservoir communicating with said arc path, said gas reservoir communicating with said arc path at a point removed from said vent opening communicating means so that gas formed during arcing may flow into said reservoir during increasing current values and flow from said reservoir over said arc path during decreasing current values, and means including the pressure of gas in said gas reservoir for biasing said relatively movable members toward each other to limit the area of the arc path during operation of the device.
2. A protective device including a pair of electrodes, relatively movable insulating members defining an arc path between adjacent faces thereof through which an arc may strike between said electrodes, means defining a vent opening communicating with said arc path, and means defining a gas reservoir communicating with said arc path, said gas reservoir communicating with said arc path at a point removed from said vent opening communicating means so that gas formed during arcing may flow into said reservoir during increasing current values and flow from said reservoir over said arc path during decreasing current values, said adjacent faces being forced together by the pressure of gas in said gas reservoir during operation of said device.
3. A protective device adapted to interrupt current including a pair of electrodes, insulating members defining an arc path between adjacent surfaces through which an arc may strike between said electrodes, one of said members being movable so as to vary the cross sectional area of said arc path, means defining a vent opening communicating with said arc path, and means defining a gas reservoir communicating with said arc path at a point removed from said vent opening communicating passage so that gas formed during arcing may flow into said reservoir during increasing current values and flow from said reservoir over said arc path to said vent during decreasing current values, and means for transferring the pressure of the gas in said reservoir to bias said movable member toward said other insulating member during operation of the device.
4. A device adapted to interrupt current including a pair of electrodes, a pair of insulating members of gas evolving material defining an arc path between adjacent faces thereof through which an arc may strike between said electrodes, a coil surrounding said electrodes with its axis perpendicular to said arc path, and means for electrically connecting said coil with the arc path between said electrodes for energizing said coil under arcing conditions so that the field produced by said coil will move said arc and thereby distribute erosion around the surfaces of said insulating members and said electrodes.
5. A protective device adapted to interrupt alternating current including a tubular shaped electrode, a second electrode having a portion within said tubular shaped electrode, a pair of insulating members defining an arc path be-

tween adjacent faces thereof through which an arc may strike between said electrodes, a coil surrounding said tubular shaped electrode, and means for electrically connecting said coil with the arc path between said electrodes and for magnetically coupling said coil with one of said electrodes for energizing said coil under arcing conditions so as to provide a relatively large electromagnetic force for moving an arc between said electrodes over said members when the current being interrupted approaches zero.

6. A protective device adapted to interrupt alternating current including a pair of electrodes, means adapted to connect said electrodes across apparatus to be protected, a coil adjacent said electrodes, and means including one of said electrodes for electrically connecting said coil in series with said electrodes and for providing a closed circuit electromagnetically coupled with said coil for energizing said coil under arcing conditions so as to provide a relatively large force for moving a power arc between said electrodes when the current being interrupted approaches zero.

7. A protective device adapted to interrupt current including a cup-shaped member providing a tubular shaped electrode, a tubular shaped member providing a second electrode within said cup-shaped member, a pair of insulating members, one of said insulating members substantially spanning the space between said tubular shaped member and said cup-shaped member, said other insulating member having an outer dimension less than an inner dimension of said cup-shaped member so that said other member is movable with respect to said first member, said cup-shaped member and said movable member providing a chamber communicating with the adjacent surfaces of said members through the space between the outer peripheral surface of said movable member and the inner surface of said cup-shaped member, and a coil around said cup-shaped member and electrically connected with the arc path between said electrodes for energizing said coil under arcing conditions.

8. A device adapted to interrupt current including a pair of spaced electrodes, relatively movable insulating members of gas evolving material defining an arc path between adjacent faces thereof through which an arc may strike between said electrodes, a coil surrounding said electrodes with its axis perpendicular to said arc path, means for electrically connecting said coil with the arc path between said electrodes for energizing said coil under arcing conditions so that the field produced by said coil will move said arc and thereby distribute erosion around the surfaces of said insulating members, and spring means for biasing said insulating members together, said spring means having a relatively weak force characteristic so that the arc produced by low current values will be able to move the insulating members sufficiently to allow rotation of the arc.

9. A device adapted to interrupt current including a pair of electrodes, insulating members of gas evolving material defining an arc path between which an arc may strike between said electrodes, one of said members being movable so as to vary the cross sectional area of the arc path, means defining a vent opening communicating with said arc path, means defining a gas reservoir communicating with said arc path at a point removed from said vent opening communicating passage, magnetic means for moving

said arc, and means including spring means and the pressure of gas in said reservoir for biasing said movable insulating member toward said other member during operation of said device.

10. A protective device adapted to interrupt 5 current including a pair of electrodes, relatively movable insulating members of gas evolving material defining an arc path between adjacent faces through which an arc may strike, said adjacent surfaces having grooves providing a zig-zag arc path when said members are relatively close together, means defining a vent opening communicating with said arc path, means defining a gas reservoir communicating with said arc path at a point removed from said vent opening communicating passage, magnetic means 10 for moving said arc, and means including spring means and the pressure of gas in said reservoir for biasing said insulating members during operation of said device.

11. A protective device including an enclosing housing, a tubular shaped member therein having electrodes at its inner periphery adjacent opposite ends, a pair of tubular shaped electrodes within said housing and each having an end spaced from one of said first-mentioned electrodes, and means including a pair of relatively movable insulating members defining a pair of arc paths between said first-mentioned electrodes and said spaced tubular electrodes.

12. A protective device adapted to interrupt current including a pair of electrodes, normally separated insulating members defining an arc path between adjacent surfaces through which an arc may strike between said electrodes, one of said members being movable so as to vary the cross sectional area of said arc path, means defining a vent opening communicating with said arc path, means defining a gas reservoir communicating with said arc path at a point removed from said vent opening communicating passage, and means for transferring the pressure of the gas developed in said reservoir to said movable member for forcing said movable member toward the other insulating member, said movable mem- 45

ber being so constructed and arranged so as to normally tend to move in a direction opposite to the direction of the force due to the gas pressure in said reservoir acting on said movable member.

13. A device adapted to interrupt current including a pair of axially spaced electrodes, tubular means radially spaced from said first-mentioned electrodes and having electrode portions providing arc gaps with the adjacent of said first-mentioned electrodes, insulating means defining arc paths for said arc gaps, said insulating means having spaced portions cooperable with said tubular means to provide a gas reservoir, said insulating means being spaced from said tubular means to provide peripheral passages communicating between said arc gaps and said gas reservoir, and means providing a vent opening communicating with at least one of said arc paths.

14. A device for interrupting alternating current including a pair of conducting members between which an arc may be drawn, means including insulating means having relatively movable portions defining an arc space between said conducting members, a gas reservoir communicating with the arc space into which arc gases may flow during increasing values of current, means defining a vent opening communicating with said arc space removed from the reservoir communicating means, movement of said relatively movable portions during operation of the device varying inversely the respective volumes of said arc space and said gas reservoir, the volume of said arc space increasing during increasing values of current, and means including the pressure of gas in said reservoir providing a force to move said relatively movable portions to decrease the volume of said arc space and increase the volume of said reservoir during decreasing values of current so as to check and restrict the flow of gas from the reservoir over the arc space in order to facilitate cooling and extinguishing of the arc.

ELMER J. WADE.