

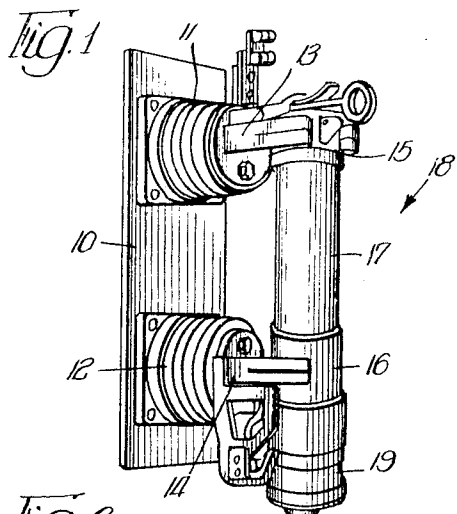
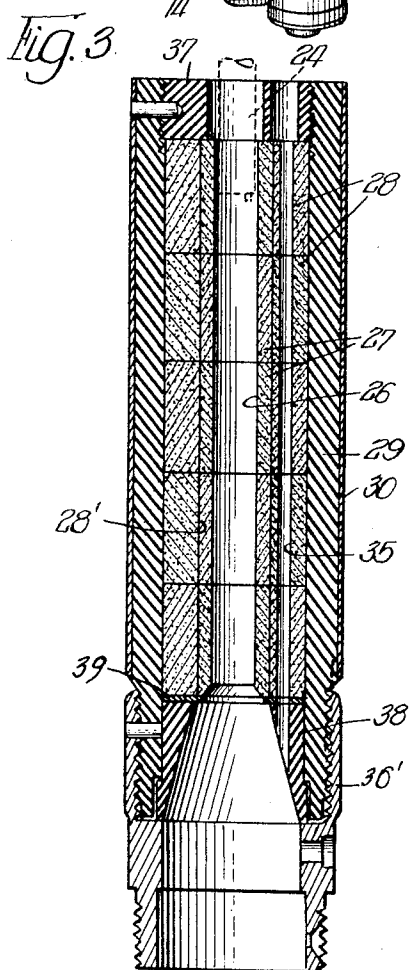
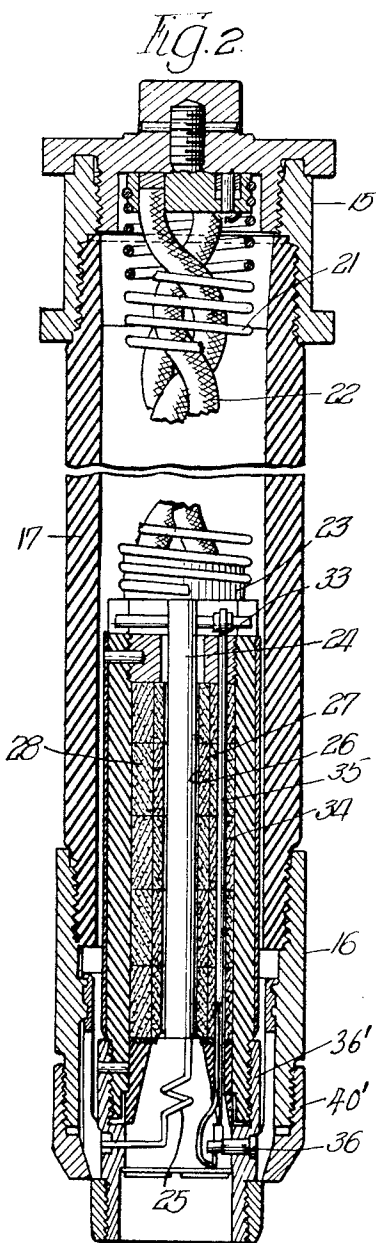
Nov. 22, 1960

S. I. LINDELL
CIRCUIT INTERRUPTER

2,961,514

Filed Jan. 19, 1959

3 Sheets-Sheet 1



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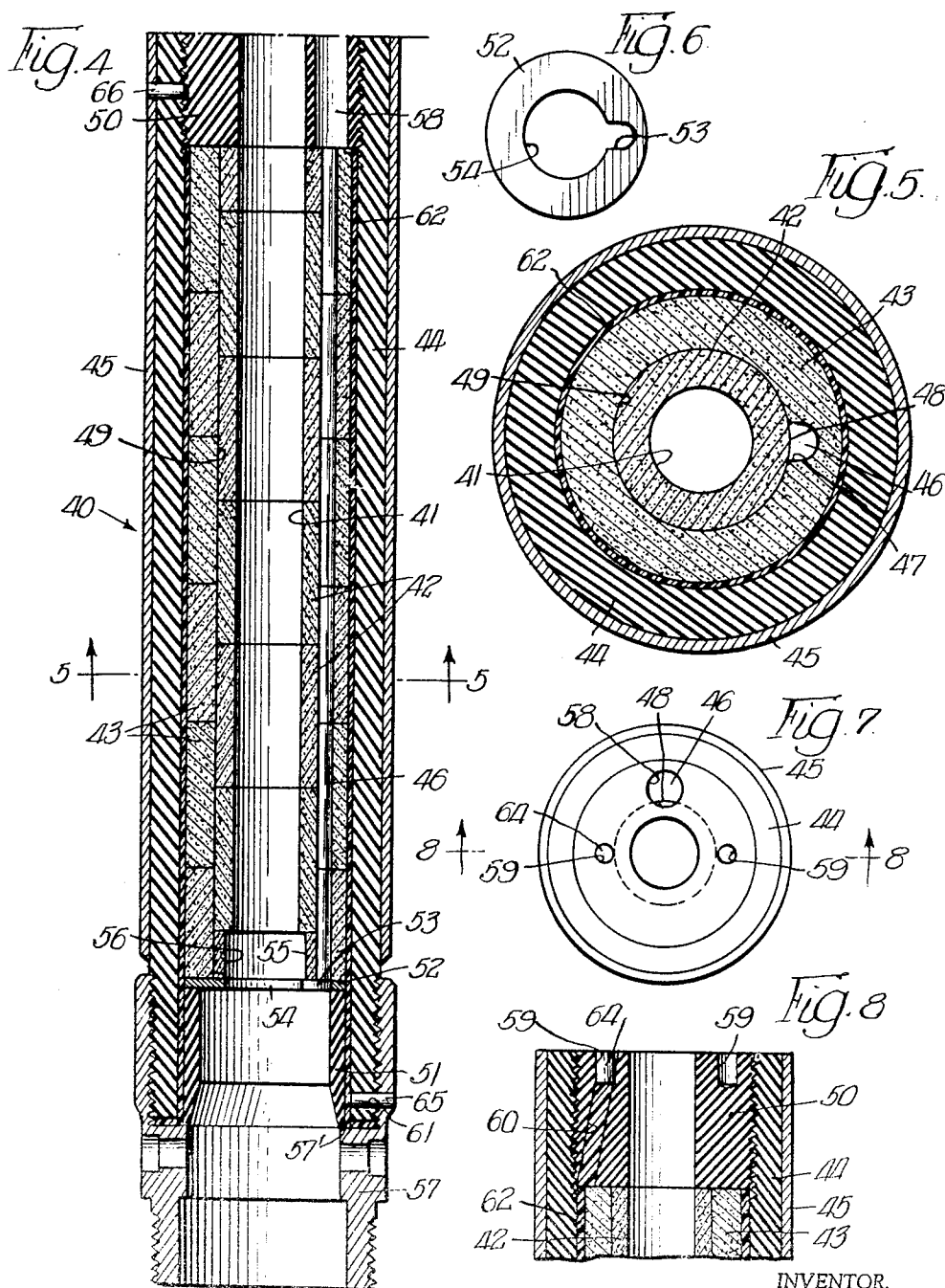
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3 Sheets-Sheet 2



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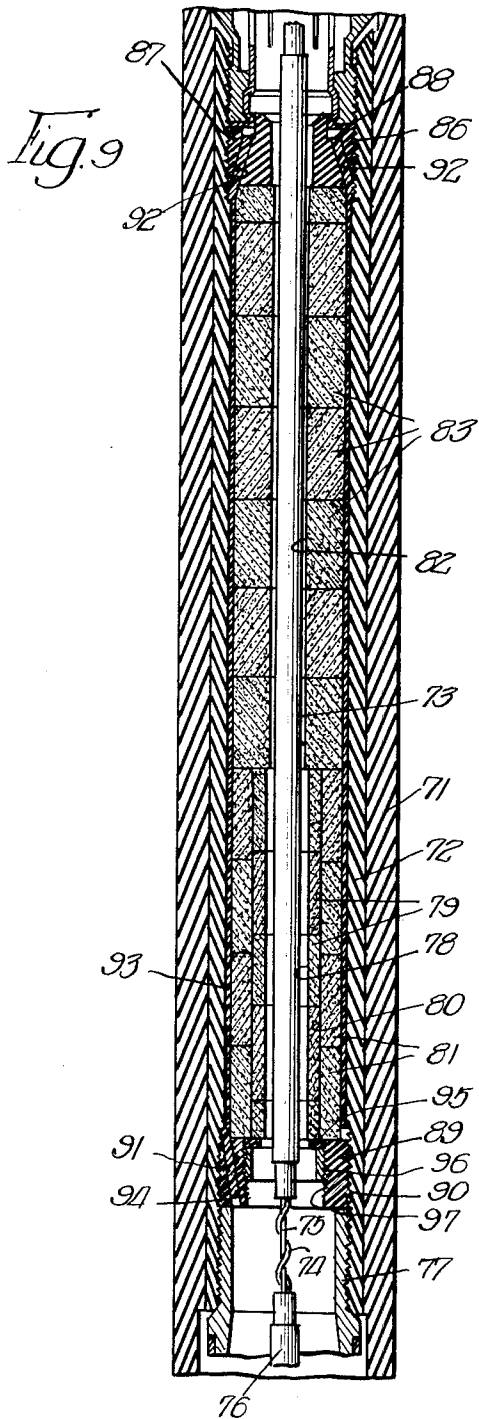
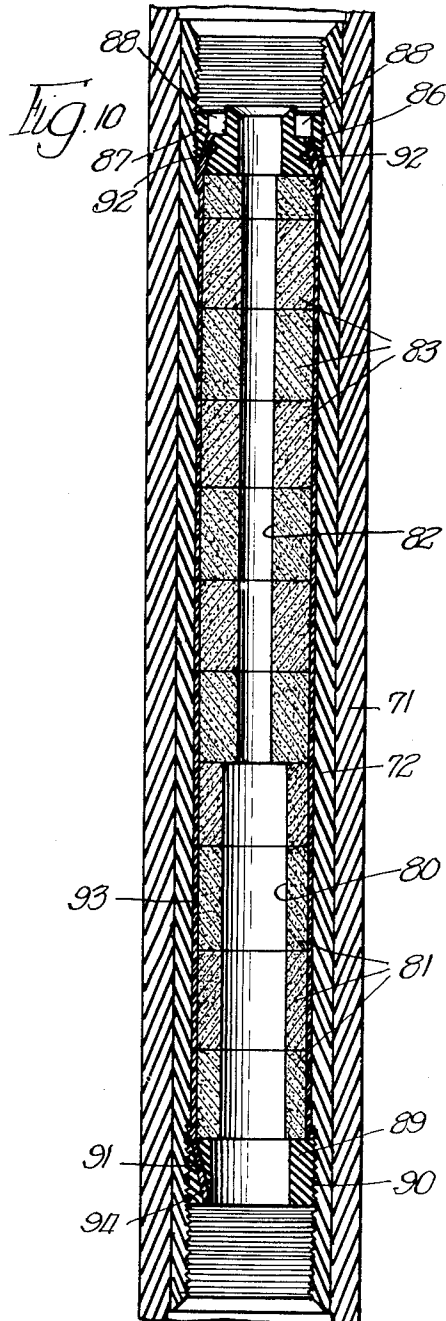
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3 Sheets-Sheet 3



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2,961,514

CIRCUIT INTERRUPTER

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21 Claims. (Cl. 200—120)

This invention relates, generally, to circuit interrupters and it has particular relation to such devices intended to interrupt extremely high currents. It constitutes an improvement over the construction shown in U.S. Patent No. 2,183,728, issued December 19, 1939, and other patents showing the use of a solid arc extinguishing material providing a bore from the surface of which water vapor is evolved due to the heat of the arc and is effective in extinguishing the same. This application is a continuation-in-part of application Serial No. 700,995, filed December 6, 1957, as a continuation-in-part of application Serial No. 596,029, filed July 5, 1956, now abandoned.

As disclosed in the patent above referred to, a fuse holder is provided with a replaceable refill unit or cartridge having a bore in which the arc is drawn at one end on blowing of a fusible element interconnecting a terminal at the end of the bore and a rod-like terminal that is movable through the other end of the bore away from the terminal. The bore is formed in annular cakes of boric acid. Surrounding these cakes is a housing including an insulating tube of substantial strength. This tube may be formed entirely of a phenolic condensation product or it may have a lining of fiber for additional strength such as disclosed, for example, in U.S. Patent Nos. 2,226,838, issued December 31, 1940, and 2,662,138, issued December 8, 1953. Instead of boric acid, the bore can be formed in a body of magnesium borate as disclosed in U.S. Patent No. 2,253,719, issued August 26, 1941. Both boric acid and magnesium borate, as arc extinguishing materials, are disclosed in U.S. Patent No. 2,662,138, issued December 8, 1953. Here it is employed alternatively for forming the bore in which the arc is drawn and extinguished. The arc is formed in these devices in a nozzle or throat which is held in place by the stationary terminal or ferrule. At the other end of the bore there is a plug through which the rod-like terminal moves. The cakes are cemented in place in the tube between the nozzle or throat and plug.

While the circuit interrupters as shown in the patents above referred to have operated satisfactorily, difficulty has been encountered in certain situations where devices of this nature have been required to interrupt extremely high currents within a relatively short time such as within one or a few half cycles of alternating current. In the past a fiber lined insulating sleeve has been used having a covering of a phenolic condensation product for surrounding the lining of boric acid or magnesium borate which provides the bore in which the arc is drawn. Under extreme operating conditions, the inner surface of the boric acid cracks and all or part of the lining itself, when suddenly exposed to high heat and pressure, tends to disintegrate in the form of relatively large pieces leaving large pockets along the bore with the pieces momentarily filling the discharge end. The cake adjacent the discharge end is particularly apt to break up since it is exposed to the arc from the very first instant after the fusible element has blown. Because of the relatively short time and high current and accompanying high

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energy release, destructive pressures are then set up tending to rupture the mechanical bond between the plug at the inner end of the bore and the fiber lined tube and to expel the plug together with the adjacent cakes and arc products into the fuse holder. This allows the arc to contact the gas evolving fiber liner at the refill unit with the resultant increase in destructive pressure. Under conditions of an extreme fault this may result in violent rupture of the refill unit and of the fuse holder and failure to interrupt the short circuit current. When the lining of magnesium borate is employed under similar circumstances, while it tends to disintegrate in the form of powder and is usually completely expelled from the insulating tube, thereby exposing the fiber lining to the arc, a non-condensable gas is evolved from the fiber lining due to the heat of the arc. This is undesirable, since the resultant energy release is greatly increased and, even though there is no severe blocking of the exhaust of gas and arc products by large pieces of inorganic liner through the restricting throat or nozzle of the refill unit, the insulating tube assembly may rupture. If a muffler or condenser is used to condense the exhaust products, it is not effective to prevent the egress of incandescent ionized gases from the fiber liner with possible secondary dielectric breakdown of the surrounding insulating air.

Accordingly, among the objects of this invention are: To provide for evolving a readily condensable gas along the path of an arc drawn in a circuit interrupter in such manner that the device is capable of withstanding without damage the pressures and high rate of heat input incident to extremely high current operation and to limit the pressure likely to be encountered; to employ for this purpose a lining of water vapor evolving material that can disintegrate into small pieces or into the form of a powder for immediate initial contact with the arc and to surround such material with a higher strength layer of water vapor evolving material positioned in a high strength insulating housing; to use a material, such as magnesium borate, a mixture of magnesium borate and boric acid or boric acid for the lining initially exposed to the heat of the arc and make the surrounding layer which would next be exposed to the heat of the arc if the lining breaks up of a mixture of magnesium borate and boric acid or boric acid alone with such layer having a relatively greater wall thickness than the lining to provide greater mechanical strength; to provide a large bore centrally of the material that acts as the lining and disintegrates into small pieces or into the form of powder in which a high current arc is drawn and a small bore through the surrounding layer of water vapor evolving material in which a low current arc is initiated and extended; to form the small bore by a groove in the layer opening toward and closed by the lining; to build up the lining and surrounding layer of water vapor evolving arc extinguishing material from cakes of such material that are molded under high pressure; to cement the layer surrounding the lining to the juxtaposed wall of the surrounding high strength insulating housing in order to retain this layer in place even though it may crack under extreme operating conditions; to employ for the cement a self setting material initially in liquid form whose volumes does not substantially change on curing; and to retain the lining in place by a frangible washer or readily expellable member which will fracture or be dislodged and allow the lining or pieces thereof to be expelled when high currents are interrupted, thus providing a larger bore and consequently less pressure.

Additional objects are: To provide a single bore through the arc extinguishing material that is held in place in an insulating housing by the self setting cement; to provide a stepped bore through the material having the larger diameter bore at the end where the arc is drawn; to provide a lining for a portion of the stepped bore that

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more readily disintegrates than does the surrounding arc extinguishing material when subjected to the heat of the arc; and to retain the lining in place by a frangible washer that is held by threaded sleeve, the lining being inserted after the outer layer of arc extinguishing has been cemented in place.

Other objects of this invention will, in part, be obvious and in part appear hereinafter.

This invention is disclosed in the embodiments thereof shown in the accompanying drawings and it comprises the features of construction, combination of elements and arrangement of parts that will be exemplified in the constructions hereinafter set forth and the scope of the application of which will be indicated in the appended claims.

For a more complete understanding of the nature and scope of this invention reference can be had to the following detailed description, taken together with the accompanying drawings, in which:

Figure 1 is a perspective view of a circuit interrupter in which the present invention is embodied;

Figure 2 is a longitudinal sectional view, at an enlarged scale, of the circuit interrupter as shown in Figure 1;

Figure 3 is an enlarged longitudinal sectional view of the tubular arc extinguishing chamber of the replaceable fuse refill unit that is shown in a fuse holder in Figure 2 in combination with the rod-like terminal and fusible element;

Figure 4 is a longitudinal sectional view of a modified form of replaceable fuse refill unit;

Figure 5 is a horizontal cross sectional view taken along the line 5-5 of Figure 4;

Figure 6 is a plan view of a retaining ring employed in the refill unit shown in Figure 4;

Figure 7 is a top plan view of the refill unit shown in Figure 4 turned 90°;

Figure 8 is a cross sectional view taken generally along the line 8-8 of Figure 7 and showing only a portion of the entire refill unit;

Figure 9 is a vertical cross sectional view of the central portion of a single bore fuse of the type disclosed in U.S. Patent No. 2,599,187, issued June 3, 1952, in which the present invention is embodied, a lining being provided for the stepped portion of the bore; and

Figure 10 is a vertical cross sectional view of the central portion of a single bore fuse of the type shown in Figure 9 employing a stepped bore without a lining for the stepped portion.

Referring now particularly to Figures 1, 2 and 3 of the drawings, it will be observed that the reference character 10 designates a base which may be a metal plate carrying upper and lower insulators 11 and 12. It will be understood that the length of the insulators 11 and 12 and their spacing apart depend upon the voltage of the system with which the present invention is employed. Upper and lower line contact clips 13 and 14 are carried by the insulators 11 and 12 at their outer ends for detachably receiving upper and lower terminals 15 and 16 that are mounted on the upper and lower ends of a tubular insulating housing or fuse holder 17 of a circuit interrupter that is indicated, generally, at 18. Associated with the lower terminal 16 is a condenser or muffler 19 which may be dispensed with under certain circumstances.

As shown in Figure 2 a coil tension spring 21 and a flexible cable 22 interconnect the upper terminal 15 and a spring and cable fastener 23 to which a rod-like terminal 24 is attached for movement upwardly through the tubular insulating housing 17 after a fusible element 25 blows, the fusible element 25 interconnecting the lower end of the rod-like terminal 24 and the lower terminal 16.

The rod-like terminal 24 substantially fills a relatively large bore 26 in a lining 27. When a high current is interrupted, the pressure generated in the bore 26 acts on the piston like terminal 24 to drive it at high speed into the housing or fuse holder 17. The lining 27 is

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formed preferably of cakes of magnesium borate or a mixture of magnesium borate and boric acid from which water vapor is evolved when it is subjected to the intense heat of an arc and which disintegrates in the form of powder or small pieces. The lining 27 can also be made of boric acid which has the advantage of being more readily molded although it disintegrates into somewhat larger pieces. Surrounding the lining 27 is a layer 28 of boric acid also in the form of cakes which preferably are cemented in place as set forth hereinafter. However, it will be understood that both the lining 27 and the layer 28 of solid arc extinguishing materials can be formed as continuous tubular members instead of being formed in cakes, if desired. Surrounding the layer 28 of boric acid is a fiber sleeve 29 of high impact strength which provides sufficient resistance to radial bursting pressure that may be created under certain operating conditions. Overlying the fiber sleeve 29 is a cover 30 that preferably is formed of a phenolic condensation product.

With a view to relieving the fusible element 25 of the stress of the spring 21, auxiliary means are provided as disclosed in U.S. Patent No. 2,183,728, issued December 19, 1939. For this purpose a pin 33 extends transversely through the rod-like terminal 24 adjacent the spring and cable fastener 23 and a strain element 34 is connected thereto and extends through a relatively small bore 35 in the layer of boric acid 28 to a strain wire pin 36 which projects radially inwardly from a lower terminal 36'.

The fiber sleeve 29 is threaded internally near its upper end for receiving a plug 37 of suitable insulating material which functions as a stop for and for locating and retaining the lining 27 and layer 28. At the lower end a retaining ring in the form of a nozzle or throat 38 is provided for a similar purpose and it is held in position by the lower terminal 36' which is secured in position on the fiber sleeve 29 through the cooperation of external threads as shown. The fiber sleeve 29 with the overlying cover 30 and the plug 37 at one end and the retaining ring 38 form a housing for the cakes comprising the lining 27 and the layer 28 of solid arc extinguishing materials. This housing resists longitudinal bursting pressure as well as radial pressure as indicated above. In addition a frangible washer 39 is interposed between the lowermost cakes of the arc extinguishing materials 27 and 28 and the upper end of the ring 38 to hold the former in place and yet offer substantially no hindrance to the discharge of the lining 27 when it is disintegrated.

In operation, on the occurrence of an overload, the strain element 34 blows first and an arc is formed in the small bore 35 following the blowing of the fusible element 25. In the event that the current is too high for the arc to be extinguished in the small bore 35, without destructive pressure in the small bore 35, it is transferred to the large bore 26 where it is extended as the rod-like terminal 24 moves upwardly under the influence of the coil tension spring 21.

When the current flow in the arc is extremely high and the bore 26 is formed in a body of boric acid, which alone fills the space between it and the fiber sleeve 29 as a single layer made up of cakes in tandem, such a single layer tends to crack and the cakes tend to disintegrate and split into relatively large pieces. When it is recalled that this takes place in a fraction of a second or within a half cycle or a few half cycles of 60 cycle alternating current, it can be appreciated that, before these pieces can be expelled from the lower end of the bore 26 through the nozzle or throat 38, extremely high pressures are generated therein which tend to drive the rod-like terminal 24 upwardly at extreme speed and to disrupt the wall of the insulating housing surrounding such a single layer and to expel these cakes and the plug 37 before the retaining ring or throat 38 is destroyed and expelled. In accordance with this invention, as de-

scribed, the large bore 26 may be formed in a lining 27 of magnesium borate, a mixture of magnesium borate and boric acid, boric acid of the like which, while evolving water vapor for assisting in extinguishing the arc when the current is within a certain range of magnitude without disintegration, disintegrates in the form of powder or small pieces rather than relatively large pieces as does a single heavier layer of boric acid when it alone is used and extremely high current is interrupted. As a result the exhaust opening through the nozzle or throat 38 is not clogged up and relatively high destructive pressures are not developed while the large bore 26 is being enlarged by expulsion of the lining 27. At the same time, when the arc persists after the lining 27 has been disrupted and partly or wholly expelled, a much larger bore 28' is provided through the layer 28 of boric acid which also evolves water vapor that is effective for assisting in extinguishing the arc. However, because of the larger bore 28' the arc voltage and the energy release are reduced and there is not the same likelihood that sufficient energy will be released to crack the layer 28 of boric acid so completely as to cause it to disintegrate in the form of relatively large pieces as is the case when a single layer of boric acid itself is employed within the fiber sleeve 29 for forming the bore 26 in which the arc first is drawn.

When the range of short circuit current or overload current to be interrupted is relatively not so great, it is unnecessary to provide the small or auxiliary bore 35. An arrangement of fusible and strain elements then can be employed, as shown, for example, in U.S. Patent No. 2,662,139, issued December 8, 1953, where only a single bore is used.

When the present invention is employed, for a given interrupting rating, it is also possible to employ a smaller diameter for the large bore 26 than heretofore has been possible for fuses of lower continuous current rating. The reason for this is that if the flow of current in the arc is sufficient to develop the heat required to disintegrate the lining 27, a larger diameter bore 28' is then available through the layer 28 of boric acid for arc extinguishing purposes. Therefore, it is necessary to provide a diameter of bore 26 through the lining 27 of magnesium borate or the like only large enough to receive the rod-like terminal 24 having a current carrying capacity sufficient to accommodate the continuous rating of the circuit interrupter. In turn this makes it possible to more expeditiously interrupt the flow of lesser amount of fault current.

When magnesium borate is used for the lining 27, it may be molded in place within the layer 28 of boric acid. However, preformed cakes can be made using both magnesium borate and boric acid. These materials can be used in equal proportions. Satisfactory results are obtained using 40% boric acid, as a binder, and the balance magnesium borate. Since boric acid is relatively more cohesive, when it is mixed with magnesium borate, the mixture can be molded into cakes which can be inserted into the bore in the layer 28 and secured in place with a suitable adhesive.

Where it is desired to reduce only the size of the pieces of lining material that result from the flow of extremely high fault current and the magnesium borate lining 27 is not used, it can be replaced by a lining of boric acid. Preferably the layer 28 of this material is installed in the fiber sleeve 29 in the form of cakes, as shown, and then the lining 27 of boric acid, also in the form of cakes, is installed. This construction provides a line of demarcation between the two bodies of arc extinguishing material. When the flow of high fault current occurs, the lining 27, because it is relatively thin, first disintegrates into relatively small pieces and there is less likelihood that the bore 26 will be clogged.

It will be appreciated that the arc is formed at the lower or outer end of the large bore 26 where maximum

erosion and disintegration thereof tend to occur. When the arc is permitted to attack the large bore 26 in this vicinity formed in magnesium borate, a mixture of this material and boric acid, or a relatively thin walled layer of boric acid, smaller particles or pieces are produced than is the case where the entire arc extinguishing material within the fiber sleeve 29 is formed of boric acid alone.

The invention, as shown in Figures 1, 2 and 3, is intended primarily for use on alternating current circuits operating at voltages of the order of 5,000 to 34,500 volts. Thus, there is little likelihood of dielectric breakdown between the lining 27 and the layer 28 during or after circuit interruption.

A clamp nut 40' acts to mechanically and electrically secure the lower terminal 36' of the refill unit to the lower terminal of the fuse holder. When the muffler or condenser 19 is used, it takes the place of the clamp nut 40'.

Figures 4, 5 and 6 show another embodiment of the refill unit. Referring particularly to Figure 4, it will be noted that the reference character 40 designates, generally, a refill unit that can be employed within the tubular insulator housing 17 of the circuit interrupter 18 in lieu of the refill unit there shown.

The refill unit 40 has a centrally positioned large bore 41 through which the rod-like terminal 24 moves to draw the arc therewithin. The large bore 41 is formed in a lining 42 that is made up of cakes of water evolving arc extinguishing material such as magnesium borate, a mixture of magnesium borate and boric acid or boric acid. The lining 42 is formed, as described hereinbefore, in such a manner that it will disintegrate into relatively small pieces under the intense heat of the arc to prevent clogging of the discharge end of the bore 41.

Surrounding the lining 42 is a layer 43 of water evolving arc extinguishing material that may be formed of cakes of boric acid. It will be observed that the layer 43 is substantially thicker than is the lining 42. Surrounding the layer 43 is a fiber sleeve 44 to provide a high strength insulating housing and overlying it is a cover 45 that preferably is formed of a phenolic condensation product.

Extending through the layer 43 is a small bore 46 which is provided for receiving the strain element 34 that is shown in Figure 2. The arc is initiated in the small bore 46 and then, if it is not extinguished there, it is transferred to the large bore 41. In order to facilitate the forming of the small bore 46, instead of providing a circular opening through the layer 43 midway between its outer and inner periphery, the small bore 46 is formed, in part by a groove 47, Figure 5, which opens inwardly toward the lining 42. A section 48 of the lining 42 overlies and closes the groove 47 and together with it defines the small bore 46. In the molding of the cakes to form the layer 43 relatively high pressure is used resulting in corresponding high friction between the formed material and the forming die to provide the small bore. When such die is separate from the die that forms the bore 49 through the cakes making up the layer 43, its cross section is such that the usual material used therefor will not withstand the force required to withdraw it. Now, when a plunger or die is employed the outer periphery of which is shaped so as to conform to the inner periphery of bore 49 of the layer 43 including the groove 47, since the portion of the die which forms the groove 47 is an integral part of the remaining portion of the die which has a relatively large cross section, the die thus constructed can be removed readily from cakes used to build up the layer 43.

The assembly is completed at the upper end of the refill unit 40 by a washer or threaded plug 50 screwed into the upper end of the fiber sleeve 44. At the lower end a retaining ring 51 or nozzle of insulating material, such as fiber, is provided. Between it and the lower-

most cake forming the layer 43 there is positioned a frangible washer 52, which is shown more clearly in Figure 6, to hold the lining 42 in place. The washer 52 is formed of insulating material of such nature that it can be readily broken when subjected to an outward thrust incident to the drawing and extinction of an arc in the large bore 41. It will be noted that the frangible washer 52 has a groove 53 that provides an opening into the lower end of the small bore 46. Also it has a large central opening 54 in alignment with the large bore 41.

If desired, a stepped construction can be provided at the lower end of the large bore 41. For this purpose a lining cake 55 of water evolving arc extinguishing material, such as boric acid, is provided having a bore 56 the diameter of which is larger than the diameter of the large bore 41 but less than the diameter of the bore through the layer 43. When this arrangement is used, the diameter of the opening 54 in the washer 52 is the same as the inner diameter of the cake 55 and is greater than the diameter of the bore 41.

At the extreme lower end of the fiber sleeve 44 there is a lower terminal 57. As shown, it is threaded onto the lower end of the fiber sleeve 44.

Particular attention is directed to the manner in which the refill unit 40 is assembled. It is preferred that the steps outlined hereinafter be followed in order to permit the refill unit 40 to interrupt relatively great short circuit current without damage to the insulating housing 17 and while the fiber sleeve 44 remains intact.

It will be recalled that the cakes forming the lining 42 and layer 43 are firmly compacted individually. The material used for the cakes for both can be boric acid throughout.

The desired numbers of cakes for the lining 42 and the layer 43 are stacked in the manner illustrated in Figure 4 so that the joints therebetween are staggered. This requires that the end cakes for the lining 42 and layer 43 be of different lengths. The end lining cake 55 of larger internal diameter than the bore 41 through the lining 42 can also be arranged in the assembly. The external diameter of the cakes making up the lining 42 is such that they easily telescope within the bore 49 through the layer 43. Preferably they are not cemented to the bore 49.

The cakes for the lining 42 and layer 43, thus stacked, with the groove portion 47 in each cake for the layer 43 in alignment to provide the small bore 46, are placed on a mandrel together with the washer or end plug 50 which has a large diameter hole 58 therethrough that registers with the small bore 46. At the other end of the stack of cakes the frangible washer 52 and the retaining ring or nozzle 51 are positioned. The mandrel is threaded and nuts thereon are screwed tight to hold the cakes forming the lining 42 and layer 43 in compression and alignment between the washer or end plug 50 and the retaining ring or nozzle 51 and frangible washer 52.

Next, a suitable adhesive, such as an epoxy cement having a suitable curing agent therein, is brushed on the external threads of the washer or end plug 50 and on the threads at the ends of the fiber sleeve 44 and also on the internal threads of the lower terminal 57. The mandrel with the assembly thereon as previously described is inserted into the fiber sleeve 44 from the upper end and it together with the washer or end plug 50 is threaded into the fiber sleeve 44. In order to accomplish this holes 59 are drilled into the washer or end plug 50, as indicated in Figure 8, for receiving a spanner wrench. The washer or end plug 50 is screwed into the fiber sleeve 44 until the lower end of the retaining ring or nozzle 51 projects slightly below the lower end of the fiber sleeve 44 as shown in Figure 4 of the drawings. Then the lower terminal 57 is screwed onto the lower end of the fiber sleeve 44 until it is hand tight and the shoulder 57' thereof abuts the lower end of the retaining ring 51.

Prior to the assembly of the washer or end plug 50, as described hereinbefore, one of the holes 59 has a passageway 60, Figure 8, drilled therefrom to the opposite end so as to communicate with the space between the outer surface of the layer 43 and the inner surface of the fiber sleeve 44. The purpose of this is to provide for a vacuum connection through the passageway 60.

At the lower end of the assembly, a hole 61 is drilled through the shell of the lower terminal 57 and through the fiber sleeve 44 to communicate with the space between the outer surface of the retaining ring or nozzle 51 and the inner surface of the fiber sleeve 44. Then a pressure gun is connected to the outer end of the hole 61 and a cement, preferably in the form of an epoxy resin having a suitable curing agent or activator, is forced through the hole 61 while vacuum is applied through the passageway 60. The combination of pressure and vacuum causes the space between the layer 43 and the fiber sleeve 44 to be filled with a layer of adhesive which is indicated at 62. It is somewhat exaggerated in thickness in order to show its presence. After the space has been completely filled with the adhesive 62, plugs or pins 64 and 65 of insulating material, Figures 8 and 4, are inserted in the holes 59 and 61 to prevent the escape of the adhesive while it is curing.

If desired, a pin 66 can be inserted in a drilled hole in the upper end of the refill unit 40, as shown in Figure 4, to prevent turning of the washer or end plug 50 with respect to the fiber sleeve 44.

The refill unit 40, assembled as described and provided with the layer 62 of adhesive, is allowed to cure for 24 or more hours. It is permitted to cure when positioned as indicated in Figure 4 so that if any void should occur in the space intended to be filled by the layer 62 of adhesive, it will appear at the upper end where the same is less critical. Since the cement employed for making the layer 62 contains no volatile matter, it is substantially of non-shrinking character. Thus, when it cures and solidifies, it provides a good void free bond between the cakes making up the layer 43 and the inner surface of the fiber sleeve 44.

Tests have shown that a refill unit 40, assembled as described, and operated to interrupt extremely high short circuit current of the order of many thousands of amperes has accomplished this satisfactorily. While the lining cake 55 and one or more of the cakes making up the lining 42 are expelled through the lower terminal 57 under these conditions involving intense arc heat and resultant pressure, the cakes making up the layer 43, while cracking at the lower end, still remain generally intact since they are securely bonded to the fiber sleeve 44. The lower portion of the bore 49 in the layer 43 is eroded under these conditions but, as stated, the cakes themselves making up the layer 43 tend to remain in place under these extreme operating conditions.

The retaining ring or nozzle 51 has a relatively large discharge opening therethrough which facilitates the expulsion of portions of the lining 42, lining cake 55 and layer 43 under conditions of intense arc heat and resultant pressure. When the small bore 46 is employed as shown in Figure 4, the inside diameter of the retaining ring or nozzle 51 is such as to leave the small bore open. When the small bore 46 is not used, the thickness of the retaining ring or nozzle 51 is such as to overlie less than half of the thickness of water evolving arc extinguishing material between the large bore 41 and the inner surface of the fiber sleeve 44.

It will be understood that the refill unit 40 can be employed in the tubular insulating housing 17, shown in Figure 3, in lieu of the refill unit there shown. The operation of the refill unit 40, when thus assembled, is generally the same as described hereinbefore for the refill unit shown in Figure 3.

Referring now particularly to Figure 9 of the drawings, it will be observed that the construction there shown

is adapted for use on circuits operating at relatively high voltage, for example at voltages of the order of 34,900 to 69,000 volts. The general construction is similar to that shown in U.S. Patent No. 2,599,187, issued June 3, 1952, modified to embody the present invention. The construction employs tubular housing 71 that may be formed of suitable insulating material such as a phenolic condensation product. Bonded to the tubular housing 71 is a liner 72 that preferably is formed of fiber to provide a high strength construction which is resistant to radial bursting pressures. Movable endwise through the tubular housing 71 is a rod-like movable terminal 73. Provision is made, as disclosed in U.S. Patent No. 2,559,187, issued June 3, 1952, for moving the rod-like terminal 73 although it will be understood that other means can be employed if desired. The rod-like movable terminal 73 is connected by a fusible element 74 and a strain wire 75 to a stationary terminal 76 which is mounted on a tubular terminal 77 which is threaded into the lower end of the fiber liner 72. It will be understood that an arc is drawn between the rod-like movable terminal 73 and the stationary terminal 76 when the fusible element 74 and strain wire 75 are blown under over current or short circuit operating conditions. The arc thus formed is drawn into a bore 78 on upward movement of the rod-like terminal 73. The bore 78 is provided in a lining that is formed by cakes 79 of arc extinguishing material, such as boric acid or magnesium borate, from which water vapor is evolved when subjected to the intense heat of the arc. The cakes 79 forming the lining are located in a larger diameter bore 80 which is formed in cakes 81 that provide a layer of arc extinguishing material such as boric acid or magnesium borate. Like the cakes forming the lining 42 and the cakes forming the layer 43 of arc extinguishing material as shown in Figure 4, the cakes 79 and the cakes 81 are so arranged and constructed that the lining formed by the cakes 79 disintegrates first and then, if the arc is sufficiently intense, the cakes forming the layer 81 are disintegrated in whole or in part depending upon the intensity of the arc that is drawn.

It will be observed that the lining formed by the cakes 79 extends only part way along the path of movement of the rod-like terminal 73. For the balance of the movement, the terminal 73 moves through a bore 82 in a body of arc extinguishing material formed by cakes 83. Preferably the cakes 83 are formed of boric acid, magnesium borate or like water vapor evolving material when subjected to sufficient arc heat. It will be noted that the diameter of the movable terminal 73 approaches the diameter of the bore 82 in the body formed by the cakes 83 of arc extinguishing material. Thus the rod-like terminal 73 substantially fills the bore 82. However, the diameter of the bore 78 in the lining provided by the cakes 79 may have a somewhat larger diameter, as shown, so that a stepped bore for the rod-like movable terminal 73 is provided.

Attention is directed to the fact that the lining formed by the cakes 79 and the layer formed by the cakes 81 correspond generally to the construction employed for the refill unit 40, shown in Figure 4 of the drawings. However, the small bore 46 is not employed. In order to take care of the higher voltage range the additional arc extinguishing material provided by the body formed by the cakes 83 is employed. By the time that the rod-like terminal 73 has moved out of the bore 78 in the lining formed by the cakes 79, the major portion of the arcing will have been completed when high short circuit currents are being interrupted.

Referring again particularly to Figure 9 it will be noted that the upper end of the fiber liner 72 is threaded at 86 for receiving an end plug 87 which is provided with drilled holes 88 for receiving a spanner wrench. The body formed by the cakes 83 of arc extinguishing material is inserted against the end plug 87 and then

the layer formed by the cakes 81 is placed in position. The arc extinguishing material thus far assembled is held in place by an outer retaining ring 89 which is threaded as indicated at 90 into the lower end of the fiber liner 72.

For the reasons which have been outlined hereinbefore it is desirable that the layer formed by the cakes 81 and the body formed by the cakes 83 be securely bonded to the inner surface of the fiber liner 72. For this purpose a passageway 91 extends through the outer retaining ring 89 to admit a thermosetting cement, such as an epoxy resin, into the space between the outer surfaces of the layer formed by the cakes 81 and the body formed by the cakes 83 and the inner surface of the fiber liner 72. Passageways 92 are provided through the end plug 87 from the bottoms of the drill holes 88 to permit the air to escape from the space just referred to. As indicated the thermosetting cement 93 is applied through the passageway 91 and it is indicated at 93 as completely filling the space referred to. The thermosetting cement 93 is introduced in liquid form through the passageway 91 with the assembly being located in the upright position as shown in Figure 9. After the filling has been completed, a plug 94 is inserted in the lower end of the passageway 91 to close it off and prevent escape of the liquid cement from the passageway 91. The assembly is allowed to cure in the upright position so that if, for any reason, the space should not be filled, that portion of the space surrounding the arcing zone will be completely filled resulting in secure bonding of the layer formed by the cakes 81 in place in the fiber liner 72.

After the thermosetting cement 93 has completely cured, the lining formed by the cakes 79 is inserted into the bore 80. Then a frangible washer 95 is placed over the lower end of the lining and it is held in place by an inner retaining ring 96 which is screwed into threads 97 on the interior of the outer retaining ring 89. One reason for inserting the lining formed by the cakes 79 in the bore 80 after the cement 93 has cured is to avoid accidental cementing of some of the cakes 79 to the bore 80 and thus interfere with the free expulsion thereof under operating conditions requiring such action.

It will be understood that the frangible washer 95 holds the lining formed by the cakes 79 in place. However, when sufficient endwise pressure is applied to the frangible washer 95, it is ruptured and the cakes forming the lining 79 are permitted to discharge through the inner retaining ring 96 and through the outer retaining ring 89 without obstruction.

Some of the features of construction employed in the circuit interrupter 18 and the refill unit 40 can be utilized for the construction illustrated in Figure 9. The diameter of the bore 78 can be the same as that of the bore 82. The lining provided by the cakes 79 can extend the full length of stroke of the rod-like movable terminal 73 of the full length of the bore 82. The cakes 79 at the upper end or the end away from the arc drawing end in such an arrangement can be cemented in place while the cakes 79 at the arc drawing end, for the reasons hereinbefore pointed out, are free to be expelled if necessary. A parallel bore, corresponding to the small bore 35 in Figure 3 or 46 in Figure 4, can be provided in the construction shown in Figure 9 where its use is required for extremely low current interrupting purposes.

The construction shown in Figure 10 is similar to that shown in Figure 9 except that the lining formed by the cakes 79 is omitted together with the frangible washer 95 and inner retaining ring 96. Here a more pronounced initially stepped bore construction is provided by the bore 80 through the cakes forming the layer 81 and the bore 82 through the body formed by the cakes 83. Since certain changes can be made in the foregoing

construction and different embodiments of the invention can be made without departing from the spirit and scope thereof, it is intended that all matter shown in the accompanying drawings and described hereinbefore shall be interpreted as illustrative and not in a limiting sense.

What is claimed as new is:

1. An electric circuit interrupter comprising, in combination, means between which an arc is formed on opening of the circuit; and a tubular housing providing a bore in which the arc is drawn between said means and having the surface thereof provided by a lining of magnesium borate directly exposed to the arc and overlying a layer of boric acid exposed to the arc only after disintegration of said lining, and a high strength insulating sleeve around said layer.

2. An electric circuit interrupter comprising, in combination, means between which an arc is formed on opening of the circuit; and a tubular housing surrounding and confining the arc drawn between said means having a lining providing a bore in which the arc is drawn and positioned within a layer surrounded by a high strength insulating sleeve, said lining being first exposed to the arc and disintegrating in advance of the disintegration of said layer, said lining being formed by a mixture of magnesium borate and boric acid.

3. An electric circuit interrupter comprising, in combination, means between which an arc is formed on opening of the circuit; and a tubular housing surrounding and confining the arc drawn between said means having a lining providing a bore in which the arc is drawn and positioned within a layer surrounded by a high strength insulating sleeve, said lining being first exposed to the arc and disintegrating in advance of the disintegration of said layer, said lining and said layer being formed of boric acid.

4. An electric circuit interrupter comprising, in combination, means between which an arc is formed on opening of the circuit including a movable rod-like terminal; and a tubular housing providing a large bore substantially filled by said rod-like terminal through which the same moves to draw a large current arc therein and a small bore in which a small current arc is drawn and extinguished, the surface of said large bore first subjected to the arc drawn therein being formed by a lining of a water vapor evolving arc extinguishing material which tends to disintegrate in the form of relatively small pieces when subjected to intense arc heat, said lining overlying a layer of water evolving arc extinguishing material which tends to disintegrate in the form of relatively large size pieces when subjected to intense arc heat, said small bore being formed in said layer of water evolving arc extinguishing material, and a high strength insulating housing surrounding and confining said layer.

5. An electric circuit interrupter comprising, in combination, means between which an arc is formed on opening of the circuit including a movable rod-like terminal; and a tubular housing providing a large bore substantially filled by said rod-like terminal through which the same moves to draw a large current arc therein and a small bore in which a small current arc is drawn and extinguished, the surface of said large bore first subjected to the arc drawn therein being formed by a lining of a water vapor evolving arc extinguishing material which tends to disintegrate in the form of relatively small pieces when subjected to intense arc heat, said lining overlying a layer of water evolving arc extinguishing material which tends to disintegrate in the form of relatively large size pieces when subjected to intense arc heat, said small bore being formed in said layer of water evolving arc extinguishing material, a high strength insulating housing surrounding and confining said layer, and readily expellable retaining means overlying said lining at the arcing end of said large bore acting to hold said lining in

position and to release the same when subjected to pressure sufficient to rupture said retaining means.

6. An electric circuit interrupter comprising, in combination, means between which an arc is formed on opening of the circuit including a movable rod-like terminal; and a tubular housing providing a large bore substantially filled by said rod-like terminal through which the same moves to draw a large current arc therein and a small bore in which a small current arc is drawn and extinguished, the surface of said large bore first subjected to the arc drawn therein being formed by a lining of a water vapor evolving arc extinguishing material which tends to disintegrate in the form of relatively small pieces when subjected to intense arc heat, said lining overlying a layer of water evolving arc extinguishing material which tends to disintegrate in the form of relatively large size pieces when subjected to intense arc heat, said small bore being formed in said layer of water evolving arc extinguishing material, a high strength insulating housing surrounding and confining said layer, and a layer of thermosetting insulating material between said layer of water evolving arc extinguishing material and said housing substantially filling the space therebetween.

7. An electric circuit interrupter comprising, in combination, means between which an arc is formed on opening of the circuit including a movable rod-like terminal; and a tubular housing providing a large bore substantially filled by said rod-like terminal through which the same moves to draw a large current arc therein and a small bore in which a small current arc is drawn and extinguished, the surface of said large bore first subjected to the arc drawn therein being formed by a lining of a water vapor evolving arc extinguishing material which tends to disintegrate in the form of relatively small pieces when subjected to intense arc heat, said lining overlying a layer of water evolving arc extinguishing material which tends to disintegrate in the form of relatively large size pieces when subjected to intense arc heat, said small bore being formed by a groove in said layer of water evolving arc extinguishing material opening toward and closed by said lining, a high strength insulating housing surrounding and confining said layer, and a frangible washer overlying said lining and layer having an opening registering with said large and small bores and acting to hold said lining in position and to release the same when subjected to pressure sufficient to rupture said washer.

8. An electric circuit interrupter comprising, in combination, means between which an arc is formed on opening of the circuit including a movable rod-like terminal; and a tubular housing providing a bore through which said rod-like terminal moves to draw the arc therein from one end, the surface of said bore subjected to the arc drawn therein being formed by a lining of a water vapor evolving arc extinguishing material which tends to disintegrate when subjected to intense arc heat and resultant pressure, said lining overlying a layer of water evolving arc extinguishing material which tends to disintegrate when subjected to intense arc heat after disintegration of said lining, a high strength insulating housing surrounding and confining said layer, and a layer of epoxy resin between said layer of water evolving arc extinguishing material and said housing substantially filling the space therebetween.

9. An electric circuit interrupter comprising, in combination, means between which an arc is formed on opening of the circuit including a movable rod-like terminal; and a tubular housing providing a bore through which said rod-like terminal moves to draw the arc therein from one end, the surface of said bore subjected to the arc drawn therein being formed by a lining of a water vapor evolving arc extinguishing material which tends to disintegrate when subjected to intense arc heat and resultant pressure, said lining overlying a layer of water evolving arc extinguishing material which tends

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to disintegrate when subjected to intense arc heat after disintegration of said lining, a high strength insulating housing surrounding and confining said layer, and non-shrinking dielectric cement between the outer surface of said layer and the inner surface of said housing substantially filling the space therebetween and securing them together substantially as an integral unit.

10. An electric circuit interrupter comprising, in combination, means between which an arc is formed on opening of the circuit including a movable rod-like terminal; and a tubular housing providing a bore through which said rod-like terminal moves to draw the arc therein from one end, the surface of said bore subjected to the arc drawn therein being formed by a lining of a water vapor evolving arc extinguishing material which tends to disintegrate when subjected to intense arc heat and resultant pressure, said lining overlying a layer of water evolving arc extinguishing material which tends to disintegrate when subjected to intense arc heat and resultant pressure after disintegration of said lining, a high strength insulating housing surrounding and confining said layer, and readily expellable restraining means overlying said lining at the arcing end of said bore therethrough acting to hold said lining in position and to release the same when subjected to pressure sufficient to rupture said retaining means.

11. An electric circuit interrupter comprising, in combination, means between which an arc is formed on opening of the circuit including a movable rod-like terminal; and a tubular housing providing a bore through which said rod-like terminal moves to draw the arc therein from one end, the surface of said bore subjected to the arc drawn therein being formed by a lining of a water vapor evolving arc extinguishing material which tends to disintegrate when subjected to intense arc heat and resultant pressure, said lining overlying a layer of water evolving arc extinguishing material which tends to disintegrate when subjected to intense arc heat and resultant pressure after disintegration of said lining, a high strength insulating housing surrounding and confining said layer and extending beyond the same at the arcing end of said bore, and a retaining ring secured within the extended portion of said housing in juxtaposition thereto and overlying only the adjacent end of said layer and permitting unobstructed discharge therethrough of said lining or portions thereof.

12. An electric circuit interrupter comprising, in combination, means between which an arc is formed on opening of the circuit including a movable rod-like terminal; and a tubular housing providing a bore through which said rod-like terminal moves to draw the arc therein from one end, the surface of said bore subjected to the arc drawn therein being formed by a lining of a water vapor evolving arc extinguishing material which tends to disintegrate when subjected to intense arc heat and resultant pressure, said lining being formed by a stack of cakes and overlying a layer of water evolving arc extinguishing material also formed by a stack of cakes which tends to disintegrate when subjected to intense arc heat and resultant pressure after disintegration of said lining, a high strength insulating housing surrounding and confining said layer, and adhesive means between the outer surfaces of said cakes forming said layer and the inner surface of said housing substantially filling the space therebetween and securing them together substantially as an integral unit.

13. An electric circuit interrupter comprising, in combination, means between which an arc is formed on opening of the circuit including a movable rod-like terminal; and a tubular housing providing a bore through which said rod-like terminal moves to draw the arc therein from one end, the surface of said bore subjected to the arc drawn therein being formed by a water vapor evolving arc extinguishing material when subjected to intense

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arc heat and resultant pressure, a high strength insulating housing surrounding and confining said arc extinguishing material having a passageway communicating with each end of the space between said arc extinguishing material and said housing whereby the filling of said space is permitted by cement in liquid form, cement substantially filling said space, and a plug closing the passageway at said one end to hold said cement in place while the same is curing.

14. An electric circuit interrupter comprising, in combination, means between which an arc is formed on opening of the circuit including a movable rod-like terminal; and a tubular housing providing a large bore through which said rod-like terminal moves to draw a large current arc therein and a small bore in which a small current arc is drawn and extinguished, the surface of said large bore first subjected to the arc drawn therein being formed by a lining of a water vapor evolving arc extinguishing material which tends to disintegrate when subjected to intense arc heat and resultant pressure, said lining overlying a layer of water evolving arc extinguishing material which tends to disintegrate when subjected to intense arc heat after disintegration of said lining, said small bore being formed by a groove in said layer of water evolving arc extinguishing material opening toward and closed by said lining, and a high strength insulating housing surrounding and confining said layer.

15. An electric circuit interrupter comprising, in combination, means between which an arc is formed on opening of the circuit including a movable rod-like terminal; and a tubular housing providing a bore through which said rod-like terminal moves to draw the arc therein from one end, the surface of said bore subjected to the arc drawn therein being formed by a water vapor evolving arc extinguishing material when subjected to intense arc heat and resultant pressure, a high strength insulating housing surrounding and confining said arc extinguishing material, and an annular retaining ring secured within said tubular housing at said one end where the arc is drawn and overlying less than half the thickness of said arc extinguishing material to hold the same in place and provide a relatively large discharge opening as compared to said bore to permit the discharge of relatively large pieces of said arc extinguishing material that are dislodged on interruption of relatively high current.

16. An electric circuit interrupter comprising, in combination, means between which an arc is formed on opening of the circuit including a movable rod-like terminal; and a tubular housing providing a bore through which said rod-like terminal moves to draw the arc therein at one end, the surface of said bore subjected to the arc drawn therein being formed in part by a relatively thin lining of a water vapor evolving arc extinguishing material which tends to disintegrate when subjected to intense arc heat and resultant pressure and in part by a relatively thick body of water vapor evolving arc extinguishing material, said lining overlying a layer of water vapor evolving arc extinguishing material which tends to disintegrate when subjected to intense arc heat and resultant pressure after disintegration of said lining, a high strength insulating housing surrounding and confining said body and layer of water vapor evolving arc extinguishing material and providing a space therebetween substantially coextensive therewith, and cement substantially filling said space.

17. An electric circuit interrupter comprising, in combination, means between which an arc is formed on opening of the circuit including a movable rod-like terminal; and a tubular housing providing a bore through which said rod-like terminal moves to draw the arc therein at one end, the surface of said bore subjected to the arc drawn therein being formed in part by a relatively thin lining of a water vapor evolving arc extinguishing material which tends to disintegrate when subjected to intense arc heat and resultant pressure and in part by a relatively

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thick body of water vapor evolving arc extinguishing material, that portion of said bore in said body of arc extinguishing material being substantially filled by said rod-like terminal and the diameter of said bore in said lining being substantially greater than the diameter of said rod-like terminal, said lining overlying a layer of water vapor evolving arc extinguishing material which tends to disintegrate when subjected to intense arc heat and resultant pressure after disintegration of said lining, a high strength insulating housing surrounding and confining said body and layer of water vapor evolving arc extinguishing material and providing a space therebetween substantially coextensive therewith, and cement substantially filling said space.

18. An electric circuit interrupter comprising, in combination, means between which an arc is formed on opening of the circuit including a movable rod-like terminal; and a tubular housing providing a bore through which said rod-like terminal moves to draw the arc therein at one end, the surface of said bore subjected to the arc drawn therein being formed by a lining of a water vapor evolving arc extinguishing material which tends to disintegrate when subjected to intense arc heat and resultant pressure, said lining overlying a layer of water vapor evolving arc extinguishing material which tends to disintegrate when subjected to intense arc heat and resultant pressure after disintegration of said lining, a high strength insulating housing surrounding and confining said body and layer of water vapor evolving arc extinguishing material, and providing a space therebetween substantially coextensive therewith, cement substantially filling said space, a retaining ring secured to said insulating housing and overlying only a portion of said layer of arc extinguishing material at the arcing end of said bore and permitting unobstructed discharge therethrough of said lining or portions thereof, a frangible washer overlying said lining at said arcing end of said bore and holding said lining in position until released by application of pressure sufficient to rupture said frangible washer, and retaining means separate from said retaining ring and overlying said frangible washer to hold the same in position whereby said lining can be inserted into said layer after said cement has set.

19. An electric circuit interrupter comprising, in combination, means between which an arc is formed on opening of the circuit including a movable rod-like terminal; and a tubular housing providing a bore through which said rod-like terminal moves to draw the arc therein from one end, the surface of said bore subjected to the arc drawn therein being formed by a water vapor evolving arc extinguishing material when subjected to intense arc

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heat and resultant pressure, a high strength insulating housing surrounding and confining said arc extinguishing material, and a non-shrinking dielectric cement between said arc extinguishing material and said housing substantially coextensive therewith providing a substantially void free layer bonding them together.

20. An electric circuit interrupter comprising, in combination, means between which an arc is formed on opening of the circuit including conductor means; and a tubular housing providing a bore through which said conductor means extends and on separation of which the arc is drawn therein, the surface of said bore subjected to the arc drawn therein being formed by a tubular body of boric acid, a high strength insulating housing surrounding and confining said tubular body of boric acid, and a layer of epoxy cement between the outer surface of said tubular body of boric acid and the inner surface of said insulating housing substantially coextensive therewith providing a substantially void free layer bonding together said tubular body of boric acid and said insulating housing.

21. An electric circuit interrupter comprising, in combination, means between which an arc is formed on opening of the circuit including conductor means; and a tubular housing providing a bore through which said conductor means extends and on separation of which the arc is drawn therein, the surface of said bore subjected to the arc drawn therein being formed by a tubular body of boric acid, a high strength insulating housing surrounding and confining said tubular body of boric acid, and a non-shrinking dielectric cement between said tubular body of boric acid and said insulating housing substantially coextensive therewith providing a substantially void free layer bonding them together.

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