Aug. 8, 1950 C. H. BAKER 2,517,624

FUSE CONSTRUCTION

Filed Jan. 6, 1947 4 Sheets-Sheet 1

Fig. 1A.

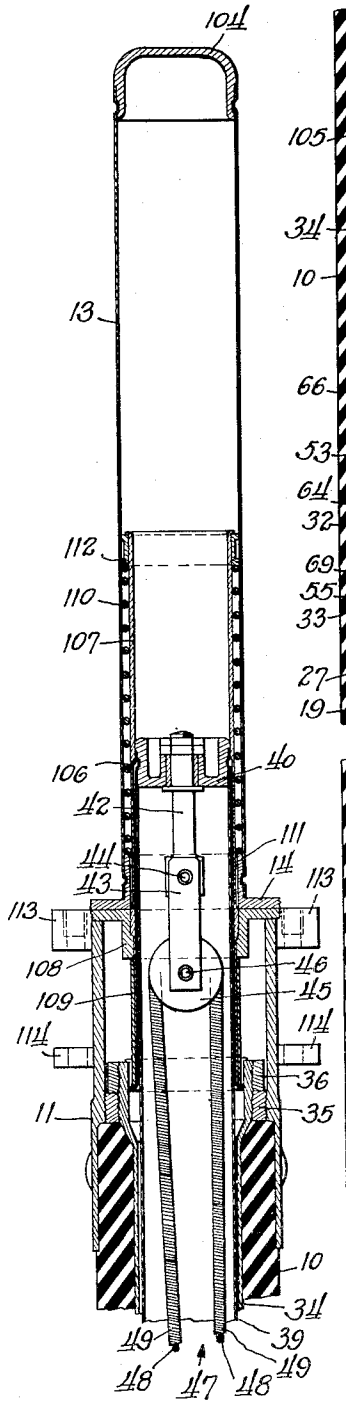


Fig. 1B.

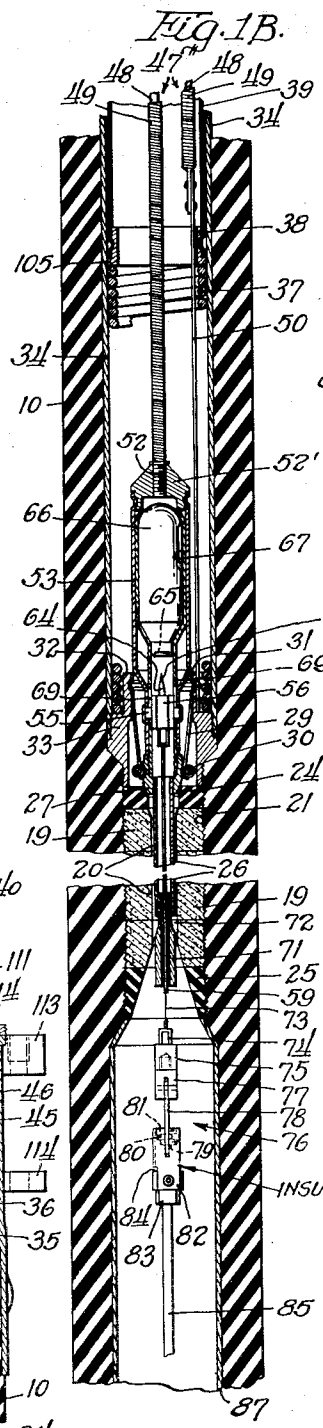
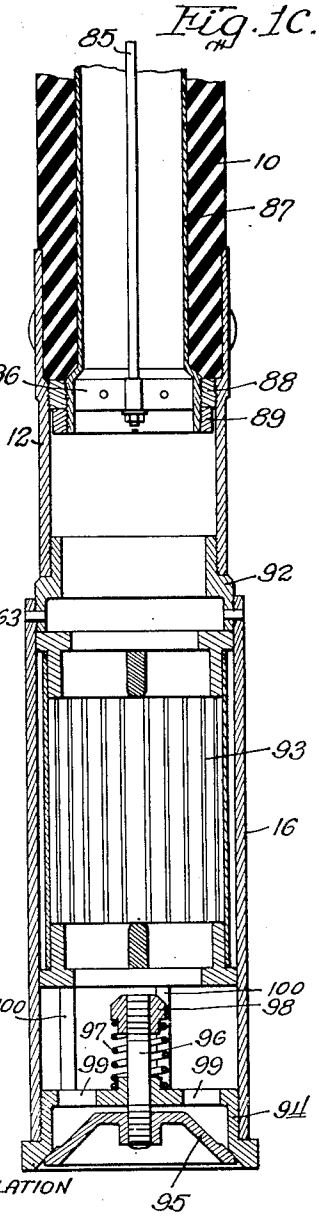


Fig. 1C.



Inventor:
Charles H. Baker.
By Brown, Jackson, Boettcher & Dienner Attys.

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Fig. 2.

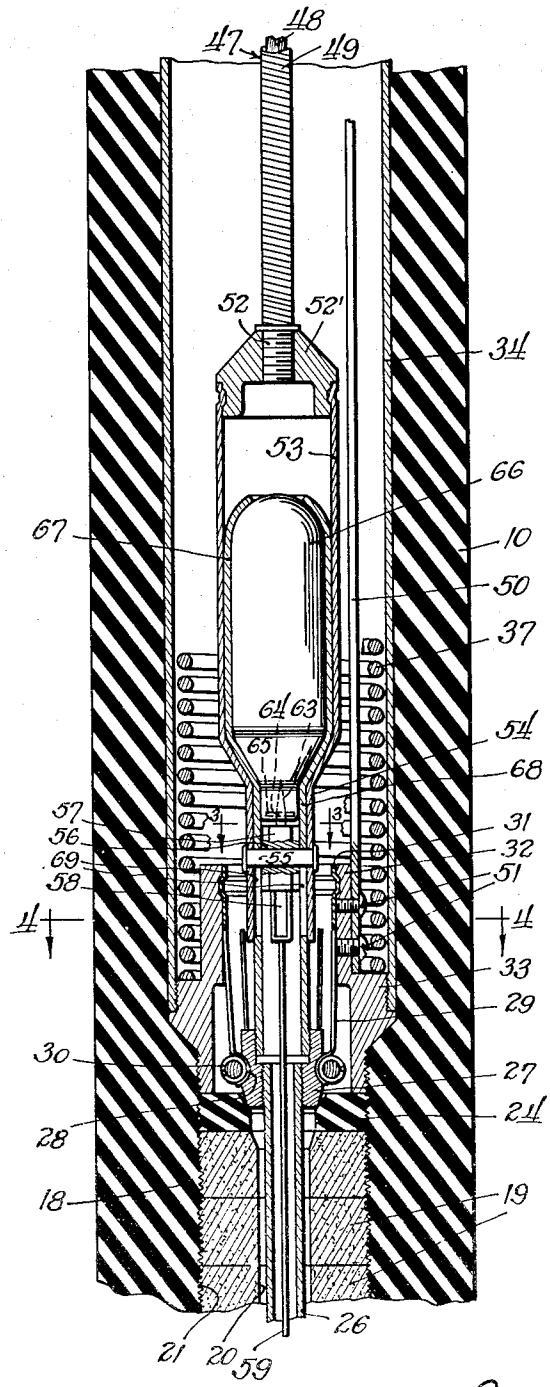


Fig. 3

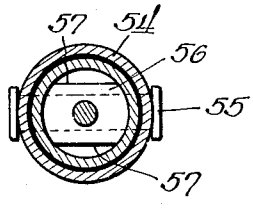
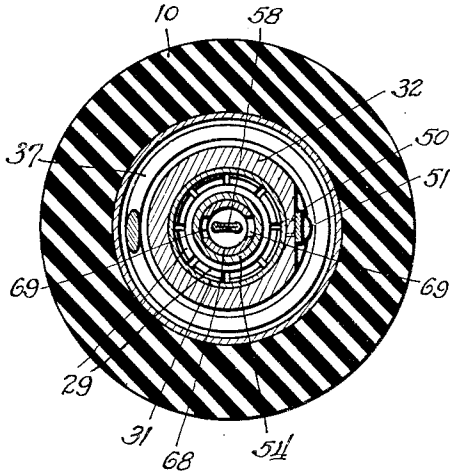


Fig. 4.



Inventor:
Charles H. Baker.
By Brown, Jackson, Boettcher & Dienner Attys.

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FUSE CONSTRUCTION

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Fig. 5A.

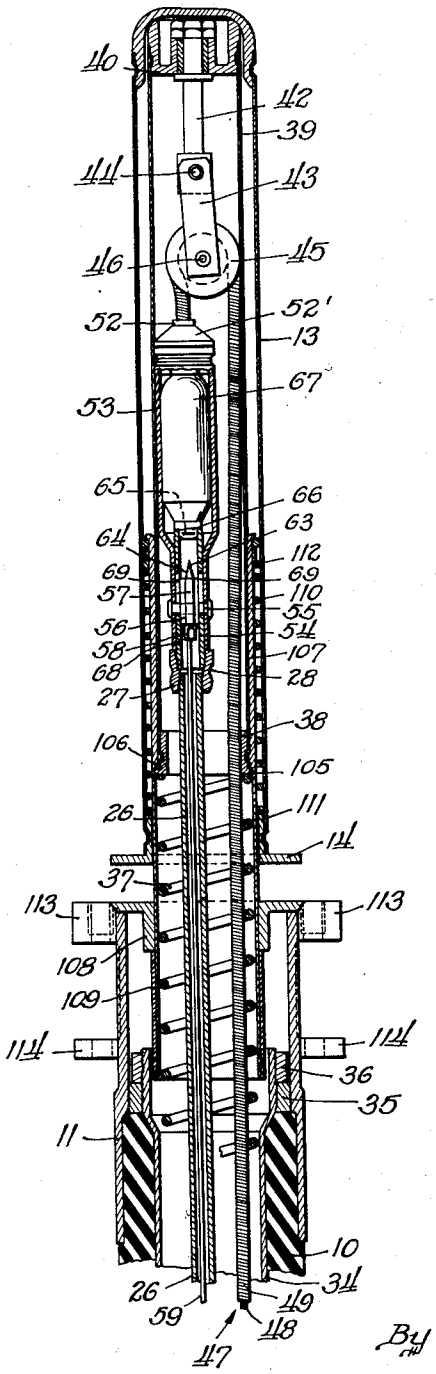
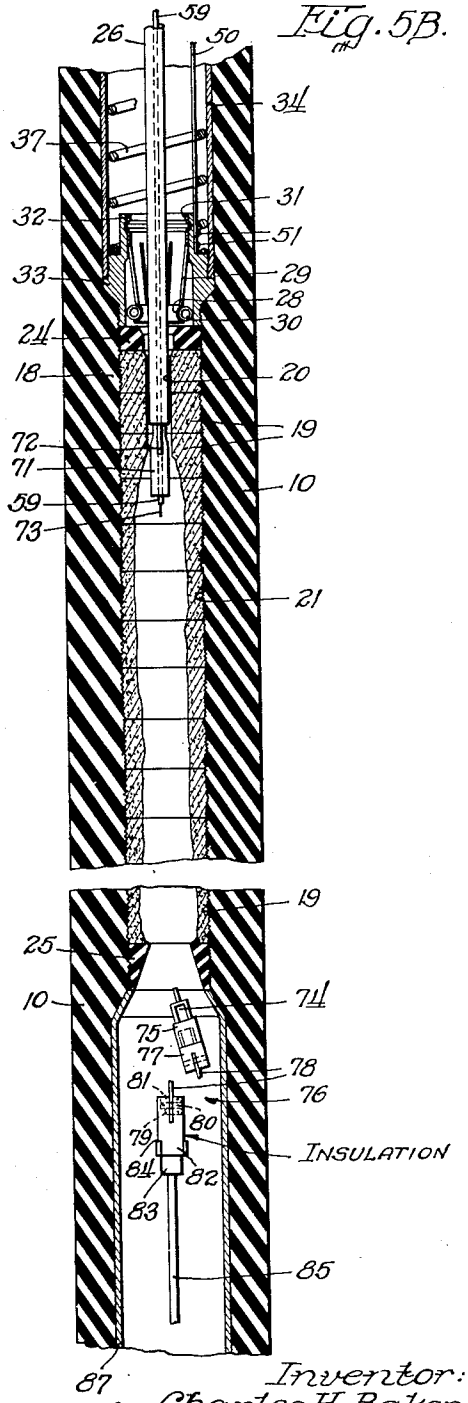


Fig. 5B.



Inventor:
Charles H. Baker.
By Brown, Jackson, Boettcher & Dienner Attys.

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Fig. 6A.

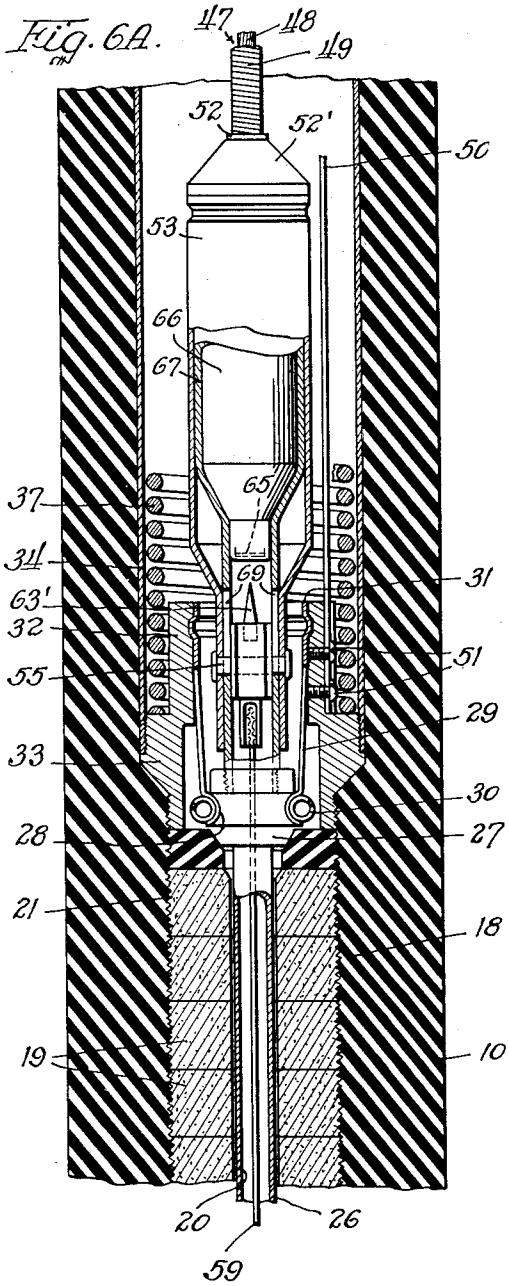


Fig. 6B.

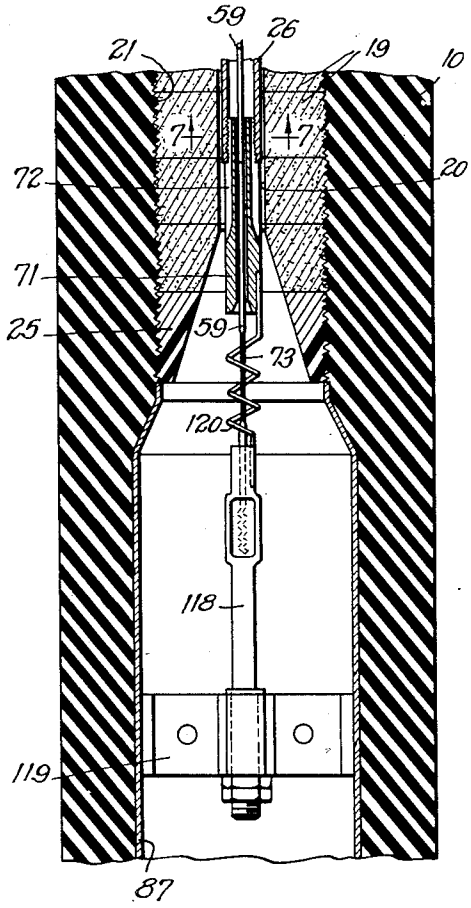
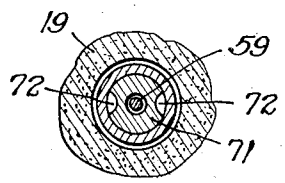


Fig. 7.



Inventor:
Charles H. Baker:
By Brown, Jackson, Boettcher & Dienner Att'ys

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UNITED STATES PATENT OFFICE

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FUSE CONSTRUCTION

Charles H. Baker, Maywood, Ill., assignor to S & C Electric Company, a corporation of Delaware

Application January 6, 1947, Serial No. 720,428

23 Claims. (Cl. 200—120)

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This invention relates, generally, to circuit interrupting devices, and it has particular relation to fuses for use on alternating-current electric-power systems operating at high voltages, of the order of 115 kv., where the transient recovery voltage may be substantially greater than the normal-frequency recovery-voltage, and where both large and small fault-currents may be encountered.

The present invention relates to the fuse construction disclosed in the copending application of Sigurd I. Lindell and Charles H. Baker, Serial No. 663,832, filed April 22, 1946. It may be employed with the terminal construction as shown in the copending application of Sigurd I. Lindell, Serial No. 663,833, filed April 22, 1946, now Patent No. 2,484,839, issued October 18, 1949, and in the dropout fuse construction disclosed in the copending application of Sigurd I. Lindell, Serial No. 663,834, filed April 22, 1946.

Fuses are extensively used in the primary connections to high voltage transformers, and must be capable of clearing any fault current within the wide range of values obtainable in such service. For example, a short circuit at the primary terminals will draw the full short-circuit current that the generators and transmission equipment can deliver to that point, which on a typical 115 kv. circuit may be as high as 6000 amperes. A fault in the secondary circuit must draw its power through the impedance of the transformer and so will produce a much lower primary current but of low power factor. An extreme case is presented by a potential transformer. Such a transformer supplying only meters and relays may draw a primary current of a few milliamperes under normal operation, and only a few amperes even when the secondary (output) terminals are short-circuited. In other installations, faults may be encountered that give rise to primary currents between these extreme values. A fuse must be capable of promptly and surely interrupting any value of current from the lowest that will sever its fusible element to the maximum that the system can deliver to it on a short circuit.

In a fuse of this type the arc-passageway must be large enough to handle the largest possible fault currents without producing destructive pressures, but a small current, which the fuse must be also capable of interrupting, produces an arc of small cross section which tends to be blown away from the walls of the passageway and does not excite the production of sufficient arc-extinguishing gas (such as water vapor) from

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those walls for the effective extinction of the arc.

In accordance with the present invention a sealed reservoir is provided which contains a fluid, such as carbon dioxide, that, when released into the arc-passageway, quickly fills it and provides a blast action in the arc-passageway which tends to sweep out the products of the arc and to scavenge the inner surface of the arc-passageway to remove therefrom material likely to form a conducting path thereover.

In some fuse constructions, it may be desirable to release the fluid from the reservoir immediately upon the occurrence of a fault and before the terminal in the arc-passageway begins to move therethrough to extend the arc. In other instances, it may be desirable to delay the introduction of the fluid from the reservoir until the terminal has completed its movement through the arc-passageway.

In accordance with the present invention, provision is made for initiating the functioning of the fuse in response to low currents, such as those produced in the primary circuit of a potential transformer on the occurrence of a secondary fault. This, in combination with the provision of the reservoir containing the arc-extinguishing fluid which is released into the arc-passageway, provides a construction which will quickly and reliably interrupt the flow of fault current before any damage can be done to the transformer and without harm to adjacent equipment, as might be the case if the arc, once drawn by the fuse, were not promptly extinguished.

However, the present invention is not limited solely for use with fuses of low current ratings, such as those used for potential transformers. Provision is made for carrying the current carrying capacity of the fuse up to higher values by employing, in addition to a strain element, a fusible element having relatively large current carrying capacity.

Accordingly these are among the objects of this invention: To provide a low current high-voltage fuse which shall be simple, efficient and accurate in operation; to release an arc-extinguishing fluid from a container or reservoir to flow into the arc-passageway of the fuse immediately upon the melting of the fusible element and before lengthening the arc; to cause the arc-extinguishing fluid to flow through a tubular terminal, movable through the arc-passageway which constitutes one of the terminals between which the arc incident to circuit interruption is drawn; to restrain the operating mechanism of the fuse by a strain wire that extends through a tubular

terminal; to provide a lost motion connection between the operating mechanism and the tubular terminal and to puncture a diaphragm of the reservoir that holds the arc-extinguishing fluid while the slack in the lost motion connection is being taken up; to restrain the initial movement of the terminal in the arc-passageway while the slack in the lost motion connection is being taken up so as to permit puncturing of the diaphragm as a result of movement of the operating mechanism while the reservoir which is attached to the terminal remains stationary; and to increase the current rating of the fuse construction by employing a fusible element in addition to the strain element which serves to restrain the operating mechanism until the fuse blows.

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 which 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 in connection with the accompanying drawings, in which:

Figures 1A–1B–1C, taken together, show a longitudinal, sectional view through a fuse construction in which the present invention is embodied, the fuse being shown in the unblown condition, Figure 1B being broken near the midsection in order to show the details of construction at the scale chosen within the limits of the space available;

Figure 2 is a detailed sectional view, at a larger scale, of the fuse construction as shown in the preceding figures at the section adjacent the reservoir, showing the relative positions of the various parts immediately after the current responsive element has parted and the lost motion has been taken up for puncturing the gas-containing reservoir, and before the terminal in the arc-passageway has begun to move;

Figure 3 is a detailed sectional view taken along the line 3—3 of Figure 2;

Figure 4 is a detailed sectional view taken along the line 4—4 of Figure 2;

Figures 5A–5B, taken together, constitute a view similar to Figures 1A–1B, showing the relative positions of the various parts of the fuse in fully-operated condition after being blown by a short circuit;

Figures 6A–6B illustrate a modification of the fuse construction shown in Figures 1A–1B–1C having a solid rather than a hollow needle for puncturing the diaphragm, having a current-responsive element of a type used for higher load-currents; and

Figure 7 is a detailed sectional view taken along the line 7—7 of Figure 6B.

Referring now particularly to Figures 1A, 1B and 1C of the drawings, it will be observed that the reference character 10 designates an insulating tube which forms the housing of the fuse or circuit interrupter to be described in detail hereinafter. At its opposite ends the insulating tube 10 is provided with external or line terminals 11 and 12 which are arranged to have contact engagement with suitable terminal clips

of a fuse mounting (not shown) as is more fully set forth in the copending application of Sigurd I. Lindell, Serial No. 663,833, referred to hereinbefore. The terminals 11 and 12 are formed of suitable conducting material, such as brass.

As disclosed more fully in the copending application of Sigurd I. Lindell, Serial No. 663,834, also referred to hereinbefore, the fuse herein disclosed is arranged to be mounted so that, when the fuse blows, it will automatically move or swing in its fuse mounting, under the influence of gravity and the biasing force of the contact clips, to a position in which an air gap is provided between the upper line terminal 11 and the associated terminal clip which is connected to the circuit. In order to provide such operation the fuse has a latch tube 13 which is secured at its lower end to a latch release flange 14 that, together with the tube 13, is arranged to be moved upwardly in a manner to be described hereinafter for the purpose of unlatching the locking mechanism on the fuse mounting and permitting the fuse to fall, or drop out, to the open-circuit position.

The fuse is arranged to expel the gases from the arc down through the lower line terminal 12. In order to cool and condense the arc products and limit the escape of flame from the lower end of the fuse, a condenser assembly may be provided on the lower line terminal 12. Its shell is indicated at 16. The internal details of construction of the condenser will be set forth more fully hereinafter.

Particular reference will now be made to Figure 1B. As there shown the fuse tube 10 is formed of insulating material. This may be a phenolic condensation product, such as "Bakelite" or it may be melamine. The tube 10 may be formed of a solid, rolled, phenolic-condensation-product and may have a baked coating of melamine enamel on the outside and the inside to provide weather and arc-resisting surfaces superior in these respects to the surface of the tube itself.

At the central portion of the tube 10 its internal diameter is smaller as indicated at 18 for the purpose of providing a section which has greater resistance to bursting pressure, because high pressures may be generated within the tube 10 in the portion thereof in which the arc is drawn and extinguished. This configuration also aids in more uniformly distributing the dielectric flux in the air outside of the tube 10 about the ends of the terminals embedded in the tube.

With a view to providing an arcing passageway from whose surface an arc-extingushing medium can be evolved, cakes 19 of solid, arc-extinguishing material are positioned along the bore of the small diameter section 18. These cakes 19 are annular in form and when placed one above the other provide a continuous bore 20 in which the arc may be drawn and extinguished. Various solid, arc-extinguishing materials may be employed. For example, boric acid or magnesium borate may be used.

As indicated in the copending application of Lindell and Baker, Serial No. 663,832, referred to hereinbefore, difficulty has been encountered in the failure of the fuse as a result of arcing over along the juxtaposed surfaces of the tube 10 and the solid arc-extinguishing material 19. This difficulty has been overcome, as there disclosed, by grooving the thickened portion 18 of the wall of the tube 10, by threading the same as indicated at 21. The cakes 19 of solid arc-extin-

guishing material, such as boric acid or magnesium borate, are placed in the fuse tube 10 and then are successively subjected to a molding pressure so that they are compacted, one by one, into intimate engagement with the melamine coated threads 21, leaving the central bore 20 which forms the arc-passageway.

At each end of the column of cakes 19 of solid arc-extinguishing material there is provided a reenforcing ring of suitable insulating material, such as fiber. One of these is indicated at 24 at the upper end in Figure 1B and the other is indicated at 25 at the lower end. The reenforcing ring 25 is flared outwardly to facilitate the outward flow of the products of the arc, as will be readily understood.

Movably mounted within the bore 20 in the cakes 19 of solid, arc-extinguishing material is a hollow, rodlike or tubular terminal 26. The terminal 26 is movable through the bore 20 by mechanism which will be described in detail hereinafter. At its upper end the terminal 26 is provided with a contact tip 27 which, as shown, is threaded onto it. As shown more clearly in Figure 2 the contact tip 27 has a circumferential groove 28 for receiving the inturned ends of contact fingers 29 that are biased inwardly by a garter spring 30. The contact fingers 29 are formed by longitudinally slotting a tubular shell 31. The base section of the shell 31 may be rolled into a flange 32 which extends upwardly from a contact fitting 33, the lower end of which is shaped to conform to the adjacent surface of the fuse tube 10 and bears against the reenforcing ring 24 and serves to hold it in place.

The contact fingers 29 by their engagement with the contact tip 27 in the groove 28, not only serve to provide a low-resistance, high-current-carrying path between the fitting 33 and the contact tip 27, but also serve to frictionally grip the latter and thereby tend to hold it and the tubular terminal 26 in place. For reasons which will appear hereinafter, it is desirable to hold the tubular terminal 26 stationary immediately after the current responsive element parts so that the operating mechanism will move the terminal 26 first to thereby take up the slack in a lost motion connection, which will be described presently, and effect the early release of an arc-extinguishing fluid into the bore 20 for scavenging its surface and assisting particularly in extinguishing low-current arcs.

As is shown best in Figures 1A and 1B, an electrical connection between the line terminal 11 and the contact fingers 29 is provided by a conducting tube, or terminal extension, 34 of brass, copper, copper alloy or other suitable conducting metals. It will be noted that the lower end of the conducting tube 34 is threaded onto the contact fitting 33 and that a nut 35 is threaded onto the upper end of the tube 34 and also is threaded into the line terminal 11, thereby forming an extension thereof. A lock nut 36 serves to hold the contact nut 35 in place.

As will hereinafter appear, it is desirable that when the fuse blows, the tubular terminal 26 be withdrawn through the bore 20 in order to extend the arc therein and permit the heat thereof to evolve an arc-extinguishing medium, such as water vapor, from the bore 20 so as to deionize the arc space and assist in extinguishing the arc. For extinguishing low-current arcs additional means are provided. In order to move the tubular terminal 26 a helical compression spring 37 lies within the conductor tube 34 and at one end bears against the fitting 33 and at the other end against the underside of a spring seat 38 which is secured to the lower end of a compression tube 39 that may be formed of brass. The compression tube 39 carries a base 40 at its upper end from which a stud 42 depends. On opposite sides of the lower end of the stud 42, straps 43 (only one of which is shown) are pivoted by a pin 44. Between the straps 43 a pulley 45 is rotatably mounted on a pin or shaft 46.

A cable assembly, shown generally at 47, extends over the pulley 45 and provides both mechanical and electrical connection to the tubular terminal 26 for effecting retraction thereof and for maintaining electrical circuit connection thereto while it is being moved through the bore 20 after the contact tip 27 has moved away from the contact fingers 29. The cable assembly 47 consists of a core 48 formed of a large number of strands of fine wire, such as copper wire, and an outer sheath 49 formed by a closely-wound coil spring, preferably of stainless steel. One end of the cable assembly 47 is connected by a strap or cable link 50 to the terminal fitting 33. It may be secured thereto by suitable means, such as screws 51, as illustrated more clearly in Figure 2 of the drawings.

The other end of the cable assembly 47 has a threaded terminal 52 which is screwed into a connecting tube terminal 52'. The upper end of a connecting tube 53 is secured, as by rolling, to the terminal 52' and its lower end 54 is reduced and has a needle-holder pin 55 extending transversely therethrough. The pin 55 carries a generally cylindrically shaped needle-holder 56, the sides of which are slabbed off as indicated at 57 in Figures 2 and 3, to permit the free flow of arc-extinguishing fluid therepast. The needle-holder 56 has an integrally formed tubular extension 58 which is deformed onto one end of a strain wire 59 which forms a part of the current responsive means employed in effecting operation of the fuse as will be described in detail hereinafter.

The needle-holder 56 carries a needle 63 which is notched as indicated at 64 to permit the escape of an arc-extinguishing fluid as soon as a diaphragm 65 of a reservoir or flask 66 is punctured. The reservoir or flask 66 may be a carbon dioxide capsule of a well known type. As soon as the diaphragm 65 is punctured the fluid in the reservoir 66 can escape in the form of a gas past the notch 64 of the needle 63 and the slabbed off sides 57 of the needle-holder 56 into the tubular terminal 26 and out the lower end thereof.

The reservoir or flask 66 is secured in a tubular holder 67 which, as indicated, may be shaped to conform to the contour of the flask. The lower end 68 of the holder 67 is reduced in diameter and is threaded into the contact tip 27. It will thus be apparent that the reservoir or flask 66 is directly mechanically connected to the tubular terminal 26 and that it has conjoint movement therewith.

It is necessary to provide for relative movement between the needle-holder 56 and the reservoir or flask 66 in order to permit the needle 63 to rupture the diaphragm 65. For this reason a lost motion connection is provided between the connector tube 53 and the tubular terminal 26. In effect, a lost motion connection is provided between the tubular terminal 26 and the operating mechanism, which latter includes the coil compression spring 37, so that a limited movement of the operating mechanism is permitted before the terminal 26 is caused to move. This

movement is sufficient to cause the needle 63 to rupture the diaphragm 65.

The desired lost motion connection is provided by a slot 69 in the lower end 68 of the holder 67, through which the pin 55 projects.

Initially, as illustrated in Figure 1B, the pin 55 is at the lower ends of the slots 69. When the strain wire 59 is no longer restrained, as when the current responsive element parts, the needle-holder 56 is no longer restrained and it begins to move upwardly under the force of the coil compression spring 37. Because of the lost motion of the pin 55 in the slotted openings 69, the tubular terminal 26 is not moved immediately. Moreover, it is retained in the initial position by the frictional engagement of the contact fingers 29 in the groove 28. Adequate lost motion is provided so that the impact of the moving parts 53, 47, 39, etc., against the stationary parts 26, 66, 67, etc., will drive the needle 63 through the diaphragm 65 and into the reservoir or flask 66 to the extent indicated in Figure 2. In this position the pin 55 engages the upper ends of the slotted openings 69 and, thereafter, the coil compression spring 37 is effective for withdrawing the tubular terminal 26 through the bore 20. At the lower end of the tubular terminal 26 a tubular arcing tip 71 is carried. Fluted openings, Figure 7, 72 in the arcing tip 71 direct the fluid arc-extinguishing medium from the inside of the tubular terminal 26 along the surface of the bore 20 at the receding end of the tubular terminal 26, thereby directly sweeping over the surface of the bore 20 and removing therefrom particles of conducting matter or the like which may facilitate the restriking of the arc once it has been extinguished.

While the carbon dioxide blast is especially helpful in the interruption of small currents it is also of material help in the case of high currents. In either case, it persists after the extinction of the arc and so sweeps out all residual ionized and conducting particles from the space between the arcing terminals and increases the rate at which the arc-space builds up its resistance to any tendency of the arc to re-strike in response to the recovery voltage that appears at the fuse terminals promptly after the arc interruption. The tip 71, by directing the carbon-dioxide blast over its outside surfaces, keeps the arc near the center of the tip so that metal at the arc root will not flow to the side of the tip to there solidify and impede the free movement of the terminal through the close-fitting bore 20.

As shown more clearly in Figure 1B, the strain wire 59 has a reduced section 73 adjacent the lower end of the arcing tip 71. The purpose of this is to provide a portion of the strain wire 59 which will melt in preference to other parts of this wire on the occurrence of relatively heavy fault current. It will be apparent that when the section 73 melts, the resulting arc will be formed near the end of the tubular arcing tip 71 so that full use can be made of the bore 20 for drawing the arc therein to aid in extinguishing it.

The lower end of the strain wire 59 is secured in a tubular terminal extension 74 of a terminal 75. The extension 74 is deformed onto the end of the strain wire 59 for providing mechanical and electrical connections to it.

As indicated hereinbefore, it may be desirable to employ the fuse construction of the present invention for protecting potential transformers. The normal current flow to the potential transformer is relatively small and, under certain conditions, the flow of fault current thereto may also be small but yet of sufficient amount to require that the circuit be interrupted. Thus, it is necessary to provide a current-responsive element which is capable of releasing the strain wire 59 at a relatively small overload but which still has sufficient mechanical strength to restrain the movement of a powerful spring, such as the coil compression spring 37. For this purpose a fuse link construction, indicated generally at 76, may be employed. The details of construction of the fuse link assembly 76 are set forth in Lindell Patent No. 2,804,495. Accordingly, only such reference will here be made as will provide a brief outline of the construction of the fuse link assembly 76.

The fuse link assembly 76 includes a terminal 77 which may be threaded into the terminal 75. One end of a conducting link 78 is pivoted to the terminal 77 and the other end has an eye that receives a lever 79 which is the first of a set of interrelated levers comprising additional levers 80 and 81. The levers 79, 80 and 81 are fulcrumed between plates 82 (only one of which is shown) of insulating material that, in turn, are supported on a terminal 83. A fusible element 84 in the form of a relatively fine wire mechanically and electrically connects the lever 81 with the terminal 83. The size of the wire 84 determines the time-current characteristics of the fuse link assembly 76. Because of the mechanical advantage provided by the levers 79, 80 and 81, the full force of the spring 37 is not applied directly to the fuse wire 84. Accordingly, it can be calibrated to melt on flow of a predetermined low current with an accuracy that would be impossible if the wire 84 were required to withstand the full force of the spring 37.

The fuse link assembly 76 is particularly intended to operate when the flow of fault current is relatively low and persists over an extended period. In such case, the fuse wire 84 will finally part and release the levers 79, 80 and 81, whereupon the spring 37 acts, as described hereinbefore, to first puncture the diaphragm 65 and release the arc-extinguishing fluid from the reservoir or flask 66 into the tubular terminal 26. In this case the arc will be drawn between the receding end of the link 78 and the terminal 83. Terminal members 75 and 77 and link 78 are small enough to enter the bore 20 for extending the arc therein to be extinguished. The arc will be of relatively small current magnitude and the arc-extinguishing fluid from the reservoir or flask 66 will materially assist in extinguishing it since the heat developed by the arc is unlikely to be sufficient to evolve the necessary amount of arc-extinguishing medium from the cakes 19 of arc-extinguishing material.

When a relatively heavy fault current flows, as in the case of a primary short circuit, both the reduced section 73 of the strain wire 59, and the fuse wire 84 will melt immediately. The functioning of the spring 37 in withdrawing the tubular terminal 26 and releasing the arc-extinguishing fluid from the reservoir or flask 66 will be same as already described. The terminal 77, being thus left unsupported, simply falls harmlessly into the exhaust passage.

The terminal 83 is connected to the lower fuse tube terminal 12 by a rod 85. The lower end of the rod 85, as viewed in Figure 1C, is secured to a narrow bridge 86 that is carried by a metal exhaust tube 87. The metal exhaust tube 87 extends well up into the lower end of the fuse tube 10 for assisting in more uniformly distributing

the electrostatic stress incident to circuit interruption, as is set forth in more complete detail in the copending application of Lindell and Baker, Serial No. 663,832, referred to hereinbefore. A nut 88 is threaded onto the lower end of the tube 87 and is also threaded into the lower fuse tube terminal 12 to provide connection thereto. A lock nut 89 holds the nut 88 in place.

In order to hold the condenser shell 16, a reducer fitting 92 is threaded into the lower end of the lower line terminal 12 and the shell 16 is threaded thereon, as illustrated in Figure 1C. Within this condenser shell 16 is a condenser 93 of the type shown in Triplett Patent No. 2,379,200 which serves to cool and condense the products of the arc resulting from the blowing of the fuse as previously described.

It is desirable that the condenser shell 16 be closed to the atmosphere except when the fuse blows. For this purpose a valve seat 94 is threaded into the lower end of the condenser shell 16 and a valve cover 95 is arranged to cooperate therewith. The valve cover 95 is slidably mounted on the valve seat 94 by a stud 96 and is held in the closed position by a coil compression spring 97 which reacts between the upper surface of the valve 94 and a nut 98 at the upper end of the stud 96. When sufficient pressure is generated within the condenser shell 16 on the blowing of the fuse, the arc products expand through apertures 99 in the valve seat 94, lift the valve cover 95 from the valve seat 94 and exhaust into the atmosphere. Three pins 100 (two of which are shown) extend upwardly from the valve seat 94 and serve to hold the condenser assembly 93 in place in the shell 16.

It will be recalled that the fuse construction disclosed herein can be employed as part of a dropout fuse construction as shown in the copending application of Lindell, S. N. 663,834. It is for this purpose that the latch tube 13 (Figure 1A) is provided. When the fuse blows and the compression tube 39 is driven upwardly by the spring 37, it carries with it the base 40 until the latter engages a cap 104 that is secured to the upper end of the latch tube 13. Thereupon, the latch tube 13 is moved upwardly, as illustrated in Figure 5A to lift therewith the flange 14 which releases the latch in the fuse mounting (not shown) so as to permit the fuse to drop out. The latch tube 13 moves upwardly until a flange 105, shown in Figure 1B, on the spring seat 38 engages a shoulder 106, Figure 1A, on the inside of a stop tube 107 that is secured to a fitting 108 which forms part of the fuse mounting contact mechanism, that is described in more detail in the copending application of Lindell, Serial No. 663,833. The stop tube 107 is held in place in the fitting 108, in part, by a sleeve 109 over which the lower end of the tube 107 is rolled and which bears against the underside of the fitting 108. The latch tube 13 is held in the position shown in Figure 1A of the drawings by a coil compression spring 110 which is located between the tubes 13 and 107 and at its lower end bears against the upper end of a tubular extension 111 from the flange 14 and at its upper end against the underside of a collar 112 which is secured to the upper end of the stop tube 107. The fitting 108 has integrally formed ears 113 and 114 on opposite sides between which links are pivoted to provide for contact engagement between the line terminal 11 and the cooperating fuse clip.

At the end of the stroke of the operating mechanism, which includes the spring 37, the connecting tube terminal 52' and connecting tube 53 occupy the position shown in Figure 5A and further upward movement thereof is prevented. During the movement of the tube 39, the accelerating force of the spring 37 opposed by the inertia of terminal 26, capsule 67 et cetera, tends to hold the needle 63 against the diaphragm 65 of the capsule 67. However, both the fluid pressure within the capsule 67 acting against the needle, and the kinetic reaction of the escaping jet of fluid tend to lift the capsule off the needle.

In any event, at the end of the stroke, terminal 52' on the connecting tube 53 strikes pulley 45 and stops suddenly. The lost motion at the slots 69 then permits the momentum of the capsule 67 and of the terminal 26, which is connected to it, to carry the capsule up to the limit of motion permitted by slots 69 and so insure that the needle is disengaged from the opening for free egress of the last of the stored arc-extinguishing fluid.

As shown in Figure 6A, I take advantage of the strong forces that are available for lifting the capsule off the needle. There a solid needle 63' is employed for rupturing the diaphragm 65 immediately after the current responsive wire melts. It will be apparent that the magnitude and effectiveness of those forces will depend in part on the size and shape of the needle itself. Thus, a needle having a large angle at its apex will have less tendency to wedge into the hole that it pierces in the diaphragm 65. The characteristics of the diaphragm material, such as its compliance and surface condition, will also affect the tendency of the needle to stick. I have found that a hard steel needle with a polished conical point having a full angle of 30° and driven into the thin steel diaphragm of the commercially available CO_2 capsule, is ejected from the opening in the diaphragm early in the travel of the terminal rod 26.

Advantage is taken of the withdrawal of the needle at the end of the stroke by so constructing the solid needle 63' in Figure 6A that it lodges in the hole. Then, when it ruptures the diaphragm 65 immediately after the fuse blows, it, in effect, seals the opening thus made. While the seal thus formed is imperfect and some of the arc-extinguishing fluid can escape from the reservoir or flask 66, it is not as free so to do as in the case of the other constructions. The needle 63' is freed from the diaphragm 65 by the sharp blow at the end of the stroke. Thus, the introduction of the arc-extinguishing fluid from the reservoir or flask 66 into the tubular terminal 26 is delayed until the operating mechanism has reached the end of its travel and the arc has been drawn out to its full length. At that time the arc-extinguishing fluid in the reservoir or flask 66 is free to escape past the needle-holder 56 into the tubular terminal 26.

As illustrated in Figure 6B, it may be desirable to omit the low-current fuse-link assembly 76, shown in Figure 1B and connect the strain wire 59, having the reduced section 73 therein to provide a preferred blowing section, directly to a connector 118 that may be supported by a narrow bridge 119 secured mechanically and electrically to the exhaust tube 87.

Where a still higher current rating is required, a fusible element 120, in the form of a coil of silver wire can also be used. As illustrated in Figure 6B the coiled fusible element can be interconnected between the arcing terminal 71 and

the connector 118 by having the ends thereof deformed thereon.

It will now be apparent that the strain wire 59, in each of the embodiments of the invention disclosed herein, is directly tensioned by the operating mechanism which includes the coil compression spring 37 and that the strain wire 59 does not directly restrain movement of the tubular terminal 26. Rather, there is provision for relative movement between the operating mechanism and the tubular terminal 26 so as to permit a slight movement of the former before the latter is moved for the purpose of releasing the arc-extinguishing fluid from the reservoir or flask 66 immediately upon the melting of the current responsive element.

Since certain further changes can be made in the foregoing constructions 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. In circuit interrupting apparatus, in combination, a body of arc-extinguishing material having a bore, a pair of relatively movable terminal members between which an arc may be formed, one of said terminal members being located adjacent one end of said bore and the other being rodlike in character and movable through said bore, a reservoir for holding material which when released is in the form of an arc-extinguishing fluid, said reservoir being located adjacent the end of said rodlike terminal member away from the arcing end thereof, mechanism for moving said rodlike terminal member, and a rupturing member responsive to the initial movement of said mechanism for puncturing said reservoir and releasing said fluid into said bore and the arc space for assisting in extinguishing the arc before and while said rodlike terminal member is withdrawn into said bore and for blowing out of said bore products of the arc deposited on the surface thereof and likely to facilitate restriking.

2. In circuit interrupting apparatus, in combination, a body of arc-extinguishing material having a bore, a pair of relatively movable terminal members between which an arc may be formed, one of said terminal members being located adjacent one end of said bore and the other being rodlike in character and movable through said bore, a reservoir for holding material which when released is in the form of an arc-extinguishing fluid, mechanism for moving said rodlike terminal member, lost motion means mounting said reservoir adjacent the end of said rodlike terminal member away from the arcing end thereof and serving to hold the same stationary relative to said mechanism during the initial movement thereof, and means responsive to said initial movement of said mechanism for releasing said fluid into said bore and the arc space for assisting in extinguishing the arc before and while said rodlike terminal member is withdrawn into said bore and for blowing out of said bore products of the arc deposited on the surface thereof and likely to facilitate restriking, said reservoir thereafter being moved with said rodlike terminal member to the end of the stroke of said mechanism.

3. In circuit interrupting apparatus, in combination, a body of arc-extinguishing material having a bore, a pair of relatively movable terminal members between which an arc may be formed, one of said terminal members being located adjacent one end of said bore and the other being tubular in character and movable through said bore, a reservoir for holding material which when released is in the form of an arc-extinguishing fluid, said reservoir being located adjacent the end of said tubular terminal member away from the arcing end thereof, mechanism for moving said tubular terminal member, and a rupturing member responsive to the initial movement of said mechanism for puncturing said reservoir and releasing said fluid to flow through said tubular terminal member into said bore and the arc space during the initial movement of said mechanism for assisting in extinguishing the arc before and while the same is withdrawn into said bore and for blowing out of said bore products of the arc deposited on the surface thereof and likely to facilitate restriking.

4. In circuit interrupting apparatus, in combination, a body of arc-extinguishing material having a bore, a pair of relatively movable terminal members between which an arc may be formed, one of said terminal members being located adjacent one end of said bore and the other being tubular in character and movable through said bore, a reservoir for holding material which when released is in the form of an arc-extinguishing fluid, mechanism for moving said tubular terminal member, lost motion means mounting said reservoir adjacent the end of said tubular terminal member away from the arcing end thereof and serving to hold the same stationary relative to said mechanism during the initial movement thereof, and means responsive to said initial movement of said mechanism for releasing said fluid to flow through said tubular terminal member into said bore and the arc space for assisting in extinguishing the arc before and while said tubular terminal member is withdrawn into said bore and for blowing out of said bore products of the arc deposited on the surface thereof and likely to facilitate restriking, said reservoir thereafter being moved with said tubular terminal member to the end of the stroke of said mechanism.

5. In circuit interrupting apparatus, in combination, a body of arc-extinguishing material having a bore, a pair of relatively movable terminal members between which an arc may be formed, one of said terminal members being positioned adjacent one end of said bore and the other being rodlike in character and movable through said bore, a capsule mounted for movement with said rodlike terminal member and containing material which when released is in the form of an arc-extinguishing fluid, a diaphragm sealing said capsule, mechanism for moving said rod-like terminal member and having a lost motion connection therewith, and means moved by said mechanism while it takes up the slack in said lost motion connection for puncturing said diaphragm to release said fluid into said bore and arc space for assisting in extinguishing the arc before and while said rodlike terminal member is withdrawn into said bore.

6. In a circuit interrupting apparatus, in combination, a body of arc-extinguishing material having an arc-passageway therein, means for drawing an arc in said passageway including a stationary terminal and a terminal movable through said passageway, a reservoir mounted for movement with said movable terminal and

containing material which when released is in the form of an arc-extinguishing fluid, spring biased mechanism for moving said movable terminal, lost motion means interconnecting said movable terminal and said mechanism and arranged to permit movement of the latter relative to the former to take up the slack therein, means operated by said mechanism while taking up said slack to release said fluid into said passageway, and fusible means interconnecting said stationary terminal and said mechanism for restraining movement of the latter until the fusible means blows.

7. The invention, as set forth in claim 6, wherein the movable terminal is tubular and the arc-extinguishing fluid flows therethrough into the arc-passageway.

8. The invention, as set forth in claim 6, wherein the movable terminal is tubular and the arc-extinguishing fluid flows therethrough into the arc-passageway and the fusible means is a part of a high tensile strength conductor which extends through the tubular movable terminal.

9. The invention, as set forth in claim 6, wherein the fusible means comprises a fusible element interconnecting the stationary and movable terminals and a strain wire interconnecting said stationary terminal and the spring biased mechanism.

10. The invention, as set forth in claim 6, wherein the movable terminal is tubular and the arc-extinguishing fluid flows therethrough into the arc-passageway and the fusible means comprises a fusible element interconnecting the stationary and movable terminals and a strain wire extending through the tubular terminal and interconnecting said stationary terminal and the spring biased mechanism.

11. The invention, as set forth in claim 6, wherein the movable terminal is tubular and the arc-extinguishing fluid flows therethrough into the arc-passageway and the arcing end of said tubular terminal has at least one aperture placing the opening therein in communication with the arc-passageway to direct the flow of the arc-extinguishing fluid onto the surface thereof.

12. In circuit interrupting apparatus, in combination, a body of arc-extinguishing material having an arc-passageway therein, means for drawing an arc in said passageway including a stationary terminal and a tubular terminal movable through said passageway, a reservoir, a rupturable diaphragm sealing said reservoir, said reservoir containing material which when released is in the form of an arc-extinguishing fluid and being mounted for conjoint movement with said tubular terminal at the end remote from its arcing end, spring biased mechanism for moving said tubular terminal, lost motion connecting means interconnecting said tubular terminal and said mechanism whereby movement of the latter relative to the former is permitted to take up the slack therein, a needle movable with said mechanism while said slack is being taken up and before said reservoir is moved for puncturing said diaphragm to release said arc-extinguishing fluid to flow through said tubular terminal, and fusible means interconnecting said terminals including a strain wire extending through said tubular terminal and connected to restrain said mechanism until the fusible section blows.

13. The invention, as set forth in claim 12, wherein the needle has a relieved section intermediate its ends which registers with the ruptured diaphragm to facilitate the escape of the arc-extinguishing fluid immediately upon puncturing thereof.

14. The invention, as set forth in claim 12, wherein the needle has a uniform cross section.

15. In circuit interrupting apparatus, in combination, an arc confining structure having a bore, a pair of terminal members between which an arc may be formed, one of said terminal members being located adjacent one end of said bore and the other being rodlike and movable through said bore, a reservoir for storing material which when released is in the form of an arc-extinguishing fluid, mechanism for moving said rodlike terminal member away from the first terminal, lost motion means mounting said reservoir adjacent the end of said rodlike terminal member away from the arcing end thereof and serving to hold said rodlike terminal member stationary during the initial movement of said mechanism, and means responsive to said initial movement for releasing said fluid into said bore and into the arc space for assisting in extinguishing the arc both before and during the movement of said rodlike terminal member into said bore and for blowing out of said bore products of the arc deposited on the surface thereof and likely to facilitate restriking, said reservoir being moved with said rodlike terminal member to the end of the stroke of the said mechanism.

16. In circuit interrupting apparatus, in combination, a pair of terminal members between which an arc may be formed, one of which is tubular, a reservoir for holding material which when released is in the form of an arc-extinguishing fluid, mechanism for moving said tubular terminal member away from the other terminal to enlarge the arc distance between them, lost motion means mounting said reservoir adjacent the end of said tubular terminal member away from the arcing end thereof and serving to hold said tubular terminal member stationary during the initial movement of said mechanism, and means responsive to said initial movement for releasing said fluid into the arc space between said terminals for assisting in extinguishing the arc before and while said tubular terminal member is being withdrawn and for blowing out of said space products of the arc likely to facilitate restriking, said reservoir being moved with said tubular terminal member to the end of the stroke of the said mechanism.

17. In a circuit interrupting apparatus, in combination, means defining an arc space and for drawing an arc therein including a pair of arcing terminals one of which is tubular, a reservoir, a rupturable diaphragm sealing said reservoir, said reservoir containing material which when released is in the form of an arc-extinguishing fluid, said reservoir being mounted for conjoint movement with said tubular terminal at the end thereof remote from its arcing end, spring biased mechanism for moving said tubular terminal relative to the other terminal, lost motion connecting means interconnecting said tubular terminal and said mechanism for providing a driving connection with limited relative movement therebetween, fusible means for initiating an arc between said terminals including a strain wire extending through said tubular terminal and connected to restrain said mechanism in such position that upon rupture of said strain wire said mechanism must take up the slack of the relative movement between said mechanism and said tubular terminal before driving said terminal, and

a needle movable with said mechanism while said slack is being taken up and before said reservoir and tubular terminal are moved, for puncturing said diaphragm to release the arc-extinguishing fluid to flow through said tubular terminal.

18. In combination in a circuit interrupter having a body of arc extinguishing material in which there is a longitudinally extending bore, a tubular arcing terminal, a reservoir of arc-extinguishing material at one end of said terminal adapted to discharge said material through said tubular terminal for assisting in extinguishing an arc drawn thereat, driving means for moving said terminal longitudinally through said bore in the direction of said one end while said arc extinguishing material is being discharged through said tubular terminal, a tension element extending through said tubular terminal for restraining said driving means, said terminal having a longitudinal slot, a pin extending through said slot for connecting said tension element to said driving means, said slot permitting limited relative movement between said terminal and driving means, and a cover for said slot.

19. In circuit interrupting apparatus, in combination, a body of arc-extinguishing material having a bore, a pair of relatively movable terminal members between which an arc may be formed, one of said terminal members being located adjacent one end of said bore and the other being rodlike in character and movable through said bore, means for retracting said rodlike terminal member away from said one terminal member, contact means frictionally engaging said rodlike terminal member and providing a current path thereto prior to movement thereof by said retracting means, and means for controlling the movement of said rodlike terminal member away from said one terminal member including a lost motion connection between said retracting means and said rodlike terminal member whereby on operation of said controlling means said retracting means moves through a predetermined distance without moving said rodlike terminal member and acquires kinetic energy to assist in overcoming the friction between said rodlike terminal member and said contact means in initiating the movement of the former away from said one terminal member.

20. In circuit interrupting apparatus, in combination, a body of arc-extinguishing material having a bore, a pair of relatively movable terminal members between which an arc may be formed, one of said terminal members being located adjacent one end of said bore and the other being rodlike in character and movable through said bore, means for retracting said rodlike terminal member away from said one terminal member, contact means frictionally engaging said rodlike terminal member and providing a current path thereto prior to movement thereof by said retracting means, and means for controlling the movement of said rodlike terminal member away from said one terminal member including a lost motion connection between said retracting means and said rodlike terminal member and a fusible element whereby on blowing of said fusible element said retracting means moves through a predetermined distance without moving said rodlike terminal member and acquires kinetic energy to assist in overcoming the friction between said rodlike terminal member and said contact means in initiating the movement of the former away from said one terminal member.

21. In circuit interrupting apparatus, in combination, a body of arc-extinguishing material having a bore, a pair of relatively movable terminal members between which an arc may be formed, one of said terminal members being located adjacent one end of said bore and the other being rodlike in character and movable through said bore, a reservoir for holding material which when released is in the form of an arc-extinguishing fluid, said reservoir being located adjacent the end of said rodlike terminal member away from the arcing end thereof, means for retracting said rodlike terminal member away from said one terminal member, contact means frictionally engaging said rodlike terminal member and providing a current path thereto prior to movement thereof by said retracting means, means responsive to the initial movement of said retracting means for releasing said fluid into said bore and the arc space for assisting in extinguishing the arc before and while said rodlike terminal member is withdrawn into said bore and for blowing out of said bore products of the arc deposited on the surface thereof and likely to facilitate restriking, and means for controlling the movement of said rodlike terminal member away from said one terminal member including a lost motion connection between said retracting means and said rodlike terminal member whereby on operation of said controlling means said retracting means moves through a predetermined distance without moving said rodlike terminal member, releases said fluid and acquires kinetic energy to assist in overcoming the friction between said rodlike terminal member and said contact means in initiating the movement of the former away from said one terminal member.

22. In circuit interrupting apparatus, in combination, a body of arc-extinguishing material having a bore, a pair of relatively movable terminal members between which an arc may be formed, one of said terminal members being located adjacent one end of said bore and the other being rodlike in character and movable through said bore, a reservoir for holding material which when released is in the form of an arc-extinguishing fluid, said reservoir being located adjacent the end of said rodlike terminal member away from the arcing end thereof, means for retracting said rodlike terminal member away from said one terminal member, contact means frictionally engaging said rodlike terminal member and providing a curent path thereto prior to movement thereof by said retracting means, means responsive to the initial movement of said retracting means for releasing said fluid into said bore and the arc space for assisting in extinguishing the arc before and while said rodlike terminal member is withdrawn into said bore and for blowing out of said bore products of the arc deposited on the surface thereof and likely to facilitate restriking, and means for controlling the movement of said rodlike terminal member away from said one terminal member including a lost motion connection between said retracting means and said rodlike terminal member and a fusible element whereby on blowing of said fusible element said retracting means moves through a predetermined distance without moving said rodlike terminal member, releases said fluid and acquires kinetic energy to assist in overcoming the friction between said rodlike terminal member and said contact means in initiat-

ing the movement of the former away from said one terminal member.

23. In circuit interrupting apparatus, in combination, a body of arc-extinguishing material having a bore, a pair of relatively movable terminal members between which an arc may be formed, one of said terminal members being located adjacent one end of said bore and the other being tubular in character and movable through said bore, a reservoir for holding material which when released is in the form of an arc-extinguishing fluid, said reservoir being located adjacent the end of said tubular terminal member away from the arcing end thereof, means for retracting said tubular terminal member, contact means frictionally engaging said tubular terminal member and providing a current path thereto prior to movement thereof by said retracting means, means responsive to the initial movement of said retracting means for releasing said fluid to flow through said tubular terminal member into said bore and the arc space during the initial movement of said retracting means, and means for controlling the movement of said tubular terminal member away from said one terminal including a lost motion connection between said retracting means and said rodlike terminal, and a fusible tension element interconnecting said retracting means and said one terminal member whereby on blowing of said fusible tension element said retracting means moves through a predetermined distance without moving said tubular terminal member, releases said fluid to flow through said tubular terminal member, and acquires kinetic energy to assist in overcoming the friction between said tubular terminal member and said contact means in initiating the movement of the former away from said one terminal member.

CHARLES H. BAKER.

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