Sept. 10, 1968 C. W. UPTON, JR., ET AL 3,401,247

CIRCUIT INTERRUPTER OF THE DUAL BORE TYPE

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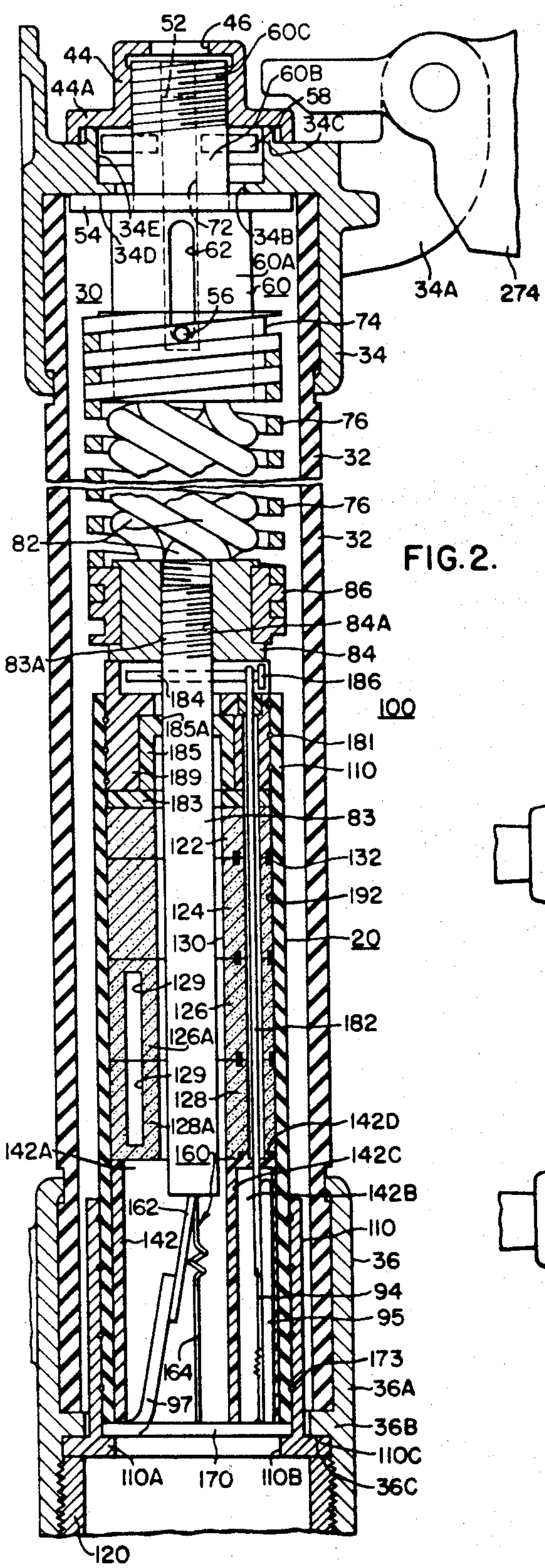


FIG. 2.

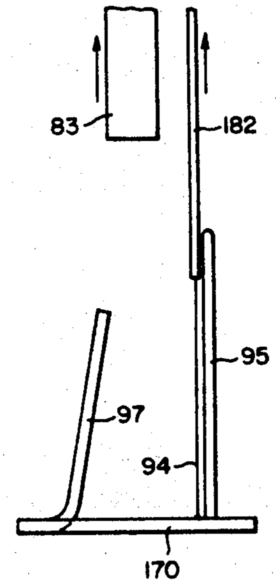
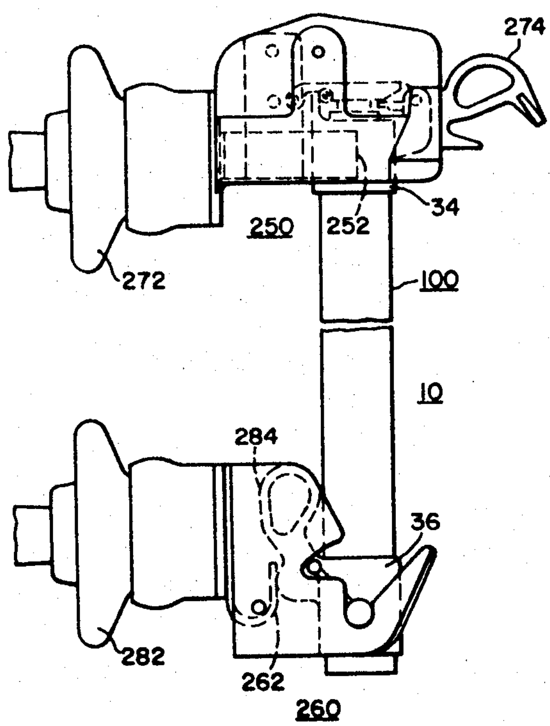


FIG. 3.

FIG. 1.



CIRCUIT INTERRUPTER OF THE DUAL BORE TYPE

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FIG.8.

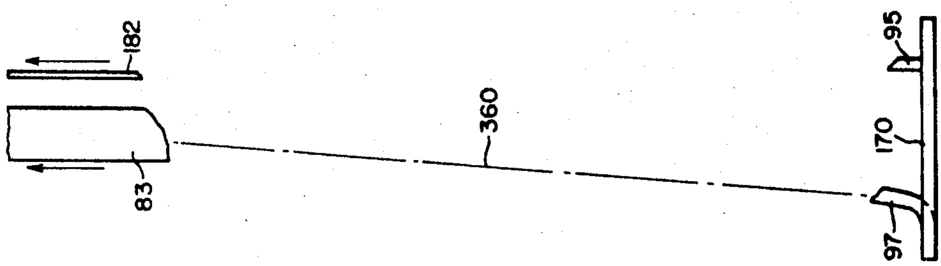


FIG.7.

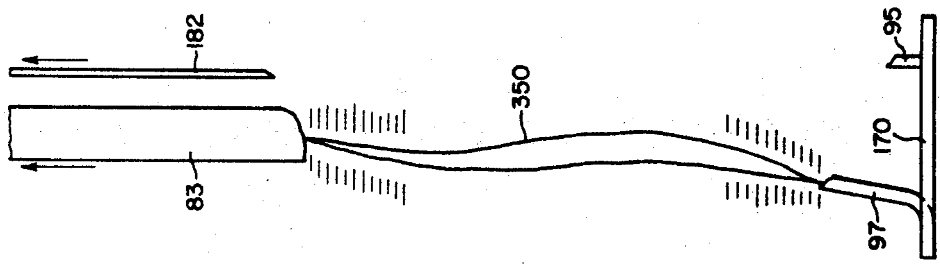


FIG.6.

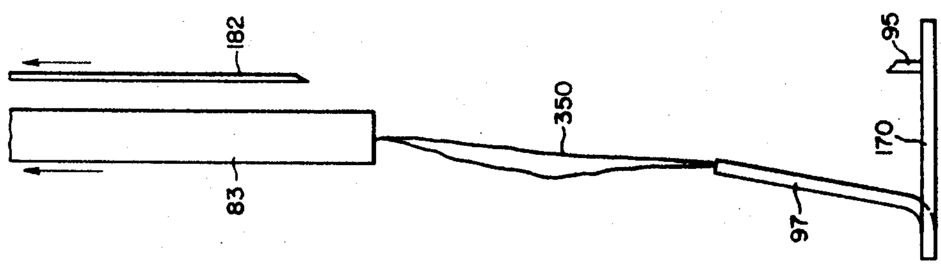


FIG.5.

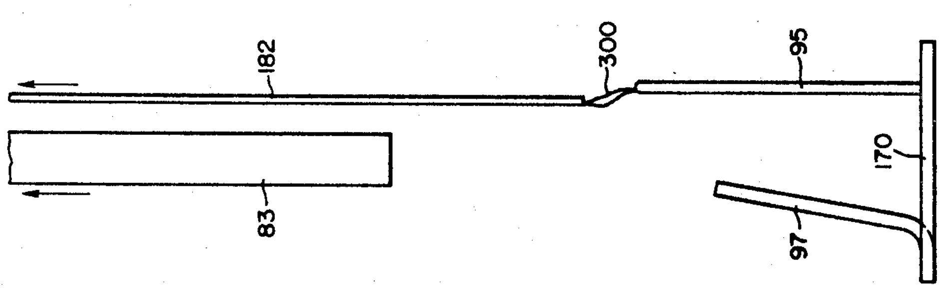
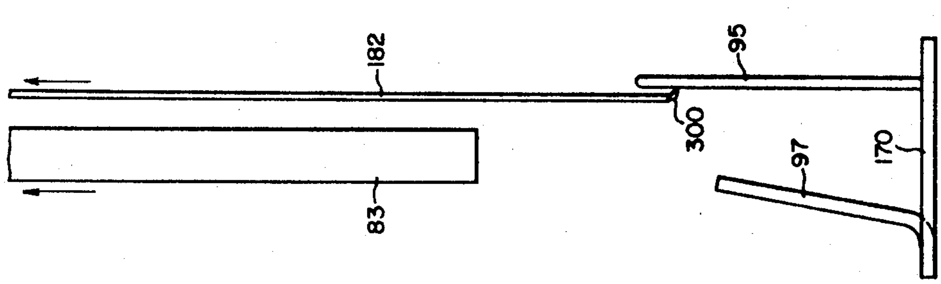


FIG.4.



United States Patent Office

3,401,247
Patented Sept. 10, 1968

3,401,247

CIRCUIT INTERRUPTER OF THE DUAL BORE TYPE

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Filed Aug. 24, 1967, Ser. No. 663,127
8 Claims. (Cl. 337—221)

ABSTRACT OF THE DISCLOSURE

A high voltage circuit interrupter construction in which a body of arc extinguishing material is disposed inside a tubular insulating casing and includes a main bore and a smaller auxiliary bore. A larger conducting rod is disposed to extend through the main bore and a smaller auxiliary conductor is disposed to extend through the auxiliary bore and is connected at one end to the larger conducting rod for axial movement therewith. A main fusible means is connected in series with the larger conducting rod between the rod and a terminal means at one end of the casing. In order to insure initiation of arcing during any interrupting operation in the auxiliary bore, a helically coiled conductor is electrically connected between the other end of the auxiliary conductor and the terminal means with an insulated arcing terminal being connected to the terminal means to project axially away from the terminal means and to overlap the end of the auxiliary conductor to which the helically coiled conductor is connected.

Background of invention

In the application of circuit interrupters, such as power fuses of the dual-bore type, at higher voltages, a problem arises in insuring that arcing during an interrupting operation is always initiated in the smaller auxiliary bore of the interrupter and that any arcing which results during the interrupting operation remains in the smaller auxiliary bore to be finally interrupted for relatively smaller fault currents which the interrupter is incapable of interrupting in the larger main bore. In order for a circuit interrupter of the type described to successfully interrupt relatively low fault currents, such as 1000 amperes or less, it is essential that the conductor in the main bore of the interrupter be permitted to move a sufficient distance to establish an adequate insulating gap and corresponding dielectric strength in the main bore prior to the time that such a relatively low fault current is finally interrupted in the auxiliary bore of the interrupter. Otherwise, the potential difference to which the main bore is subjected upon the interruption of a relatively low fault current in the auxiliary bore of an interrupter of the type described will be sufficient to cause a restrike of the arc in the main bore in which the interrupter is not capable of interrupting relatively low fault currents of the type described. Among the reasons for the problem described found in certain known power fuse structures is the elongation of certain conducting parts associated with the main bore of the interrupter which may permit relative travel of the conductors in the main and auxiliary bores such as to produce a greater insulating gap in the auxiliary bore than in the main bore of the interrupter for relatively low fault currents. Another reason for the problem described has been found to be the premature displacement or "blow out" of the relatively stationary auxiliary contact provided in the auxiliary bore of an interrupter of the type described. It is therefore desirable to provide an improved high voltage circuit interrupter or power fuse construction of the dual-bore type which overcomes the problem described and which insures successful interruption of relatively low fault currents in the smaller auxiliary bore of the interrupter.

Summary of invention

It is an object of this invention to provide a new and improved high voltage circuit interrupter construction.

Another object of this invention is to provide an improved means for insuring that arcing is always initiated in the smaller bore of a circuit interrupter having parallel large and small bores.

A further object of this invention is to provide an improved power fuse construction of the dual-bore type including means for insuring that relatively smaller fault currents will be interrupted in the smaller bore of the fuse.

A more specific object of this invention is to provide an improved auxiliary current path in a power fuse of the dual-bore type.

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

For a fully understanding of the nature and objects of the invention, reference should be had to the following detailed description, taken in conjunction with the accompanying drawings in which:

FIGURE 1 is a side elevational view of a high voltage power fuse structure which embodies the principles of the present invention and which is shown in the normally closed operating condition;

FIG. 2 is an enlarged, longitudinal, sectional view of a fuse unit which forms part of the fuse structure shown in FIG. 1 with portions of the end fittings of the fuse unit omitted;

FIGS. 3, 4 and 5 are diagrammatic views illustrating different stages in the operation of the fuse unit shown in FIG. 2 while interrupting relatively low fault currents; and

FIGS. 6, 7 and 8 are diagrammatic views illustrating different stages in the operation of the fuse unit shown in FIG. 2 while interrupting relatively high fault currents.

Referring now to the drawings, and FIG. 1 in particular, the structure shown comprises a power fuse structure of the high voltage, drop-out type, the general arrangement of which is set forth more fully in copending application Ser. No. 663,020 filed Aug. 24, 1967, by R. E. Frink and C. T. Walker, which is assigned to the same assignee as the present application.

As illustrated in FIG. 1, the fuse structure **10** includes a base (not shown) formed of sheet metal and a pair of outwardly extending insulator supports **272** and **282**. The upper insulator support **272** fixedly supports in position a latching assembly **250**, which includes a break contact **252**, as described in greater detail in the copending application just mentioned. A lower insulator support **282** supports a hinge assembly **260** which pivotally supports a fuse unit **100** and which includes a hinge contact **262** as described in the copending application just mentioned. As illustrated in FIG. 1, the fuse unit **100** serves to electrically bridge the break contact **252** and the hinge contact **262** so that electric current will normally pass therebetween by way of terminal pads (not shown) to which an external electrical circuit may be connected.

The fuse unit **100** includes a generally tubular fuse holder **32** which is formed from a suitable weatherproof, electrically insulating material, such as a filament wound glass epoxy material or the like, and a pair of upper and lower end fittings or terminals **34** and **36**, respectively, which are disposed at the opposite ends of the holder **32** and which are formed from an electrically conducting material. The upper and lower end fittings **34** and **36**, respectively, are securely fastened to the opposite ends of the associated holder or tube **32** by suitable means, such as cement, and a plurality of pins which pass transversely through both the end fittings and the associated holder **32**. As illustrated, the fuse unit **100** also includes a hook eye **274** which is pivotally mounted on a laterally projecting portion **34A** of the upper end fitting **34** and which may be utilized for effecting opening and closing movements of the fuse unit **100** by means of a conventional hook-stick. The lower end fitting **36** includes a hinge lifting eye **284** which may be formed integrally with the lower end fitting **36** and which may be employed in conjunction with a conventional hook-stick to effect physical removal of the fuse unit **100** from the hinge assembly **260** for replacement of the fuse unit **100**. The lower end fitting or terminal **36** also includes an inwardly projecting flange portion **36B** against which the lower end of the holder **32** bears, as shown in FIG. 2.

The fuse unit **100** further includes a renewable or refillable unit **20** which is mounted within the holder structure that includes the outer tube **32** and the upper and lower end fittings or terminals **34** and **36**, respectively. The renewable unit **100** includes its own supporting tube **108** which is formed from a suitable electrically insulating material having sufficient strength to withstand the internal gas pressures and intense heat which result during an interrupting operation of the fuse unit **100**, such as a filament wound glass epoxy material. A body of gas evolving material, such as boric acid, which may include a plurality of generally annular blocks **122, 124, 126** and **128**, is disposed inside the tube **108** and spaced from the ends thereof. Each of the blocks **122, 124, 126** and **128** includes a relatively larger central opening and a relatively smaller opening at one side thereof, both of which extend axially through the individual blocks. When the blocks **122, 124, 126** and **128** are axially stacked in end-to-end relation as shown in FIG. 2, with the respective larger and smaller openings thereof substantially aligned, a main bore **130** is formed through the body of gas evolving material which includes said blocks and a relatively smaller auxiliary bore **192** is formed through the body of gas evolving material.

In order to prevent the travel of ionized gases between the main bore **130** and the auxiliary bore **192** during an interrupting operation of the fuse unit **100** as described in greater detail in copending application Ser. No. 663,-018, filed Aug. 24, 1967, by C. W. Upton, Jr. and J. A. Sensue, which is assigned to the same assignee as the present application, the meeting surfaces of the blocks **122, 124, 126** and **128** are structurally joined to one another around the relatively smaller openings of said blocks which form the auxiliary bore **192** by a sealing and bonding material having a relatively high dielectric strength, such as an epoxy resin. More specifically, as explained in the copending application just mentioned, the meeting surfaces of the blocks **122, 124, 126** and **128**, each includes a groove or recess which extends substantially around and is spaced from the relatively smaller opening in each of said blocks and forms with the recess in the adjacent block a combined passageway which is substantially filled with the sealing and bonding material, as indicated at **132** in FIG. 2. It is to be noted that the manner in which the blocks **122, 124, 126** and **128** are bonded to one another around the auxiliary bore **192** substantially prevents the entrance of the sealing and bonding material employed into either the auxiliary bore **192** or into the main bore **130**.

In order to limit the gas pressures which result during an interrupting operation of the fuse unit **100** inside the tube **108** to a value within the rupture strength of the tube **108**, as disclosed in greater detail in copending application Ser. No. 663,126, filed Aug. 24, 1967, by C. C. Patterson, which is assigned to the same assignee as the present application, each of the blocks **126** and **128** includes a generally C-shaped recess, as indicated at **129**, which entends axially from one end of each and said blocks to a point which is adjacent to and axially spaced from the other end of the respective blocks, with each of the recesses terminating peripherally short of the portion of said blocks which include the relatively smaller openings which form part of the auxiliary bore **192**. Each of the blocks **126** and **128** therefore includes around a major portion of its inner periphery an integral frangible inner wall, as indicated at **126A** and **128A**, respectively, which is arranged to disintegrate when the fuse unit **100** is called upon to interrupt relatively large currents and when intense heat results within the main bore **130** and the gas pressure within the main bore **130** exceeds a predetermined value. During such an interrupting operation, the size of the main bore through the blocks **126** and **128** is effectively increased by the disintegration of the inner walls **126** and **128A** of the blocks **126** and **128**, respectively, to thereby increase the size of the gas passageway and decrease or limit the gas pressure which would otherwise result.

In order to retain the blocks **122, 124, 126** and **128** in assembled relationship with the associated tube **108**, as shown in FIG. 2, the outer surfaces of said blocks may be coated with a suitable cement, such as an epoxy bonding material, prior to assembly of the blocks inside the tube **108**. In addition, a generally annular retaining member or plug **189** may be disposed at the upper end of the blocks **122, 124, 126** and **128** with the major portion of the retaining member **189** extending axially inside the tube **108**. The retaining member **189** may be formed or molded from a suitable, electrically insulating material having sufficient strength to assist in retaining the blocks **122, 124, 126** and **128** in assembled relationship with the tube **108** during an interrupting operation of the fuse unit **100**, such as a glass polyester material. A washer **183** formed from similar material may be disposed between the retaining member **189** and the block **122** and may be employed during the preassembly and bonding of the blocks **122, 124, 126** and **128** together prior to the assembly of said blocks inside the tube **110**. It is to be noted that the retaining member **189**, as well as the washer **183**, includes a relatively larger central opening which forms an extension of the main bore **130** and a relatively smaller opening which forms an extension of the auxiliary bore **192**.

In order to assist in retaining the member **189** in assembled relation with the associated tube **108** during an interrupting operation of the fuse unit **100**, the outer surface of the retaining member **189** and the inner surface of the tube **108** at the upper end of the tube **108** include adjacent helical grooves which together form a passageway in which a helical wire **181** is disposed to firmly secure the retaining member **189** in assembled relation with the tube **108**. The retaining member **189** may be assembled with the upper end of the tube **108** by first assembling the helical wire **181** in the helical groove around the outer surface of the retaining member **189** and then screwing the retaining member **189** into the upper end of the tube **108** to the final position shown in FIG. 2. It is to be noted that the outer surface of the retaining member **189** may also be coated with a suitable cement, such as an epoxy bonding material, to additionally secure the retaining member **189** to the tube **108**.

In order to substantially prevent the escape of ionized gases from the upper end of the renewable unit **20** around the elongated conducting member **83** which extends through the main bore **130**, a generally tubular member **185** is disposed in concentric or nested relation with the retaining member **189**, as shown in FIG. 2, and is preferably formed from an electrically insulating material having a relatively low coefficient of friction, such as polytetrafluoroethylene which is sold under the trademark "Teflon." A shoulder portion **185A** is provided at the upper end of the tubular member **185** and includes an opening of reduced cross-section or size through which the conducting member **83** passes and which forms a substantially gas-tight seal with the conducting member **83** during an interrupting operation of the fuse unit **100** when the conducting member **83** is actuated to move axially. The tubular member **185** also acts as a bearing to guide the axial movement of the conducting member **83**. In order to prevent the tubular member **185** from being blown out of the upper end of the tube **108** during interrupting operation of the fuse unit **100**, the retaining member **189** includes an inner shoulder portion against which the upper end of the tubular member **185** bears, as shown in FIG. 2. The escape of ionized gases from the upper end of the renewable unit **20** from the auxiliary bore **192** may be adequately prevented by reducing the size of the relatively smaller opening through the retaining member **189** in which the auxiliary conductor **182** is disposed so that the cross-section of the auxiliary conductor **182** substantially fills the relatively smaller opening through the retaining member **189**.

In order to further assist in retaining the blocks **122**, **124**, **126** and **128** in assembled relationship with the tube **108** during an interrupting operation of the fuse unit **100**, a generally tubular or annular retaining member **142** is disposed inside the tube **108** at the lower end of the blocks **122** through **128**, as shown in FIG. 2, and is formed or molded from an electrically insulating material having sufficient strength to assist in retaining the blocks **122** through **128** inside the tube **108** during such an interrupting operation such as a glass polyester material. The outer surface of the retaining member **142** is preferably coated with a suitable cement, such as an epoxy bonding material, prior to the assembly of the retaining member **142** inside the tube **108** which bonds the retaining member **142** to the inside of tube **108**. The retaining member **142** includes a relatively larger opening which extends axially therethrough, as indicated at **142A**, into which the lower end of the main bore **130** opens and which may serve as an exhaust passageway for high pressure gases which result during the operation of the fuse unit **100**. The opening **142A** also serves as a chamber in which the fusible means **160** is disposed. The retaining member **142** also includes a relatively smaller opening **142B**, which extends axially therethrough, into which the lower end of the auxiliary bore **192** opens and into which the lower end of the auxiliary conductor **182** projects. The insulating wall or partition **142C** around the relatively smaller opening **142B** through the retaining member **142** assists in preventing certain arc products which may result during operation of the fuse unit **100** in the relatively smaller opening **142B** of the retaining member **142** from being deflected into the relatively larger opening **142A** of the retaining member **142** and impinging on parts of the fusible means **160**. The retaining member **142** also includes an upwardly projecting tubular portion **142D** adjacent to the relatively smaller opening **142B** through the retaining member **142** with the projecting portion **142B** being joined to the adjacent block **128** around a recess in the clock **128** which is adapted to receive the projecting portion **142D** by a flexible bonding material, such as silicone rubber. This joint between the retaining member **142** and the block **128** around the auxiliary bore **192** serves to prevent the travel of ionized gases between the auxiliary bore **192** and the main bore **130** and between the auxiliary bore **192** and the relatively large opening **142A** through the retaining member **142** during an interrupting operation of the fuse unit **100**.

The elongated conducting member or rod **83** of the renewable unit **20** is normally disposed, as shown in FIG. 2, to extend through the main bore **130** with the upper end of the conducting rod **83** projecting axially beyond the upper end of the tube **108** and with the upper portion of the conducting rod **83** being externally threaded, as indicated at **83A**. The conducting rod **83** is normally held in the position shown in FIG. 2 by a connection through the fusible means **160** to the generally annular or ring-shaped stationary conducting member or contact

100 which is disposed at the lower end of the casing **108** with the lower ends of the casing **108** and the retaining member **142** bearing against the top of the conducting member **100** around the central opening of the conducting member **100**.

More specifically, the fusible means **160** comprises a strain element **162** and a fusible element or link **164**. The upper end of the strain element **162** is secured by suitable means, such as brazing, to the lower end of the conducting rod **83**, while the other end of the strain element **162** is secured by suitable means, such as brazing, to the connecting conductor or terminal **97** which is of the flat strip type. The connecting conductor **97** is secured in turn to the lower contact **100** by suitable means, such as brazing. Similarly, the upper end of the fusible element or link **164** is secured to the lower end of the conducting rod **83** by suitable means, such as brazing, while the lower end of the fusible element or link is secured to the lower contact **100** by suitable means, such as brazing. It is to be noted that the strain element **162** and fusible element **164** are electrically connected in parallel between the lower end of the conducting rod **83** and the lower contact **100** of the renewable unit **20**.

Similarly, the auxiliary conductor **182** which is a relatively smaller cross-section or size than the conducting rod **83** normally extends through the auxiliary bore **192** with the upper end of the auxiliary conductor **182** extending axially beyond the upper end of the auxiliary bore **192** and being both mechanically and electrically connected to the upper portion of the conducting rod **83** by a transversely extending spring pin **184** which is disposed in a transversely extending recess provided at the upper end of the retaining member **189** to prevent rotation of the conducting rod **83** after assembly in the renewable unit **20**. The upper end of the auxiliary conductor **182** may be formed as a loop which is assembled over the conducting spring pin **184** and retained thereon by the head **186** of the spring pin **184**. The lower end of the auxiliary conductor **182** extends or projects into the relatively smaller opening **142B** of the retaining member **142** and is electrically connected through a helical conducting wire of reduced cross-section, as indicated at **94**, to the lower contact **100** of the renewable unit **20**. The upper end of the helical wire **94** which is disposed inside the relatively smaller opening **142B** of the retaining member **142** is secured to the lower end of the auxiliary conductor **182** by suitable means, such as brazing, and the lower end of the helical wire **94** is secured to the lower contact **100** at the inner periphery thereof by suitable means, such as crimping or brazing.

The lower contact or conducting member **100** also includes an elongated arcing terminal **95** which projects upwardly from the lower contact **100** into the relatively smaller opening **142B** of the retaining member **142** to axially overlap the lower end of the auxiliary conducting member **182** with the lower portion of the arcing terminal **95** being disposed adjacent to and generally parallel to the axis of the helical wire **94**. The arcing terminal **95** is electrically insulated along its length by a coating or film of electrical insulation, such as an insulating enamel or heat shrinkable tubing, provided on the arcing terminal **95** to prevent the electrical shorting out of the helical wire **94**. The arcing terminal **95** which is formed from an electrically conducting material may be structurally secured to the lower contact **100** at the inner periphery thereof by suitable means, such as brazing, or may be formed integrally therewith in a particular application. It is to be noted that the auxiliary current path which extends from the upper portion of the conducting rod **83** through the cross-pin **184**, the auxiliary conductor **182** and the helical wire **94** to the lower contact **100** is also electrically connected in parallel with the conducting paths which include the strain element **162** and the fusible element **164**.

In order to retain the lower contact **100**, as well as the other parts of the renewable unit **20**, in assembled relationship with the tube **108**, particularly during an interrupting operation of the fuse unit **100**, a generally tubular external terminal member or ferrule **110** is disposed to telescope or extend axially over the lower end of the tube **108**. In order to firmly secure the external terminal member or end cap **110** to the lower end of the tube **108**, the internal surface of the external terminal member **110** and the external surface of the adjacent portion of the tube **108** include aligned helical grooves which, when the parts are assembled, form a generally helical passageway in which a helical wire **173** is disposed. In the assembly of the external terminal member **110** on the lower end of the tube **108**, the helical wire **173** may be first assembled in the helical groove on the lower end of the tube **108** and the external terminal member **110** may be then screwed onto the lower end of the tube **108** until the parts reach their final positions, as shown in FIG. 2.

In order to assist in retaining the stationary lower contact **100** in assembled relationship with the other parts of the renewable unit **20**, the external terminal member **110** includes an inwardly projecting flange portion **110A** around a central opening, as indicated at **110B**, with the inwardly projecting flange portion **110A** bearing against the bottom of the lower contact **100** around the periphery thereof to prevent the displacement or "blow out" of the lower contact **100** during an interrupting operation of the fuse unit **100**. In order to form a conducting path which extends between the lower end fitting **36** and the lower contact **100** of the renewable unit **20**, the external terminal member **110** also includes an external flange portion, as indicated at **110C**, which bears against the inwardly projecting flange portion **36B** of the lower end fitting **36**. The conducting path thus formed extends from the lower contact **100** through the inwardly projecting flange portion **110A** of the external terminal **110** and through the external projecting flange portion **110C** to the inwardly projecting flange portion **36B** of the lower end fitting **36**. The area of the current transfer path between the external terminal member **110** of the renewable unit **20** and lower end fitting **36** may also be augmented by the contact ring **120** which may be formed of electrically conducting material and which is disposed to threadedly engage the internally threaded opening at the lower end of the end fitting **36** and bear against the external terminal member **110** of the renewable unit **20**, as shown in FIG. 2.

In order to actuate the axial movement of the conducting rod **83**, as well as that of the auxiliary conductor **182**, during an interrupting operation of the fuse unit **100** and to electrically connect the renewable or refillable unit **20** just described to the upper end fitting or terminal **34**, previously mentioned, a spring and cable assembly **30** is disposed inside the outer holder or tube **32** between the renewable unit **20** and the upper end fitting **34**. The spring and cable assembly **30** includes at its lower end a generally tubular conducting member or socket **84** having an internally threaded central opening, as indicated at **84A**, to receive the upper threaded end **83A** of the conducting rod **83**. A lower spring seat member **86** is fixedly mounted on the socket **84** for movement therewith by assembling the spring seat **86** over the outer periphery of the socket **84** with the lower end of the spring seat **86** bearing against a shoulder provided on the outer periphery of the socket **84** and with the upper end of the spring seat **86** being engaged by a plurality of portions of the socket **84** at the upper end of the socket **84** which serve to stake or secure the spring seat **86** on the socket **84**. The spring and cable assembly **30** also includes an upper spring seat **74** which is slidably disposed over the lower portion **60A** of a generally cylindrical conducting member **60** whose integral upper portion **60B** extends axially through an opening **34B** in the upper end fitting **34** and is externally threaded at the upper end thereof, as indicated at **60C**. As illustrated, the generally cylindrical conducting member **60** secured to the upper end fitting **34** by an internally threaded end cap **44** which may be screwed down on the upper threaded portion **60C** of the conducting member **60** until the flange portion **44A** of the end cap **44** bears against the upper end fitting **34** around a flange or shoulder portion, as indicated at **34C** in FIG. 2. A helical tension spring **76** is secured at its upper end to the external helically threaded portion of the upper spring seat **74**, while the lower end of the spring **76** is secured to the externally helically threaded portion of the lower spring seat **86** to bias the conducting rod **83**, as well as the auxiliary conductor **182**, in a generally upward direction, as viewed in FIG. 2, away from the lower contact **100**. It is important to note that the turns of the spring **76** are generally rectangular or square in cross-section to substantially prevent any overlapping of the turns of the spring **76** and the consequent damage to the spring that might otherwise result during an interrupting operation of the fuse unit **100**, as explained in greater detail in copending application Ser. No. 663,021, filed Aug. 24, 1967, by C. C. Patterson, which is assigned to the same assignee as the present application.

In order to electrically connect the renewable unit **20** and more specifically the conducting rod **83** to the upper end fitting **34** both prior to and during an interrupting operation of the fuse unit **100**, a plurality of helically coiled flexible cables or conductors **82** are electrically and structurally connected at the bottom end thereof to the conducing socket **84** into separate openings (not shown) provided in the socket **84** by suitable means, such as brazing or by staking, and at the upper end thereof are secured to the conducting member **60** in separate openings provided in the conducting member **60** by suitable means, such as brazing and staking. In order to increase the effective current transfer area between the conducting member **60** and the upper end fitting **34**, a washer **54** formed of electrically conducting material may be disposed between the shoulder which is formed at the inner section of the upper and lower portions **60A** and **60B**, respectively, of the conducting member **60** and the shoulder which is formed inside the upper end fiitting **34**, as indicated at **34D**, around the central opening **34B**.

In order to facilitate the assembly of the renewable unit **20** and the associated spring and cable assembly **30** inside the outer holder **32**, as will be explained hereinafter, a pair of spring pins **58** may be disposed in associated openings provided at the opposite sides of the upper portion **60B** of the conducting member **60** to be positioned finally within an enlarged central opening or recess **34E** in the upper end fitting **34**, as shown in FIG. 2.

In order to actuate the release of the latching assembly **250** shown in FIG. 1 following an interrupting operation by the fuse unit **100** as disclosed and claimed in copending application Ser. No. 663,021, filed Aug. 24, 1967, by C. C. Patterson, which is assigned to the same assignee as the present application, a tripping rod or member **52** is slidably disposed inside a central opening or passageway **72** which is provided in the conducting member **60** with the upper end of the tripping rod **52** being normally positioned below the top of the end cap **44**, as shown in FIG. 2. The lower end of the tripping rod **52** is fixedly coupled to the upper spring seat **74** for axial movement therewith by the cross pin **56** which passes laterally through aligned transverse openings in the tripping rod **52** and the upper spring seat **74** and through a pair of elongated slots **62** provided on the opposite sides of the conducting member **60** with the cross pin **56** being normally positioned at the lower end of each of the elongated slots **62**, as shown in FIG. 2. In order to permit the axial movement of the tripping rod **52** upwardly through the end cap **44** following an interrupting operation of the fuse unit **100**, the top of the end cap **44** includes a central opening **46** through which the tripping rod **52** may pass upwardly to actuate the release of the latching assembly **250** shown in FIG. 1. When the latching assembly **250** is released by the movement of the tripping rod **52**, the upper end of the fuse unit **100** will be actuated to rotate in a clockwise direction as viewed in FIG. 1 about the lower hinge assembly **260** to thereby provide an electrically insulating gap between the upper break contact **252** and the lower stationary hinge contact **262** by such drop-out action.

In order to assemble the renewable unit **20** and the associated spring and cable assembly **30** into the outer holder **32**, the threaded end of the conducting rod **83** is first screwed into the socket **84** at the lower end of the spring and cable assembly **30**. A refill fusing tool (not shown) is then screwed into the internally threaded central opening or passageway **72** at the other end of the spring and cable assembly **30**. The spring and cable assembly **30** is then inserted into the outer holder **32** with the upper end of the spring and cable assembly **30** being inserted first into the lower end of the outer holder **32**, as viewed in FIG. 2, until the refill tool (not shown) passes through the central opening **34B** of the upper end fitting **34**. By use of the refill tool, the spring **76** is stretched and placed in tension until the cross pins **38** mounted at the sides of the conducting member **60** are drawn upwardly through a pair of radial slots (not shown) provided in the upper end fitting **34** around the central opening **34B**. The upper conducting member **60** and the spring and cable assembly **30** are then rotated until the pins **58** rest on the shoulder provided at the bottom of the enlarged opening **34E** in the upper end fitting **34**. The end cap **44** may then be screwed down on the upper threaded portion **60C** of the conducting member **60** to further stretch the spring **76** to the final position shown in FIG. 2 in which the cross pins **58** are drawn upwardly away from the shoulder in the upper end fitting **34** at the bottom of the enlarged opening **34E**. It is to be noted that when the spring and cable assembly **30** and the renewable unit **20** are assembled inside the outer holder **32** as just described, the cross pin **56** which couples the upper spring seat **74** to the tripping rod **52** is disposed at the bottom of each of the elongated axially extending slots **62** at the opposite sides of the conducting member **60** to permit limited upward travel of the upper spring seat **74** along with the cross pin **56** and the tripping rod **52** to a final position of the tripping rod **52** in which the tripping rod **52** projects beyond the end cap axially to release the latching assembly **250**, as previously mentioned. The washer **54** acts as a stop surface against which the upper end of the spring seat **74** bears to limit the upward travel of the tripping rod **52**, the cross pin **56** and the spring seat **74**.

In considering the operation of the fuse unit **100** it is to be noted first that the current paths which include, respectively, the strain element **162**, the fusible element **164** and the helical wire **94**, which is connected in series with the auxiliary conductor **182**, are all electrically connected in parallel between the upper end of the conducting rod **83** and the lower contact **100** at the lower end of the renewable unit **20**. The resistance of the current path which includes the fusible element **164** and which is calibrated to have predetermined time-current characteristics is arranged to be relatively much less than the resistance of either the path which includes the strain element **162** or the path which includes the helical wire **94** so that normally most of the current which flows through the fuse unit **100** is carried by the fusible element **164**. Although the resistance of the current path which includes the strain element **162** is relatively greater than the resistance of the path which includes the fusible member **164**, the resistance of the path which includes the strain element **162** is relatively less than that of the path which includes the helical wire **94** so that when the fusible element **164** melts or blows, most of the current which was formerly carried by the fusible element **164** will be transferred to the strain element **162**. In other words, when the current which is flowing through the fuse unit **100** increases to a value which is of sufficient magnitude and duration to melt or blow the fusible element **164**, most of the current which is flowing through the fuse unit **100** then transfers from the fusible element **164** to the strain element **162**. When the current which is transferred to the strain element **162** after the melting of the fusible element **164** is sufficient to melt or blow the strain element **162**, the current which was previously carried by the strain element **162** is finally transferred to the current path through the auxiliary bore **192** which includes the auxiliary conductor **192** and the helical wire **94**. When the strain element **162** melts or blows, the conducting rod **83** is no longer restrained from upward movement under the influence of the biasing spring **76** and the conducting rod **83** and the auxiliary conductor **182** will start to move upwardly under the influence of the spring **76** to thereby stretch the helical wire **94** which is electrically connected to the bottom of the auxiliary conductor or rod **192**. It is to be noted that the stretching of the helical wire **94** permits limited travel of both the conducting rod **83** and the auxiliary conductor **182**, while maintaining a continuous electrical circuit through the auxiliary bore **192** and that as long as the current path which includes the auxiliary conductor **182** and the helical wire **94** is intact, no arcing will take place in either the main bore **130** or in the auxiliary bore **192**. In other words, the stretching of the helical wire **94** during the initial movement of the conducting rod **83** and the auxiliary conductor **182** following the melting or blowing of the fusible element **164** and the strain element **162** will permit the formation of an insulating gap in the main bore **130**, while initially delaying the formation of an insulating gap in the auxiliary bore **192**.

After the strain element **162** melts or blows as just described, and the arcing or conducting rod **83** and the auxiliary conductor **182** begin to move upwardly to thereby stretch the helical wire **94**, the helical wire **94** will either fracture mechanically when stretched to its limit, as shown in FIG. 3, or the current transferred to the current path which includes the auxiliary conductor **182** and the helical wire **94** will be sufficient to melt or blow the helical wire **94** which is of reduced cross-section compared with that of the auxiliary conductor or rod **182**. After the helical wire **94** is melted or otherwise broken, an arc will be initiated between the retreating end of either the broken helical wire **94** or the auxiliary conductor **182** and the arcing terminal **95** which axially overlaps the lower end of the auxiliary conductor **182** as shown in FIG. 4 to thereby burn through the electrical insulation on the arcing terminal **95**.

It is to be noted that the smaller cross-section or diameter of the helical wire **94** compared with that of the auxiliary conductor **182** controls the location at which arcing is always initiated in the auxiliary current path of the fuse unit **100** at the lower end of the renewable unit **20** in the relatively smaller opening **142B** of the retaining member **142**, as shown diagrammatically in FIG. 4. In addition to the initial delay in the formation of an insulating gap in the auxiliary current path due to the presence of the helical wire **94** as previously explained, the formation of a significant insulating gap in the auxiliary current path of the fuse unit **100** is further delayed by the overlapping of the auxiliary conductor **182** by the arcing terminal **95** until the retreating free end of the helical wire **94** or the auxiliary conductor **182** passes the upper end of the arcing terminal **95** whose insulation will have burned through by this time, as shown in FIG. 5, which indicates the arc between the free end of the auxiliary conductor **182** and the upper end of the arcing terminal **95** at **300**. It is important to note that the insulating gap in the main bore **130** between the separated ends of the fusible means **160** or between the conducting rod **83** and the stationary conducting parts of the lower end of the renewal unit **20**, as shown diagrammatically in FIGS. 3–5, will increase at a faster rate than the formation of an insulating gap in the auxiliary current path just described due to both the delay in the formation of an arc in the auxiliary current path because of the presence of the helical wire **94**, as previously described, and due to the overlapping of the auxiliary conductor **182** by the arcing terminal **95** at the lower end of the auxiliary conductor **182**. It is also important to note that when any abnormal current flows in the fuse unit **100** which is sufficient to melt or blow the fusible element **164** and the strain element **182** and the melting or breaking of the helical wire **94** results in the auxiliary current path, any arcing which takes place in the fuse unit will always take place initially in the auxiliary bore or auxiliary current path, as just explained. The relatively larger cross-section or size of the auxiliary conductor **182** compared with the helical wire **94** and the relatively larger cross-section or size of the arcing terminal or contact **95** provides resistance to relatively fast burn-back of the auxiliary current path when arcing is initiated as just described. In addition, the relatively rigid stationary arcing contact or terminal **95** along with the lower stationary contact **170** will remain in place during an interrupting operation to avoid the premature displacement or "blow out" and thus provide a positive terminal on which the arcing initiated in the auxiliary current path can impinge to keep the arc initially resulting in the auxiliary bore **192** in the path of relatively high velocity, high pressure un-ionized path flow. In order words, when the retreating end of the helical wire **94** or the auxiliary conductor **182** passes the upper end of the arcing terminal **95**, the arcing which takes place initially in the auxiliary bore **192** will cause gases to be evolved from the gas evolving material around the auxiliary bore **192** which will be un-ionized.

When the current to be interrupted by the fuse unit is relatively low, such as 1000 amperes or less, as indicated diagrammatically in FIGS. 4 and 5, and when the gas pressure of the evolved gases in the auxiliary bore **192** increases to thereby increase the dielectric strength in the auxiliary bore **192**, the insulating gap which is formed in the auxiliary bore **192** along with the increased dielectric strength will be sufficient to interrupt the alternating current following a particular current zero in the auxiliary bore **192** during the formation of an insulating gap in the auxiliary bore **192**, as just described. The insulating gap which is formed simultaneously in the main bore **130** of the fuse unit **100** will have sufficient dielectric strength considering the potential difference between the separated conducting parts in the main bore fuse unit to prevent a restrike of the arc in the main bore for such relatively low fault currents. In other words, when any fault current is interrupted by the fuse unit **100** as just described, arcing will always be initiated in the auxiliary bore **192** and for relatively small fault currents the arcing which results will be finally interrupted in the auxiliary bore. One important reason for this is that the relative dielectric strength in the main bore at the time that the arc is finally interrupted in the auxiliary bore will be relatively higher than that in the auxiliary bore to prevent a restrike or breakdown of the main bore due to the potential difference which results between the separated connecting parts in the main bore.

For relative higher fault currents, the arcing which is initiated in the fuse unit **100** will always be initiated in the auxiliary bore **192** in the manner just described. As shown diagrammatically, however, in FIG. 6, the separated ends of the conducting parts in the auxiliary current path which includes the auxiliary conductor **182** and the arcing terminal **95** will burn back to a much greater degree than for relatively low current faults and the gas pressure which builds up in the auxiliary bore **192** during the initial arcing of the fuse unit will be sufficiently high to result in a relatively higher dielectric strength in the auxiliary bore **192** compared with that in the main bore **130** between the upwardly moving conducting rod **83** and the remaining stationary conducting parts at the lower end of the fuse unit **100**. If the instantaneous potential difference between the separated ends of the conducting parts in the main bore **130** is sufficient when the dielectric strength of the main bore becomes relatively less than that of the auxiliary bore **130**, the arc will restrike in the main bore **130**, as indicated at **350** in FIG. 6, to thereby cause the evolution of un-ionized gases in the main bore **130** to thereby increase the gas pressure in the main bore **130** as well as the associated dielectric strength. In addition, as the conducting rod **83** continues to move upwardly, as indicated in FIG. 7, the conducting rod **83** may also burn back, along with the stationary conducting parts remaining in the lower end of the renewable unit **20**, to thereby elongate the arc **350** and increase the un-ionized gases evolved from the gas evolving material around the main bore **130**. The arc **350** will be finally interrupted, as indicated in FIG. 8, following a particular current zero in the alternating current which is being interrupted when the insulating gap in the corresponding dielectric strength in the main bore **130** is sufficient to withstand the potential difference between the separated conducting parts in the main bore **130**. If the fault current which is being interrupted is of a relatively still higher magnitude, the gas pressure in the main bore **130** along the intense heat which results may be sufficient to disintegrate the inner walls of the blocks **126** and **128** to thereby limit the gas pressure of the evolved gases to a value within the rupture strength of the tube **108**, as previously explained. It is to be noted that when the arc is interrupted in the main bore **130** as just described to thereby cause the evolution of gas from the gas evolving material in the blocks **122**, **124**, **126** and **128** which surround the main bore **130**, the upward movement of the conducting rod **130** along with the upward movement of the auxiliary conductor **182** will be accelerated additionally by the gas pressure of the evolved gases in the main bore **130** along with the force exerted on the conducting rod **83** by the bias from the spring **76**.

During an interrupting operation as just described, when the conducting rod **83** is released and moved upwardly under the influence of the springs **76** or under the influence of both the spring **76** and the gas pressure of the evolved gases inside the renewable unit **20**, the turns of the spring **76** which are normally held in tension will tend to collapse toward a compressed condition, but after the turns of the spring **76** partially collapse, the upper spring seat **74** will begin to slide axially on the conducting member **60** and continue to slide axially until the upper end of the spring seat **74** impacts or bears against the washer **54** to thereby drive the tripping rod **52** in an upward direction. The tripping rod **52** will be actuated from the position shown in FIG. 2 until the upper end of the tripping rod **52** actuates the release of the latching means **250**, as described in the copending application previously mentioned and in U.S. Patent 2,403,121 which issued July 2, 1946, to H. L. Rawlins et al. It is to be noted that the upward movement of the conducting rod **83** and the auxiliary conductor **182** will establish the insulating gaps previously described between the separated ends of the conducting parts inside the renewable unit **20** following an interrupting operation. As previously mentioned, the fuse unit **100** would be actuated by the release of the latching means **250** to rotate in a clockwise direction about the lower hinge assembly **260** in a drop-out movement to establish an additional insulating gap between the break contact **252** and the lower stationary hinge contact **262** of the fuse structure **10**.

It is to be noted that during an interrupting operation of the fuse unit **100** for either relatively low fault currents or relatively high currents as previously described, the electrically insulating wall or barrier **142C** provided in the retaining member **142** substantially prevents the deflection or impingement of arc products from the arcing which is initiated in the auxiliary current path for all magnitudes of currents from impinging on the separated conducting parts in the main bore or relatively larger opening **142A** of the retaining member **142** and possibly causing an undesirable restrike of the arc in the main current path of the fuse unit **100**.

It is to be understood that the teachings of the applicants' invention may be applied to power fuses for high voltage applications which are the non drop-out type as disclosed in copending application Ser. No. 663,021, filed Aug. 24, 1967, by C. C. Patterson, which is assigned to the same assignee as the present application. It is also to be understood that the teachings of the applicants' invention may be applied to power fuses for high voltage applications which include a tubular conducting member or shield of the type disclosed in copending application Ser. No. 663,029, filed Aug. 24, 1967, by F. L. Cameron, which is also assigned to the same assignee as the present application.

The apparatus embodying the teachings of this invention has several advantages. For example, arcing is always initiated in the auxiliary current path of the fuse structure disclosed due to the delay in the formation of a significant insulating gap in the auxiliary current path which is due both to the stretching of the helical wire **94**, as disclosed, and also to the overlapping of the lower end of the auxiliary conductor **182** by the elongated arcing terminal **95**, as previously described. In addition, the disclosed construction assures a positive stationary terminal at the lower end of the auxiliary current path in a fuse unit as disclosed which is prevented from being displaced or blown out during an interrupting operation to improperly cause the dielectric strength of the auxiliary current path to exceed that of the main current path when the fuse unit is called upon to interrupt relatively low fault currents. A further advantage of the disclosed construction is that a fuse structure as disclosed including an auxiliary current path as disclosed permits a relatively large exhaust gas passageway at the lower end of the fuse structure to permit the exhaust of relatively high pressure gases which may be evolved or resulting during an interrupting operation of the fuse unit.

Since numerous changes may be made in the above described apparatus and different embodiments of the invention may be made without departing from the spirit and scope thereof, it is intended that all the matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

We claim:

1. A circuit interrupter comprising a tubular insulating casing, a body of arc extinguishing material disposed inside of and spaced from the ends of the casing and including a larger opening extending axially therethrough and a smaller opening extending axially therethrough, terminal means disposed adjacent to at least one end of the casing, an elongated, larger conducting member disposed to extend axially through the larger opening, fusible means disposed inside the casing and connecting between one end of the elongated conducting member and the terminal means, an elongated, smaller conducting member disposed to extend axially through the smaller opening and secured at one end to the larger conducting member adjacent to the other end of the larger conducting member for axial movement therewith, a helically coiled conducting member of relatively smaller cross-section than that of the smaller elongated conducting member disposed inside the casing and connected between the other end of the smaller elongated, conducting member and the terminal means, and an electrically insulated arcing terminal connected to said terminal means and disposed adjacent to the helically coiled conducting member to project axially away from the terminal means and to axially overlap the other end of the smaller, elongated conducting member.

2. The combination as claimed in claim **1** wherein the fusible means including a strain element and a main fusible element electrically connected in parallel between the larger conducting member and the terminal means.

3. The combination as claimed in claim **1** wherein a generally tubular, electrically insulating member is disposed inside the casing between the body of arc extinguishing material and the terminal means, said insulating member including a larger opening extending axially therethrough in which the fusible means is disposed and a smaller opening therethrough in which the helically coiled conducting member and at least a portion of the arcing terminal are disposed.

4. The combination as claimed in claim **1** wherein an electrically insulating partition is disposed inside the casing between the fusible means and both the helically coiled conducting member and the arcing member.

5. The combination as claimed in claim **1** wherein means is connected to the larger conducting member adjacent to the end away from the terminal means for actuating the larger conducting member and the smaller conducting member axially away from the terminal means when the fusible means blows.

6. The combination as claimed in claim **5** wherein an electrically insulating partition is disposed inside the casing between the fusible means and both the helically coiled conducting member and the arcing terminal.

7. The combination as claimed in claim **5** wherein the fusible means includes a separate strain element which normally restrains the axial movement of the larger and smaller conducting means away from the terminal means.

8. The combination as claimed in claim **5** wherein a generally tubular, electrically insulating member is disposed inside the casing between the body of arc extinguishing material and the terminal means, said insulating member including a larger opening extending axially therethrough in which the fusible means is disposed and a smaller opening extending axially therethrough in which the helically coiled conducting member and at least a portion of the arcing terminal are disposed.

References Cited

UNITED STATES PATENTS

2,183,728	12/1939	Triplett	200—120 XR
2,319,277	5/1943	Triplett	200—120
2,961,514	11/1960	Lindell	200—120
2,976,381	3/1961	Lindell	200—120

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