Sept. 10, 1968 C. C. PATTERSON 3,401,244

SPRING AND SHUNT ASSEMBLY FOR CIRCUIT INTERRUPTERS

Filed Aug. 24, 1967

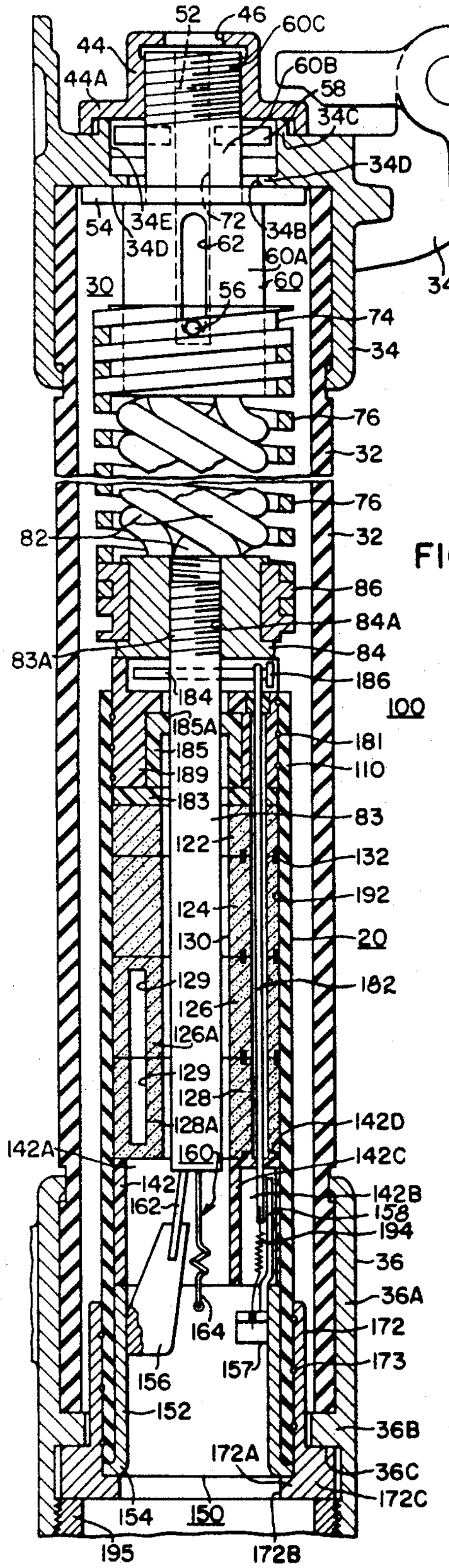


FIG. 2.

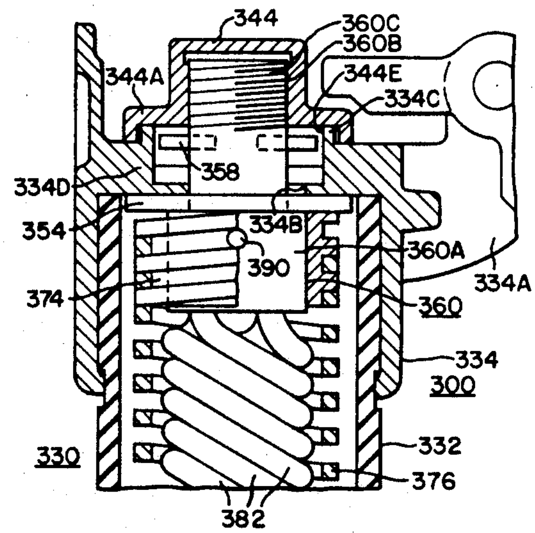
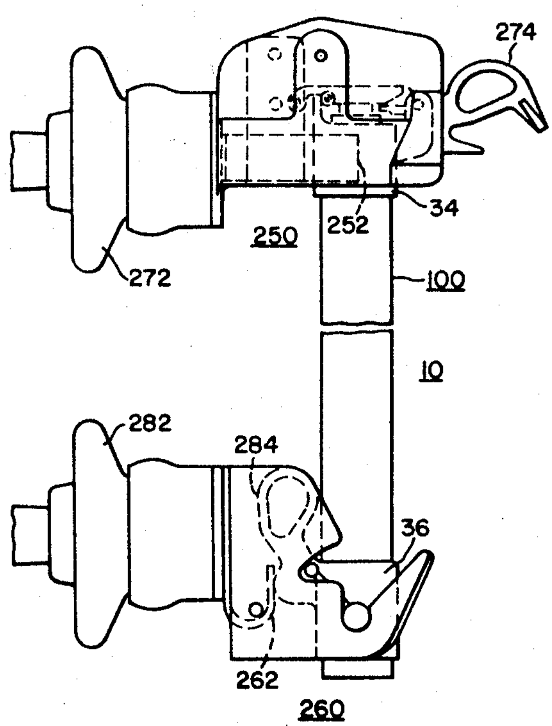


FIG. 3.

FIG. 1.



United States Patent Office

3,401,244
Patented Sept. 10, 1968

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SPRING AND SHUNT ASSEMBLY FOR CIRCUIT INTERRUPTERS

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Filed Aug. 24, 1967, Ser. No. 663,021
8 Claims. (Cl. 337—178)

ABSTRACT OF THE DISCLOSURE

The invention relates to a high voltage circuit interrupter construction in which a fusible means is disposed inside a tubular insulating casing or holder and electrically connected in series with an elongated conducting member which is axially movable through a body of arc-extinguishing material, and is biased upwardly by a helically coiled tension spring, each turn of which may be rectangular in cross-section to prevent overlapping of the turns which might damage the spring and prevent its repetitive use.

Background of invention

In the construction of circuit interrupters for higher voltage, such as power fuses of the dropout type which include a conducting rod that is movable through an arc-extinguishing means, such as a body of gas evolving material, a problem arises in providing a reliable means for actuating the movement of the conducting rod during arc interruption and a reliable means for actuating the dropout action of the circuit interrupter following arc interruption. In certain known interrupter structures of the type described, the movement of the conducting rod is actuated by an associated biasing spring and to initiate dropout action of the interrupter, the conducting rod includes an extension which is rigidly mounted on the conducting rod for movement therewith and which is actuated to move through at least a portion of the turns of the associated biasing spring to actuate the dropout action of the interrupter. It has been found in such known interrupter structures, the movement of the conducting rod which is required for both arc interruption and for actuating the dropout action of the overall interrupter may be prevented by the jamming of the extension of the conducting rod with either the turns or the associated biasing spring or with flexible conductors which may be provided as part of a current path extending through the turns of the biasing spring. It has also been found that the turns of the biasing spring in known structures of the type described may tend to overlap during an interruption operation of the circuit interrupter to prevent proper operation of the interrupter or to cause damage to the turns of the spring to thereby prevent repetitive operations with the same biasing spring. It is therefore desirable to provide an improved circuit interrupter of the type described which includes a more reliable means for both actuating the movement of a conducting rod during an interrupting operation and to actuate the dropout action of the overall interrupter following arc interruption. It is also desirable to provide an improved circuit interrupter construction of the type described which may be either of the dropout or non-dropout type in which overlapping of the turns of the biasing spring along with the consequent damage to the spring is prevented during an interrupting operation.

Summary of invention

In order to actuate the movement of the elongated conducting member, a helically coiled tension spring is connected between one end of the elongated conducting member and a movable spring seat which is slidably

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mounted on a relatively stationary conducting member at one end of the casing and which is coupled to a separate tripping rod mounted inside of a tubular portion of the stationary conducting member. When the fusible means blows or fuses, the spring collapses at least partially to actuate the elongated conducting member during arc interruption and collapses fully to actuate the movable spring seat and the tripping rod to thereby actuate dropout movement of the interrupter. Another feature of the invention relates to a circuit interrupter construction of the dropout or non-dropout type including a spring having turns of a rectangular cross-section to prevent overlapping of the turns and damage to the spring during an interrupting operation.

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 actuating the dropout action of a power fuse.

A more specific object of this invention is to provide a common means for actuating movement of the conducting parts of the circuit interrupter during arc interruption and the release of a releasable latch means for a power fuse following arc interruption.

A further object of this invention is to provide an improved means for preventing overlapping and consequent damage to the turns of the spring which actuates the movement of the conducting parts in a circuit interrupter during an interrupting operation.

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

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description, taken in conjunction with the accompanying drawing 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 of the dropout type which forms part of the fuse structure shown in FIGURE 1 with portions of the end fittings of the fuse unit omitted; and

FIG. 3 is an enlarged, longitudinal, sectional view of a portion of a fuse unit of the non-dropout type which embodies certain features of the invention.

Referring now to the drawings, and FIGURE 1 in particular, the structure shown comprises a power fuse structure of the high voltage, dropout 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** which is mounted in a relatively stationary position on the lower insulator support **282**, 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 which is formed from a suitable weather-proof, 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 or terminals **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 may pass transversely through both the end fittings **34** and **36** 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** on 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 removable or refillable unit **20** which is mounted within the holder structure which includes the outer tube **32** and the upper and lower end fittings or terminals **34** and **36** respectively. The removable unit **20** includes its own supporting tube for insulating casing **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** include 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 or arc-extinguishing material which includes said blocks and a relatively small 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 corresponding recess in the end of the adjacent blocks a larger 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 **100**, 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** in FIG. 2, which extends axially from one end of each of 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 each of said blocks which includes 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 a 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 the 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 or cross-section of the main bore **130** through the blocks **126** and **128** is effectively increased by the distintegration of the inner walls **126A** 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 or bonding material, such as an epoxy bonding material prior to assembly of the blocks inside the tube **108**. In addition, a generally tubular or 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 uppermost block **122**, as shown in FIG. 2, 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 **108**. 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 or bonding material, 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 refillable or 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 a central opening of reduced cross-section or size through which the conducting member passes and which forms a substantially gastight 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 upwardly, as viewed in FIG. 2. 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 an 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** through which the auxiliary conductor **182** passes 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**, **124**, **126** and **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**, **124**, **126** and **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 or bonding material, such as an epoxy bonding material, prior to the assembly of the retaining member **142** inside the tube **108**. This bonding material serves to secure the retaining member **142** to the inside of the tube **108**. The retaining member **142** includes a relatively larger opening **142A** which extends axially therethrough, 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 **142** may also serve 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. The lower end of the auxiliary bore **192** opens into the opening **142B** and the lower end of the auxiliary conductor **182** projects into the same opening. The insulating wall or partition **142C** which is formed integrally with the retaining member **142** around the relatively smaller opening **142B** through the retaining member **142** assists in preventing certain arc products which may result during the operation of the fuse unit **100** in the relatively smaller opening **142B** 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 **142D** being joined to the adjacent block **120A** around a recess in the block **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** assists in preventing the travel or escape of ionized gases between the auxiliary bore **192** and the main bore **130** and between the auxiliary bore **192** and the relatively larger opening **142B** through the retaining member **142** during an interrupting operation of the fuse at **100**.

The elongated conducting member or rod **83** of the refillable 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 tubular lower conducting member or contact **150**.

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 **156** which is of the flat strip type. The connecting conductor **156** is secured, in turn, to the lower contact **150** adjacent to the upper end of the lower contact **150** 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 **150** adjacent to the upper end of the lower contact **150** by suitable means, such as brazing. It is to be noted that the strain element **162** and the fusible element **164** are electrically connected in parallel between the lower end of the conducting rod **83** and the lower contact **150** of the removable unit **20**.

Similarly, the auxiliary conductor **182** which is of a relatively smaller cross section or size compared with that of 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**. The pin **184** is disposed in a transversely extending recess or opening provided at the upper end of the retaining member **189** to prevent rotation of the conducting rod **83** after assembly of the rod **83** into 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**, as shown in FIG. 2, and is electrically connected through a helical conducting wire of reduced cross section as indicated at **194** to an angle-shaped auxiliary stationary terminal **157** which is secured to the tubular conducting member or contact **150** adjacent to the upper end of the member **150** by suitable means, such as brazing. The upper end of the helical wire **194** which is disposed inside the relatively smaller opening **142B** 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 **194** is secured to the auxiliary terminal **157** by suitable means, such as crimping or brazing, as disclosed in greater detail in copending application Ser. No. 663,127, filed Aug. 24, 1967 by C. W. Upton, Jr., C. C. Patterson and F. L. Cameron which is assigned to the same assignee as the present application.

The lower contact or conducting member **150** also includes an elongated arcing terminal **158** as disclosed in the copending application just mentioned which projects upwardly from the upper end of the contact **150** 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 **158** being disposed adjacent to and generally parallel to the axis of the helical wire **194**. The arcing terminal **158** is electrically insulated along its length by a coating or film of electrically insulating material, such as an insulating enamel, which is provided on the arcing terminal **158** to prevent the electrical shorting out of the helical wire **194**. The arcing terminal **158** which is formed from an electrically conducting material may be structurally secured to the upper end of the lower contact **150** 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 **194** to the auxiliary terminal **157** on the lower contact **150** is also electrically connected in parallel with the conducting paths which include, respectively, the strain element **162** and the fusible element **164**.

In order to assist in retaining the blocks **122, 124, 126** and **128** and the retaining member **142** in assembled relationship outside the tube **108**, as well as for another important purpose, during an interrupting operation of the fuse unit **100**, the lower tubular conducting member or contact **150** includes a main portion **152** which extends axially inwardly from the lower end of the tube **108** to bear against the lower end of the retaining member **142**. The lower contact **150** also includes a flange portion **154** at the lower end thereof against which the lower end of the tube **108** bears when the conducting member **150** is assembled with the fuse tube **108**.

In order to retain the lower contact **150**, as well as other parts of the renewable unit **20**, in assembled relationship with the tube **108** during an interrupting operation of the fuse unit **100**, a generally tubular external terminal member or ferrule **172** is disposed to telescope or extend axially over the lower end of the tube **108**. In order to firmly secure the external terminal member **172** to the lower end of the tube **108**, the internal surface of the external terminal member **172** and the external surface of the portion of the tube **108** adjacent to the member **172** include adjacent helical grooves which, when the parts are assembled, form a helical passageway in which a helical wire **173** is disposed. In the assembly of the external terminal member **172** 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 **172** may then be screwed onto the lower end of the tube **108** until the parts reach their final positions as shown in FIG. 2. In order to additionally assist in retaining the external terminal member **172** on the lower end of the tube **108**, the outer surface of the tube **108** and the inner surface of the external terminal member **172** may be coated with a cement or bonding material, such as an epoxy bonding material, prior to the assembly of the external terminal member **172** on the lower end of the tube **108**. It should be noted that the external terminal member **172** also includes an inwardly projecting flange portion **172A** around a central opening **172** which bears against the adjacent flange portion **154** of the tubular conducting member **150** to assist in retaining the tubular conducting member **150** in assembled relation with the other parts of the renewable unit **20**.

In order to form a current conducting path which extends between the lower end fitting **36** and the lower contact **150** of the renewable unit **20**, the external terminal member **172** also includes an external flange portion **172C** which bears against the inwardly projecting flange portion **36B** at the shoulder **36C** of the lower end fitting **36**. The electrically conducting path thus formed extends to the lower contact **150** through the inwardly projecting flange portion **172A** of the external terminal **172** and through the externally projecting flange portion **172C** to the inwardly projecting flange portion **36B** of the lower end fitting **36**. The area of the current transfer path between the external terminal **172** of the removable unit **20** and the lower end fitting **36** may also be augmented by the contact ring **195** which may be formed of electrically conducting material and which is disposed to threadedly engage the internally threaded opening provided at the lower end of the end fitting **36** and to bear against the external terminal member **172** of the renewable unit **20** as shown in FIG. 2.

It is important to note that in order to prevent the concentration of relatively high potential stresses adjacent to the external terminal member **172** during an interrupting operation of the fuse **100** at relatively high voltages, the upper end of the lower contact **150** extends axially beyond the upper end of the external terminal member **172** toward the other end of the tube **108** a minimum distance to prevent such a concentration of relatively high potential stresses externally of the tube **108** adjacent to the external terminal member **172** as disclosed in greater detail in copending application Ser. No. 663,029 filed Aug. 24, 1967, by F. L. Cameron which is assigned to the same assignee as the present application.

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**, 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** which is also generally tubular in configuration includes a helically threaded outer surface and is fixedly mounted on the socket **84** for movement therewith by assembling the spring seat **86** over the outer surface of the socket **84** with the lower end of the spring seat **86** bearing against a shoulder provided on the outer surface 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 a generally tubular upper spring seat **74** which includes a helically threaded outer surface and which is slidably disposed over the lower portion **60A** of a generally cylindrical conducting member **60**. As shown in FIG. 2, the lower portion **60A** of the conducting member **60** projects axially inside the upper end of the outer holder **32**. The integral upper portion **60B** of the conducting member **60** 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** may be 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 helically coiled 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 external, 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 **150**. It is important to note that each of the turns of the spring **76** is 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 **76** that might otherwise result during an interrupting operation of the fuse unit **100** and otherwise prevent the repetitive use of the spring **76**. Since the turns of the spring **76** are not required to conduct electrical current during the operation of the fuse **100**, the turns of the spring **76** may be formed from a material having a greater mechanical strength and higher electrical resistance, such as stainless steel.

In order to electrically connect the renewable unit **20** and more specifically the conducting rod **83** of the renewable unit **20** 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 ends thereof to the conducting 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 electrically and structurally connected to the conducting member **60** in separate openings provided in the lower portions **60A** of the conducting member **60** by suitable means, such as brazing or 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 intersection 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 fittings **34**, as indicated at **34D**, around the central opening **34B** of the upper end fitting **34**. Since the electrical resistance of the flexible conductors **82** is relatively much less than that of the spring **76**, substantially all of the current which flows between the conducting rod **83** and the upper end fitting **34** both prior to and during an interrupting operation of the fuse unit **100** will flow through the flexible conductors **82** without producing any thermal stress in the turns of the spring **76**. It is also to be noted that the flexible conductors **82** which are helically coiled will maintain a continuous electrically conducting path between the conducting rod **83** and the conducting member **60** during an interrupting operation of the fuse unit **100** substantially without any retarding effect on the rate of movement of the turns of the spring **76**.

In order to facilitate the assembly of the removable 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 in 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** provided 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**, a tripping rod or member having a generally cylindrical, elongated shape is slidably disposed inside a central opening or passageway **72** which is internally threaded at its upper end and which extends axially from a point which is axially spaced from the lower end of a conducting member **60** to the other end of the conducting member **60**, as shown in FIG. 2. The upper end of the tripping rod **52** is 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**. The cross pin **56** passes laterally through aligned transverse openings provided in the tripping rod **52** and the upper spring seat **74** and through a pair of elongated slots **62** which are provided at the opposite sides of the lower portion **60A** of the conducting member **60** and which open into the central passageway or opening **72**. The cross pin **56** is normally positioned at the lower ends of the 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 may pass 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 dropout 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 fusing tool (not shown) passes through the central opening **34B** of the upper end fitting **34**. By use of the refill fusing tool, the spring **76** is stretched and placed in tension until the cross pins **58** mounted at the sides of the upper portion **60B** 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 portions **60C** of the conducting member **60** to further stretch the spring **76** to the final charged condition or position shown in FIG. 2 in which the cross pins **58** are drawn upwardly away from the shoulder in the upper end pin **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** to insure that the tripping rod **52** move axially with the upper spring seat **74** during an interrupting operation of the fuse unit **100** is disposed at the bottom of the 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 axially beyond the end cap **44** to release the latching assembly **250**, as previously mentioned. The washer **54** also acts as a stop surface against which the upper end of the spring seat **72** 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 **194**, 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 **150** 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 **194** 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 that of the path which includes the fusible element **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 **194** so that when the fusible element **164** melts or blows, most of the current which was formerly carried by the fusible element **164** is then 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 fuse element **164**, most of the current of which is flowing through the fuse unit **100** then transfers 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 **183** and the helical wire **194**. 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 **194** which is electrically connected to the bottom of the auxiliary conductor **182**. It is to be noted that the stretching of the helical wire **194** permits limited travel of both the conducting rod **83** and the auxiliary conductor **182** while maintaining a continuous electric circuit or path through the auxiliary bore **192** and that as long as the current path which includes the auxiliary conductor **182** and the helical conductor **194** is intact, no arcing will take place in either the main bore **130** or an auxiliary bore **192**. In other words, stretching of the helical wire **194** 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 electrically insulating gap in the main bore **130** while initially delaying the formation of a significant insulating gap in the auxiliary bore **192**.

After the strain element **162** melts or blows as just described, and the conducting rod **83** and the auxiliary conductor **182** begin to move upwardly to thereby stretch the helical wire **194**, the helical wire **194** will either fracture mechanically when stretched to its limit or the current transferred to the current path which includes the helical wire **194** and the auxiliary conductor **182** will be sufficient to melt or blow the helical wire **194** which is of reduced cross-section compared to that of the auxiliary conductor or rod **182**. After the helical wire **194** is melted or otherwise broken, an arc will be initiated between the retreating end of either the broken helical wire **194** or the auxiliary conductor **182** and the terminal **157** or the arcing terminal **158**, which axially overlaps the lower end of the auxiliary conductor **182**, to thereby burn through the electrical insulation on the arcing terminal **158**. Even after the wire **194** melts or is broken, the formation of a significant electrically insulating gap in the auxiliary bore **192** is further delayed by the overlapping of the auxiliary conductor **182** by the arcing terminal **158** until the retreating free end of either the wire **194** or the conductor **182** passes the upper end of the arcing terminal **158** whose insulation will have burned through by this time. It is important to note that the insulating gap in the main bore **130** between the separated ends of the conducting parts will increase at a faster rate than the formation of an insulating gap in the auxiliary bore **192** due to both the delay in the formation of an arc in the auxiliary bore **192** because of the presence of the helical wire **194** and due to the overlapping of the auxiliary conductor **182** by the arcing terminal **158**. It is also important to note that the arcing which takes place in the fuse unit **100** during an interrupting operation will always take place initially in the auxiliary bore **192** as just explained. When the retreating end of either the helical wire **194** or the auxiliary conductor **182** passes the upper end of the arcing terminal **158**, 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 **100** is relatively low, such as 1000 amperes or less, and when the gas pressure of the evolved gases in the auxiliary bore **192** increases to thereby increase the corresponding dielectric strength in the auxiliary bore **192**, the insulating gap which is formed in the auxiliary bore **192** along with the corresponding increased dielectric strength, will be sufficient to interrupt the alternating current being interrupted following a particularly current zero in the auxiliary bore **192**. The insulating gap which is formed simultaneously in the main bore **130** of the fuse unit **100** at a relatively faster rate will have sufficient dielectric strength considering the instantaneous potential difference between the separating conducting parts in the main bore **130** of the fuse unit **100** to prevent a restrike of the arc in the main bore **130** 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 smaller fault currents, the arcing which results will be finally interrupted in the auxiliary bore **192**. One important reason for this is that the dielectric strength of the main bore **130** at the time that the arc is finally interrupted in the auxiliary bore **192** will be relatively higher than that in the auxiliary bore **192** to prevent a restrike or breakdown of the main bore **130** due to the instantaneous potential difference which exists or results between the separated conducting parts in the main bore **130** at the time of arc interruption in the auxiliary bore **192**.

For relatively higher fault currents, the arcing which is initiated in the fuse unit **100** will still be initiated in the auxiliary bore **192** in the manner just described. For such relatively higher current faults, however, the gas pressure which builds up in the auxiliary bore **192** during an interrupting operation and the burning back of the separating conducting parts in the auxiliary bore **192** will result in a relatively higher dielectric strength in the auxiliary bore **192** compared with that in the main bore **130** between the separated conducting parts in the main bore **130**. If the instantaneous potential difference between the separate ends of the conducting parts in the main bore **130** is sufficient when the dielectric strength of the main bore **130** becomes relatively less than that of the auxiliary bore **192**, the arc will restrike in the main bore **130** 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 corresponding dielectric strength in the main bore **130**. The arc which restrikes the main bore **130** will be elognated both by the upward movement of the conducting rod **83** and by the burning back of the separated conducting parts in the main bore **130** to thereby increase the quantity of un-ionized gases evolved from the gas evolving material disposed around the main bore **130**. The arc in the main bore **130** will be finally interrupted following a particular current zero in the alternating current which is being interrupted when the insulating gap and the corresponding dielectric strength in the main bore **130** is sufficient to withstand the instantaneous 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 with 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 additionally accelerated by the force of the gas pressure of such evolved gases in the main bore **130** along with the force exerted on the conducting rod **83** by the biasing force of the spring **76**.

During an interrupting operation of the fuse unit **100** as just described, when the conducting rod **83** is released and moved upwardly under the influence of the spring **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 fully compressed condition but after the turns of the spring **76** partially collapse, the upper spring seat **74** will begin to slide axially on the lower portion **60A** of the conducting member **60**. The upper spring seat **74** will continue to slide axially on the lower portion **60A** of the conducting member **60** until the upper end of the spring seat **74** impacts or bears against the washer **54** and the turns of the spring **76** reach a fully compressed or fully collapsed condition. During the initial partial collapse of the spring **76**, the conducting rod **83** and the auxiliary conductor **182** will be actuated upwardly to finally interrupt the arc which is formed either in the main bore **130** or in the auxiliary bore **192**, as previously described. During the final collapse of the turns of the spring **76** and the axial movement of the upper spring seat **74** until the upper end of the spring seat **74** impacts against the washer **54**, the tripping rod **52** will be actuated from the position shown in FIG. 2 until the upper end of the tripping rod **52** projects axially beyond the upper end of the end cap **44** to actuate 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 a common spring **76** is employed in a sequential operation to first actuate the movement of the conducting rod **83** and the auxiliary conductor **182** which is required to accomplish arc interruption either in the main bore **130** or in the auxiliary bore **192** and then after arc interruption is accomplished to actuate the tripping rod **52** to thereby actuate the release of the latching means **250** and the dropout action of the fuse structure **10**. It is also to be noted that the upward movement of the conducting rod **83** and the auxiliary conductor **182** will establish the electrically insulating gaps previously described between the separated ends of the conducting parts inside the renewable unit **20** during an interrupting operation. In addition, the fuse unit **100** will be actuated by the release of the latching means **250** by the tripping rod **52** to rotate in a clockwise direction about the lower hinge assembly **260** in a dropout movement to establish a larger electrically insulating gap between the break contact **252** and the lower stationary hinge contact **262** of the fuse structure **10**.

Referring now to FIG. 3 there is illustrated a modified fuse unit structure **300** which is intended for use in a nondropout application rather than in a dropout application as is the fuse unit **100** previously described. In general the construction of the fuse unit **300** is similar to the fuse unit **100** previously described except that the fuse unit **300** does not include any means, such as the tripping rod **52**, for actuating the release of a latching mechanism at the upper end of the fuse unit. Since the lower portion of the fuse unit **300** is identical to the corresponding portion of the fuse unit **100** previously described in detail, only the upper portion of the fuse unit **300** will be described.

More specifically the fuse unit **300** includes a spring and cable assembly **330** which is disposed inside an outer holder **332** between a renewable unit which is identical to the renewable unit **20** previously described and the upper end fitting **334** of the fuse unit **300**. The spring and cable assembly **330** includes a spring **376** which is structurally identical to the spring **76** previously described with the lower end of the spring **376** being secured to a lower spring seat (not shown) which is identical to the spring seat **86** previously described. The upper end of the spring **376** is connected to the external helically threaded portion of the upper generally tubular spring seat **374** which is concentrically mounted on a lower portion **360A** of a generally cylindrical conducting member **360**. The upper spring seat **374** is fixedly secured to the lower portion **360A** of the generally cylindrical conducting member **360** by suitable means, such as the cross pin **390**, which passes through substantially aligned transverse openings provided in the spring seat **374** and the lower portion **360A** of the conducting member **360**. The conducting member **360** includes an upper portion **360B** which passes through a central opening **334B** in the upper end fitting **334** with the upper end of the upper portion **360B** being externally threaded, as indicated at **360C**. In order to secure the conducting member **360** to the upper end fitting **334**, an internally threaded end cap **344** may be screwed down on the upper portion **360B** of the conducting member **360** until a shoulder portion **344A** of the end cap **344** engages a shoulder portion **334C** of the upper end fitting **334**. A pair of spring pins **358** may be disposed in associated openings provided in the upper portion **360B** of the conducting member **360** to project laterally and to aid in the assembly of the renewable unit and the associated spring and cable assembly of the fuse unit **300** in the outer holder **332**, as explained in detail in connection with the fuse unit **100**. A washer **334** may be disposed between the shoulder which is formed at the intersection of the upper and lower portions **360B** and **360A**, respectively, of the conducting member **360** and the inwardly projecting flange portion of the upper end fitting **334**, as indicated at **334D** in FIG. 3.

In order to electrically connect the renewable unit (not shown) of the fuse unit **300** and the conducting member **360**, a plurality of helically coiled flexible conductors **382** may be electrically and structurally connected at the lower end to openings provided in a conducting socket (not shown) which would be structurally identical to the socket **84** of the fuse unit **100** while the upper end of the flexible conductors **382** may be electrically and structurally connected to associated openings (not shown) provided at the lower end of the lower portion **360A** of the conducting member **362** by suitable means, such as brazing. It is important to note that the turns of the spring **376** are substantially rectangular or square in cross section to prevent overlapping of the turns of the spring **376** during an interrupting operation and the consequent damage that would otherwise result and prevent repetitive use of the spring **376**.

The operation of the fuse unit **300** is similar to that of the fuse unit **100** previously described in detail except that during an interrupting operation the turns of the spring **376** would simply collapse or compress during an interrupting operation to actuate the movement of the conducting rod and the auxiliary conductor in the associated renewable unit which has a structure identical to the renewable unit **20** previously described without the spring **376** actuating the tripping rod, such as the tripping rod **52** which is provided as part of the fuse unit **100**. In other words, the upper spring seat **374** would be fixed in a relatively stationary position during an interrupting operation and the turns of the spring **376** would simply fully collapse against the washer **354** during an interrupting operation. It is to be noted that the end cap **334** is fully closed in the fuse unit **100** since the central opening is not required to permit the passage of a tripping rod therethrough as in the fuse unit **100**. It is also to be noted that the spring **376** in the fuse unit **300** similarly to the spring **76** of the fuse unit **100** carries only a negligible amount of current since the resistance of the flexible conductors **382** is relatively much less than the resistance of the material from which the spring **376** is formed which may have a higher mechanical strength and a relatively higher electrical resistance, such as stainless steel.

It is to be understood that the teachings of the applicant's invention may be applied to power fuses for high voltage applications which do not include a tubular conducting member or shield, such as the lower contact **150** shown in FIG. 2, but which instead employed a lower contact ring of the type disclosed in copending application Ser. No. 663,127 previously mentioned. It is also to be understood that a releasable end closure cap may be provided at the lower end of either the fuse unit **100** or the fuse unit **300**.

The apparatus embodying the teachings of this invention has several advantages. For example, in the applicant's construction, a common spring actuates both the movement of the conducting rod which is required for arc interruption and also actuates a separate tripping rod to release an associated latching mechanism to accomplish dropout operation without requiring an extension of a conducting rod to move axially through the turns of an associated actuating spring. In addition, the turns of the actuating spring in the applicant's construction are not required to conduct substantial current either before or during an interrupting operation of the associated fuse unit. A positive and continuous electric circuit is maintained between the conducting rod and the end fitting or terminal at the other end of the fuse unit by the helically coiled flexible conductors which permits substantially unhampered movement of the associated actuating spring and spring seat in the applicant's construction. A further advantage is that the applicant's construction substantially prevents the entrance of moisture or other contaminating materials into the fuse unit at the upper end of the fuse unit where the release of the associated latching means is actuated by the tripping rod in the applicant's construction. In one embodiment of the applicant's invention, overlapping of the turns of the actuating spring is substantially prevented, along with the consequent damage the spring that might otherwise result and prevent repetitive operations of the actuating spring which is required for certain applications. Finally if the fault current which the disclosed fuse unit is called upon to interrupt exceeds the rating for which the fuse unit is designed, the dropout action will be initiated by the release of the tripping rod independently of arc interruption in the renewable unit of the fuse unit. In other words, an insulating gap will be established by the dropout action of the fuse unit independently of the magnitude of the fault current and even if the fault current which is involved is greater than the rating of the particular fuse unit to substantially prevent any internal arcing which might otherwise continue in the fuse unit.

Since numerous changes may be made in the above-described apparatus, 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 drawing shall be interpreted as illustrative and not in a limiting sense.

I claim as my invention:

1. A high voltage circuit interrupter comprising a tubular insulating holder, a body of arc extinguishing material disposed inside of and spaced from the ends of the holder and including at least one passageway extending axially therethrough, terminal means disposed adjacent to each end of the holder, an elongated conducting member disposed to extend axially through said passageway, fusible means disposed inside the holder and connected between one end of the conducting member and one of the terminal means, a generally cylindrical conducting member secured to the other terminal means and having a main portion projecting axially into the holder, a generally tubular member slidably disposed on the main portion of the cylindrical conducting member, a spring connected between the other end of the elongated conducting member and the tubular member, a plurality of flexible, helically coiled conductors connected between the main portion of the cylindrical conducting member and the other end of the elongated conducting member, and means movably mounted on the cylindrical conducting member and coupled to the tubular member to be actuated by said spring when the fusible means blows for projecting axially beyond the other terminal means.

2. The combination as claimed in claim **1** wherein the cylindrical conducting member includes a central passageway which extends axially from a point which is spaced from the end of the cylindrical member which projects into the holder to the other end of the cylindrical member and a pair of axially extending slots at the opposite sides thereof which open into the central passageway, and the last-mentioned means comprises an elongated tripping rod disposed in the central passageway and coupled to the tubular member through the slots for movement with the tubular member under the influence of the spring when the fusible means blows.

3. The combination as claimed in claim **1** wherein the spring comprises a plurality of helically coiled turns and the plurality of coiled conductors are disposed inside the turns of the spring.

4. The combination as claimed in claim **2** wherein the spring comprises a plurality of helically coiled turns and the plurality of coiled conductors are disposed inside the turns of the spring.

5. The combination as claimed in claim **2** wherein a pair of vertically spaced, relatively stationary contacts is provided, means is provided for pivotally supporting the holder adjacent one end near the lower of the contacts to permit movement of said other terminal means into and out of engagement with the other contact, and a latch means is disposed adjacent to the other contact for releasably maintaining the holder in a closed circuit position with both of said contacts until actuated by said tripping rod to release the holder.

6. The combination as claimed in claim **5** wherein the spring comprises a plurality of helically coiled turns and the plurality of coiled conductors are disposed inside the turns of the spring.

7. The high voltage circuit interrupter comprising a tubular insulating holder, a body of arc extinguishing material inside of and spaced from the ends of the holder and including at least one passageway extending axially therethrough, terminal means disposed adjacent to each end of the holder, an elongated conducting member disposed to extend axially through said passageway, fusible means disposed inside the holder and connected between one end of the elongated conducting member and one end of the terminal means, a helically coiled spring connected between the other end of the elongated conducting member and the other terminal means to actuate the movement of the elongated conducting member away from said one of the terminal means upon the fusion of the fusible means, said spring including a plurality of turns each having a rectangular cross-section.

8. The combination as claimed in claim **7** wherein the turns of the spring are each substantially square in cross-section.

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