Feb. 14, 1967 S. I. LINDELL 3,304,390

CURRENT-LIMITING FUSE WITH DUAL ELEMENT RELEASE AND HAVING EXTENSIONS OF THE CURRENT-LIMITING ELEMENTS CUT BY ARC BLASTS IN ARC CHUTES AND BY A MECHANICAL CUTTER

Filed Jan. 27, 1966 2 Sheets-Sheet 1

Fig. 1

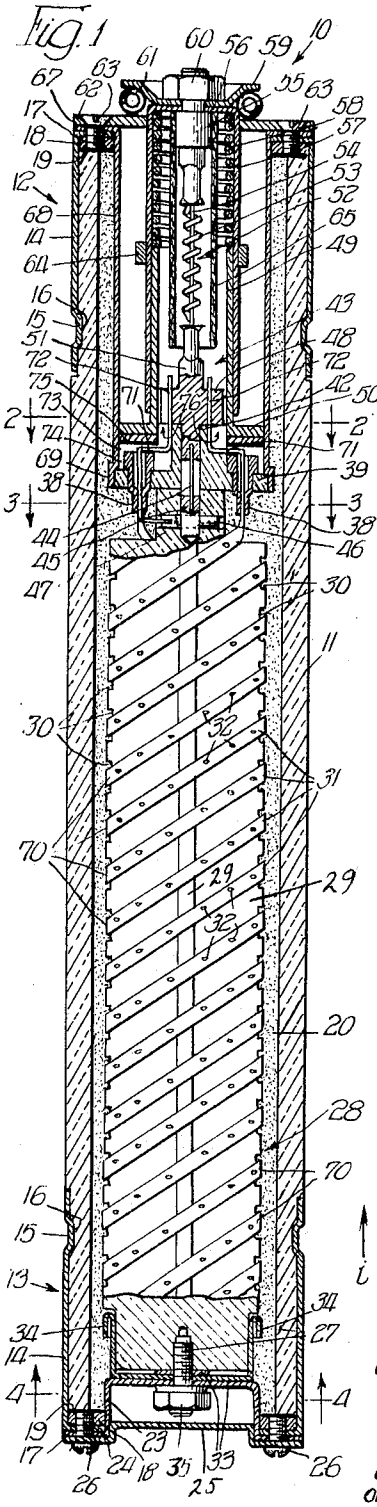


Fig. 2

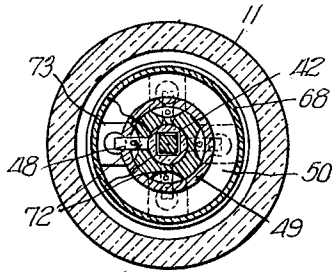


Fig. 3

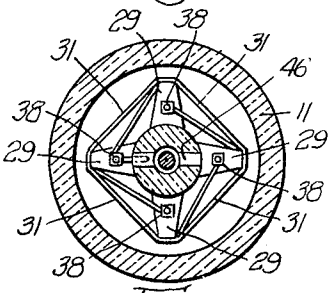


Fig. 4

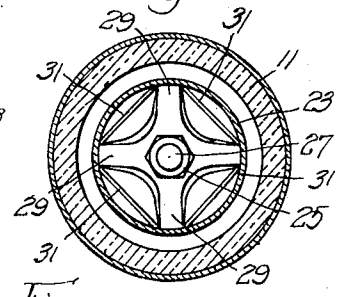


Fig. 5

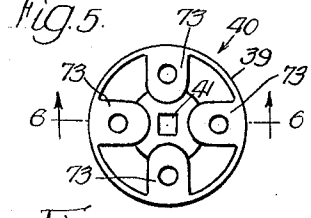


Fig. 6

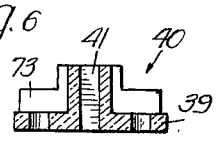


Fig. 7

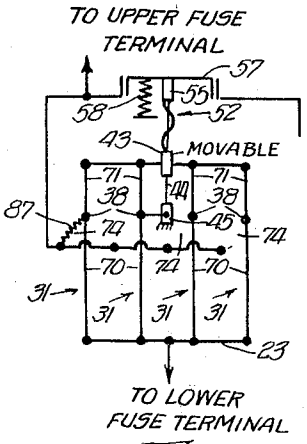


Fig. 8

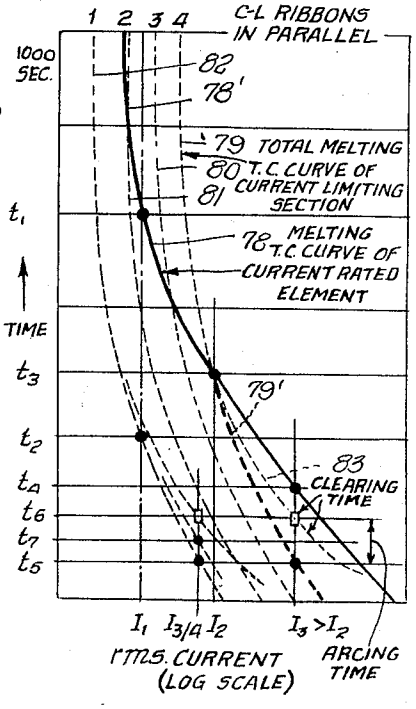
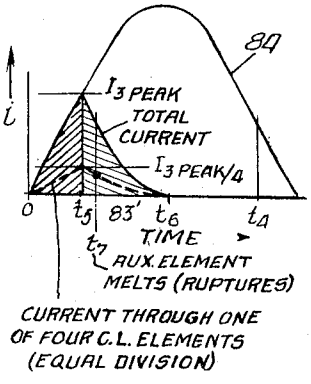


Fig. 9



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CURRENT-LIMITING FUSE WITH DUAL ELEMENT RELEASE AND HAVING EXTENSIONS OF THE CURRENT-LIMITING ELEMENTS CUT BY ARC BLASTS IN ARC CHUTES AND BY A MECHANICAL CUTTER

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Fig. 10

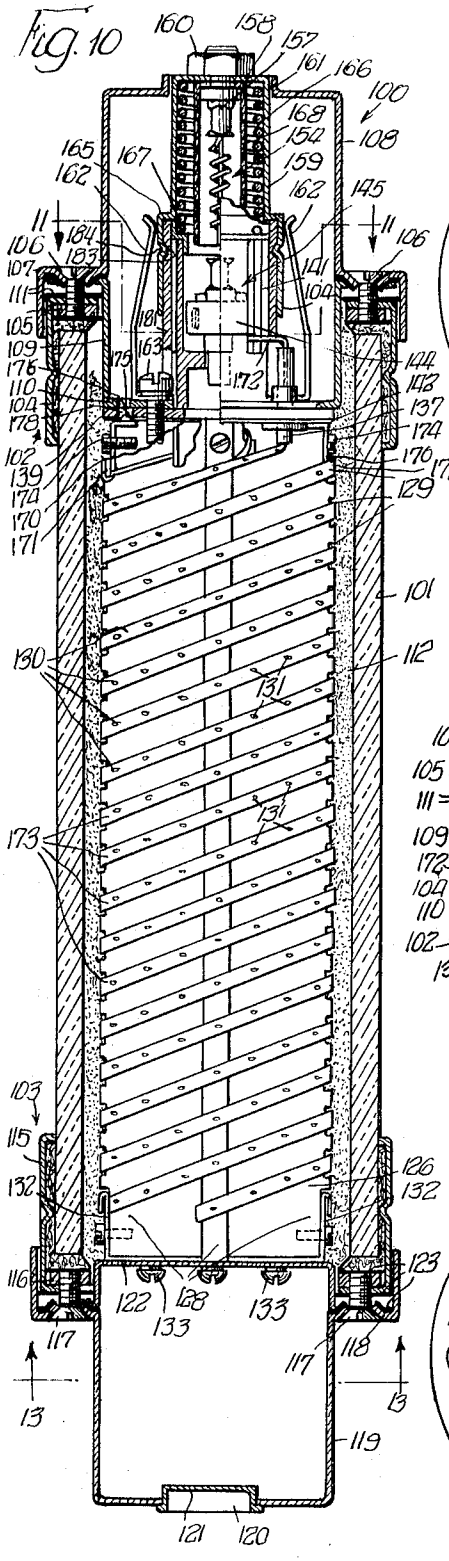


Fig. 11

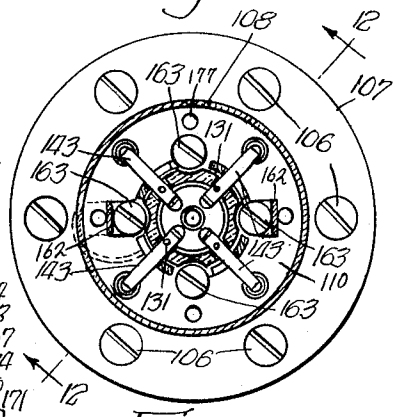


Fig. 14

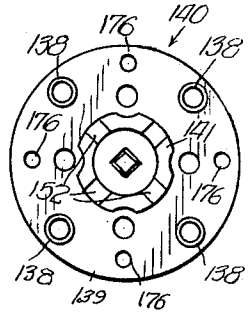


Fig. 12

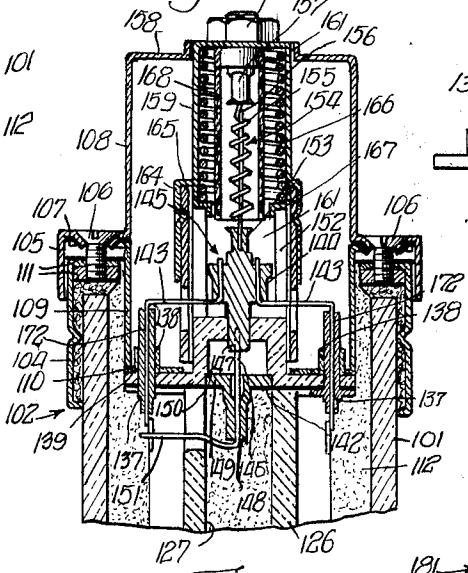


Fig. 15

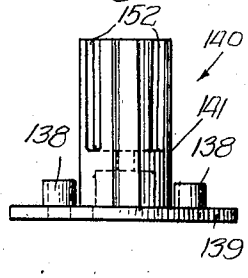


Fig. 16

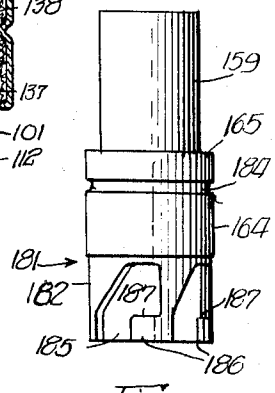


Fig. 13

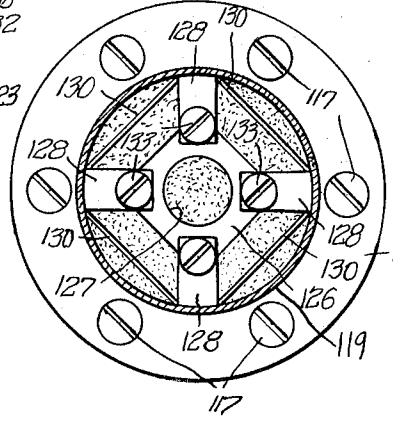
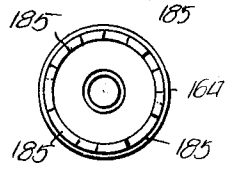


Fig. 17



United States Patent Office 3,304,390 Patented Feb. 14, 1967

3,304,390

CURRENT-LIMITING FUSE WITH DUAL ELEMENT RELEASE AND HAVING EXTENSIONS OF THE CURRENT-LIMITING ELEMENTS CUT BY ARC BLASTS IN ARC CHUTES AND BY A MECHANICAL CUTTER

Sigurd L. Lindell, Northbrook, Ill., assignor to S & C Electric Company, Chicago, Ill., a corporation of Delaware

Filed Jan. 27, 1966, Ser. No. 523,442
18 Claims. (Cl. 200—120)

This invention relates, generally, to fuses and it has particular relation to current-limiting fuses for use on alternating current circuits operating at voltages at and above 2,400 volts in which the normal current flow may range from 3 to 200 amperes. It constitutes an improvement over the current-limiting fuses described in my applications as follows: Serial No. 522,676, filed January 24, 1966; Serial No. 523,228, filed January 26, 1966; Serial No. 523,312, filed January 27, 1966; and assigned to the assignee of this application.

In the application first above referred to a current-limiting fuse is described having current calibrated fusible element means located in air within one of the fuse tube terminals and connected in series circuit relation with a plurality of parallel connected current-limiting fusible elements located in a filling of granular relatively inert material, such as sand, and having a common terminal at the junction with the calibrated fusible element means. Expressed in magnitude of current, the time-current curve for the current calibrated fusible element means lies below the time-current curve for the combined parallel connected current-limiting fusible elements while the time-current curve for an individual one of them lies below the time-current curve for the current calibrated fusible element means. In order to cause the current-limiting fusible elements to blow one by one on flow of relatively low fault current sufficient to blow the current calibrated fusible element means, spark gaps are provided one for each current-limiting fusible element. These spark gaps are connected in parallel with the gap that is formed on blowing of the current calibrated fusible element means. One electrode of each spark gap is connected to the junction between a major portion of the respective current-limiting fusible element and a minor portion or extension thereof. One of the spark gaps breaks down at random on blowing of the current calibrated fusible element means and the fault current divides between the major portion of the associated current-limiting fusible element and the minor portion or extension thereof which now is connected in series with the other parallel connected current-limiting fusible elements. As a result, a larger portion of the fault current flows through the extension or minor portion and it blows or melts. Then the total fault current flows through the major portion of the current-limiting fusible element and causes it to blow or melt at several points of reduced cross section along its length. Thereafter another of the spark gaps breaks down at random and this sequence is repeated until all of the current-limiting fusible elements have blown or melted and the circuit is finally completely opened.

An improvement over the current-limiting fuse of the first application above referred to is set forth in the application second above referred to. According to it the several minor portions or extensions of the current-limiting fusible elements are positioned in arc blast chutes in which the respective spark gaps also are located. These minor portions or extensions are positively cut or severed one by one mainly as the result of the heat and vapor heat generated by arcs formed at the spark gaps added to the heat generated by current flowing therethrough. Then

it is unnecessary to depend entirely upon the flow of a part of the fault current for opening the circuits through the minor portions or extensions of the current-limiting fusible elements.

In the applicaiton third above referred to there is described a further improvement over the current-limiting fuse of the first application. A spring biased mechanical impact member is employed for simultaneously severing the several minor portions or extensions of the current-limiting fusible elements. It is released on blowing of the current calibrated fusible element means. This action effectively opens the circuits through the minor portions or extensions of the current-limiting fusible elements on relatively low fault currents without requiring that a part of the fault current be used for melting or blowing them.

Among the objects of this invention are: In current-limiting fuses of the types referred to above to provide for increasing the time delay in the blowing of the current calibrated fusible element means for relatively low fault current below the current-limiting range to facilitate coordination with other circuit interrupting devices in the circuit; to employ a relatively slow current calibrated fusible element to respond to and initiate the clearing of relatively low fault currents in series with a relatively fast current-limiting section to respond to and interrupt high fault currents by current-limting action before the calibrated element blows; as expressed in current magnitude to position the low current long time end of the time-current characteristic of the current calibrated fusible element below the time-current characteristic of the current-limiting section but having the short time end of the latter substantially below the short time end of the former; to provide separate current responsive means to release an indicator before the current-limiting section has cleared a high fault current; to provide an indication that the current-limiting fuse has operated whether as a result of a low current fault or of a high current fault and whether or not the current calibrated fusible element means has blown; to movably mount the intermediate terminal to which one end of the current calibrated fusible element means is connected and to restrain it by an auxiliary fusible element that is connected in shunt with the minor portion or extension of one of the current-limiting fusible elements and in series with the major portion thereof; to employ the arc chutes of the second above identified application in conjunction with the dual element current calibrated fusible element means described herein; and to employ the mechanical impact member of the third above identified application in conjunction with the dual element current calibrated fusible element means disclosed herein.

In the drawings: FIG. 1 is a vertical sectional view, substantially at full scale, of a current-limiting fuse embodying one species of this invention. FIGS. 2, 3 and 4 are horizontal sectional views taken generally along the lines 2—2, 3—3 and 4—4 of FIG. 1. FIG. 5 is a top plan view of the ceramic arc chute member. FIG. 6 is a vertical sectional view taken generally along the line 6—6 of FIG. 5. FIG. 7 illustrates diagrammatically the circuit connections embodied in the current-limiting fuse shown in FIG. 1. FIG. 8 shows graphically the relation between the melting times of the various current carrying elements of the current-limiting fuse for different current flows therethrough. FIG. 9 shows graphically the current flow when the available short circuit magnitude of alternating current is so high that the current-limiting section melts on rise of current and the current flow is interrupted in a fraction of the first current loop by the current-limiting fuse embodying this invention. FIG. 10 is a vertical sectional view, substantially at full scale, of another cur-

rent-limiting fuse embodying this invention. FIG. 11 is a horizontal sectional view taken generally along the line 11—11 of FIG. 10. FIG. 12 is a vertical sectional view taken generally along the line 12—12 of FIG. 11. FIG. 13 is a horizontal sectional view taken generally along the line 13—13 of FIG. 10. FIG. 14 is a top plan view of the ceramic guide member shown in FIG. 15. FIG. 15 is a view, in side elevation, of the ceramic guide member shown in FIG. 14. FIG. 16 is a view, in side elevation, of the combined metallic indicator tube and impact member. FIG. 17 is a bottom plan view of the combined metallic indicator tube and impact member shown in FIG. 16.

In FIG. 1 the reference character 10 designates, generally, a current-limiting fuse which includes an elongated insulating housing 11 of ceramic material such as porcelain. It may be formed of other insulating material. The elongated insulating housing 11 has a fuse upper end terminal indicated, generally, at 12 and a fuse lower end terminal indicated, generally at 13. Each of the end terminals 12 and 13 includes a metallic ferrule 14 that is intended to be positioned in suitable fuse clips. Each metallic ferrule 14 has an indented portion 15 that fits into a groove 16 in the housing 11. Flanges 17 extend radially inwardly from the ends of the metallic ferrules 14 in overlying relation to connector plates 18 that are welded thereto and overlie the respective ends of the housing 11. Gaskets 19 are interposed, as shown, in order to prevent egress of inert granular material 20, such as sand, with which the housing 11 is filled.

The lower end terminal 13 includes a connector member 23 which has a radial flange 24 that overlies the flange 17 on the adjacent metallic ferrule 14. The lower end of the fuse housing 11 is closed by a cover plate 25 after the relatively inert granular material 20 has been inserted. Screws 26, extending through the peripheral portion of the cover plate 25 and the flanges 24 and 17 into the connector plates 18, serve to hold the several parts tightly in position. A threaded stud 27 extends through the central portion of the connector member 23 into the lower end of a ceramic core that is indicated, generally, at 28 and extends upwardly through the housing 11. The core 28 is provided with four vertical ribs 29 which are grooved as indicated at 30.

The current-limiting portion of the current-limiting fuse 10 is formed, for example, by four current-limiting fusible elements or ribbons 31 which are disposed in the grooves 30 and wound spirally around the ribs 29 of the ceramic core 28. Larger or smaller numbers of current-limiting fusible elements or ribbons 31 can be employed. The current-limiting fusible elements or ribbons 31 are formed of silver, silver alloy or nickel. They are provided with perforations 32 that are uniformly spaced from end to end to provide localized restricted cross sections to initiate fusion and arcing on flow of fault current. Terminal strips 33 have their ends 34 crimped to the lower ends of the current-limiting fusible elements or ribbons 31. The terminal strips 33 extend crosswise of the lower end of the ceramic core 28 with the threaded stud 27 extending therethrough. A nut 35 serves to securely clamp the central portion of the connector member 23 to the juxtaposed portions of the terminal strips 33. This construction provides a relatively low resistance connection from the lower ends of the current-limiting fusible elements or ribbons 31 to the lower end terminal 13 of the current-limiting fuse 10.

The upper ends of the current-limiting fusible elements or ribbons 31 extend through and are securely connected to terminal fittings 38 and thereby constitute a junction to which reference will be made hereinafter. The terminal fittings 38 are secured in a radial flange 39 of a ceramic arc chute member indicated, generally, at 40 and shown in more detail in FIGS. 5 and 6. The arc chute member 40 has a central opening 41 that is square in cross section for receiving a correspondingly shaped stem 42 that forms a part of an intermediate terminal which is indicated, generally, at 43 and is movably mounted near the upper end of the insulating housing 11. The stem 42 extends downwardly into the upper end of the central aperture 41 in the arc chute member 40.

The intermediate terminal 43 is held against upward movement by an auxiliary fusible element or strain wire 44 which is secured at its upper end to the stem 42 and extends downwardly through the central opening 41. Its lower end is anchored to an auxiliary terminal 45 which is secured by a transverse anchor pin 46 to the reduced upper end portion 47 of the ceramic core 28. The intermediate terminal 43 includes an enlarged body portion 48 which is slidably mounted at the lower end of a guide tube 49 that is formed preferably of ceramic insulating material. The guide tube 49 has an integral radially extending flange 50 at its lower end.

The intermediate terminal 43 also includes a lower fuse element terminal 51 to which the lower end of a current calibrated fusible element means, shown generally at 52, is connected. The current calibrated fusible element means 52 includes a coiled silver fusible element 53 and a strain wire 54. They are secured at their upper ends to an upper fuse element terminal 55 which extends upwardly through the top 56 of a metallic indicator tube 57 which is slidably mounted on the guide tube 49. The metallic indicator tube 57 is biased from the non-indicating position shown in FIG. 1 to an indicating position by a coil compression spring 58. It is interposed between the top 56 of the metallic indicator tube 57 and the upper end of the guide tube 49. As long as the current calibrated fusible element means 52 remains intact or unblown, the spring 58 is restrained and the metallic indicator tube 57 is held in the non-indicating position.

The upper fuse element terminal 55 also extends through a dished washer 59 and a nut 60 threaded on the upper end serves to hold the assembly in position. A garter spring 61 of berylium copper is interposed between the underside of the dished washer 59 and a conducting washer 62 to complete the current path to the upper end terminal 12. Screws 63 extend through the washer 62 and into the connector plates 18 to complete the assembly. A stop ring 64 is secured to the metallic indicator tube 57 intermediate its ends for limiting its upward movement to the indicating position. With a view to increasing voltage that appears between the fuse element terminals 51 and 55 when the current calibrated fusible element means 52 blows, it is surrounded by a fiber sleeve 65 which is secured at its upper end to the upper fuse element terminal 55.

Provision is made for extending the connection from the upper end terminal 12 into the upper end of the insulating housing 11. For this purpose a flange 67 is positioned under the washer 62 and is clamped thereto by the screws 63. The flange 67 extends radially outwardly from the upper end of a metallic tube 68 which projects inwardly of the insulating housing 11 and is surrounded by the relatively inert granular material 20, such as sand. The lower end of the metallic tube 68 is stepped at 69 for receiving the periphery of the flange 39 which forms an integral part of the ceramic arc chute member 40.

Those portions of the current-limiting fusible elements or ribbons 31 which are located between the lower end terminal 13 and the terminal fittings 38, FIG. 7, are referred to herein and in the claims as major portions 70 while the portions 71 that project upwardly from the terminal fittings 38 are referred to herein and in the claims as minor portions or extensions 71. The latter at 72 extend through the body portion 48 of the movable intermediate terminal 43 and are secured thereto by crimping. Each terminal fitting 38 is connected to the current-limiting fusible element or ribbon 31 at the junction between the perforated major portion 70 and perforated minor portions or extensions 71.

It will be observed that cavities or arc blast chutes **73** are formed between the flanges **39** and **50** of the ceramic arc chute member **40** and of the guide tube **49**. The lower ends of the arc blast chutes **73** are closed off by the flange **39** and their upper ends open into the space within the guide tube **49**. Since the terminal fittings **39** are mounted in the insulating flange **39**, they are insulated from the juxtaposed lower end portion of the metallic tube **68**. The spaces therebetween form spark gaps **74**, there being a spark gap **74** for each of the arc blast chutes **73** through each of which one of the perforated minor portions or extensions **71** of the current-limiting fusible elements or ribbons **31** extends. Preferably, each of the arc blast chutes **73** is provided with gas evolving material **75** for the purpose of increasing the blast action of the arc that is formed at the respective spark gap **74**. The material **75** can be an inorganic material such as calcium carbonate, magnesium borate or the like.

On low current operation on the formation of an arc at any of the spark gaps **74**, there is a flow of arc plasma and a blast action therefrom as indicated by arrows **76**. The arc blast impinges on the perforated minor portion or extension **71** in the respective arc blast chute **73** and it is promptly severed at the perforation **32** therein to interrupt the current flow therethrough.

Under normal operating conditions with the current-limiting fuse **10** in the unblown condition, the current path is from the upper end terminal **12**, through the garter spring **61** to the upper fuse element terminal **55**. The current path continues through the current calibrated fusible element means **55** to the movable intermediate terminal **43** and thence through the current-limiting fusible elements or ribbons **31** in parallel to the lower end terminal **13**. As seen in FIG. 7, a part of this current path extends through the auxiliary fusible element or strain wire **44** that is connected between the movable intermediate terminal **43** and stationary auxiliary terminal **45** in parallel with one of the minor portions or extensions **71**.

FIG. 8 shows the time-current characteristic for the several fusible elements. Here curve **78** represents the time-current relationship for the current calibrated fusible element means **52**. It is calibrated so as to melt or blow as indicated by solid line curve **78** and by its response at the long time end of this curve to determine the ampere rating of the current-limiting fuse **10**, which rating is conventionally approximately one-half of the five minute or ten minute melting current. The position of the curve **78** at its short time end indicates that the time-current characteristic of the current calibrated fusible element means **52** is relatively slow at intermediate and high currents with respect to the time-current characteristic of the combined current-limiting fusible elements or ribbons **31** to provide time delay at low and intermediate fault currents for coordination with other circuit interrupters, such as secondary breakers used in conjunction with distribution transformers. Broken line curve **79** indicates the time-current relationship for the blowing of all four of the parallel connected current-limiting fusible elements or ribbons **31**. In general terms, the time-current characteristics shown by curve **78** is relatively slow while the time-current characteristic shown by curve **79** is relatively fast and they intersect. This indicates that the arrangement is such that the current calibrated fusible element means **52** at the high current short time end of curve **78** would not blow or melt on flow of fault current before blowing or melting of the current-limiting fusible elements or ribbons **31** has occurred and the current has been interrupted by their current-limiting action. The succeeding curves, shown by broken lines **80**, **81** and **82**, show the time-current characteristics for the blowing of **3**, **2** and **1**, respectively, of the current-limiting fusible elements or ribbons **31**. The overall time-current characteristic of the current-limiting fuse **10** is shown by the upper end **78'** of the curve **78** and the lower end **79'** of the

curve **79** which is illustrated by a heavy broken line. To simplify the presentation the curves **78–82** here shown illustrate typical average R.M.S. current values. It is understood that allowance for plus or minus deviations are to be made with sufficient margin for coordination with other series connected current interrupting means and with sections within the current-limiting fuse **10**.

In some cases the flow of fault current may be so high that the circuit will be interrupted by the blowing of the current-limiting fusible elements or ribbons **31** without blowing or melting of the current calibrated fusible element means **52** and without the formation of arcs at the spark gaps **74**. This is shown by dotted line curve **83** in FIG. 8 for all four of the current-limiting fusible elements **31**. Curve **83'** in FIG. 8 shows the clearing time for one of the current-limiting fusible elements **31**. Under such operating conditions, if the intermediate terminal **43** were stationary, the metallic indicator tube **57** would not be released to show that the circuit had been interrupted by the current-limiting fuse **10**. It is for this reason that the auxiliary fusible element or strain wire **44**, which preferably is formed of relatively high resistance, high strength Nichrome wire and has a minimum current carrying capacity compatible with the tensile strength required to restrain the indicator tube **57**, is provided to melt or blow when the current-limiting fusible elements or ribbons **31** melt or blow and clear the circuit.

Curve **84** in FIG. 9 indicates the instantaneous current in a half loop of alternating current that is available to flow in the event of a high current fault provided some means is not introduced to limit such current flow to a value well below the maximum here indicated. Assuming that the current flow is as indicated at I_3 in FIG. 8 at time t_5, the current-limiting fusible elements or ribbons **31** blow substantially simultaneously. Because they are embedded in the filling of relatively inert granular material **20**, such as sand, the resistance of the circuit provided thereby rises rapidly so that the fault current I_3, instead of following the curve **84**, FIG. 9, rises only to a relatively low peak value and is rapidly decreased. At time t_6 it is reduced to zero.

In the event that the current calibrated fusible element means **52** does not blow under the fault conditions just described, after blowing of the minor portion or extension **71** in parallel with the auxiliary fusible element or strain wire **44**, the current flow shifts to it and it blows at time t_7 in FIGS. 8 and 9. This action, which occurs immediately following the melting of the current-limiting fusible elements **31** at the perforations **32** and before the flow of fault current has been interrupted thereby, releases the intermediate terminal **43** for movement together with the unblown or intact current calibrated fusible element means **52** under the influence of the spring **58** and the metallic indicator tube **57** is moved endwise of the insulating housing **11** to indicating position.

The above described coordinated melting or rupture of the auxiliary strain element **44** is provided at all current levels above I_2 up to the highest current-limiting level, i.e., for all time intervals shorter than t_3. During the melting period at these current levels the current is divided substantially equally between the parallel current-limiting fusible elements **31**. This is illustrated in FIGS. 8 and 9. For current level I_3 in the current-limiting region, the equal division may be substantially maintained during the arcing period until the current is interrupted as shown in FIGS. 8 and 9. At current levels above I_2 but below the current-limiting levels, when the melting time may be appreciable, the current is also divided approximately equally between the parallel current-limiting fusible elements **31**. A difference in melting time may cause current to shift from one of these elements to another during the arcing period which may extend through several current zeros, while the

initial short arch at the perforations 32 melt part or all of the unfused portions of the respective element until final interruption takes place. There is sufficient margin in time and current while arcing occurs in the current-limiting fusible element 31 with which the auxiliary fusible element or strain wire 44 is paired up to insure its melting or rupture to release the metallic indicator tube 57.

The time-current characteristics of the fusible elements of the current-limiting fuses disclosed in the above application are coordinated to effect release of the indicator at all fault levels. This does not permit the additional coordination that can be obtained employing fusible elements having the time-current characteristics as disclosed herein with which the auxiliary fusible element or strain wire 44 is employed to release the indicator tube 57 under certain conditions as herein disclosed.

As pointed out in the application first above referred to particular difficulty of interrupting the current is encountered when the flow of fault current is substantially lower. For example, it is conventional to rate a fuse to blow at a minimum value at approximately twice its normal current carrying rating. Such a fault current is indicated at I_1 in FIG. 8. In that case it will be observed that the flow of fault current is not sufficient to blow all four of the current-limiting fusible elements or ribbons 31 but it would be sufficient to blow one of them as indicated at t_2 along curve 82. By providing the spark gaps 74 in the manner described in said first application, it is possible successively to blow the major portion 70 of the current-limiting fusible elements or ribbons 31 so that, under the assumed conditions where the current flow is as indicated at I_1, they will be blown one by one.

As disclosed in the application second above referred to, the current calibrated fusible element means 52 is blown under conditions of relatively low fault current, such as the current I_1 at time t_1 in FIG. 8, and the voltage across the resulting gap between the fuse element terminals 51 and 55 is applied across the spark gaps 74 which, as shown in FIG. 7, are connected in parallel. One of them will break down at random so that an arc is formed therebetween, for example as indicated at 87. The action will be made more clear from a consideration of FIG. 1 which represents the conditions that exist when the arc 87 is drawn between the terminal fitting 38 shown to the left and adjacent the lower end of the metallic tube 68. The arc 87 is formed at the lower end of the arc blast chute 73. There is a tendency for the arc 87 to progress along the arc blast chute 83 and to impinge upon the adjacent part of the minor portion or extension 71 therein which is promptly severed. As a result the entire flow of fault current then takes place through the arc 87 and the associated current-limiting fusible element or ribbon 31 which blows or melts out at several perforations 34 therealong. This operation is repeated at random among the three remaining spark gaps 74, and under the low fault current conditions represented by the current I_1, the succeeding current-limiting fusible elements or ribbons 31 are blown one by one.

At the instant that the first spark gap 74 breaks down and the arc 87 is formed, one-fourth of the fault current flows through the perforated major portion 70 of the respective current-limiting fusible element or ribbon 31 and three-fourths of the fault current flows through the respective perforated minor portion or extension 71 and through the other three current-limiting fusible elements or ribbons 31. While this amount of fault current flowing through the perforated minor portion or extension 71 may be sufficient to cause it to blow or melt, this action is made much more certain by the provision of the arc blast chute 73 and the arrangement for causing the arc 87 positively to cut the adjacent perforated minor portion or extension 71, without depending upon this portion or extension to melt as a result of flow of a portion of the fault current therethrough. This action is enhanced through the provision of the arc extinguishing material 75. Since the arc blast chutes 73 and the portions or extensions 71 of the current-limiting fusible elements or ribbons 31 extending therethrough are segregated from the filling of inert granular material 20, such as sand, the cutting of the minor portions or extensions 71 sequentially in the manner described is unimpeded by the presence of the filling material 20.

In FIG. 10 the reference character 100 designates, generally, another embodiment of a current-limiting fuse that embodies the features of the current-limiting fuse disclosed in the application last above referred to. The current-limiting fuse 100 includes an elongated insulating housing 101 of ceramic material such as percelain. It may be formed of other insulating material. The elongated insulating housing 101 has a fuse upper end terminal indicated, generally, at 102 and a fuse lower end terminal indicated, generally, at 103. The upper end terminal 102 includes a metallic ferrule 104 that is secured by cement or other means to the upper end of the housing 101. The ferrule 104 has connector plates 105 welded thereto for receiving screws 106 that extend through a radial flange 107 that forms an integral part of a metallic terminal cap 108. The end terminal 102 also includes a metallic tube 109 that extends downwardly into the tubular insulating housing 101 and is provided with a radially inwardly extending flange 110. It will be understood that the metallic ferrule 104, metallic terminal cap 108 and the metallic tube 109 are solidly interconnected and that the metallic terminal cap 108 is arranged to be positioned in a fuse clip. Gaskets, shown collectively at 111, serve to prevent the egress of relatively inert granular material 112, such as sand, which fills the tubular insulating housing 101.

The lower end terminal 103 includes a metallic ferrule 115 that is suitably secured by cement to the lower end of the insulating housing 101. It has connector plates 116 welded thereto for receiving screws 117 that extend through a flange 118 which extends outwardly from a metallic terminal cap 119. The metallic terminal cap 119 has an opening 120 through which the granular material 112 can be introduced. A closure cap 121 is provided for the opening 120. The lower end terminal 103 also includes a connector plate 122. Gaskets, shown collectively at 123, are employed to prevent the egress of the granular material 112. It will be understood that the ferrule 115, metallic terminal cap 119, and the connector plate 122 are solidly interconnected and that metallic terminal cap 119 is arranged to be received by a fuse clip.

Extending centrally of the tubular insulating housing 101 is a ceramic core that is indicated, generally, at 126. The ceramic core 126 is provided with a central opening 127 and has four vertical ribs 128 that are provided with grooves 129 for receiving in spiral fashion preferably four or more current-limiting fusible elements or ribbons 130 which may be formed of silver, silver alloy or of a relatively high melting point higher resistivity metal such as nickel for current-limiting fuses of low ampere rating. Perforations 131 are uniformly spaced along each of the current-limiting fusible elements 130 to provide localized restricted cross-sections to initiate fusion and arcing on flow of fault current. The lower ends of the current-limiting fusible elements or ribbons 130 are connected by terminal clips 132 secured to the connector plate 122 by screws 133. Thus the lower ends of the current-limiting fusible elements or ribbons 130 are solidly connected to the fuse lower end terminal 103.

As shown at the upper end of FIG. 10 and in FIG. 12 the upper ends of the current-limiting fusible elements or ribbons 130 extend through metallic terminals 137 that are generally tubular in form and are suitably crimped to provide good contact engagement with the

current-limiting fusible elements or ribbons **130**. The terminals **137** extend through sleeves **138**, FIGS. 14–15, that are formed integrally with a flange **139** that forms a part of a guide member, shown generally at **140**, which has a central upstanding guide tube **141**. A gasket **142** underlies the flange **139** and serves to prevent egress of the granular material **112** from the insulating housing **101**.

As shown in FIGS. 10, 11 and 12 the current-limiting fusible elements or ribbons **130** extend horizontally as indicated at **143** from the upper ends of the terminals **137** and into intimate contact with a body portion **144** of an intermediate terminal that is indicated, generally at **145**, and is slidably mounted in the guide tube **141**. The body portion **144** is suitably crimped to the ends of the current-limiting fusible elements or ribbons **130**.

As pointed out, in accordance with this invention, the intermediate terminal **145** is slidably mounted in the guide tube **141**. It is restrained from upward movement therein by an auxiliary fusible element or strain wire **146** which is secured at its upper end to an extension **147** which depends from the body portion **144** of the intermediate terminal **145**. The lower end of the auxiliary fusible element or strain wire **146** is secured in an auxiliary terminal **148** which has a radial flange **149** that bears against a shoulder **150** at the top of a counter bore in the flange **139** of the guide member **140**. A conductor **151** connects the auxiliary terminal **148** to one of the current-limiting fusible elements or ribbons **130** for a purpose to be described. Slots **152** are provided in the guide tube **141** to receive the horizontal portions **143** of the current-limiting fusible elements or ribbons **130**.

The intermeditae terminal **145** also includes a lower fuse element terminal **153** to which the lower end of current calibrated fusible element means, shown generally at **154**, is connected. It includes a coiled silver fusible element **155** and a strain wire **156** with their upper ends being secured to an upper fuse element terminal **157** that projects through an apertured flange **158** of a metallic indicator tube **159**. A nut **160**, threaded on the upper end of the upper fuse element terminal **157** serves to hold the assembly in place as long as the current calibrated fusible element means **154** and the auxiliary fusible element or strain wire **146** remain unblown.

The upper end of the metallic indicator tube **159** extends into a flanged opening **161** in the metallic terminal cap **108**. Contact engagement is maintaned with the metallic indicator tube **159** when it moves from the non-indicating to indicating position by contact fingers **162** which are secured by screws **163** to the radially inwardly extending flange **110** from the metallic tube **109**. The screws **163** project into the upper ends of the vertical ribs **128** of the ceramic core **126**. The metallic indicator tube **159** has an enlarged lower end portion **164** which forms a shoulder **165** that is arranged to limit the upward movement of the metallic indicator tube **159** as it is urged upwardly by a coil compression spring **166** on blowing of the current calibrated fusible element means **154**. The coil compression spring **166** is positioned between the underside of the apertured flange **158** and a stepped metallic ring **167** which overlies the upper end of the guide tube **141**. A fiber fuse tube **168** is secured to the upper fuse element terminal **157** and extends downwardly over the current calibrated fusible element means **154**. The fiber fuse tube **168** is employed for evolving an arc extinguishing medium on blowing of the current calibrated fusible element means **154** and for increasing the arc voltage between the fuse element terminals **153** and **157**.

It is desirable that provision be made for blowing the current-limiting fusible elements or ribbons **130** one by one, particularly on flow of relatively low fault current. In order to accomplish this terminal conducting strips **170** are connected to a junction **171** between a minor portion or extension **172** of the respective current-limiting fusible element or ribbon **130**, which includes the horizontal portion **143**, and a major portion **173** of the respective current-limiting fusible element or ribbon **130**. The arrangement is generally similar to that illustrated diagrammatically in FIG. 7 with reference to the current-limiting fuse **10**. The terminal conducting strips **170** are held in place by screws **174** that are threaded into the respective vertical rib **128** of the ceramic core **126**. Each of the terminal conducting strips **170** is provided at its upper end with an electrode **175** that extends into an opening **176** in the flange **139** of the guide member **140**. Above each opening **176** there is a vent opening **177** in the radially inwardly extending flange **110** of the metallic tube **109**. This arrangement provides a spark gap **178** between the electrode **175** and the adjacent portion of the flange **110** which constitutes the other electrode.

On blowing of the current calibrated fusible element means **154** as the result of flow of fault current therethrough or on blowing of the auxiliary fusible element or strain wire **146**, the spring **166** no longer is restrained. It moves the metallic indicator tube **159** upwardly until the shoulder **165** engages the underside of the top of the metallic terminal cap **108**. This indicates that the current-limiting fuse **100** has blown and should be replaced. The blowing of the current calibrated fusible element means **154** is accompanied by the formation of a gap between the fuse element terminals **153** and **157** across which a voltage appears that is applied to the spark gaps **178**. One of them at random breaks down and an arc is formed at this spark gap. This arc corresponds to the arc **87**, FIG. 7, that is formed under similar conditions in the operation of the current-limiting fuse **10**. One fourth of the fault current then flows through the major portion **174** of the respective current-limiting fusible element or ribbon **130** while three fourths of it flows through the respective minor portion or extension **172** thereof to the intermediate terminal **145** and thence through the remaining three current-limiting elements or ribbons **130**. While this amount of fault current flowing through the perforated minor portion or extension **172** may be sufficient to cause it to blow or melt, this action is made more certain by use of a mechanical impact member, shown generally at **181** and in detail in FIGS. 16 and 17. The mechanical impact member **181** preferably is formed of insulating material, such as a ceramic material, and it has a cylindrical body portion **182** that telescopes into the enlarged lower end portion **164** of the metallic indicator tube **159**. The cylindrical body portion **182** has an annular groove **183** for receiving an indented portion **184** of the enlarged lower end portion **173**. At its lower end the cylindrical body portion **182** has slots **185** to permit application of the mechanical impact member **181** with respect to the horizontal portions **143** of the current-limiting fusible elements or ribbons **130** and positioning integrally formed teeth **186** the upper cutting or impacting edges **187** of which are arranged to engage the undersides of the horizontal portions **143** under the influence of the coil compression spring **166** to sever them mechanically immediately upon blowing of the current calibrated fusible element means **154**. Preferably the spring **166** is capable of exerting a force of the order of 10 pounds. Since the horizontal portions **143** are arranged to be relatively taut, they can be severed readily by the mechanical impact member **181** when it moves upwardly under the influence of the coil compression spring **166**.

Thus it is unnecessary to rely upon the transfer of fault current to the minor portions or extensions **173** of the current-limiting fusible element or ribbons **130** for blowing them by fault current flowing therethrough and transferring the flow of fault current back to the major portion **173** in each case. Instead, on blowing of the current calibrated fusible element means **154**, the minor portions or extensions **172** are promptly severed mechani-

cally by the mechanical impact member **181**. The voltage then appearing at the gap formed by the blowing of the current calibrated fusible element means **154** is applied across the spark gaps **178** in parallel. One of them at random breaks down and the fault current then flows through the respective major portion **173** until it blows at several points therealong as determined by the locations of the perforations **131**. The arc voltage then is transfererd to the remaining spark gaps **178** and they break down at random followed by the successive blowing of the remaining current-limiting fusible elements or ribbons **130**.

Under normal operating conditions with the current-limiting fuse **100** in the unblown condition, the current path is from the upper end terminal **102** through the contact fingers **162** to the metallic indicator tube **159** and thence through upper fuse element terminal **157**, the current calibrated fusible element means **154**, intermediate terminal **145** and current-limiting fusible elements or ribbons **130** to the lower end terminal **103**.

The current path also includes the auxiliary fusible element or strain wire **146** which interconnects the intermediate terminal **145** and the auxiliary terminal **148**, with the latter being connected through conductor **151** to the junction **171** between the minor portion or extension **172** and the major portion **173** of one of the current-limiting fusible elements or ribbons **130**. Thus the auxiliary fusible element or strain wire **146** is connected in parallel circuit relation with the minor portion or extension **172** of one of the current-limiting fusible elements or ribbons **130**.

The reason for the provision of the auxiliary fusible element or strain wire **146** is that, as pointed out above, in some cases the flow of fault current may be so high that the circuit will be interrupted by the blowing of the current-limiting fusible elements **130** without blowing or melting of the current calibrated fusible element means **154**. Under such operating conditions, as indicated hereinbefore, if the intermediate terminal **145** were held stationary, the metallic indicator tube **159** would not be released to show that the circuit had been interrupted by the current-limiting fuse **100**.

In the event that the current calibrated fusible element means **154** does not blow under fault conditions that result in the blowing of the current-limiting fusible elements or ribbons **130**, after blowing of the minor portion or **172** in parallel with the auxiliary fusible element or strain wire **146**, the current flow shifts to it and it blows at time t_7 shown in FIGS. 8 and 9. The intermediate terminal **145** then is no longer restrained and it moves upwardly together with the unblown current calibrated fusible element means **154** under the influence of the coil compression spring **166**. Also, the metallic indicator tube **159** is moved upwardly of the insulating housing **101** to indicating position.

Since the curves shown in FIGS. 8 and 9 of the drawings and described hereinbefore with reference to the operation of the current-limiting fuse **10** are also applicable to the operation of the current-limiting fuse **100**, a description thereof will not be repeated with respect to the functioning of the current-limiting fuse **100**.

It will be understood that the provision of the current-limiting fuse disclosed in the application first above referred to can be constructed to have time-current characteristics as shown by FIGS. 8 and 9. In such case the auxiliary fusible element or strain wire **44** or **146** can be employed in the manner described herein to insure release of the indicator under all fault current conditions.

What is claimed as new is:

1. A current-limiting fuse including:
- an elongated insulating housing with end terminals,
- an intermediate terminal in said housing insulated from said end terminals,
- fusible element means interconnecting one end terminal and said intermediate terminal,
- a plurality of current-limiting fusible elements embedded in an inert filling in said housing and connected in parallel circuit relation between said intermediate terminal and the other end terminal,
- a minor portion of each current-limiting fusible element adjacent said intermediate terminal constituting an extension of a major portion thereof,
- means providing a spark gap individual to each current-limiting fusible element, one terminal of each spark gap being connected to the junction between the respective extension and the major portion of its current-limiting fusible element, the other terminal of each spark gap including conductor means connected to said one end terminal thereby placing said spark gaps in shunt circuit relation to the gap formed on blowing of said fusible element means on flow of fault current therethrough,
- an auxiliary terminal connected to the junction of one of said current-limiting elements,
- means interconnecting said intermediate terminal and said auxiliary terminal, and
- means responsive to blowing of at least one of said current-limiting fusible elements for interrupting the connection between said intermediate terminal and said auxiliary terminal.

2. The current-limiting fuse according to claim **1** wherein:
- the intermediate terminal is movably mounted,
- spring means act through the fusible element means to bias said intermediate terminal, and
- the means interconnecting said intermediate terminal and the auxiliary terminal prevents movement of said intermediate terminal by said spring means.

3. The current-limiting fuse according to claim **2** wherein the means interconnecting the intermediate terminal and the auxiliary terminal comprises auxiliary fusible element means.

4. The current-limiting fuse according to claim **3** wherein an indicator is movable endwise of the elongated housing, is biased to indicating position by the spring, and is restrained in non-indicating position as long as both the fusible element means and the auxiliary fusible element means remain intact.

5. The current-limiting fuse according to claim **1** wherein means responsive to blowing of the fusible element means sever the extensions of the major portions of the current-limiting fusible elements.

6. The current-limiting fuse according to claim **1** wherein means individual to each extension provide an arc blast chute in which the extension is located.

7. The current-limiting fuse according to claim **4** wherein each arc blast chute has at least a portion of its inner surface formed by a material capable of evolving a gaseous medium when subjected to the heat of the arc formed at the respective spark gap for increasing the blast action in the chute.

8. The current-limiting fuse according to claim **1** wherein means operated in response to blowing of the fusible element means mechanically severs the extensions.

9. The current-limiting fuse according to claim **8** wherein:
- the severing means is a mechanical impact member movable endwise of the elongated housing, and
- spring means restrained by fusible element means and the auxiliary fusible element means bias said mechanical impact member to sever said extensions.

10. The current-limiting fuse according to claim **9** wherein at least the impact portion of the impact member is formed of insulating material.

11. The current-limiting fuse according to claim **9** wherein the means interconnecting the intermediate terminal and auxiliary terminal comprises auxiliary fusible element means.

12. The current-limiting fuse according to claim **11** wherein an indicator is movable endwise of the elongated

housing conjointly with the impact member from non-indicating position to indicating position on blowing of either the fusible element means or the auxiliary fusible element means.

13. The current-limiting fuse according to claim 1 wherein each current-limiting fusible element is provided with substantially uniformly spaced reduced cross sections to provide locations at which it blows on flow of fault current.

14. In a current-limiting fuse, in combination:
current calibrated fusible element means,
a movable terminal connected to said current calibrated fusible element means,
a plurality of parallel connected current-limiting fusible elements connected to said movable terminal and thereby in series circuit relation with said current calibrated fusible element means,
a spring,
a movable indicator biased by said spring to indicating position and restrained by said current calibrated fusible element means,
a stationary auxiliary terminal connected to a junction between a minor portion of one of said current-limiting fusible elements and the major portion thereof,
an auxiliary fusible element interconnecting said movable and stationary auxiliary terminals and restraining said indicator from movement by said spring in tandem wtih said current calibrated fusible element means, and
means responsive to blowing of said current calibrated fusible element means for causing said current-limiting fusible elements to blow one by one,
said indicator being released for movement to indicating position on blowing of said current calibrated fusible element means, and
said auxiliary fusible element being blown on flow of relatively high fault current sufficient to blow said current-limiting fusible elements without blowing said current calibrated fusible element means whereby said indicator is released for movement to indicating position.

15. In a current-limiting fuse, in combination:
current calibrated fusible element means,
a plurality of parallel connected current-limiting fusible elements connected in series circuit relation with said current calibrated fusible element means,
the current values of the long time end of the time-current characteristic curve for said current calibrated fusible element means lying below the current values of the long time end of the time-current characteristic curve for said plurality of parallel connected current-limiting fusible elements,
the current values of the short time end of said time-current characteristic curve for said current calibrated fusible element means lying above the current values of the short time end of said time-current characteristic curve for said plurality of parallel connected current-limiting fusible elements, and
means responsive to blowing of said current calibrated fusible element means at current values along said long time end of its time current characteristic curve including a spark gap individual to and connected in series circuit relation with each current-limiting fusible element and connected in parallel circuit relation with said current calibrated fusible element for causing said current-limiting fusible elements to blow one by one.

16. In a current-limiting fuse, in combination:
current calibrated fusible element means,
a plurality of parallel connected current-limiting fusible elements connected in series circuit relation with said current calibrated fusible element means,
the current values of the long time and of the time-current characteristic curve for said current calibrated fusible element means lying below the current values of the long time end of the time-current characteristic curve for said plurality of parallel connected current-limiting fusible elements,
the current values of the short time end of said time-current characteristic curve for said current calibrated fusible element means lying above the current values of the short time end of said time-current characteristic curve for said plurality of parallel connected current-limiting fusible elements,
means responsive to blowing of said current calibrated fusible element means at current values along said long time end of its time-current characteristic curve for causing said current-limiting fusible elements to blow one by one,
indicator means biased from non-indicating to indicating position and restrained from movement as long as said current calibrated fusible element means remains intact,
auxiliary means cooperating with said current calibrated fusible element means to restain said indicator means, and
means responsive to blowing of said current-limiting fusible elements without blowing of said current calibrated fusible element means for releasing said indicator means.

17. The current-limiting fuse according to claim 15 wherein:
means connect each spark gap in series circuit relation with a major portion of the respective current-limiting fusible element and to the current calibrated fusible element means through the respective minor portion of said current-limiting fusible element, and
an arc blast chute through which the respective minor portion extends.

18. The current-limiting fuse according to claim 15 wherein:
means connect each spark gap in series circuit relation with a major portion of the respective current-limiting fusible element and to the current calibrated fusible element means through the respective minor portion of said current-limiting fusible element, and
means operated in response to blowing of said current calibrated fusible element means for mechanically severing said minor portions.

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BERNARD A. GILHEANY, *Primary Examiner.*

H. B. GILSON, *Assistant Examiner.*