Feb. 14, 1967 S. I. LINDELL 3,304,388

CURRENT-LIMITING FUSE HAVING ARC CHUTES IN WHICH ARCS ARE FORMED TO CUT EXTENSIONS OF THE CURRENT-LIMITING ELEMENTS

Filed Jan. 26, 1966

2 Sheets-Sheet 1

Fig. 1

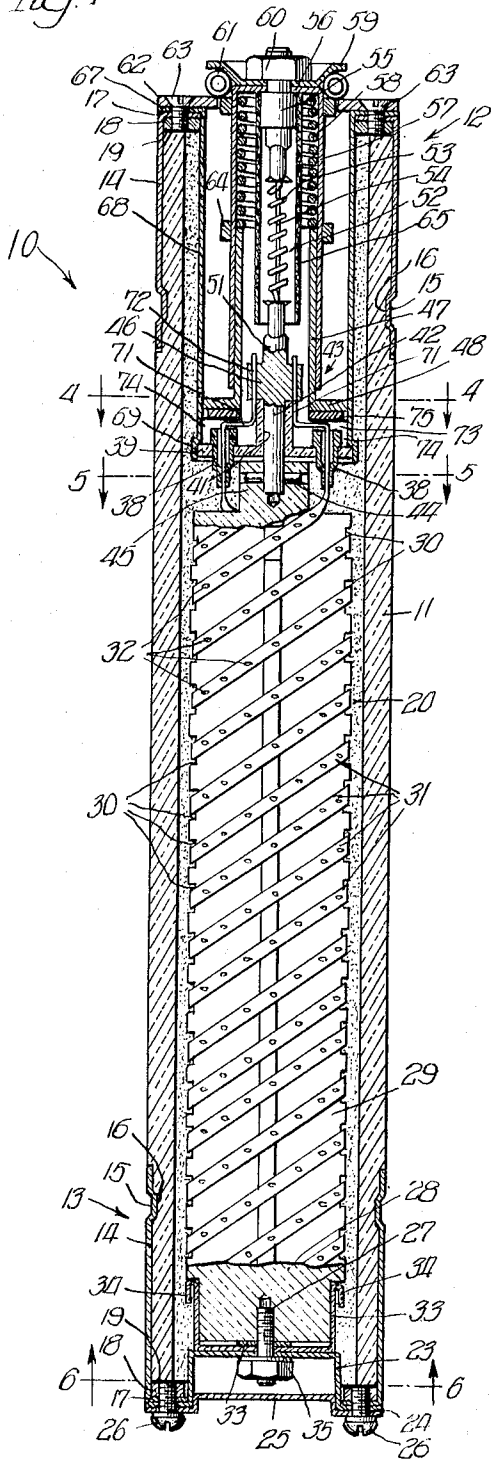


Fig. 2

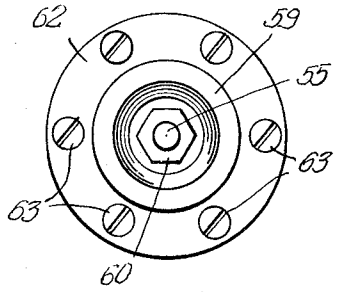
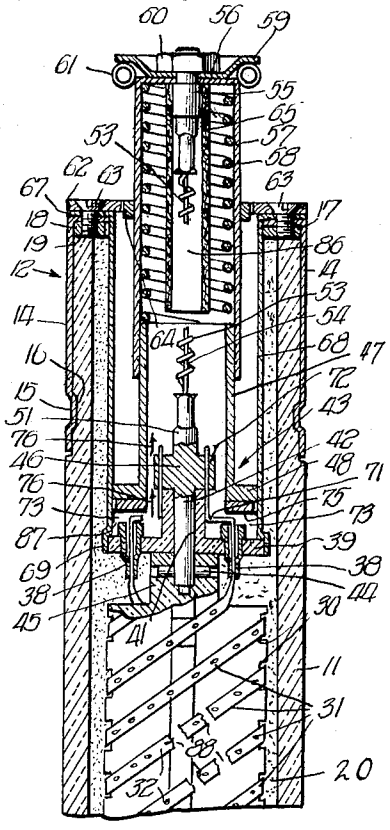


Fig. 3



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Fig. 4

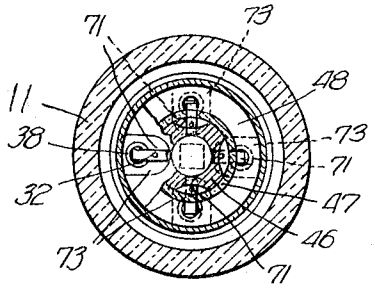


Fig. 5

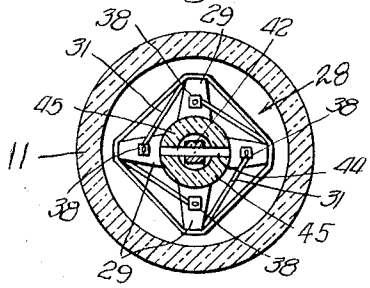


Fig. 6

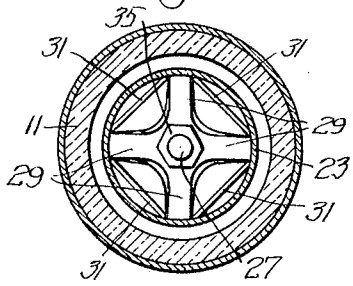


Fig. 7

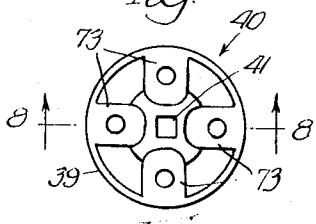


Fig. 8

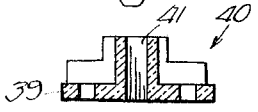


Fig. 9

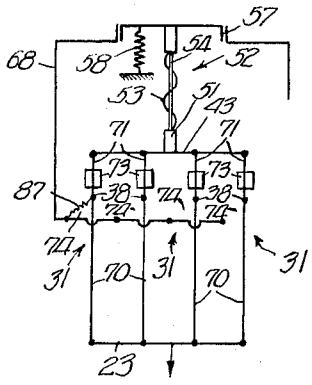


Fig. 10

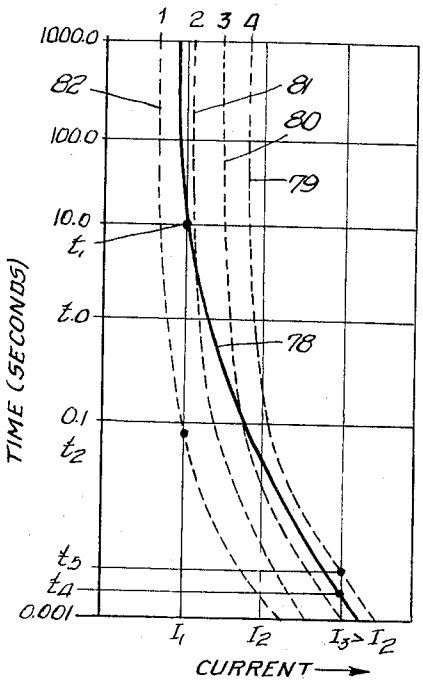
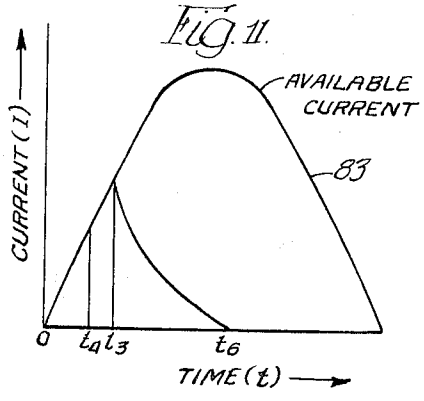


Fig. 11



United States Patent Office 3,304,388
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3,304,388

CURRENT-LIMITING FUSE HAVING ARC CHUTES IN WHICH ARCS ARE FORMED TO CUT EXTENSIONS OF THE CURRENT-LIMITING ELEMENTS

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Filed Jan. 26, 1966, Ser. No. 523,228
13 Claims. (Cl. 200—120)

This invention relates to fuses and particularly to current-limiting fuses for use in 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 invention disclosed in my application Serial No. 522,676 filed January 24, 1966, and assigned to the assignee of this application.

In the application 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 current calibrated fusible element. 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 a major portion of the associated current-limiting fusible element and a 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 blows or melts it whereupon 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. Then 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.

Among the objects of this invention are: In a current-limiting fuse of the type referred to above to provide for segregating the minor portions or extensions of the current-limiting fusible elements from the major portions thereof and to cause these minor portions or extensions to blow on flow of lower values of fault current than is the case for the construction shown in the above application; to locate the minor portions or extensions in air; to sever the minor portions or extensions one by one from the common terminal; to accomplish this by providing an arc chute for each minor portion or extension in which the respective spark gap is located and by employing the heat of the arc formed at the spark gap directly and through a blast of plasma therefrom to cut the minor portion or extension of each current-limiting fusible element rapidly; to increase the blast action of the arc by providing in each arc chute a material from which a gaseous medium is evolved due to the heat of the arc at the respective spark gap; by these means to blow all of the parallel current-limiting fusible elements more rapidly in a shorter total time at a given total low fault current; and to provide greater latitude in the selection of material for and design of the current-limiting fusible elements and in the shape and relative locations of their time-current curves with respect to the time-current curve of the current calibrated fusible element.

In the drawings:

FIG. 1 is a vertical sectional view at substantially full scale of a current-limiting fuse embodying this invention.

FIG. 2 is a top plan view of the current-limiting fuse shown in FIG. 1.

FIG. 3 is a view similar to FIG. 1 but showing only the upper end thereof with the indicator tube in the alternate position showing that the fuse has blown.

FIGS. 4, 5 and 6 are horizontal sectional views taken generally along the lines 4—4, 5—5 and 6—6, respectively, of FIG. 1.

FIG. 7 is a top plan view of the ceramic arc chute member.

FIG. 8 is a vertical sectional view taken generally along the line 8—8 of FIG. 7.

FIG. 9 illustrates diagrammatically the circuit connections embodied in the current-limiting fuse shown in FIG. 1.

FIG. 10 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. 11 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.

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 by several current-limiting fusible elements

or ribbons 31 which are disposed in the grooves 30 and wound around the ribs 29 of the ceramic core 28. Preferably four or more elements or ribbons 31 are employed. The current-limiting fusible elements or ribbons 31 may be formed of silver. For the lower ampere ratings, when it is desirable to use the greatest practical number of elements in parallel, they are formed of materials having a higher resistivity and higher mechanical strength than silver. For example nickel and alloys of silver can be used. 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 clamp securely 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 by crimping to terminal fittings 38 and thereby constitute a junction to which reference will be made hereinafter. The terminal fittings 38 are secured as by cementing to a radial flange 39 of a ceramic arc chute member as indicated, generally, at 40 and shown in more detail in FIGS. 7 and 8. 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 common terminal which is indicated, generally, at 43 and is located near the upper end of the insulating housing 11. The stem 42 extends downwardly through the central aperture 41 in the arc chute member 40 and into the upper end of the ceramic core 28 where it is secured by a transverse anchor pin 44 that extends through a reduced upper end portion 45 of the ceramic core 28. The intermediate terminal 43 includes an enlarged body portion 46 which is located at the lower end of a guide tube 47 that is formed preferably of ceramic insulating material. The guide tube 47 has an integral radially extending flange 48 at its lower end.

The intermediate terminal 43 also includes a lower fuse element terminal 51 to which the lower end of current calibrated fusible element means, shown generally at 52, is connected. It 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 47. The metallic indicator 57 is biased from the non-indicating position shown in FIG. 1 to the indicating position shown in FIG. 3, 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 47. 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 preferably 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 position as shown in FIG. 3. With a view to increasing the 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 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 46 of the intermediate terminal 43 and are secured thereto by crimping. The terminal fittings 38 then are connected by crimping to the current-limiting fusible elements or ribbons 31 at the junction provided by these terminal fittings between the perforated major portions 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 48 of the ceramic arc chute member 40 and of the guide tube 47. The lower ends of the arc blast chutes 73 are closed off by the flange 39 and their upper ends open through channels in the intermediate terminal 43 into the space within the guide tube 47. Since the terminal fittings 38 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 gas generating material 75 is in the form of an annular washer and 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 lateral part of the perforated minor portion or extension 71 in the respective arc blast chute 73 and the minor portion or extension 71 is promptly cut at the perforation 32 therein to interrupt the current flow therethrough. This leaves the entire fault current flowing through the corresponding major portion 70 to melt at the numerous perforations 32.

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 52 to the intermediate terminal 43 and thence through the current-limiting fusible elements or ribbons 31 in parallel to the lower end terminal 13.

FIG. 10 shows the time-current characteristics 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 curve 78 and by its response at the upper or 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. 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**. It will be observed that curve **78** is entirely to the right or above the curve **78**. This indicates that the arrangement is such that the current calibrated fusible element means **52** blows or melts first on flow of fault current followed by blowing or melting of the current-limiting fusible elements or ribbons **31**. The succeeding curves, shown by broken lines **80**, **81** and **82**, show the time-current relationships for the blowing of **3**, **2** and **1**, respectively, of the current-limiting fusible elements or ribbons **31**. To simplify the presentation the curves **78–82** here shown illustrate typical average 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 the sections within the current-limiting fuse **10**. A greater number of current-limiting fusible elements or ribbons **31** in parallel permits the use of smaller cross section individual current-limiting elements for a given current rating and provides a higher speed of response of each individual current-limiting element on low current operation.

Curve **83** in FIG. 11 indicates the 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. 10 at time t_4, the current calibrated fusible element means **52** blows. This is indicated at t_4 in FIG. 11, and is followed at t_5 by the blowing of the current-limiting fusible elements or ribbons **31** 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, instead of following the curve **83**, is rapidly decreased and at time t_6, FIG. 11, is reduced to zero.

No particular difficulty is encountered in the operation of the current-limiting fuse **10** in the event that it is subjected to the flow of relatively high fault current. When this occurs, the current calibrated fusible element means **52** blows and forms a gap **86**, FIG. 3. This is accompanied by the simultaneous melting or blowing of the current-limiting fusible elements or ribbons **31** which perform their current-limiting function in the manner described. As a result of blowing of the current calibrated fusible element means **52**, the coil compression spring **58** no longer is restrained. It moves the metallic indicator tube **57** to the position shown in FIG. 3 to indicate that the current-limiting fuse **10** has blown and should be replaced.

As pointed out in the application above referred to particular difficulty is encountered when the flow of fault current is substantially lower. For example, it is conventional to rate the 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. 10. 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, it is possible successively to blow 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.

After 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. 10, the voltage across the resulting gap **86** is applied across the spark gaps **74** which, as shown in FIG. 9, 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** in FIG. 9. The action will be made more clear from a consideration of FIG. 3 which represents the condition that exists when the arc **87** is struck between the terminal fitting **38** shown to the left and the adjacent lower end of the metallic tube **68**. The arc **87** is formed at the outermost lower end of the arc blast chute **73** in a pocket formed by the arc chute member **40**, the radial flange **48** and guide tube **47** all of which are formed of insulation. The arc **87** persists between the spark gap electrodes. There is a tendency for the arc **87** to progress along the arc blast chute **73** and to impinge upon the adjacent part of the minor portion or extension **71** therein. This together with the blast of plasma impinging on the perforated portion promptly cuts it. As a result the flow of current to the intermediate common terminal **43** ceases and the entire flow of fault current then takes place through the arc **87** and the major portion **70** of the associated current-limiting fusible element or ribbon **31** which blows or melts out promptly at numerous perforations **34** therealong as indicated at **88** in FIG. 3. 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 to interrupt the current flow.

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 and rapid by the provision of the arc blast chute **73** and the arrangement for causing the heat of the arc **87** and the blast therefrom 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 gas producing material **75** which intensifies the blast. Since the arc blast chutes **73** and the portions or extensions **71** of the current-limiting fusible elements or ribbons **31** extending therethrough are located in air and thus 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**.

When the arc blast chutes **73** are employed in the manner herein described, it is possible to employ relatively larger conductors for the current-limiting fusible elements or ribbons **31** than would otherwise be the case. Accordingly, the current-limiting fuse **10** can be made in lower ampere ratings since it is possible from a mechanical standpoint to handle more readily the larger cross sections of current-limiting fusible elements or ribbons **31** made from high resistivity high strength materials and provide the perforations therein. In the current-limiting fuse disclosed in the above referred to application the long time end of the time-current curve of a single current-limiting fusible element must be low enough in amperes so that the minor portion or extension of the next to the last element to be blown melts at one-half the total low fault current. In the present invention the heating of each of the current-limiting fusible elements **31** by current flow therethrough is so augmented and overshadowed by the arc blast effect in the respective arc blast chute **73** that it can be cut at current values even below the long time melting current of the current-limiting fusible element. This not only permits a wider choice in the selection of size and material for the current-limiting fusible elements but also al-

lows greater latitude in the shape and position of the time-current characteristic of the individual element and the time-current characteristic of the combined parallel current-limiting fusible elements 31 with respect to the time-current characteristic of the current calibrated fusible element means 52. For a particular fuse having a given number of parallel current-limiting fusible elements 31 the time-current characteristic curve 79 of the current-limiting section can be placed farther from the long time end of the time-current characteristic curve 78 of the current calibrated fusible element means 52 to reduce current density and heating in the current-limiting section so long as the total lowest fault current remains sufficient to melt the major portion 70 of an individual current-limiting fusible element 31 promptly at several places, such as shown at 88 in FIG. 3.

What is claimed as new is:

1. In a current-limiting fuse including:
an elongated insulated housing with end terminals,
an intermediate terminal in said housing insulated from said end terminals,
current calibrated fusible element means interconnecting one end terminal and said intermediate terminal, and
a plurality of current-limiting fusible elements embedded in a granular filling in said housing and connected in parallel circuit relation between said intermediate terminal and the other end terminal,
the improvement comprising:
a minor portion of each current-limiting fusible element adjacent said intermediate terminal constituting an extension of a major portion thereof,
means individual to each extension providing an arc blast chute in which the extension is located, and
means providing a spark gap individual to each current-limiting fusible element in the respective arc blast chute, 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 current calibrated fusible element means on flow of fault current therethrough.

2. The current-limiting fuse according to claim 1 wherein the conductor means is a metallic tube extending from the one end terminal into the elongated housing.

3. The current-limiting fuse according to claim 2 wherein:
the inner end of the metallic tube provides a common electrode for the spark gaps, and
the other electrode for each spark gap comprises a terminal member connected to the respective junction in spaced relation to said inner end of said metallic tube.

4. The current-limiting fuse according to claim 3 wherein the extension of each current-limiting fusible element and the respective arc blast chute are located externally of the relatively inert filling in the housing.

5. The current-limiting fuse according to claim 1 wherein on blowing of the current calibrated fusible element means the voltage across the resulting gap is applied to the spark gaps one of which breaks down at random to cause part of the fault current to flow through the major portion of the associated current-limiting fusible element and the balance of the fault current to flow through the associated extension causing it to blow as assisted by the heat of the arc in the respective arc blast chute, this sequence of operations being repeated until all of the current-limiting fusible elements have blown.

6. The current-limiting fuse according to claim 5 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 arc formed at the respective spark gap for increasing the blast action in the chute.

7. The current-limiting fuse according to claim 5 wherein a spring tensions the fusible element means and lengthens the gap formed on blowing thereof.

8. The current-limiting fuse according to claim 7 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 the current calibrated fusible element means remains intact.

9. The current-limiting fuse according to claim 5 wherein:
the intermediate terminal is located at one end of the insulated housing, and
the minor portions of the current-limiting fusible elements and their arc blast chutes are located in air at said one end of said insulated housing.

10. The current-limiting fuse according to claim 1 wherein the intermediate terminal is stationarily mounted in the insulating housing.

11. The current-limiting fuse according to claim 1 wherein the current-limiting fusible elements are formed of metal having a higher resistivity and higher strength than silver.

12. 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 elements 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 and above the long time end of the time-current characteristic curve for one of said parallel connected current-limiting fusible elements, and
means responsive to blowing of said current calibrated fusible elements means for causing said current-limiting fusible elements to blow one by one including:
a spark gap individual to and connected in series circuit relation with a major portion of each current-limiting fusible element and connected in parallel circuit relation through a minor portion of the respective current-limiting fusible element with said current calibrated fusible element, and
an arc blast chute for each spark gap through which the respective minor portion extends.

13. The current-limiting fuse according to claim 12 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.

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