June 14, 1966 T. F. BRANDT 3,256,409

CURRENT-LIMITING ELECTRIC FUSE

Filed June 22, 1964

FIG. 1.

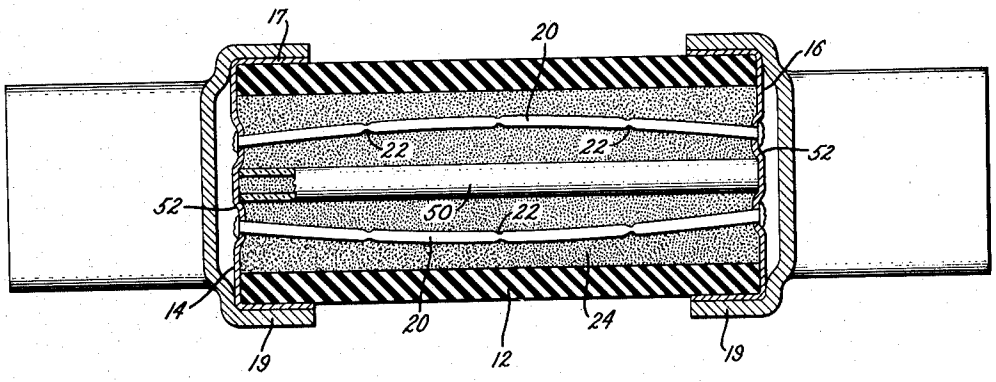


FIG. 2.

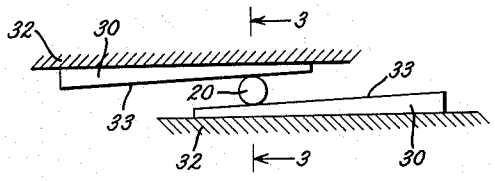


FIG. 3.

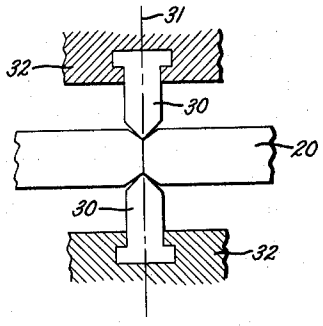


FIG. 4.

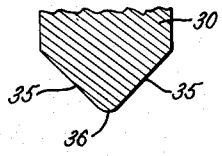


FIG. 5.

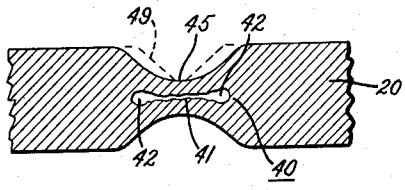
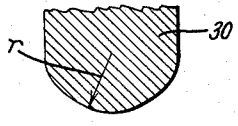


FIG. 6.



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United States Patent Office 3,256,409
Patented June 14, 1966

3,256,409

CURRENT-LIMITING ELECTRIC FUSE

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Filed June 22, 1964, Ser. No. 376,837
8 Claims. (Cl. 200—120)

This invention relates to a current-limiting type of electric fuse and, more particularly, to a fuse of this type comprising one or more fusible elements of wire form, each of which is surrounded about its entire periphery along most of its length by a granular arc-extinguishing filler.

It is customary to provide each fusible element of a current-limiting fuse with one or more regions of reduced cross section. Current flowing through the fusible element produces local hot spots at these regions of reduced cross section, and these hot spots serve to establish the temperature conditions along the fusible element necessary for melting at the desired times. In addition, these regions of reduced cross section control the rate at which arc voltage builds up when the fuse interrupts a large short-circuit current.

The present invention is particularly concerned with a fusible element of wire form in which each region of reduced cross section is formed by providing the wire element with a notch that extends about its periphery at a longitudinally restricted location. A problem that arises from the use of such a notch is that the notched portion of the wire tends to be mechanically weak, particularly if the wire is of a small diameter. This weakness makes the notched wire element susceptible to mechanical failures when subjected to mechanical shocks or vibrations or to differential thermal expansion of the fuse components.

Merely increasing the cross sectional area of the notched portion is not a satisfactory solution to the mechanical strength problem because usually it detrimentally affects the electrical performance of the fuse. This is the case because the increased cross section reduces the element resistance, which, in turn, unduly prolongs the melting time for both overcurrents and short circuit currents.

An object of my invention is to improve the ability of a notched-wire fusible element to withstand mechanical shocks and vibrations and thermally-induced stresses, yet without producing any lengthening of the melting time of the fusible element under overcurrent or short circuit currents.

Another object is to provide a notched wire fusible element capable of attaining the above objective and also capable, upon melting, of building up an arc voltage at a higher rate than was the case with prior fusible elements of similar configuration.

In carrying out my invention in one form, I provide the wire-type fusible element with a notch that extends about the circumference of the fusible element and has a rounded root that defines a region of minimum cross-section. The portions of the notch immediately adjacent the root and on longitudinally opposed sides of the root are formed of a concave configuration to define regions of gradually increasing cross section on longitudinally opposed sides of the minimum cross sectional region. Provided within the fusible element is an internal void that comprises a narrow elongated hollow and a pair of enlarged cavities at opposite ends of the hollow. The hollow extends longitudinally of the fusible element through the region of minimum cross section and is located near the central longitudinal axis of the fusible element. As will soon be explained in detail, this internal void plays an important role in enabling me to attain the objectives of the invention.

For a better understanding of my invention, reference may be had to the following description taken in conjunction with the accompanying drawing, wherein:

FIG. 1 is a cross sectional view taken through a current limiting fuse embodying form one of my invention.

FIG. 2 is a diagrammatic view illustrating a process and machine for providing a notch in each of the fusible elements used in the fuse of FIG. 1.

FIG. 3 is a cross sectional view taken along the line 3—3 of FIG. 2.

FIG. 4 is an enlarged view of a prior art tool which has been used in the machine of FIGS. 2 and 3.

FIG. 5 is an enlarged sectional view of a portion of a fusible element used in the fuse of FIG. 1.

FIG. 6 is a cross sectional view of a tool used for forming the notch illustrated in the fusible element of FIG. 5.

Referring now to FIG. 1 there is shown an electric fuse that comprises a tubular housing **12** of insulating material and a pair of metallic end caps **14** and **16** disposed at opposite ends of the tubular housing **12**. The end caps are of a cup form and are suitably secured to the tubular housing, as by an appropriate adhesive **17** disposed between the outer periphery of the tubular housing and the tubular flange of each end cap. A metallic ferrule **19** is press fitted on to each of these end caps to provide at each end of the fuse a terminal that is adapted to fit into an appropriate fuse clip (not shown).

Extending between the two spaced-apart end caps **14** and **16** are a plurality of fusible elements **20** which are of a wire form and are preferably of a highly conductive material such as silver. The cross-sectional size of the wires has been considerably exaggerated in the drawing to facilitate their illustration. For fuses having a lower continuous current rating, fewer fusible elements, or even a single element, can be used; and for fuses with a higher continuous current rating, a greater number of fusible elements are used. Each of the fusible elements **20** is provided at spaced-apart locations along its length with portions **22** of reduced cross section, which will soon be described in greater detail. Filling the tubular housing **12** between the end caps **14** and **16** is a granular arc-quenching material **24**, preferably quartz sand, in which the fusible elements **20** are imbedded. This sand surrounds each of the fusible elements about its entire periphery along substantially its entire length.

When the fuse is connected in an electric circuit, current flows between the end caps **14** and **16** through the fusible elements **20**. In the event of an electrical overload, the fusible elements melt after a protracted time interval, the duration of which varies inversely with the magnitude of the overload current. This melting, which is initiated at one or more of the regions **22** of reduced cross section, establishes along the length of each fusible element one or more arcs which are quickly extinguished by the reaction between the arc and the surrounding arc-quenching material. This melting and subsequent arc-extinguishing action interrupt the circuit and thus terminate current flow therethrough to provide protection against these overload currents.

In the event of a short circuit, as contrasted to an overload, much higher currents flow through the fusible element **20**. The illustrated fuse is designed to interrupt these higher currents with a current-limiting action that limits the maximum current permitted to flow to a value appreciably less than the maximum available short circuit current that the system is otherwise capable of supplying. This current-limiting action results from a rapid vaporization of the fusible element by the high short circuit current followed by rapid arc-extinguishing action produced by the reaction of the filler **24** with the resultant arcs.

Each region **22** of reduced cross section is formed by providing the wire element with a notch that extends about the periphery of the wire element in a longitudinally restricted location. Preferably, this notch is formed by the rolling process and the machine disclosed and claimed in application S.N. 161,933—Twele, filed December 26, 1961, and assigned to the assignee of the present invention. This process and machine are schematically depicted in FIGS. 2 and 3 and will be briefly described described herein. Referring to FIGS. 2 and 3, it will be noted that the machine comprises a pair of spaced-apart blades **30** disposed in a common plane **31** best seen in FIG. 3. The blades **30** are supported for relative horizontal movement in this common plane by suitable blade-guides **32** and can be horizontally driven toward and away from each other along the plane **31** by suitable means (not shown). There is a gap between the blades **30**, and the wire element **20** is placed in this gap with its longitudinal axis generally perpendicular to the plane of blade movement **31**. The edge **33** of each blade is inclined relative to the horizontal direction of blade movement so that the edges of the opposing blades will converge as the blades are driven toward each other. Thus, when the blades are driven horizontally toward each other, the opposing edges of the blades bear against opposite sides of the wire **20** and move in both a tangential and radial direction with respect to the wire. The tangential movement turns the wire about its axis, and the radial movement gradually compresses the wire in a localized region to form the annular notch therein.

Heretofore in this machine each blade **30** is used for forming the notch has been of the general cross-sectional configuration shown in FIG. 4 (i.e., it has had straight edge-surfaces **35** disposed at about 90 degrees with respect to each other and has had a tip of rounded cross section extending along the length of the blade in the region **36** where the edges intersect). This tip has had a radius of .013 inch. It has been found, however, that a silver fuse element of a typical diameter, 1/16 inch, having its notches formed with such a tool in the manner described hereinabove does not have as much physical strength as might be desired. Such elements have sometimes broken as a result of vibrations and mechanical shocks applied to the fuses in which they were incorporated.

But perhaps the most severe mechanical stresses have been applied to the fusible elements by the thermal conditions resulting from motor starting duty. Here, current several times the fuse rating flows for a short time and heats the fusible element substantially but not to melting. In the short time associated with starting, the fuse filler **24** and body **12** have little chance to heat up so that the fusible element expands with respect to its original mounting. This, of course, subjects the fusible elements to relatively high mechanical stresses which, for reasons soon to be explained, tend to produce flexing of the elements.

Increased mechanical strength can, of course, be obtained merely by increasing the cross sectional area of the notched portion of the fusible element, but this is not a satisfactory solution to the mechanical strength problem because it detrimentally affects the electrical performance of the fuse. More specifically, the increased cross section reduces the resistance of the reduced cross sectional portion **22**, and this, in turn, unduly prolongs the melting time for both overcurrents and short-circuit currents.

I have overcome the mechanical strength problem by controlling the above-described notch-forming process in such a manner that it produces internally of the fusible element a void of the general configuration depicted at **40** in FIG. 5. This internal void **40** comprises a narrow elongated hollow portion **41** and a pair of enlarged cavities **42** at opposite ends of the elongated hollow portion **41**. The elongated hollow portion **41** is located generally along the longitudinal central axis of the fusible element and extends through the region **45** where the notched portion of the fusible element has its minimum cross section. This region **45** of minimum cross section is occasionally referred to hereinafter as the root of the notch.

This internal void **40** is produced during the above-described notch-forming process by using (instead of a blade that has a substantially V-shaped working surface, as in FIG. 4) a blade that has a working surface of a rounded configuration with a relatively large radius of curvature. For example, in a preferred embodiment of my invention, the blade used for forming a notch in a silver wire of 1/16 inch diameter has a radius of curvature of about .047 inch for this rounded configuration. A blade of this configuration is shown in the enlarged cross section view of FIG. 6, with the radius of curvature being designated *r*.

However, the mere use of a notch-forming blade with the rounded configuration of FIG. 6 is not in itself enough to produce an internal void such as **40** in FIG. 5. Even when such a blade is used, the diameter of the wire at the root **45** must be reduced at least to a certain maximum value before the void begins appearing. For example, when forming the notch with two tools such as shown in FIG. 6, each having a radius of .047 inch, it has been found that the diameter of the silver wire must be reduced to a value of between .025 and .017 inch before the void begins appearing. As the diameter is further reduced, the void becomes more pronounced. But when the minimum diameter was kept greater than .025 inch, no void was found to be present.

The large radius of curvature of the tool permits the void **40** to be formed in the wire at relatively large root diameters. If a tool with a reduced radius of curvature is used, the root diameter must be correspondingly decreased in order to produce the void. Once the radius of curvature of the tool has been decreased beyond a certain value, the void fails to appear at any usable root diameter. For example, when a tool with a radius of .013 inch was used for forming the notch in a silver wire, no void could be detected at any root diameter.

As explained in the aforesaid Twele application, S.N. 161,933, the notch-forming process causes a considerable elongation of the wire element in the region of deformation. Such elongation causes a notch formed with the rounded blade of FIG. 6 to have a substantially parabolic cross sectional contour, as viewed in FIG. 5. This parabolic notch may be thought of as having a concave configuration on opposite sides of the root **45** or region of minimum cross section.

In FIG. 5, dotted lines **49** have been included to illustrate the configuration of a notch having straight sides as compared to the illustrated notch with the concave sides, both notches having the same root diameter. It will be apparent from this figure that in the regions of the notch immediately adjacent the root **45**, the fusible element with the concave notch has a smaller cross section than the element with the straight edged notch. This means that with the notches of equal root diameter illustrated, the electrical resistance of the concave-notched element is higher than that of the straight-edged notched element. This permits me to use a larger root diameter for the notch of concave configuration as compared to that for the straight-edged notch and yet to have the same resistance. By maintaining the resistance the same, the melting times can be maintained substantially the same; but the concave-notched element, since it has a larger root diameter, has considerably more mechanical strength. Thus, the concave configuration enables me to provide more mechanical strength without changing the resistance and, correspondingly, the melting time of the fusible element.

The central void **40** also contributes to a higher resistance without significantly detracting from the strength of the fusible element. In this respect since the void is

located along the central, or neutral axis, of the fusible element, it does not significantly impair the ability of the fusible element to withstand flexing or bending loads. This is a particular advantage since these are the loads that are imposed during the particularly severe conditions of thermal cycling accompanying motor-starting. As compared to a wire element of equal notch resistance that has no central void, an element with a central void (such as **40**) can have its root diameter made considerably larger than that of the void-free element. This larger diameter results in greater mechanical strength. Thus, the void makes it possible to obtain further increases in mechanical strength without changing the resistance and corresponding melting time of the fusible element.

Another important contribution of the void **40** is that its presence increases the rate at which arc voltage can be built up upon melting of the fusible element (as compared to the rate available from the corresponding fusible element with no void). This is believed to result from the fact that the void reduces the volume of metal requiring dispersal when the notched portion of the fusible length vaporizes during arcing. The less metal there is to disperse, the more quickly the arc can be lengthened and exposed to the surrounding sand to build up the arc voltage.

In a preferred embodiment of my invention, the fusible elements **20** are bowed to a smooth curve along their length, as is illustrated in FIG. 1. This bowing gives the elements a preferred direction of migration under conditions of differential thermal expansion (e.g., when the length of the fusible element increases faster than that of the casing **12**, as during motor-starting inrush currents). With this preferred direction of migration available, the stresses imposed upon the fusible element under these conditions become flexural rather than buckling.

It is especially advantageous to force these thermally induced stresses to be carried by the fusible elements as flexural loads, rather than buckling loads, because it is with the flexural type of load that the void makes no appreciable reduction in mechanical strength (in view of its location along the neutral axis, as described hereinabove). Hence, the bowed configuration of the element and the void along the central axis are cooperative features that further contribute to improved ability of the fusible element to withstand breakage under the thermal conditions accompanying motor-starting.

As pointed out hereinabove, other types of loads that the flexible element must be capable of withstanding without breakage are the loads imposed by vibrations and by shocks. The various structural features of the fusible element which impart increased resistance to breakage under the thermally induced loads also are effective to help resist the loads resulting from vibrations and shocks. But there is one additional feature that helps to reduce the chances for breakage by vibrations. This is a ceramic post **50** which is located between the end caps **14** and **16** generally along the central axis of the fuse. This ceramic post **50** acts as a baffle that restricts the tendency of the filler to move laterally in response to vibrations. Restricting the sand movement has been found to improve the ability of the fusible element to withstand vibrations without breakage. The ceramic post **50** is preferably captured in suitably aligned recesses **52** formed in the end caps to anchor the post in a fixed position between the end caps.

When a post **50** of a hollow form is used, it is filled with sand to prevent any of the granular filler material from leaking into the interior of the post from the surrounding space thereby leaving voids in the surrounding space that could undesirably promote shifting of the filler during vibrations.

While I have shown and described particular embodiments of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from my invention in its broader aspects and I, therefore, intend in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a current limiting electric fuse comprising a hollow casing of insulating material, conductive end members at opposite ends of said casing, a granular filler within said casing, and a conductive fuse element of wire-form imbedded within said filler and electrically interconnecting said end members, said fuse element being surrounded by said filler about its entire periphery over most of its length; said fuse element having at least one notch formed therein at a location intermediate its ends, said notch extending about the circumference of said fuse element and having a rounded root that defines a region of minimum cross-section, the portions of said notch immediately adjacent said root and on longitudinally opposed sides thereof being of a concave configuration to define regions of gradually increasing cross section on longitudinally opposed sides of said minimum cross sectional region, an internal void in said fuse element comprising a narrow elongated hollow and a pair of enlarged cavities at opposite ends of said hollow, said hollow extending longitudinally of said fusible element through said region of minimum cross section and being located near the central longitudinal axis of said fusible element.

2. In a current-limiting electric fuse comprising a hollow casing of insulating material, conductive end members at opposite ends of said casing, a granular filler within said casing, and a conductive fuse element of wire-form imbedded within said filler and electrically interconnecting said end members, said fuse element being surrounded by said filler about its entire periphery over most of its length; said fuse element having at least one notch formed therein at a location intermediate its ends, said notch extending about the circumference of said fuse element and defining a root region of minimum cross section and regions of gradually increasing cross section on longitudinally opposed sides of said minimum cross sectional region, an internal void in said fusible element comprising a narrow elongated hollow and a pair of enlarged cavities at opposite ends of said hollow, said hollow extending longitudinally of said fusible element through said region of minimum cross section and being located near the central longitudinal axis of said fusible element.

3. The fuse of claim **2** in which said fusible element is smoothly bowed along its length so that unequal thermal expansion of said fusible element and said casing loads said fusible element primarily in flexure.

4. The fuse of claim **2** in which there are a plurality of fusible elements of the structure defined in claim **2** electrically connected in parallel between said end caps.

5. The fuse of claim **2** in which there are a plurality of fusible elements of the structure defined in claim **2** electrically connected in parallel between said end caps and in which an insulating post embedded within said filler material is provided for reducing shifting of said filler material under conditions of vibration.

6. In a current-limiting electric fuse comprising a hollow casing of insulating material, conductive end members at opposite ends of said casing, a granular filler within said casing, and a conductive fuse element of wire-form imbedded within said filler and electrically interconnecting said end members, said fusible element being surrounded by said filler about its entire periphery over most of its length; said fusible element having at least one notch formed therein at a location intermediate its ends, said notch extending about the circumference of said fusible element and having a rounded root that defines a region of minimum cross section, the portions of said notch immediately adjacent said root and on longitudinally opposed sides thereof being of a concave configuration to define regions of gradually increasing cross section longitudinally opposed sides of said minimum cross sec-

tional region, an internal void in said fusible element extending longitudinally thereof through said region of minimum cross section and being located near the central longitudinal axis of said fusible element.

7. In a current-limiting electric fuse comprising a hollow casing of insulating material, conductive end members at opposite ends of said casing, a granular filler within said casing, and a conductive fuse element of wireform imbedded within said filler and electrically interconnecting said end members, said fusible element being surrounded by said filler about its entire periphery over most of its length; said fusible element having at least one notch formed therein at a location intermediate its ends, said notch extending about the circumference of said fusible element and having a rounded root that defines a region of minimum cross section, an internal void in said fusible element extending longitudinally thereof through said region of minimum cross section and being located near the central longitudinal axis of said fusible element.

8. The fuse of claim **7** in which said fusible element is smoothly bowed along its length so that unequal expansion of said fusible element and said casing loads said fusible element primarily in flexure.

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