FILE NAME: McGraw-Edison (ME)

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May 24, 1966 A. J. FISTER 3,253,104

PROTECTORS FOR ELECTRIC CIRCUITS

Original Filed Feb. 16, 1959 2 Sheets-Sheet 1

FIG. 1

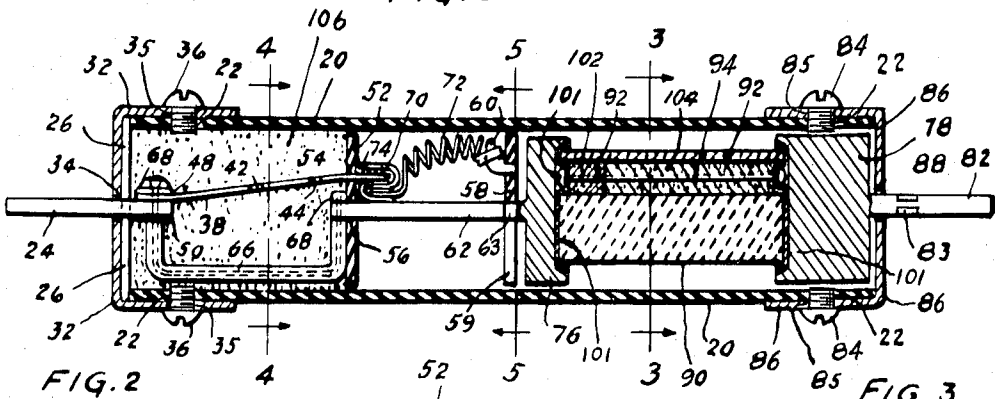


FIG. 2

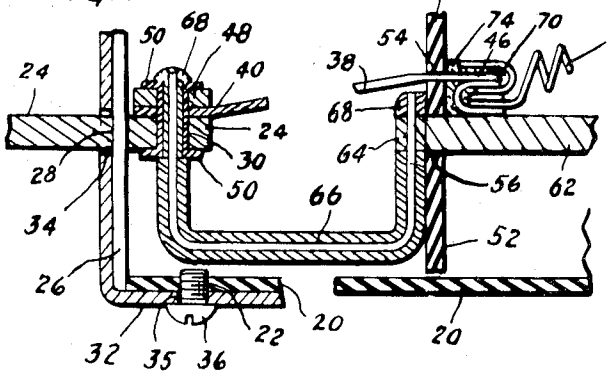


FIG. 3

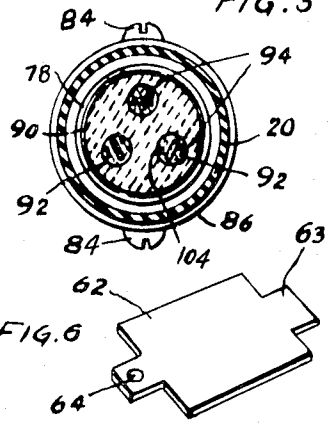


FIG. 6

FIG. 4

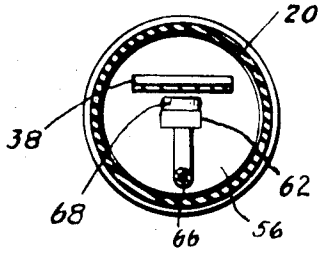


FIG. 5

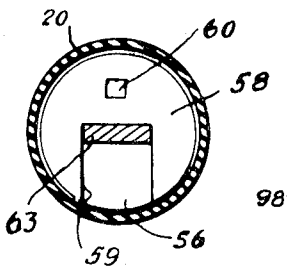


FIG. 7

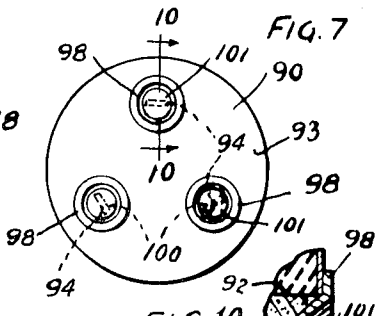


FIG. 10

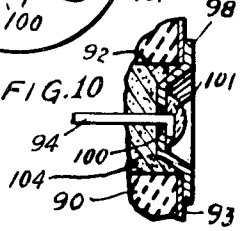


FIG. 8

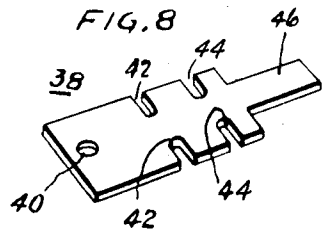
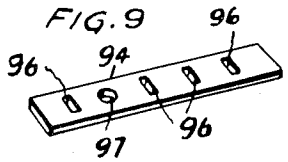


FIG. 9



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PROTECTORS FOR ELECTRIC CIRCUITS

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FIG. 11

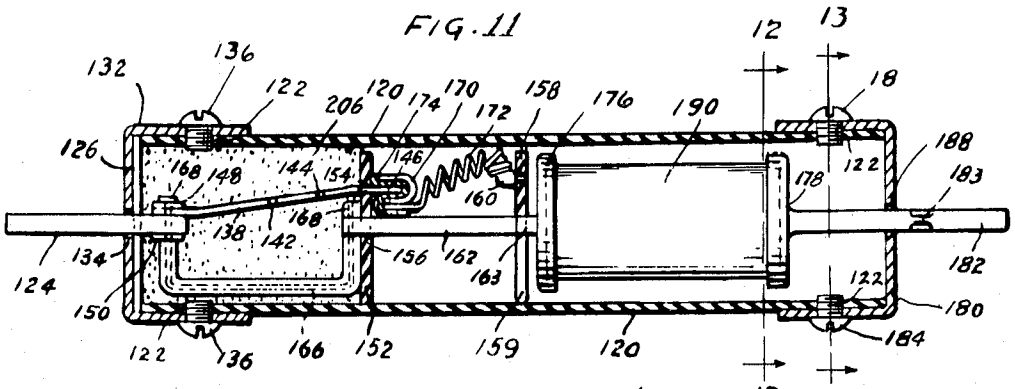


FIG. 12

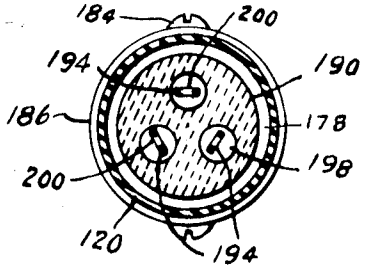


FIG. 13

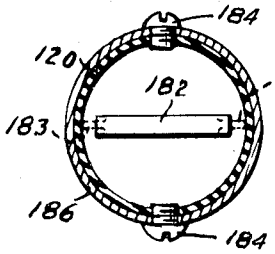


FIG. 14

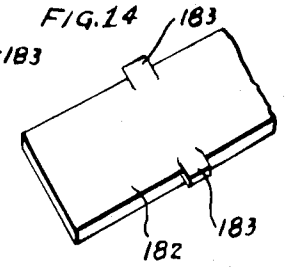


FIG. 15

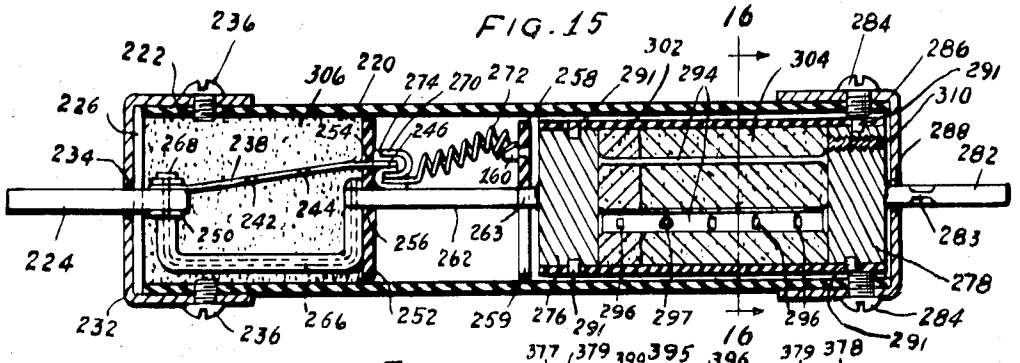


FIG. 16

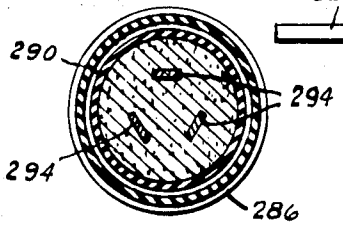
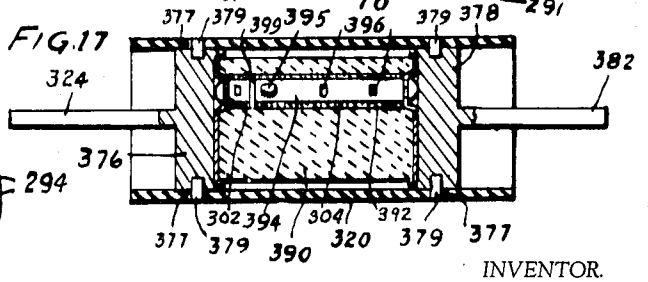


FIG. 17



INVENTOR.

BY ALOYSIUS J. FISTER

Ray Filers ATT'Y.

United States Patent Office 3,253,104 Patented May 24, 1966

3,253,104

PROTECTORS FOR ELECTRIC CIRCUITS

Aloysius J. Fister, Overland, Mo., assignor to McGraw-Edison Company, Elgin, Ill., a corporation of Delaware

Original application Feb. 16, 1959, Ser. No. 793,415, now Patent No. 3,122,619, dated Feb. 25, 1964. Divided and this application May 16, 1963, Ser. No. 280,968

5 Claims. (Cl. 200—120)

This is a division of my co-pending application Serial No. 793,415 for Protectors for Electric Circuits which was filed February 16, 1959, now Pat. No. 3,122,619.

This invention relates to improvements in protectors for electric circuits. More particularly, this invention relates to improvements in dual element fuses.

It is therefore an object of the present invention to provide an improved dual element fuse.

It is desirable, in the protection of many electric circuits, to equip those circuits with dual element fuses. Such fuses have thermal cut-outs that can respond to long-continued low overloads to open, and thereby protect the circuits, and they also have fuse links that can respond to higher overloads to open, and thereby protect the circuits. Whether the dual element fuses open in their thermal cut-outs or in their fuse links, those fuses limit the current passing through the electric circuits and thereby protect those circuits. A number of such dual element fuses have been proposed, and some of them have been sold widely.

The capacities of electric circuits have exhibited steady growths throughout the years, and hence it has become important to make some fuses with current-limiting characteristics that are even greater than those possessed by prior dual element fuses. It would be desirable to have a fuse that possesses the time-lag characteristics of a dual element fuse on light overloads but that responds to higher overloads to open the circuit more rapidly than can prior dual element fuses. Such a fuse could open the electric circuit, and thereby limit the current in that circuit, before that current reaches the capacity of that circuit. The present invention provides such a fuse; and it does so by providing a short-circuiting chamber which is equipped with fast-blowing fuse links and which is connected in series with a thermal cut-out. A heat-generating conductor is disposed adjacent one end of the thermal cut-out and the short-circuiting chamber is disposed adjacent the other end of that thermal cut-out; and both the heat-generating conductor and the fuse links of the short-circuiting chamber will generate heat whenever current flows through the fuse. It would not be desirable to have unlimited interchange of heat between the heat-generating conductor and the short-circuiting chamber, and such interchange of heat is prevented by the present invention by providing the heat-absorbing member of the thermal cut-out with a portion of reduced cross section.

The heat-generating conductor and the short-circuiting chamber, and the connector and heat-absorbing member of the thermal cut-out are all intimately bonded together; and they essentially constitute one continuous and integral conductor. There is, as a result, minimum contact resistance between the various current-carrying components of the fuse provided by the present invention; and hence local heating due to contact resistance is avoided. While the present invention minimizes contact resistance between the various current-carrying components of the fuse by intimately bonding those components together, it still limits the interchange of heat between the heat-generating conductor and the fuse links of the short-circuiting chamber by reducing the cross section of that end of the heat-absorbing member which is bonded to the short-circuiting chamber. As a result, the heat-absorbing member can be intimately bonded to the short-circuiting chamber and to the connector, and can be given enough mass and enough surface area to absorb sizeable quantities of heat and then to radiate appreciable portions of that heat, and yet not permit undue interchange of heat between the heat-generating conductor and the fuse links of the short-circuiting chamber. It is therefore an object of the present invention to provide a heat-absorbing member which has a large mass and a large surface area and which can be intimately bonded to the short-circuiting chamber and to the connector without permitting undue interchange of heat between the heat-generating conductor and the fuse links of the short-circuiting chamber.

The heat-generating conductor of the fuse provided by the present invention supplies heat to heat-softenable material that normally holds the connector in mechanical and electrically-conducting engagement with the heat-generating conductor and with the heat-absorbing member. That heat-generating conductor must be kept from applying binding forces to the connector which could keep that connector from moving out of the said mechanical and electrically-conducting engagement when the heat-softenable material softens; and yet the recurrent and appreciable expansions and contractions of that heat-generating conductor during the operation of the fuse can tend to warp and distort that heat-generating conductor and thereby tend to cause that heat-generating conductor to apply such binding forces to the connector. The expansions and contractions of the heat-generating conductor can be appreciable where the fuse is subjected to high overloads that are continued long enough to raise the heat-softenable material to its softening temperature or to raise the fuse links of the short-circuiting chamber to their blowing temperature even though those high overloads are not continued long enough to soften the heat-softenable material or to blow the fuse links of the short-circuiting chamber. Expansions and contractions of the housing of the fuse can also tend to cause the heat-generating conductor to apply binding forces to the connector, and those expansions and contractions can easily be caused by varying conditions of temperature and humidity. The present invention compensates for such expansion and contractions of the heat-generating conductor and of the housing for the fuse and thereby keeps the heat-generating conductor from applying binding forces to the connector by mounting the heat-absorbing member and the short-circuiting chamber of the fuse so they can move relative to the housing of the fuse as the heat-generating conductor or the fuse housing expands and contracts. That movement of the heat-absorbing member and of the short-circuiting chamber permits the heat-generating conductor to remain substantially stress-free despite its expansion and contraction or that of the fuse housing; and that movement minimizes the likelihood that the heat-generating conductor will apply binding forces to the connector. It is therefore an object of the present invention to provide an electric fuse wherein the heat-absorbing member and the short-circuiting chamber are mounted to move relative to the fuse housing as the heat-generating conductor or the fuse housing expands and contracts.

The short-circuiting chamber of the fuse provided by the present invention has a casing that is shorter and is smaller in cross-section than the housing for the fuse; and that short-circuiting chamber has end bells which close the ends of that casing. Those end bells coact with that casing to provide a tight chamber for the fuse links of the fuse; and such a chamber confines any pressures that are generated when the fuse links blow, and those pressures help quench any arcs that may form when the fuse links blow. Further, those end bells and that casing hold arc-

quenching filler in engagement with those fuse links while keeping that filler from impeding the movement of the heat-absorbing member and of the short-circuiting chamber as the heat-generating conductor or the fuse housing expands and contracts.

The casing for the short-circuiting chamber is made of a sturdy, air-impervious and dimensionally-stable dielectric material. Such a casing is desirable because it makes it possible to use an inexpensive dielectric material in making the housing for the fuse. Further, such a casing is desirable because it can be given a tight fit with the end bells, and it can then be depended upon to maintain that tight fit. Such a casing is additionally desirable because it prevents the expulsion of vaporized metal or of hot gases when the fuse links blow.

To make the fuse links really fast-acting, those fuse links should be made quite short. However, short fuse links mean that the end bells of the short-circuiting chamber will be close together; and the closeness of those end bells creates the possibility of an arc traveling along the exterior of the short-circuiting chamber when the fuse links blow. Any such arc would be momentary, and would be due to the fact that the voltage drop across the short-circuiting chamber can rise, during the blowing of the fuse links, to two or three times its normal value; but any such arc could not be tolerated at the exterior of the fuse housing. However, by using the fuse housing to completely enclose the short-circuiting chamber, the present invention makes it possible to tolerate momentary arcs that could form at the exterior of the short-circuiting chamber during the blowing of the fuse links within that chamber; and it thereby makes it possible to use very short, and thus very fast-acting, fuse links.

The housing of the fuse protects the exterior of the short-circuiting chamber and keeps that exterior clean. In doing so, that housing keeps dirt or contaminants from providing paths, at the exterior of the short-circuiting chamber, which have low enough resistances to enable arcs to form and to follow those paths during the blowing of the fuse links of that short-circuiting chamber. Such paths could not only foster the striking of arcs, but they could also maintain those arcs; and hence the action of the fuse housing in keeping the exterior of the short-circuiting chamber clean is very important.

The fuse housing includes an elongated tube of insulating material; and that tube overlies and insulates the heat-absorbing member and its bonded connections to the short-circuiting chamber and to the connector. In doing so, that tube provides important protection against arcing which might otherwise occur if two of the fuses were set in adjaent recesses of a fuseholder equipped with cut-away insulating baffles. Such baffles are cut-away to provide openings, adjacent the centers of the fuses, to facilitate ready removal of the fuses from the fuseholder; and those openings could permit arcing between the heat-absorbing members of the adjacent fuses if those fuses were not provided with tubes of insulating material.

In a number of instances, sand is used as an arc-quenching filler at one end of a short-circuiting chamber, and an inert material is provided at the other end of that short-circuiting chamber. The sand can respond to arcs, that form during the blowing of the fuse links of that short-circuiting chamber, to form fulgurites during the quenching of arcs. The inert material keeps those fulgurites from extending all the way between the two end bells of the short-circuiting chamber, and thereby keeps those fulgurites from establishing after-blow, current-carrying paths between those end bells. Different inert materials have been used to keep the fulgurites from extending all the way between the end bells of the short-circuiting chamber; and while most of those inert materials do keep the fulgurites from extending all the way between those end bells, those inert materials seem to respond to the blowing of the fuse links to permit after-blow, current-carrying paths to form in the short-circuiting chamber. Those paths are undesirable, and they can be obviated by using anhydrous calcium sulphate as the inert material in the short-circuiting chamber. It is therefore an object of the present invention to provide anhydrous calcium sulphate as the inert material in a short-circuiting chamber.

The heat-absorbing member of the fuse provided by the present invention has the heat-generating conductor adjacent one end thereof and has the fuse links of the short-circuiting chamber adjacent the other end thereof, and that heat-absorbing member can become quite warm. A terminal will be connected to the opposite end of the short-circuiting chamber, and that terminal will be kept cool by the fuse clips of the fuse holder; and that terminal will cool the said opposite end of the short-circuiting chamber. The present invention disposes the arc-quenching sand adjacent the said opposite end of the short-circuiting chamber, and thereby keeps the sand cool. This is desirable because the cooler the sand, the smaller the cross-section that can be given the fuse links; and small cross-section fuse links can be very fast-acting fuse links.

The heat-absorbing member of the fuse provided by the present invention is not cylindrical because a cylindrical heat-absorbing member would have its periphery immediately adjacent the inner surface of the fuse housing and could have its heat-absorbing action materially affected by the temperature of that fuse housing. The heat-absorbing member of the fuse provided by the present invention is flat; and the greatest portion of the surface of that heat-absorbing member is spaced from the inner surface of the fuse housing to provide an air space. That air space acts as an insulator and thereby keeps the temperature of the fuse housing from materially affecting the heat-absorbing action of the heat-absorbing member of the fuse.

Electric fuses are usually made in standard sizes. Thus, fuses that are to be used to protect circuits utilizing currents in the range of zero to thirty amperes will be of one size, fuses that are used to protect circuits utilizing currents in the range of thirty one to sixty amperes will be of a larger size, fuses that are used to protect circuits utilizing currents in the range of sixty one to one hundred amperes will be of a still larger size, and so on. Heretofore the current-limiting abilities, of the fuses that had the same physical dimensions but had different ampere ratings, differed; and therefore to be sure that fuses, made to have ampere ratings that differ from the standard and usual ampere ratings, would have the desired current-limiting abilities, it was necessary to make detailed tests of the current-limiting abilities of those fuses. Such tests are expensive and time-consuming; and the present invention minimizes the need of such tests. It does so by providing current-limiting fuse links, for the short-circuiting chamber, that can be used with most of the differently rated fuses having the same physical dimensions. As a result, to make a fuse that has a desireed ampere rating, a desired size, and a known current-limiting ability, it is only necessary to make up a thermal cut-out having the desired ampere rating and then intimately bond the heat-absorbing member of that thermal cut-out to the short-circuiting chamber for the desired size fuse. It is therefore an object of the present invention to provide a short-circuiting chamber which can provide predetermined current-limiting characteristics and to use that short-circuiting chamber with thermal cut-outs of diferent ampere ratings to provide fuses with predetermined current-limiting characteristics but with different ampere ratings.

When the connector of a dual element fuse is separated from the heat-generating conductor of that fuse to open the circuit, an arc can tend to form. It is impractical to surround the connector with arc-quenching filler because that filler would interfere with the requisite ready separation of the connector from the heat-generating conductor; and hence an arc at the connector could continue to

burn. Such an arc can be of appreciable duration where the fuse opens a circuit which utilizes direct current. The present invention obviates arcing at the connector when that connector moves to open the circuit; and it does so by placing a readily fusible shunt wire in parallel with the heat-generating conductor. That shunt wire will be unable to carry the rated current of the fuse, much less overload currents, and it will fuse and open the circuit after the connector moves. However, that shunt wire will take a fraction of a second to heat up to its fusing temperature; and it will carry all of the current through the fuse as it does so, thereby preventing arcing when the connector moves. The shunt wire will be embedded in filler, and any arc that might form when the shunt wire fuses will quickly be quenched by the filler. It is therefore an object of the present invention to provide a shunt wire for the heat-generating conductor of a dual element fuse and to embed that shunt wire in filler that will quench arcs that form when the shunt wire fuses.

Other and further objects and advantages of the present invention should become apparent from an examination of the drawing and accompanying description.

In the drawing and accompanying description, several preferred embodiments of the present invention are shown and described but it is to be understood that the drawing and accompanying description are for the purpose of illustration only and do not limit the invention and that the invention will be defined by the appended claims.

In the drawing, FIG. 1 is a longitudinal section through one embodiment of fuse that is made in accordance with the principles and teachings of the present invention,

FIG. 2 is a broken, longitudinal section, on a greatly enlarged scale, of the left-hand portion of the fuse shown in FIG. 1,

FIG. 3 is a sectional view through the fuse shown in FIG. 1, and it is taken along the plane indicated by the line **3—3** in FIG. 1,

FIG. 4 is another sectional view through the fuse shown in FIG. 1, and it is taken along the plane indicated by the line **4—4** in FIG. 1,

FIG. 5 is another sectional view through the fuse shown in FIG. 1, and it is taken along the plane indicated by the line **5—5** in FIG. 1,

FIG. 6 is a perspective view of the heat-absorbing member of the fuse shown in FIG. 1,

FIG. 7 is an end view, on a large scale, of the short-circuiting chamber of the fuse shown in FIG. 1 before the end bells are affixed to that short-circuiting chamber,

FIG. 8 is a perspective view of the heat-generating conductor of the fuse shown in FIG. 1,

FIG. 9 is a perspective view of one of the fuse links in the short-circuiting chamber of the fuse shown in FIG. 1.

FIG. 10 is a sectional view, on a considerably enlarged scale, through the short-circuiting chamber of FIG. 7, and it is taken along the plane indicated by the line **10—10** in FIG. 7,

FIG. 11 is a longitudinal section through another embodiment of fuse that is made in accordance with the principles and teachings of the present invention,

FIG. 12 is a sectional view through the fuse shown in FIG. 11, and it is taken along the plane indicated by the line **12—12** in FIG. 11,

FIG. 13 is another sectional view through the fuse shown in FIG. 11, and it is taken along the plane indicated by the line **13—13** in FIG. 11,

FIG. 14 is a perspective view of the right-hand terminal of the fuse shown in FIG. 11, and it shows that terminal after it has been provided with protuberances at the opposite sides thereof,

FIG. 15 is a longitudinal section through another embodiment of fuse that is made in accordance with the principles and teachings of the present invention,

FIG. 16 is a sectional view through the fuse shown in FIG. 15, and it is taken along the plane indicated by the line **16—16** in FIG. 15, and

FIG. 17 is a longitudinal section through another form of fuse that is made in accordance with the principles and teachings of the present invention.

Referring to the drawing in detail, the numeral **20** denotes tubular housing for one embodiment of fuse that is made in accordance with the principles and teachings of the present invention. That housing can be made of a readily available, inexpensive, insulating material such as fiber. That housing has a smooth and uninterrupted interior surface, and it has threaded openings **22** adjacent the ends thereof.

A terminal **24**, that is rectangular in plan, has a width that is less than the inner diameter of the housing **20**. That terminal has an opening **30** adjacent the right-hand end thereof, and it has a second opening **28** spaced to the left of the opening **30**. A bar-like pin **26** is pressed into and fixedly held, by the opening **28**, and that pin extends transversely of that terminal. That pin has a length equal to the outer diameter of the housing **20**. As a result, the pin **26** limits the extent to which the right-hand end of the terminal **24** can be telescoped into the left-hand end of the housing **20**. When the flat face of the pin abuts the left-hand end of the housing **20**, the opening **30** in the terminal **24** is disposed within that housing.

The numeral **32** denotes a cup-shaped closure for the left-hand end of the housing **20**, and that closure has an inside diameter which is slightly larger than the outer diameter of that housing. The closure **32** has a slot **34** in it, and that slot is just slightly larger than the cross section of the terminal **24**. The closure **32** also has openings **35** which can be set in register with the openings **22** in the housing **20**. The alined openings **22** and **35** receive threaded fasteners **36**, and the threaded shanks of those fasteners extend through the openings **35** and seat in the openings **22** to rigidly secure the closure **32** to the housing **20**. Also, the fasteners **36** enable the closure **32** to hold the pin **26** and the terminal **24** rigidly fixed relative to the housing **20**.

The numeral **38** denotes a conductor which is made so it will generate appreciable amounts of heat whenever currents greater than the rated current of the fuse pass through it. That conductor has an opening **40**, adjacent the left-hand end thereof, which can be set in register with the opening **30** in the terminal **24**. The conductor **38** has two portions **42** and **44** of reduced cross section, and those portions of that conductor will be the hottest portions of that conductor. The conductor **38** also has a reduced cross-section, right-hand end **46**. As indicated particularly by FIGS. 1 and 2, the conductor **38** is bent upwardly at a point to the right of the opening **40**, and it is bent downwardly at a point adjacent the left-hand end of the reduced cross-section portion **46**.

The numeral **52** denotes a support which has the form of a circular disc; and that support is made small enough, relative to the inner diameter of the housing **20**, to enable that support to move freely relative to that housing in the axial direction. The support **52** is of insulating material, such as fiber, and it has two slots **54** and **56** in it. The slot **54** accommodates the reduced cross-section, right-hand and **46** of the heat-generating conductor **38**, and the slot **56** accommodates the reduced cross-section, left-hand end of a heat-absorbing member **62**. That reduced cross-section end of the heat-absorbing member has an opening **64** in it, and that opening will be disposed to the left of the support **52** whenever that heat-absorbing member is assembled with that support. The heat-absorbing member is flat and it is wide, but its edges are spaced inwardly of the interior surface of the housing **20** to provide an insulating air space intermediate the heat-absorbing member and the housing. The right-hand end **63** of the heat-absorbing member **62** is also reduced in cross-section, but it is wider than the reduced cross-sec-

tion, left-hand end of the heat-absorbing member. The width of the right-hand end **63** of the absorber **62** is approximately one half of that of the absorber **62**.

The numeral **50** denotes a sleeve-like rivet that is telescoped through the aligned openings **30** and **40** of the terminal **24** and heat-generating conductor **38**, respectively; and it is also telescoped through a washer **48**. That rivet permanently secures the terminal **24** and the heat-generating conductor **38** together; and it coacts with the support **52** to hold the heat-generating conductor **38** adjacent the geometric axis of the housing **20**.

The numeral **66** denotes a wire that has a cross section that is much smaller than the cross section of the heat-generating conductor **38**, and that wire will blow whenever it has to carry all of the rated current of the fuse. That wire is encased in asbestos or some other heat-insensitive insulating material. One end of the wire **66** is stripped of its insulation and is extended up through the sleeve-like rivit **50**, and the other end of that wire is stripped of its insulation and is extended up through the opening **64** in the reduced cross-section, left-hand end of the heat-absorbing member **62**. Bonding material **68**, such as solder, holds the wire **66** in electrically-conducting relation with the terminal **24** and with the heat-absorbing member **62**. The wire **66** is made long enough so it can be spaced from the heat-generating conductor, and thereby kept from being heated appreciably by that heat-generating conductor. An inert filler **106**, such as calcium sulfate, is disposed in the compartment defined by the closure **32** and the support **52**, and that filler will help keep the wire **66** from being appreciably heated by the heat-generating conductor **38**. Also, that filler will help quench any arc that may form when the wire **66** blows.

The numeral **70** denotes a connector that is made from two U-shaped pieces of metal, from a square piece of metal, and from one end of a helical extension spring **72**. One of the U-shaped pieces of metal is lighter in weight than the other, and it is disposed so its open end faces to the left, as that connector is viewed in FIG. 2. The other U-shaped piece of metal is disposed so its open end faces to the right, and so its upper arm overlies the lower arm of the upper U-shaped piece of metal. The square piece of metal is disposed within the other U-shaped piece of metal; and it underlies the lower arm of the upper U-shaped piece of metal. The left-hand end of the helical spring **72** is disposed between the square piece of metal and the lower arm of the other U-shaped piece of metal.

The two U-shaped pieces of metal, the square piece of metal, and the left-hand end of the spring **72** are set in position, and then a heavy pressure is applied to the upper and lower faces of the upper and lower arms, respectively, of the other U-shaped piece of metal. That pressure is heavy enough to clamp the arms of that other U-shaped piece of metal tightly enough to hold all four components of the connector **70** in permanently assembled relation. When the connector **70** is completed, its upper U-shaped piece of metal will define a recess that can telescope freely over the right-hand end **46** of the heat-generating conductor **38**. A mass **74**, of heat-softenable material such as solder, fills that recess and also engages the heat-absorbing member **62**. That mass normally holds the connector **70** in mechanical and electrically-conducting engagement with the heat-generating conductor **38** and with the heat-absorbing member **62**. However, that mass can respond to heat to soften and release that connector for movement out of that engagement; and when that connector moves it will move as a unit.

A support **58** of insulating material has the form of a notched circular disc; and the diameter of that disc is smaller than the inner diameter of the housing **20**. As a result, that support can move freely relative to the housing **20** in the axial direction. The notch **59** in the support **58** is wide enough to slip over the reduced cross-section end **63** of the heat-absorbing member **62**, as shown by FIG. 5. A hook **60** is set in a slot in the support **58**, and the right-hand end of that hook is riveted over to maintain that hook in assembled relation with that support. That hook receives and holds the other end of the helical extension spring **72**, and that spring biases the connector **70** for movement out of its normal engagement with the heater **38** and with the heat-absorbing member **62**. As a result, when the heat softenable material **74** responds to heat to soften and release the connector **70**, that connector will respond to the spring **72** and move out of its normal mechanical and electrically-conducting engagement with the heater **38** and with the absorber **62**.

The numeral **76** denotes an end bell of metal which has its right-hand face machined away to form a shallow, cup-like recess. The numeral **78** denotes an end bell of metal which has its left-hand face machined away to form a shallow, cup-like recess; and the end bell **78** is materially thicker and thus has more thermal capacity than the end bell **76**. The end bells **76** and **78** are made so their diameters are smaller than the inner diameter of the housing **20**; and therefore those end bells can move freely relative to the housing **20** in the axial direction. The reduced cross-section portion **63** of the heat-absorbing member **62** is permanently connected to the left-hand face of the end bell **76**, as by silver solder or the like; and a terminal **82** is permanently connected to the right-hand face of the end bell **78**, as by silver solder or the like. The terminal **82** is rectangular in plan, and it is narrow enough to permit the left-hand end thereof to telescope within the right-hand end of the housing **20**; but it is as wide as the diameter of the end bell **78**. The terminal **82** has protuberances **83** thereon, and those protuberances are conveniently formed by a staking operation.

A closure **86** of cup-shaped configuration has an inner diameter which is slightly larger than the outer diameter of the housing **20**, and that closure can be telescoped over the right-hand end of that housing. A slot **88** is provided in the closure **86**, and that slot is sufficiently larger than the terminal **82** to enable that terminal to move longitudinally relative to that closure. The closure **86** will be telescoped over the terminal **82** and over the right-hand end of the housing **20** before the protuberances **83** are formed on that terminal, and those protuberances will prevent unlimited movement of the terminal **82** to the left. The closure **86** has openings **85** which can be set in register with the threaded openings **22** in the housing **20** adjacent the right-hand end of that housing. Fasteners **84** with threaded shanks can be passed through the openings **85** and seated in the threaded openings **22** to fixedly prevent separation of the closure **86** from the housing **20**.

The numeral **90** denotes a right-circular cylinder which is made of a high-alumina ceramic; and one such high-alumina ceramic is Frenchtown Porcelain Company No. 4462. That cylinder is resistant to abrasion, corrosion, thermal shock and mechanical shock, and it has good dielectric properties. The cylinder **90** has a number of cylindrical passages **92** through it; and in the embodiment shown by FIGS.1–10, there are three passages **92**. However, more or fewer passages **92** can be formed in the cylinder **90**. The end faces, and the end portions of the outer surface, of the cylinder **90** are provided with thin coatings **93** of metal; and those coatings are preferably formed by a metallizing process. In that process, a material such as Frenchtown Porcelain Company Nicote is painted on, or otherwise applied to, the end faces and the end portions of the outer surface of the cylinder **90**, and then that cylinder is fired at a high temperature. Soft solder is then applied to the metallized coatings to "tin" them; and then the cylinder **90** is cleaned to free it of solder flux.

The numeral **94** denotes a fusible conductor or fuse link which has a number of transversely-directed narrow

openings 96 therein and which has a circular opening 97 therein. That conductor will preferably be made of silver; and it is dimensioned so it can be disposed within one of the cylindrical passages 92 without having any portion thereof touch the wall of that passage. The fuse shown in FIGS. 1–10 has three fusible conductors 94; one for each passage 92.

Cup-shaped washers 98 are provided to close the ends of the passages 92 in the cylinder 90; and the tapered walls of those washers engage and are centered by the passage-defining portions of that cylinder, as shown particularly by FIG. 10. Each of the cup-shaped washers 98 has a diametric slot 100 therein, and those slots are made slightly larger than the cross sections of the fusible conductors 94. The tapered walls of the cup-shaped washers 98 will center the slots 100 relative to the passages 92, and those slots will center the fuse links 94 relative to those passages 92. The overall result is that the fusible conductors 94 are positively centered with regard to the passages 92. Solder 101 engages the cup-shaped washers 98 and also engages the tinned coatings 93 of metal and the fuse links 94. That solder hermetically seals the ends of the passages 92 and electrically bonds the fuse links 94 and the cup-shaped washers 98 and the tinnned metal coatings 93 together. The cup-shaped washers 98 not only center the links 94 but also provide adequate contact area between those links and the end bells 76 and 78.

The numeral 102 denotes quantities of anhydrous calcium sulfate that are disposed within the passages 92 of cylinder 90 and that embed the left-hand ends and the left-handmost openings 96 of the fusible conductors 94. The numeral 104 denotes quantities of quartz sand that are disposed within the passages 92 of cylinder 90 and that embed the circular openings 97 and the remaining openings 96 of the fusible conductors 94. The interfaces between the quantities of anhydrous calcium sulfate and quartz sand will be intermediate the circular openings 97 and the left-handmost openings 96 of the fusible conductors 94. The quartz sand can respond to blowing of the fuse links 94 to form fulgurites during extinction of arcs that form when those fuse links blow. The anhydrous calcium sulfate keeps the fulgurites from spanning the full lengths of the passages 92 of the cylinder 90, and it also prevents the establishment of after-blow resistance paths through the passages 92 of cylinder 90.

In assembling the fuse links 94 with the cylinder 90, each of the fuse links 94 has one of its ends bent, and then has its other end inserted through a slot 100 in one of the cup-shaped washers 98. The fuse links 94 are then moved through the slots 100 until the bent ends thereof prevent further movement. At such time, solder 101 is used to bond those fuse links to the cup-shaped washers 98. Thereafter, the other ends of the fuse links 94 are telescoped through the passages 92 until the tapered walls of the cup-shaped washers 98 intimately engage and are held and centered by the passage-defining portions of the cylinder 90; and at that time further solder 101 is used to seal those cup-shaped washers to the tinned metal coatings 93.

Preferably the bent ends of the fuse links 94 will be adjacent the right-hand end of cylinder 90, and the other ends of those fuse links will be adjacent the left-hand end of that cylinder, as that cylinder is viewed in FIG. 1. Where that is the case, the cylinder 90 can be rotated ninety degrees in the clockwise direction from the position shown in FIG. 1, and quartz sand 104 can be introduced in the passages 92. That sand will embed the circular opening 97 and the three narrow openings 96 intermediate that circular opening and the lower end of each of the fuse links 94. Once this has been done, anhydrous calcium sulfate will be introduced into, and will be used to fill, the upper ends of the passages 92. That anhydrous calcium sulfate will embed the uppermost opening 96 in each of the fuse links 94.

Three additional cup-shaped washers 98 will then have the slots 100 thereof telescoped over the upper ends of the fuse links 94, and those upper ends will then be bent over to maintain those cup-shaped washers in assembled relation with those fuse links. Further solder 101 will be used to bond those cup-shaped washers 90 to the upper ends of the links 94, and also to secure those cup-shaped washers to the tinned metal coatings 93 on the ends of the cylinder 90. This further solder 101 coacts with the solder 101 at the opposite end of the cylinder 90, and with the cup-shaped washers 98 at both ends of the cylinder 90, to hermetically seal the passages 92. The cylinder 90, with its fuse links 94 and its fillers 102 and 104, serves as the short-circuiting chamber of the fuse shown in FIGS. 1–10.

At this time the end bell 78, to which the terminal 82 has previously been permanently secured, is set so its recessed end is uppermost. That end bell is then heated to the melting point of solder, the cylinder 90 is set so the sand-filled end thereof is within the recessed end of end bell 78, solder is applied to that recessed end and is caused to melt and bond that cylinder and end bell together, and then the end bell and solder are permitted to cool. That solder will mechanically and electrically bond the short-circuiting chamber to the end bell 78.

The end bell 76, to which the absorber 62 has previously been permanently secured, is then set with its recessed end uppermost. That end bell is then heated to the melting point of solder, the short-circuiting chamber with its attached end bell 78 and terminal 82 will then be inverted and set in the recess of the end bell 76. Solder will then be applied to the recess in the end bell 76, and that solder will melt and intimately bond that end bell to the short-circuiting chamber; and then that end bell and the solder will be permitted to cool.

The support 52 will then have its slot 54 telescoped over the reduced cross-section, left-hand end of the absorber 62; and the heater 38, which has previously been riveted to the terminal 24, will have its reduced cross-section portion 46 telescoped through the slot 54 in that support 52. The axis of the terminal 24 will then be alined with the axis of the absorber 62, and thereafter the connector 70 will be set so the lower loop thereof rests upon the absorber 62 and so the upper loop thereof telescopes over the reduced cross-section end 46 of the heater 38. Heat-softenable material 74 will then be applied to the connector 70, to the heater 38, and to the absorber 62; and that heat-softenable material will mechanically and electrically bond the connector 70 to that heater and absorber.

The notch 59 is the support 58 will then be telescoped down over the reduced cross-section portion 63 of the absorber 62; and that support will thus be intermediate the end bell 76 and the full-width portion of the heat-absorbing member 62. The right-hand end of the helical extension spring 72 will then be secured to the upper end of the hook 60. That spring will be under tension and will bias the connector 70 for movement out of its mechanical and electrically-conducting engagement with the heater 38 and absorber 62.

The opposite ends of the wire 66 will be stripped of their insulation and will then be telescoped upwardly through the rivet 50 and through the opening 64 in the absorber 62. Solder 68 will be applied to those ends of that wire to bond those ends to the terminal 24 and to the absorber 62. At this time, all of the electrically-conducting components of the fuse will be electrically bonded together to constitute one, continuous, integrated conductor.

The wire 66 will be in parallel with, and will thus shunt, the heater 38. The overall resistance of the wire 66 will be materially greater than that of the heater 38; and, therefore, as long as the connector 70 is in its normal, electrically-conducting engagement with the heater 38 and absorber 62, the shunt wire 66 will carry very little

current. However, when the connector **70** is moved out of its normal, electrically-conducting engagement with the heater **38** and absorber **62**, the wire **66** will have to carry all of the current; and that current will cause that wire to blow.

The fusible conductors **94** are in parallel with each other, and each of those fusible conductors will carry its proportionate share of the total current passing through the fuse. The openings **96** and **97** provide weak spots in those fusible conductors, and those weak spots will generate the greatest temperatures generated by those fusible conductors. The amount of heat generated by those fusible conductors will be great enough to blow those fusible conductors on heavy overloads and on short circuits. Because the quartz sand **104** within the passages **92** is kept relatively cool by the end bell **78** and the terminal **82**, the fuse links **94** can be made of smaller-than-normal cross section, and the openings **96** and **97** can be made larger than normal. The overall result is that the fuse links **94** are very fast-acting and can provide important and desirable current-limiting characteristics.

The overall integrated conductor, including the terminals **24** and **82**, the heater **38** and the shunt wire **66**, the connector **70**, the absorber **62**, the short circuiting chamber **90**, and the end bells **76** and **78** is then telescoped into the housing **20**. That telescoping will be done by passing the terminal **82** all the way through the housing **20**; and that telescoping will be limited by the engagement of the pin **26** with the left-hand end of the housing **20**. Once the overall integrated conductor has been telescoped within the housing **20**, the compartment defined by the support **52** and the left-hand end of the housing **20** will be filled with a filler such as calcium sulfate **106**. Thereupon, the closure **32** will have its slot **34** alined with, and telescoped over, the terminal **24**; and then that closure will be moved into holding engagement with the pin **26**. The fasteners **36** can then be passed through the openings **35** in the closure **32** and seated in the threaded openings **22** adjacent the left-hand end of the housing **20** to permanently secure the overall integrated conductor and the closure **32** to the housing **20**. Thereafter, the closure **86** will have its opening **88** alined with, and telescoped over, the terminal **82**; and that closure will be moved until its openings **85** are in register with the threaded openings **22** adjacent the right-hand end of the housing **20**. At this time, the fasteners **84** will have their threaded shanks passed through the openings **85** and seated in those openings **22**. Those fasteners will permanently secure the closure **86** to the housing **20**; but the terminal **82**, the end bell **78**, the cylinder **90**, the end bell **76**, the support **58**, the absorber **62**, the connector **70** and the support **52** will be free to move axially of the housing **22**. Thereafter, the terminal **82** will be staked to form the protuberances **83** at each side thereof; and those protuberances are spaced a short distance to the right of the closure **86**, and they project outwardly beyond the sides of the slot **88** of closure **86**. Those protuberances will keep a heavy pressure or a severe blow from driving the terminal **82**, the end bell **78**, the cylinder **90**, the end bell **76** and the absorber **62** to the left to cause binding between the connector **70** and the heater **38**.

Under normal conditions of operation, the fuse of FIGS. 1–10 will carry its rated current and will occasionally carry transient overloads. The reduced cross-section portions **42** and **44** of the heater **38** will respond to the passage of the rated current through the fuse to generate heat, and the weak spots in the fuse links **94**, formed by the openings **96** and **97**, will also respond to the passage of that current to generate heat. The heat absorber **62** will respond to the heating of the heater **38** and of the fuse links **94** to become heated, but that absorber will not become hot enough to permit the heat-sofenable material **74** to soften. Only where an objectionable overload is continued for an objectionable length of time will the heat supplied to, and held by, the absorber **62** be great enough to soften the heat-softenable material **74**. However, once that material does soften, it will release the connector **70**; and the spring **72** will thereupon move that connector out of its electrically-conducting engagement with the heater **38** and absorber **62**. At such time, the circuit through the heater **38** will be interrupted, but the circuit through the shunt wire **66** will be intact. The circuit through the shunt wire **66** will prevent or minimize arcing in the compartment defined by the supports **52** and **58**; and this is very desirable. The shunt wire **66** will be unable to carry the rated current of the fuse, much less any overloads that cause the heat-softenable material **74** to soften; and hence that wire will blow. However, any arcs that form when that wire blows will be quickly extinguished by the filler **106** which embeds that wire.

If the overloads to which the fuse is subject are extremely heavy overloads or are short circuits, the fuse links **94** will blow in one or more of their openings **96**. Any arcs that form will be extinguished by the fillers **102** and **104**. The fuse links **94** will open very promptly, and thus they will limit the current that has to be carried by the circuit whenever a heavy overload or a short circuit occurs.

Where heavy overloads of short duration are recurrently applied to the fuse, the heater **38** will expand and contract appreciably; and that heater can tend to force the connector **70** to move axially of the housing **20**. Such movement will not cause binding of that connector because that movement will be compensated for by the axial movement of the absorber **62** and of the short circuiting chamber with its end bells. That axial movement thus compensates for expansions and contractions of the heater **38**; and it also compensates for changes in the overall length of the housing **20** due to expansion or contraction of that housing.

The fuse of FIGS. 1–10 thus provides the desirable time lag of a dual element fuse on low overloads, and provides current-limiting operation on heavy overloads and on short circuits. Thus, the fuse of FIGS. 1–10 provides exceptionally desirable circuit protection.

FIGS. 11–14 show a fuse which is very similar to the fuse of FIGS. 1–10. The principal difference between the fuse of FIGS. 11–14 and the fuse of FIGS. 1–10 is the substitution of stamped end bells for the machined end bells of the fuse of FIGS. 1–10.

The fuse of FIGS. 11–14 has a tubular housing **120** of a readily available, inexpensive insulating material such as fiber. That housing has an unobstructed interior surface, and it has threaded openings **122** adjacent the opposite ends thereof. A terminal **124** has an opening, not shown, adjacent the right-hand end thereof, and it also has a second opening, not shown, to the left of the first opening. That second opening receives and fixedly holds a transversely-directed, bar-like pin **126**; and that pin bears against the left-hand end of the housing **120**.

The numeral **132** denotes a cup-shaped closure that can telescope over the left-hand end of the housing **120**; and that closure has a slot **134** which telescopes over the terminal **124**. That closure can abut the pin **126** and fixedly hold that pin and the terminal **124** rigid relative to the housing **120**. The closure **132** has openings that can be set in register with the threaded openings **122** adjacent the left-hand end of the housing **120**; and fasteners **136** have threaded shanks which pass through the openings in the cup-shaped closure **132** and seat in the threaded openings **122**. Those fasteners fixedly secure the terminal **124**, the pin **126** and the closure **132** to the housing **120**.

The numeral **138** denotes a heater that has an opening, not shown, in the left-hand end thereof which can be set in register with the first opening in the terminal **124**. That heater has two reduced cross-section portions **142** and **144**, and it also has a reduced cross-section, right-hand end **146**. A washer **148** has the opening therein alined

with the opening in the heater **138** and with the first opening in the terminal **124**; and a sleeve-like rivet **150** telescopes through those openings and is riveted over to fixedly secure the heater **138** in permanent engagement with the terminal **124**.

The numeral **152** denotes a support of insulating material, and that support has the form of a circular disc. The outer diameter of the support **152** is less than the inner diameter of the housing **120**, and therefore the support **152** can be moved relative to that housing in the axial direction. That support has a slot **154** therein that accommodates the reduced cross-section, right-hand end **146** of the heater **138**, and it has a slot **156** that accommodates the reduced cross section, left-hand end of a heat-absorbing member **162**. That left-hand end of the absorber **162** has an opening, not shown, through it; and that opening accommodates one end of a shunt wire **166** which is encased in asbestos or some other heat-insensitive insulating material. The other end of that shunt wire extends upwardly through the sleeve-like rivet **150**; and solder **168** bonds the ends of the wire **166** to the terminal **124** and to the absorber **162**. Filler material **206** will embed the wire **166** and will quench any arcs that may tend to form when that wire blows.

A connector **170**, which is identical to the connector **70** of the fuse of FIGS. 1–10, is bonded to the heater **138** and to the absorber **162** by heat-softenable material **174**. That connector is normally bonded in mechanical and electrically-conducting engagement with the heater **138** and the absorber **162**; but it can move out of that engagement when that heat-softenable material softens.

The right-hand end of the absorber **162** has a reduced cross-section portion **163**, and that reduced cross-section portion has a width approximately one half of the width of the absorber **162**. The reduced cross-section portion **163** accommodates a notch **159** in a circular support **158** of insulating material. That support receives and holds a hook **160**; and that hook receives and holds the right-hand end of a helical extension spring **172**. That spring biases the connecter **170** for movement out of its electrically-conducting engagement with the heater **138** and absorber **162**.

The reduced cross-section, right-hand end **163** of the absorber **162** is permanently secured, as by silver solder or the like, to a cup-shaped end bell **176**. That end bell is preferably formed by a stamping operation; and while that end bell is not as thick as the end bell **76** of the fuse of FIGS. 1–10, that end bell has appreciable thermal mass. Bonded to the right-hand face of the end bell **176** by solder is a short-circuiting chamber including the cylinder **190**, three fuse links **194**, and six cup-shaped washers **198** which have diametric slots **200** to accommodate the fuse links **194**. The right-hand end of that short-circuiting chamber is bonded, by solder, to a cup-shaped end bell **178**; and that end bell is preferably formed by a stamping operation. That end bell is permanently secured, as by silver solder or the like, to the left-hand end of a terminal **182**; and that terminal is longer than the terminal **82** of the fuse of FIGS. 1–10. That terminal has protuberances **183** at the sides thereof comparable to the protuberances **83** on terminal **82** of the fuse of FIGS. 1–10.

The right-hand end of the housing **120** is covered by a cup-shaped closure **186**; and that closure has a slot **188** which loosely accommodates the terminal **182**. Fasteners **184** extend through openings in the closure **186** and seat in threaded openings **122** adjacent the right-hand end of the housing **120**; but while the fasteners **184** fixedly hold the closure **186** in assembled relation with the housing **120**, they do not preclude axial movement of the terminal **182**, of the short-circuiting chamber and its end bells **176** and **178**, of the absorber **162**, of the conductor **170**, of the connector **170**, and of the supports **152** and **158**.

Because of the substitution of the stamped end bells **176** and **178** for the machined end bells **76** and **78**, the current-limiting characteristics of the fuse of FIGS. 11–14 will not be as great as those of the fuse of FIGS. 1–10. However, the fuse of FIGS. 11–14 will have important and desirable current-limiting characteristics; and it will provide important and valuable circuit protection, as by permitting the connector **170** to move on low overloads and by permitting the links in the short-circuiting chamber to blow on heavy overloads and short circuit.

Referring to FIGS. 15 and 16, the numeral **220** denotes a tubular housing of a readily available, inexpensive insulating material such as fiber. That housing has an unobstructed interior surface, and it has threaded openings **222** adjacent the opposite ends thereof. A terminal **224**, similar to the terminals **24** and **124**, has an opening, not shown, adjacent the right-hand end thereof; and it has a second opening, not shown, to the left of the first opening. That second opening receives and holds a bar-like, transversely-extending pin **226**. That pin is longer than the inner diameter of the housing **220**, and the flat face of that pin abuts the left-hand end of that housing. A cup-shaped closure **232** has a slot **234** which accommodates the terminal **224**; and it also has openings which can can be alined with the threaded openings **222** adjacent the left-hand end of the housing **220**. Fasteners **236** have threaded shanks that extend through the openings in the closure **232** and seat in the threaded openings **222** of the housing **220**.

The numeral **238** denotes a heater which has reduced cross-section portions **242** and **244** and which has a reduced cross-section, right-hand end **246**. That heater is substantially identical to the heaters **38** and **138** of the fuses of FIGS. 1–10 and 11–14, respectively. An opening, not shown, in the left-hand end of the heater **238** is alined with the first opening in the right-hand end of the terminal **224**; and a washer **246** has its opening alined with those openings. A sleeve-like rivet **250** extends through the alined openings in the heater **238**, the terminal **224**, and the washer **246**; and that rivet permanently secures the heater **238** to the terminal **224**.

A support **252** of insulating material has the form of a circular disc; and that support has a diameter smaller than the inner diameter of the housing **220**. The support **252** has a slot **254** that accommodates the reduced cross-section, right-hand end **246** of the heater **238**, and it also has a slot **256** to accommodate the reduced cross-section, left-hand end of a heat-absorbing member **262**. That left-hand end of the absorber **262** has an opening through it; and one end of a shunt wire **266** extends through that opening. The other end of that shunt wire extends through the sleeve-like rivet **250**; and the ends of that shunt wire are bonded to the absorber **262** and to the terminal **224**. That wire is encased in asbestos or some other heat-insensitive insulating material. Filler material **306** will embed the wire **266** and will quench any arcs that may tend to form when that wire blows.

The numeral **258** denotes a support which is smaller than the housing **220** and which can move freely within the housing **220** in the axial direction; and that support has a notch **259**. That notch telescopes over the reduced cross-section, right-hand end **263** of the absorber **262**. That support carries a hook **260**, and that hook receives and holds the right-hand end of a helical extension spring **272**. That spring biases a connector **270** out of its normal, mechanical and electrically-conducting engagement with the heater **238** and the absorber **262**. The connector **270** is identical with the connectors **70** and **170** of the fuses of FIGS. 1–10 and 11–14, respectively. Heat-softenable material **274** normally holds the connector **270** in that mechanical and electrically-conducting engagement, but it will respond to heat to soften and release that connector. When that heat-softenable material softens, the spring **272** will move the connector **270** to the right and open the circuit of the fuse.

The numeral 276 denotes an end bell which is permanently secured, as by silver solder or the like, to the reduced cross-section end 263 of the absorber 262. That end bell is a solid, cylindrical, metal disc, but it has a number of radially-extending openings at the periphery thereof. The numeral 278 denotes a similar end bell, and those end bells are dimensioned to telescope within a sleeve 290 of glass melamine. That sleeve will be dimensionally stable, and it can be made so it has a very close fit with the peripheries of the end bells 276 and 278. The sleeve 290 has openings adjacent the ends thereof, and those openings will accommodate steel pins 291. Those pins will have press fits with the radial openings at the peripheries of the end bells 276 and 278, and those pins will permanently secure the sleeve 290 to the end bells 276 and 278. The inner diameter of the sleeve 290 is larger than the width of the absorber 262 but is smaller than the width of the terminal 282.

Intermediate the end bells 276 and 278 are a number of fusible conductors 294; and each of those fusible conductors has four narrow openings 296 therein plus one circular opening 297 therein. As indicated particularly by FIG. 15, the circular opening 297 is adjacent the left-hand end of the fusible conductor 294 but is spaced from that left-hand end by an intermediate narrow opening 296. The ends of the fusible conductors 294 are permanently secured to the confronting faces of the end bells 276 and 278, as by solder. Where desired, slots or notches can be formed in the confronting faces of the end bells 276 and 278, and those slots or notches will accommodate the ends of the fuse links 294. Anhydrous calcium sulfate 302 embeds the left-hand ends of the fusible conductors 294, and quartz sand 304 embeds the middles and also the right-hand ends of the fusible conductors 294. This arrangement of fillers is exactly the same as the arrangement of fillers in the fuse of FIGS. 1–10.

A terminal 282 is permanently secured, as by silver solder or the like, to the right-hand face of the end bell 278. That terminal has protuberances 283 at the opposite sides thereof. That terminal has the left-hand end thereof loosely lodged within a slot 288 in a cup-shaped closure 286 for the right-hand end of the housing 220. That closure has openings which accommodate fasteners 284; and the threaded shanks of those fasteners extend through those openings and seat in threaded openings 222 adjacent the right-hand end of the closure 220.

In fabricating the short-circuiting chamber which includes the sleeve 290, the end bells 276 and 278, the fusible conductors 294, and the filler materials 302 and 304, the end bells 276 and 278 are first equipped with the absorber 262 and the terminal 282, respectively; and thereafter the fusible conductors 294 are soldered to the end bells 276 and 278. At such time, the end bell 276 is telescoped part way into the tube 290, and then anhydrous calcium sulfate 302 is poured into the sleeve 290. The end bell 278 is then telescoped within the right-hand end of the tube 290, and thereupon the threaded plug 310 can be removed from the threaded opening in the end bell 278. Quartz said 304 is then introduced through that opening; and once the compartment defined by the end bells 276 and 278 and the sleeve 290 is filled, the threaded plug 310 can be replaced.

The fuse of FIGS. 15 and 16 differs from the fuses of FIGS. 1–10 and 11–14 in the construction of the short-circuiting chamber; but the operation of the fuse of FIGS. 15 and 16 is the same as the operations of those other fuses. The short-circuiting chamber shown in FIGS 15 and 16 is cheaper and easier to make than are the short-circuiting chambers of the fuses of FIGS. 1–10 and 11–14.

Referring to FIG. 17, the numeral 320 denotes a housing of a dimensionally stable dielectric material, and one such material is glass melamine. Disposed within, and located adjacent the left-hand end of, the housing 320 is an end bell 376 which differs from the end bell 76 of FIGS. 1–10 because it had radially-directed openings 377 at the periphery thereof and because it has a terminal, rather than a heat-absorbing member, permanently secured to it. An end bell 378, which is identical to the end bell 376, is disposed within and adjacent the other end of the housing 320; and that end bell has radially-directed peripheral openings 377, and has a terminal 382 permanently secured to it, as by silver solder or the like. Steel pins 379 extend through openings in the housing 320 and seat in the radially-directed peripheral openings 377 in the end bells 376 and 378 to permanently secure those end bells to that housing.

The confronting faces of the end bells 376 and 378 are machined to form cup-like recesses, and those cup-like recesses accommodate the ends of a cylinder 390 which is identical to the cylinder 90 of the fuse of FIGS. 1–10. That cylinder has metal coatings at the opposite ends thereof, has cup-shaped washers, and has fusible conductors 394 extending through the cylindrical passages 392 therein. The only differences between the short-circuiting chamber of FIGS. 10 and 17 are that each of the fusible conductors 394 has a mass 395 of alloying material pressed into the circular opening 397 thereof and that insulating discs 399 are intermediate the filler materials 302 and 304. The masses 395 are made of an alloying material such as tin, which will respond to heat to alloy with the metal of the fusible conductors 394 and thereby causes blowing of those conductors. This alloying action will occur whenever objectionable overloads continue for objectionable periods of time.

The fuse of FIG. 17 will protect against heavy overloads and short circuits by blowing at the openings 396 of the links 394; and that fuse will protect against lesser overloads by the alloying action between the masses 395 and the metal of the fusible conductors 394. Thus the fuse of FIG. 17 provides full circuit protection.

Whereas the drawing and accompanying description have shown and described several preferred embodiments of the present invention, it should be apparent to those skilled in the art that various changes may be made in the form of the invention without affecting the scope thereof.

What I claim is:

1. In an electric fuse, a body of insulating material, a passage through said body of insulating material, metallized deposits on the ends of said body of insulating material adjacent the opposite ends of said passage, a cup-shaped washer that has the dished portion thereof disposed within one end of said passage, a second cup-shaped washer that has the dished portion thereof disposed within the other end of said passage, openings in said washers that receive the ends of a fusible conductor, said dished portions of said cup-shaped washers centering said cup-shaped washers relative to said passage and said openings in said cup-shaped washers centering said fusible conductor relative to said cup-shaped washers, whereby said fusible conductor is centered relative to said passage, filler within said passage that embeds said fusible conductor, end bells, and solder that directly engages said end bells and said metallized deposits and said washers and said fusible conductor and that bonds said end bells to said metallized deposits on the ends of said body of insulating material and to said cup-shaped washers and to said fusible conductor.

2. In an electric fuse, a body of insulating material, a passage through said body of insulating material, metallized deposits on the ends of said body of insulating material adjacent the opposite ends of said passage, a washer disposed at one end of said passage, a second washer disposed at the other end of said passage, openings in said washers that receive the ends of a fusible conductor, said washers being centered relative to said passage and said openings in said washers centering said fusible conductor relative to said washers, whereby said fusible conductor is centered relative to said passage,

end bells, and solder that directly engages said end bells and said metallized deposits and said washers and said fusible conductors and that bonds said end bells to said metallized deposits on the ends of said body of insulating material and to said washers and to said fusible conductor.

3. In an electric fuse, a body of insulating material, a passage through said body of insulating material, metallized deposits on the ends of said body of insulating material adjacent the opposite ends of said passage, a washer disposed at one end of said passage, a second washer disposed at the other end of said passage, openings in said washers that receive the ends of a fusible conductor, end bells, and solder that directly engages said end bells and said metallized deposits and said washer and said fusible conductor and that bonds said end bells to said metallized deposits on the ends of said body of insulating material and to said washers and to said fusible conductor to hermetically seal the ends of said passage.

4. An electric fuse that comprises a housing, a fusible conductor disposed within said housing, a closure adjacent one end of said housing, a second closure adjacent the other end of said housing, sand in said housing that embeds and directly engages a substantial portion of the length of said fusible conductor adjacent one end of said fusible conductor, said sand surrounding said substantial portion of said length of said fusible conductor to a depth sufficient to enable said sand to form a fulgurite as said fusible conductor blows to open the circuit, said fusible conductor responding to a heavy electrical overload to blow and permit an arc to form within said housing, said sand adjacent said substantial portion of said length of said electrical conductor responding to said arc to fuse and thereby absorb heat from said arc to help extinguish said arc, said sand adjacent said substantial portion of said length of said fusible conductor forming a fulgurite adjacent said substantial portion of said length of said fusible conductor as said sand fuses to absorb heat from said arc, and anhydrous calcium sulfate that embeds and directly engages a further portion of said length of said fusible conductor adjacent the other end of said fusible conductor, said anhydrous calcium sulfate surrounding said further portion of said length of said fusible conductor for a length and to a depth sufficient to space said sand far enough away from said further portion of said length of said fusible conductor to keep said sand from forming a fulgurite coextensive with said further portion of said length of said fusible conductor, said anhydrous calcium sulfate being free of chemically-bound or mechanically-held water so it will prevent the formation of an after-blow resistance path through said fuse, said anhydrous calcium sulfate preventing the formation of a closure-to-closure fulgurite as said fusible conductor blows, said anhydrous calcium sulfate preventing the formation of an after-blow resistance path by helping quench the arc, which tends to form as the fusible conductor blows, without evolving water vapor.

5. An electric fuse that comprises a housing, a fusible conductor disposed within said housing, said fusible conductor having a plurality of portions of reduced cross section intermediate the ends thereof, an alloying metal of low alloying temperature mounted on said fusible conductor adjacent one of said portions of reduced cross section, a closure adjacent one end of said housing, a second closure adjacent the other end of said housing, sand in said housing that embeds and directly engages said one portion of reduced cross section and said alloying metal, said sand surrounding said one portion of reducer cross section and said alloying metal to a depth sufficient to enable said sand to form a fulgurite as said fusible conductor blows to open the circuit, said fusible conductor responding to a heavy electrical overload to blow and permit an arc to form within said housing, said sand surrounding said one portion of reduced cross section and said alloying metal responding to said arc to fuse and thereby absorb heat from said arc to help extinguish said arc, said sand surrounding said one portion of reduced cross section and said alloying metal forming a fulgurite adjacent said portion of reduced cross section and said alloying metal to absorb heat from said arc, and anhydrous calcium sulfate that embeds and directly engages another of said portions of reduced cross section, said anhydrous calcium sulfate surrounding said other portion of reduced cross section for a length and to a depth sufficient to space said sand far enough away from said other portion of reduced cross section to keep said sand from forming a fulgurite coextensive with said other portion of reduced cross section, said anhydrous calcium sulfate being free of chemically-bound or mechanically-held water so it will prevent the formation of an after-blow resistance path through said fuse, said anhydrous calcium sulfate preventing the formation of a closure-to-closure fulgurite as said fusible conductor blows, said anhydrous calcium sulfate preventing the formation of an after-blow resistance path by helping quench the arc, which tends to form as the fusible conductor blows, without evolving water vapor.

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