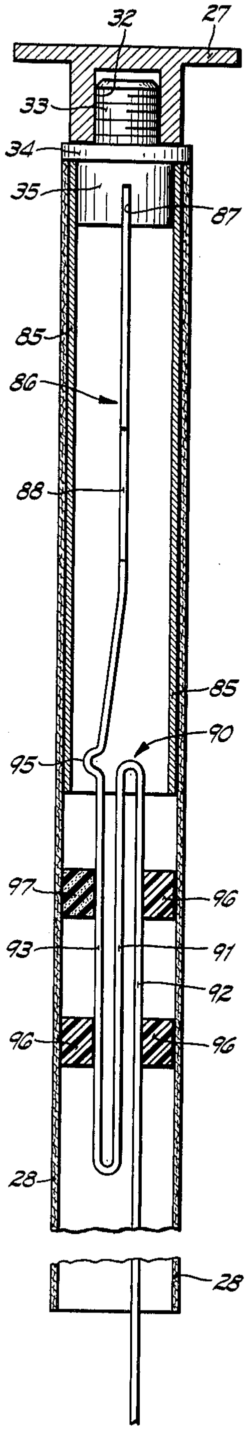
March 1, 1966 H. W. MIKULECKY 3,238,332

FUSE HAVING MEANS TO MODIFY CHARACTERISTIC IN HIGH FAULT CURRENT RANGE

Filed Jan. 21, 1963

3 Sheets-Sheet 1

Fig. 10



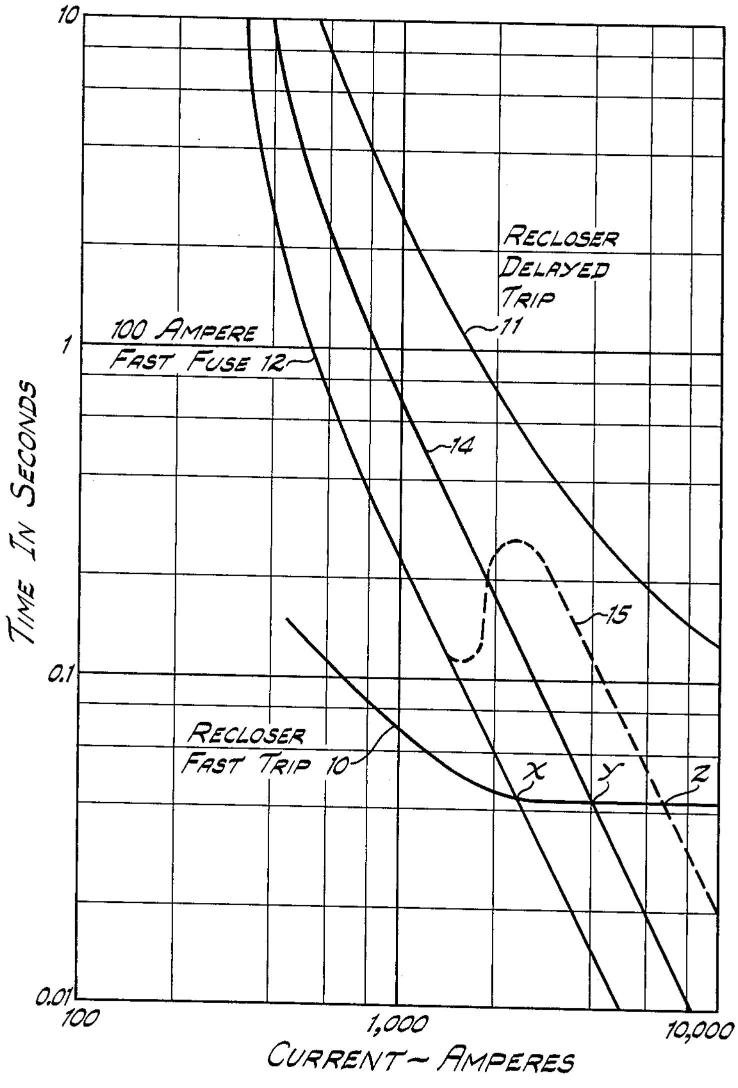


Fig. 1

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3 Sheets-Sheet 2

Fig. 2

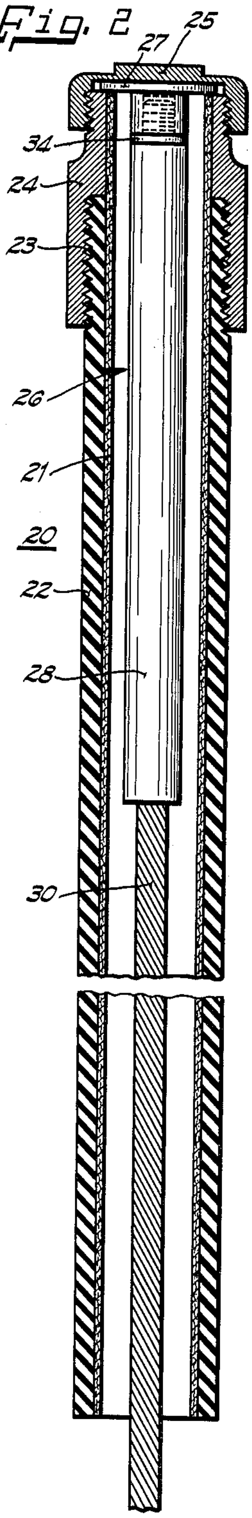


Fig. 3

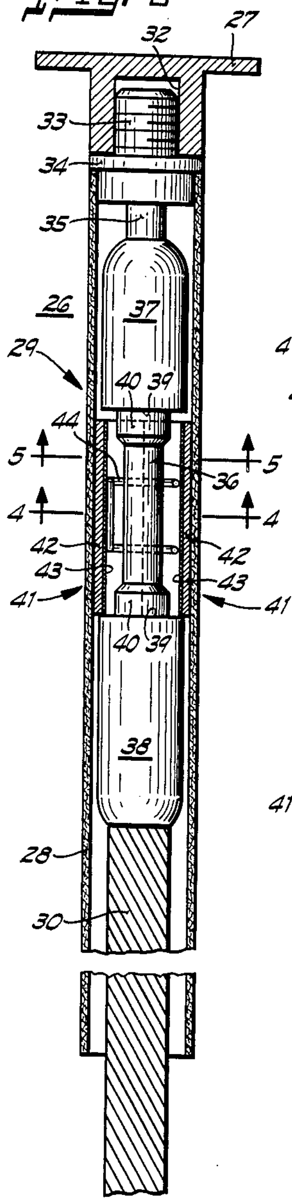
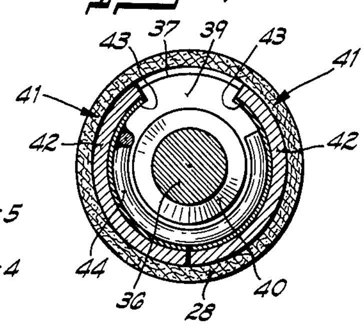


Fig. 4



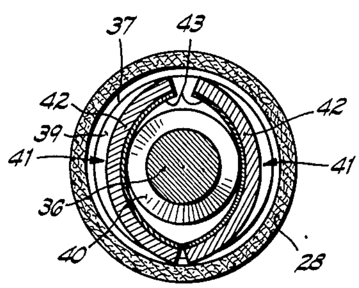


Fig. 5

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Fig. 8

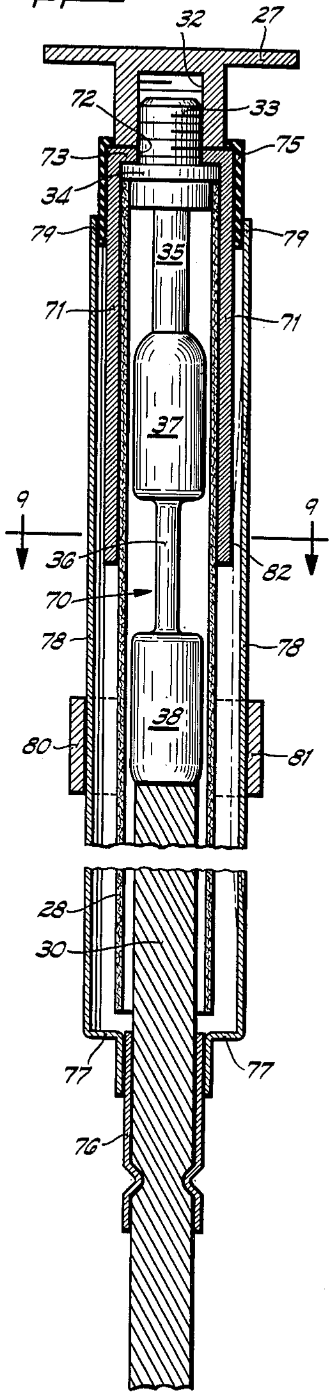


Fig. 9

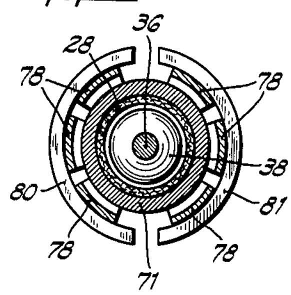


Fig. 7

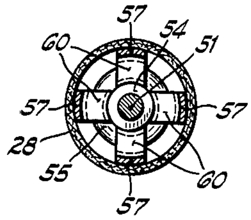
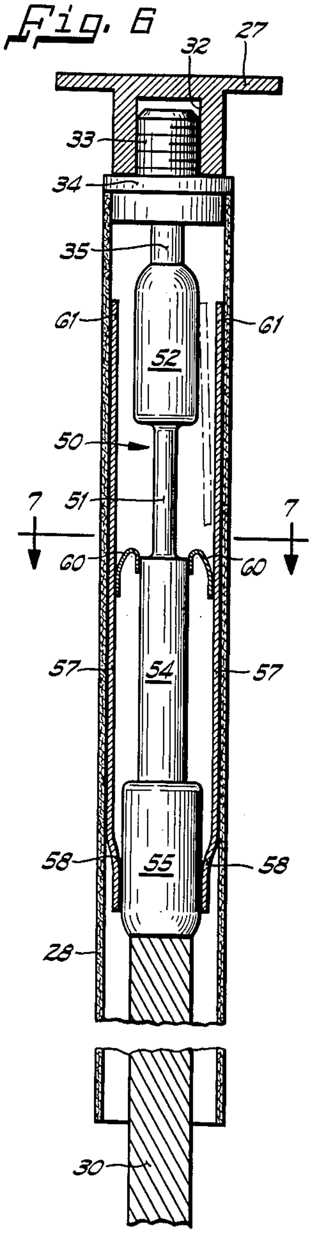


Fig. 6



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3,238,332
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3,238,332

FUSE HAVING MEANS TO MODIFY CHARACTERISTIC IN HIGH FAULT CURRENT RANGE

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Filed Jan. 21, 1963, Ser. No. 252,725
15 Claims. (Cl. 200—120)

This invention relates to electric fuses for overcurrent protection and in particular to primary distribution line-sectionalizing and transformer fuses of the coordination type.

Fused cutouts are used extensively for line sectionalizing and transformer protection in primary distribution systems. In radial primary distribution systems fused cutouts are utilized for line sectionalizing in the main feeders, in three phase branches, and also in single phase laterals. However, oil reclosers are often used on the main feeder and the three phase branches because they offer the advantage of rapidly resetting themselves after clearing a temporary fault. The fuse links used in fused cutouts must be properly coordinated with other fuses in series therewith, with sectionalizers, and with oil reclosers. When fuses in series are properly coordinated, a fault on any part of a radial circuit will cause the fuse nearest the fault on the substation side to blow, thereby isolating the faulted section. Oil reclosers provide a choice of operating characteristics, but most designs provided four openings to lockout, two of which are very fast opening to protect small transformer fuses and avoid burndown on small primary laterals on transient trouble. Usually the two fast trips are followed by two time-lag openings to clear faulted sections before lockout, if possible. The recloser fast and delayed curves are coordinated with fuse curves so that the protected fuse characteristics are bracketed between the recloser fast and slow curves. Conventional fuses which coordinate with reclosers and are selected to provide adequate protection in the low fault current range often result in outages in the high fault current range, whereas fuses which are properly coordinated with reclosers on high fault current often result in sacrifice of protection on low fault currents. If a fuse link having a time-current curve closer to the delayed recloser characteristic curve is selected in order to provide longer melting times on high fault currents, the minimum current at which the fuse link will melt is also increased with the result that protection is inadequate on low fault currents.

It is an object of the invention to provide a fuse which has long melting times in the high fault current range without sacrifice of protection in the low fault current range.

It is a further object of the invention to provide a fuse which has better coordination with reclosers, sectionalizers, and other fuses than was possible with prior art fuses.

Another object of the invention is to provide a fuse of the coordination type having means to modify the melting characteristics in one fault current range without affecting the characteristic in another fault current range.

Still another object of the invention is to provide a fuse for a coordination having a current-time characteristic which is closely adjacent the recloser fast curve in the low fault current range and which closely approaches the slow characteristic of the recloser in the high fault current range.

In accordance with the invention, the magnetic field generated by the flow of fault current of predetermined magnitude through a fusible section of a fuse actuates a movable member to complete a low resistance path in parallel to the fusible section and through which a portion of the fault current flows, thereby modifying the melting characteristics of the fuse at fault currents above this predetermined magnitude.

These and other objects and advantages of the invention will be more readily apparent from the following detailed description when taken in conjunction with the accompanying drawing wherein:

FIG. 1 illustrates the coordination of the fuse of the invention with an oil recloser;

FIG. 2 is a longitudinal cross section view through a cutout fuseholder which may be provided a fuse link in accordance with the invention;

FIG. 3 is a longitudinal cross section view through a preferred embodiment of a fuse link embodying the invention and which may be utilized in the fuseholder of FIG. 2;

FIG. 4 is a view taken on line 4—4 of FIG. 3 and showing the normal position of the shunting members;

FIG. 5 is a view taken on line 5—5 of FIG. 3 and showing the position to which the shunting members have been actuated in response to the flow of fault current of predetermined magnitude through the fuse link;

FIGS. 6 and 8 are longitudinal cross section views through alternative embodiments of the invention;

FIG. 7 is a view taken on line 7—7 of FIG. 6;

FIG. 9 is a view taken on line 9—9 of FIG. 8; and

FIG. 10 is a longitudinal cross section view taken through still another embodiment of the invention.

Similar elements of the various embodiments of the invention are given the same reference numeral throughout the description.

Referring to FIG. 1 of the drawing, an oil recloser having a 225 ampere rating may typically have two fast-opening settings represented by the clearing time versus current, or time-current, characteristic **10** followed by two delayed-opening settings along the time-current characteristic **11**. Fuse links coordinated with such recloser should have a time-current characteristic bracketed between the reclosed fast and slow curves **10** and **11**. The time-current characteristic **12** is for a conventional 100 ampere "fast" fuse having a speed ratio between 6 and 8.1. The minimum melting curve **12** of such fuse crosses the fast trip curve **10** for the recloser at point X which represents approximately 2300 amperes. Fault currents above 2300 amperes would always melt the fuse link before the recloser could clear the fault. Consequently, an unnecessary outage would occur on the branch protected by this 100 ampere fuse link if the fault were of a transient nature. Such unnecessary outages might be prevented by use of a conventional 100 ampere "slow" fuse link having a slower melting time and a speed ratio between 10 and 13.1 whose characteristics are shown in the time-current curve **14**. This fuse link coordinates up to approximately 4000 amperes where it crosses the recloser fast curve **10** at point Y, but it will be noted that the minimum melting current of the fuse at the 10 second point is appreciably greater than that of the "fast" fuse having the characteristic **12**, thereby sacrificing protection in the low current range.

On high fault current the fuse of the invention shunts part of the current from the fusible section and thus modifies the melting characteristic at high fault currents without affecting the characteristics in the low fault current range. A 100 ampere "fast" fuse link would have the time-current characteristic **12** when constructed in conventional manner, but when constructed to embody the invention it would have the time-current characteristic in the high fault current range shown by the dashed line curve **15**. When the oil recloser is coordinated with a fuse of the invention having the minimum melting time versus current characteristic 15, the recloser would interrupt the circuit in sufficient time to prevent the fuse link from melting at any current below 6500 amperes (where the dashed line curve 15 crosses the recloser fast-trip curve 10 at point Z), and yet the fuse would have the low current characteristics of the "fast" fuse shown by curve 12. In other words, the fuse current-time characteristic would be shown by the solid line curve 12 between approximately the 0.12 second point and the 10 second point and by the dashed-line curve 15 below the 0.12 second point. It will also be noted that the time-current characteristic of the fuse of the invention including the dashed-line curve 15 lies completely below the delayed-time curve 11 of the recloser, thus assuring that the fuse link will melt on the delayed trip if the fault is permanent.

The preferred embodiment of the invention utilizes the tendency of a magnetic member to assume a position of minimum reluctance in a magnetic field in order to accomplish shunting of the fusible element and modification of the time-current characteristic of the fuse link on high fault currents. FIG. 2 illustrates a refuseable fuseholder, or fuse tube 20 of the expulsion type for use in a fuse cutout. Fuseholder 20 includes an inner tubular liner 21 of a material such as vulcanized rag fiber adapted to evolve electrical arc extinguishing gases when subjected to an arc. Liner 21 is positioned within an outer tubular member 22 of a material such as glass fibre impregnated or bonded together with a resin to impart high bursting strength. The upper exterior end of tubular member 22 has threads 23 formed thereon, and an internally threaded cylindrical sleeve, or contact 24 is removably secured to the upper end of member 22. The upper exterior end of sleeve 24 is threaded and has an interiorly threaded expendable cap 25 removably secured thereto to close the upper end of the fuseholder 20. A replaceable fuse link 26 embodying the invention and having a button head 27 thereon is positioned within the fuseholder 20 with button head 27 clamped between sleeve 24 and expendable cap 25 and thus electrically connected to the fuseholder upper contact. A kraft paper or horn fibre fuse link auxiliary tube, or protector tube, 28 surrounds the fusible element 29 (see FIG. 3) and the upper portion of the flexible leader 30 which preferably comprises woven strands of tinned copper wire and extends out of the open lower end of the fuseholder 20.

As shown in FIG. 3 the button head 27 of the fuse link may have an internally threaded bore 32 which receives a threaded stud 33 on the upper end of the fusible element 29. Stud 33 has a circumferential flange 34 against which one end of the protector tube 28 may be positioned and a shank 35 which extends into tube 28. Fusible element 29 may be die cast of pure tin (or silver and tin combination) and include a central fusible section 36 of minimum cross sectional area integral with an upper end portion 37 of increased diameter die cast around shank 35 and a lower end portion 38 of increased diameter die cast around the end of leader 30. Alternatively fusible element 29 may be die cast around a strain wire (not shown) secured through holes in the shank 35 and in a ferrule (not shown) or other member crimped as otherwise secured to the end of leader 30 in order to remove all tension on the fusible section 36 of minimum cross sectional area. Alternatively the fusible element 29 may be lap soldered to the shank 35 and to a ferrule (not shown) crimped to the end of flexible leader 30.

Fusible element upper and lower end portions 37 and 38 have circumferential shoulders 39 extending radially from reduced diameter neck portions 40 which are integral with, but of greater diameter than, fusible section 36. A pair of movable arcuate shunting members 41 are adapted to electrically engage and bridge the neck portions 40 on opposite ends of the minimum diameter fusible section 36 and thus provide a low resistance path in shunt to the minimum cross sectional area fusible section 36 of the fusible element 29. Each shunting member 41 comprises an outer arcuate magnetic member 42 of material such as magnetic stainless steel having an inner arcuate liner 43 of a high conductivity material such as copper or silver bonded or clad thereto, and it will be appreciated that high conductivity liner 43 may constitute a layer of copper or silver sprayed or otherwise deposited on magnetic member 42. A spring 44 of stainless steel wire normally retains the shunting members 41 against the inner surface of the protector tube 28 in the position shown in FIG. 4 wherein the copper liners 43 are spaced from the neck portions 40 of the fusible element 29. The radially extending shoulders 39 on upper and lower end portions 37 and 38 prevent axial movement of the shunting members 41.

When a high fault current of predetermined magnitude flows through the fuse link 26, the magnetic field generated thereby attracts the shunting members 41 from the radially outer position shown in FIG. 4 wherein they are spaced from the neck portions 40 of the fusible element 29, to the radially inner position shown in FIG. 5 wherein the copper liners 43 electrically engage the neck portions 40 of the fusible element 29 on opposite ends of the minimum diameter fusible section 36. The force of attraction results from the inherent tendency of a magnetic member to assume a position of minimum reluctance within a magnetic field and under high fault current provides high pressure engagement against neck portions 40 on opposite ends of the fusible section 36. Consequently, a portion of the fault current flows through the parallel path provided by the shunting members 41, thereby decreasing the current through the fusible section 36, which has the highest resistance, and modifying the time-current characteristic of the fuse link approximately in accordance with the dashed-line curve 15 shown in FIG. 1.

Once the two shunting members 41 carry current, an additional force of attraction exists between these two members and between these two members and fusible element 29 carrying current in the same direction which augments the forces holding the copper liners 43 in high pressure engagement with the neck portions 40 of fusible element 29.

In alternative embodiments of the invention the spring 44 may be eliminated. Apparently the voltage drop across the minimum diameter fusible section 36 is so small on load currents and low magnitude fault currents that the contact resistance between the neck portions 40 of fusible element 29 and the shunting members 41 effectively prevents appreciable current from flowing in the parallel path through the shunting members 41. When the fault current is sufficiently high to create high contact pressure of the shunting members 41 against the neck portions 40 of the fusible element 29 and to develop a relatively large voltage drop across the fusible section 36, a substantial magnitude of current flows in the parallel path through shunting members 41 and modifies the time-current characteristic of the fuse link 26.

The embodiment of FIGS. 6 and 7 is also adapted for use in fuseholder 20 but utilized the forces of attraction between two members carrying current in the same direction to complete the current path in shunt to the minimum diameter fusible section and thus modify the time-current characteristic in the high fault current range. A fusible element 50 preferably of tin within protector tube 28 includes a central fusible section 51 of minimum cross sectional area integral with an increased diameter upper end portion 52, which may be die cast around shank 35, and also with an increased diameter neck portion 54, which in turn, is integral with a lower end portion 55 which is of still greater diameter and may be die cast around a ferrule (not shown) crimped to flexible leader 30. A plurality of elongated, parallel, thin strips 57 of high conductivity material such as copper or beryllium copper are positioned in circumferentially spaced apart relation around the inner periphery of insulating protector tube 28. Four conductive strips 57 are illustrated in FIGS. 6

and 7, and each has an inwardly bent portion 58 adjacent its lower end which is mechanically and electrically secured by suitable means such as solder to the lower end portion 55 of fusible element 50. Relatively weak spring members 60 generally of U-shape and of relatively high conductivity material normally resiliently urge the conductive strips 57 against the internal periphery of protector tube 28 and provide a low resistance path between the strips 27 and neck portion 54 adjacent fusible section 51.

One leg of each generally U-shaped spring 60 may be secured intermediate the ends of a conductive strip 57 and the other leg may abut against neck portion 54. Conductive strips 57 are normally resiliently urged by springs 60 to the position shown in full lines wherein the upper free end 61 of the strips 57 is radially spaced from the upper end portion 52 of fusible element 50. A portion of the current through the fuse flows through each conductive strip 57 in a path in shunt to neck portion 54 and beginning at the inwardly bent portion 58 and returning to fusible element 50 through spring 60. The current flowing in parallel paths through the conductive strips 57 and neck portion 54 creates an attractive force between strips 57 and neck portion 54 and also between strips 57. When a fault current of predetermined magnitude passes through the fuse, this attractive force is sufficient to overcome the bias of springs 60 and cause strips 57 to assume their operated position shown in dotted lines in FIG. 6 wherein the free end 61 electrically engages the upper end portion 52 of fusible element 50. In their operated position the conductive strips 57 provide a current path in shunt to the minimum diameter fusible section 51 and through which a portion of the fault current flowing through the fuse is diverted, thereby modifying the melting characteristics of the fuse in the high fault current range. Once the free ends 61 of conductive strips 57 engage upper end portion 52 of the fusible element and current flows through the strips 57 (beginning at inwardly bent portions 58 and returning through the free ends 61) in parallel paths which shunt the fusible section 51, the force of attraction between conductive strips 57 and between strips 57 and neck portion 54 carrying current in the same direction is increased and holds the free ends of the strips 57 in high pressure engagement with the upper end portion 52 of fusible element 58.

The embodiment of the invention illustrated in FIGS. 8 and 9 is analogous to the embodiment of FIGS. 3–5 but differs therefrom in that the movable magnetic members are exterior of the insulating protector tube and do not directly shunt the fusible section but rather actuate other members to complete the path in shunt to the fusible section. A fuse link 70 housed within an insulating protector tube 28 includes, in conventional manner, a threaded stud portion 33 having a circumferential flange 34 integral with a shank 35 around which may be die cast the upper cylindrical end portion 37 of a tin fusible element having a central fusible section 36 of minimum cross sectional areas which, in turn, is integral with a lower end portion 38 which may be die cast around a ferrule (not shown) crimped to a flexible leader 30. A metallic stationary contact member 71 of inverted cup shape is telescoped over the upper end of insulating protector tube 28 and has an axial aperture 72 in the transverse wall 73 thereof which receives the threaded stud 33 so that the transverse wall 73 electrically engages the circumferential flange 34 of fuse link 70. A tubular insulation member 75 surrounds the end of stationary contact member 71 adjacent the transverse wall 73.

A metallic ferrule 76 is crimped to flexible leader 30 below protector tube 28. A plurality of parallel, thin, elongated, flexible strips 78 of high conductivity material such as copper or beryllium copper have offset portions 77 adjacent their lower end secured mechanically and electrically to the ferrule 76 by suitable means such as soldering. The flexible conductive strips 78 are spaced apart circumferentially and extend parallel to the axis of protector tube 28 and have their upper ends 79 disposed against insulation member 75 so that the strips 78 are normally spaced radially from the stationary contact member 71. An arcuate magnetic member 80 of suitable material such as magnetic stainless steel is bonded intermediate the ends of three circumferentially successive strips 78, and a similar arcuate magnetic member 81 is bonded intermediate the ends of the three remaining flexible strips 78. The adjacent ends of arcuate magnetic members 80 and 81 are normally spaced circumferentially a sufficient distance to permit radial movement of conductive flexible strips 78. A force of attraction exists between the magnetic members 80 and 81 as a result of the magnetic field generated by the flow of current through fuse link 70 and the inherent tendency of magnetic members to assume a position of minimum reluctance within a magnetic field. When a fault current of predetermined magnitude flows through fuse link 70, the attractive force tending to move magnetic core members 80 and 81 together actuates flexible conductive strips 78 radially inward to the position shown in dotted lines in FIG. 8 wherein strips 78 electrically engage metallic stationary contact member 71 at point 82 to form a low resistance path in shunt to the fusible section 36, thereby changing the melting time of the fusible section and modifying the characteristics of the fuse in the high fault current range. After conductive strips 78 engage member 71 and divert a portion of the current from fusible section 36, the attraction between conductive strips 78 and fusible element carrying current in the same direction augments the contact pressure with which strips 78 engage stationary contact member 71.

The embodiment of the invention illustrated in FIG. 10 may be used in fuseholder 20 and utilizes the forces of repulsion between parallel portions of a fuse link carrying current in opposite directions in order to complete a low resistance path in shunt to the fusible element and thus modify the melting characteristics of the fuse link in the high fault current range. A tubular metallic liner 85 of high conductivity material such as copper covers a portion of the axial length of the inner periphery of the insulating protector tube 28 and is secured by suitable means such as solder or brazing to the shank 35 of a threaded stud 33 at one end of the fuse link. One end of an elongated fuse element 86 of suitable high conductivity and resilient material such as beryllium copper is secured within an axially extending slot 87 in shank 35 by suitable means such as brazing. Fuse element 86 extends through protector tube 28 and has a necked-down fusible section 88 of minimum cross sectional area. Within the lower portion of protector tube 28 fusible element 86 includes a folded-over portion 90 generally of S-shape, or in the form of a double hairpin, comprising an inner leg 91 which is parallel to two outer legs 92 and 93 in which the current flows in a direction opposite to the direction of current flow in inner leg 91. A generally U-shaped bend in fusible element 86 forms a contact 95 adjacent the lower end of conductive liner 85. Two relatively rigid pads of insulating material 96 are bonded to outer leg 92 of fusible element 86, a similar relatively rigid pad 96 is bonded to the lower portion of outer leg 93, and a pad 97 of relatively resilient insulating material such as sponge rubber is bonded to the upper portion of outer leg 93 in order to position fusible element 86 axially of protector tube 28. A force of repulsion exists between inner leg 91 and outer legs 92 and 93 as a result of current flow in opposite directions through these legs. A force of attraction exists between outer legs 92 and 93 as a result of current flow in the same direction therethrough, but inasmuch as the spacing between outer legs 92 and 93 is greater than that between inner leg 91 and outer legs

92 and 93, a resultant force of repulsion tends to move contact 95 into engagement with conductive liner 85. When a fault current of predetermined magnitude flows through fusible element 86, this force of repulsion is sufficient to engage contact 95 with conductive liner 85 and thus complete a low resistance path in shunt to fusible section 88. This low resistance shunt path carries a portion of the fault current through the fuse and modifies the melting characteristics thereof so that the time-current curve of the fuse approximately follows the dashed curve 15 in the high fault current range as seen in FIG. 1.

Fuses embodying the invention have long melting times in the high fault current range without sacrifice of protection in the low fault current range, and their current-time characteristic is closely adjacent the recloser fast curve in the low fault current range and also closely approaches the slow characteristic of the recloser in the high fault current range. While only a few embodiments of the invention have been illustrated and described, many modifications and variations thereof will be readily apparent to those skilled in the art, and consequently it is intended in the appended claims to cover all such modifications and variations which fall within the true spirit and scope of the invention.

I claim:

1. In a fuse, in combination, a current carrying fusible element having a fusible section of reduced cross sectional area, a conductive element extending parallel to said fusible element adjacent said fusible section, one of said elements being fixed and the other element being movable relative to said fixed element between an operated position, wherein said conductive element is electrically connected to portions of said fusible element on opposite sides of said fusible section and completes a low resistance path in shunt to said fusible section, and a normal position wherein the resistance of said shunt path is substantially greater than that of said fusible section, and electroresponsive means for actuating said movable element from said normal to said operated position in response to the magnetic field generated by the flow of current of a predetermined magnitude through said fusible element and for releasing said movable element and permitting it to return to said normal position upon interruption of current flow through said fusible element.

2. The fuse defined by claim 1 and including resilient means for normally retaining said movable element in spaced relation to at least one of said portions of said fusible element on opposite sides of said fusible section.

3. The fuse defined by claim 1 wherein said electroresponsive means includes magnetic material carried by said movable member and said movable member is actuated from said normal to said operated position by the tendency of said magnetic material to assume a position of minimum reluctance within said magnetic field.

4. In a fuse, in combination, an insulating tube, a fusible element extending axially through said tube and having a fusible section of minimum cross sectional area and portions of increased diameter on opposite sides of said fusible section, a plurality of magnetic shunting members within said tube extending parallel to the axis thereof and being disposed between said fusible section and the internal periphery of said tube, said shunting members being adapted to electrically engage said increased diameter portions on opposite sides of said fusible section and having internal faces of high conductivity material opposite said increased diameter portions, said magnetic shunting members being actuated in response to the magnetic field generated by the flow of a predetermined magnitude of fault current through said fuse into engagement with said increased diameter portions and completing a low resistance current path in shunt to said fusible section, the resistance of said shunt path through said shunting members normally being substantially greater than the resistance of said fusible section.

5. In a fuse, in combination, a fuse link having a fusible section of minimum cross sectional area and a plurality of flexible conductive elements extending parallel to said fusible section and being electrically connected to said fuse link on one side of said fusible section, resilient means for normally biasing said conductive elements in spaced relation from said fuse link on the opposite side of said fusible section, said conductive elements electrically engaging longitudinally spaced apart points of said fuse link on said one side of said fusible section and forming a low resistance current path in shunt to said fuse link between said longitudinally spaced apart points through which a portion of the current passing through said fuse link flows in the same direction as the current through said one side, said conductive elements being actuated against the force of said resilient biasing means into electrical engagement with said fuse link on said opposite side of said fusible section in response to the force of attraction resulting from the flow of currents in the same direction through said elements and the portion of said one side of said fuse link between said longitudinally spaced points when fault current of a predetermined magnitude flows through said fuse link and being returned by said resilient biasing means to said normal position in spaced relation from said fuse link upon interruption of current flow through said fuse link, whereby the melting characteristics of said fuse link are modified in the current range above said predetermined magnitude.

6. In a fuse, in combination, a fuse link having a fusible section of minimum cross sectional area and at least one conductive member extending parallel to said fusible section and being adapted to electrically contact portions of said fuse link on opposite sides of said fusible section and being normally electrically disconnected from said fuse link on at least one of said sides, said conductive member carrying magnetic material and being attracted into electrical engagement with said portions on opposite sides of said fusible section in response to the magnetic field generated by the flow of current of predetermined magnitude through said fuse link, whereby said conductive member shunts a portion of the current flowing through said fusible section and modifies the time-current characteristic of said fuse in the current range above said predetermined magnitude, said conductive member carrying magnetic material being released upon interruption of current flow through said fuse link and returning to said normal position wherein it is disconnected from said fuse link.

7. In a fuse, in combination, a fusible element having a fusible section of minimum cross sectional area and being folded back in three generally parallel, spaced apart leg portions, said leg portions being electrically connected in series and in series with said fusible section and current flowing in opposite directions in adjacent leg portions, a conductive element extending generally parallel to said fusible section and being adjacent to but spaced from one of said leg portions and being electrically connected to said fusible element on the side of said fusible section opposite said leg portions, said one leg portion being movable into electrical contact with said conductive member in response to the force of repulsion between adjacent leg portions when a current of predetermined magnitude flows through said fusible element and completing a low resistance path in shunt to said fusible section, whereby the characteristics of said fuse are changed in the current range above said predetermined magnitude.

8. In a fuse, in combination, an insulating tube, a fuse link having a fusible section of minimum cross sectional area extending axially through said tube, a plurality of elongated flexible conductive strip elements within said tube and extending parallel to the axis thereof and being adapted to bridge said fusible section, said conductive strip elements engaging said fuse link at a first point on one side of said fusible section, a plurality of resilient conductive members engaging said conductive strip elements

and also engaging said fuse link at a second point on said one side spaced longitudinally of said fuse link from said first point and normally holding said conductive strip elements in spaced relation from said fuse link on the side of said fusible section opposite said one side and completing a low resistance current path through said conductive strip elements in shunt to the portion of said fuse link between said first and second points, whereby current flows in the same direction in said fuse link and said conductive strip elements, the force of attraction between said elements and said fuse link carrying current in the same direction actuating said conductive strip elements into electrical engagement with said opposite side of said fuse link when a current of predetermined magnitude flows through said fuse link, whereby said conductive strip elements shunt said fusible section and change the characteristics of said fuse in the current range above said predetermined magnitude, said resilient members returning said conductive strip elements to said normal position in spaced relation from said fuse link upon interruption of current flow through said fuse link.

9. In a fuse, in combination, a fuse link having a fusible section of minimum cross sectional area, an insulating tube surrounding said fusible section, a plurality of fusible strips of high conductivity electrically connected at one end to said fuse link on one side of said fusible section, a conductive sleeve electrically connected to said fuse link on the side thereof opposite said one side and surrounding said insulating tube, said flexible strips extending generally parallel to said fuse link exterior of and in spaced relation to said insulating tube, an insulating member interposed between said conductive sleeve and the other end of said flexible strips, said strips being sufficiently flexible so that a portion thereof intermediate their said ends is adapted to engage said conductive sleeve, said flexible strips carrying magnetic material intermediate their ends and being flexed sufficiently in response to the magnetic field generated by the flow of current of predetermined magnitude through said fuse link to electrically engage said conductive sleeve, whereby said flexible strips shunt said fusible section and change the characteristics of said fuse in the current range above said predetermined magnitude.

10. In a fuse, in combination, an insulating tube, a fuse link extending axially through said tube and having a fusible section of minimum cross sectional area and cylindrical conductive portions of greater diameter than said fusible section on opposite sides of said fusible section, a pair of arcuate magnetic shunting members in surrounding relation to said fusible section within said tube and being adapted to bridge said greater diameter cylindrical portions on opposite sides of said fusible section and having material of high conductivity on the inner faces thereof opposite said greater diameter cylindrical portions, said shunting members being actuated into a position of minimum reluctance within the magnetic field generated by the flow of fault current of predetermined magnitude through said fuse link and urging said high conductivity material thereon into high pressure engagement with said greater diameter cylindrical portions of said fuse link, whereby a low resistance current path is completed in shunt to said fusible section and the characteristics of said fuse are changed in the current range above said predetermined magnitude.

11. In a fuse, the combination of a current-carrying fusible element having a fusible section of reduced cross sectional area, and means for modifying the time-current characteristic of said fuse in the current range above a predetermined current magnitude including electroresponsive means operable in response to current of said predetermined magnitude through said fusible element to shunt said section of reduced cross sectional area, said electroresponsive means opening said shunt upon interruption of current flow through said fusible element.

12. In a fuse, the combination of a current-carrying fusible element having a fusible section of reduced cross sectional area, means for completing a low resistance electrical circuit in shunt to said fusible section, and electroresponsive means for actuating said last-named means to complete said electrical circuit in response to the magnetic field generated by the flow of current of predetermined magnitude through said fusible element and for releasing said last-named means to open said low resistance shunt circuit upon interruption of current flow through said fusible element, whereby the time-current characteristic of said fuse is modified in the current range above said predetermined magnitude.

13. In a fuse in accordance with claim **12** wherein said electroresponsive means includes a magnetic element movable between a normal position and an operated position and said magnetic element actuates said circuit completing means in moving from said normal to said operated position and said magnetic element is actuated from said normal to said operated position by its tendency to assume a position of minimum reluctance within said magnetic field.

14. In a fuse in accordance with claim **12** wherein said electroresponsive means includes a movable conductor electrically connected to normally carry at least a portion of the current flowing through said fusible element and said conductor is moved in response to the interaction between the magnetic field generated by said portion of the current and the current flowing through said fusible element and resilient means for normally biasing said movable conductor to a position wherein said low resistance electrical shunt circuit is open, said resilient means returning said movable conductor to said normal position wherein said low resistance electrical shunt circuit is open upon interruption of current flow through said fusible element.

15. In a fuse, the combination of a current-carrying fusible element having a fusible section of reduced cross sectional area, means including a conductive element extending generally parallel to said fusible section for completing a low resistance path in shunt to said fusible section, one of said elements being fixed and the other being movable relative to said fixed element, and electroresponsive means for actuating said low resistance path completing means in response to the flow of current of predetermined magnitude through said fusible element and for releasing said path-completing means to open said low resistance shunt path upon interruption of current flow through said fusible element, whereby the time-current characteristic of said fuse is modified in the current range above said predetermined magnitude.

References Cited by the Examiner

UNITED STATES PATENTS

1,294,621	2/1919	Conrad	200—88
1,413,997	4/1922	Schweitzer	200—120
1,807,228	5/1931	Starr	200—113
2,084,495	6/1937	Lindell	200—117
2,180,975	11/1939	Brown	200—120
2,741,726	4/1956	Branflick et al.	200—114 X
2,838,634	6/1958	Kesselring et al.	200—114
2,989,606	6/1961	Walker	200—88

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