Nov. 9, 1948. E. H. YONKERS 2,453,396

FUSE

Filed Dec. 28, 1946

FIG. 1

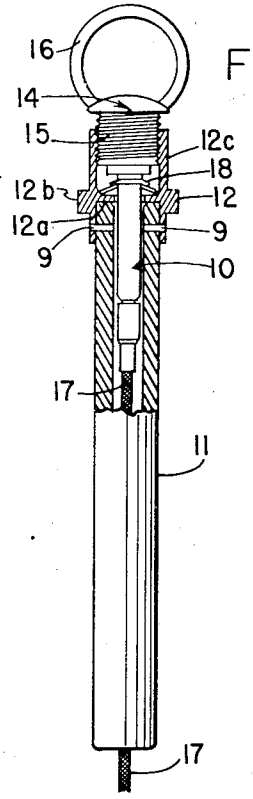


FIG. 2

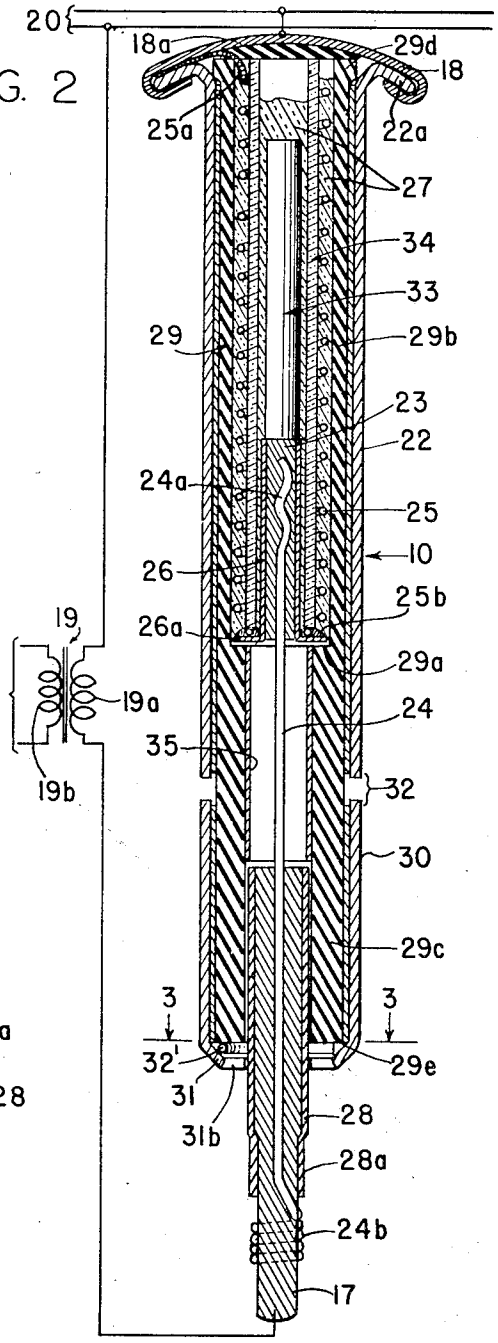
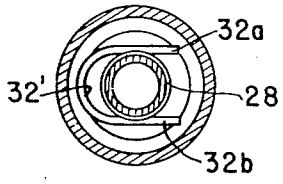


FIG. 3



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UNITED STATES PATENT OFFICE

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FUSE

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11 Claims. (Cl. 200—115)

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The present invention relates to electrical fuses and more particularly to an improved fuse link which is well adapted for use in providing current overload protection for a power distribution transformer of low kva. capacity and yet is itself protected against rupture when subjected to lightning surges. This application is a continuation in part of copending application Serial No. 533,824, filed May 1, 1944.

One of the problems involved in providing fuse protection for a power distribution transformer energized from a high voltage overhead distribution line is that of providing a fuse link having a time-current fusing characteristic which approximates the time-overload characteristic of the transformer, so that effective protection is obtained under any and all overload conditions. A second problem involved in providing effective fuse protection of a power distribution transformer is that of preventing the fuse from rupturing when subjected to a lightning surge that may cause high current flow through the fuse for only a few micro-seconds. The latter problem is particularly troublesome in the use of fuse links having fractional ampere ratings to protect transformers having low kva. ratings and equipped with primary windings adapted to operate at high voltages. In the usual commercial fuse link, no facilities whatever are provided to eliminate this problem. In the patent literature, however, this problem is referred to and various solutions are suggested. These suggestions all embrace the concept of connecting a surge gap in parallel with the fusible element of the fuse to by-pass lightning surge currents around the fusible element. The structures proposed for this purpose, however, either lack effectiveness in building up a surge gap breakdown voltage or are wholly impractical from the standpoint of commercial production.

It is an object of the present invention, therefore, to provide a fuse link having a time-current fusing characteristic which approximates with tolerable accuracy the time-overload characteristic of the device it is utilized to protect, and yet is of simple and rugged construction, is small in size, and is capable of being easily and economically manufactured in production quantities.

It is another object of the present invention to provide a fuse link of the character described which retains its initial time-current fusing characteristic over long operating periods and yet is highly effective to effect current interruption and arc extinction when subjected to overloads exceeding its time-current rating.

According to a further object of the invention,

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an improved fuse link is provided which is capable of effecting current interruption and arc extinction without resorting to the use of expulsion tubes or the equivalent, even when used in high voltage circuits and subjected to heavy overload currents of the order of several hundred amperes.

It is still another object of the invention to provide improved and exceedingly simple facilities for defining a surge gap of fixed width which is connected in shunt with the fusible element of the link to protect this element against rupture when the link is subjected to lightning surges or the like.

The invention, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the specification taken in connection with the accompanying drawings, in which:

Fig. 1 is a side view partially in section illustrating the present improved fuse link when assembled within a fuse tube;

Fig. 2 is a side sectional view of a fuse link characterized by the features of the present invention, which view also schematically illustrates the manner of inserting the link in a transformer primary circuit; and

Fig. 3 is an end view of the link shown in Fig. 2.

Referring now to the drawings and more particularly to Fig. 1 thereof, the present improved fuse link is indicated generally at 10 as being supported within a hollow fuse tube which is formed of a suitable insulating material. At its upper end, the tube 11 is provided with a brass contact ferrule 12 which is suitably pinned to the upper wall portion of the tube by means of pins 9, and is provided with an inwardly extending annular portion 12a which overlies the upper end of the tube. The ferrule 12 is also provided with an enlarged rib portion 12b which may be appropriately positioned within the contact fingers of a fuse tube holding arm of the character conventionally embodied in cutout assemblies, with the sharp lower edge of the rib engaging the contact fingers. The upper portion 12c of the ferrule is provided with internal threads for receiving the threaded portion 15 of an assembly cap 14. This cap is provided at its upper end with a ring 16 which may be used to facilitate assembly of the connected parts 11, 10 and 14 upon the supporting and connecting arms of a cutout assembly by means of a "hot-stick" or the like. At its upper end, the fuse link 10 is provided with an enlarged head 18 which func-

tions as one terminal thereof and is clamped between the assembly cap 14 and the inwardly extending flange portion of the ferrule 12. A pigtail conductor 17 projecting from the lower end of the link 10 functions as the opposite terminal thereof. With this arrangement, contact of the ferrule 12 with the contact fingers of a supporting arm may be utilized to provide an electrical connection between one terminal of the fuse link and one side of the supply line, and the circuit through the fuse link may be extended by means of the pigtail conductor 17 which is suitably anchored between the contact fingers of a second arm of the cutout assembly. More specifically, and as best shown in Fig. 2 of the drawings, the fuse link 10 may be serially included in the circuit for energizing the primary winding 19*a* of a transformer 19 from an open wire high voltage current supply circuit which includes the two bracketed conductors 20.

Briefly considered, the fuse link 10 comprises a metal tubular casing member 22 having, at its upper end, an outwardly extending flange 22*a* which is embraced by the inturned edges of the metal contact head 18. Disposed within the tube 22 and arranged in series circuit relationship between this tube and the pigtail conductor 17, are three fusible elements 23, 24 and 25. The two elements 24 and 25 are both formed of Nichrome wire or another metal wire or ribbon of the desired resistivity, and are both of the same cross-sectional area, such that they possess substantially identical time-current fusing characteristics. The fusible element 24 is substantially straight throughout the major portion of its length and the lower end portion thereof is centrally disposed within the upper end portion of the stranded pigtail conductor 17, the overlapping portions of the two elements 17 and 24 being telescoped within a metal assembly sleeve 28. This sleeve is crimped adjacent the lower end thereof, as indicated at 28*a*, and the lower end of the fusible element 24 is brought out through the strands of the conductor 17 and wrapped around the conductor 17 as indicated at 24*b*. After the three elements 28, 24, and 17 have been assembled to occupy the relative positions illustrated in Fig. 2 of the drawings, the crimp 28*a* may be formed around the lower portion of the sleeve 28 for the purpose of providing a rigid mechanical connection between the three named parts. Thereafter, the lower end portion of the sleeve 28, the adjacent portion of the pigtail conductor 17 and the wrapped end portion 24*b* of the fusible element 24 may be soldered to provide a rigid connection therebetween.

The fusible element 25 may more properly be designated a combination impedance element and heating element in that it functions in conjunction with the improved surge gap facilites described below to prevent surge currents of large magnitude from traversing the fusible elements 23 and 24 and also acts to heat the fusible element 23 to a fusing temperature when the link is subjected to an overload current for a sustained time interval. In order to perform these two functions the element 25 is constructed in the form of a helically coiled conductor, and the upper end portion 25*a* thereof is electrically and mechanically connected to the under side of the contact head 18 by crimping the same between the flange 22*a* and the cap 18.

The convolutions of the element 25 are spaced apart axially of the tube 22, and the spaced apart relationship between the turns is maintained by

embedding the same in a body of dielectric refractory material 27. This body is preferably formed of a refractory cement and serves several functions which are pointed out with particularity below. It may, for example, be formed of Portland cement or any ceramic material which is chemically inert, has high specific heat, and is possessed of good electrical insulating properties. In order to increase the inductance of the element 25, thereby to enhance the surge current blocking function thereof, particles of magnetic material, such, for example, as iron powder or magnetite, may be dispersed throughout the body 27, but in no case should the density of the magnetic particles be such as to provide conductive paths capable of short-circuiting the convolutions of the element 25. Among other functions, the body 27 serves rigidly to position or support the turns of the element 25 within the tube 22, and to this end entirely fills the upper portion of the tube. It also serves to support a tubular conductor 26 centrally of the tube 22, this element being utilized in the connection of the fusible element 24 with the lower end portion of the combination heating and inductance element 25. More specifically, the upper tubular portion of the connecting element 26 is projected well within the turns of the element 25 in spaced apart relationship therefrom, and is embedded in the body 27. At its lower end this connecting element is provided with an outwardly extending flange 26*a* which serves to seat the lower turn of the element 25 in a manner such that the tubular portion of the element 26 is substantially concentrically disposed within the turns of the element 25. This lower turn of the element 25 is electrically and mechanically connected to the flanged portion 26*a* of the element 26 by means of a high melting point solder 25*b*, or the like. The upper end of the connecting element 26 is electrically and mechanically connected to the upper serpentine end 24*a* of the fusible element 24 through the fusible element 23, the latter element being in the form of a body of alloy solder having a melting point of approximately 365° F. It is to be noted that the fusible element 23, as thus formed within the tubular portion of the connecting element 26, is disposed well within the turns of the element 25 so that heat generated by current conduction through the latter element may be transferred to the fusible element 23 through that portion of the refractory body 27 which separates the fusible element 23 from the adjacent turns of the element 25. Spring tension imposed upon the free lower end of the pigtail conductor 17 may be utilized to rapidly withdraw the end 24*a* of the fusible element 24 from the connecting element 26 when the named fusible element is heated to a melting temperature, and to widen a break in the fusible element 24 occasioned by heating this element to a fusing temperature.

For the purpose of increasing the heat storage capacity of the structure including the fusible element 23, a thermal storage element 33 is provided which is arranged in heat transfer relationship with the element 23 and the heating element 25. This element is in the form of a copper or brass rod disposed centrally of the tubular casing 22 and having its lower end contacting the exposed upper surface of the fusible element 23. It is held in an upright position in axial alignment with the tubular conductor 26 by virtue of its being embedded in the body 27.

During prolonged use of the link, the upper

portion of a fusible element 23 may many times be heated to a fluid state without actual rupture of the element due to lack of persistence of the current overload responsible for the excessive heat energy. Also, repeated heating and cooling of the body 27 may result in the formation of small interstices therein through which the fluid metal could be dispersed to short-circuit the lower convolutions of the coiled conductor 25. This would result in undesired modification of the time-overload characteristic of the link. In order to obviate this possibility, a ceramic insulating tube 34 is provided to act as a barrier between the parts 23, 26 and 33 and the turns of the coiled conductor element 25. Specifically, this tube is telescoped over the tubular conductor 26 to rest upon the flange 26*a* and is embedded in the body 27 in the manner illustrated. Being of heat resistant ceramic material, the tube 34 is not subject to cracking and hence acts as a leak-proof barrier between the fusible element 23 and the convolutions of the coiled conductor element 25. Also, since the tube 34 has approximately the same heat transfer characteristics as the body 27, its presence in the zone of heat transfer between the elements 23 and 33 and the element 25 does not seriously complicate the problem of producing links having substantially the same time-overload characteristics in production quantities. Further, provision of the tube 34 in the structure facilitates assembly of the component elements of the structure in the manner explained below.

In order to maintain the turns of the element 25 out of contact with the metal casing 22, to maintain the element 24 out of contact with the tubular casing 22 and to provide a support for the surge gap facilities described below, the entire assembly within the casing 22 and a part of the sleeve 28 are surrounded by a tube 29 formed of Bakelite or other suitable insulating material. At its upper end, this tube is provided with a flange 29*d* pressed against the metal casing flange 22*a* by means of a soft rubber cushion 18*a* disposed between the upper end of the tube and the cap 18. This tube fits snugly within and is adhesively bonded to the tubular member 22, and the lower end portion 29*e* thereof projects outwardly from the open lower end of the casing. It is counterbored from the upper end to provide a first portion 29*b* of large internal diameter for receiving the parts 25, 26, 27, 33 and 34, and a second portion 29*c* of smaller internal diameter for receiving the fusible element 24. The flange 26*a* of the tubular conductor 26 is seated upon the step 29*a* between these two portions of the tube 29.

In order to assist in producing arc extinction within the tube 29 when the link is ruptured either through fusing of the element 23 or fusing of the element 24, that part of the tube portion 29*c* through which the fusible element 24 extends may be lined with a gas evolving material 35. Preferably, this lining is in the form of a layer of long fiber cellulose adhesively secured to the inner surface of the tube portion 29*c* between the flange 29*a* and the upper end of the sleeve 28 to surround the fusible element 24.

As indicated above, in order to prevent lightning surges from rupturing the fusible elements within the tube 29, a surge gap having relatively immovable electrodes is connected in shunt with the three series connected elements 24, 23 and 25. The casing 22 comprises one electrode of this gap. The second electrode comprises a metallic sleeve 30 which is connected or otherwise fixedly secured to the projecting portion 29*c* of the insulating

tube 29 and is spaced from the open lower end of the casing 22. Thus an annular surge gap 32 of fixed width is formed between the adjacent ends of the two metal parts 22 and 30. At its lower inturned end 31, the sleeve 30 supports a resilient conductive element 32 which acts to provide a conductive path between the sleeve and the pigtail conductor 17 without interfering with withdrawal of the parts 17, 24 and 28 from the insulating tube 29. Specifically, the element 32 is of U-shaped configuration, having legs 32*a* and 32*b* extending across the open lower end 29*e* of the insulating tube 29 and engaging the sleeve 28 at opposite sides thereof. The base and leg ends of the element 32' are pressed against the end 29*e* of the tube 29 by the inturned flange 31 and the distance between the legs is slightly less than the diameter of the sleeve 28, whereby they are self biased into gripping engagement with the sleeve 28.

In the assembly of the above described parts of the fuse link 10, the soldered connection between the upper end 24*a* of the fusible element 24 and the tubular portion of the connecting element 26 is first made through the fusible body 23, following which the heating element 25 is telescoped over the tubular portion of the connecting element 26 and soldered to the flange portion 26*a* thereof. Following these operations, the lower end of the fusible element 24 is inserted through the sleeve covered strands of the pigtail conductor 17, with the end 24*b* thereof being brought out and wrapped around the conductor 17. The next operations are those of crimping the sleeve 28 at the portion 28*a* thereof, and of providing a soldered connection between the lower ends of the sleeve 28, the end portion 24*b* of the element 24 and the portion of the pigtail conductor 17 which is adjacent the lower end of the sleeve 28. As a separate assembly operation, the insulating tube 29 is inserted into the tubular casing member 22 through the open upper end thereof until the flnge 29*d* abuts the casing flange 22*a*. The sleeve 30, with the resilient element held by the flange 31 at the bottom thereof, may now be telescoped over the projecting portion 29*e* of the tube 29 until the resilient element 32' abuts the lower end of the tube, thus automatically fixing the width of the surge gap 32. An adhesive cement coating placed upon the outside of the tube 29 prior to assembly of the parts 22, 29 and 30 may be relied upon to maintain the named parts assembled. The fusible element assembly may now be positioned within the tube 22 by threading the pigtail conductor 17 through the insulating tube 29 and the resilient legs of the element 32'. Movement of the assembly through the tube 29 is obviously arrested when the flanged portion 26*a* of the tubular conductor 26 is moved into engagement with the internal step 29*a* of the tube. Incident to this operation, the conductive sleeve 28 is drawn between the legs 32*a* and 32*b* to spread these legs apart and thus create a spring tensioned contact between the sleeve and each of the legs.

As thus partially assembled, the upper end portion 29*c* of the tube 29 serves to maintain the turns of the coiled conductor element 25 disposed substantially concentrically within the casing 22 and prevents the turns of this element from contacting the casing. The insulating sleeve 34 is next inserted into the tube 29 and telescoped over the tubular conductor 26 until its lower end rests upon the flange 26*a*, following which the thermal storage element 33 is inserted into the tube 34 to

bring its lower end into contacting engagement with the upper end of the fusible element 23. With the parts 26, 33 and 34 concentrically positioned within the tube 29, the next operation is that of filling the unoccupied space within the portion 29b of the insulating tube 29 with the refractory cement or the mixture of refractory cement and magnetic particles. This may be accomplished by simply pouring the cement within the tube through the upper end thereof until all unoccupied space within the indicated tube portion is filled. During this pouring operation the elements 25, 26, 33 and 34 are embedded in the cement, and the cement is prevented from entering the lower chamber within the tube 29 due to the sealing engagement of the connector flange 26a with the step 29a. After the body of refractory cement has been allowed to set, or has been baked to enhance the setting operation, the projecting upper end 25a of the element 25 is wrapped around the flange 22a. The cap 18 may now be positioned over the flange 22a with the cushion 18a thereunder, following which an appropriate die assembly operation may be utilized to attach the terminal head 18 to the upper end of the casing 22. Following the last mentioned operation the fuse link 10 is fully assembled and ready for use.

In considering the mode of operation of the fuse link 10, it may be assumed that this link is to be serially included in the primary circuit of the transformer 19 for the purpose of protecting this transformer against damage occasioned by current overloads. It may be assumed further that the transformer 19 is provided with a low voltage secondary load which under normal conditions approximates the full load capacity of the transformer 19, and that this secondary load includes motors and other devices which, during the starting periods thereof, are capable of producing heavy transient currents of relatively short duration in both the primary and secondary windings of the transformer 19. In this regard, it will be understood that due to the heat radiating capabilities of the transformer parts, the transformer 19 may be capable of withstanding an overload current of reasonable magnitude such, for example, as 200 to 300 per cent, for a relatively long time interval; whereas it can withstand current of the order of 500 per cent of normal for only a short time interval. It will also be understood that the transformer is capable of being damaged by a sustained increase in the voltage appearing between the conductors 20 of the supply circuit.

The fuse link 10 operates to protect the transformer against damage occasioned by overload currents caused by any one of the mentioned factors. At the same time, the fuse link permits the transformer to be operated under sustained overload current conditions for a period less than that required to damage the transformer, and will not rupture when subjected to the normal and non-injurious high currents which are produced incident to motor starting, or the like. In this regard it will be understood that since the three serially related elements 25, 23 and 24 of the link 10 are traversed by the current flowing through the primary winding 19a of the transformer 19, they are all heated by current conduction and that the temperature of each element varies with changes in the magnitude of this current. The fusible element 23 is also heated by the heat conducted thereto from the element 25 through the walls of the connecting element 26. Heat energy is also transferred from the turns of the element 25 to the fusible element 23 through that portion of the refractory body 27 and the tube 34 which are disposed between the tubular portion of the connecting element 26 and the surrounding turns of the element 25, and also from the thermal storage element 33. Under constant load current conditions and with a constant voltage between the conductors 20 of the current supply circuit, the amount of energy transferred to the fusible element 23 per unit time element interval remains substantially constant. Accordingly, so long as the load current through the secondary winding 19b of the transformer does not substantially exceed the full load capacity of this transformer, the fusible element 23 is operated at a temperature well below that required to produce fusion thereof. When, however, the secondary load current of the transformer 19 gradually rises and is sustained for a period approaching that at which the transformer will be damaged, the temperature of the fusible element 23 is raised accordingly. Thus, as the load current increases, the current traversing the three elements 23, 24 and 25 is correspondingly increased so that more heat is produced in the fusible element 23 by current conduction. Concurrently the amount of heat conducted to this fusible element from the fusible elements 24 and 25 is increased. Also concurrently, the amount of heat transferred from the turns of the element 25 to the fusible element 23 through the refractory body 27 and the tube 34 is increased. A portion of the heat energy accumulating in the element 23 is transferred to the storage element 33 by conduction. After a predetermined time interval, required for the accumulation of heat within the fusible element 23, this element is heated to its fusing temperature and melts. Provision of the storage element 33 materially increases this time interval over that which would obtain in the absence of this element in the combination. When the element 23 is thus ruptured, the fusible element 24, the sleeve 28, and the upper end of the pigtail conductor 17, are quickly expelled from the lower ends of the tubes 22 and 29 under the influence of the spring means connected to the pigtail conductor, thereby rapidly to break the circuit for energizing the primary winding 19a of the transformer 19. The sliding engagement of the fingers 31b with the sleeve 28 does not appreciably impede withdrawal of the named parts from the tube 29.

During the described separation of the element 24 from the tubular conductor 26 upon fusing of the element 23, an arc is drawn within the portion 29c of the tube 29. This arc instantly heats the coating 35 to gas evolving temperature, with the result that gases are evolved therefrom which accelerate extinction of the arc. It has been found that provision of the gas evolving coating 35 permits the link itself to effectively extinguish heavy current arcs of the order of several hundred amperes even when the link is used in high voltage circuits of several thousand volts and without the use of conventional expulsion tubes. Thus the link, being also completely weather protected, is well adapted for use as a self-contained protective element in high voltage transformer primary circuits, without providing the usual auxiliaries of an expulsion tube and associated fittings.

To consider the action of the fuse link 10 further, it may be pointed out that the refractory body 27 and the tube 34 prevent the fusible ele-

ment 23 from being heated to its melting temperature when surge currents are produced in the primary circuit of the transformer 19 as a result of motor starting or the like. Such surge currents are of short duration, being of the order of only a few seconds. The resulting momentary increase in heat generation within the fusible element 23 is wholly insufficient to raise the temperature of the element to its melting point. Moreover, those portions of the refractory body 27 and the tube 34 which are disposed between the tubular portion of the connecting element 26 and the storage element 33 and the turns of the heating element 25 dissipate a large portion of the heat resulting from the current surge through the element 25 away from the element 24. They also delay the transmission of the increased increment of heat produced by the element 25 to the storage element 33 and the adjacent walls of the connecting element 26 for an interval which will normally exceed the duration of the current transient. Accordingly, the increased increment of heat energy arriving at the surfaces of the connecting element 26 and storage element 33 from the element 25 as a result of the momentary high current, effects an insufficient increase in the temperature of the fusible element 23 to cause this element to melt. In other words, the total heat accumulated in the fusible element 23 as a result of the transient high current is insufficient to heat this element to its fusing temperature. Thus it will be understood that the refractory body 27 and the tube 34, or more exactly the thermal impedance of this composite structure, protects the fusible element 23 against outages occasioned by transient currents of the character which frequently occur in the load pattern of any transformer secondary load. This is accomplished moreover, without increasing the thermal capacity of the fusible element 23 to a point such that it will provide no protection for sustained overload currents.

The thermal impedance of the refractory body 27 and the tube 34 also prevents the fusible element 23 from immediately rupturing when the transformer 19 is subjected to a high current, such, for example, as that which is produced when the secondary winding 19b of the transformer 19 is short-circuited. In the absence of an additional protective element, therefore, the transformer 19 could easily be damaged by an overload current of this character during the period required to transfer sufficient heat from the heating element 25 to the fusible element 23 to cause the latter element to melt. The second fusible element 24 functions to guard the transformer 19 against damage when subjected to an overload current of this type. Thus, immediately the element 24 is subjected to a transient current of the particular character just referred to, a portion thereof lying between the upper end of the sleeve 28 and the lower end of the fusible element 23 is heated to a fusing temperature, permitting this element to rupture. As a result, the lower portion of the element 24 is withdrawn from the lower end of the tube 29 under the influence of the pull-out spring.

In this regard, it will be understood that the heat generated within that portion of the fusible element 24 which is surrounded by the sleeve 28, is rapidly conducted away from the enclosed portion of the element 24 by the strands of the pigtail conductor 17, whereby this portion of the element 24 is prevented from fusing when subjected to the described surge current of large magnitude.

As previously indicated, the elements 24 and 25 are so constructed that the inherent time-current characteristics thereof are substantially the same. It may be pointed out, however, that the body of refractory material 27 and the insulating tube 34 have substantial heat capacity; whereas the air which surrounds the fusible element 24 has relatively little heat capacity. Accordingly, the heat generated by the fusible element 25 as a result of the heavy surge current flow therethrough is absorbed by the body 27 and the tube 34 at a relatively high rate, while the heat generated by the surge current flow through the fusible element 24 is only slowly absorbed by the air which surrounds this element. As a result, the temperature of the fusible element 24 rises much more rapidly than the temperature of the heating element 25, whereby fusing of the element 24 is insured before the element 25 is heated to its melting temperature. Thus, the fusible element 24 not only acts as a heavy current-short interval protective device for the transformer 19, but in addition, functions to protect the heating element 25 against damage when the fuse link 10 is subjected to heavy surge current overloads.

As previously indicated, the annular surge gap 32, as provided between the sleeve 30 and the lower end of the metal tube 22, serves to protect the fusible elements of the link 10 and more particularly the element 24 thereof, against rupture when voltage transients of short duration but high value and steep wave front appear between the conductors 20 of the high voltage current supply circuit. In this regard it will be understood that lightning or other disturbances may cause voltage transients to appear between the line conductors 20 which are of insufficient duration to cause damage to the transformer 19 and yet may be of sufficient magnitude to cause the fast responding fusible element 24 of the link 10 to rupture. When a transient of this character appears between the line conductors 20, the voltage i. e. the current-impedance drop across the turns of the impedance element 25 instantly rises to a value sufficient to cause ionization of the shunt connected surge gap 32. If the wave front of the voltage transient is sufficiently steep, this breakdown of the surge gap 32 will occur before the fusible element 24 can be damaged. Once the gap 32 is ionized, the electrical resistance thereof immediately drops to an exceedingly low value such that the predominant portion of the surge current is by-passed around the fusible elements 23, 24 and 25 of the link 10. As the transient dies out, the voltage between the elements 22 and 30 decreases to a value insufficient to sustain ionization of the gap 32, with the result that surge current flow across this gap is arrested. From the above explanation it will be understood that the impedance of the coiled heating element 25 delays the build-up of current flow through the fusible elements 23, 24, and 25 for an interval sufficient to insure breakdown of the surge gap 32 before the current traversing the fusible element 24 can reach a magnitude sufficient to cause this fusible element to rupture. Moreover, the particles of magnetic material dispersed throughout the refractory body 27, in enhancing the electrical inductance of the heating element 25, serve to increase the delay in current build-up through this element and the two serially related elements 23 and 24 when a voltage

transient of the character described appears between the line conductors 20.

From the foregoing explanation it will be understood that the disclosed link structure is exceedingly simple in arrangement, may be easily and cheaply manufactured, and yet provides positive protection against damage to an associated transformer or the like when the link is subjected to all types of overload currents of the character normally encountered in operating practice. It will also be noted that in several instances the individual elements of the structure are utilized to perform two or more functions. Thus the element 25 not only acts as a heating element to impart the desired time-current characteristic to the fusible element 23, but additionally functions as an electrical impedance element to insure breakdown of the surge gap 32 before the fusible elements 23 and 24 can be ruptured by a transient of large magnitude and steep wave front. Again, the body 27 of refractory material and the tube 34 not only function to render the fusible element 23 nonresponsive to surge currents of short duration, but additionally function to protect the heating element 25 against burnouts or damage when the link is subjected to exceedingly heavy surge currents. Further, the element 24 not only functions as a surge current protective element, but additionally acts as a pull-out wire to break the electrical circuit through the fusible element 23 when the latter element is heated to a melting temperature. It is to be noted that in the described embodiment of the invention, the electrodes 22 and 30 defining the annular surge gap 32 are relatively immovable, such that the breakdown voltage thereacross is reasonably fixed and is unaffected by movement of the sleeve 28 within the bore of the tube part 29c.

While one embodiment of the invention has been disclosed, it will be understood that various modifications may be made therein without departing from the true spirit and scope of the invention as set forth in the appended claims.

I claim:

1. A fuse link comprising an elongated insulating tube, a coiled heating conductor disposed within said tube and having its convolutions spaced axially of said tube, a tubular conductor extending within the convolutions of said coiled conductor to receive heat from said coiled conductor, a fusible body filling at least a portion of said tubular conductor, a conductor having an end embedded in said fusible body, means including a second insulating tube telescoped over said tubular conductor within said coiled conductor for insulating said coiled conductor convolutions from said fusible body and said tubular conductor and a thermal storage rod extending through said second insulating tube and provided with an end contacting with said fusible body so that heat may be transferred between said rod and fusible body.

2. A fuse link comprising a tubular metal casing having an open end, first insulating tube means fitting within and extending through said casing, said tube means having portions of different internal diameters and an internal step intermediate the ends thereof, a tubular conductor having a flange seated on said step and extending away from said step through the portion of said tube means having the largest internal diameter, a second conductor extending through the portion of said tube means having the smallest internal diameter and including a part projecting within said tubular conductor, a fusible body electrically and mechanically connecting said pair of said second conductor to said tubular conductor, a coiled conductor surrounding said tubular conductor and disposed within the space between said insulating tube means and said tubular conductor, said coiled conductor being connected in series with said fusible body and said second conductor, a second insulating tube telescoped over said tubular conductor within said coiled conductor to insulate the coil convolutions from said tubular conductor and said fusible body, and a body of insulating material at least partially embedding the convolutions of said coiled conductor and filling the unoccupied spaces within that portion of said first tube means having said largest internal diameter.

3. A fuse link comprising a tubular metal casing having an open end, first insulating tube means fitting within and extending through said casing, said tube means having portions of different internal diameters and an internal step intermediate the ends thereof, a tubular conductor having a flange seated on said step and extending away from said step through the portion of said tube means having the largest internal diameter, a second conductor extending through the portion of said tube means having the smallest internal diameter and including a part projecting within said tubular conductor, a fusible body electrically and mechanically connecting said part of said second conductor to said tubular conductor, a coiled conductor surrounding said tubular conductor and disposed within the space between said insulating tube means and said tubular conductor, said coiled conductor being connected in series with said fusible body and said second conductor, a second insulating tube telescoped over said tubular conductor within said coiled conductor to insulate the coil convolutions from said tubular conductor and said fusible body, a thermal storage rod extending through said second insulating tube and provided with an end contacting said fusible body for heat transfer therebetween, and a body of insulating material at least partially embedding the convolutions of said coiled conductor and filling the unoccupied spaces within that portion of said first tube means having said largest internal diameter, thereby to retain said tubular conductor, coiled conductor, second insulating tube and thermal storage element in assembled relationship.

4. A fuse link comprising a tubular metal casing having an open end, a first insulating tube fitting within and extending through said casing, said tube having portions of different internal diameters and an internal step intermediate the ends thereof, a tubular conductor having a flange seated on said step and extending away from said step through the portion of said tube having the largest internal diameter, a fusible conductor extending through the portion of said tube having the smallest internal diameter and including a part projecting within said tubular conductor, a gas evolving material lining at least a portion of said tube through which said fusible conductor extends to assist in producing arc extinction within said last-named tube portion, a fusible body electrically and mechanically connecting said part of said fusible conductor to said tubular conductor, a coiled conductor surrounding said tubular conductor and disposed within the space between said insulating tube and said tubular conductor, said coiled conductor being connected in series with said fusible body and said second

conductor, a second insulating tube telescoped over said tubular conductor within said coiled conductor to insulate the convolutions of said coiled conductor from said tubular conductor and said fusible body, and a body of insulating material at least partially embedding the convolutions of said coiled conductor and filling the unoccupied spaces within that portion of said first tube having said largest internal diameter.

5. A fuse link comprising a tubular metal casing having an open end, a first insulating tube fitting within and extending through said casing, said tube having portions of different internal diameters and an internal step intermediate the ends thereof, a tubular conductor having a flange seated on said step and extending away from said step through the portion of said tube having the largest internal diameter, a fusible conductor extending through the portion of said tube having the smallest internal diameter and including a part projecting within said tubular conductor, a gas evolving material lining at least a portion of said tube through which said fusible conductor extends to assist in producing arc extinction within said last-named tube portion, a fusible body electrically and mechanically connecting said part of said fusible conductor to said tubular conductor, a coiled conductor surrounding said tubular conductor and disposed within the space between said insulating tube and said tubular conductor, said coiled conductor being connected in series with said fusible body and said second conductor, a second insulating tube telescoped over said tubular conductor within said coiled conductor to insulate the convolutions of said coiled conductor from said tubular conductor and said fusible body, a thermal storage rod extending through said second insulating tube and provided with an end contacting said fusible body for heat transfer therebetween, and a body of insulating material at least partially embedding the convolutions of said coiled conductor and filling the unoccupied spaces within that portion of said first tube having said largest internal diameter, thereby to retain said tubular conductor, coiled conductor, second insulating tube and thermal storage element in assembled relationship.

6. A fuse link comprising a tubular metal casing having an open end, a first tube of insulating material fitting within said casing and projecting outwardly from the open end of said casing, said tube being provided with a first portion of large internal diameter, a second portion of smaller internal diameter and an internal step between said two portions, a tubular conductor disposed within said first portion of said tube and provided with a flange seated on said step, a second conductor extending through said second portion of said tube and including a part projecting within said tubular conductor, a fusible body electrically and mechanically connecting said part of said second conductor to said tubular conductor, a coiled conductor surrounding said tubular conductor and disposed within the space between said insulating tube and said tubular conductor, said coiled conductor being connected between said tubular conductor and said casing, a second tube of insulating material telescoped over said tubular conductor within said coiled conductor to insulate the convolutions of said coiled conductor from said tubular conductor and said fusible body, a body of insulating material at least partially embedding the convolutions of said coiled conductor and filling the unoccupied spaces within that portion of said first tube having said largest internal diameter, a conductive sleeve carried by the projecting end of said first tube and spaced from the open end of said casing to define a surge gap, and a resilient conductive element extending across the projecting end of said first tube in engagement with said second conductor and said sleeve, thereby to provide a conductive path therebetween while permitting withdrawal of said second conductor from said first tube upon fusing of said fusible body.

7. A fuse link comprising a tubular metal casing having an open end, a first tube of insulating material fitting within said casing and projecting outwardly from the open end of said casing, said tube being provided with a first portion of large internal diameter, a second portion of smaller internal diameter and an internal step between said two portions, a tubular conductor disposed within said first portion of said tube and provided with a flange seated on said step, a second conductor extending through said second portion of said tube and including a part projecting within said tubular conductor, a fusible body electrically and mechanically connected said part of said second conductor to said tubular conductor, a coiled conductor surrounding said tubular conductor and disposed within the space between said insulating tube and said tubular conductor, said coiled conductor being connected between said tubular conductor and said casing, a second tube of insulating material telescoped over said tubular conductor within said coiled conductor to insulate the convolutions of said coiled conductor from said tubular conductor and said fusible body, a thermal storage element disposed within said second insulating tube in heat transfer relationship with said fusible body, a body of insulating material at least partially embedding the convolutions of said coiled conductor and filling the unoccupied spaces within that portion of said first tube having said largest internal diameter, a conductive sleeve carried by the projecting end of said first tube and spaced from the open end of said casing to define a surge gap, and a resilient conductive element extending across the projecting end of said first tube in engagement with said second conductor and said sleeve, thereby to provide a conductive path therebetween while permitting withdrawal of said second conductor from said first tube upon fusing of said fusible body.

8. A fuse link comprising a tubular metal casing having an open end, a first tube of insulating material fitting within said casing and projecting outwardly from the open end of said casing, said tube being provided with a first portion of large internal diameter, a second portion of smaller internal diameter and an internal step between said two portions, a tubular conductor disposed within said first portion of said tube and provided with a flange seated on said step, a second fusible conductor extending through said second portion of said tube and including a part projecting within said tubular conductor, a fusible body electrically and mechanically connecting said part of said second conductor to said tubular body, a gas evolving material lining at least a portion of said tube through which said fusible conductor extends to assist in producing arc extinction within said second portion of said tube incident to fusing of said fusible body or said second conductor, a coiled conductor surrounding said tubular conductor and disposed within the space between said insulating tube and said tubular conductor, said coiled conductor being connected between said tubular con-

ductor and said casing, a second tube of insulating material telescoped over said tubular conductor within said coiled conductor to insulate the convolutions of said coiled conductor from said tubular conductor and said fusible body, a body of insulating material at least partially embedding the convolutions of said coiled conductor and filling the unoccupied spaces within that portion of said first tube having said largest internal diameter, a conductive sleeve carried by the projecting end of said first tube and spaced from the open end of said casing to define a surge gap, and a resilient conductive element extending across the projecting end of said first tube in engagement with said second conductor and said sleeve, thereby to provide a conductive path therebetween while permitting withdrawal of said second conductor from said first tube upon fusing of said fusible body.

9. A fuse link comprising a tubular metal casing having an open end, a first tube of insulating material fitting within said casing and projecting outwardly from the open end of said casing, said tube being provided with a first portion of large internal diameter, a second portion of smaller internal diameter and an internal step between said two portions, a tubular conductor disposed within said first portion of said tube and provided with a flange seated on said step, a second fusible conductor extending through said second portion of said tube and including a part projecting within said tubular conductor, a fusible body electrically and mechanically connecting said part of said second conductor to said tubular body, a gas evolving material lining at least a portion of said tube through which said fusible conductor extends to assist in producing arc extinction within said second portion of said tube incident to fusing of said fusible body or said second conductor, a coiled conductor surrounding said tubular conductor and disposed within the space between said insulating tube and said tubular conductor, said coiled conductor being connected between said tubular conductor and said casing, a second tube of insulating material telescoped over said tubular conductor within said coiled conductor to insulate the convolutions of said coiled conductor from said tubular conductor and said fusible body, a thermal storage element disposed within said second insulating tube in heat transfer relationship with said fusible body, a body of insulating material at least partially embedding the convolutions of said coiled conductor and filling the unoccupied spaces within that portion of said first tube having said largest internal diameter, a conductive sleeve carried by the projecting end of said first tube and spaced from the open end of said casing to define a surge gap, and a resilient conductive element extending across the projecting end of said first tube in engagement with said second conductor and said sleeve, thereby to provide a conductive path therebetween while permitting withdrawal of said second conductor from said first tube upon fusing of said fusible body.

10. A fuse link comprising a tubular metal casing open at one end and having a terminal cap closing the other end, an insulating tube fitting within and extending through said casing, a coiled heating conductor disposed within said tube and having its convolutions spaced axially of said tube, a tubular conductor extending within the convolutions of said coiled conductor to receive heat from said coiled conductor, said heating conductor being connected in series between said tubular conductor and said casing, a fusible body filling at least a portion of said tubular conductor, a circuit conductor having an end embedded in said fusible body and extending out of said insulating tube, an elongated and conductive heat storage element in heat transfer relationship with said fusible body and extending through the convolutions of said heating conductor toward said end cap, and insulating means disposed within said insulating tube to insulate said tubular conductor and said heat storage element from the convolutions of said heating conductor.

11. A fuse link comprising a tubular metal casing open at one end and having a terminal cap closing the other end, first tube means of insulating material fitting within and extending through said casing, said tube means having portions of different internal diameters and an internal step intermediate the ends thereof, a tubular conductor having a flange seated on said step and extending away from said step through the portion of said tube means having the largest internal diameter, a second conductor extending through the portion of said tube means having the smallest internal diameter and including a part projecting within said tubular conductor, a fusible body at least partially filling said tubular conductor to electrically and mechanically connect said part of said second conductor to said tubular conductor, a coiled heating conductor surrounding said tubular conductor and disposed within the space between said insulating tube means and said tubular conductor, said coiled conductor being electrically connected between said casing and said tubular conductor, a second tube of insulating material telescoped over said tubular conductor within said coiled conductor to insulate the coil convolutions from said tubular conductor and said fusible body, an elongated and conductive heat storage element in heat transfer relationship with said fusible body and extending through said second tube toward said end cap, and insulating material at least partially embedding the convolutions of said coiled conductor and filling at least a portion of the unoccupied spaces within that portion of said first tube means having said largest internal diameter

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