May 19, 1953 E. H. YONKERS 2,639,346

TRANSFORMER PROTECTIVE APPARATUS

Original Filed Sept. 25, 1948 2 Sheets-Sheet 1

Fig. 2.

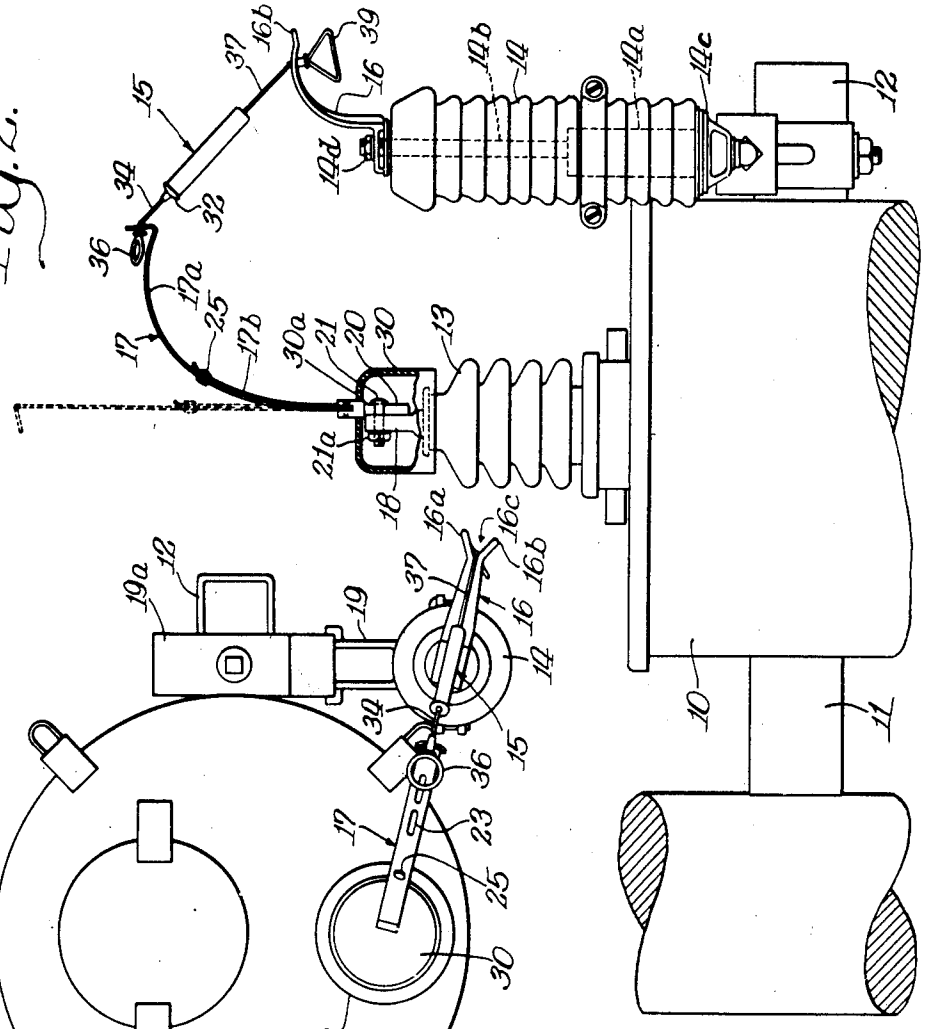


Fig. 1.

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Fig. 3.

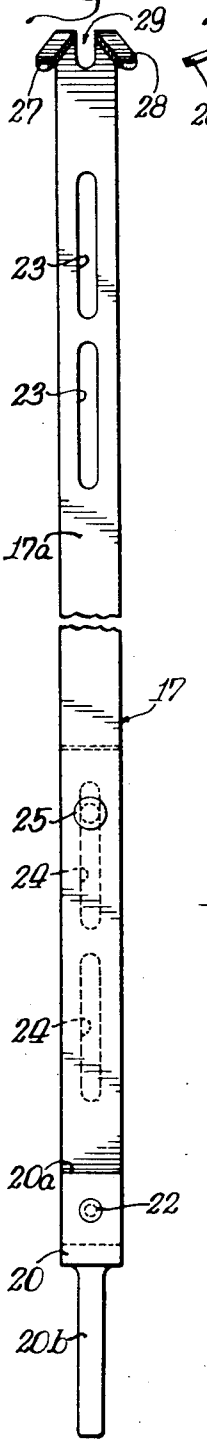


Fig. 4.

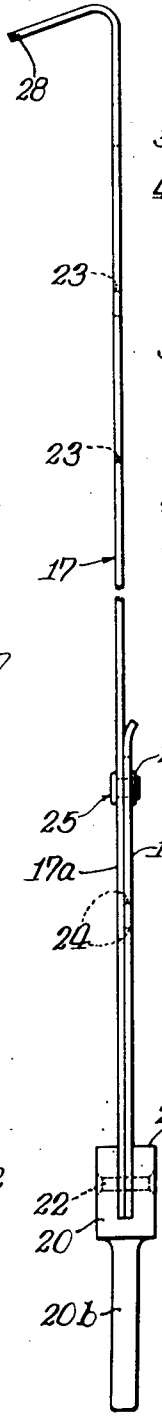


Fig. 6.

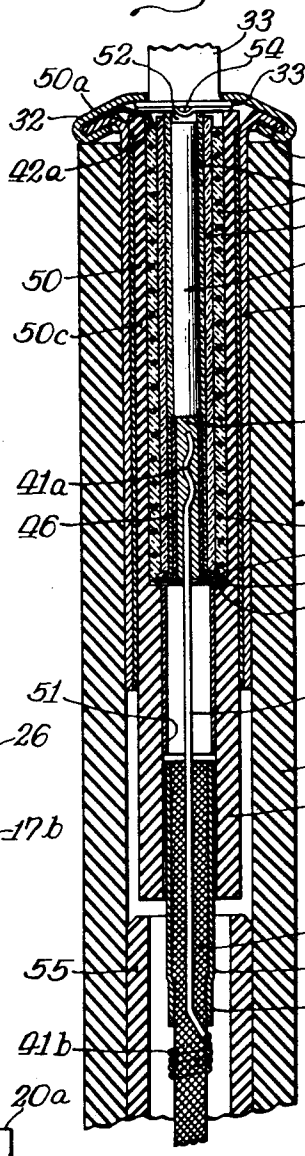
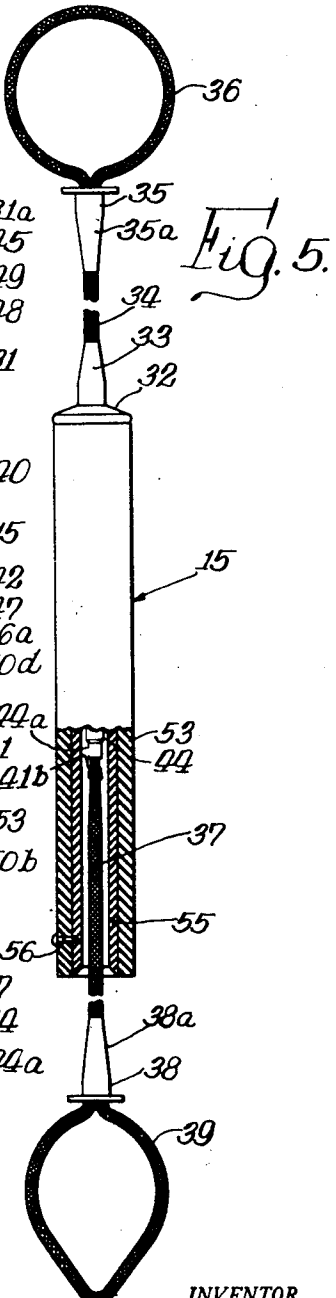


Fig. 5.



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TRANSFORMER PROTECTIVE APPARATUS

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Original application September 25, 1948, Serial No. 51,236, now Patent No. 2,572,901, dated October 30, 1951. Divided and this application September 20, 1951, Serial No. 247,442

4 Claims. (Cl. 200—115)

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The present invention relates to protective apparatus and more particularly to improvements in apparatus for protecting a pole-supported electrical distribution transformer and for disconnecting the transformer from its current supply line when a fault occurs therein. This application is a division of applicant's copending application, Serial No. 51,236, filed September 25, 1948, now Patent No. 2,572,901, dated October 30, 1951, and assigned to the same assignee as the present invention.

Apparatus for the purpose described is in certain installations mounted directly upon the housing or tank of the transformer which it is used to protect and conventionally includes entirely independent lightning arrester and fused cutout units for protecting the transformer primary winding against damage occasioned by lightning surges and overload conditions, respectively. In commercial practice few attempts have been made to provide a single unitary device for providing complete transformer protection against dangerous over-voltage and overloads while at the same time providing the usual feature of protecting the line against a short circuit caused by a fault in the transformer. As a result, the cost of providing and maintaining commercially available protective equipment is relatively high.

It is an object of the present invention, therefore, to provide an improved combination arrester-cutout unit of low cost construction which may be easily and quickly installed on any electrical distribution transformer of standard commercial construction, is easy to refuse and fully protects the transformer against damage by lightning surges and overload condition.

It is another object of the invention to provide for use in a combination arrester-cutout unit, an improved fused cutout of simple low cost construction which may be easily and quickly installed upon the available supporting facilities of a standard electrical distribution transformer.

The present 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 following specification taken in connection with the accompanying drawings in which:

Fig. 1 is a top perspective view of a conventional electrical distribution transformer equipped with the present improved protective apparatus;

Fig. 2 is a side perspective view of the transformer and protective apparatus illustrated in Fig. 1;

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Fig. 3 is a shortened front perspective view of the spring arm forming a part of the cutout embodied in the protective apparatus;

Fig. 4 is a side edge view of the spring arm shown in Fig. 3;

Fig. 5 is a side view partially in section illustrating the structure of the fuse link assembly forming a part of the cutout embodied in the protective apparatus; and

Fig. 6 is an enlarged view of a portion of Fig. 5 better illustrating certain of the components of the fuse link assembly.

Referring now to the drawings, and more particularly to Figs. 1 and 2 thereof, the present improved protective apparatus is there illustrated as comprising a combination lightning arrester and fused cutout unit supported by the existing supporting facilities of a standard electrical distribution transformer 10. Specifically, this transformer comprises two sets of supporting brackets 11 and 12 which are arranged in spaced-apart relationship around the sides of the transformer tank to project radially therefrom, are fixedly mounted upon the transformer tank and are adapted for alternative use in supporting the tank upon a supporting pole or similar supporting structure. The purpose of providing two sets of brackets is to facilitate connection of secondary circuit conductors to the secondary terminals of the transformer (not shown) which are brought out through a terminal block disposed along the hidden side of the transformer tank approximately midway between the brackets. As best shown in Figs. 1 and 2 of the drawings, the transformer is also equipped with the usual bushing insulator 13 which projects upwardly from the top of the transformer tank and serves insulatingly to support the usual terminal stud 18. This stud and the unused set of supporting brackets 11 and 12, are employed to support all parts of the present improved combination arrester-cutout unit.

In brief, this unit comprises a self-contained lightning arrester 14a, the parts of which are housed within a petticoated insulator 14, a fuse tube assembly 15, a terminal subassembly 16 for supporting the fuse tube assembly for pivotal swinging movement about the long axis of the stud 18 and a stationary terminal assembly 17 with which the contact provided at the swing end of the fuse tube assembly 15 is latchingly engageable. More specifically, the electrode structure of the lightning arrester 14a shown in dash lines in Fig. 2 of the drawings is housed within a cavity extending upward from the lower end of the insulator 14. Preferably, this arrester

is of the improved expulsion type disclosed and claimed in Patent No. 2,164,720 granted July 4, 1939, to Ralph R. Pittman. Among other elements it comprises a pair of spaced electrodes, one of which is connected to a conductive rod 14b extending through the insulator 14 to the upper end thereof to support the terminal assembly 17, and the other of which is connected to a gap electrode 14c.

For the purpose of adjustably supporting the insulator 14 and associated parts in a desired vertical and horizontal position upon either of the two sets of radially extending brackets 11 and 12, two cooperating brackets 19 and 19a are provided. More specifically, the two cooperating brackets 19 and 19a are constructed and arranged in the exact manner disclosed and claimed in applicant's prior Patent No. 2,508,055, granted May 16, 1950. The construction is such that the insulator 14 may be supported upon either of the two transformer brackets 11 and 12 at any desired elevation, within limits, and any desired angular setting. The arrangement is also such that the electrode 14c of the arrester assembly coacts with the supporting bracket 19 to provide an isolating gap which is appropriately designed as to length to prevent system current leakage through the arrester.

As indicated above, the cutout assembly comprises a bracket 16 mounted upon the terminal conductor 14b of the insulator 14 at the upper end of this insulator and a spring arm 17 mounted upon the bushing conductor or stud 18 of the transformer assembly. Preferably, the bracket 16 is of arcuate configuration and is fixedly mounted upon the terminal conductor 14b by means of a nut 14d threaded onto this conductor. As will be evident, the angular setting of the bracket 16 relative to the insulator 14 may be adjusted as desired by rotating this bracket about the terminal conductor 14b. At its extended end, the bracket 16 is provided with a pair of ears 16a and 16b which are spaced apart to define an opening or slot 16c for receiving one of the pigtail ferrules of the fuse link assembly in the manner more fully explained below.

As best shown in Figs. 3 and 4 of the drawings, the spring arm 17 is of laminated construction throughout the lower portion of its length. More specifically, this arm is comprised of a long lamination 17a and a short lamination 17b having their lower ends received within a slot formed in the head 20a of a mounting piece 20 which is arranged to extend into the eye of an eye bolt 21 in mounting the arm 17 upon the transformer bushing stud 18. The lower end portions of the spring arm laminations 17a and 17b are anchored within the slotted head 20a of the piece 20 by means of a rivet 22 extending through registering openings in the two laminations and the head part 20a of the piece 20. In order to increase the resiliency of the laminations, thereby to provide the desired tension upon the fuse link 15 supported between the extended end of the arm 17 and the bracket 16, lamination 17a is provided with elongated weakening slots 23 longitudinally spaced apart along the upper part of this arm lamination and the lamination 17b is similarly provided with elongated weakening slots 24 throughout the length thereof. The short lamination 17b acts as a damping element to damp out oscillation of the arm 17 in response to release of the arm 17 from the deformed closed circuit position thereof illustrated in Fig. 2 of the drawings which occurs incident to rupture of

the fusible element forming a part of the fuse link 15. Maximum effectiveness of the short lamination 17b to perform this assigned function is obtained by tying the upper end of this lamination to the adjacent section of the long lamination 17a in such manner as to permit relative sliding movement therebetween. To this end, a rivet 25 is extended through an opening in the lamination 17a and through the upper slot 24 in the lamination 17b to receive a washer 26 which is loosely held against the lamination 17b by peening over the rivet in the usual manner. This arrangement permits relative sliding movement to occur between the two laminations 17a and 17b while restraining the same against deformation in either direction independent of each other. Thus, a mechanical system is provided which minimizes oscillation of the upper end of arm 17 in response to release of the arm following deformation thereof. At its extended upper end, the spring arm lamination 17a is provided with bent over ears disposed at an angle of approximately seventy-five degrees relative to the other portions of the arm which are spaced apart to define an opening or slot 29 for receiving the contact ferrule of the other pigtail conductor forming a part of the fuse link assembly 15. This opening extends throughout the length of the ears 27 and 28 and into the upper end portion of the arm in the manner best illustrated in Fig. 3 of the drawings.

As indicated above, the mounting piece 20 is arranged to coact with an eye bolt 21 in mounting the arm 17 upon the transformer bushing stud 18. As best shown in Fig. 2 of the drawings, the eye of this bolt is arranged to enter an eye receiving slot provided at the upper end of the stud 18 and is threaded to receive a nut 21a which is used in pulling the eye into the slot to clamp the shank 20b of the mounting piece 20 against one side of the stud 18. Preferably the shank 20b of the mounting piece 20 is of round cross sectional configuration in order to permit the arm 17 to be angularly adjusted about its longitudinal axis so that it is readily deformable flatwise toward the bracket 16. Protection against birds falling upon the arm 17 or the bushing stud 18 and producing a short circuit to the transformer tank 10 is obtained by enclosing this stud and the major portion of the mounting piece 20 within an inverted cup-shaped insulator 30. The top wall 30a of this insulator is slotted to receive the head 20a of the mounting piece 20 so that it may be telescoped upward along the arm 17 while the arm assembly is being mounted upon the stud 18 and then dropped down after the mounting operation is completed to enclose the stud 18 and the co-extending part of the mounting piece 20.

Referring now more particularly to Figs. 5 and 6 of the drawings, the fuse link 15 is there illustrated as comprising a tubular metal casing 31 having an open lower end and a flanged upper end which is closed by the terminal cap 32. This cap rigidly mounts a small metallic ferrule 33 within which is solder-connected one end of a pigtail conductor 34. This flexible pigtail conductor extends away, from the end cap 32 and is provided at its extended end with a ferrule 35 and a manipulating loop 36. The ferrule 35 is provided with a conical part 35a adapted for wedging engagement with the ears 27 and 28 of the spring arm 17 in the manner more fully explained below. Preferably, the ferrule 33 employed in electrically and mechanically connect-

ing the pigtail conductor **34** to the end cap **32** is inserted through an opening in this cap and is provided at its lower end with a flange **33***a* seated against the under side of the cap and solder-connected thereto.

A second pigtail conductor **37** projecting from the lower end of the link **15** functions as the opposite terminal thereof. This conductor is provided at its extended end with a contact ferrule **38** and a manipulating loop **39** of different configuration from the loop **36** in order to permit the two ends of the link to be readily distinguished for the purpose stated below. Preferably, the configuration of the loop **39** is as shown in Fig. 5 of the drawings. The ferrule **38** is provided with a conical portion **38***a* adapted for wedging engagement with the ears **16***a* and **16***b* of the bracket **16** within the slot **16***c* between these ears.

The pigtail **34** is formed from a short length of braided conductive strands, and in the construction thereof is threaded through the ferrule **35** until the length remaining at the upper end thereof is just sufficient to form a loop **36** of the desired diameter. The upper end of the conductor is now inserted back into the upper portion of the ferrule, following which the loop and ferrule are submerged in a solder bath to impregnate the loop portion of the cable with solder. When this solder is permitted to cool, the loop is stiffened, the end part of the conductor is fixedly anchored within the ferrule **35** and the ferrule is rigidly anchored to the intermediate portion of the conductor adjacent the loop part thereof. The pigtail **37** is formed in an identical manner, except that a differently shaped forming mandrel is employed in the loop forming operation. The construction and mode of operation of the fuse link components provided within the metallic casing **31** are substantially the same as disclosed and claimed in applicant's prior Patent No. 2,453,396, granted November 9, 1948, with the important exceptions pointed out below. This casing **31** houses three fusible elements **40**, **41** and **42** which are connected in series circuit relationship between the casing **31** and the pigtail conductor **37**. The two elements **41** and **42** 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 **41** 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 **37**, the overlapping portions of the two elements **41** and **37** being telescoped within a metal assembly sleeve **44**. This sleeve is crimped adjacent the lower end thereof, as indicated at **44***a*, and the lower end of the fusible element **41** is brought out through the strands of the conductor **37** and wrapped around the conductor **37** as indicated at **41***b*. After the three elements **41**, **37**, and **44** have been assembled to occupy the relative positions illustrated in Fig. 6 of the drawings, the crimp **44***a* may be formed around the lower portion of the sleeve **44** for the purpose of providing a rigid mechanical connection between the three named parts. Thereafter, the lower end portion of the sleeve **44**, the adjacent portion of the pigtail conductor **37** and the wrapped end portion **41***b* of the fusible element **41** may be soldered to provide a rigid connection therebetween.

The fusible element **42** may be more properly designated a combination impedance element and heating element in that it functions in conjunction with the improved surge gap facilities described below to prevent surge currents of large magnitude from traversing the fusible elements **40** and **41** and also acts to heat the fusible element **40** 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 **42** is constructed in the form of a helically coiled conductor, and the upper end portion **42***a* thereof is electrically and mechanically connected to the underside of the contact head **32** by crimping the same between the flange **31***a* and the cap **32**.

The convolutions of the element **42** are spaced apart axially of the tube **31**, and the spaced apart relationship between the turns is maintained by embedding the same in a body of dielectric refractory material **45**. 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 **42**, 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 **45**, 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 **42**. Among other functions, the body **45** serves rigidly to position or support the turns of the element **42** within the tube **31**, and to this end entirely fills the upper portion of the tube. It also serves to support a tubular conductor **46** centrally of the tube **31**, this element being utilized in the connection of the fusible element **41** with the lower end portion of the combination heating and inductance element **42**. More specifically, the upper tubular portion of the connecting element **46** is projected well within the turns of the element **42** in spaced apart relationship therefrom, and is embedded in the body **45**. At its lower end this connecting element is provided with an outwardly extending flange **46***a* which serves to seat the lower turn of the element **42** in a manner such that the tubular portion of the element **46** is substantially concentrically disposed within the turns of the element **42**. This lower turn of the element **42** is electrically and mechanically connected to the flanged portion **46***a* of the element **46** by means of a high melting point solder **47**, or the like. The upper end of the connecting element **46** is electrically and mechanically connected to the upper serpentine end **41***a* of the fusible element **41** through the fusible element **40**, 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 **40**, as thus formed within the tubular portion of the connecting element **46**, is disposed well within the turns of the element **42** so that heat generated by current conduction through the latter element may be transferred to the fusible element **40** through that portion of the refractory body **45** which separates the fusible element **40** from the adjacent turns of the element **42**. Spring tension imposed upon the free lower end of the pigtail conductor **37** may be utilized to rapidly withdraw the end **41***a* of the fusible element **41** from the

connecting element 46 when the named fusible element is heated to a melting temperature, and to widen a break in the fusible element 41 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 40, a thermal storage element 48 is provided which is arranged in heat transfer relationship with the element 40 and the heating element 42. This element is in the form of a copper or brass rod disposed centrally of the tubular casing 31 and having its lower end contacting the exposed upper surface of the fusible element 40. It is held in an upright position in axial alignment with the tubular conductor 46 by virtue of its being embedded in the body 45.

During prolonged use of the link, the upper portion of the fusible element 40 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 45 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 42. This would result in undesired modification of the time-overload characteristic of the link. In order to obviate this possibility, a ceramic insulating tube 49 is provided to act as a barrier between the parts 40, 46, and 48 and the turns of the coiled conductor element 42. Specifically, this tube is telescoped over the tubular conductor 46 to rest upon the flange 46*a* and is embedded in the body 45 in the manner illustrated. Being of heat resistant ceramic material, the tube 49 is not subject to cracking and hence acts as a leak-proof barrier between the fusible element 40 and the convolutions of the coiled conductor element 42. Also, since the tube 49 has approximately the same heat transfer characteristics as the body 45, its presence in the zone of heat transfer between the elements 40 and 48 and the element 42 does not seriously complicate the problem of producing links having substantially the same time-overload characteristics in production quantities. Further, provision of the tube 49 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 42 out of contact with the metal casing 31, to maintain the element 41 out of contact with the tubular casing 31 and to provide a support for the surge gap facilities described below, the entire assembly within the casing 31 and a part of the sleeve 44 are surrounded by a tube 50 formed of Bakelite or other suitable insulating material. At its upper end, this tube is provided with a flange 50*a* pressed against the metal casing flange 31*a* when the cap 32 is fastened to the flange 31*a*. This tube 50 fits snugly within and is adhesively bonded to the tubular member 31, and the lower end portion 50*b* thereof projects outwardly from the open lower end of the casing 31. It is counterbored from the upper end to provide a first portion 50*c* of large internal diameter for receiving the parts 42, 45, 46, 48, and 49, and a second portion 50*b* of smaller internal diameter for receiving the fusible element 41. The flange 46*a* of the tubular conductor 46 is seated upon the step 50*d* between these two portions of the tube 50.

In order to assist in producing arc extinction within the tube 50 when the link is ruptured either through fusing of the element 40 or fusing of the element 41, that part of the tube portion 50*b* through which the fusible element 41 extends may be lined with a gas evolving material 51. Preferably, this lining is in the form of a layer of long fiber cellulose adhesively secured to the inner surface of the tube portion 50*b* between the flange 50*d* and the upper end of the sleeve 44 to surround the fusible element 41.

For the purpose of preventing moisture, dirt and the like from coming into contact with the active components of the fuse link there is provided in accordance with the present invention a viscous sealing material, preferably comprising one of the recently developed silicones, which is inserted in the space between the tube 50 and the sleeve 44. If desired this viscous sealing material may also fill a substantial portion of the space between the liner 51 and the fusible element 41 to insure good sealing action. It has been found that the use of such material in the space between the liner 51 and the fusible element 41 does not interfere with arc interruption and does not impede the separation of the parts of the fuse link upon interruption thereof.

As indicated above, in order to prevent lightning surges from rupturing the fusible heating element 42, a surge gap having relatively immovable electrodes is connected in shunt with this element. Specifically, and in accordance with one feature of the present invention, the heat storage element 48 having its lower end in electrical and mechanical contact with the upper end of the fusible body 40, is provided with an upper end which is spaced apart from a member 54 associated with the cap assembly 32 in a manner so as to define a small air gap 52 between the member 54 and the adjacent end of the heat storage member 48. This gap in combination with the storage element 48 and the fusible body 40 provides a surge path in shunt with the heating element 42 for by-passing surges around this element.

In order to assist in weatherproofing the above described active components of the link 15 and more important to assist in producing arc extinction in response to rupture of the link by heavy overloads, a weatherproof tube 53 is provided which is wholly supported by the casing 31. More specifically, the upper portion of this tube as viewed in Fig. 5 of the drawings is press fitted onto the casing 31 to bring the upper end thereof into abutting engagement with the ends of the cap 32. The lower end of the tube 53 extends outwardly beyond the lower end of the insulating tube 50 to house an appreciable portion of the pigtail conductor 37. In order to aid in the arc extinguishing action the portion of the tube 53 below the end of the tube 50 is lined with a short length of a tube 55 preferably formed of a gas evolving insulating material which is pinned into position within the expulsion tube 53 by means of a small pin 56. It should be understood that the tubes 50 and 53 could comprise a single tube in which case the casing 31 would be dispensed with. With such an arrangement a much longer arc extinguishing section is provided without the requirement of a separate expulsion tube. In the illustrated embodiment the two separate tubes 50 and 53 are provided so that a standard fuse link may be employed while affording the same operation as when a single tube is used.

When using the fuse link 15 to fuse the cutout

embodied in the protective apparatus shown in Figs. 1 and 2 of the drawings, the round configuration of the loop 36 provides an indication to the lineman that this end of the link should be connected to the upper end of the spring arm 17. In this regard it will be understood that the line connection is brought into the terminal conductor 14b of the arrester 14a so that with the apparatus unfused, a connection is first made with the dead spring arm 17 during the fusing operation. This connection may conveniently be made by using the hook of a "hot-stick" to position the contact ferrule 35 in the channel 29 between the ears 27 and 28 with the conical part of this ferrule engaging the edges of the two ears. After this connection is made, the hot-stick hook may be shifted to the loop 39 and the link 15 pulled toward the bracket 16 to insert the contact ferrule 38 into the slot 16c between the ears 16a and 16b of this bracket. As this operation is performed, the spring arm 17 is de-formed toward the bracket 16 in the manner illustrated in Fig. 2 of the drawings. After the contact ferrule 38 is positioned between the bracket ears 16a and 16b, the pulling force exercised on the loop 39 through the hot-stick may be relieved permitting the ferrule 38 to move into the channel 16a to bring the conical part 38a thereof into wedging engagement with the sides of the ears 16a and 16b. Thus the fusing operation is completed through the performance of a relatively few simple steps.

As best shown in Fig. 2 of the drawings, with the cutout of the unit fused, the fuse link 15 is angularly disposed with respect to the horizontal with its open end disposed in the lowermost portion. This positioning of the link insures against rain entering the expulsion tube 53 and assists the viscous sealing material in preventing moisture, dirt and the like from coming into contact with the active components of the link. Thus there is no necessity for housing the link to protect the same.

As indicated above, the conical portions of the two ferrules 35 and 38 are wedgingly engaged with the ears provided at the extended ends of the spring arm 17 and the bracket 16 respectively. This wedging engagement insures good electrical conductivity between the contact ferrules and the spring arm and bracket without the necessity of imposing an excessive pull upon the fusible element 40 of the link which might destroy the current-time characteristics thereof.

As pointed out above, the live or high voltage side of the line feeding the transformer 10 is connected to the terminal conductor 14b of the arrester unit 14a so that current is normally fed to the transformer primary winding over a path which includes the bracket 16, the contact ferrule 38, the pigtail conductor 37, the fusible elements 41, 40 and 42 in series, the casing terminal cap 32, the pigtail conductor 34, the contact ferrule 35, the spring arm 17, mounting piece 20 and the transformer bushing stud 18. The tank of the transformer 10 provides the usual ground connection. With the circuit thus arranged, the arrester 14a provides a lightning surge path between the high voltage side of the line and ground which serves to by-pass the link 15 and the primary winding of the transformer when lightning surges are impressed upon this side of the line. Such surges are prevented from burning out or damaging the heating element 42 of the fuse link through the action of the facilities including the gap 52 for by-passing this element. In this regard, it is noted that the character of the surges which may be permitted to act upon the fusible elements 41 and 42 by the arrester 14a is such that these two elements are not susceptible of being ruptured.

In considering the mode of operation of the fuse link 15, it may be assumed that the transformer 10 is provided with a low voltage secondary load which under normal conditions approximates the full load capacity of the transformer 10, 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 10. In this regard, it will be understood that due to the heat radiating capabilities of the transformer parts, the transformer 10 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 applied thereto.

The fuse link 15 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 40, 41 and 42 of the link 15 are traversed by the current flowing through the primary winding of the transformer, they are all heated by current conduction and the temperature of each element varies with changes in the magnitude of this current. The fusible element 40 is also heated by the heat conducted thereto from the element 42 through the walls of the connecting element 46. Heat energy is also transferred from the turns of the element 42 to the fusible element 40 through that portion of the refractory body 45 and the tube 49 which are disposed between the tubular portion of the connecting element 46 and the surrounding turns of the element 42, and also from the thermal storage element 48. Under constant load current conditions and with a constant voltage so long as the load current through the secondary winding of the transformer does not substantially exceed the full load capacity of this transformer, the fusible element 40 is operated at a temperature well below that required to produce fusion thereof. When, however, the secondary load current of the transformer gradually rises and is sustained for a period approaching that at which the transformer will be damaged, the temperature of the fusible element 40 is raised accordingly. Thus, as the load current increases, the current traversing the three elements 40, 41 and 42 is correspondingly increased so that more heat is produced in the fusible element 40 by current conduction. Concurrently the amount of heat conducted to this fusible element from the fusible elements 41 and 42 is increased. Also concurrently, the amount of heat transferred from the turns of the element 42

to the fusible element 40 through the refractory body 45 and the tube 49 is increased. A portion of the heat energy accumulating in the element 40 is transferred to the storage element 48 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 48 materially increases this time interval over that which would obtain in the absence of this element in the combination. When the element 40 is thus ruptured, the fusible element 41, the sleeve 44, and the upper end of the pigtail conductor 37, are quickly expelled from the lower ends of the tubes 31 and 50 under the influence of the spring arm 17, thereby rapidly to break the circuit for energizing the primary winding of the transformer.

During the described separation of the element 41 from the tubular conductor 46 upon fusing of the element 40, an arc is drawn within the portion 50b of the tube 50. This arc instantly heats the coating 51 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 51 permits the link itself to effectively extinguish heavy current arcs of the order of several hundred ampers even when the link is used in high voltage circuits of several thousand volts.

To consider the action of the fuse link 15 further, it may be pointed out that the refractory body 45 and the tube 49 prevent the fusible element 40 from being heated to its melting temperature when surge currents are produced in the primary circuit of the transformer 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 40 is wholly insufficient to raise the temperature of the element to its melting point. Moreover, those portions of the refractory body 45 and the tube 49 which are disposed between the tubular portion of the connecting element 46 and the storage element 48 and the turns of the heating element 42 dissipate a large portion of the heat resulting from the current surge through the element 42 away from the element 41. They also delay the transmission of the increased increment of heat produced by the element 42 to the storage element 48 and the adjacent walls of the connecting element 46 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 46 and storage element 48 from the element 42 as a result of the momentary high current, effects an insufficient increase in the temperature of the fusible element 40 to cause this element to melt. In other words, the total heat accumulated in the fusible element 40 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 45 and the tube 49, or more exactly the thermal impedance of this composite structure, protects the fusible element 40 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 40 to a point such that it will provide no protection for sustained overload currents.

The thermal impedance of the refractory body 45 and the tube 49 also prevents the fusible element 40 from immediately rupturing when the transformer is subjected to a high current, such, for example, as that which is produced when the secondary winding of the transformer is short-circuited. In the absence of an additional protective element, therefore, the transformer could easily be damaged by an overload current of this character during the period required to transfer sufficient heat from the heating element 42 to the fusible element 40 to cause the latter element to melt. The second fusible element 41 functions to guard the transformer against damage when subjected to an overload current of this type. Thus, immediately the element 41 is subjected to a transient current of the particular character just referred to, a portion thereof lying between the upper end of the sleeve 44 and the lower end of the fusible element 40 is heated to a fusing temperature, permitting this element to rupture.

When the fuse link 15 is ruptured in response to an overload condition of any one of the types mentioned above, i. e., through melting of the fusible body 40 or melting of the fusible element 41, the holding forces imposed upon the de-forming spring arm 17 are instantly released permitting this arm to swing to the left from its closed circuit position illustrated in Fig. 2 of the drawings. Incident to this operation the link 15 is pulled away from the pigtail 37 to produce arc elongation within the tube 50. As the arm 17 swings away from the bracket 16, the tubes 31 and 50 are pulled away from the pigtail 37 and describe an arc above the extended end of the arm 17. The elements of the link being pulled away from the element 16 obviously gather momentum as the movement of the arm 17 proceeds with the result that when this arm stops at a position to the left of its unrestrained position as shown in Fig. 2 of the drawings the contact 35 is pulled out of the channel 29 and drops to the ground. In this regard, it will be noted that all of the components within the tube 31 which may become heated to a high temperature incident to rupture of the fuse and extinction of the arc are contained within the tube 31, the outside of which remains at a low temperature. Hence there is no possibility of the production of grass fires when the parts of the link 15 fall to the ground. When the pigtail 37 becomes disengaged from the remaining components of the link through the action of the spring arm 17 in the manner just explained, it falls down over the bracket 16 and remains in this position until such time as the cutout is refused. In this regard it is pointed out that the length of the pigtail 37 is substantially less than the distance between the upper end of the insulator 14 and the grounded brackets supporting this insulator so that there is no possibility of this conductor short-circuiting the high voltage side of the line to ground. The manner in which the cutout may be refused will be clearly apparent from the foregoing explanation.

From the preceding explanation it will be understood that the disclosed protective apparatus 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 transformer is subject to all types of overloads

and lightning surges of the character normally encountered in operating practice. Thus the cut-out portion of the apparatus requires only three elements in addition to those normally provided in transformer protective equipment, namely, the small bracket 16, the simple spring arm assembly 17, and the fuse link 15. All of these elements are of very simple construction and may be easily manufactured at low cost. Further, the operations required in refusing the assembly may easily be performed by relatively unskilled linemen without danger and in a very short time.

While there has been described what is at present considered to be the preferred embodiment of the invention, it will be understood that various modifications may be made therein which are within the true spirit and scope of the invention as defined in the appended claims.

What is claimed as new and is desired to be secured by Letters Patent of the United States is:

1. Protective apparatus for a transformer provided with a terminal conductor extending upward from the transformer tank, comprising an elongated lightning arrestor supported at one side of said tank in a substantially vertical position and provided with a terminal conductor at its upper end, a conductive bracket mounted upon one of said terminal conductors, and a spring arm mounted upon and extending upwardly from the other of said terminal conductors, said bracket and arm being provided with means at the extended ends thereof for mechanically holding the opposed terminal conductors of a fuse link and said arm being deformable toward said bracket to permit connection of the terminal conductors of the link to said holding means and to bias the link for arc elongation in response to rupture of the fusible element of the link, said bracket and arm being so supported and arranged that the inner portions of the holding means thereof form a pair of acute angles with respect to the tensioned fuse link.

2. Protective apparatus for a transformer provided with a terminal conductor extending upward from the transformer tank, comprising an elongated lightning arrestor supported to one side of said tank in a substantially vertical position and provided with a terminal conductor at its upper end, a conductive bracket mounted upon one of said terminal conductors, and a spring arm mounted upon and extending upwardly from the other of said terminal conductors, said bracket and arm having slots at their extended ends for receiving the terminal conductors of a fuse link and said arm being deformable toward said bracket to permit connection of the terminal conductors of the link to said arm and bracket and to bias the link for arc elongation in response to rupture of the fusible element of the link, said bracket and arm being so supported and arranged that the closed end of the slotted portions thereof form a pair of acute angles with respect to the tensioned fuse link.

3. Protective apparatus for a transformer provided with a terminal conductor extending upward from the transformer tank, comprising an elongated lightning arrestor supported to one side of said tank in a substantially vertical position and provided with a terminal conductor at its upper end, a conductive bracket mounted upon one of said terminal conductors, a spring arm mounted upon and extending upwardly from the other of said terminal conductors, and a fuse link provided with oppositely extending pigtail conductors each provided with a ferrule having a conical part embracing the conductor, said bracket and said arm having slots at their extended ends for wedgingly receiving the conical parts of said ferrules and said arm being deformable toward said bracket to permit insertion of the conical parts of said ferrules in said slots and to bias the link for arc elongation in response to rupture of the fusible element of the link, said ferrules being so supported by the slots that said slotted ends form a pair of acute angles with the tensioned pigtail conductors whereby the wedging of the ferrules with respect to the slots is increased.

4. Protective apparatus for a transformer provided with a terminal conductor extending upward from the transformer tank, comprising an elongated lightning arrestor supported to one side of said tank in a substantially vertical position and provided with a terminal conductor at its upper end, a conductive bracket mounted upon one of said terminal conductors and extending away from said one terminal conductor, a partially laminated spring arm mounted upon and extending upwardly from the other of said terminal conductors, the laminated portion of said arm extending from a point intermediate the ends of said arm to said other terminal conductor, and a fuse link provided with oppositely extending pigtail conductors each provided with a ferrule having a conical part embracing the conductor, said bracket and said arm having slots at their extended ends for wedgingly receiving the conical parts of said ferrules and said arm being deformable toward said bracket to permit insertion of the conical parts of said ferrules in said slots and to bias the link for arc elongation in response to rupture of the fusible element of the link.

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