United States Patent

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[54] **ELECTRICAL INDUCTIVE APPARATUS**
13 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** **317/15,**
337/249, 337/276
[51] **Int. Cl.** **H02h 704**
[50] **Field of Search** 317/15;
337/279, 280, 246, 247, 249, 250, 158, 276;
200/149

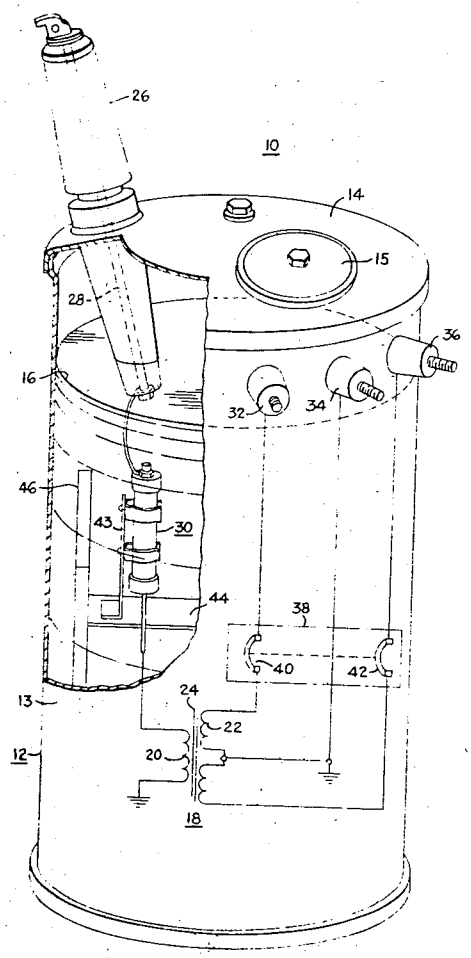
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ABSTRACT: Electrical inductive apparatus, including a casing filled to a predetermined level with liquid dielectric means, a magnetic core-winding assembly disposed within the casing and immersed in the liquid dielectric means, a plurality of insulating bushings disposed to introduce electrical conductors into the casing through openings therein, and at least one fuse assembly. The fuse assembly is disposed within the casing, below the level of the liquid dielectric, and is conductively interconnected between the electrical conductor of an insulating bushing, and one of the windings of the magnetic core-winding assembly. The fuse assembly includes a sealed fuse tube having a pair of electrically conductive terminal elements at its ends, a solid liner of arc extinction material of the type which emits water vapor, or other condensable gas, when subjected to the heat of an arc, an arcing passageway between the ends of the fuse tube, and a fusible element disposed in the arcing passageway, conductively interconnecting the pair of terminal elements.



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SHEET 1 OF 3

FIG. 1.

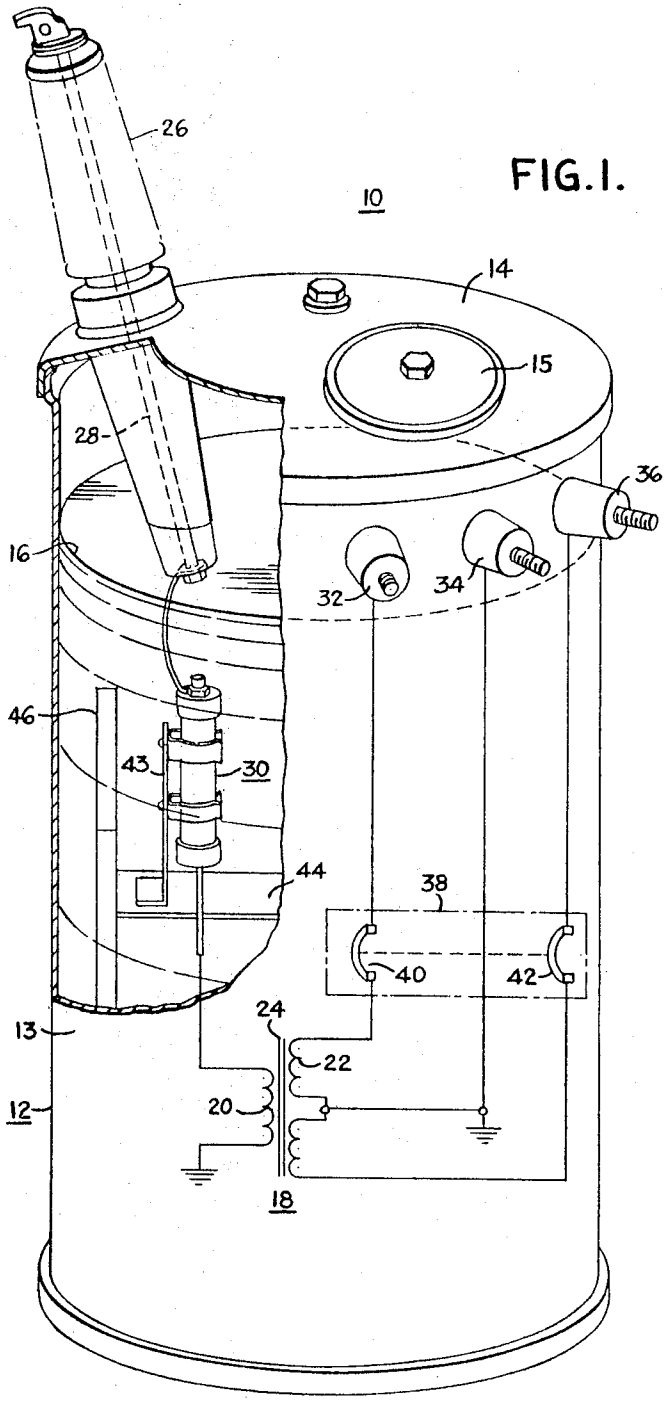
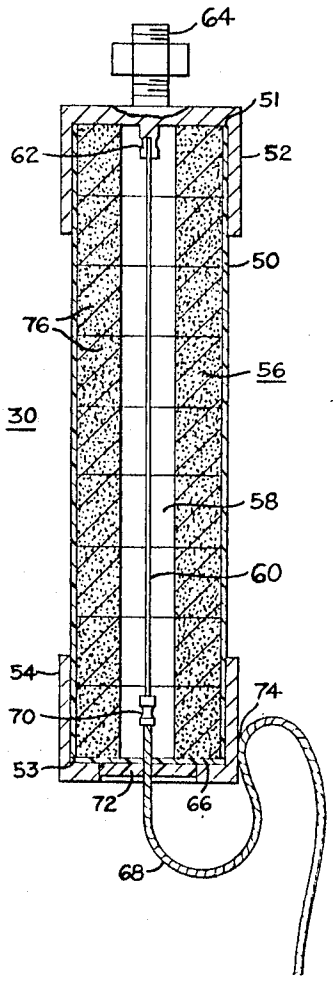


FIG. 2.



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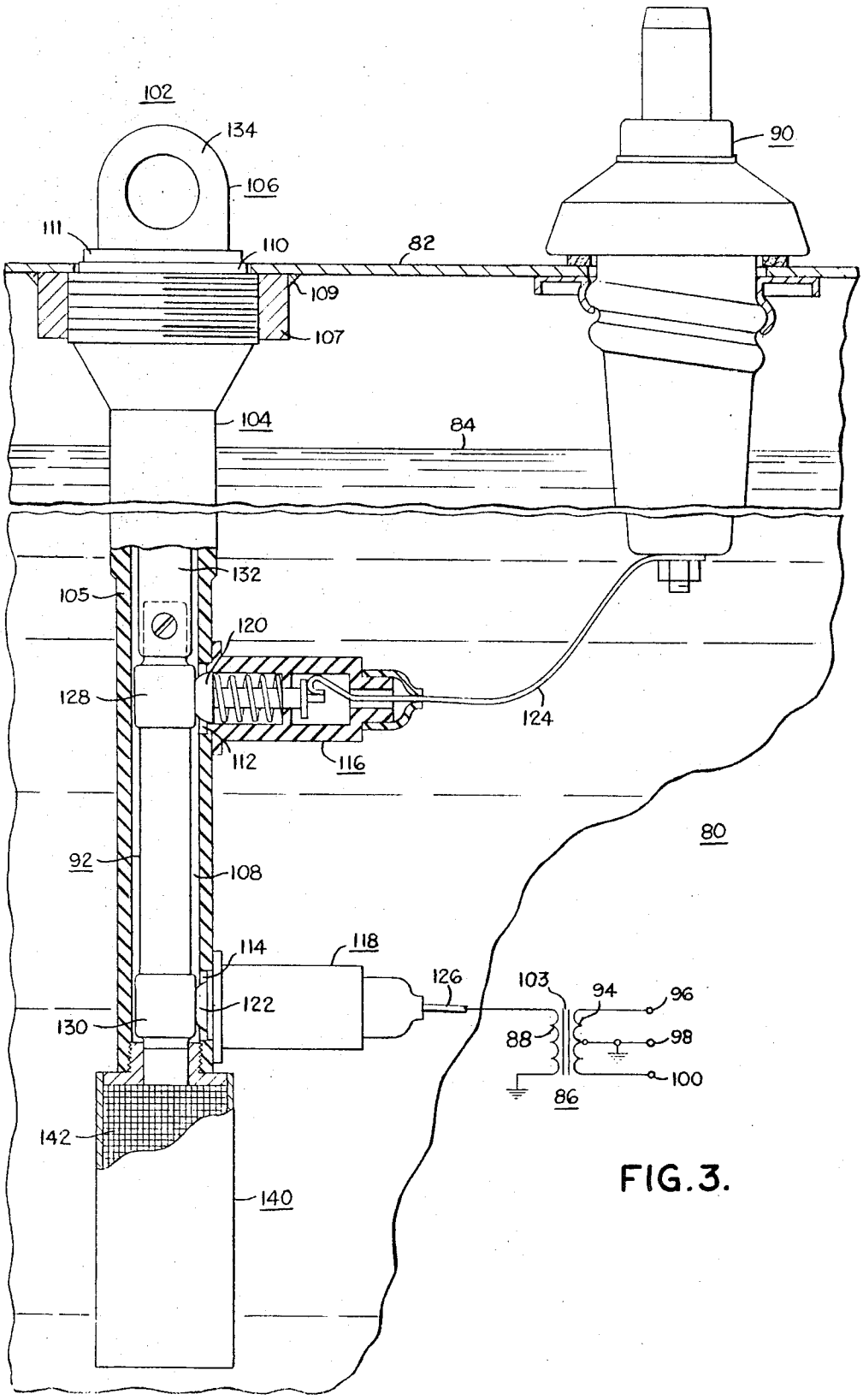

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FIG. 3.

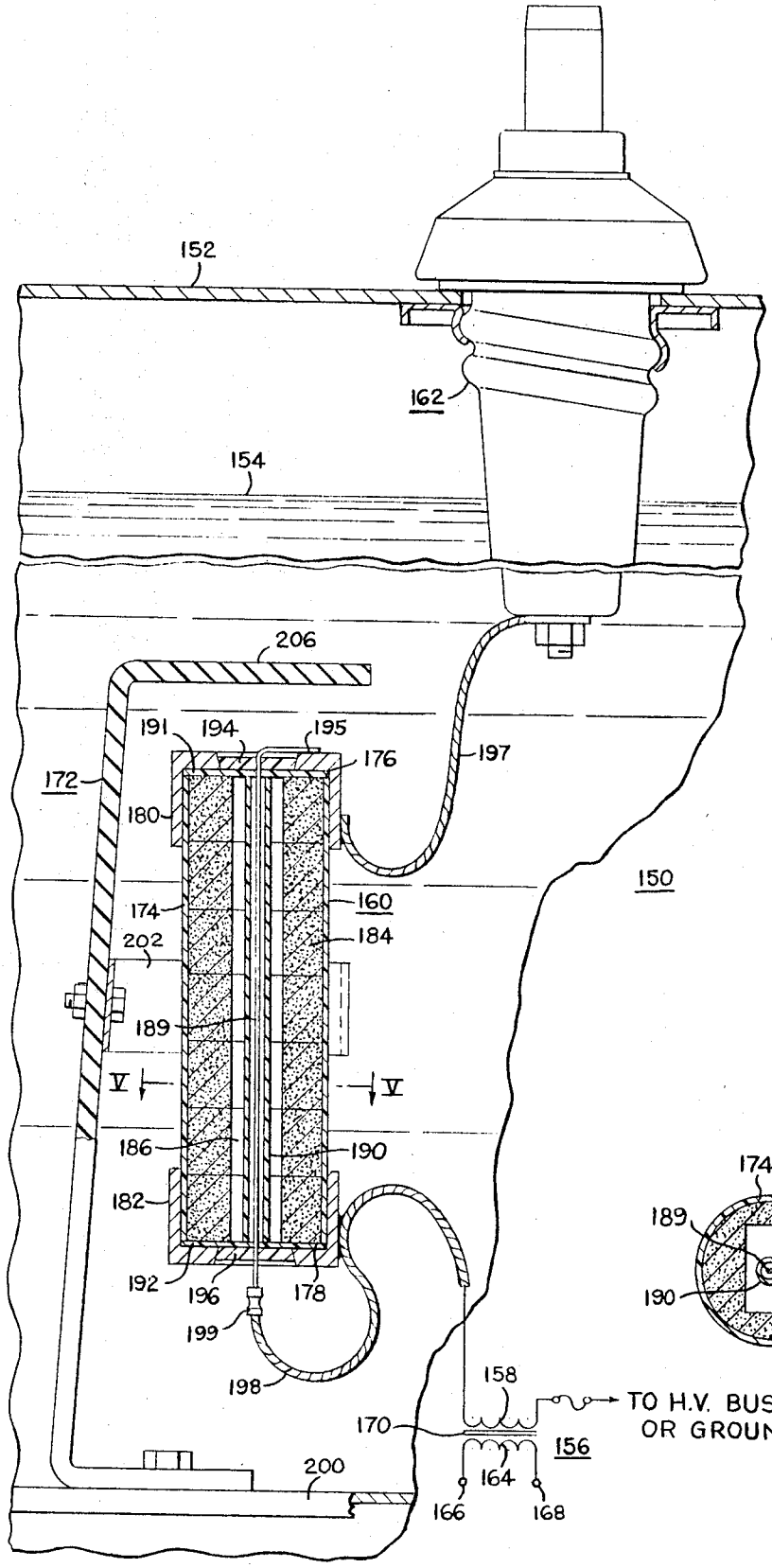

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TO H.V. BUSHING
OR GROUND
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FIG.4.

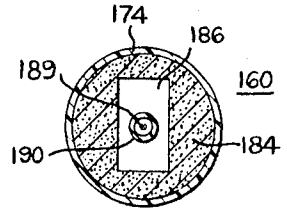

174
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FIG.5.

ELECTRICAL INDUCTIVE APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates in general to electrical inductive apparatus of the liquid filled type, such as distribution transformers, and more particularly to protected electrical inductive apparatus.

2. Description of the Prior Art

It is common in electrical distribution transformers to protect the transformer against overloads and short circuits external to the transformer, with a circuit breaker disposed within the transformer tank, which is connected to the secondary winding or load side of the transformer. The electrical distribution system is protected against lockout due to an internal fault in the transformer, by a protective or fusible link, disposed either in the high voltage bushing of the transformer, or block mounted within the transformer casing, under oil, and connected to the primary winding or high voltage side of the transformer. The fusible links of the prior art have certain disadvantages. For example, at 7200 volts, the fusible links are rated 3500 amperes interrupting capacity when bushing mounted, and 1,000 amperes interrupting capacity when block mounted. While bushing mounting is preferred because of its higher interrupting rating, the block mounting is less costly since it does not require a special, more complicated insulating bushing, and block mounting provides better corona performance.

With the present modern electrical power distribution systems, and those proposed for the future, even 3,500 amperes interrupting capacity at 7,200 volts may be inadequate, making it necessary to add a current limiting fuse in series with the conventional protective link. Thus, it would be desirable to provide a protected transformer having a single fusible circuit interrupting device or fusible link which will have a rating of 10,000 amperes, or more, at 7,200 volts, and it would be desirable to be able to obtain this rating even when the fusible device is block mounted within the transformer.

The interrupting rating of a protective device disposed within a transformer tank depends upon two factors. First, the device must clear the circuit, without restriking or flashover, and second, in clearing the circuit, it must not damage the transformer externally. In other words, it must interrupt the circuit without blowing the cover off the transformer, or otherwise rupturing the tank. The reasons for the relatively low interrupting ratings of prior art protected transformers are clear when the mechanics of the circuit interruption of the prior art protective links are examined. The fault current melts the fuse wire of the protective link, and an arc, inside a bubble of ionized gas, forms along the path of the fuse wire. The ionized bubble is the result of oil decomposition. The intense heat of the arc continues to break down the oil, as well as breaking down the walls of the tube surrounding the fuse wire of the protective link. The tube is usually formed of bone fiber. This breakdown of oil and fiber tube liberates hydrogen and carbon monoxide gases, which have a low dielectric strength and are noncondensible, flammable and explosive. Thus, while the prior art fusible link is interrupting the circuit, the pressure within the tank is increasing because more and more oil is being decomposed into noncondensible gases, and the hazard of flashover is created which may occur through the low dielectric strength gas bubble, if the gas bubble engulfs a live part and ground. At the upper limit of the interruption rating of the prior art fusible links, the fusible link cannot clear the circuit, causing the pressure to build up within the transformer tank until its cover is blown off, or until the gas bubble envelops a live part and ground which causes restrike and continuous arcing.

It would, therefore, be desirable to provide a new and improved protected electrical inductive apparatus, such as a distribution transformer, which has a much higher interrupting rating than those of the prior art, and which will provide this higher interrupting rating while utilizing new and improved protective links, block mounted below the oil level of the apparatus. Further, the new and improved protected electrical inductive apparatus should have a cost competitive with those of the prior art.

In some applications, the transformers do not contain an internally mounted protective device for protecting the transformer against overloads. However, even in those applications, it would still be desirable to protect the transformer against an external short circuit, for example in underground electrical distribution systems. With the prior art protective link, this may be accomplished by selecting the current rating at which the fusible element will melt to be in the range of 3 to 6 times rated full load current. Since the prior art fuse does not evolve water when it clears the circuit, the transformer will not be contaminated, and only the fusible device need be replaced when it interrupts the circuit due to an external short circuit. Thus, it would be desirable for the new and improved protected inductive apparatus, having the higher interrupting rating than the prior art protected inductive apparatus, to also have the ability to interrupt the circuit without being contaminated with water, when the circuit is interrupted due to a short circuit external to the transformer. When the circuit is interrupted due to a fault within the transformer itself, much higher currents flow, and since the usefulness of the transformer is destroyed by the fault itself, circuit interruption may occur without regard to whether the transformer is contaminated.

SUMMARY OF THE INVENTION

Briefly, the present invention is a new and improved protected transformer, which will interrupt fault currents up to 10,000 amperes, and even higher in certain embodiments. The transformer includes a casing, liquid dielectric means disposed within the casing, a magnetic core-winding assembly disposed in the casing, below the level of the liquid dielectric, insulating bushings disposed to introduce electrical conductors through sealed openings in the casing, for connection to the windings, and at least one fuse assembly disposed in the casing, below the level of the liquid dielectric. The fuse assembly includes a sealed, tubular fuse tube or housing, having a solid liner of arc extinguishing means of the type which emits water vapor when subjected to the intense heat of an arc, such as boric acid. The solid liner defines an arcing passageway between the ends of the fuse tube. Conductive terminal elements are disposed at the ends of the fuse tube, and a fusible element is disposed within the arcing passageway, which extends for substantially the full length of the arcing passageway, and which electrically interconnects the conductive terminal elements at the ends of the fuse tube. In one embodiment of the invention, the fuse tube or housing has a least one end sealed with a frangible member which ruptures when the fusible element melts to establish an arc and generate gas from the solid liner, which builds up a tremendous pressure within the fuse tube. The evolved gas from the decomposing solid liner discharges from the fuse tube, and condenses in the liquid dielectric, thus precluding a substantial buildup of pressure within the transformer casing. Further, the evolved water vapor is nonflammable, nonexplosive and has a high dielectric strength which prevents restriking or flashover from live parts to ground. In this embodiment of the invention, the function of the fuse assembly is to protect against internal faults in the transformer and its fusible element is selected accordingly. Thus, when it operates due to a fault within the transformer, the contamination of the liquid dielectric with water is not a problem, as the usefulness of the transformer has been destroyed by the internal fault. The only function of the fuse assembly is to clear the circuit without damaging the transformer externally. Since the internal tank pressure is raised only slightly and since no low dielectric, noncondensible, flammable gases are evolved, the fuse assembly will safely interrupt currents up to 10,000 amperes.

In another embodiment of the invention, a new and improved fuse assembly is utilized which will clear the circuit in response to short circuits external to the transformer, as well as to clear the circuit due to faults within the transformer itself. This new and improved fuse assembly is similar to the fuse assembly of the first embodiment, and additionally includes a tubular insulating member disposed about the fusible element, between the fusible element and the walls of the arcing passageway, with the tubular insulating element being formed of arc extinguishing material of the type which does not evolve water vapor upon decomposing in response to the arc heat. The lower current magnitudes, such as those which would flow due to external short circuits, will melt the fusible element, and the arc will be extinguished by the gases from the decomposing tubular insulating member, without decomposing the solid liner of water vapor evolving material. Thus, the circuit will be cleared without contaminating the transformer, allowing the fuse assembly to be replaced and the transformer placed back in service. If the fuse assembly is called upon to interrupt the circuit due to an internal fault in the transformer, much higher currents will flow and the tubular insulating member will be decomposed without extinguishing the arc. The arc will then decompose the solid liner of water vapor evolving material, extinguishing the arc.

In still another embodiment of the invention, the fuse assembly of the first embodiment is sealed at one end with a condenser, which condenses the evolved water vapor without increasing the pressure within the transformer casing, and without contaminating the liquid dielectric of the transformer. The interrupting rating of the fuse assembly is extended beyond 10,000 amperes, in this embodiment. In those applications where the fusible element is sized to melt on external short circuits, the fuse may be replaced without contaminating the transformer, if the transformer has not been internally damaged, as the water vapor is confined to the condenser.

BRIEF DESCRIPTION OF THE DRAWINGS

Further advantages and uses of the invention will become more apparent when considered in view of the following detailed description and drawings, in which:

FIG. 1 is a perspective view, partially cut away, and partially schematic, of a protected transformer which may utilize the teachings of the invention;

FIG. 2 is an elevational view, in section, of a new and improved fuse assembly constructed according to the teachings of the invention, for use in the transformer shown in FIG. 1;

FIG. 3 is a fragmentary elevational view, partially in section, of a protected transformer constructed according to another embodiment of the invention;

FIG. 4 is a fragmentary elevational view, partially in section, of a protected transformer constructed according to still another embodiment of the invention; and

FIG. 5 is a cross-sectional view of the fuse assembly shown in FIG. 4, taken along the line V–V.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to the drawings, and FIG. 1 in particular, there is shown a perspective view of a protected transformer 10, which may utilize the teachings of the invention. Transformer 10 is shown partially cut away, and with the magnetic core-winding assembly of the transformer being shown schematically. More specifically, transformer 10 includes a casing 12 which includes a tank 13 and a cover 14 which seals the tank 13, with the tank 13 being filled to a predetermined level 16 with a liquid dielectric means such as oil. Cover 14 may have a sealed hand hold cover 15 for gaining access to the inside of the transformer for inspection and maintenance. A magnetic core-winding assembly 18, comprising primary and secondary windings 20 and 22 disposed in inductive relation with a magnetic core 24, is disposed within the tank 13, below the level 16 of the liquid dielectric means.

A plurality of high and low voltage bushings are disposed through suitable openings in the casing 12, introducing electrical conductors into the casing while insulating the conductors from the casing and sealing the openings therein. If the primary or high voltage winding 20 has one end grounded, as shown in FIG. 1, a single high voltage bushing assembly 26 may be used, cover or sidewall mounted, which has an axially extending electrical conductor 28, the encased end of which is connected to the high voltage or primary winding 20 through a protective or fusible link 30. If the primary winding 20 is of the type which has both ends adapted to be connected to the electrical distribution system, two high voltage bushing assemblies would be utilized, each connected to an end of the primary winding through a fusible link. Since the high voltage bushings and fusible links would be similar for each end of the primary winding, the invention will be described relative to protected transformers having a single high voltage bushing.

The secondary winding 22, in this embodiment, is connected to low voltage bushings 32, 34 and 36, with the ends of the secondary winding being connected to bushing 32 and 36 via the contacts 40 and 42 of a circuit breaker 38, and the center tap of secondary winding 22 may be connected to bushing 34 and to ground.

The protective or fusible link 30 is disposed below the level 16 of the liquid dielectric, and is block mounted by any suitable arrangement, such as a bracket 43 mounted on the horizontal support member 44 which joins the upper extension of the magnetic core end frame 46.

In the embodiment of the invention shown in FIG. 1 the circuit breaker 38 will protect the transformer 10 against external overloads and short circuits, and the protective link 30 will be sized, such as at ten times the rated current of the transformer, to protect the electrical system connected to the high voltage bushing 26 from internal faults in the transformer. Since the protective link 30 will only interrupt or clear the circuit when the transformer will be replaced due to the internal fault, the protective link 30 may be mounted without regard to easy replacement.

In the prior art, the block mounted protective link 30 would include a fusible element, disposed within a fiber tube, with the fusible element being immersed in the liquid dielectric. The maximum interrupting rating of this device is 1,000 amperes, as beyond this rating the internal tank pressure generated by noncondensible gases from the decomposing liquid dielectric and fiber tube, become excessive, and the ionized bubble of gases, which include hydrogen and carbon monoxide, may cause flashover from live parts to ground.

The interrupting rating of the protected transformer 10 may be extended to 10,000 amperes by constructing the protective link 30 according to a first embodiment of the invention, which cooperates with the liquid filled inductive apparatus to clear the circuit without excessive tank pressure, and without significantly increasing the chances of flashover between live parts and ground.

FIG. 2 illustrates a new and improved fusible link assembly 30 which may be block mounted within the transformer 10 shown in FIG. 1, and which cooperates with the liquid filled inductive apparatus 10 to extend the interrupting rating of the apparatus to 10,000 amperes. Specifically, fusible link assembly 30 is a fuse of the expulsion type, having a housing or tubular fuse tube 50, which has upper and lower ends 51 and 53, respectively, formed of an insulating material, a pair of conductive electrodes 52 and 54 disposed at the ends of the fuse tube 50, a solid liner 56 of water vapor evolving arc extinguishing material, which extends for the length of the fuse tube, having an axial opening which defines an arcing passageway 58 between the ends of the fuse tube, and a fusible element 60 which extends for substantially the complete length of the arcing passageway 58, and which conductively interconnects the terminal elements 62 and 70. The fuse 30 must be sealed to prevent entry of the liquid dielectric, in which it is immersed. Thus, the fuse tube 50 must be formed of a high strength, oil resistant insulating material, such as one of

the laminated plastics, a glass filled nylon, or a filament wound glass material. One end of the fuse tube may be sealed with an electrode, such as electrode 52, which is formed of good electrical conductor such as copper and which telescopes tightly over the upper end of the fuse tube 50, and secured thereto by cementing, such as with an epoxy adhesive. The upper terminal element 62, which may be an integral part of electrode 52, is disposed within the arcing passageway 58, which mechanically and electrically connects the fusible element 60 to the upper electrode 52. Electrode 52 may also include means 64, such as a threaded shaft and nut assembly, for connecting the fuse assembly 30 with an electrical conductor.

The lower end 53 of the fuse tube 50 is sealed with a frangible or breakable seal member, such as a thin disc of a suitable laminated plastic material, or molded plastic, which will seal the fuse assembly 30 until the fuse operates to clear the circuit, at which time the seal will rupture due to the pressure of the gases generated within the fuse, to expel the gases without rupturing the fuse tube 50. For example, as shown in FIG. 2, a thin oil resistant disc 66 may be disposed over the lower end of the fuse tube 50, and held in place with the lower electrode 54, which has an open end axially aligned with the arcing passageway 58. The disc 66 may have a small opening therein to allow a conductor 68 to gain access to the arcing passageway 58 where it is connected to the fusible element 60 via the lower terminal element 70. The opening in the disc 66 may be sealed with an oil resistant sealing compound 72, such as a silicone rubber, or an epoxy adhesive. The conductor 68 is brazed or welded to the lower electrode 54 at 74, in order to prevent stressing the fusible element 60. Therefore, the function of the lower electrode 54 is more mechanical than electrical, and may be eliminated if other means for preventing stressing the fusible element is provided.

The solid liner 56 of water vapor evolving arc extinguishing material is preferably formed of boric acid (H_3BO_3) because of its superior arc extinguishing capabilities, but other water vapor evolving inorganic arc extinguishing materials may be used, such as magnesium borate. The arc extinguishing material, which may be initially in the form of a powder, is pressed into either a continuous solid liner, which extends the full length of the fuse tube 50, or as shown in FIG. 2, the arc extinguishing material may be compressed into solid cakes 76 having a central opening therein, which cakes are axially stacked with their openings in alignment to provide the desired liner length and the arcing passageway 58. While the openings in the cakes 76 may be circular, defining a cylindrical arcing passageway 58, more turbulence will be provided, for more effective arc quenching capabilities, if the arcing passageway is noncircular. For example, as will be more fully described in a subsequent embodiment, the arcing passageway 58 may have a square or a rectangular cross section.

Boric acid is readily compressible into cakes having the desired dimensions, which have sufficient mechanical strength to allow their use without difficulty. When the boric acid liner is acted upon by an arc along the path of the fusible element 60, it is decomposed, giving off water vapor and boric oxide (B_2O_3). The water vapor is in the form of steam, which provides a turbulence which rapidly intermixes freshly generated un-ionized evolved gas from the decomposing boric acid with the confined arc, causing a rapid deionization at the first current zero.

The rapidly evolving gas from the boric acid ruptures the frangible disc member 66, expelling flame from the arc and the hot gases into the liquid dielectric. The arc is extinguished so rapidly within the fuse tube, that the circuit is cleared before the liquid dielectric enters the fuse tube. The liquid dielectric cools and condenses the steam and water vapors expelled from the fuse tube, preventing excessive pressures from being built up within the transformer casing. Any steam or water vapor which would escape the liquid dielectric however, is not a difficult problem, as steam or water vapor has a high dielectric strength and is not flammable or explosive. Therefore, there would be little danger of flashover from live parts to ground within the transformer casing. The arc, playing only on inorganic water vapor evolving materials, such as boric acid, instead of the organic materials of the prior art, such as bone fiber, liberates mostly steam and not the hydrogen and carbon monoxide liberated by organic materials.

The length of the liner 56 and the cross-sectional dimensions of the arcing passageway depend upon the circuit volts per inch of fuse length, at a given current, that is to be interrupted. Increasing the length of the arcing passageway increases the volts per inch that may be interrupted, as the arc will liberate more gas. It should be noted that the fusible element 60 extends for substantially the full length of the arcing passageway, which will instantaneously generate an arc the full length of the passageway, unlike certain prior art devices which utilize a mechanical spring to pull an arc through an arcing passageway, which was initiated with a relatively short length of fusible material. Decreasing the cross-sectional dimensions of the arcing passageway also increases the volts per inch which may be interrupted, as the arc will be closer to the water vapor evolving material, causing a larger amount of gas to be evolved and a more concentrated turbulence and gas blast.

The fuse assembly 30 shown in FIG. 2 may be modified, as will be hereinafter explained in detail in other embodiments of the invention. For example, instead of expelling the gases only from the lower end of the fuse tube 50, which requires a high strength mounting means for the fuse assembly, to counteract the reaction of the gas blast from one end of the fuse tube, the upper end of the fuse assembly 30 may be constructed similar to the lower end, thus expelling the gases from both ends of the fuse tube simultaneously, which substantially reduces the stresses imposed upon the fuse mounting means.

In those applications where the secondary circuit breaker is not desired, the fusible link may be sized to protect the transformer from an external short circuit, as well as from internal faults. For example, instead of fusing to ten times the rated current of the transformer, which is a typical rating for protecting the electrical system against internal faults in a transformer, the fusible link may be selected to fuse in the range of 3 to 6 times the rated current. In these applications, the fusible or protective link should be mounted within the transformer casing such that it is accessible and replaceable after interrupting the circuit due to an external short circuit. Further, the transformer should not be contaminated with water vapor after the fuse has cleared the circuit due to an external short circuit. FIG. 3 is a fragmentary elevational view, partially in section, of protected transformer apparatus constructed according to an embodiment of the invention which meets these requirements, as well as providing an interrupting capacity which exceeds 10,000 amperes.

Specifically, FIG. 3 illustrates protective transformer apparatus 80 which includes a casing 82, filled to a predetermined level 84 with a liquid dielectric, such as oil, having a magnetic core-winding assembly 86 disposed in the casing, below the oil level 84. The magnetic core-winding assembly 86 is shown schematically, and it includes a high voltage or primary winding 88 connected to a high voltage bushing assembly 90 via a protective link 92, a secondary winding 94 connected to terminals or low voltage bushings 96, 98 and 100, and a magnetic core 102.

The protective link or fuse assembly 92 may be similar in internal construction to the fuse assembly 30 shown in FIG. 2, but is modified externally to allow it to be removably inserted into the casing 82 via a "plug-in" type fuse holder 102 which includes an insulating receptacle 104, and a removable portion 106, to which the fuse assembly 92 is attached. The receptacle 104 includes an elongated tubular body member 105 having a central or axial opening 108 which extends between its ends. Tubular body member 105 is formed of an electrical insulating material, such as a glass polyester, or a filament wound glass fiber impregnated with an epoxy resin system. An opening is provided in casing 82 with an annular boss 107 being welded at 109 to the inside of casing 82, about

the opening. The boss **107** has a threaded inside diameter, for receiving the upper end of the receptacle **104**. The removable portion **106** has threads which cooperate with threads on the inside diameter of the receptacle **104**, to secure the removable portion **106**. A flange **111** may be disposed to compress a gasket member **110**, to seal the assembly.

In addition to the axial opening **108**, tubular body member **105** includes first and second transverse openings **112** and **114** through its sidewall portion, spaced a predetermined axial distance, which provides access openings for first and second electrical contact assemblies **116** and **118**, respectively. First and second electrical contact assemblies **116** and **118** have spring loaded contact members **120** and **122**, respectively, connected to first and second electrical conductors **124** and **126**, respectively. Contact assemblies **116** and **118** are suitably gasketed adjacent the transverse openings in body member **105**, and sealed at the entry of the electrical conductors **124** and **126** to prevent the entry of oil into the axial opening **108**.

The removable portion **106** of the protective fuse holder **102** includes the fusible link **92**, which has first and second spaced electrodes or contacts **128** and **130**, respectively. When the removable portion **106** is in assembled relation with receptacle **104**, the first and second electrodes **128** and **130** make electrical contact with the first and second electrical contacts **120** and **122**, respectively, of the receptacle **104**. The fuse assembly **92** is similar to the fuse assembly **30** shown in FIG. **2**, having its central opening sealed at its upper end, but unlike the fuse assembly **30**, its lower end is open, being sealed when it is in its operating position, as will be hereinafter described.

The first electrode **128** may include an outwardly extending tang having an opening therein, for fastening the fuse assembly **92** to a rod member **132** with a bolt, or other suitable fastening means. Rod member **132** is formed of an electrical insulating material, such as fiber. Insulating rod member **132** is secured to a metallic handle portion **134**, formed of a suitable material, such as brass, which includes an opening for receiving a hook-stick and means for threadably engaging the receptacle **104** and forming a seal therewith. The protective fuse holder **102** may be mounted on the cover of casing **82**, or a suitably formed sidewall portion.

The axial opening **108** of receptacle **104** is sealed with condensing means **140**, which may be threadably secured to the end of the body member **105** and suitably gasketed, or otherwise sealed against the entry of the liquid dielectric. Condensing means **140** includes screens **142**, such as copper screen, which readily condenses the steam ejected from the fuse assembly **92**. The lower end of fuse assembly **92** is sized to enter the throat of the condensing means and provide a seal therewith, such that the gas discharge from the fuse assembly **92** will be confined to the condenser **140**.

It should be noted that the receptacle **104** is completely sealed against the entry of liquid dielectric, and that the products evolved from the fuse assembly **92** will be completely contained in the condensing means **140**. Thus, when the fuse assembly **92** clears the circuit due to an external short circuit, the fuse assembly **92** may be removed and replaced without contaminating the transformer. Since the fuse operation occurs without increasing the pressure within the casing **82**, and without any by-products which increase the chances of flashover from live parts to ground within the casing, the interrupting rating of the protective apparatus is even higher than in the first embodiment of the invention, up to 15,000 amperes interrupting capacity.

After the fuse assembly has interrupted a fault and cleared the circuit, when the fuse holder is turned to disengage itself with the threads of the receptacle, any pressure which is built up in the condensing means **140** will be relieved into the axial chamber **108**, which may be vented through suitable means in the handle portion of the fuse holder, before the holder and receptacle are completely disengaged.

The condensing means **140** is large enough to condense the steam from several fuse operations, and need not be replaced after each operation. However, it would also be practical to provide a condenser which has the same or smaller radial dimensions than the fuse assembly itself, allowing the condenser to be secured to the fuse assembly, with both the fuse assembly and condenser being removed after the operation of the fuse in clearing a fault. In this instance, the fuse and condenser would form a sealed unit, and the receptacle would not have to be sealed.

In this embodiment of the invention, since all by-products which are evolved from the fuse assembly upon clearing a circuit are contained within the condensing means, it is not necessary to provide additional insulating means on the exposed live parts within the transformer, as there will be no possibility of flashover from the live parts to ground through the by-products of the arc extinction.

FIG. **4** illustrates protected inductive apparatus **150** constructed according to still another embodiment of the invention. This embodiment of the invention, like the embodiment shown in FIG. **3**, will interrupt an arc and clear the circuit due to a short circuit outside of the transformer, without contaminating the transformer, and will interrupt the arc and clear the circuit due to internal faults within the transformer, with an interrupting rating of 10,000 amperes.

More specifically, FIG. **4** illustrates protected transformer apparatus **150**, which includes a casing **152** filled to a predetermined level **154** with a liquid dielectric means, such as oil, and having a magnetic core-winding assembly **156** immersed therein. Magnetic core-winding assembly **156** includes a primary winding **158** connected to a high voltage bushing assembly **162** via a fuse assembly **160**, and its other end is connected to a similar high voltage bushing via similar fuse assembly, or to ground, depending upon the application. Magnetic core-winding assembly **156** also includes a low voltage or secondary winding **164** connected to low voltage bushing **166** and **168**, with the primary and secondary windings being disposed in inductive relation with a magnetic core **170**.

The fuse assembly **160** is similar to the fuse assembly **30** shown in FIG. **2**, except in this embodiment both ends of the fuse assembly are shown with frangible seals, to reduce the forces generated on the mounting means **172** of the fuse assembly, and further, an additional or subliner of arc quenching material is disposed about the fusible element, between the fusible element and the liner of water vapor evolving arc quenching material. The subliner of arc quenching material is formed of a material which does not emit water vapor upon clearing the circuit.

More specifically, fuse assembly **160** includes a tubular housing or fuse tube **174** having upper and lower ends **176** and **178**, respectively, formed of an oil resistant insulating material, a pair of electrically conductive electrodes **180** and **182** which are disposed at the ends **176** and **178**, respectively, of the fuse tube **174**, a solid liner **184** of water vapor evolving arc quenching material, which extends for substantially the complete length of the tube **174**, and having an axial opening which defines an arcing passageway **186** between the ends of the fuse tube, a fusible element **189** which extends substantially the complete length of the arcing passageway **186**, and which conductively interconnects the electrodes **180** and **182**, and a subliner **190** of arc quenching material of the type which does not liberate water vapor when subjected to the heat of an arc. The subliner **190** is disposed about the fusible element **189**, between the solid liner **184** and the fusible element **189**.

The fuse assembly **160** must be sealed to prevent entry of the liquid dielectric, in which it is immersed. As illustrated in FIG. **4**, in this embodiment of the invention the fuse assembly is sealed at both ends with frangible seals, which will break when the fuse assembly is called upon to interrupt and clear a circuit. The seals may be formed of any suitable insulating means, such as one of the laminated plastics. Providing a fuse assembly which will rupture at both ends when the fuse is called upon to interrupt a fault simplifies the mounting of the

fuse assembly, as it substantially reduces the forces exerted on the mounting means when the fuse assembly clears the circuit. Since, in this embodiment of the invention, the fuse assembly must be mounted such that it may be replaced, reducing the forces which will be exerted upon the mounting means has a definite advantage. Therefore, each end of the fuse tube is sealed with a frangible disc, such as discs **191** and **192** disposed at ends **176** and **178**, respectively, of the fuse tube **174**. The discs may be held in place by the electrodes **180** and **182**, which telescope snugly over the ends of the fuse tube, and which have openings axially aligned with the arc passageway, to allow the frangible disc to be ruptured as the result of gas being generated within the arcing passageway. Since the discs must have openings for the fusible element, or for connections thereto, the openings may be sealed with an oil resistant compound at **194** and **196**.

As shown in FIG. **4**, the fusible element **189** may extend completely through the arcing passageway **186**, being resistance welded to electrode **180** at **195**, or otherwise metallurgically secured thereto, with the electrode being connected to the bushing assembly **162** via conductor **197**. The other end of fusible element **189** may be crimped to a conductor **198**, via a crimping terminal **200**, with conductor **198** being connected to primary winding **158**. Or, both ends of fusible element **189** may be attached to electrical conductors by crimping type terminals.

When crimp type terminals are utilized, the electrical conductors connected thereto may be brazed to the electrodes **180** and **182**, in order to remove the mechanical stresses from the fusible element.

The subliner **190**, which may be generally tubular in cross section, extends for substantially the complete length of the fusible element **189**, and is in close proximity thereto, between the inside wall of the solid liner **184** and the fusible element **189**. The relative spacing is selected to decompose the subliner **189** and extinguish the arc on current magnitudes which indicate an external short circuit, without decomposing the solid liner **184**. Higher current magnitudes, which indicate a fault within the transformer itself, will decompose the subliner **190** without extinguishing the arc, with the heat of the arc then decomposing the solid liner **184**, which extinguishes the arc. The subliner **190** must be formed of arc-extinguishing material which will not liberate water, or otherwise contaminate or deleteriously affect the dielectric strength of the insulating liquid within the casing. There are many suitable materials, such as the plastics made of a polyvinyl chloride resin, fiber, aluminatrihydrate filled resins, such as the epoxy resins, or the polyoxymethylenes, as disclosed in U.S. Pat. Nos. 3,027,352 and 3,059,081. These materials generate arc-extinguishing gases upon the occurrence of an arc, which will not contaminate the transformer. The subliner is disposed relative to the fusible element **189**, such that upon current magnitudes of 3 to 6 times the rated current of the inductive apparatus, the subliner will extinguish the arc and clear the circuit without decomposing liner **184**. Upon higher current magnitudes, which indicate an internal fault within the transformer, the subliner will decompose without extinguishing the arc, and liner **184** will decompose and evolve water vapor which will extinguish the arc. In the former instance, the fuse assembly may be replaced, as the dielectric strength of the transformer will not be deleteriously affected. In the latter instance, the usefulness of the transformer will be destroyed by the internal fault, so the contamination of the transformer with water vapor is immaterial.

The fuse assembly **160** may be mounted on suitable mounting means **172**, which is bolted to the end frame superstructure **200** of the transformer. Since both ends of the fuse assembly **160** will rupture upon fusing of the fusible element **189**, there will be very little force on the mounting bracket, and the fuse assembly **160** may be inserted into a suitable clip-type holder **202**, or other suitable means such as hose clamp type members. Since both ends of the fuse assembly **160** will emit water vapor and flame from the arc, there is a possibility that the flame and stream from the end of the fuse assembly closest to the oil level will be ejected therethrough and into the air space above it, before the vapors are condensed and the flame extinguished. Therefore, deflector means is necessary which will divert the steam and flame from the end of the fuse assembly closest to the oil level, away from the surface **154** of the oil. As shown in FIG. **4**, the mounting means **172** may include an integral deflection member **206**, disposed between the upper end of the fuse assembly **160** and the oil level **154**. The mounting means **172** should be formed of a good nontracking insulator, such as a nontracking glass polyester. When fuse assembly **160** clears the circuit due to a fault external to the transformer, the fuse assembly **160** may be replaced through the hand hold cover of the transformer, such as shown in FIG. **1**.

As illustrated in FIG. **5**, which is a cross-sectional view of fuse assembly **160**, taken along the line V–V the arcing passageway **186** is preferably noncircular, as a noncircular cross section promotes more turbulence and more rapid extinction of the arc. The subliner **190** may be circular, while the liner **184** may define an arcing passageway which has a rectangular cross section, as shown, or any other desirable configuration.

In summary, there has been disclosed new and improved protected electrical inductive apparatus, such as distribution transformers, which will interrupt currents due to internal faults as high as 10,000 amperes, and even higher in certain embodiments. This is accomplished with a single, block mounted protective device which is competitive in cost with prior art block mounted protective links, and less costly than bushing mounted protective links, which require special bushings. Prior art protected transformer apparatus has protective links rated at 1,000 amperes and 3,500 amperes for block mounting and bushing mounting, respectively, and require additional current limiting fuses for those applications which require higher interrupting capacities. The protective apparatus constructed according to the teachings of the invention provide interrupting capacities of 10,000 amperes, and higher, without resorting to bushing mounting or to auxiliary current limiting fuses.

Further, certain embodiments of the invention teach the construction of protected apparatus which includes a single protective link having interrupting capabilities of 10,000 amperes, or higher, and which will protect the apparatus against external short circuits without contaminating the liquid dielectric of the transformer. In one embodiment of the invention, this is accomplished by utilizing a fuse assembly having a main liner of water vapor evolving material, such as boric acid, and a subliner of nonwater vapor evolving material, disposed in spaced relation between the main liner and the fusible element. Upon an external short circuit, the subliner will extinguish the arc without contaminating the transformer. Upon an internal fault in the transformer, the water vapor evolving material will provide the additional extinction capability required to extinguish the arc. In another embodiment of the invention, condensing means is utilized to condense the water vapor and seal the water vapor from entering the liquid dielectric of the transformer.

Since numerous changes may be made in the above described apparatus, and different embodiments of the invention may be made without departing from the spirit thereof, it is intended that all matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. Electrical inductive apparatus, comprising:

a casing;

liquid dielectric means disposed in said casing to a predetermined level;

a magnetic core-winding assembly disposed in said casing;

at least one insulating bushing disposed to introduce an electrical conductor into said casing, through an opening therein;

at least one fuse assembly, having an elongated fuse tube of insulating material, a pair of terminal elements at the ends of said fuse tube, a solid inorganic liner of water vapor evolving arc extinction material disposed within said fuse tube which defines an arcing passageway between the ends thereof, a fusible element disposed in the arcing passageway, conductively interconnecting said pair of terminal elements, and means sealing the ends of said fuse tube, with the means sealing at least one of the ends including a frangible member which maintains the seal until an arc is formed in the arcing passageway;

said fuse assembly being disposed completely within said casing, below the predetermined level of said dielectric means; and

means conductively interconnecting said fuse assembly between the electrical conductor of said insulating bushing and a winding of said magnetic core-winding assembly.

2. The electrical inductive apparatus of claim 1 wherein the solid liner of arc extinction material includes boric acid.

3. The electrical inductive apparatus of claim 1, wherein both ends of the fuse tube include a frangible member, which maintain the sealed condition of the fuse tube until an arc is formed in the arcing passageway.

4. Electrical inductive apparatus, comprising:

a casing;

liquid dielectric means disposed in said casing to a predetermined level;

a magnetic core-winding assembly disposed in said casing;

at least one insulating bushing disposed to introduce an electrical conductor into said casing, through an opening therein;

at least one fuse assembly, having an elongated fuse tube of insulating material, a pair of terminal elements at the ends of said fuse tube, a solid liner of water vapor evolving arc extinction material disposed within said fuse tube which defines an arcing passageway between the ends thereof, a fusible element disposed in the arcing passageway, conductively interconnecting said pair of terminal elements, and means sealing the ends of said fuse tube;

said fuse assembly being disposed completely within said casing, below the predetermined level of said dielectric means;

means conductively interconnecting said fuse assembly between the electrical conductor of said insulating bushing and a winding of said magnetic core-winding assembly,

both ends of said fuse tube including a frangible member, which maintain the sealed condition of the fuse tube until an arc is formed in the arcing passageway; and

arc deflector means disposed within the liquid dielectric, oriented to maintain the products ejected from the fuse assembly upon the occurrence of an arc, below the predetermined level of the liquid dielectric means.

5. The electrical inductive apparatus of claim 1 wherein the arcing passageway defined by the solid liner of arc extinguishing material has a noncircular cross section.

6. The electrical inductive apparatus of claim 1 wherein the arcing passageway defined by the solid liner of arc extinguishing material has a rectangular cross section.

7. Electrical inductive apparatus, comprising:

a casing;

liquid dielectric means disposed in said casing to a predetermined level;

a magnetic core-winding assembly disposed in said casing;

at least one insulating bushing disposed to introduce an electrical conductor into said casing, through an opening therein;

at least one fuse assembly, having an elongated fuse tube of insulating material, a pair of terminal elements at the ends of said fuse tube, a solid liner of water vapor evolving arc extinction material disposed within said fuse tube which defines an arcing passageway between the ends thereof, a fusible element disposed in the arcing passageway, conductively interconnecting said pair of terminal elements, and means sealing the ends of said fuse tube, with the means sealing one of the ends of the fuse tube including condenser means, which contains and condenses the water vapor produced by the solid liner of arc extinguishing material upon the occurrence of an arc in the arcing passageway;

said fuse assembly being disposed completely within said casing, below the predetermined level of said dielectric means; and

means conductively interconnecting said fuse assembly between the electrical conductor of said insulating bushing and a winding of said magnetic core-winding assembly.

8. The electrical inductive apparatus of claim 1 wherein the means conductively interconnecting the fuse assembly between the electrical conductor of the insulating bushing and a winding of the magnetic core-winding assembly, includes a tubular stationary holding member having a pair of spaced electrical contacts connected to the electrical conductor of the insulating bushing and a winding of the magnetic core-winding assembly, respectively, and a cooperative element adapted to removably insert the fuse assembly into the tubular stationary holding member, through an opening in the casing, such that its pair of terminal elements make electrical contact with the pair of spaced electrical contacts of the tubular stationary holding element.

9. Electrical inductive apparatus, comprising:

a casing;

liquid dielectric means disposed in said casing to a predetermined level;

a magnetic core-winding assembly disposed in said casing;

at least one insulating bushing disposed to introduce an electrical conductor into said casing, through an opening therein;

at least one fuse assembly, having an elongated fuse tube of insulating material, a pair of terminal elements at the ends of said fuse tube, a solid liner of water vapor evolving arc extinction material disposed within said fuse tube which defines an arcing passageway between the ends thereof, a fusible element disposed in the arcing passageway, conductively interconnecting said pair of terminal elements, and means sealing the ends of said fuse tube;

said fuse assembly being disposed completely within said casing, below the predetermined level of said dielectric means,

means conductively interconnecting said fuse assembly between the electrical conductor of said insulating bushing and a winding of said magnetic core-winding assembly, including a tubular stationary holding member having a pair of spaced electrical contacts connected to the electrical conductor of the insulating bushing and a winding of the magnetic core-winding assembly, respectively, and a cooperative element adapted to removably insert the fuse assembly into the tubular stationary holding member, through an opening in the casing, such that its pair of terminal elements make electrical contact with the pair of spaced electrical contacts of the tubular stationary holding element, said tubular stationary holding element including condenser means, with the means sealing one of the ends of the fuse assembly including said condenser means.

10. The electrical inductive apparatus of claim 1 including a substantially tubular element of nonwater vapor evolving arc quenching material disposed about the fusible element, between the fusible element and the walls of the arc quenching passageway defined by the solid liner of water vapor evolving arc quenching material, said substantially tubular element quenching an arc formed by currents up to a predetermined magnitude, without activating the water vapor evolving arc quenching material.

11. The electrical inductive apparatus of claim 10 wherein the tubular element of nonwater vapor evolving arc quenching material is formed of polyvinyl chloride.

12. The electrical inductive apparatus of claim 10 wherein the arcing passageway has a substantially rectangular cross section, sized to provide a space between its walls and the tubular element of nonwater vapor evolving arc quenching material.

13. The electrical inductive apparatus of claim 1 wherein the fusible element extends substantially the length of the arcing passageway.