United States Patent

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[54] **ELECTRICAL APPARATUS IN AN UNDERGROUND CASE**
9 Claims, 5 Drawing Figs.

[52] U.S. Cl. .... 174/17 R, 204/196, 336/94
[51] Int. Cl. H01f 27/02
[50] Field of Search .... 174/17 R, 17 LF, 37; 204/196, 197; 336/94

[56] **References Cited**
UNITED STATES PATENTS

3,390,225	6/1968	Couch	174/37
3,405,283	10/1968	Leonard	174/37 X

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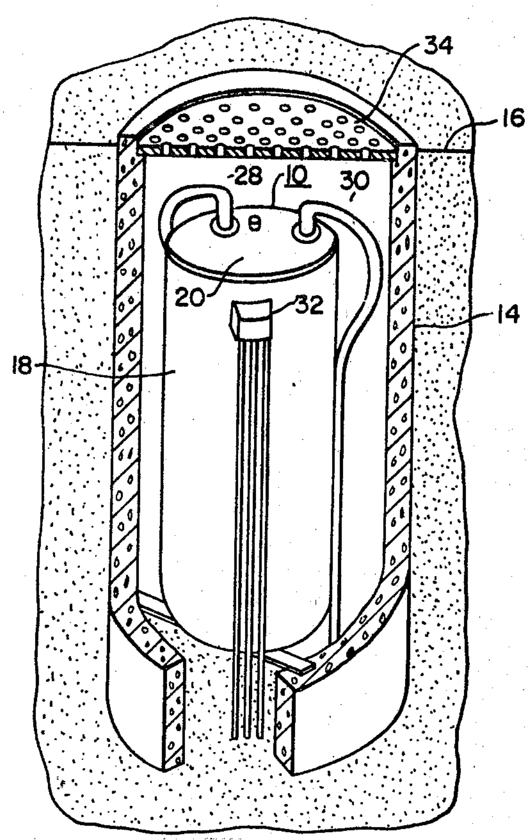
ABSTRACT: Fluid filled electrical apparatus, such as transformers, suitable for underground or vault mounting. The electrical apparatus includes a laminated tank or casing, having at least three metallic layers, with the layer materials and thicknesses being selected to provide a good structural material having long service life in corrosion conducive environments, without undue economic penalty.



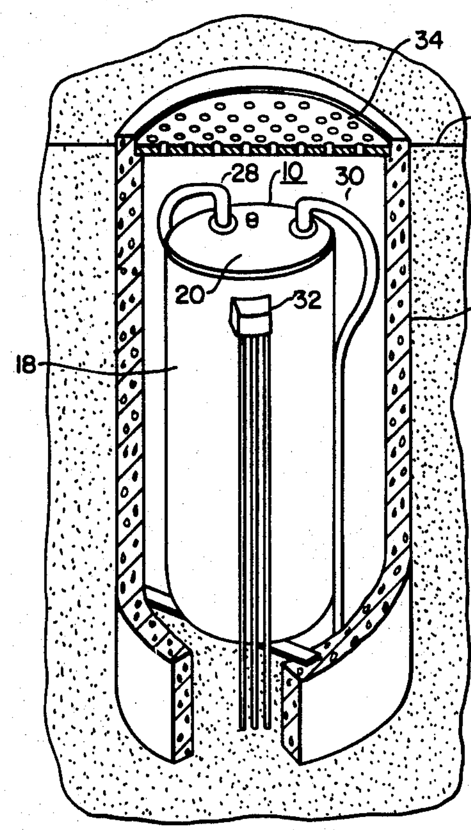


FIG. 1.

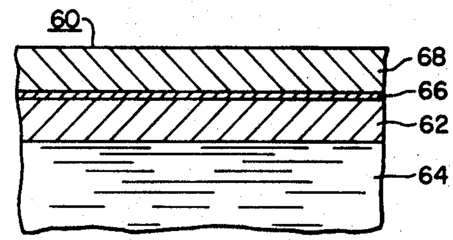


FIG. 3.

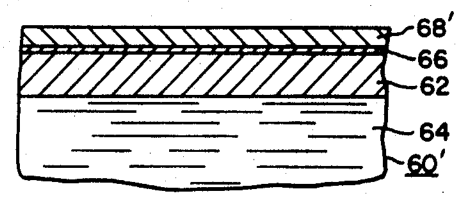


FIG. 4.

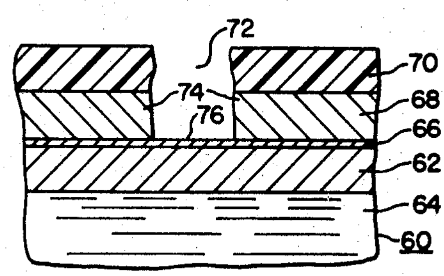


FIG. 5.

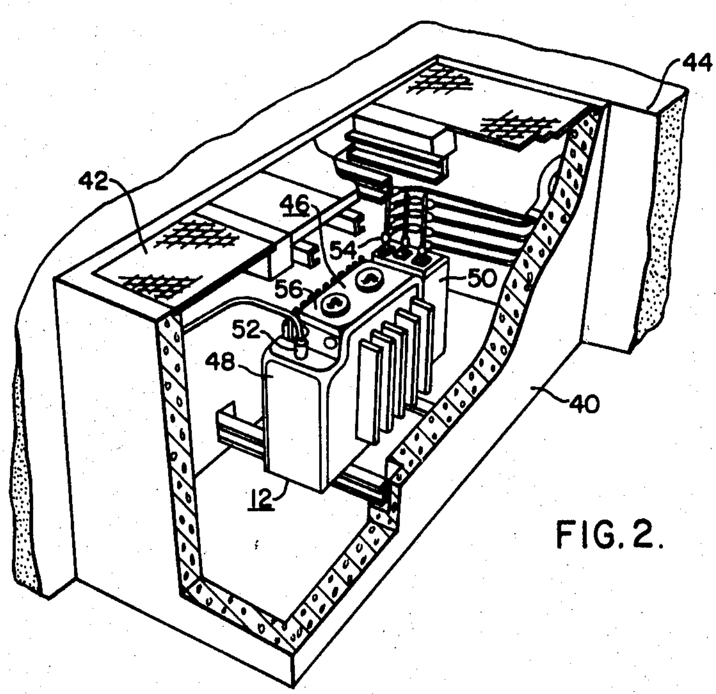


FIG. 2.

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ELECTRICAL APPARATUS IN AN UNDERGROUND CASE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to fluid filled electrical apparatus having an electrically conductive element disposed in a tank or casing, which element is adapted for connection to an electrical potential.

2. Description of the Prior Art:

Corrosion problems associated with the tanks of electrical apparatus disposed wholly or partially underground, such as in specially constructed concrete vaults, seriously limit the useful service life of such apparatus, compared with the life of similar apparatus mounted above grade. Power transformers of the network type are usually mounted in underground vaults, with the conventional approach to corrosion protection being to coat the external tank surfaces with specially formulated coal tar epoxy resin systems. Protective coatings, however, are only as good as the uniformity of the coating, with any pin holes or scratches in the coating, such as those due to handling and installing the apparatus, causing more rapid corrosion at the exposed areas than if the tank had no protective coating.

The use of a corrosion resistant material for the tank, such as stainless steel or nodular iron, while extending the service life of the apparatus compared with mild steel tanks, has the disadvantage of a substantially higher cost. Even with corrosion resisting materials, separate cathodic protection, such as a sacrificial anode constructed of zinc and connected to the tank, is required to protect the tank material from corrosion, when the tanks are directly buried in the earth, or disposed in vaults which may be flooded.

The recent trend to underground residential distribution of electrical power, in which distribution transformers are disposed in underground vaults, or directly buried in the earth, has provided new impetus for developing corrosion resistant tanks. The thinner materials of which distribution transformer tanks are formed, compared with the tanks of network type power transformers, have experienced failure due to corrosion in as little as 3 months time when disposed in highly corrosive environments. Thus, the need exists for reliable, low cost tanks or casings for both the vault mounted network transformer, and the underground residential type of distribution transformer, whether vault mounted or directly buried, as well as for any other type of fluid filled electrical apparatus which is to be mounted in a highly corrosive environment.

SUMMARY OF THE INVENTION

Briefly, the present invention is a new and improved fluid filled electrical apparatus of the type suitable for vault or below grade mounting. The electrical apparatus includes a tank formed of a laminated material, having at least three metallic layers. The layer adjacent the fluid in the tank, i.e., the innermost or first layer of the laminated structure, is selected for its structural properties and cost, without regard to its ability to resist corrosion, and thus this layer may be a mild or plain carbon steel. The next or second layer, which forms the core of the "sandwich," is selected for its overall corrosion resistance, such as a steel alloy containing at least 12 percent chromium, commonly called stainless steel. Since the structural requirements of the tank are met by the innermost or first layer, this core or barrier layer may be relatively thin and is preferably so in order to minimize the cost of the laminated material. The third or outer layer is selected to be anodic to the core or barrier layer, and is thus sacrificial to the barrier layer. Again, since the structural requirements of the tank are met by the first or inner layer, the thickness of the outer layer may be selected strictly from the viewpoint of its sacrificial action. Since carbon steel is anodic to stainless steel, and has a relatively low cost, this third or outer layer, like the first layer, may be a mild or plain carbon steel. This sacrificial outer layer prevents, or at least delays, pitting corrosion of the barrier layer, greatly extending the service life of the tank.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be more readily understood when considered in view of the following detailed description of exemplary embodiments thereof, taken in connection with the accompanying drawings, in which:

FIG. 1 is a perspective view of an electrical distribution transformer of the residential distribution-type, which may be constructed according to the teachings of the invention;

FIG. 2 is a perspective view of an electrical transformer of the network-type, disposed in an underground vault, which may be constructed according to the teachings of the invention;

FIG. 3 is a fragmentary, sectional view of the tank or casing of electrical apparatus constructed according to an embodiment of the invention;

FIG. 4 is a fragmentary, sectional view of a tank or casing of electrical apparatus constructed according to another embodiment of the invention; and

FIG. 5 is a fragmentary, sectional view of the tank shown in FIG. 2, modified to include a protective outer coating of insulating material.

DESCRIPTION OF PREFERRED EMBODIMENTS

The invention relates to new and improved fluid filled electrical apparatus of the type which is mounted in highly corrosive environments, such as below grade level, and in general is applicable to any electrical apparatus of this type having an electrical element disposed in a tank, with the element being adapted for connection to an external electrical potential. Electrical transformers filled with mineral oil, askarel, water, SF_6, or the like, may utilize the teachings of the invention, as well as capacitors and protective apparatus, such as circuit breakers, which require a corrosion resistant tank or casing.

FIGS. 1 and 2 are perspective views of electrical transformers **10** and **12**, respectively, of the type which may be constructed according to the teachings of the invention. Transformer **10** shown in FIG. 1 is a distribution transformer of the type commonly used for underground residential distribution, and it may be disposed in a vault **14** below grade level **16**, as illustrated, it may be disposed in a vault which is partially below grade level, or it may be directly buried in the earth without the benefit of a surrounding vault, as dictated by the requirements of the electrical utility. Transformer **10** includes a casing **18** having a cover **20** which encloses the core-winding assembly (not shown) of the transformer **10**. A suitable insulating and cooling fluid, such as mineral oil, is also disposed in casing **18**, to aid in insulating and cooling the electrical windings of the transformer. Transformer **10** is hermetically sealed, with the electrical connections to the encased high voltage winding being made through the sealed high voltage bushing-connector assemblies **28** and **30**, and to the low voltage winding through the sealed low voltage bushing assembly **32**. The vault **14** has a heavy access cover **34**, which may be perforated to aid in the removal of heat from the transformer **10**.

Transformer **12** shown in FIG. 2 is a power transformer of the network type, installed in a vault **40** which has a plurality of access covers thereon, such as cover **42**. The top of vault **40** is usually at grade level **44**. Transformer **12** includes the main transformer section **46**, a high voltage switch **48**, and a network protector **50**. An external high voltage electrical potential is connected to the high voltage switch **48** through a multiple conductor single bushing **52**, or through separate bushings, and the lower voltage distribution potential is obtained from the secondary bushings, such as secondary bushing **54**. The main transformer portion **46** includes a tank **56** which encloses the core-winding assembly of the transformer, and also an insulating and cooling fluid, such as mineral oil or askarel.

Transformers **10** and **12** are both subjected to highly corrosive environments, and must withstand flooding of their respective vaults with corrosive, polluted water for extended periods of time. Such environments have caused the failure of electrical transformers due to tank corrosion in periods much shorter than their normally expected service life.

Excellent organic coatings for underground transformers have been developed, but since coatings are not always pinhole free, and since coatings may be scratched during the handling and installation of the electrical apparatus, coatings alone do not provide the desired answer. Transformers and other fluid filled electrical apparatus only require one hole through the casing or tank to cause costly damage and even failure of the apparatus. The fact that 99 percent of the casing may be corrosion free is of no benefit if one small portion of the casing is severely attached by corrosion. In fact, an excellent protective coating with one scratch may cause failure of the tank at the exposed area faster than if the tank had no protective coating.

Constructing the tanks of corrosion resistant materials, such as stainless steel, is not desirable because of the economic penalty, and also because stainless steel, while not generally susceptible to corrosion may, in certain environments, be subject to a localized pitting corrosion which is very rapid, perforating the casing at the point of attack while the majority of the surface is corrosion free. This localized attack may also promote stress-corrosion cracking of stainless steel which may cause failure of the tank even before perforation due to pitting occurs.

Broadly, the present invention is new and improved fluid filled electrical apparatus having a tank formed of a laminated structure. The laminated tank structure includes at least first, second and third metallic layers, which will also be referred to as the inner, core and outer layers, respectively, from the viewpoint of the tank or casing construction. In other words, the external surface of the inner layer is adjacent to the fluid inside the casing, the external surface of the outer layer is adjacent to the environment in which the electrical apparatus is placed, and the core layer is sandwiched between the inner and outer layers.

Laminated metals for reducing corrosion are known in the prior art, but they have either been unsuccessful in arresting certain types of corrosion, too costly, or both. For example, cladding the external surface of a core material is known in which a relatively thick mild steel core has thin layers of stainless steel disposed on its two major opposed surfaces. This approach, however, at least for electrical apparatus disposed underground, suffers from the functional disadvantage of tanks formed of stainless steel, as the thin layers of stainless steel are subject to pitting and stress corrosion, exposing the mild steel core. Another example of cladding known in the art utilizes a relatively thick core of stainless steel, clad with thin layers of steel containing about 12 percent chromium. While this structure may be suitable functionally for the tanks of underground electrical apparatus, it is not economically attractive.

FIG. 3 is a fragmentary, cross-sectional view of fluid filled electrical apparatus having a tank or casing **60** constructed according to the teachings of the invention. Casing **60** may be the tank **18** or cover **20** of transformer **10** shown in FIG. 1, the tank **56** of transformer **12** shown in FIG. 2, or the casing of any fluid filled electrical apparatus having an electrically conductive member therein adapted for connection to an electrical potential. Casing **60** has a first or inner layer **62** adjacent to the fluid **64**, a second or core layer **66** and a third or outer layer **68**. The present invention economically solves the corrosion problem of underground electrical apparatus by selecting the material and thickness dimension of the first layer **62** only for its mechanical properties and cost, without regard to its ability to resist corrosion. The thickness of layer **62** is selected to provide at least the structural requirements of the casing while it is in service. For distribution transformers of the residential type, this layer may be about 0.030 to 0.050 inch thick, while power transformers of the network type may have a first or inner layer of about 0.100 to 0.250 inch thick. Since the mild or carbon steel commonly used for tanks of electrical apparatus mounted above grade, such as S.A.E. 1010,is economically attractive, and possesses the requisite mechanical properties for forming the tanks, the first layer is preferably a mild or plain carbon steel.

The second or core layer **66** of casing **60** is selected for its ability to resist corrosion and protect the structural layer **62**. One of the stainless steels i.e., noncorroding alloys of iron and chromium, including at least 12 percent chromium in order to produce the required passivity, may be used. For example, suitable stainless steels are the AISI types 304 and 308, or the 18–8 stainless steels, such as AISI type 302. Since stainless steel is relatively costly, compared with carbon steel, the thickness of the second layer **66** should only be that required to protect the structural layer. Thicknesses in the range of about 0.001 to 0.020 inch are suitable, with the thickness selected depending upon the thickness of the structural layer **62**. For example when the structural layer is about 0.030 to 0.050 inch thick, the core layer **66** may be about 0.006 inch thick.

Stainless steel, while not subject to general attack by the usual environments surrounding underground electrical apparatus, is subject to localized attack, called pitting corrosion, which may be very severe, causing rapid penetration, especially when subjected to environments containing chlorides. Chlorides promote the formation of active-passive electrolytic cells between the large passive or cathodic area and the small anodic area being attacked. Further, severe localized attack may cause failure of the core layer before perforation, as it promotes cracking of the stainless steel due to stress corrosion.

The function of the third or outer layer **68** is to protect the core layer **66** from pitting and stress corrosion. It accomplishes these functions by forming a sacrificial anode for the core layer, and as such the material of which the outer layer is formed must be higher in the galvanic series than the material of which the core layer is formed. Since stainless steel is the preferable material for the core layer **66**, the outer layer may be formed of such materials as carbon steel, magnesium, aluminum, or zinc. In order to prevent the outer layer from being sacrificed too rapidly, however, it will usually be preferable to select a material which is higher than the core material in the galvanic series, but not too much higher. Thus, carbon steel, which is above, but close to stainless steel in the galvanic series, is an excellent material for the third layer **68**, and it additionally has the benefit of being relatively low in cost.

The thickness dimension of the third layer **68** depends upon the corrosiveness of the intended environment. Since the outer layer will be sacrificed, it eventually will provide reduced structural strength for the casing and its thickness need not be influenced greatly by strength requirements. As hereinbefore stated, the inner layer **62** is selected to provide adequate structural requirements of the casing while the transformer is in service. The third layer **68** will provide additional structural strength for the casing during manufacturing and shipment of the transformer, when it requires the greatest strength. Thus, the inner layer **62** must be selected to at least provide the in-service strength requirements of the casing, and the inner and outer layers together must provide adequate structural strength for manufacture and shipment.

When the outer layer **68** is attacked to the point where the core or barrier layer is exposed, the outer layer **68** will continue to be attacked in preference to the core layer **66** due to their relative locations in the galvanic series, thus stopping the penetration of the corrosion through the tank wall. The outer layer will continue to be sacrificial in preference to the core layer, as long as the area of the third layer material exposed by the corrosion, i.e., the sides of the craters produced by the corrosion, plus a predetermined surface area of the third layer immediately adjacent the crater, such as about a 2 inch radius about the center of the corrosive attack for carbon steel, is greater than the area of the core material exposed by the corrosion. This is why the thickness of the outer layer is selected with the corrosiveness of the intended environment in mind. If the third layer is selected to be a metal higher in the galvanic series than carbon steel, such as zinc, more core area may be exposed before the core layer is attacked.

In the example shown in FIG. 3, the first and third layers **62** and **68** are shown to have the same thickness dimension, but FIG. 4 illustrates a fragmentary sectional view of a tank or casing in which the first and third layers have different dimensions. Like reference numerals in FIGS. 3 and 4 indicate like components, and like reference numerals with a prime mark indicates similar but modified components.

More Specifically, FIG. 4 illustrates a tank **60'** having first and second layers **62** and **66**, such as illustrated in FIG. 3, but having a third layer **68'** which is substantially thinner than the third layer **68** shown in FIG. 3, as functionally it will usually not be necessary to make the third layer as thick as the structural layer. inch

FIG. 5 is a fragmentary, cross-sectional view of the tank **60** shown in FIG. 3, including a protective coating **70** disposed on the outer surface of the third layer **68**. Protective coating **70** may be selected from a large number of organic coatings specially developed to protect metals against corrosion, such as coatings formed of the epoxies, acrylics, asphaltics, alkyds, or polyesters. The thickness of the outer protective coating depends upon the particular coating selected, with about 0.001 to 0.020 inch being the usual range. With the laminated tank construction disclosed herein, however, it would be suitable to use one of the lower cost protective coatings, such as an alkyd, which allows a slow diffusion of moisture. A coating which allows a slow diffusion of moisture is actually better than one which is more moisture resistant, as pinholes and scratches in the coating will not cause the underlying metal to be as severely and rapidly attacked as would occur at openings in a more perfect coating.

FIG. 5 also illustrates a corrosion crater **72** in the tank **60**, and shows how the crater is stopped by the barrier layer **66**. The corrosion penetrates the outer layer **68** through an opening in the coating **70**, and proceeds inwardly until the barrier layer **66** is exposed. At this point, the outer layer **68** becomes sacrificial to the barrier layer **66**, and the corrosion attacks the outer layer, usually along the surface of the barrier layer, enlarging the size of the crater without pitting or otherwise attacking the barrier layer. As long as the area of the wall **74**, plus a predetermined surface area about the crater, does not exceed the area **76** of the barrier layer which is exposed, the outer layer will corrode in preference to the barrier layer.

The laminated structure of which the casings or tanks are formed may be produced by any suitable method, such as by heating metal slabs of the layer materials to welding temperature, and then rolling them together to bond the slabs together.

The laminated material, when being fabricated into the tank or casing structure, may be welded by conventional methods, with stainless steel welding rods generally being preferable if the core layer is stainless steel, although mild steel rods may also be successfully used. In general, it is preferable that the third or sacrificial layer be at least as sacrificial to the welding material used as it is to the core layer. Welded joints in which the core layers are tied together via the weld material are most desirable, but overlap welds are suitable if the overlap dimension is relatively large.

In summary, there has been disclosed new and improved electrical apparatus of the fluid filled type suitable for mounting in highly corrosive environments, such as underground, which apparatus would be severely damaged or rendered useless in the event of a perforation in its tank or casing. The electrical apparatus includes a tank or casing constructed of a laminated metallic structure which greatly extends the useful service life of the tank, without undue economic penalty. The tank material includes three layers of metal, with the outer layers functioning properly even if constructed of plain carbon steel, such as commonly used for tanks and casings of similar apparatus mounted in noncorrosive environments, and the core material, which may be selected from one of the stainless steels, while being more costly per pound than carbon steel, is a relatively thin layer, such as form about 0.001 to 0.020 inch. The additional cost of the thin layer of core material, and the cost of producing the laminated structure, is substantially less than a tank constructed completely of stainless steel, and is easier to fabricate. The additional cost of the laminated tank, compared with a tank constructed of mild steel, is more than offset by the increased service life of the apparatus when disposed in corrosive environments.

I claim as my invention:

1. Electrical apparatus comprising:
a casing,
an electrically conductive element disposed in said casing, said electrically conductive element being adapted for connection to an electrical potential;
and fluid means disposed in said casing,
said casing being at least partially constructed from a laminated metallic structure having at least first, second and third layers, said first layer being a structural layer, in contact with said fluid means, said second layer being a barrier layer, disposed between said first and third layers, to protect said first layer from corrosion, and said third layer being anodic to said second layer, forming a sacrificial anode to reduce pitting corrosion of the second layer.

2. The electrical apparatus of claim 1 wherein at least the first layer is a carbon steel and the second layer is a steel alloy containing at least 12 percent chromium.

3. The electrical apparatus of claim 1 wherein at least the third layer is a carbon steel and the second layer is a steel alloy containing at least 12 percent chromium.

4. The electrical apparatus of claim 1 wherein the first and third layers are carbon steels and the second layer is a stainless steel.

5. The electrical apparatus of claim 1 wherein the first layer is substantially thicker than the second layer.

6. The electrical apparatus of claim 1 wherein the second layer has a thickness dimension in the range of about 0.001 to 0.020 inch.

7. The electrical apparatus of claim 1 including an insulating coating disposed on the third layer.

8. The electrical apparatus of claim 1 wherein the first and third layers are carbon steels and the second layer is a stainless steel, and the first layer is substantially thicker than the second layer.

9. The electrical apparatus of claim 1 wherein the first and third layers are carbon steels and the second layer is a stainless steel, and the second and third layers are each thinner than the first layer.