Feb. 15, 1966 P. W. DAVIS, JR 3,235,825

ELECTRICAL COILS AND INSULATION SYSTEMS THEREFOR

Filed Jan. 2, 1963

Fig. 1.

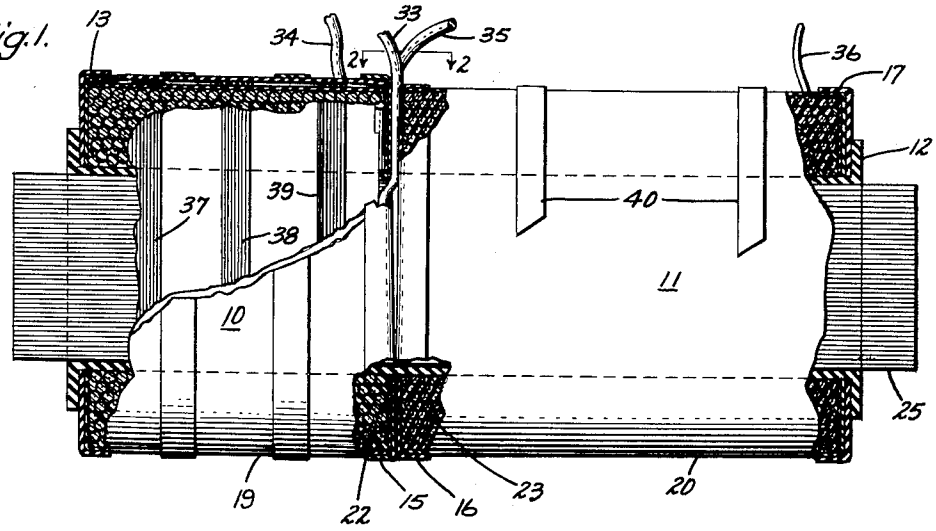


Fig. 3.

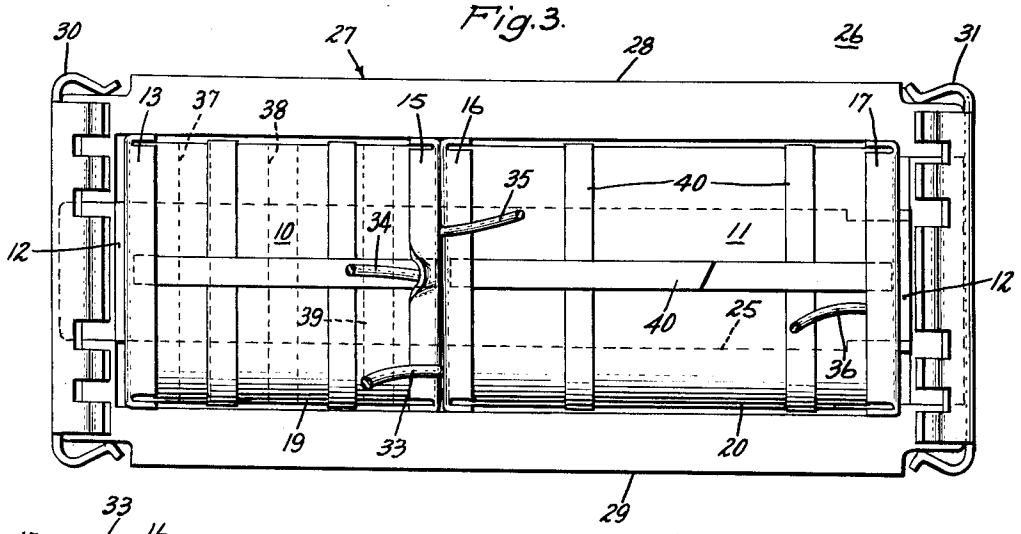
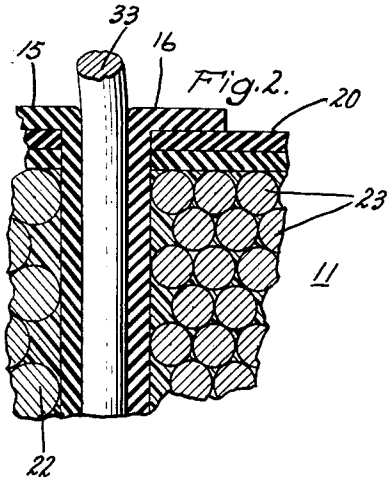


Fig. 2.



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3,235,825

ELECTRICAL COILS AND INSULATION SYSTEMS THEREFOR

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2 Claims. (Cl. 336—205)

This invention relates to electrical coils and insulation systems therefor. More particularly it relates to such electrical coils and electrical systems that are adaptable for use as electrical coils in ballast transformers and other similar devices.

Electrical coils for dry type transformers, such as ballast transformers for operating fluorescent lamps, are usually constructed of superposed layers of turns of insulated conductor wire separated between layers by paper layer insulation. The superposed layers of turns are formed by winding the insulated conductor wire on a suitable spool, as for example, a spool made of a kraft paper. In a commonly used ballast coil arrangement the end turns of the coil layers are insulated from the magnetic core of the transformer by winding the coil with paper layer insulation interleaved betweet conductor wire layers so that the paper layer insulation extends beyond the conductor wire layers. This extension of the paper layer insulation provides a space between the end turns and the adjacent parts of the magnetic core and prevents the end turns from grounding by contacting the magnetic core. The paper spool on which the coil turns are wound also serves to insulate the inner coil turn layer from the magnetic core of the ballest transformers.

One of the restrictions imposed on a ballast is that the cross-sectional area of the ballast case must not exceed certain standardized cross-sectional dimensions. As a result, the high voltage coils of ballasts are elongated in configuration since these dimensional restrictions limit the number of conductor wire layers that can be utilized in a particular coil design. Further, these dimensional restrictions result in an increase in the volts-per-layer stresses of the ballast coil as compared with other comparable dry type of transformer coils having an equivalent number of turns and a shorter length.

The insulating systems which have been used in the past for ballast coils include a nylon, a polyvinyl formal resin or polyamide resin as an insulating coating for the conductor wire, kraft paper for layer and ground insulation, and an asphaltic impregnating material such as a mixture of wax and asphalt. The present invention relates to an electrical coil and insulating system that does not require the use of insulation between layers of the conductor wire and is particularly adaptable for use in connection with the invention disclosed in my application Serial No. 249,099 for Ballast Apparatus and Electrical Coils Therefor filed concurrently with this application and assigned to the assignee of the present invention.

Accordingly, it is a general object of my invention to provide an improved electrical coil an dinsulating system.

It is another object of my invention to provide an improved insulating system for an electrical coil that does not require the use of paper layer insulation between layers of conductor wire.

A more specific object of my invention is to provide an improved insulating system for an electrical coil used in a ballast transformer for operating fluorescent lamps.

In one form of my invention I have provided an electrical coil including a winding formed of superposed turns of conductor wire insulated with a polyvinyl formal resin and including paper ground insulation, preferably of cyanoethylated parer, for protecting exposed turns. Both the winding and ground insulation are impregnated with a resinous reaction mixture cured in situ to form a substantially insoluble resin. The reaction mixture comprises by weight thereof (a) from 50 to 70 percent of a copolymer of 1,3-butadiene and styrene, (b) from 20 to 50 percent of a monomer containing vinyl unsaturation and (c) a peroxide catalyst. The copolymer of 1,3-butadiene and styrene may contain between 50 and 70 percent of the 1,4 addition and between 30 and 50 percent of the 1,2 addition, these latter percentages being by weight of the copolymer. Further, the preferred monomers used in the resinous reaction mixture are vinyl toluene and divinyl benzene, and a preferred polymerization initiator is benzoyl peroxide. If it is desired to formulate a more economical impregnant, mineral oil may be added to the reaction mixture in amounts ranging up to 150 parts per 100 parts of the reaction mixture described above. With the winding and ground insulation impregnated with this reaction mixture cured in situ, it was possible to employ coils in a ballast for operating fluorescent lamps without need for layer insulation.

The subject matter I regarded as my invention is set forth in the appended claims. The invention itself, however, together with further aspects, objects and advantages thereof may be better understood by referring to the following description taken in connection with the accompanying drawings in which:

FIGURE 1 is a view partially sectionalized of a coil arrangement in which the electrical coil insulating system of one form of my invention is embodied;

FIGURE 2 is an enlarged view in section of a corner of the high voltage coil shown in FIGURE 1 illustrating in more detail the relative disposition of the turns of conductor wire and the insulating arrangement of the coil; and

FIGURE 3 is a plan view of a ballast transformer showing the coils shown in FIGURE 1 arranged on the center winding leg of the transformer magnetic core.

Referring now more particularly to FIGURE 1, a pair of electrical coils **10**, **11** embodying the invention are shown on a common spool **12**. Ground insulation for the exposed turns of the coils **10**, **11** is provided by the spool **12**, the flanges **13**, **15**, **16**, **17** and the coil wrappers **19**, **20**. The coils **10**, **11** are impregnated with a resinous reaction mixture which is cured in situ to an insoluble resin, as will hereinafter be more fully described. It will be noted that no paper layer insulation is interposed between the layers of coil turns **22**, **23** of the coils **10**, **11**.

Preferably, the coil turns **22**, **23** are formed of conductor wire insulated with a polyvinyl formal resin. As the term is used herein, a polyvinyl formal resin denotes a resin which is formed by the reaction of an aldehyde with a polyvinyl alcohol or a reactive derivative of the polyvinyl alcohol. In the exemplification of the invention which I reduced to practice, the conductor wire was coated with a phenolic modified polyvinyl formal enamel described in U.S. Patent No. 2,307,588 granted to Jackson et al. on January 5, 1943. Although a magnet wire having an enamel coating of polyvinyl formal resin was used in the practice of my invention, other resins may be used, such as for example, terephthalate polyester resins, acrylic resins, ureaformaldehyde epoxy resins, polyester-polyurethane resins or polyester-polyamide epoxy resins.

The spool **12**, the insulating flanges **13**, **15**, **16**, **17**, and coil wrappers **19**, **20** were preferably constructed of a cyanoethylated kraft paper. It will be appreciated that an untreated kraft or manila paper may be used in the practice of the invention. A cyanoethylated kraft paper was used in the preferred embodiment because it has a higher dielectric constant as compared with untreated kraft paper.

By cyanoethylated paper, as the term is used herein, is meant a paper which is made from either a pulp containing wood as is used in making kraft paper or a pulp comprised of manila fibers such as is used in the pulp for the manufacture of manila paper. The pulp in either case is reacted with an acrylic nitrile to form the desired cyanoethyl ether groups. A method of manufacturing cyanoethylated paper is described in U.S. Patent 2,535,690 granted to Miller et al.

I have found that a cyanoethylated paper impregnated with a reaction mixture cured in situ and containing a copolymer of butadiene and styrene, a monomer having a vinyl unsaturation, such as vinyl toluene and divinyl benzene, and a polymerization initiator or catalyst, provided a ten fold increase in the dielectric strength of the insulating material as compared with an unimpregnated cyanoethylated paper. Comparable benefits were also achieved by impregnating an ordinary kraft or manila paper with the reaction mixture and curing the reaction mixture in situ.

Depending upon the particular application of the electrical coil, it will be appreciated that some of the ground insulating pieces as shown in FIGURE 1 may not be required. However, where an electrical coil is used in a ballast transformer, due to the stringent restrictions of space and the disposition of the electrical coil in a shell-type of magnetic core, adequate ground insulation must be provided to protect the exposed turns of the coils **10, 11**.

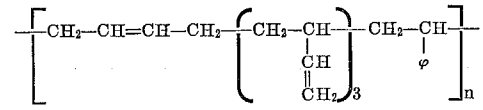
In FIGURE 3, I have shown the coils **10, 11** disposed on the center winding leg **25** of a shell-type of ballast transformer **26**. It will be noted that coils **10, 11** are arranged so that at each side thereof the coils are adjacent to the magnetic core **27**. Coils **10** and **11** are assembled on the magnetic core **27** by inserting the center winding leg **25** inside of the spool **12** and then placing the outer yoke legs **28, 29** at the sides of the coils **10, 11** and the center winding leg **25**. A pair of core clamps **30, 31** are then placed on the magnetic core **27** to hold the magnetic core **27** in assembled relation. As is shown in FIGURE 3, the start and finish leads **33, 34** of coil **10** and the start and finish leads **35, 36** of coil **11** are brought out to the top sides of the coils **10, 11** for connecting the coils **10, 11** in particular circuit arrangement. Similar leads (not shown) are brought out from the cathode heating windings **37, 38, 39** which are wound over the main winding of coil **10** that serves as the primary of the ballast transformer **26**. Pressure sensitive tape **40** may be used to hold the coil wrapper **20** in position over the coil turns and may be used to prevent end turns from being displaced as the coil **11** is handled during the assembly operation.

The reaction mixture used as an impregnating material was comprised essentially of a copolymer of 1,3-butadiene and styrene, a cross-linking monomer and a peroxide initiator. The 1,3-butadiene styrene copolymer was a sodium polymerized material wherein the butadiene normally adds to a growing polymer chain by either a 1,2- or a 1,4-method of attachment. Preferably, the copolymer should contain between 50 and 70 percent by weight of the 1,2 addition, since the residual double bond of the 1,2 addition is active in inter molecular cross-linking reactions. For the purpose of the invention, it has been found that preferably a copolymer with a relatively high proportion of vinyl unsaturation should be used. It is desirable that the copolymer comprise from about 30 to 70 percent of the reaction mixture.

The coplymers of 1,3-butadiene and stryrene are produced by copolymerizing about 75 to 85 parts of the 1,3-butadiene with 15 to 25 parts of styrene. About 1 to 3 parts of metallic sodium is used as a polymerization catalyst. The polymerization may be carried out at a temperature ranging between 20 and 100 degrees centigrade.

A typical butadiene and styrene copolymer which may

be used in the reaction mixtures used in the practice of the invention has the following general structural formula:



The symbol φ used in the above formula represents a benzene ring.

The following example and the other specific examples are presented as specific illustrations of the present invention. In the examples all percentages and parts set forth therein are by weight unless otherwise expressly stated.

EXAMPLE 1

Coils of the type shown in FIGURE 1 were wound on a revolving arbor to the desired number of turns with a magnet wire coated with a polyvinyl formal resin enamel. After the winding operation was completed, the outer layer of each coil was wrapped with cyanoethylated kraft paper wrapper, while it was still on the winding arbor. The coils were then removed and the end turns of the coil were held in place by placing a strip of pressure sensitive adhesive tape over each coil. A pair of coils were then assembled on a spool formed of cyanoethylated paper along with the insulating flanges, which were also made of cyanoethylated paper. The coils were then assembled on the core, and the coil reductors were soldered on terminal pads which are not shown.

The coil and core assembly was then placed in an oven and preheated at a temperature of about 85 degrees centigrade for a period of about 1 hour to partially remove moisture and volatile constituents. After completion of the drying operation the coil and core assembly was placed in a vacuum chamber. The reaction mixture used to impregnate the coil assembly in this example had the following formulation:

	Percent
1,3-butadiene and styrene copolymer (4/1 mol ratio)	57
Vinyl toluene	38
Divinyl benzene (50 percent solution)	3.8
Benzoyl peroxide (50 percent paste)	1.2

After subjecting the coil assembly to a vacuum for 10 minutes, the reaction mixture was admitted in an amount sufficient to cover the coils. The vacuum in the chamber was then cut off and the reaction mixture was maintained under atmospheric pressure for twenty minutes to allow the mixture to penetrate. The coil and core assembly was then removed, and a B-stage cure of the reaction mixture was effected by heating the assembly in an oven at a temperature of 120 degrees centigrade. A final cure was affected by heating the assembly at a temperature of 165 degrees centigrade for one hour. The cured resin was found to be resilient and not hard and brittle as might be expected. A hard and brittle resin is not desirable in a ballast coil since upon shrinking, the resin will cause the laminations of the magnetic material to be stressed and thereby increase the core losses.

In order to illustrate the advantages obtained by the use of the insulating system of the invention, surge breakdown voltage tests were conducted on twenty identical coils, ten of which were impregnated and ten of which were unimpregnated. The ten impregnated coils used the reaction mixture of Example 1 and were cured in situ by the two-stage cure as described above. The surge breakdown voltage tests were carried out on a General Electric Winding Insulation Tester Cat. 8014459G4 machine, and the surge voltage was increased in increments of 100 volts and applied to the coil in both directions. None of the ten impregnated coils failed when tested up to the maximum voltage of 12,000 volts R.M.S. However, all of the ten unimpregnated coils failed. The average breakdown voltage recorded for the unimpregnated coils was

9,020 volts. It was noted that the voltage breakdown usually occurred at the end of the coil where maximum layer-to-layer stress apparently occurred. A visual examination of the winding disclosed that arcing occurred between turns.

In order to demonstrate the improved thermal endurance characteristics of the insulation system of Example 1, thermal endurance tests similar to AIEE Specification Code 57 were carried out. As is summarized in Table 1, impregnated and unimpregnated twisted wire samples without wrapping, with a cyanoethylated paper wrapping and with a plain kraft paper were used in the thermal endurance tests.

Table 1

Twisted wire samples	Impregnated samples		Unimpregnated samples	
	Time, hrs.	No. of failures	Time, hrs.	No. of failures
10 samples without wrapping	168	1	168	10
	336	9		
10 samples wrapped with cyanoethylated paper.	168	0	168	7
	336	4	262	3
	360	4		
	384	2		
10 samples wrapped with kraft paper.	168	0	168	9
	336	6	262	1
	360	0		
	383	3		
	408	1		

All of the wire samples were wound with a 0.0320 inch single build copper wire insulated with a polyvinyl formal resin enamel. The paper strip used was spirally wrapped around the twisted wire sample and was a quarter inch wide and 0.005 of an inch in thickness. The reaction mixture of Example 1 was used as an impregnating material. The samples were impregnated by dipping them in the reaction mixture for a period of two minutes and the samples were then cured by heating them at a temperature of 120 degrees for a period of one hour followed by a heat cure at 165 degrees centigrade for one hour. All of the impregnated and unimpregnated samples were aged in a forced circulating air over controlled at an approximate temperature of 175 degrees centigrade. This temperature was maintained within plus or minus one degree centigrade. The aging samples were periodically removed from the oven, cooled to room temperature and subjected to a potential of 2,800 volts at 60 cycles per second for a ten second interval. The samples which failed this voltage test were classed as failures. This procedure was followed until all samples had failed.

From the data presented in Table 1 it will be seen that the unimpregnated samples without any paper wrapping failed within 168 hours while the impregnated samples without the paper wrapping did not fail until 336 hours. All the wrapped unimpregnated samples failed within 262 hours. From the foregoing data it will be apparent that the aging characteristics of the wire samples were improved by providing the sample with a paper wrapping and impregnating the wrapped sample with the reaction mixture in accordance with the present invention.

The following formulations were also found to be satisfactory impregnants, all percentages being by weight:

EXAMPLE II

	Percent
1,3-butadiene and styrene copolymer (4/1 mol ratio)	57
Vinyl toluene	38
Divinyl benzene (50 percent solution)	3.8
Methylethyl ketone peroxide	1.2

EXAMPLE III

1,3-butadiene and styrene copolymer (4/1 mol ratio)	57
Vinyl toluene	38
Divinyl benzene (50 percent solution)	3.8
t-Butyl hydroperoxide	1.2

It will be appreciated that the heating temperatures and periods of heating used in curing as described in the above described examples will vary with different formulations. The curing cycle conditions depend upon the particular resin composition used, the size of the coil assembly, the polymerization initiator, the resin to monomer ratio and other factors.

It will be understood that the 1,3-butadiene-styrene copolymer used in the practice of the present invention may be cured to an insoluble resin without peroxide catalysts by heating the resin at high temperatures for extended periods of time. Preferably, the dialkyl or dialkyl aryl peroxides, such as dicumyl peroxide or di-tertiarybutyl peroxide, may be used. Benzoyl peroxide may be used where a hard cure is not desired. The amount of the polymerization initiator or combinations of polymerization initiators that may be incorporated in the reaction mixture can be varied considerably but generally will be within the range of .025 percent to 10 percent by weight.

The divinyl benzene in the illustrative examples was added to the reaction mixture as a solution since divinyl benzene is commercially available in the form of a solution. The quantity of the solution was adjusted to provide the desired amount of divinyl benzene in the reaction mixture. Preferably, divinyl benzene may be used in an amount ranging from 1 to 10 percent of the mixture. Other compounds which are present in the divinyl benzene solution are usually inert as far as the thermosetting or crosslinking properties of the reaction mixtures are concerned. These materials are diethyl benzene, ethyl vinyl benzene, and certain volatile constituents such as saturated hydrocarbons. The divinyl benzene solutions used in the reaction mixture typically had the following percent by weight composition:

Meta-divinyl benzene	50–55
Diethyl benzene+ethyl vinyl benzene	45–50
Volatile constituents	10

The vinyl toluene used in the reaction mixture was a mixture of isomers of vinyl toluene and contained approximately 60 percent of meta-vinyl toluene and 40 percent para-vinyl toluene. Preferably, the vinyl toluene is added in an amount ranging from 20 to 50 percent.

While particular compositions for the reaction mixtures have been specifically set forth and described above, it is not intended to limit the invention to the specific compositions disclosed. It will be apparent that the specific ingredients may be varied from the proportions described while still producing satisfactory results in accordance with the invention. Further, it will be apparent the insulation system of the present invention may be used in electrical coils differing in construction from the coils described herein to illustrate the invention.

Although the present invention has been described with reference to particular embodiments thereof, it will be understood that many modifications may be made therein by those skilled in the art without departing from the scope of the invention. Therefore, it is intended in the appended claims to cover such modifications that fall within the true spirit and scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A fluorescent lamp ballast comprising a shell-type magnetic core having an inner leg and two outer legs; cyanoethylated paper surrounding at least a part of said inner leg of said core; a coil surrounding said paper, said coil being formed of a plurality of layers each having a plurality of turns of insulated conductor wire, each of said layers being wound without electrical sheet insulation

therebetween; and a reaction mixture impregnating said ballast, said reaction mixture comprising by weight (a) from 40 to 70 percent of a 1,3-butadiene and styrene copolymer, (b) from 20 to 60 percent of liquid monomers containing vinyl unsaturation, and (c) from .25 to 10 percent of a peroxide initiator.

2. An electrical fluorescent lamp ballast comprising a shell-type magnetic core having a center leg and two outer legs; first and second cyanoethylated paper spools positioned on said center leg; first and second electrical coils respectively wound on said first and second spools, each of said coils having a plurality of layers each consisting of a plurality of turns of polyvinyl formal resin insulated conductor wire, and each succeeding layer being wound without electrical sheet insulation between said succeeding layer and the adjacent preceding layer; cyanoethylated paper wound about said coils; and a reaction mixture impregnating at least said spools, said paper, and said coils, said reaction mixture comprising by weight (a) from 40 to 70 percent of a 1,3-butadiene and styrene copolymer, said 1,3-butadiene being present in a mole ratio of approximately 4 to 1 with respect to said styrene (b) from 20 to 60 percent of vinyl toluene and (c) from .25 to 10 percent of a free radical type initiator.

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