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PULSE TRANSFORMERS

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Fig. 1.

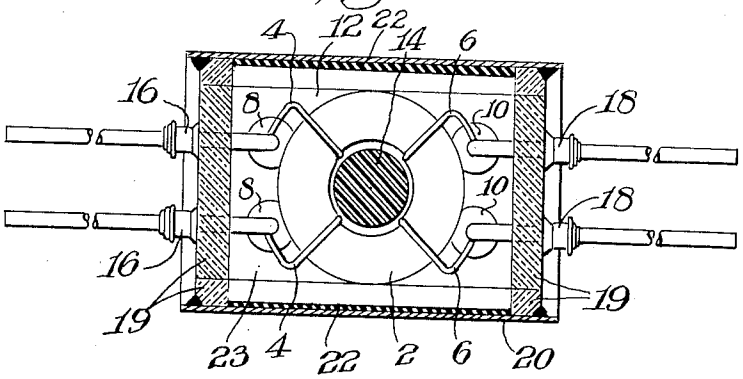
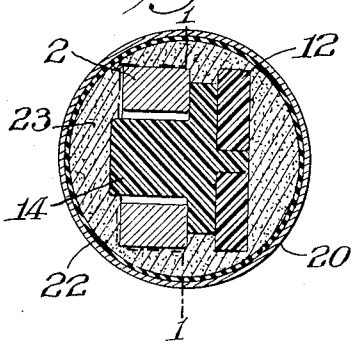


Fig. 2.



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PULSE TRANSFORMERS

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5 Claims. (Cl. 336—96)

This invention relates to pulse transformers and more particularly to hermetically sealed impregnated pulse transformers of exceptional life and reliability of electrical characteristics.

In electronic equipments utilizing pulses of electrical energy, e. g. radar and computers, pulse transformers have suffered from lack of continuing reliability of electrical characteristics and mediocre operational life. Further required of the pulse transformer is extremely fast repetition rates, ability to transmit extremely short pulses with substantially no distortion and relatively high pulse permeabilities. A portion of these characteristics have been met by the utilization of a non-metallic ferromagnetic material as the core member which cores have been of the configurations commonly known as the "E" and "Pot" types. These latter devices still primarily suffer from unreliability of electrical characteristics and mediocrity of lifetime.

It is an object of this invention to overcome the foregoing and related disadvantages. It is a further object to produce a hermetically sealed pulse transformer of much increased operational life, thus avoiding the service difficulties associated with the complex electronic gear. A further object of this invention is to produce a hermetically sealed pulse transformer having operational reliability and characterized by a high pulse permeability.

The objects herein have been achieved in accordance with this invention by the preparation of a pulse transformer comprising an insulated toroid of non-metallic ferromagnetic material, a plurality of insulated conductors wound about said toroid, hermetically sealed container means enclosing said toroid, terminal means for said conductors exterior of said container means and a hydrophobic slightly magnetostrictive dielectric impregnant confined within said container means. More particularly, the objects of this invention have been achieved by the production of a pulse transformer comprising an insulated toroid of non-metallic ferromagnetic material, a plurality of insulated conductors wound about said toroid, said toroid insulation having a dielectric constant of at least 1½ times that of said conductor insulation, container means hermetically sealing toroid and associated windings, terminal means for said conductors exterior of said container means, and a wax having a melting point of from 90° C. to 125° C. substantially filling the volume defined by said container means. A preferred embodiment of this invention is a pulse transformer comprising a lacquered toroid of a ferrite having a pulse permeability of from 400 to 500 for .1 microsecond pulse, a plurality of enamel insulated conductors wound about said toroid, supporting means of a low dielectric constant thermoset resin maintaining said toroid in a fixed position, a cellulose lined metallic can having glass secured terminals hermetically sealing said toroid, said conductors terminated by said glass secured terminals, and a wax having a melting point of from 90° C. to 125° C. substantially filling said volume defined by said can.

This invention is featured by a distribution of the electrical flux within a pulse transformer so as to position the non-metallic ferromagnetic material in a region of low voltage stress which thus avoids initiation of conduction within the toroid which in turn works up to substantial conduction and breakdown of the device. A further feature of this invention is the impregnation of the pulse transformer with an insulating substance which is hydrophobic, slight to non-magnetostrictive and of a low dielectric constant. It has been discovered that the incorporation of a number of features, including the foregoing, into pulse transformers, as they are presently known, yields a device which is extremely reliable over a much extended operational life and whose characteristics appear to be much more than the cumulative effect of the features.

One of our initial discoveries was that for reliability of operation over extended periods it was necessary to confine substantially all the magnetic flux to the regions adjacent to the windings. Introductions of an air gap such as were inherent with the presently used "E" and "Pot" type cores so distorted and extended the flux away from the windings that the output was unreliable in that variations in temperature, shock, vibration and other external forces were transmitted to the inductive assembly. The toroid avoided the above difficulties as substantially all the magnetic flux was confined within the core. For electrical characteristics the core material was chosen to be the non-metallic ferromagnetics commonly known as the ferrites. The use of the ferrite in toroid configuration facilitated a further discovery that the non-metallic ferromagnetics suffer from the defect that when substantial potentials are imposed upon it conduction is initiated and continued stress of that magnitude avalanches said conduction until the unit undergoes breakdown and further that the susceptibility to breakdown of the device is intimately woven into the penetration of moisture into the component. Our structure has thus been produced so that the stress of imposed potential is primarily concentrated on dielectric materials other than the non-metallic ferromagnetic material which has much extended the operational life over present transformers. Any advantage obtained through such a system can well be masked by the presence of moisture within the device which has been avoided by the expedient of hermetically sealing the structure in a fully impregnated container, the impregnant of which is hydrophobic. Of substantial influence upon the reliability of the electrical characteristics of the device is the above mentioned impregnant, for it was further discovered that the aforesaid impregnant must have a negligible magnetostrictive coefficient so as to avoid imposing undue stresses and strain upon the ferromagnetic core member. Surprising as it was, we found that indeed there are suitable impregnants which are hydrophobic, of high resistance, low dielectric constant, temperature stabile and slight to non-magnetostrictive, of which wax is preferred.

Fig. 1 shows an axial cross-section of the preferred form of the device of our invention as taken on line 1—1 of Fig. 2. Fig. 2 shows a radial section of the device of our invention including the impregnant in a modified form.

Reference should now be made to Fig. 1 which portrays a cross-section of the preferred device of our invention. The basic element of the pulse transformer is the non-metallic ferromagnetic toroid 2 about which are wound a plurality of windings, in this case the input conductor 4 and the output conductor 6. These leads are connected to their respective terminal posts 8 and 10. The posts are connected to an insulator supporting member 12 which has a raised central portion 14 onto which

the toroid itself 2 is positioned. The member 12 is of rectangular shape and of thickness of about one thirty-second of an inch. The center was drilled so that central portion 14 could be inserted so as to provide means for positioning the toroid 2. The supporting member 12 and the central portion 14 are preferably of a molded thermoset resin of relatively low dielectric constant. The input and output terminal posts 8 and 10, respectively, are in turn electrically connected to the exterior terminals 16 and 18. The entire assembly is positioned in a metallic container 20 which is hermetically sealed after impregnation by bringing the respective leads of the assembly outwardly by means of the terminals 16 and 18 through the Kovar glass insulated cover 19. The container 20 is thus a cylinder with each end sealed by the glass insulator cover in a manner well-known in the capacitor art. The interior surface of the can has disposed in contact with it a layer of kraft paper 22 which provides a positioning means for the supporting base 12 so as to avoid physical contact of the enclosed assembly and the can 20. Our entire assembly is thus seen to be substantially completely impregnated with a hydrophobic material, not shown in Fig. 1, and contained in a hermetically sealed structure in such a fashion that the potential gradient is minimized in the region adjacent to the core member.

As indicated in the foregoing, the ferromagnetic material having satisfactory electrical properties for use as a core material for a pulse transformer, is the non-metallic type, commonly known as ferrites. The preferred ferrites include the manganese zinc and nickel type having a Curie point in excess of 130° C. and an initial permeability of from 500 to 1200. Other important electrical characteristics include a pulse permeability of at least 400 for a .1 microsecond pulse and a frequency response up to 10 megacycles. Commonly available ferrites suitable for such use are Ferroxcube 3C sold by Ferroxcube Corporation of America, Ferramic H sold by General Ceramics, and Ceramag 5N sold by Stackpole, all of which are manganese zinc ferrite. The electrical characteristics set forth rather than the chemical material of the core material establishes a criteria for judging the applicability of the ferromagnetic material to this invention. It is, however, one of the features of our invention that a suitable core material be utilized in a certain configuration, namely as a toroid or form presenting a substantially closed path for induced magnetic flux.

It was not realized by us until our discovery that the insulation of the ferromagnetic core could indeed exert a substantial influence upon the operational life available with the use of such material. Realizing finally that the imposition of a substantial potential across the ferromagnetic material initiated conduction and accelerated the breakdown of the core, it thus became necessary to protect the core from excessive amounts of imposed potential which we have accomplished by insulating to a substantial thickness the exterior of the core with a dielectric of high breakdown voltage and resistance and further by imposing a plurality of dielectrics between the two points of potential of the assembly so as to impose upon the ferromagnetic core a small segment of the overall potential developed in the component. This was accomplished by the expedient of lacquering the core with a material of higher dielectric constant than the impregnant and the insulation on the primary conductors and which lacquer in our preferred embodiment has a dielectric constant in excess of 4. The preferred lacquer thus includes the copolymer of vinyl chloride and vinyl acetate and must be of a thickness within the range of from .2 mil to 0.5 mil. This high dielectric constant insulation coated on the ferromagnetic material of dielectric constant 10 so divided the field that only a small portion of the total potential is placed across or adjacent to the ferromagnetic material. As indicated above, the primary and secondary conductors are insulated with an outer low dielectric constant layer. This dielectric layer serves both the function of avoiding the shorting of the adjacent turns on the core and absorbing in combination with the impregnant the major amount of the electrical stress imposed upon the dielectric materials positioned within the field of electrical stress. The conductors are coated with an enamel having a dielectric constant of from 2½ to 3 as contrasted with the lacquer imposed upon the surface of the ferromagnetic toroid having a dielectric constant in excess of 4. As representative lacquers any of the various cellulose esters might be used, for example, cellulose acetate, cellulose nitrate, cellulose butyrate, etc.

As indicated in the foregoing portion of the specification, the impregnant cooperates with the other features to yield a pulse transformer of much improved characteristics over those presently known. The impregnant serves both as a barrier to moisture penetration which penetration has been found to be extremely detrimental to the breakdown resistance of the component, has a low dielectric constant, a high resistance and excellent ability to withstand electrical stress, and has slight to no magnetostrictive characteristics. Magnetostriction by the impregnant has been found to degrade the output of the pulse transformer and cause unreliability as the magnetostriction of the impregnant so stresses the core that its electrical characteristics are altered. Wax meets these requirements and if of a melting point of from 90° C. to 125° C., is our preferred impregnant. The low temperature limit is imposed by the operating temperature for it must be in the solid phase and upper limit imposed so as to avoid shrinkage after impregnation which can result in substantial undesired voids. Although wax forms an integral part of our preferred structure, as shown in Fig. 2 it might well and is for certain applications filled with a ferromagnetic particular material 23 which serves to confine further any stray flux to a region close to the toroid 2 proper.

As many apparently widely different embodiments of this invention may be made without departing from the spirit and scope hereof, it is to be understood that the invention is not limited to the specific embodiments hereof except as defined in the appended claims.

What is claimed is:

1. A pulse transformer comprising an insulated toroid of non-metallic ferromagnetic material, a plurality of insulated conductors wound about said toroid, hermetically sealed container means enclosing said toroid, said conductors having terminals sealed through the wall portions of the container means, and a high resistance hydrophobic dielectric impregnant no more than slightly magnetostrictive confined within said container means, said impregnant having a dielectric constant lower than said toroid insulation and a melting point at least as high as 90° C.

2. A pulse transformer comprising an insulated toroid of non-metallic ferromagnetic material, a plurality of insulated conductors wound about said toroid, said toroid insulation having a dielectric constant of at least 1½ times that of said conductor insulation, terminals for said conductors, container means hermetically sealing said toroid and associated windings but leaving the ends of the terminals projecting outside said container means, and a high resistance wax having a melting point of from 90° C. to 125° C. and a dielectric constant lower than said toroid insulation substantially filling the volume defined by said container means.

3. A pulse transformer comprising a lacquered toroid of a ferrite having a pulse permeability of from 400 to 500 for .1 microsecond pulse, a plurality of enamel insulated conductors wound about said toroid, supporting means of a low dielectric constant thermoset resin maintaining said toroid in a fixed position, a cellulose lined metallic can having glass secured terminals hermetically sealing said toroid, said conductors terminated by said glass secured terminals, and a wax having a melting point of

from 90° C. to 125° C. substantially filling said volume defined by said can.

4. A pulse transformer comprising a toroid of non-metallic ferromagnetic material, a dielectric coating having a dielectric constant of at least 4 around the toroid, conductor windings interlinked with the toroid, a low dielectric constant, high resistance hydrophobic, dielectric solid no more than slightly magnetostrictive impregnated in and encased around the assembly, said solid having a melting point of at least 90° C. and a lower dielectric constant than said toroid coating, and a metallic container hermetically sealed around the encased assembly.

5. The combination of claim 4 in which the dielectric solid is filled with ferromagnetic particles.

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