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BONDING OF TRANSFORMER LAMINATIONS

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Fig. 1.

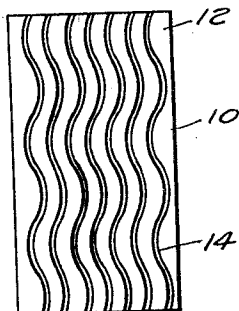


Fig. 2.

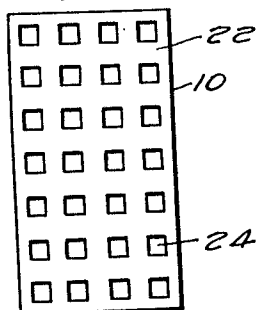


Fig. 3.



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BONDING OF TRANSFORMER LAMINATIONS

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7 Claims. (Cl. 175—356)

This invention relates to bonding, and more particularly the bonding of laminated transformer cores.

An object of this invention is to provide for bonding laminated transformer cores.

A further object of this invention is to provide for bonding laminated transformer cores with a high electrical resistance between laminations for a predetermined space factor.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the several steps and the relation and order of one or more of such steps with respect to each of the others and the article possessing the features, properties and the relation of elements which are exemplified in the following detailed disclosure, and the scope of application of which will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in conjunction with the accompanying drawing, in which:

Figure 1 is a plan view of a lamination;

Fig. 2 is a plan view of a modified form of the invention; and

Fig. 3 is an end view of a series of consolidated laminations.

In the construction of transformers, it is customary to construct the iron core of a plurality of thin sheets of metal. The laminated core is electrically more economical in that the eddy current losses are considerably reduced. In addition the laminations of sheet metal may be coated with a thin layer of enamel or some electrically resisting composition in order to further prevent the eddy current phenomenon.

The thickness of the laminations is of the order of 14 to 20 mils. The coating between laminations may be of the order of 1/2 to 2 mils in thickness.

The most economical construction of a transformer from a manufacturing cost standpoint would call for the least space between laminations. The introduction of the composition between laminations reduces the amount of iron per unit volume. The volume of iron per unit of core volume is known as the space factor. In commercial installations, the transformer core space factor ranges between 85% and 97%. The highest space factors employ the least amount of electrically resistant composition between laminations, and consequently the eddy current

losses will be somewhat higher than in the other constructions.

It is the purpose of this invention to increase the electrical resistance between the laminations of a bonded iron core for a given composition at a given space factor. This improved electrical resistance is obtained by applying a bonding composition as a coating in the manner as disclosed hereinafter.

The composition which is employed between laminations to both bond and insulate the laminations into a core comprises a solution of a mixture of resins. The resins, which have been found to accomplish this function, are compounded in the following proportions:

	Per cent
Polyvinyl acetal	42 1/2
Polyvinyl acetate	42 1/2
Heat-hardening phenol-aldehyde type of resin (for example—cresylic acid-formaldehyde condensate)	15

The resins are dissolved in a solvent composed of 70% toluene, coal tar naphtha, xylene or mixtures thereof and 30% ethyl alcohol. The proportion of resins in the solution is from 20% to 40%. The composition may be varied by omitting the polyvinyl acetate when it is desired to have a high temperature composition useable at temperatures from 100 to 140° C. Furthermore, the phenol-aldehyde type of resin may be modified with additions of tung oil for use at temperatures below 100° C. The polyvinyl acetal may be a condensate of an aldehyde with polyvinyl alcohol or partially hydrolyzed polyvinyl ester depending upon the softening point desired.

The solvents which may be used in preparing the solution of the resins are toluene, xylene, coal tar naphtha and ethyl alcohol. The first three may be used interchangeably. However, approximately one-third of the solvent is preferably ethyl alcohol. Since the solvent is merely for the purpose of carrying the resin and to facilitate its application to the laminations, the particular solvent or mixtures is not critical.

The general method of employing the composition for bonding laminations comprises the following steps: Punchings of transformer steel are coated with the above solution of resins. The punchings are then subjected to a high temperature for a brief period of time in order to flash the solvent. Flashing as referred to in this application is a rapid evaporation of the solvent without combustion. The temperatures and the respective times which have been found satis-

factory are a 20-second flash period at 450° C., 40 to 70 seconds at 350° C., and 125 to 150 seconds at 250° C. Flashing below 250° C. is not satisfactory. Flashing above 450° C. may result in deterioration of the resins.

After flashing, the coated punchings are stacked into cores of predetermined size and clamped together. The stack is heat treated in furnaces at temperatures of from 200° C. to 260° C. A heat treatment time of five hours for a core measuring 4 inches by 6 inches by 12 inches is satisfactory. At the end of this period, the core is removed from the oven and the clamps are adjusted to give the selected space factor. The core is cooled and is in a bonded condition for further processing in manufacturing the transformer.

A stack of laminations subjected to this treatment and having a substantially uniform coating of the composition between laminations at a space factor of 95% will show a resistance of 0.55 ohm per square inch.

An increase in this electrical resistance with the same space factor, or an improvement in the space factor for the same resistance, is obtained by subjecting the laminations to a treatment to provide thin and thick areas of composition when first applied.

For an example of such treatment, Figure 1 of the drawing shows a lamination 10 which has been coated with a uniform layer 12 of the resin in solution. The lamination is combed or scraped to remove most of the resin at portions 14. The combing apparatus may consist of a rake-like member with tines of a width conforming to the desired lateral dimensions of 14. Substantially the greater proportion of the composition will be removed by this combing treatment. It is preferred that about 0.1 mil thickness of the composition remain in these combed areas. This very thin layer of resin should be left at portions 14 in order to accomplish the invention.

Upon subjecting the combed lamination to the flashing temperature preferably above 350° C., the composition in these thin areas loses its solvent extremely rapidly. The resins in the thin areas reach a considerably higher temperature than the resins present in composition at the thicker areas at 12. The thick areas have just lost most of their solvent at about the termination of the flashing period and have not reached the temperatures prevalent at areas 14.

The heat hardening phenol aldehyde type resin at these thinner portions in particular changes its chemical composition to a great extent and becomes extremely hard. A similar effect occurs with respect to the other resins to a lesser degree.

The flashed laminations are stacked and heat treated for several hours at the lower heat-treating temperature of 200° C. to 260° C. The thicker resin layer at 12 flows under the heat and pressure and provides the bond between the laminations. The hard thinner layer of resin at 14 attains a higher electrical resistance than resin layer 12 during the flashing and heat-treating operation.

It has been found that a stack of laminations with a combed composition will have a resistance of 0.65 ohm per square inch at a space factor of 96½%. This corresponds to approximately 0.80 ohm for a 95% space factor.

A modified form of the invention is illustrated in Fig. 2. The laminations 10 are coated by

means of a roller or other composition applying device having high and low areas somewhat like a waffle grid in appearance. The high areas of the composition applying roll will press most tightly against the lamination and will convey only a thin coating of composition at portions 24. The low spots of the composition applying roll will apply a thick coating 22 of the usual thickness. When subjected to flashing and heat treating, the Fig. 2 lamination will also behave as the Fig. 1 laminations and will show the increased electrical resistance exhibited by the Fig. 1 lamination.

A stack of heat treated and bonded laminations suitable for a transformer core is shown in Fig. 3. Any number of laminations may be consolidated under temperature and pressure to form a stack similar to Fig. 3 for use in transformers.

The particular coating composition described in the body of the specification is merely for illustrating the particular values obtained for the specific bonding composition and is not intended to be a limitation on the use of the process. It is believed that numerous other compositions may be employed and subjected to treatment such as combing, in order to improve the electrical resistance. Ordinary insulating varnish enamels may be applied in thick and thin areas, and heat-treated to achieve the better insulating coatings.

Since certain changes in carrying out the above process and certain modifications in the article which embody the invention may be made without departing from its scope, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

I claim as my invention:

1. A bonded laminated transformer core comprising a plurality of laminations of magnetic material and a heat treated adhesive bonding and insulating the laminations, the adhesive, which when applied in a uniform coating between laminations with a predetermined space factor having a predetermined electrical resistance, being present on the laminations as a non-uniformly thick coating having relatively thick areas and other relatively thin areas, the non-uniform coating upon the consolidating of the laminations under heat and pressure having increased electrical resistance at the predetermined space factor, the adhesive including thermosetting resins therein.

2. A bonded laminated transformer core comprising a plurality of laminations of magnetic material and a heat treated composition bonding and insulating the laminations, the composition, which when applied in a uniform coating between laminations with a predetermined space factor having a predetermined electrical resistance, being present as a non-uniformly thick coating between laminations having relatively thick and thin areas, the non-uniform coating, upon flashing and consolidation of the laminations under heat and pressure, having a greater electrical resistance than the electrical resistance for the predetermined space factor, the relatively thick areas providing for the bonding of the laminations, while the relatively thin areas are hard and of higher electrical resistance than the thick areas.

3. The method of improving the space factor and electrical resistance between laminations of a transformer core bonded with a heat treated

composition exhibiting predetermined electrical resistance for a selected space factor when applied as a coating of uniform thickness between laminations, the step which comprises applying the composition in a non-uniformly thick coating on the laminations with a substantial difference in thickness between the thin and thick portions of the coating, and heat treating the laminations to cause the thin areas to reach a hard and highly resistant state.

4. The method of improving the electrical resistance between laminations of a transformer core bonded with a heat treated composition with a selected space factor, the composition exhibiting predetermined electrical resistance for the selected space factor when applied as a coating of substantially uniform thickness between laminations, which comprises applying the composition as a coating of substantially uniform thickness to laminations, removing the greater proportion of adhesive from selected areas on the laminations, flashing the laminations at a temperature to remove the solvent from the thick areas, and consolidating the laminations under heat and pressure to the selected space factor.

5. A bonded laminated transformer core comprising a plurality of laminations of magnetic material and a heat treated composition between laminations for bonding and insulating the whole, the composition, which when applied as a substantially uniformly thick coating between laminations having a predetermined electrical resistance for a selected space factor, occurring between laminations as a coating of non-uniform thickness by removing substantially the greater

proportion of composition to provide relatively thinner areas, the coating of non-uniform thickness having increased electrical resistance when the laminations are consolidated under heat and pressure to the selected space factor.

6. The method of improving the electrical resistance between laminations of a transformer core bonded with a heat treated composition with a selected space factor, the composition exhibiting predetermined electrical resistance for the selected space factor when applied as a coating of substantially uniform thickness between laminations, which comprises applying the composition as a coating of substantially non-uniform thickness to laminations, and consolidating the laminations under heat and pressure to the selected space factor.

7. A bonded laminated transformer core comprising a plurality of laminations of magnetic material and a heat treated composition between laminations for bonding the whole, the heat treated composition providing a high dielectric resistance to reduce the eddy current losses during operation, the heat treated composition being present between the laminations in relatively thick areas having good bonding properties and in other areas considerably thinner and harder, the thinner and harder areas exhibiting greater electrical resistance than the thicker areas, the combination of the thick and thin areas of the heat treated composition resulting in an improved overall electrical resistance between laminations as compared to uniform coating at the same space factor.

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