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COATINGS FOR MAGNETIC SHEET MATERIAL

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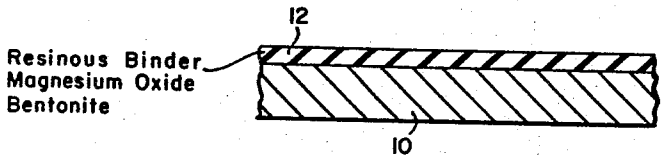



Fig. 1.

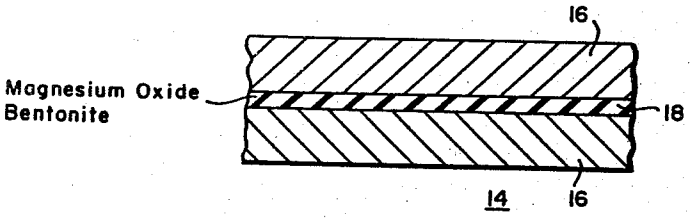



Fig. 2.

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# COATINGS FOR MAGNETIC SHEET MATERIAL

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Application Jan. 15, 1959, Ser. No. 786,922 which is a division of application Ser. No. 452,472, Aug. 26, 1954, now Patent No. 2,904,875, dated Sept. 22, 1959. Divided and this application Oct. 26, 1962, Ser. No. 233,369

4 Claims. (Cl. 117—222)

This application is a division of our application Serial No. 786,922, filed January 15, 1959, now abandoned, which, in turn is a division of application Serial No. 452,472, filed August 26, 1954, now U.S. Patent No. 2,904,875, issued September 22, 1959.

The present invention relates to magnetic sheet material and has particular reference to the provision of adherent electrically insulating coatings for application to magnetic sheet materials.

It is a common practice in the electrical industry when manufacturing cores for transformers, magnetic amplifiers, and the like, to provide the magnetic sheet material employed therein with a coating of magnesium oxide. One known method for applying such a coating consists of preparing a slurry in which water and magnesium oxide are the sole ingredients, applying the slurry to magnetic sheet material, and then drying the applied slurry to remove substantially all the water. The coating of magnesium oxide thus deposited is not completely satisfactory because it does not adhere tenaceously to the magnetic sheet material and tends to fall off readily during the usual operations of building magnetic cores therefrom. As a result, after the coated sheet material has undergone core punching or core winding, annealing, and other necessary handling operations, only a relatively small proportion of the magnesium oxide coating is found between the windings or laminations of the core. Uncoated areas of the magnetic sheet will short circuit on contact and have high alternating current losses.

The object of the present invention is to provide an adherent electrically insulating coating composition adapted to be applied to magnetic sheet material prior to winding or other fabricating operations of the magnetic material into cores or the like.

Another object of the invention is to provide a process for applying an adherent electrically insulating coating to magnetic sheet material.

A still further object of the invention is to provide magnetic sheet material with an adherent electrically insulating coating which is highly resistant to flaking and powdering on handling.

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

For a more complete understanding of the present invention, reference is made to the following description taken in conjunction with the accompanying drawing in which:

FIGURE 1 is a sectional view of a sheet of magnetic material provided with a tenaciously adhering resinous refractory coating, and

FIGURE 2 is a sectional view of a portion of a magnetic core including a plurality of sheets of magnetic material separated by a mixture of magnesium oxide and bentonite.

It now has been discovered that the above and other and further objects are obtained when magnesium oxide is applied to magnetic sheet material from a coating composition containing a thermosetting aminotriazine-aldehyde resin, particularly melamine-formaldehyde resins. Coating compositions containing such resins possess unexpected characteristics not possessed by other known coating compositions whereby unusually effective, tenaciously adhering electrically insulating refractory film coatings are provided on magnetic sheet material.



Broadly, the coating compositions of this invention comprise an aqueous composition consisting essentially of from 5% to 15% by weight of at least one partially reacted aminotriazine-aldehyde resin which is soluble in water-alcohol mixtures, from 5% to 15% by weight of magnesium hydroxide, from 0.1% to 1% by weight of bentonite, from 30% to 50% by weight of at least one low molecular weight aliphatic monohydric alcohol, and from 30% to 50% by weight of water.

In producing magnetic sheet material with an adherent electrically insulating coating in accordance with this invention, the liquid coating composition is first applied to the sheet material in any convenient manner. To illustrate, the coating may be applied simply by dipping the sheet material in the coating composition, or the composition may be rolled onto the sheet material using rubber or felt rollers; or the composition, after being applied as a heavy, non-uniform coating by dripping or the like, may be reduced to a thin film coating by passing the sheet material under a knife blade; or electrophoretic deposition techniques may be used. The applied coating of the liquid composition is heated to a temperature high enough to drive off the water and the alcohol and effect curing of the resin. Temperatures within the range of from 100° C. to about 150° C. are satisfactory to achieve these results. The coating thus deposited on the sheet material adheres thereto tenaciously. The coated sheet will withstand the relative rough handling frequently encountered during shipping of the sheet material to fabricating plants or to core winding stations. Little, if any, of the coating flakes off during such handling operations or during subsequent punching, core winding and fabricating operations or during the final annealing operation. The wound cores are annealed at temperatures within the range of from about 900° C. to 1300° C. in an atmosphere of a reducing gas to remove stains set up by punching and other fabricating operations. At such high temperatures, the aminotriazine-aldehyde resins decompose and the decomposition products are carried off by the reducing gas leaving a tenaciously adhering solid coating on the sheet material consisting essentially of magnesium oxide and bentonite.

Referring to the drawing, FIGURE 1 is a sectional view of a sheet of magnetic material **10** provided with a tenaciously adhering resinous refractory coating **12**. Coating **12** is the coating present on the magnetic sheet material after the sheet, coated with the above-described aqueous composition consisting of resin, magnesium hydroxide, bentonite, alcohol, and water, has been heated to about 100° C. to about 150° C. The heat treatment serves to drive off the water and alcohol, convert the magnesium hydroxide to magnesium oxide, and cure the resin. The cured resin binds the magnesium oxide and bentonite tenaciously to the magnetic sheet.

After the sheet thus prepared has been wound into a core, and on heating to an annealing temperature, the resin burns off leaving, see FIG. 2, a magnetic core **14** including a plurality of magnetic sheets **16** separated by a composition **18** consisting essentially of magnesium oxide and bentonite.

The resin employed in the coating composition of this invention is produced by condensing formaldehyde with an aminotriazine or condensed aminotriazone. Among these amino compounds, melamine and its derivatives such as 2,4,6-triethyl-and-triphenyl-triamino-1,3,5-tri-

azines, 2,4,6-trihydrazino-1,3,5-triazine and the corresponding condensed triazines such as melam and melem are preferred. Among the other triazine compounds which may be used, the following are included: triazines containing one or two amino groups such as ammeline, ammelide, formoguanamine, 2-amino-1,3,5-triazine and their substitution products as well as nuclear substituted aminotriazines such as 2-chloro-4,6-diamino-1,3,5-triazine, 2-phenyl-4-amino - 6 - hydroxy-1,3,5-triazine. Obviously, commercial mixtures of the various triazines or mixtures thereof with other amino compounds may be used if desirable. One example of such commercial mixtures is the product obtained by heating dicyandiamide sufficiently to obtain a significant amount of melamine, together with other reactive amino bodies.

The aminotriazines mentioned above are preferably partially condensed with formaldehyde but any suitable aldehyde of the aliphatic, aromatic or heterocyclic series may be used in the reaction such as acetaldehyde, propionaldehyde, butyraldehyde, hexaldehyde, heptaldehyde, crotonaldehyde, allylaldehyde, benzaldehyde, cinnamylaldehyde, furfural, etc.

The condensation products may be produced by any suitable process and with any desired combining ratio of aldehyde to aminotriazine from 1:1 up to 6:1, or even higher.

A particularly suitable resin is the melamine reaction product of 1,3,5-triamino-2,4,6-triazine and formaldehyde. This reaction product may be prepared conveniently by reacting the components for a brief period of time at about 80° C. to 120° C. in the presence of an alkaline catalyst such, for example, as lime, barium hydroxide, ammonia, ethylenediamine, and propylenediamine. The amount of catalyst is of the order of one-half percent. The resinous reaction product should be soluble in 25% aqueous ethanol.

It is preferred to employ substantially completely hydrated magnesium hydroxide in preparing the aqueous coating compositions of this invention.

Magnesium oxide may be employed in the aqueous coating composition although additional water may be present to be taken up as water of hydration since magnesium oxide will tend to take up water on standing thereby changing the predetermined viscosity of the aqueous composition. From about 5% to 50% by weight of the magnesium hydroxide employed in the aqueous coating composition may be replaced by one or more finely divided inert refractory insulating solids selected from the group of metal oxides, metal silicates and metal phosphates. Examples of such refractory solids are aluminum oxide, zirconium oxide, silica, iron oxides, calcium silicate, aluminum silicate, calcium phosphate, magnesium silicate and magnesium phosphate.

The bentonite employed in the aqueous composition is a naturally occurring colloidal crystalline inorganic aluminum silicate. A variety which has been found to be particularly suitable for use in forming the coating compositions of the present invention is that known as montmorillonite.

The alcohol is an essential ingredient in the compositions of this invention. The partially reacted aminotriazine-aldehyde resin is not completely soluble in water. Alcohol functions somewhat in the manner of a common solvent in the aqueous compositions. Alcohols which have been found to be particularly suitable for use in the coating compositions are those aliphatic monohydric alcohols having 1 to 4 carbon atoms including methyl, ethyl, propyl, and isopropyl alcohol.

In order to indicate even more fully the advantages and capabilities of the present invention, the following examples are set forth. These examples are presented for illustrative purposes only and they are not intended to limit the scope of the invention in any manner. The parts given are by weight unless otherwise indicated.



## EXAMPLE I

A mixture is prepared by introducing about 4 parts of bentonite into about 1500 parts of ethyl alcohol (90%) and about 1500 parts of water. The mixture is stirred for about 10 to 20 minutes whereupon about 350 parts of a partially reacted melamine-formaldehyde resin is added over a period of about 10 minutes with stirring. Thereafter, about 350 parts of magnesium hydroxide are added slowly and the resulting mixture is stirred for about 15 minutes. The mixture is then passed through a 20 mesh screen to remove any large particles and then through a paint mill whose stones are not more than 0.001 inch apart to yield a smooth uniform coating composition.

Coating compositions which are equally satisfactory to that described in Example I may be prepared by replacing from 5% to 50% by weight of the magnesium hydroxide with aluminum oxide, silica flour, or other finely divided inert refractory solids. It is preferable that these latter solids be of a fineness to pass through a sieve having 200 meshes per lineal inch or finer.

## EXAMPLE II

A composition composed of 210 parts of a partially reacted, aqueous-alcohol soluble melamine-formaldehyde resin, 470 parts magnesium hydroxide, 4 parts bentonite, 1500 parts ethyl alcohol and 1500 parts water are admixed to form homogeneous mixture according to the procedure described in Example I. Strips of magnetic material are passed through the composition and then beneath a doctor blade whereby a thin uniform liquid coating is obtained. The magnetic strips with the applied liquid coatings then are passed through a gas fired furnace where they reach a temperature of about 145° C., being exposed to this temperature for approximately 5 to 10 seconds whereby water and alcohol are driven off and the resin is substantially completely thermoset.

The dry coating thus developed on the strips of magnetic material is very adherent whereby the strips may be shipped with little, if any, of the coating composition coming loose.

## EXAMPLE III

A magnetic core is prepared by passing strips of magnetic material through an aqueous coating composition, prepared as described in Example I, which has the following composition:

| | Parts |
|---|---|
| Melamine-formaldehyde resin (aqueous-alcohol soluble) | 470 |
| Magnesium hydroxide | 210 |
| Bentonite | 4 |
| Isopropyl alcohol | 1500 |
| Water | 1500 |

The strips with the applied liquid coating then are passed through a furnace provided with suitable heating elements maintained at a temperature sufficiently high to effect vaporization of the water and alcohol and to complete the curing of the resin to a thermoset material. The strips having dry, tenaciously adhering coatings, then are introduced onto a core winding machine where they are wound into an assemblage of superimposed laminations in the form of a wound magnetic core. The wound core then is placed in an annealing furnace and heated to a temperature of about 1050° C. to 1230° C. in the presence of a moving stream of hydrogen, whereby all traces of the alcohol, water, and melamine-formaldehyde resin and decomposition products thereof are removed. The annealed magnetic core thus produced comprises a plurality of superimposed sheets of magnetic material having a thin electrically insulating coating therebetween consisting essentially of magnesium oxide and bentonite. The cores built up in this manner have a space factor of about 99%.

As indicated hereinabove, the coating compositions of this invention may be applied to magnetic sheet material by electrophoretic deposition. The following example describes such a process.

EXAMPLE IV

A coating composition is prepared according to the method described in Example I utilizing the following ingredients:

| | Parts |
|---|---|
| Melamine-formaldehyde resin (aqueous-alcohol soluble) | 400 |
| Magnesium hydroxide | 275 |
| Bentonite | 10 |
| Methyl alcohol | 1500 |
| Water | 1500 |

The composition is introduced into a cell having a stainless steel blade as an anode. A one-quarter inch wide strip of a magnetic material namely an alloy (nickel 50%, iron 50%) of a thickness of 0.002 inch is passed through the cell, the strip being made the cathode. The pH of the coating composition is maintained at about 9.5 to 10.5. An electrical current of 110 volts direct current is applied to the strip and the anode, the two being separated to pass a current of 55 amperes per square foot of the strip in the bath. The strip is passed through the bath at a speed of approximately 30 feet per minute, about 1½ feet of the strip being immersed in the bath. A coating of a thickness of about 0.001 inch is deposited on the strip, which on drying at a temperature of 150° C. results in a shrinkage of the coating to about 0.0001 inch.

The coated strip thus prepared may be wound into magnetic cores and annealed at temperatures of about 900° C. to 1300° C. to provide a tenaciously adhering coating of magnesium oxide and bentonite.

The thickness of the layer of the liquid coating composition applied to the magnetic sheet material preferably is within the range of about 25% to 150% of the thickness of the sheet. For extremely thin gauge magnetic sheet material, namely from 0.004 inch to 0.0005 inch thick silicon-iron alloys, nickel-iron alloys, cobalt-iron alloys, and the like, the applied coating preferably is from 50% to 150% of the thickness of this sheet. For heavier magnetic steel of the order of 14 to 22 mils, the coatings may be from 5 to 15 mils in thickness. After heat treatment during which the water and alcohol are driven off and the resin cured, the coatings shrink considerably, and constitute only about 5% to 20% of the thickness of the applied liquid composition. The coated sheet magnetic material may be punched after the resin curing heat treatment to produce rotor and stator laminations. Furthermore, the coated magnetic sheet material may be cut into strips and wound into cores with little, if any, of the coating coming loose therefrom.



When employed in cores, rotors, and stators the coated magnetic sheet materials produced in accordance with this invention may be subjected to varnish impregnation and other conventional insulating treatments without causing undesirable changes in the varnishes or other insulating compounds.

The coating compositions of this invention are extremely adherent to magnetic sheet materials and have been found to be impervious to oils, moisture, and commonly encountered solvents. The electrical resistance of the coatings is outstanding, particularly when their extreme thinness is considered.

While the present invention has been disclosed with reference to particular examples and embodiments thereof, it will be understood, of course, that numerous changes, substitutions and modifications may be made therein without departing from its true scope.

We claim as our invention:

1. Magnetic sheet material coated on at least one side thereof with a tenaciously adhering coating consisting of from 3.45 to 10.45 parts by weight of a mixture of magnesium oxide containing up to 50% of its weight of a finely divided inert refractory insulating solid selected from the group of metal oxides, metal silicates and metal phosphates, and from 0.1 to 1 part by weight of bentonite, said coating bonded to the sheet by at least one fully cured aminotriazine-aldehyde resin.

2. Magnetic sheet material coated on at least one side thereof with a tenaciously adhering coating consisting of from 3.45 to 10.45 parts by weight of magnesium oxide and from 0.1 to 1 part by weight of bentonite, said coating bonded to the sheet by at least one fully cured aminotriazine-aldehyde resin.

3. The coated magnetic sheet material of claim 2 wherein the coating has a thickness of about 1.25% to about 30% of the thickness of the sheet material.

4. The coated magnetic sheet material of claim 2 wherein the coating is bonded to the sheet material by a fully cured melamine-formaldehyde resin.

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