Oct. 29, 1946. W. P. LANGWORTHY 2,410,220

CORE LAMINATION AND METHOD OF PRODUCTION THEREOF

Filed Dec. 9, 1943

Fig. 1.

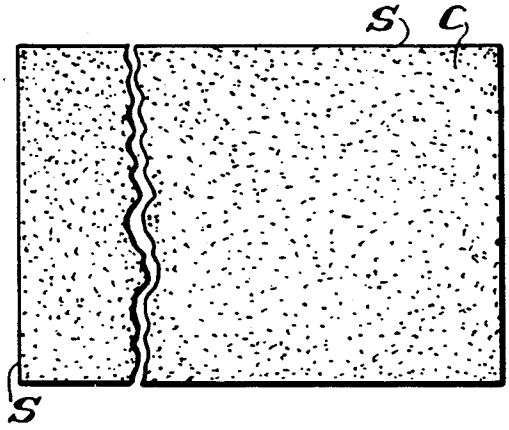


Fig. 2.

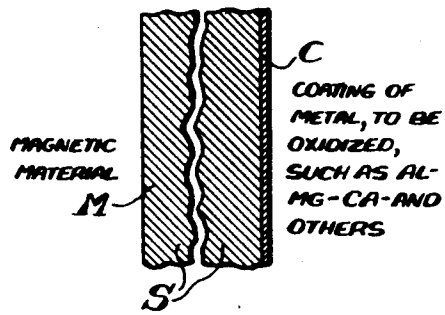


Fig. 3.

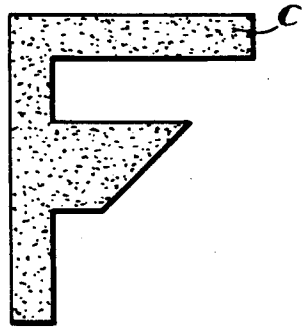


Fig. 4.

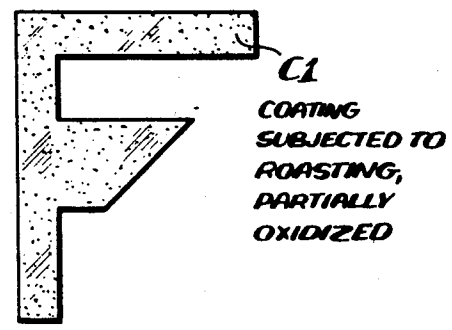
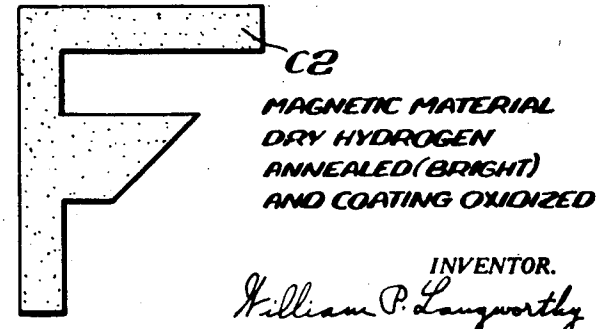


Fig. 5.



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CORE LAMINATION AND METHOD OF PRODUCTION THEREOF

William P. Langworthy, Philadelphia, Pa.

Application December 9, 1943, Serial No. 513,604

9 Claims. (Cl. 148—6)

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My invention relates to magnetic material, generally in the form of strips or sheets, and to elements formed therefrom, including laminations stamped or otherwise formed therefrom, utilizable as or constituting magnetic cores of transformers, inductances and other electro-magnetic devices having windings traversed by alternating currents of commercial or other low frequencies or of higher frequencies, including radio frequencies; and my invention relates to methods of producing the magnetic material or elements, laminations or the like.

It is the purpose of my invention to attain, among others, one or more of the objects following: the prevention of welding or otherwise sticking to each other of elements of magnetic or magnetizable material when in association with each other they are subjected to high temperatures, particularly those obtaining when annealing the elements; the provision, upon at least one of the surfaces of such sheets or elements, of metal oxide firmly adherent thereto electrically to insulate neighboring elements from each other and to maintain them magnetically discrete; and to dispense with the use of granular or powdered alumina or like non-oxidizable material between neighboring surfaces of the material while undergoing treatment at elevated temperatures, particularly temperatures utilized in annealing the elements of magnetic material.

In accordance with my invention the magnetic (magnetizable) material, of whatever shape or form prior to or after conversion into the shape or form in which ultimately to be used, is treated by application to a preliminarily or eventually exposed surface thereof by spraying electro-plating or otherwise, a continuous or a discontinuous or perforate coating of a metal, or mixture of metals, of the class exemplified for the purposes of my invention by aluminum magnesium calcium and others, which is oxidizable, as when raised to oxidizing temperature in the presence of air or other preferably gaseous oxidizing agent, resulting in the formation upon the magnetic material of a preferably very thin layer or coating of oxide of the applied metal; the oxidation of the applied metal may be effected either prior to or during or concurrently with an annealing treatment, such as a dry hydrogen annealing treatment, of the magnetic material at high temperature, usually within the range from about 2000° to about 2500° F.; the eventual oxide of the applied metal preferably should be stable, not substantially variable or changeable by any effects to which the oxide coated magnetic metal

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may be subjected either during manufacture or when in use in an electro-magnetic device; the oxide coating preferably should adhere to the magnetic material with firmness or be sufficiently strongly bonded thereto to the end that the oxide is not to material extent lost in later operations or during use of the oxide coated magnetic material in electro-magnetic devices; the thickness of the oxide coating preferably is of a thickness or volume compared to the thickness or volume of the magnetic metal which it coats which is relatively small, even in the case where the magnetic material itself is of the small thickness of core sheets or laminations utilized at radio frequencies.

My invention resides in the methods and products hereinafter described and claimed.

For an understanding of my invention reference may be had to the accompanying drawing, in which:

Fig. 1 is a plan view of a sheet or blank of magnetic material coated with a metal to be oxidized;

Fig. 2 is a fragmentary cross-sectional view, for clarity on exaggerated scale, of a coated sheet such as illustrated in Fig. 1;

Fig. 3 is a plan view of a lamination element stamped from a blank sheet of the character illustrated in Fig. 1;

Fig. 4 is a plan view of a similar stamping which with its metal coating has been roasted and the coating metal partly oxidized;

Fig. 5 is a plan view of a stamping similar to that of Fig. 4 and whose metal coating has been fully oxidized or partial oxidation of whose coating has been completed, while the magnetic metal of the stamping has been subjected to a dry hydrogen annealing treatment.

The magnetic material, on whose surface is to be provided a metal oxide, may be so-called pure iron, low-carbon steel, or of iron or steel alloyed with suitable other materials or metals such as silicon, nickel and others well known in the field of magnetic or magnetizable alloys.

The principal magnetic alloys among those requiring or improved in permeability or otherwise by treatment at elevated temperature, such as about 1250° to about 2500° F., and by treatment such as a dry hydrogen annealing treatment at temperature for example, within a range from about 2000° to about 2500° F., are those of nickel and iron or steel containing any suitable or desired proportion of nickel such as approximately 50% nickel or approximately 75% to approximately 90% nickel, the latter usually accompan-

ied by some other alloying elements such as molybdenum, chromium or copper.

The magnetic materials may be also alloys of pure iron or steel with silicon; they too are benefited by high temperature treatment, including such as the dry hydrogen annealing, with improvement in their magnetic characteristics to approach those of the aforesaid annealed nickel alloys.

The source of the oxide upon the surface of the magnetic material is a metal or mixture of metals, different from the magnetic material, which after application to the magnetic material is, in situ, converted to the desired oxide or oxides thereof. For example, the metal coated magnetic material is given a heat treatment in the presence of oxygen or oxygen-containing gas, such as air, either prior to or during or both prior to and during, a dry hydrogen annealing at high temperature, effecting oxidation of the applied metal while attached to the magnetic material, with the oxide bonded to or otherwise sufficiently adherent to the magnetic material; the oxide is chemically stable, preferably irreducible, as by the hydrogen in a high temperature hydrogen annealing treatment of the magnetic material.

The metals to be oxidized are those of a class exemplified by aluminum, magnesium, calcium and any of the other non-ferrous metals whose oxides are sufficiently stable not to be reduced in any heat treatment to which the magnetic material is to be subjected, or sufficiently stable not to be reduced by hydrogen in the temperature range from about 2000° to 2500° F. when the magnetic material is to be given such annealing treatment. Two or more of the metals comprised in the class may be utilized in mixture with each other; for example, the metal to be oxidized may be Dowmetal, a mixture or alloy of aluminum and magnesium.

Some of the metals applied to the magnetic materials and to be oxidized are bland and suave, and actually some of them, such as aluminum, magnesium or calcium, or mixtures thereof, to substantial extent operate or behave as lubricants for the cutting tools or dies used to form or stamp elements, such as laminations or parts thereof, from a sheet or blank of metal-coated magnetic material particularly before oxidation of the coating metal or metals; with the result there is no adverse effect on the life of the cutting tools or dies, because by use of such coating metals wear of the tools or dies is greatly reduced. Furthermore the use of such coating metals dispenses with the need of application of oil or grease as a lubricant, which must be removed from the stampings or elements, before they are annealed, usually by resort to degreasing chemicals, followed by roasting. Particularly where the hydrogen annealing treatment aforesaid is to be restorted to, it is not permissible to allow oil or grease to remain on the parts or elements during the hydrogen anneal.

Heretofore it was observed that, in submitting the magnetic material to aforesaid annealing at high temperature in the presence of dry hydrogen, which produces an exceedingly bright and shiny surface on the annealed laminations or elements, neighboring laminations or elements tended to stick to each other, weld to each other, during the high temperature treatment, unless careful and therefore expensive precautions were taken to prevent such result.

In accordance with my invention such sticking or welding of laminations or elements to each other is prevented by the oxide of metal applied, before oxidation thereof, to the magnetic material.

It heretofore has been a practice to place powder, such as pure aluminum oxide (alumina), a highly refractory material, to prevent the aforesaid sticking or welding of neighboring laminations or pieces incident to the hydrogen annealing treatment. The labor involved in placing the alumina or the like between the laminations or other elements before subjecting them to high temperature, and completely removing the applied oxide after the laminations or elements have been subjected to high temperature for annealing or otherwise, in order further to operate upon them or prepare them for shipment, involves considerable expense, as well as processing hazards, elimination of both of which is effected by the practice of my invention.

The oxide self-adhering in accordance with my invention to the magnetic material proper serves also as surface insulation for the laminations or elements in prevention of interlamination or inter-element eddy current losses, and in addition maintains neighboring laminations or elements magnetically discrete, separated from each other to effect interlamination reluctance which restrains magnetic flux in each lamination or element from freely straying into undesired magnetic circuits or paths, as into the neighboring laminations or elements.

Practically all types of protective coatings of liquid heretofore commonly applied to the sheets or blanks of magnetic material before forming or die-stamping elements or laminations therefrom, have carried or contained either free or combined water, or contaminating chemical, which adversely affected the magnetic properties of the magnetic material in the course of annealing or other treatment. It has been found also the covering of the magnetic material with such a liquid coating apparently prevents the hydrogen annealing treatment from freely enough penetrating the liquid coating to the metal, which is the case also when the surface of the magnetic material is covered as aforesaid with dry powder, such as alumina. In my process however the application to the magnetic metal of a metal, such as aluminum, calcium, magnesium or the like, in a film or coating itself adhering or bonded to the magnetic material and thin enough to be discontinuous, porous or perforate permits the penetration and action of the hydrogen, the purpose and function of the hydrogen being twofold, first, to prevent undue oxidation of the surface of the magnetic material at the high temperature employed and to reduce the minute quantities of sulphur, carbon, phosphorous and oxygen at or within the surface of a magnetic alloy, and, second, apparently by reduction of such last-named impurities at the grain boundaries, to permit a grain growth better adapted to improve the magnetic properties of the magnetic material or alloy.

Referring to Figs. 1 and 2, S represents a base strip, sheet or blank of magnetizable material, of any suitable character or composition, including the compositions herein referred to, to which has been applied a coating C of any of the metals, or mixture of metals, of the class above described, which ultimately is to be oxidized in conversion of the applied metalic coating into a coating of oxide or oxides.

The metal may be in any suitable form, for example fine solid particles, rolled on or into the

magnetic material by passing it and the applied metal through rolls while cold, i. e. at any suitable temperature, preferably below that at which the applied metal will materially oxidize in the presence of air or other oxygen-containing gas; or the metal when applied may be soft or plastic; the amount of rolling or percentage reduction of thickness of the coated magnetic material may be chosen to govern and procure any desired final thickness of the applied metal or the final oxide thereof. The exposed surface of coating C after rolling, if resorted to, is or may be, as indicated in Fig. 2, quite smooth. Or the metal may be applied for example by a metallizing spray gun, such, for example, as now on the market; or the metal may be applied by electro-plating it on the magnetic material or sprayed thereon while molten; or by depositing or applying on the magnetic core material metallic aluminum, or equivalent, in suspension, or a solution of a compound or salt, of aluminum or equivalent, whose aluminum or equivalent separates or is separated with adherence thereof in metallic form to the magnetic core material.

The strip or sheet S, before application of the metal may first be prepared by roughening the surface to which the metal is to be applied, as by acid etching or sand blasting, or, preferably, by maintaining the base strip or blank S at a moderately elevated temperature, such as between 400° and 1000° F. at the time the particles of metal are sprayed on or otherwise applied to the sheet S. The metallic particles accordingly cling to the heated surface of sheet S and to sufficient degree themselves adhere thereto that the particles are not to any material extent lost in subsequent operations upon the coated sheet or strip S. The coated strip preferably is subjected to light rolling, as by passage between rolls, resulting in flattening out of the metal particles and forcing them into the grain of the sheet or strip S.

The applied metal is preferably self-adherent or bonded to the magnetic material, without recourse to adhesive or bonding material.

The gauge or thickness of the sheet S, or of the resulting laminations or elements stamped or formed therefrom may be anything suitable or desirable. For example where the laminations or elements are utilized in or as core structures which are influenced by alternating currents, or currents having alternating components, the gauge generally will be greatest for low frequencies of about 25 to 60 or more cycles per second, smallest for radio frequencies including ultra high frequencies, and of intermediate magnitude for frequencies, including audio, intermediate the low and radio frequencies. For radio frequencies the gauge of sheet S or of the ultimate laminations or elements may be of the order of from about .015'' down to about .006'', and even as thin as about .003''.

The applied metal coating may be continuous or substantially so, or it desirably may be sufficiently discontinuous, porous or perforate to permit access to the magnetic material itself, notwithstanding the applied metal and/or its oxide, of the hydrogen or equivalent in a subsequent annealing treatment of the coated magnetic material.

In any event the coating of metal upon the magnetizable material is preferably very thin, and applied usually only upon one side, or on both sides of the sheet or other mass S of magnetizable material. In general the coating C of metal, before oxidation, is of thickness preferably of the order of .0001'' to .0005'', or such that when ultimately oxidized the coating of the oxide of the applied metal is very thin, for example about .0001'' to about .0005'' thick.

After the magnetic material has been coated with metal, and preferably before any substantial oxidation of the metal, laminations elements or core parts which are to constitute or form layers or units eventually assembled to constitute a composite or laminated core structure, are stamped or formed from the coated sheet or mass S by dies or other suitable cutting or forming tools. Or, though generally not so desirable, the laminations or core parts may be stamped or formed from the mass S while uncoated by the metal, and the coating then applied to one or both sides and/or to the edges of the laminations or core parts individually or while grouped together in bulk in regular or irregular array.

The aluminum, magnesium, calcium or Dowmetal, and such others of aforesaid class to be oxidized in accordance with my invention, as are in suitable degree similarly bland or suave, have an effect which is comparable with lubrication, in that, without recourse to liquid or other lubricant, the stamping or formation of laminations or core elements may be effected with little or very much reduced wear upon the stamping dies or other cutting tools employed; a result which materially contributes to reduction in cost of the dies or cutting tools and their upkeep, and contributes materially to reduction of the ultimate or total cost of production of the stamping or forming of laminations or core elements.

Whether or not the coated magnetic material is to be annealed, as by dry hydrogen annealing treatment, it may be subjected to or roasted at temperatures ranging, for example, from about 1200° to about 1500° F., in the presence of air or other oxidizing gas or vapor to effect oxidation of at least a substantial part of the coating metal or, under suitable conditions of temperature the coating metal may be subjected to an oxidizing agent, to be fully and completely oxidized.

For improving the magnetic properties of the magnetizable material, as heretofore known in the art, it may be subjected to a suitable annealing treatment, preferably, usually, to a dry hydrogen or bright annealing treatment, characterized by subjecting the magnetic material to high temperature, for example about 2100° F., generally within the range from 2000° to 2500° F., in the presence of dry hydrogen which effects the desired annealing and causes the surfaces of the magnetic material to become bright and clean. The laminations or core elements, metal coated, as above described, may, whether or not the metal coating has theretofore been partially oxidized as above referred to, be enclosed in a container and annealed at the high temperature aforesaid, in the presence of a continuous flow of pure dry hydrogen in contact with the coated elements or laminations, which treatment alone, effects high or complete oxidation of the applied metal coatings, notwithstanding the presence of the hydrogen, which is a reducing gas. It is believed, without positively asserting, oxygen, molecular or nascent, is in sufficient quantity present or liberated in the annealing zone with resultant immediate or ultimate reaction with the coating metal to form the oxide or oxides thereof which are, preferably and usually, of such high and desirable stability that they are irreducible in the presence of the hydrogen. Where the metal coatings of the core elements or laminations are first par-

tially oxidized, as in the roasting treatment aforesaid, they become fully oxidized in a subsequent dry annealing treatment, heretofore described.

The oxide or oxides, of the applied metal or metals, are self-adherent, like the applied metal, to the core elements or laminations; they prevent the welding or sticking to each other of the laminations or elements of magnetic material otherwise occurring as a result of the high temperature annealing treatment; prevention of such sticking or welding is a principal object of my invention, in that heretofore it has been common practice to apply, pack or maintain between the core elements or laminations, in advance of subjecting them to high temperatures, as in the dry hydrogen annealing treatment, powder or granules of stable oxide or oxides, including alumina; as compared with the expense incident to such practice, my method is very much cheaper, because of the time and labor saved. As compared with the cost of prior practice of annealing operations involving the packing of the core elements ar laminations in alumina or the like, in preparation for the annealing treatment, and in cleaning off the alumina or the like after the annealing treatment and in preparation for shipment of the annealed parts, the labor and cost when following my herein described method may be reduced to one-fifth, and even one-tenth, of the cost of aforesaid prior practice.

Furthermore by practice of my method there remains self-adherent or bonded to the laminae or core elements the oxide or oxides of the coating metal or metals referred to, which are highly insulating in character, preventing electric conduction between adjacent surfaces of distinct elements or laminations, preventing core losses of the type known as eddy currents, and preventing magnetic fluxes from straying from their desired assigned paths, in effect maintaining each lamination or core element in the desired assigned isolation from its neighbors.

My invention is applicable not only to core elements or laminations stamped or formed from sheet material, but is applicable as well to the case where a ribbon or strip of magnetizable material is formed or wound into a spiral, in which case the oxide or oxides of the applied metal or metals on either or both sides of the ribbon or strip magnetically and electrically isolate from each other the neighboring surfaces of neighboring turns or convolutions, thereof, as in the case of stampings which are generally relatively short or small, as compared with the length or bulk of a spiral or helix of core material.

The oxides of the applied metals constitute in a sense a porous coating, more or less continuous, which property makes possible application to the annealed laminations of materials of distinctive colors, each having its own significance, such, for example, as identifying the nature, quality or a characteristic of the laminations.

In the appended claims the term "lamination" includes magnetic core elements in general, and those in sheet form stamped or otherwise formed from sheet core material.

What I claim is:

1. A method of producing ferro-magnetic core laminations having increased permeability resulting from high temperatre treatment in hydrogen which comprises applying to at least one face of a sheet of ferro-magnetic core material a discontinuous coat of a substance selected from the group consisting of aluminum, magnesium and calcium whereby a perforate coated sheet is formed permitting access to ferro-magnetic material in exposed porous areas and in the uncoated edges, forming laminations from the perforate coated sheet with uncoated edges, and subjecting the perforate coated laminations with porous areas and uncoated edges to a high temperature treatment in the presence of an oxygenated atmosphere containing hydrogen and at a temperature of at least 2000° F. to cause reduction of material in porous areas and uncoated edges of said ferro-magnetic material while at the same time oxidizing said substance of said discontinuous coating whereby the permeability of the ferro-magnetic material is increased and the said substance is oxidized to form a self-adherent discontinuous coating preventing the sticking of one lamination with a neighboring one during the aforesaid high temperature operation and preventing electric conduction from one lamination to a neighboring one, preventing core losses and preventing magnetic fluxes from straying when said laminations are subsequently used in core structures subjected to alternating currents.

2. A method of producing ferro-magnetic core laminations having increased permeability resulting from high temperature treatment in hydrogen which comprises applying to at least one face of a sheet of ferro-magnetic core material a discontinuous coat of at least one metal selected from the group consisting of aluminum, magnesium and calcium whereby a perforate coated sheet is formed permitting access to ferro-magnetic material in exposed porous areas and in the uncoated edges and whereby said coating substance provides lubricant for cutting tools, cutting laminations from the perforate coated sheet leaving the cut edges of said laminations in an exposed uncoated condition, and subjecting the cut perforate coated laminations with porous areas and uncoated edges to a high temperature treatment in the presence of an oxygenated atmosphere containing hydrogen and at a temperature of at least 2000° F. to cause reduction of material in porous areas and uncoated edges of said ferro-magnetic material while at the same time oxidizing said substance of said discontinuous coating whereby the permeability of the ferro-magnetic material is increased and the said substance is oxidized to form a self-adherent discontinuous coating preventing the sticking of one lamination with a neighboring one during the aforesaid high temperature operation and preventing electric conduction from one lamination to a neighboring one, preventing core losses and preventing magnetic fluxes from straying when said cut laminations are subsequently used in core structures subjected to alternating currents.

3. A method of producing ferro-magnetic core laminations having increased permeability resulting from high temperature treatment in hydrogen which comprises applying to at least one face of a sheet of ferro-magnetic core material a discontinuous coat of a substance selected from the group consisting of aluminum, magnesium and calcium whereby a perforate coated sheet is formed permitting access to ferro-magnetic material in exposed porous areas and in the uncoated edges and whereby said coating substance provides lubricant for stamping tools, stamping laminations from the perforate coated sheet leaving the stamped edges of said laminations in an exposed uncoated condition, stacking said stamped laminations over one another to form a pile thereof and subjecting the pile of stamped

perforate coated laminations with porous areas and uncoated edges to a high temperature treatment in the presence of an oxygenated atmosphere containing hydrogen and at a temperature of at least 2000° F. to cause reduction of material in porous areas and uncoated edges of said ferro-magnetic material while at the same time oxidizing said substance of said discontinuous coating whereby the permeability of the ferro-magnetic material is increased and the said substance is oxidized to form a self-adherent discontinuous coating preventing the sticking of one lamination with a neighboring one during the aforesaid high temperature operation and preventing electric conduction from one lamination to a neighboring one, preventing core losses and preventing magnetic fluxes from straying when said stamped laminations are subsequently used in core structures subjected to alternating currents.

4. A method of producing ferro-magnetic core laminations having increased permeability resulting from high temperature treatment in hydrogen which comprises roughening at least one surface of a ferro-magnetic blank to provide a rough surface, metallizing at least said roughened surface with a very think, discontinuous, self-adherent coat of a substance selected from the group consisting of aluminum, magnesium and calcium whereby a perforate coated sheet is formed permitting access to said ferro-magnetic material in exposed areas and in uncoated edges and whereby said coating substance provides lubricant for stamping tools, light rolling said ferro-magnetic blanks provided with said discontinuous coating, stamping laminations from the perforate coated blank leaving the stamped edges of said laminations in an exposed uncoated condition, stacking said stamped laminations over one another to form a pile thereof, roasting said pile of stacked laminations at a temperature of at least 1200° F. in the presence of an oxygen-containing atmosphere to effect oxidation of said discontinuous coating substance to provide a discontinuous porous oxide coating preventing the sticking of neighboring laminations to each other and subjecting the stamped perforate coated laminations with porous areas and uncoated edges to a high temperature treatment in the presence of an atmosphere containing hydrogen and oxygen and at a temperature of at least 2000° F. to cause reduction of material in porous areas and uncoated edges of said ferro-magnetic material while at the same time oxidizing said substance of said discontinuous coating whereby the permeability of the ferro-magnetic material is increased and the said substance is oxidized to form a self-adherent discontinuous coating preventing the sticking of one lamination with a neighboring one during the aforesaid high temperature operation and preventing electric conduction from one lamination to a neighboring one, preventing core losses and preventing magnetic fluxes from straying when said stamped laminations are subsequently used in core structures subjected to alternating currents.

5. In the method of producing a core element having a base of magnetic material and having a high permeability resulting from high temperature treatment in the presence of hydrogen which comprises applying to at least one face of said base of magnetic material a discontinuous coat of a non-ferrous metal capable of being converted into an oxide irreducible in the presence of hydrogen at temperatures up to at least about 2500° F. whereby a perforate coated base material is formed permitting access to magnetic material in exposed porous area, and subjecting the perforate coated core element with porous areas to a high temperature treatment in the presence of an oxygenated atmosphere containing hydrogen and at a temperature of at least 2000° F. to cause a reduction of the magnetic material in said porous areas while at the same time oxidizing said non-ferrous metal of said discontinuous coat whereby the permeability of the magnetic material is increased and said non-ferrous metal is oxidized to form a self-adherent discontinuous coating preventing the sticking of one core element with a neighboring one during the aforesaid high temperature operation and preventing electric conduction from one core element to a neighboring one, preventing core losses, and preventing magnetic fluxes straying when said core elements are subsequently used in core structures subjected to alternating currents.

6. As a new article of manufacture, a core element having high permeability resulting from high temperature treatment in hydrogen comprising a ferro-magnetic base material and a self-adherent, perforate coating of oxide products covering at least one face of said base material and consisting of at least one oxide of a metal selected from the group consisting of aluminum, magnesium and calcium, said oxide coating being discontinuous and exposing porous areas of said ferro-magnetic base material while being sufficiently stable not to be reduced by hydrogen at a temperature of at least 2000° F. whereby the permeability of the ferro-magnetic material is increased and the said substance is oxidized to form a self-adherent discontinuous coating preventing the sticking of one lamination with a neighboring one during the aforesaid high temperature operation and preventing electric conduction from one lamination to a neighboring one, preventing core losses and preventing magnetic fluxes from straying when said laminations are subsequently used in core structures subjected to alternating currents.

7. A method of producing ferro-magnetic core laminations having increased permeability resulting from high temperature treatment in hydrogen which comprises applying to at least one face of a sheet of ferro-magnetic core material a discontinuous coat of a non-ferrous metal which forms an adherent oxide coating sufficiently stable not to be reduced in an oxygenated atmosphere containing hydrogen at temperatures up to at least 2500° F., whereby a perforate coated sheet is formed permitting access to ferro-magnetic material in exposed porous area and in the uncoated edges, forming laminations from the perforate coated sheet with uncoated edges, and subjecting the perforate coated laminations with porous areas and uncoated edges to a high temperature treatment in the presence of an oxygenated atmosphere containing hydrogen and at a temperature of at least 2000° F. to cause reduction of material in porous areas and uncoated edges of said ferro-magnetic material while at the same time oxidizing said substance of said discontinuous coating whereby the permeability of the ferro-magnetic material is increased and the said substance is oxidized to form a self-adherent discontinuous coating preventing the sticking of one lamination with a neighboring one during the aforesaid high temperature operation and preventing electric conduction from one lamination to a neighboring one, preventing core losses and preventing magnetic fluxes from stray-

ing when said laminations are subsequently used in core structures subjected to alternating currents.

8. As a new article of manufacture, a core element having high permeability resulting from high temperature treatment in hydrogen comprising a hydrogen, heat treated base of magnetic material, and a perforate, oxide coating self-adherent to said base and covering at least one face thereof, said oxide coating resulting from the oxidation of a non-ferrous metal the oxide of which is sufficiently stable not to be reduced by hydrogen at temperatures up to at least about 2500° F., said coating being self-bonded to said base and being chemically stable and irreducible in the presence of hydrogen at a temperature of at least about 2000° F. whereby the permeability of the ferro-magnetic material is increased and the said substance is oxidized to form a self-adherent discontinuous coating preventing the sticking of one lamination with a neighboring one during the aforesaid high temperature operation and preventing electric conduction from one lamination to a neighboring one, preventing core losses and preventing magnetic fluxes from straying when said laminations are subsequently used in core structures subjected to alternating currents.

9. As a new article of manufacture, a lamination of magnetic material having high permeability resulting from high temperature treatment in hydrogen comprising a magnetic base material with exposed edges and with a thickness ranging from about .003'' to about .015'' and a self-adherent, perforate coating of about .0001'' to about .0005'' in thickness on at least one surface of said lamination and consisting of oxide products of a substance selected from the group consisting of aluminum, magnesium and calcium, bonded to said base material and converted in situ into stable oxide by a high temperature treatment at a temperature of at least 2000° F., said coating being discontinuous and exposing porous areas of said magnetic base material while being chemically stable and irreducible in the presence of hydrogen at a temperature of at least 2000° F. whereby the permeability of the ferro-magnetic material is increased and the said substance is oxidized to form a self-adherent discontinuous coating preventing the sticking of one lamination with a neighboring one during the aforesaid high temperature operation and preventing electric conduction from one lamination to a neighboring one, preventing core losses and preventing magnetic fluxes from straying when said laminations are subsequently used in core structures subjected to alternating currents.

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