Jan. 5, 1937. W. M. BISHOP 2,066,515

METHOD OF HEAT TREATING MAGNETIC MATERIALS

Filed July 6, 1934

FIG. 1

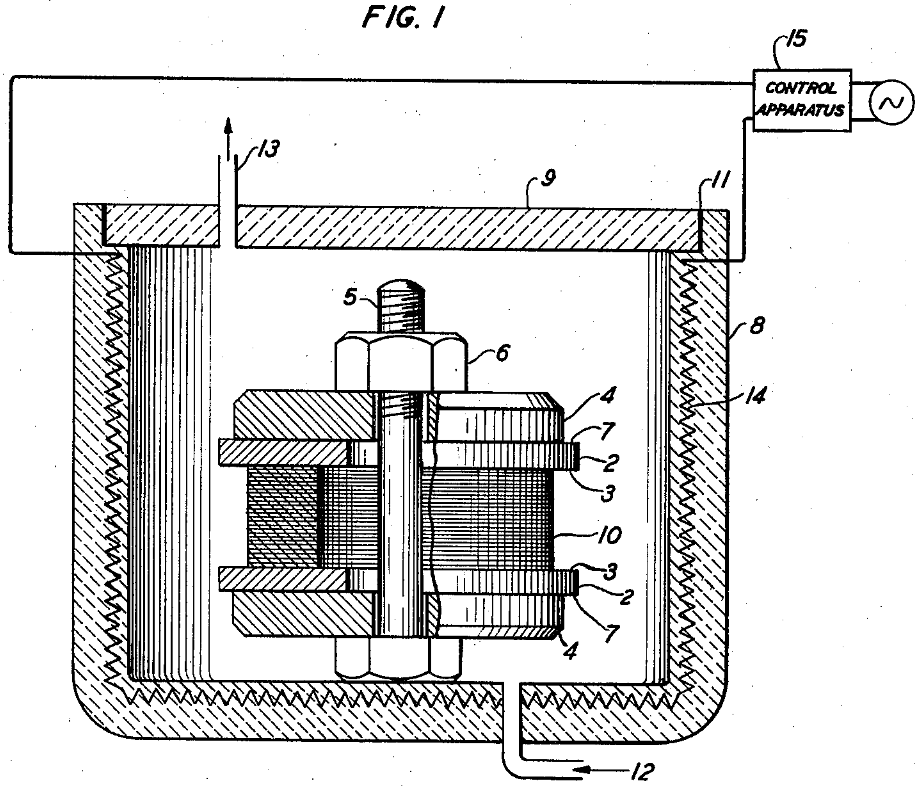
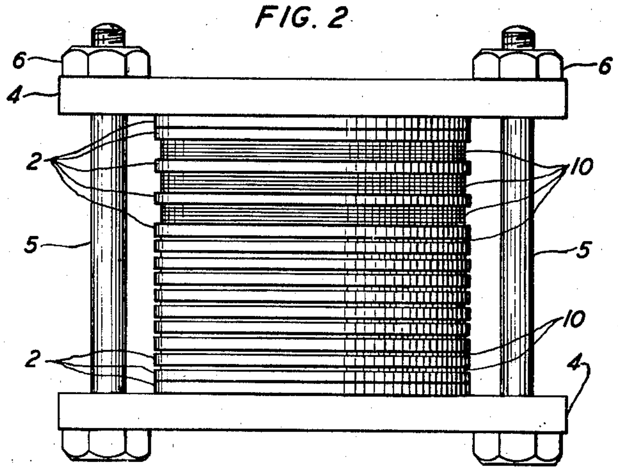


FIG. 2



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METHOD OF HEAT TREATING MAGNETIC MATERIALS

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1 Claim. (Cl. 148—13)

This invention relates to a method of improving the magnetic properties of magnetic materials and more particularly to a method of increasing the permeability of thin sheets or laminations of magnetic material as used for the cores of transformers, loading coils, and inductances as well as diaphragms for telephone receivers and other parts of magnetic circuits. It has been known for some time that thin sections or laminations of approximately ten thousandths of an inch or less in thickness behave differently magnetically than thicker laminations of the same material. The most noticeable difference is the lower permeability of the thin laminations. The permeability appears to decrease as the thicknesses decrease.

The object of this invention is to provide a method whereby the permeability of these thin laminations may be materially increased.

A further object of the invention is to remove the stresses and strains in the completely formed laminations and laminated core.

In brief, the method consists in clamping a stack or core of completely formed laminations between blocks of the same material as said laminations or a material having substantially the same coefficient of expansion as said laminations and then heat treating the clamped stack of laminations.

In order that the invention may be more fully understood an embodiment of it will now be described with reference to the attached drawing of which:

Fig. 1 shows one method of practicing this invention on one specific type of core; and

Fig. 2 shows another arrangement for practicing the invention.

The term lamination as used in this specification refers to any thin sheet, member, or section of a magnetic circuit and includes cores or portions of cores for transformers, loading coils, inductances, relays, electromagnets, and also thin sections or portions of magnetic circuits such as diaphragms for telephone receivers.

Referring to Fig. 1, 10 represents a stack of laminations which are clamped between blocks 2—2. These laminations may be individually dusted or insulated with some refractory powder such as quartz dust to prevent them from sticking together. Any suitable number may be clamped in a stack; as for example, the number required for a single core; some extra laminations in addition to those necessary for a complete core, or enough laminations to form a number of cores may be stacked and clamped between the blocks 2—2. If these blocks or washers 2—2 are not of sufficient thickness, other blocks or washers 4—4 may be provided to further increase the strength of washers 2—2 so that they will not be deformed by the clamping action of bolt 5 and nut 6. Blocks 2—2 may be of the same dimensions or area as the laminations or of any other suitable dimensions. In case washers 2—2 are of sufficient thickness and strength, it will not be necessary to provide the additional washers or blocks 4 to more evenly-distribute the clamping forces to the laminations 10. After the laminations have been placed between blocks 2—2 which in turn are placed between blocks 4—4, bolt 5 is inserted and nut 6 tightened to firmly clamp laminations 10 between the blocks 2—2 with a greater force than the weight of the laminations and clamp. The laminations are then heat treated by placing them in a heat treating furnace. After the material has been heated, it is usually allowed to cool slowly.

A suitable furnace for heat treating clamped laminations is represented by 8 in Fig. 1. Top 9 is provided to completely enclose the laminations. In case it is desired to heat treat the material in a controlled atmosphere, such as a N_2,H_2,A, He, Ne, CO, CO_2CH_4 or other inert or hydrocarbon gases and vapors either alone or in combination atmosphere, top 9 may be sealed to furnace 8 at 11 in any suitable manner. Pipe 12 is then connected to a supply of gas or vapor to be used during heat treatment. The excess escapes at 13 where it may be burned if it is combustible. The furnace may be heated in any manner, as for example, by heating wires 14 which are connected to a source of electrical power through switching and regulating mechanism 15. The material is thus heated to a high temperature in a controlled atmosphere after which it is usually allowed to slowly cool in this atmosphere, but need not be so cooled.

In case the laminations to be treated are in the form of diaphragms, it may be desirable to employ a plurality of washers 2—2 of the same material as the laminations or diaphragms. These washers are distributed throughout the stack between the laminations to insure that each lamination or diaphragm will be very flat after the heat treatment.

This arrangement is illustrated in Fig. 2. At the top of this stack a washer 2 is inserted between each five laminations or sheets while at the bottom of the stack a washer is placed between each lamination. It is to be understood, however, that as many or as few washers 2 are provided as are needed. In case it is necessary to have extremely flat laminations or sheets, it may be desirable to provide a washer between each lamination as shown in the bottom of the stack of Fig. 2. In other cases one washer every five or more laminations may be all that is required.

If the material of washers 2 is different or has a different coefficient of expansion than that of laminations 10, frictional forces between the laminations and the washers will cause stresses and strains to be set up within laminations 10 during the cooling time due to the change in the relative dimensions of the laminations and washers. These strains will greatly reduce the permeability of the laminations. By using blocks 2—2 of the same material or a material having the same thermal coefficient of expansion as the laminations 10, these forces and thus these stresses are largely eliminated.

In order that the stresses and strains may be further eliminated, if necessary, the surfaces of blocks 2—2, such as 3, may be made smooth or polished so that small frictional forces, that may be due to differences in cooling rates of washers 2—2 and laminations 10, may be easily removed by slipping or sliding of the washers relative to laminations 1. Thus the stresses or strains will not be transferred to the laminations to cause a reduction of their permeability. In some cases the other surface 7 of blocks 2—2 and even the adjacent surfaces of block 4 may be polished if desirable. This readily enables relative motion to be made between the various components of the clamp to relieve the stresses and strains set up due to differences in the cooling rates and the different coefficients of expansion of the various members of the clamp. In other cases it may be desirable to laminate washers 2—2 or employ more than one on each side of the stack of core laminations as shown at the ends of the stack in Fig. 2. In addition, it may be necessary to discard some of the laminations adjacent to the clamping surfaces if the frictional forces between the clamping surfaces and adjacent laminations are still large enough to materially reduce the permeability of these laminations. These discarded laminations may be used repeatedly as the laminated washers to take up all the frictional forces tending to strain the core laminations during cooling. However, the discarded laminations may be reheat treated in the next lot and then utilized as magnetic sheets.

This method of heat treating thin laminations for magnetic cores has the further advantage that the surfaces of these laminations are in contact with similar materials and thus do not readily become contaminated from the clamping blocks, refractories or other material including furnace gases. Neither does the material nor its constituents evaporate during the heat treatment. The composition, therefore, will remain substantially the same throughout the lamination.

This manner of treating laminations has been found to materially increase the permeability of thin laminations. For example, in the specific case of laminations three thousandths of an inch thick of an alloy comprising 78½% nickel, 3.8% molybdenum and the remainder iron when heat treated in the normal manner have an initial permeability of less than 7000. However, when laminations of this same material only one thousandth of an inch thick are heat treated when clamped together as described above, they have an initial permeability of approximately 10,000 which is very close to the permeability of the material in much thicker sections or laminations.

In another case laminations approximately two thousandths of an inch thick made of an alloy comprising approximately 45% nickel and the remainder chiefly iron were clamped together in accordance with this invention and heated in a furnace which was maintained at 1000° C. for an hour and then allowed to slowly cool. A hydrogenous atmosphere was maintained in the furnace during this time. The initial permeability of these laminations after this treatment is about the same as for thicker laminations and is given in the following Table A.

Table A

Specimen	μ_0	Remarks
27	1900	Lightly clamped
29	2470	Tightly clamped
30	2750	Tightly clamped
33	2190	Tightly clamped

This manner of treating magnetic materials will also improve other magnetic properties in addition to the permeability. For example, the iron-nickel-cobalt alloys characterized by a substantially constant permeability at low magnetic fields are improved by a heat treatment in accordance with this invention. These alloys usually react to various treatments in an opposite manner to the usual magnetic materials. The initial permeability μ_0 is increased by cold working, strains produced by reducing them to thin laminations. In addition, the permeability is not constant at low fields. The constancy is sometimes designated λ which is defined as

$$\lambda = \frac{\mu - \mu_0}{\mu_0 B_m}$$

where μ_0 is the initial permeability and μ the permeability in the field in which the material is used or tested and B_m the maximum value of induction in the material in this field. The following Table B lists these factors for laminations two thousandths of an inch thick made from an alloy comprising approximately 37% nickel, 25% cobalt, 7.5% molybdenum, and the balance chiefly iron which have been clamped together in accordance with this invention and heated in a hydrogenous atmosphere in a furnace which was maintained at 1000° C. for one hour and then allowed to slowly cool.

Table B

Specimen	μ_0	$\lambda \times 10^4$	Remarks
20	1070	9.0	Lightly clamped.
21	1535	9. approximate	Lightly clamped.
24	895	1.7	Lightly clamped.
25	1233	13.6	Lightly clamped. First heat treated.
25	865	1.9	Lightly clamped. Heat treatment repeated.
28	930	.35	Tightly clamped.
31	937	.30	Tightly clamped.
32	890	.50	Tightly clamped.

The values obtained for the tightly clamped specimens listed in both Tables A and B are substantially the same as those for much thicker specimens of the same alloys heat treated without being clamped.

The foregoing description is to illustrate the features of the invention but is not to limit or restrict the scope of the appended claim.

What is claimed is:

A method of manufacturing a magnetic core composed of a considerable number of laminations of highly strain sensitive magnetic material less than 0.003 inch in thickness which comprises stacking a sufficient number of completely formed laminations together to form a complete magnetic core, forcibly clamping said completely assembled core between flat smooth-faced blocks of material having the same coefficient of expansion with temperature as the laminations, heat treating and cooling said core while so clamped to increase the permeability of the material of said core.

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