United States Patent

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[33] **Japan**
[31] **41/85381**

[54] **MAGNETIC ALLOY AND CORE**
8 Claims, 7 Drawing Figs.

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[51] **Int. Cl.** **H01f 1/14,** H01f 3/02, C22c 19/00
[50] **Field of Search** ..... 75/123 K, 126 F, 170; 148/31.57, 31.55, 108, 120, 121

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ABSTRACT: A magnetic alloy consisting essentially of less than 30 weight percent of cobalt, less than 30 weight percent of iron, less than 5 weight percent of a metal selected from the group consisting of copper and molybdenum, and the balance being essentially nickel and cores made therewith. The alloy has a Curie point greater than 620° C. and excellent rectangular hysteresis loop characteristics, such as, a Br/B_{10} value greater than about 90 percent.

FIG. 1

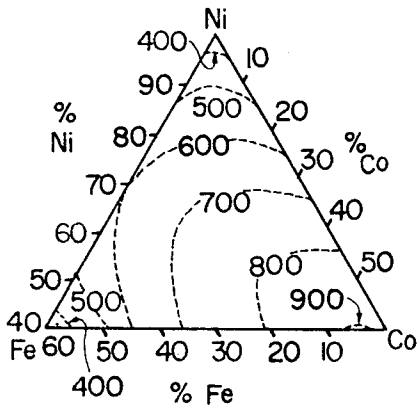


FIG. 2

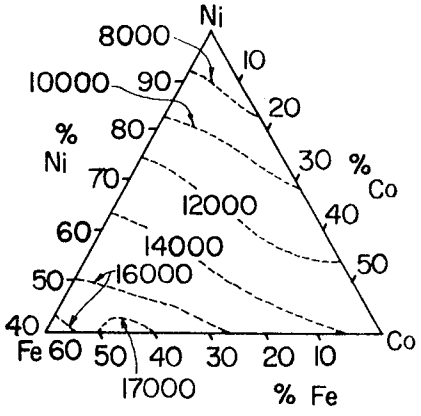


FIG. 3

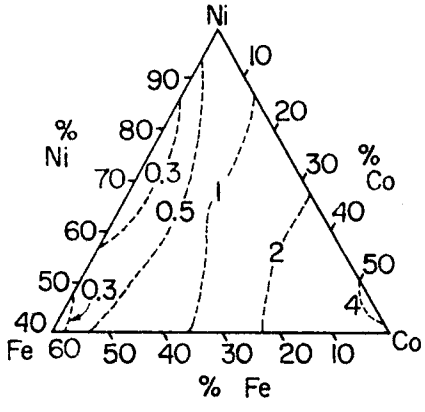
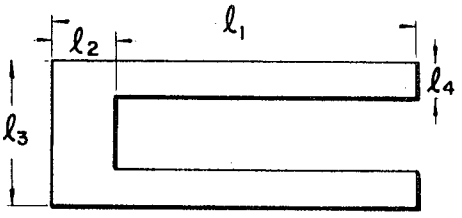


FIG. 4



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FIG. 5

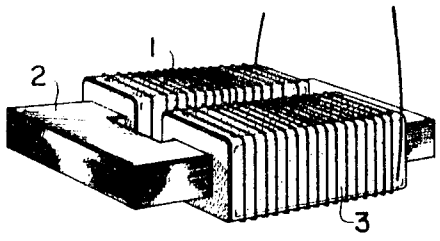


FIG. 6

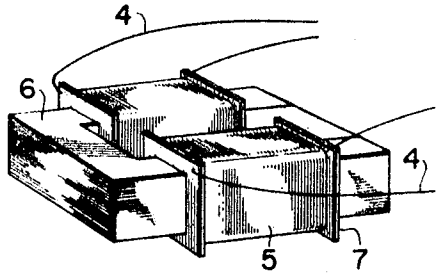
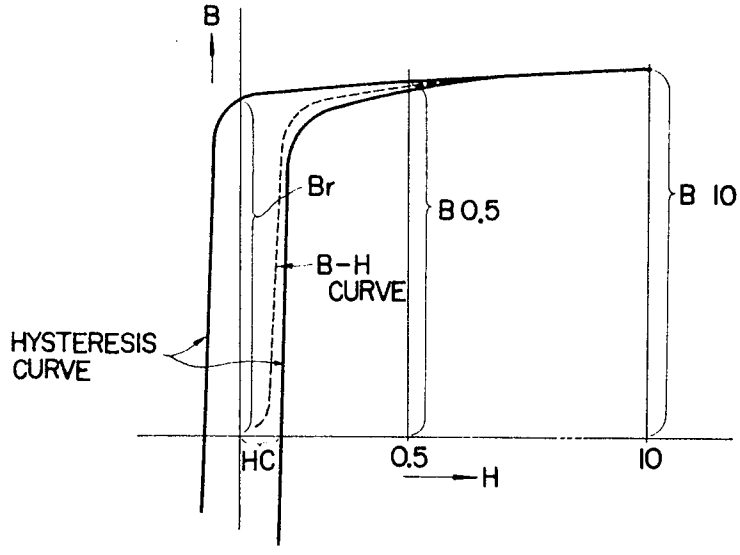


FIG. 7



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MAGNETIC ALLOY AND CORE

BACKGROUND OF THE INVENTION

The present invention relates to a magnetic alloy and, more particularly, to a magnetic alloy having rectangular hysteresis loop characteristics to be used in saturable rector cores.

Saturable reactor cores to be employed in magnetic devices for automatic control or instrumentation, such as a magnetic amplifier or a magnetic multivibrator, are required to have a hysteresis loop characteristic which is as nearly rectangular as possible. On the other hand, in order to exhibit the most effective magnetic characteristics, anisotropic material has been formed into a toroidal core so that in the magnetic path there is no air gap that has a detrimental effect on the rectangular hysteresis loop characteristics of the core. Material such as oriented 50–Permalloy or oriented Si-steel sheet, which has orientation achieved by rolling and annealing, is most preferably used as a toroidal core.

From the standpoint of use, however, toroidal cores have certain disadvantages in their difficult winding operation and their poor space factor when assembled in a circuit device, as compared with the usual laminated cores punched out in E, I-type. Therefore, development of punched laminated cores having superior rectangular hysteresis loop characteristics has been desired for a long time.

Magnetic properties which are required for cores to be used in magnetic amplifier or magnetic multivibrators may be listed as follows:

1. Large magnetic flux density.

If a core material has a large magnetic flux density, a small sectional area of the core can be sufficient for a predetermined magnetic flux and the size of the device can be reduced greatly.

2. Small coercive force.

To have a large coercive force is not advantages for a core material since it requires a proportionally large exciting current. Furthermore, a large coercive force increases power loss in an alternating magnetic field and results in a temperature rise of the core.

3. Rectangular hysteresis loop characteristics.

Core material for magnetic amplifiers or magnetic multivibrators is required to have such hysteresis loop characteristics that the rise of magnetization curve is sharp and the approaching portions of the curve to the saturation of magnetization are flat.

Generally speaking, a saturable reactor is required to have a rectangular ratio Br/Bm or Bk/Bm greater than 0.9, where Br is the residual magnetic flux density, Bk is the magnetic flux density at the knee point of the magnetization curve, and Bm is the maximum magnetic flux density.

4. Small temperature coefficient of magnetic properties.

A metallic magnetic substance has a distinguished merit with respect to small temperature coefficient of magnetic properties as compared with ferrite (an oxide magnetic substance). Although even metallic substances have different temperature coefficients according to the compositions of the alloys thereof, the change of magnetic properties of cores should be as small as is practicably possible when they are used as circuit elements for automatic control or instrumentation.

5. Large electrical resistivity.

When the core is placed in an alternating magnetization field, the resulting eddy current loss is inversely proportional to the electrical resistivity of the core material. Therefore, its electrical resistivity should be as large as is practically possible.

6. Small change in magnetic properties owing to external stress.

Although core material of both a small coercive force and rectangular hysteresis loop characteristics tends to change its magnetic properties owing to an external stress, as small a change in magnetic properties as possible is desirable from the practical point of view.

SUMMARY OF THE INVENTION

Accordingly, it is the main object of the present invention to provide a new magnetic alloy having superior rectangular hysteresis loop characteristics.

Another object of the invention is to provide a core material of rectangular hysteresis loop characteristics which substantially satisfies most of the above-mentioned requirements.

Still another object of the invention is to provide a core material of the above character which essentially satisfies all of the six requirements above-mentioned.

Still a further object of the present invention is the provision of a punched core element of the above character which has the advantage of an easy winding operation.

According to the invention, there is provided a magnetic alloy consisting essentially of a FE-Co-Ni system alloy which less than 5 weight percent of Mo or Cu is and which has a Curie point higher than 620° C. This alloy is effectively influenced by magnetic annealing treatments.

These and other objects and features of the invention will be apparent from the following drawings and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows the Curie points of Fe-Co-Ni system alloys plotted as a Fe, Co, Ni ternary phase diagram;

FIG. 2 shows spontaneous magnetizations of the same alloys plotted similarly to FIG. 1;

FIG. 3 shows coercive forces of the same alloys plotted similarly to FIG. 1;

FIG. 4 is a plan view showing a U-shaped core element made of a magnetic alloy according to the invention;

FIG. 5 is an explanatory view to show a magnetic annealing treatment of a core constructed by lamination of the core elements shown in FIG. 4;

FIG. 5 is an explanatory view to show a magnetic annealing treatment of a core constructed by lamination of the core elements shown in FIG. 4;

FIG. 6 is a perspective view of a core constructed by lamination of the U-shaped core elements according to the invention; and

FIG. 7 shows a part of a magnetization curve to explain the definition of the rectangular ratio Br/Bm or Bk/Bm.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As noted above, the applicants have provided Fe-Co-ni system alloys to develop a core material of rectangular hysteresis characteristics which satisfies the six requirements previously pointed out, have adopted the magnetic annealing treatment to achieve its rectangular hysteresis characteristics, and have studied the shapes of a core element about the same, such as U shape, ring shape and the like. Next will be explained the magnetic properties of Fe-Co-Ni alloys in reference to ternary phase diagrams as a basis for this invention.

FIGS. 1, 2 and 3 show the Curie points, spontaneous magnetization (in Gauss) and coercive forces (in Oersted), respectively, of Fe-Co-Ni system alloys. These drawings are derived from the book "Ferromagnetism," written by R. M. Bozorth and published by D. Van Nostrand Co. in 1951. As will be clear from the drawings, if the amount of Ni is greater than 50 weight percent, the Curie point increases as the amount of Co increases. On the other hand the Curie point decreases rapidly as the amount of Fe increases beyond 30 weight percent. Where Co <30% and Fe <10% the spontaneous magnetization of the alloys decreases to a large extent and where Co >30% and FE <10%, the coercive forces of the alloys are large. It will be apparent that the closer to 1 that the atomic ratio of Ni and Co plus Fe is, the larger is the induced magnetic anisotropy due to the magnetic annealing treatment, and that the higher the Curie point of the alloy, the lower is the temperature coefficient of the magnetic properties thereof.

In order to satisfy the objects of the invention, possible ranges of compositions of alloy will be limited to such Fe-Co-Ni system alloys that Fe plus Co <50%, 10% <Fe <30 %, and the amount of Ni is not excessively great, preferably less than 80 weight percent in view of its practical amount insofar as spontaneous magnetization is concerned. The amounts of Co and Fe contents do not include zero percent.

Increased amounts of Co in such Fe-Co-Ni system alloys result in increasing the Curie points and an improvement of the induced magnetic anisotropy, while the increased amount of Co not only makes its coercive force large, but also its coefficient of magnetostriction so large that its magnetic properties tend to change because of an external stress. Accordingly, the amount of cobalt should be limited to less than 30 weight percent.

On the other hand, if the amount of cobalt in the alloy is too small, the Curie point and the spontaneous magnetization of the alloy decrease considerably and superior magnetic properties cannot be expected. To accomplish the foregoing objects of the present invention, it is necessary that the amount of cobalt be more than at least 5 weight percent. Preferred amounts thereof are within the range of from 7 to 21 weight percent.

From the foregoing observations, it will be clear that desirable Fe-Co-Ni system alloys have such composition ranges that 50 %<Ni <80 %, 5 %<Co <30 %, and 10 %<Fe<30 %. These alloys, however, have a disadvantage in that, because of their small electrical resistivity, they cannot satisfy the six requirements previously pointed out, and they cannot be suitably used in magnetic devices such as a magnetic amplifier or a multivibrator where a small power loss is required.

In order to solve this problem of small electrical resistivity, many studies and experiments were carried out and the applicants found that the addition of a proper amount of either molybdenum or copper is effective for increasing the electrical resistivity of the alloy. Furthermore, the addition of Mo or Cu has been found to be effective for improving the rectangular hysteresis characteristics thereof. One of the objects of the invention is not only to improve the magnetic properties of an alloy, such as the coercive force and rectangular ratio, but also to increase the electrical resistivity thereof; this can be attained by the addition of less than 5 weight percent of either molybdenum or copper to the base alloy. Furthermore, if core material according to the invention is employed, a core to be used in a magnetic amplifier or a multivibrator can be formed in a U-shape, which still retains the desired rectangular hysteresis loop characteristics thereby greatly improving the space factor and making the winding operation quite simple and easy.

EXAMPLES OF THE INVENTION

The following examples are given merely as illustrative of the present invention and are not to be considered as limiting. Unless otherwise noted, the percentages therein are by weight.

EXAMPLE I

Fifteen different alloys (Sample Nos. 1–15,shown in table 1) were produced by melting in a vacuum. Electrolytic Fe, Co, and Ni of very high purity were used in preparing the alloys and, as for molybdenum and copper, element metals of very high purity were also used.

An ingot was made into a billet of a thickness of 10 mm. by hot working which was in turn intermediately annealed and rolled into a plate of final thickness of 0.3 mm. by cold rolling. Subsequently, ring samples of an outer diameter of 45 mm. and an inner diameter of 33 mm. were punched out from the plate and were utilized for experimentation. In order to reduce the strain caused by working, the samples were annealed at a temperature greater than 900° C. in a hydrogen gas atmosphere so as to prevent oxidation of the samples or contamination of the samples by the atmosphere. Subsequently, the samples were subjected to a magnetic annealing treatment. First, a ring core was wound with a coil to produce a magnetic field therein and was heated again up to 700° C. The core was cooled gradually under the magnetic field from 700° C. to 400° C., wherein the cooling rate is about 25° C. /hr. — 200° C. /hr. and the strength of the magnetic field is about 2–8 oersteds.

Table 1 shows the magnetic flux density B10, rectangular ratios Br/B10 and BO.5/B10, coercive force Hc, the Curie point Tc, electrical resistivity $\rho(\mu\Omega\text{-cm.})$ cm.) and temperature coefficient of the magnetic flux density α_{B10} of each sample when it was annealed at 1,100° C. for 2 hours, heated again up to 700° C. and kept there for one-half hour and thereafter cooled under a magnetic field of 5 oersteds to 400° C. at a cooling rate of 100° C. /hr. In the table, α_{B10} is an average temperature coefficient between −20° C. and +30° C., and B10, Br/B10,BO. 5/B10 are determined according to an indication of magnetization values as shown in FIG. 7. The superiority of rectangular hysteresis characteristics can be seen by the extent of closeness of the values of Br/B10 and BO. 5 /B10 to 100 percent.

TABLE 1

Sample No.	Chemical compositions in weight percent	B10 (kg.)	Br/B10 (percent)	B0.5/B10 (percent)	Hc (oe.)	Tc (° C.)	δ ($\mu\Omega$-cm.)	α_{B10}
1	7Co-25Fe-Ni	12.7	86.6	90.4	0.047	680	17.3	-2.6×10^{-4}
2	7Co-23Fe-2Mo-Ni	12.1	90.6	93.8	0.041	630	35.1	-2.5×10^{-4}
3	7Co-23Fe-2Cu-Ni	12.2	93.2	98.0	0.030	640	31.4	-2.5×10^{-4}
4	7Co-21Fe-4Mo-Ni	11.0	86.6	81.3	0.105	580	55.1	-2.3×10^{-4}
5	7Co-21Fe-4Cu-Ni	11.3	75.5	87.5	0.066	600	44.0	-2.3×10^{-4}
6	14Co-26Fe-Ni	13.8	88.9	92.2	0.038	690	17.2	-2.2×10^{-4}
7	14Co-24Fe-2Mo-Ni	12.8	91.3	95.0	0.033	640	36.3	-2.3×10^{-4}
8	14Co-24Fe-2Cu-Ni	13.0	92.4	95.1	0.031	650	31.0	-2.3×10^{-4}
9	14Co-22Fe-4Mo-Ni	11.4	80.7	85.4	0.092	600	56.2	-2.4×10^{-4}
10	14Co-22Fe-4Cu-Ni	11.5	88.3	92.3	0.043	620	46.5	-2.4×10^{-4}
11	21Co-26Fe-Ni	14.6	87.8	92.9	0.046	710	18.4	-2.0×10^{-4}
12	21Co-24Fe-2Mo-Ni	13.7	89.3	93.8	0.030	670	36.7	-2.1×10^{-4}
13	21Co-24Fe-2Cu-Ni	13.9	91.0	95.2	0.025	670	31.9	-2.1×10^{-4}
14	21Co-22Fe-4Mo-Ni	12.6	85.8	91.1	0.040	630	55.9	-2.3×10^{-4}
15	21Co-22Fe-4Cu-Ni	12.9	85.9	90.7	0.035	640	45.1	-2.3×10^{-4}

From table 1 it will be noted that although Fe-Co-Ni ternary alloy Sample Nos. 1, 6 and 11 have higher Curie points and relatively good magnetic properties, their electrical resistivities are considerably small. A small electrical resistivity causes a large eddy current loss in a core which is subjected to alternative magnetization.

On the contrary, Fe-Co-Ni-Mo or Fe-Co-Ni-Cu alloys which contain a proper amount of molybdenum or copper, other than Fe, Co, and Ni, have a large electrical resistivity. Except for Samples Nos. 4 5 and 9, the alloys have a Curie point higher than 620° C. and have superior magnetic properties.

In order to improve the rectangular hystersis characteristics, the alloy should be effectively influenced by a magnetic annealing treatment so as to have strong magnetic anisotropy. The inventors have found that the amount of influence of the magnetic annealing treatment on an alloy has an important relationship with the Curie point of the alloy; generally speaking, alloys of high Curie points show superior magnetic properties.

In the Sample Nos. 4, 5 and 9, the coercive force is large and both Br/B10 and BO.5/B10 are small although these samples have compositions falling within ranges that Fe<30 % Co <30 %, Mo or Cu <4 %, and the balance is Ni. Their Curie points tend to be lower than 620° C. since, as will be understood from the FIG. 1, a small percentage of cobalt tends to make the Curie point lower and, furthermore, the addition of molybdenum or copper functions to lower the Curie point.

Accordingly, the amount of molybdenum or copper to be added should be preferably chosen such that the Curie point of the alloys may be higher than at least 620° C. The temperature coefficient α_{B10} of the B10 of Fe-Co-Ni-Mo or Fe-Co-Ni-Cu system alloys are $-(2.0-2.6\times10^{14})$ for the average value between −20° C. and +30 ° C. and is about one-half of those of the usual known materials used as toroidal cores, such as oriented 50–Permalloy [50 percent Ni-Fe alloy, $\alpha_{B10}\approx-(5.5\times10^{14})$], Supermalloy [5 percent Mo –79 percent Ni-Fe alloy; $\alpha_{B10}\approx-(6.0\times10^{14})$]. On the other hand, it is noted among the samples that those having higher Curie points tend to have small absolute values of α^{B10}.

The samples Nos. 2, 3, 7, 8, 10, 12, 13, 14 and 15 satisfy the conditions that B10≧11.5 kg. (k gauss), Br/B10>85 %, Hc<0.05 Oe, $\Phi\rho>30\mu\Omega$-cm. and $\alpha_{B10}<2.5\times10^{14}$ and, therefore, are found to be quite suitable for a core material of rectangular hysteresis loop characteristics to be used in a magnetic amplifier, a magnetic multivibrator and the like. Though table 1 shows only annealing conditions at the high temperatures prior to the magnetic field cooling treatment, it goes without saying that the samples were in turn subjected to the magnetic field cooling so as to impart the anisotropy and the rectangular hysteresis loop characteristics required for the saturable reactor core to the alloys.

EXAMPLE II

Two kinds of alloys were examined as to the influence of annealing temperatures, as shown in table 2. The samples are alloys composed of the Sample Nos. 2 and 3 in table 1.

TABLE 2

Annealing Condition	B10 (kg.)	Br/B10 (%)	Hc(Oe)
Sample 2			
800° C.×2 hours	11.0	89.7	0.125
900° C.×2 hours	11.4	89.8	0.065
1,000° C.×2 hours	11.4	89.0	0.050
1,100° C.×2 hours	11.6	90.1	0.040
1,200° C.×2 hours	11.7	84.5	0.031
1,300° C.×2 hours	11.7	80.5	0.033
Sample 3			
800° C.×2 hours	11.9	91.7	0.055
900° C.×2 hours	11.9	93.4	0.045
1,000° C.×2 hours	12.0	92.8	0.038
1,100° C.×2 hours	12.1	93.2	0.027
1,200° C.×2 hours	12.1	86.6	0.023
1,300° C.×2 hours	12.1	82.6	0.020

EXAMPLE III

The influence of the cooling rate under a magnetic field on two kinds of alloys composed of Sample Nos. 2 and 3 were examined as shown in table 3.

TABLE 3

Sample	Cooling Condition	B10 (kg.)	Br/B10 (%)	Hc(Oe)
2	200° C./hr.	11.5	78.1	0.055
2	100° C./hr.	11.6	90.1	0.040
2	50° C./hr.	11.7	90.5	0.032
3	200° C./hr.	11.6	88.6	0.045
	100° C./hr.	12.1	93.2	0.027
	50°c./hr.	12.1	93.8	0.026

These samples were first maintained at 700° C. for 30 minutes and then they were cooled at various cooling rates as shown in table 3 under a magnetic field of 5 oersteds until 400° C. was reached.

EXAMPLE IV

Table 4 shows the magnetic properties of Fe-Co-Ni base alloys when 2 weight percent of copper and transition metals such as molybdenum, chromium and vanadium were added thereto. Samples were formed having a ring-shape with a thickness of 0.3 mm. and were annealed at about 1,100° C. As the magnetic annealing treatment, the samples were first maintained at 700° C. for 30 minutes and then were cooled at the rate of 50° C. per hour under a magnetic field of 5 oersteds until a temperature of 400° C. was reached.

TABLE 4

Sample	Composition (weight percent)	B10 (kg.)	Br/B10 (%)	Hc (Oe)
16	7Co-21Fe-2Mo-Ni	11.1	86.1	0.039
17	7Co-21Fe-2Cu-Ni	11.9	90.6	0.041
18	7Co-21Fe-2Cr-Ni	11.0	66.6	0.066
19	7Co-21Fe-2V-Ni	10.5	65.6	0.046

As will be clear from table 4, the effects of the addition of these metals on magnetic properties, especially rectangular hysteresis characteristics, are quite different, although all of them were expected to improve the magnetic properties as well as to increase the electrical resistivity. For Fe-Co-Ni base alloys, copper and molybdenum were found to be the most preferable additive elements not only to increase the electrical resistivity but to improve the rectangular hysteresis characteristics by a magnetic annealing treatment.

EXAMPLE V

A core was made by lamination of U-shaped core elements, as shown in FIG. 4, which were punched out from a plate or plates composed of the Sample No. 3 or No. 10 which displayed excellent characteristics as shown in table 1.The core element in FIG. 4 has a thickness of about 0.3 mm., l_1 of four different lengths as shown in table 5, l_2 of 10 mm., l_3 of 20 mm. and l_4 of 5 mm. After being punched, the core element was annealed at a high temperature and subsequently it was annealed under a magnetic field from 700° C. to 400-20 400°at a rate of 100° C./hr. The magnetic annealing was done as shown in FIG. 5, wherein 1 is a coil, 2 is a U-shaped laminated core and 3 is a ceramic cylinder on which the coil 1 is wound. Legs of each core element were inserted into the ceramic cylinders from opposite sides alternatively in order to form a flame-type core. 400°C.

A current was applied to the coil to produce a magnetic field of 4 oersteds therein. After completion of the magnetic annealing treatment, the core elements were taken out and 30 of them were assembled as a unit to form a core by lamination in which the open ends of legs of each core element were piled on the closed ends of legs of other core elements, as shown in FIG. 6, wherein 4 are leads of solenoidal coils 5, 6 is a laminated U-shaped core and 7 are insulating plate members.

The magnetic properties of these laminated cores are shown in table 5.

TABLE 5

Sample No.	Magnetic properties	Length of legs =50 mm.	=55 mm.	=70 mm.	=100 mm.
3	B10 (kg.)	12.0	12.1	12.1	12.1
	Br/B10 (percent)	83.0	88.5	89.7	89.4
	B0.5/B10 (percent)	90.4	93.7	95.5	96.0
	Hc (oe.)	0.036	0.037	0.037	0.038

TABLE 5—Continued

Sample No.	Magnetic properties	Length of legs =50 mm.	=55 mm.	=70 mm.	=100 mm.
10	B10 (kg.)	11.3	11.4	11.4	11.4
	Br/B10 (percent)	80.2	86.5	87.3	87.0
	B0.5/B10 (percent)	88.1	92.9	93.2	94.0
	Hc (oe.)	0.050	0.050	0.051	0.054

As will be understood by a comparison of table 1 with table 5, the rectangular hysteresis characteristics of the laminated U-shaped core are somewhat inferior to those of the ring core. This is caused by small gaps formed about the opposite ends of the legs of the laminated core by alternative lamination of U-shaped core elements in opposite directions. If l_1 of the laminated core is greater than is greater than 55 mm., however, its rectangular hysteresis characteristics are such that Br/B10>percent and BO.5/B10>90 percent, these being suitable for a core for a magnetic amplifier or a magnetic multivibrator. It will be also noted in table 5 that as l_1 increases, both its rectangular ratio and its coercive force tend to increase. Furthermore, it is apparent that a ratio of the length l_1 of the legs to length l_3 of the yoke should be at least 2.5, most preferably within a range of from three to five.

As compared with the usual toroidal cores, a laminated core according to the present invention has a further advantage with respect to its resistance to deterioration of magnetic properties by externally applied stress or shock. As an experiment, such an external force as having an amplitude of 3 g, where g is the acceleration of gravity, was applied for a whole day and night to both a U-shaped core according to the invention and a toroidal core of oriented 50-**Permalloy having a thickness of** 0.1 mm. Although the rectangular ratio of the toroidal core decreased by 5–7 percent, no deterioration of any magnetic properties was observed in regard to the core according to the present invention.

While the invention has been described in connection with certain modifications thereof, it should be understood that further modifications may now suggest themselves to those skilled in the art, and it is intended to cover such modifications as fall within the scope of the appended claims without departing from the spirit and scope of the invention.

We claim:

1. A magnetic alloy having a Curie point greater than about 620° C. and a rectangular hysteresis loop characteristic represented by a Br/B_{10} ratio greater than 0.9 imparted by a magnetic cooling treatment, consisting essentially of from about 7 to 21 percent by weight of cobalt, from about 20 to 25 percent by weight of iron, from about 1.5 to 4 percent by weight of at least one additive element selected from the group consisting of molybdenum and copper, and the balance being nickel.

2. A magnetic alloy according to claim 1, wherein said additive element is copper.

3. A magnetic alloy according to claim 1, wherein said additive element is molybdenum.

4. A magnetic sheet material used for a saturable reactor core which comprises a magnetic alloy having rectangular hysteresis loop characteristics represented by a Br/B_{10} value greater than about 90 percent, imparted by a magnetic cooling treatment, a sharply rising magnetization curve characteristic, and a Curie point greater than about 620° C., consisting essentially of from about 7 to 21 percent by weight of cobalt, from about 20 to 25 percent by weight of iron, from about 1.5 to 4 percent by weight of an element selected from the group consisting of molybdenum and copper, and the balance being nickel.

5. A magnetic sheet material according to claim 4, in which the sheet material is U-shaped and the ratio of the length l of the legs to the length l_3 of the yoke is at least 2.5.

6. A magnetic sheet material according to claim 4, in which the magnetic alloy has an electric resistivity greater than about 30Ω-cm.

7. A magnetic alloy sheet material according to claim 4, wherein said additive element is copper.

8. A magnetic alloy sheet material according to claim 4, wherein said additive element is molybdenum.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,615,910 Dated October 26, 1971

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It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In Column 2, line 16, change "FE-Co-Ni" to read -- Fe-Co-Ni --,
line 46, change "Fe-Co-ni" to read -- Fe-Co-Ni --,
line 69, change "FE" to read -- Fe --.

In Column 4, line 27, change "($\mu\Omega$-cm.)cm.)" to read -- ($\mu\Omega$-cm.) --.

In Column 5, line 13, change "10^{14}" to read -- 10^{-4} --,
line 17, change "10^{14}" to read -- 10^{-4} --,
line 18, change "10^{14}" to read -- 10^{-4} --,
line 23, change "$\rho\mathcal{S}$ " to -- $\mathcal{S}$ --,
line 23, change "10^{14}" to -- 10^{-4} --.

In Column 6, line 52, delete "400-20",
line 58, change "flame-type" to -- frame-type --.

In Column 8, line 39, change "Ω-cm" to read -- $\mu\Omega$-cm --.

Signed and sealed this 5th day of December 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

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