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(54) **Core of a noise filter comprised of an amorphous alloy.**

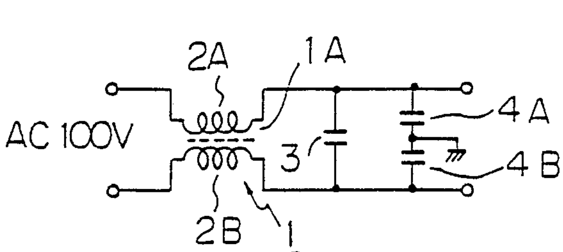
(57) The present invention relates to the core of a noise filter.

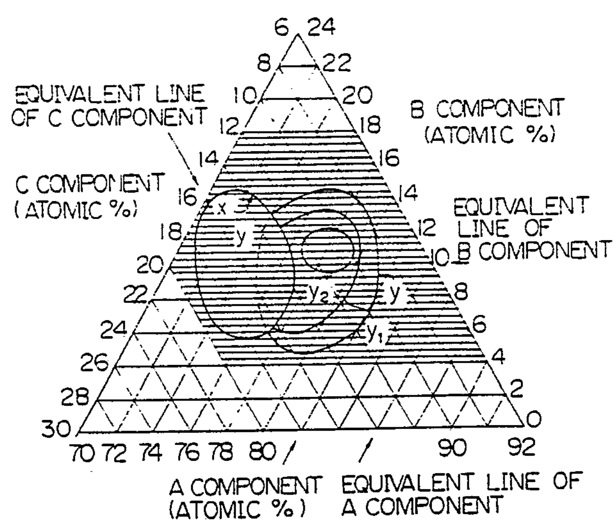
Conventionally, ferrite or iron powder is used as the core of a noise filter. Some patent publications disclose the core of a noise filter made of an amorphous magnetic alloy.

An amorphous magnetic alloy which has a low pulse-noise resistance deterioration percentage is that on or within the curve X and Y of Fig. 3.

Fig. 3

Fig. 1





EP 0 384 491 A2

CORE OF A NOISE FILTER COMPRISED OF AN AMORPHOUS ALLOY

Field of the Invention

The present invention relates to the core of a noise filter comprised of amorphous alloy. More particularly, it relates to the core of a noise filter for eliminating pulse noise, the noise filter comprising a core and a pair of windings for generating magnetic fluxes which offset each other.

Description of the Prior Art

(1) Soft Magnetic Materials

Conventionally, ferrite is used as the core of a noise filter. Ferrite has an excellent permeability characteristic but its saturation flux density is low. Silicon steels are also conventionally used as the core of a noise filter. Silicon steels have a high permeability at a low frequency and a high magnetic flux density. However, the frequency characteristic of the permeability is not excellent. In addition, compacted iron powder is conventionally used as the core of a noise filter. Compacted iron powder has a high saturation density but its permeability is low.

Amorphous alloys can be excellent magnetic materials because of their disordered structure and a watt loss as low as one third that of conventional crystalline alloys. Therefore, as is well known, enormous efforts have been made to investigate the thermally stable soft magnetic properties, such as a high residual flux density, a high saturation flux density, and a low watt loss of amorphous alloy compositions. Such soft magnetic properties can usually be attained when the BH curve has a rectangular shape and is longitudinally elongated, i.e., when the coercive force is low the magnetization at a predetermined magnetic field is high.

Japanese Unexamined Patent Publication No. 54-148122 discloses an amorphous alloy which contains from 80 to 84 atomic % of iron, from 12 to 15 atomic % of boron, and from 1 to 8 atomic % of silicon and which exhibits a high saturation flux density, a high ductility, and a high-temperature stability.

United States Patent No. 4,217,315 illustrates the composition of an Fe-B-Si-based amorphous alloy by a curved area and describes an $Fe_{81}B_{13.3\ .\ 15.7}\ Si_{3-5}$ composition as a typical one which has a high saturation magnetization, a high cyrstallization temperature, and a low coercive force and is thus excellent for use as a motor and a transformer.

United States Patent No. 4,219,355 discloses that in an $Fe_aB_bSi_cC_d$-based amorphous alloy the composition a = 80.0 - 82.0 atomic %, b = 12.5 - 14.5 atomic %, c = 2.5 - 5.0 atomic %, and d = 1.5 - 2.5 atomic % is superior in coercive force, magnetic flux desnity, and watt loss at a commercial frequency.

Japanese Unexamined Patent Publication No. 57-116750 corresponding to EP-A-55327, discloses that in an $Fe_aSi_bB_c$-based amorphous alloy the composition a = 75 - 78.5 atomic %, b = 4 - 10.5 atomic %, and c = 11 - 21 atomic % has excellent alternating-current excitation characteristics, i.e., a low watt loss and a low exciting force. In this publication, it is specifically disclosed that the magnetic properties are improved by carrying out a heat treatment under a magnetic field.

Japanese Unexamined Patent Publication No. 57-137451 discloses that an amorphous alloy which consists of from 77 to 80 atomic % of iron, from 12 to 16 atomic % of boron, and from 5 to 10 atomic % of silicon exhibits the following properties: 15 kG or more of a saturation magnetization, approximately 3.2 A/m (0.04 Oe)or less of a coercive force, and0.22 W/Kg(0.1W/pound)of watt loss (1.26T (12.6 kG), 60 Hz).

Japanese Unexamined Patent Publication No. 58-34162 discloses that an amorphous alloy which consists of from 78 to 82 atomic % of iron, from 8 to 14 atomic % of boron, from 5 to 15 atomic % of silicon, and up to 1.5 atomic % of carbon has an anti-magnetic aging property and good watt loss and magnetic flux density.

Japanese Unexamined Patent Publication No. 58-42751 discloses that in an amorphous alloy which consists of from 77 to 79 atomic % of iron, from 8 to 12 atomic % of silicon, from 9 to 11 atomic % of boron, and from 1 to 3 atomic % of carbon, the secular change of magnetic properties is very small.

Japanese Unexamined Patent Publication No. 56-127749 discloses that when x is from 4 to 9.5 atomic % and a is from 82 to 86 atomic % in an $Fe_{a-x}B_{100-a-x}Si_{2x}$ composition, the amorphous alloy has thermally stable soft magnetic properties.

Japanese Unexamined Patent Publication No. 57-190304 discloses that in the $Fe_{100-a-b-c}Mo_aX_bY_c$ composition (X is Ni, Co or the like, Y is Si, Al, B, C or the like, a is from 0.1 to 6 atomic %, b is from 0 to 30 atomic %, and c is from 15 to 30 atomic %). Mo is effective for enhancing the squareness ratio, i.e., providing the amorphous alloy with a squareness ratio of 60% or more under a direct current magnetization.

In the above-described prior art, most of the investigations are directed to finding the appropriate content ranges of Fe, B, Si, and C while setting the Fe content at around approximately 80 atomic %. In these prior arts, no composition which can exhibit excellent properties as the core of a noise filter can be found except for Japanese Unexamined Patent Publication No. 57-116750, in which appropriate B and Si contents at an Fe content of 75 atomic % are investigated, and except for Japanese Unexamined Patent Publication No. 57-190304, in which the enhancement of the squareness ratio due to Mo is reported. However, since in Japanese Unexamined Patent Publication No. 57-116750 the amorphous alloy is subjected to a heat treatment under a magnetic field so as to provide a square and longitudinally long BH curve, properties suitable for a core of a noise filter cannot be obtained.

Proc. 4th Int. Conf. on Rapidly Quenched Metals (Sendai, 1981) pp1035-1038 reprots a study of the permeability change depending upon the frequency regarding the $(Fe_{0.76}B_{0.14}Si_{0.10})_{98}(Be,C,Al,Co,Ni,Cr,Nb)_2$ and $(Fe_{1-x}Co_x)_{74}Cr_2B_{14}Si_{10}$ compositions.

Disclosed in this study is an abnormal phenomenon in which the permeability drastically decreases at a certain frequency, e.g., in the vicinity of 50 kHz, by approximately 20 percent.

The report also discloses that this abnormal decrease in the permeability is attributable to a magnetomechanical resonance, and is mainly influenced by the magnetostriction; that is, the abnormal decrease in the permeability is most remarkable in amorphous alloys having a large magnetostriction.

(2) Noise Filter

The noise filter may be referred to as a two-line power filter for digital equipment, such as in USP No. 3,996,537, or a power supply filter for noise suppression, such as in USP No. 3,683,271.

The prior art of a noise filter is described with reference to Fig. 1.

In the drawings:

Fig. 1 is a circuit of a noise filter;

Fig. 2 is a graph illustrating the relationship between the noise input voltage and the noise output voltage;

Fig. 3 is a diagram showing the range of A, B, and C components according to the present invention;

Fig. 4 is a graph illustrating the permeability and permeability changes depending upon applied magnetic field;

Fig. 5 is a ternary diagram of amorphous alloys; and,

Fig. 6 is a graph illustrating a relationship between the μ_2 (after demagnetization) and μ_2 (after pulse deterioration) or the pulse-deterioration percentage;

Referring to Fig. 1, the noise filter 1 comprises the core 1A and a pair of windings 2A and 2B. The alternating current indicated by AC 100 V is applied to the noise filter and generates magnetic fluxes when it is conducted through the windings 2A and 2B. The sum of the magnetic fluxes produced by the windings 2A and 2B is zero.

A capacitor 3 and capacitors 4A and 4B are connected between the windings 2A and 2B. The capacitors 4A and 4B are connected to each other and are grounded at the connecting point thereof. The relationship between the noise input voltage and the noise output voltage is shown in Fig. 2. As is apparent from Fig. 2, the noise output voltage abruptly increases when the noise input voltage exceeds a critical value. The reason for this is because the core 1A (Fig. 1) of the noise filter is magnetically saturated, and when such an abrupt increase in the noise output voltage occurs, the noise filter does not function. The curve shown in Fig. 2 has in the low-noise output range an inclination which is determined by the inductance of the noise filter 1 (Fig. 1), i.e., the permeability of the core 1A. The inclination is lessened in accordance with an increase in permeability. The noise input voltage, at which the curve shown in Fig. 2 abruptly increases, is determined by the saturation flux density of the core 1A. Therefore, the core of a noise filter must have a high permeability and a high saturation flux density. In addition, when a noise filter is used for filtering noise of a high frequency voltage, the frequency characteristic of the permeability must be excellent.

Japanese Unexamined Patent Publication No. 56-46516 discloses a core of a noise filter which consists of an essentially completely amorphous alloy. This core is remarkably improved over the conventional ones, especially when it is used for filtering a high noise voltage. However, it is insufficient for suppressing a high-voltage noise pulse of 1,000 V or more generated for 1 µsec or more. Such a noise pulse is frequently superimposed on the current of a power line or power circuit.

Japanese Unexamined Patent Publication No. 57-24519 discloses a core of a noise filter which consists of a magnetic amorphous alloy which partially contains precipitated crystals. The core was invented by the present inventors, who discovered that when precipitated cyrstals are present in an amorphous alloy the core can effectively suppress a high-voltage noise pulse.

Japanese Unexamined Patent Publication No. 57-24518 specifies the BH curve of an amorphous alloy for use as a noise filter. More in detail, as is noted hereinabove with refernce to Figs. 1 and 2, a high inductance for a high permeability of the core of a noise filter usually results in a decrease in the noise output voltage. However, in the case of a square and longitudinally long BH curve which is obtained by increasing the permeability, a high-voltage noise pulse cannot be eliminated. Therefore, in this publication the BH curve is specified to have a slanted shape in terms of0.2 T $\leqq B_2 \leqq$ 0.7 Bs (T)(2,000 G $\leqq B_2 \leqq$ 0.7 Bs-(G)), wherein B_2 is the magnetic flux density at a magnetization of160 A/m(2 Oe)and 50 kHz and Bs is the saturation flux density. In this publication, $Fe_{76}Co_4B_{18.9}Si_{2.1}$, $Fe_{78.4}Ni_{1.6}B_{12}Si_8$, $Fe_{62.4}Ni_{16}Mo_{1.6}B_{16}Si_4$, and the like are mentioned as amorphous alloys.

Japanese Patent Application No. 56185201, corresponding to Unexamined Patent Publication No. 58-87803, discloses that an amorphous alloy which has a specified BH curve in terms of µi (initial permeability) = 2,000 -5,000, Br $\leqq$ 0.3 T (3 kG), B_2 =0.6 - 0.9 T(6 - 9 kG), an $B_s \geqq$ 1.2 T(12 kG) can eliminate a high-voltage noise pulse when used as a noise filter.

Preferable magnetic properties of the core of a noise filter are different from those of a core of a conventional transformer, an electric motor, or the like in the following respects. In the core of a noise filter, the BH curve should be slanted, i.e., a constant permeability characteristic or an unchanged permeability µ, depending upon the magnetic field, and a not very high residual flux density Br. Such BH curve is undesirable for the core of a transformer, an electric motor, or the like.

Presumably, the properties required for the noise filter can be obtained by adjusting the composition of the amorhous alloy to have zero magnetostriction, since the above described abnormal decrease in the permeability, which is undesirable for the core of a noise filter, can be avoided by the zero-magnetostrictive composition, according to the report Proc. ... Rapid Quench Metal. In the Co-based amorphous alloy having zero magnetostriction, the properties other than the magnetostriction especially the magnetic flux density, are poor, and further, the magnetic properties exhibit a great secular change. This makes the zero-magnetostrictive alloy inappropriate for the core of a noise filter.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an amorphous alloy which can prevent deterioration of the properties of the core of a noise filter, particularly a pulse-resistance deterioration, which deterioration may occur in a known noise-filter core composed of, for example, approximately 80% of Fe and, occasionally, Co or Ni, the balance being B and/or Si.

Pulse-resistance deterioration, discovered by the present inventors, is a phenomenon in which a high-volt age noise pulse can be eliminated as desired the first time a noise filter is used but cannot be eliminated at subsequent times the noise filter is used.

The core of a noise filter according to the present invention comprises a coiled thin strip of an amorphous magnetic alloy which essentially consists of an A component which is Fe or Fe together with at least one transition metal element, a B component which is at least one selected from the group consisting of Si and Al, and a C component which is at least one selected from the group consisting of B, C, and P, contains the A, B, and C elements in an amount falling on or within curve X shown in Fig. 3, and exhibits a permeability (μ_2) of from approximately 2,000 to approximately 5,000, i.e., a permeability measured at 100 kHz and a magnetic field of0.16 A/m (2 mOe), a 0.3 T (3 kG)or less of a residual flux density (Br) determined on a BH curve at a frequency of 2 kHz and and a maximum applied a magnetic field of160 A/m (2 Oe), and from0.6 to 0.9 T(6 kG to 9 kG)of a magnetic flux density (B_2), i.e., a magnetic flux density at 160 A/m (2 Oe). The composition of this amorphous magnetic alloy is hereinafter referred to as the first composition. An amorphous magnetic alloy having the first composition has a low pulse-resistance deterioration.

The core of a noise filter according to the present invention comprises a coiled thin strip of an amorphous magnetic alloy which essentially consists of an A component which is Fe or Fe together with at least one transition metal element, a B component which is at least one selected from the group consisting of Si and Al, and a C component which is at least one selected from the group consisting of B, C, and P, contains the A, B, and C elements is an amount falling on or within curve Y and falling outside the curve X shown in Fig. 3, and exhibits a permeability (μ_2) of approximately 4,000 or more, i.e., a permeability measured at 100 kHz and a magnetic field of 0.16 A/m (2 mOe), a 0.3 T (3 kG)or less of a residual flux density (Br) determined on a BH curve at a frequency of 2 kHz and a maximum applied a magnetic field of160 A/m(2 Oe), and from0.5 to 1.1 T(5 kG to 11 kG)of a magnetic flux density (B_2), i.e., a magnetic flux density at 2 Oe. The composition of this amorphous magnetic alloy is hereinafter referred to as the second composition. An amorphous magnetic alloy having the second composition has a low pulse-resistance deterioration and a high permeability.

Pulse-resistance deterioration is not quantitatively determined in the industrial standards of inductors or the like. The VDE 0565 Teil 3.3.6 inductance 3.6.2 of West Germany is an industrial standard which specifies general inductors, and in this standard it is mentioned that when current is supplied to a rod core or a choke coil made of a dust core, the variation in inductance from the nominal value must be ±20% or less. This variation can undoubtedly be satisfied according to the first and second compositions.

The pulse-resistance deterioration percentage is defined herein by the euation:

$$\frac{\mu e\begin{pmatrix}\text{after application}\\ \text{of a magnetic}\\ \text{field of 320 A/m (4 Oe)}\end{pmatrix} - \mu e\begin{pmatrix}\text{demag-}\\ \text{netiza-}\\ \text{tion}\end{pmatrix}}{\mu e\ (\text{demagnetization})} \times 100\ (\%),$$

wherein μe is the permeability at 100 kHz and 0.16 A/m 2 mOe (0.002 Oe) and the demagnetization is a demagnetized state of zero magnetic flux density.

Prior to defining the pulse-resistance deterioration percentage, the present inventors manufactured amorphous alloy cores in a toroidal form 31 mm in outer diameter, 19 mm in inner diamter and 8 mm in height, applied a magnetic field of 1600 A/m (20 Oe)or less to them, demagnetized them, and measured the following permeability changes:

$$\frac{\mu e\begin{pmatrix}\text{after application}\\ \text{of a magnetic}\\ \text{field}\end{pmatrix} - \mu e\begin{pmatrix}\text{demag-}\\ \text{netiza-}\\ \text{tion}\end{pmatrix}}{\mu e\ (\text{demagnetization})} \times 100\ (\%),$$

The present inventors obtained the results shown in Fig. 4.

As is apparent from Fig. 4, the reduction in permeability (μe) is the greatest at320 A/m(4 Oe)of the applied magnetic field. That is, when a mangetic field of320 A/m(4 Oe) is applied to the amorphous alloy cores, the permeability (μe) is reduced by approximately 30% compared with the permeability (μe) before application of the magnetic field, i.e., the permeability (μe) which an amorphous alloy primarily exhibits. This means that a high-voltage noise pulse, which can ordinarily be primarily eliminated, may not be able to be eliminated since the ability to eliminate noise decreases by approximately 30% when an extraneous noise which generates a magnetic field of 320 A/m (4 Oe)is applied to a core.

Based on the results obtained by the present inventors, the pulse-resistance deterioration percentage is determined as above. By controlling the pulse-resistance deterioration percentage, it is possible to control the most serious pulse-resistance deterioration which can possibly occur in cores. When the pulse-resistance deterioration percentage is appropriately controlled, pulse-resistance deterioration which may occur at a magnetic field higher than 320 A/m (4 Oe)can be controlled. In addition, the permeability (μ_2) represents the noise-pulse suppression characteristics of a core to which a magnetic field higher than 0.16 A/m (2 mOe)is applied due to a noise-pulse voltage.

Previously, there have been no quantitative methods for evaluating deterioration in pulse suppression, presumably because the inherent unforeseeable variation of a noise pulse, i.e., a great noise-pulse voltage variation and plus or minus charge variation, hindered the development of such quantitative methods.

In the present invention, the permeability is one of the important factors. However, since the permeability of amorphous alloys is structure-sensitive, accurate measurement thereof is not always easy. In the experiments carried out by the present inventors, the permeability was measured as accurately as possible using a 4274 tester of HP Corporation. However, measurement of the permeability can involve a 5% error at the maximum.

The amorphous magnetic alloy according to the present invention is essentially amorphous. It may, however, optionally contain precipitated fine crystals in a minor amount. Precipitated fine crystals in the amorphous magentic alloy cause almost no change of the saturation flux density (B_s) but cause a reduction of the magnetic flux density. The heat treatment for precipitating the fine crystals is carried out, if necessary, for providing the properties required for the noise filter. That is, if the essentially amorphous alloy cannot attain the above-described Br and B_2 , the heat treatment for precipitating the fine crystals is carried out. In this case, the above-described Br and B_2 can also be attained by a heat treatment which does not result in appreciable precipitation of fine crystals. Desirably, the Br is as low as possible and may actually be zero (Br ≒ 0), provided that B_2 and μ_2 are as specified above, since an amorphous alloy actually having a zero Br can provide a core which has a small deterioration due to noise-pulse voltage, i.e., low variance in inductance, and which can stably eliminate a high-voltage pulse.

The second composition, in which Fe of the first composition is partly replaced with Mo preferably in an amount of 3% or more, attains a pulse-resistance deterioration equivalent or superior to that of the first composition, where the contents of A, B, and C components are outside the curve X shown in Fig. 3.

An effect of Mo discovered by the present inventors is described with reference to Table 1.

Table 1

Properties \ Amount of Mo x (at %)	0	3	6
μ_2 (after demagnetization)	5,000	7,100	6,100
μ_2 (after pulse-deterioration)	4,000	5,700	5,700
Pulse resistance deterioration percentage (%)	20	20	7

Table 1 shows the properties of the amorphous alloy having an $Fe_{76-x}Mo_xSi_6B_{18}$ composition. As is apparent from Table 1, the pulse-resistance deterioration percentage is drastically decreased due to the addition of Mo. The μ_2 (after pulse deterioration) in Table 1 and in the descriptions herein below is the permeability which is measured, after application of a magnetic field pulse of 4 Oe, under the condition of 100 kHz and 0.16 A/m 2 mOe (0.002 Oe).

Mo is more effective for the properties of amorphous alloy for the noise filter, than are the other additives, such as Nb, Cr, and or the like, disclosed in the first composition, as is now described with reference to Table 2.

Table 2

$Fe_{76-x}M_xSi_6B_{18}$

IVa	Va	VIa	VIIa	VIIIa	
Ti 0.5%	V 3%	Cr 3%	Mn 3%	Co 3%	Ni 3%
	7,100	6,800	5,000	4,400	4,600
	4,700	4,200	4,000	3,700	3,200
	34	38	20	15	30
	Nb 3%	Mo 3%			
	5,900	7,100			
	4,500	5,700			
	24	20			
		W 1%			
		5,000			
		4,000			
		20			

In Table 2, Fe of the fundamental composition $Fe_{76}Si_6B_{18}$ is partly replaced with the components shown therein.

The upper, middle, and lower values of the replaced composition indicate μ_2 (after demagnetization), μ_2 (after the pulse deterioration), and the pulse-resistance deterioration percentage, respectively.

The $Fe_{76}Si_6B_{18}$ composition has the following properties:

μ_2 (after demagnetization) = 5000

μ_2 (after pulse deterioration) = 4000

Pulse-resistance deterioration percentage = 20%.

As is apparent from Table 2, Mo drastically enhances μ_2 (after demagnetization and after pulse deterioration) while maintaining the pulse deterioration percentage at 20%. W and Mo do not virtually change these properties. Ni impairs all of these properties. The other elements improve only either the μ_2 - (after demagnetization and after pulse deterioration) or the pulse-resistance deterioration percentage.

Incidentally, if Ti is included in an amount of 1% and W in an amount of 3%, the production of an amorphous alloy ribbon is impossible.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The first composition is now described.

The A component is Fe or Fe and at least one transition metal element. The at least one transition metal element is selected from the 4s-transition elements (Sc - Zn), the 5s-transition elements (Y - Cd), the 6s-transition elements (La - Hg), and elements having atomic numbers equal to or greater than Ac and may be Co, Ni, Cr, Cu, Mo, Nb, Ti, W, V, Zr, Ta, Y or a rare earth element.

M is preferably Mn, Cr, Mo, Nb, Ni, or Co, more preferably Mn. When Ni, Co, and Fe are used as M, Ni and Co may be approximately 20% or less based on M. When, in addition to one or more of Ni, Co, and Fe, the other elements are used as M, their amount is usually approximately 5 atomic % or less.

The B component is at least one element selected from the group consisting of Si and Al. The content of Al is preferably 10 atomic % or less based on the total content of Si and Al.

The C component is at least one element selected from the group consisting of B, C, and P. The content of C is preferably 20 atomic % or less based on the total of B, C, and P, and the content of P is preferably 5% or less based on the total of B, C, and P.

In addition to the A, B, and C components, at least one element selected from the group consisting of Be, Ge, Sb, and In may be contained in the first composition since such element does not impede the effects of the present invention.

If the composition of an amorphous alloy is on or within the curve X, the soft magnetic properties are somewhat inferior to those outside the curve X but not only can a high-voltage noise pulse be effectively eliminated but also pulse-resistance deterioration is not appreciable.

When the A, B, and C components are located on or within the four-sided region formed by connecting (73, 9, 18), (73, 12, 15), (76, 9, 15), and (76, 6, 18) expressed by the ternary ordinate in atomic %, pulse-resistance deterioration is very small.

The magnetic properties of the amorphous alloy having the first composition are now described.

If the permeability (μ_2) is less than approximately 2,000, the inductance of the core of a noise filter is low so that the noise output voltage is disadvantageously high. On the other hand, if the permeability (μ_2) is more than approximately 5,000, the BH curve markedly tends to saturate at low pulse voltage, with the result that a high-voltage noise pulse cannot be eliminated. The residual flux density (Br) should be as low as possible. If the residual flux density (Br) is more than0.3 T(3 kG), the constant permeability characteristic is lost and the compositional range of the amorphous alloy, in which the eliminating ratio of pulse voltage is high, tends to be disadvantageously narrowed.

In an embodiment of the present invention (the first composition), the pulse-resistance deterioration percentage is 10% or less.

In another embodiment, in which the A, B, and C components are appropriately selected within the curve X, the pulse resistance deterioration percentage is 5% or less.

Referring to Fig. 5, the range of the first composition is denoted by curve X in the ternary diagram. Curves Y and Z indicate compositions having a pulse-resistance deterioration percentage of -20% and -30%, respectively.

If the content of the A component is less than 70 atomic %, vitrification of an alloy which consists of the A, B, and C components becomes difficult.

Curves U, V, and W indicate compositions having, after demagnetization, a permeability of 10,000, 7,500, and 5,000, respectively, measured at 100 kHz. The permeability measured at 25 kHz is the highest within the curve U. The compositional range within the curve U is almost coincident with that where the permeability (μ_2) is the highest.

As will be understood from the descriptions with reference to Fig. 5, the content range of the A, B, and C components where the pulse-resistance deterioration percentage is low is not coincident with that where the permeabilities are the highest.

Curve S in Fig. 5 indicates the amounts of the A, B, and C components, at which amounts the saturation flux density measured at 2 kHz of alternating current and800 A/m(10 Oe)of magnetization force becomes approximately 15 kG. When the amounts of the A, B, and C components are on the right-hand side of the curve S (on the iron-rich side), the above-mentioned saturation flux density becomes high. Therefore, the amounts of the A, B, and C components indicated by the curve X according to the present invention are such that the above-mentioned saturation flux density (B_s) is low.

A preferable ratio of crystals to glass (glass/crystals) is usually 50% or less regarding the first composition.

The second composition is now explained.

The A component is Fe and Mo or Fe plus Mo and at least one transition metal element selected from the 4s-transition elements (Sc - Zn), the 5s-transition elements (Y - Cd), the 6s-transition elements (La - Hg). The Mo and the at least one transition element are hereinafter referred to as the M. The M other than Mo is preferably Co, Ni, Cr, Cu, Nb, Ti, W, V, Zr, Ta, Y or a rare earth element. Ni and Co of the M components can be contained in the second composition in an amount up to approximately 20 atomic % based on Fe. The other M components (except for Mo) can be contained in the second composition in an amount up to approximately 5% based on Fe.

M is preferably V, Mn, Cr, Nb, Ni, or Co, more preferably Mn, V, or Nb.

The B component is at least one element selected from the group consisting of Si and Al. The content of Al is preferably 10 atomic % or less based on the total content of Si and Al.

The C component is at least one element selected from the group consisting of B, C, and P. The content of C is preferably 20 atomic % or less based on the total of B, C, and P, and the content of P is preferably 5% or less based on the total of B, C, and P.

When the A, B, and C components fall on or within the curve y_1 shown in Fig. 3, the μ_2 (after demagnetization) of 5000 or more ($\mu_2 \geqq 5000$) is obtained. When the A component is 80% or more, the crystallization temperature becomes low, and the secular change of permeability is seriously increased. A preferred content of the A component is less than 80%. In addition when the A, B, and C components fall on or within the curve y_2 shown in Fig. 3, the μ_2 (after demagnetization) of 6000 or more ($\mu_2 \geqq 6000$) can be obtained.

The A, B, and C components are in an amount falling on or within the curve 3 shown in Fig. 3, because, in amounts outside the curve 3, the pulse-deterioration resistance is impaired and μ_2 = 4000 is occasionally not attained.

The permeability (μ_2), the residual flux density (Br), and the magnetic flux density (B_2) are determined in the second composition so as to provide the core of a noise filter which can effectively eliminate a high-voltage pulse, as specifically described hereinafter.

When the permeability (μ_2) is less than approximately 4000, the inductance of the core of a noise filter becomes too low to attain a high attenuation of noise or a low noise output voltage.

The lower the residual flux density (Br), the more advantageous are the characteristics of the core of a noise filter obtained. In other words, when the A, B, and C components are outside the curve Y, the magnetic properties, such as a high magnetic flux density and low core loss required for the soft magnetic material, can be attained, since the conventional amorphous soft magnetic material having the Fe amount of around 80% do have such properties, but the pulse-resistance is seriously impaired. The amount of A, B, and C components, which is indicated by the overlapping curves X and Y, is not included in the fourth composition, since the permeability (μ_2) is generally low, e.g., approximately 3000.

When the residual flux density (Br) exceeds0.3 T(3 kG) (Br > 3 kG), the constant characteristic of permeability disadvantageously tends to be lost, with the result that, an efficient pulse-voltage elimination, which is attained at the constant permeability, is restricted.

When the magnetic flux density (B_2) is less than 0.5 T (5 kG), the permissible input voltage of noise disadvantageously becomes low. On the other hand, when the magnetic flux density (B_2) is more than 11 kG, the BH curve tends to have a non-linear portion, i.e., the permeability tends to become inconstant, and the permissible input voltage of noise becomes low. This means that steep increase of the curve shown in Fig. 2 occurs at a low input voltage.

In order to investigate whether or not the decrease in the pulse-resistance deterioration percentage due to Mo is attributable to a decrease in the magnetomechanical resonance, the present inventors measured the magnetostriction of the amorphous alloys shown in Table 3.

Table 3

Composition	Magnetic Properties						
	B_2 (T)	Br (T)	B_{10} (T)	Hc (A/m)	μ_2 (after demagnetization	μ_2 (after pulse deterioration)	Pulse deterioration percentage (%)
$Fe_{76}Si_6B_{18}$	0.79	0.09	1.18	10.4	5000	4000	20
$Fe_{73}Mo_3Si_6B_{18}$	0.97	0.08	1.09	8.0	7130	5700	20
$Fe_{70}Mo_6Si_6B_{18}$	0.91	0.18	0.98	10.4	6130	5700	7

The magnetostriction amount was not essentially changed by the addition of Mo.

In addition, the squareness ratio of the alloys according to the present invention was measured. This was less than 50%, and usually 20% or less.

It is therefore not believed that Mo is effective for enhancing the squareness ratio of the alloys according to the present invention.

Furthermore, it was discovered that Co, Ti, and W caused change in the magnetostriction amount.

Neither the squareness ratio nor the magnetostriction are attributable to the low pulse-resistance deterioration percentage.

Trial investigations from view points other than those discovered above could not clarify which one of the physical properties is attributable to the low pulse-resistance deterioration percentage.

During the heat treatment of the completely amorphous alloy, a small amount of the fine crystals may be precipitated depending upon the temperature and time of the heat treatment. The fine crystals precipitated in the amorphous alloy at a minor amount are detected by the following procedure. A thin strip of the amorphous alloy is subjected to ion-etching or electrolytic polishing to reduce its thickness to 50 nm or less. The thin strip is then observed by a transmission type electron microscope under the conditions of an accelerated voltage of 100 - 200 kV and magnification of 10,000 to 100,000. The presence and quantity of precipitated fine crystals can be determined by contrast.

Where the fine crystals are precipitated in the amorphous alloy of the second composition, they are 3% by area or less, usually 0.5% by area or less.

A condition of the heat treatment for precipitating the fine crystals is explained with reference to Table 4.

The amorphous alloy subjected to the heat treatment is $Fe_{75}Mo_5Si_{12}B_8$, and under the conditions Nos. 3 through 7, the properties according to the present invention are attained.

Table 4

Nos.	Condition	Fine Crystals	B_2	Br	μ_2 (After demagnetization)	μ_2 (After pulse deterioration)	Pulse-resistance deterioration percentage
1	460°C x 30 min	No	0.93	0.53	7,300	1,970	73
2	460°C x 60 min	No	0.92	0.34	5,280	3,010	43
3	460°C x 120 min	Yes	0.92	0.45	5,510	4,790	13
4	460°C x 240 min	Yes	0.76	0.45	4,970	4,570	8
5	470°C x 90 min	Yes	0.87	0.18	5,590	4,750	15
6	470°C x 120 min	Yes	0.84	0.17	5,010	4,560	9
7	470°C x 180 min	Yes	0.74	0.15	4,500	4,050	10

The precipitation of fine crystals causes virtually no change in the saturation flux density (B_s) (not shown in Table 4) and causes the reduction in the residual flux density (Br). No matter if the fine crystals are not precipitated, during the heat treatment at a temperature below the crystallization temperature, the residual flux density (Br) is reduced without virtually causing the change in the saturation flux density (Bs).

The $Fe_{73}Mo_5Si_9B_{13}$ amorphous alloy (the second composition) was subjected to various heat treatments to change the μ_2 (after demagnetization). The influence of the μ_2 (after demagnetization) upon the μ_2 (after pulse deterioration) and the pulse-resistance deterioration percentage was investigated. The results are shown in Fig. 6.

As is apparent from Fig. 6, the μ_2 (after pulse deterioration) lies slightly lower than the μ_2 (after demagnetization) = μ_2 (after pulse deterioration) line when the μ_2 (after demagnetization) is approximately 5000 or less. The μ_2 (after pulse deterioration) lies far below this line, and the pulse-deterioration percentage is drastically decreased, when the μ_2 (after demagnetization) is more than approximately 5500.

Such a tendency as shown in Fig. 6 is present in the amorphous alloy having the second composition but is mitigated due to Mo as compared with the amorphous alloy which is free of Mo.

The core may be disposed in a nonmagnetic resin case, a nonmagnetic or magnetic metal case or a ceramic case. The thin strip of an amorphous alloy can have a thickness of from approximately 10 µm to 100 µm, preferably from 10 µm to 50 µm, and a width of from 0.1 cm to 50 cm. One end of the coiled thin strip may be fixed to another part of the strip by any appropriate means, such as bonding, welding, taping, or caulking, and insulating material may be sandwiched between the opposed surface parts of the coiled thin strip.

A heat treatment for precipitating fine crystals may be carried out in the ambient air, an inert gas, or a non-oxidizing atmosphere. This heat treatment has also a purpose of stress relief-annealing of the coiled thin strip of an amorphous magnetic alloy.

The present invention is hereinafter described with regard to examples.

Example 1

Amorphous magnetic alloy thin strips 18 µm thick and 8 mm wide were produced by a known single-roll method, were wound as cores, and were heat-treated. The properties of the heat-treated cores were measured. These properties and the compositions of the amorphous magnetic alloy thin strips are shown in Table 5.

Table 5

No.	Composition	B_2 (kG)	B_r (kG)	μ_2 (Demagnetization)	μ_2 (Pulse)	Pulse-Resistance Deterioration Percentage
1	$Fe_{73}Si_{18}B_9$	0.81 ~~8.1~~	~~4.5~~ 0.45	3.083	2.072	32.9
2	$Fe_{73}Si_{15}B_{12}$	0.85 ~~8.5~~	~~4.5~~ 0.45	4.484	3.796	15.3
3*	$Fe_{73}Si_{12}B_{15}$	0.78 ~~7.8~~	~~1.0~~ 0.10	4.903	4.636	5.4
4*	$Fe_{73}Si_9B_{18}$	0.70 ~~7.0~~	~~1.5~~ 0.15	3.888	3.605	7.3
5	$Fe_{73}Si_6B_{21}$	0.82 ~~8.2~~	~~2.2~~ 0.22	3.985	3.111	21.9
6	$Fe_{76}Si_{15}B_9$	0.82 ~~8.2~~	~~4.8~~ 0.48	4.372	2.150	50.8
7	$Fe_{76}Si_{12}B_{12}$	0.81 ~~8.1~~	~~2.2~~ 0.22	5.198	4.304	17.2
8*	$Fe_{76}Si_9B_{15}$	0.67 ~~6.7~~	~~1.2~~ 0.12	4.793	4.351	9.2
9*	$Fe_{76}Si_6B_{18}$	0.79 ~~7.9~~	~~0.9~~ 0.09	4.679	4.687	4.1
10	$Fe_{76}Si_3B_{21}$	0.84 ~~8.4~~	~~1.0~~ 0.10	5.252	3.724	29.1
11	$Fe_{78}Si_{15}B_7$	0.86 ~~8.6~~	~~4.3~~ 0.43	3.315	2.215	33.2
12	$Fe_{78}Si_{12}B_{10}$	0.86 ~~8.6~~	~~3.5~~ 0.35	3.902	2.769	29.0
13	$Fe_{78}Si_9B_{13}$	0.66 ~~6.6~~	~~0.9~~ 0.09	4.724	3.687	22.0
14	$Fe_{78}Si_6B_{16}$	0.79 ~~7.9~~	~~0.8~~ 0.08	5.034	4.093	18.7
15	$Fe_{78}Si_3B_{19}$	0.76 ~~7.6~~	~~1.8~~ 0.18	5.116	3.556	30.5

No.	Composition	B_2 (kG)	B_r (kG)	μ_2 (Demagnetization)	μ_2 (Pulse)	Pulse-Resistance Deterioration Percentage
16	$Fe_{80}Si_9B_{11}$	~~6.7~~ 0.67	~~2.2~~ 0.22	3.442	2.224	35.4
17	$Fe_{80}Si_6B_{14}$	~~7.6~~ 0.76	~~1.1~~ 0.11	4.741	3.267	31.1
18	$Fe_{80}Si_3B_{17}$	~~7.1~~ 0.71	~~0.7~~ 0.07	4.724	2.967	37.2
19	$Fe_{82}Si_6B_{12}$	~~8.5~~ 0.85	~~7.3~~ 0.73	2.364	826	65.1
20	$Fe_{82}Si_3B_{15}$	~~9.1~~ 0.91	~~7.6~~ 0.76	2.117	950	55.1
21	$Fe_{82}Si_{0.5}B_{17.5}$	~~8.2~~ 0.82	~~7.0~~ 0.70	3.033	1.099	63.8
22*	$Fe_{72}Mn_1Si_9B_{18}$	~~7.6~~ 0.76	~~1.0~~ 0.10	4.860	4.670	3.9
23*	$Fe_{72}Cr_1Si_9B_{18}$	~~7.3~~ 0.73	~~1.3~~ 0.13	4.370	4.170	4.6
24*	$Fe_{72}Mo_1Si_9B_{18}$	~~7.3~~ 0.73	~~1.8~~ 0.18	4.510	4.150	7.9
25*	$Fe_{72}Nb_1Si_9B_{18}$	~~7.5~~ 0.75	~~1.3~~ 0.13	4.560	4.200	4.1
26*	$Fe_{70}Ni_3Si_9B_{18}$	~~7.7~~ 0.77	~~2.7~~ 0.27	3.160	2.860	9.5
27*	$Fe_{70}Co_3Si_9B_{18}$	~~7.1~~ 0.71	~~2.5~~ 0.25	2.970	2.700	9.1
28*	$Fe_{73}Si_9B_{14.2}C_{3.5}P_{0.3}$	~~7.1~~ 0.71	~~1.2~~ 0.12	4.850	4.680	3.5
29*	$Fe_{73}Si_9B_{14.2}C_{3.5}P_{0.3}Al_{0.1}$	~~6.7~~ 0.67	~~0.9~~ 0.09	4.750	4.390	7.6

In Table 5, the compositions indicated by * are those of the present invention, and the compositions not indicated by * are comparative examples. As is apparent from Table 8, the amounts of the A component (Fe alone or a combination of Fe and M), the B component (Si alone or a combination of Si and Al), and the C component (B alone or a combination of B, C, and P) are critical for obtaining improved resistance to pulse.

Example 2

Amorphous alloy thin strips 18 μm in thickness and 8 mm in width were produced by a known single roll method, wound in the form of a wound core, and heat treated. The properties of the cores and the composition of the amorphous alloy are shown in Table 6.

Table 6

	Composition				B_2 (kG)	Br (kG)	μ_2 (After demagnetization)	μ_2 (After pulse deterioration)	Pulse-resistance deterioration percentage (%)
	Fe	Mo	Si	B					
1	73	3	12	12	0.98	0.13	5,610	4,600	18
2	75	3	6	14	1.01	0.11	7,400	6,360	14
3	75	3	9	13	1.01	0.08	6,800	6,320	7
4	75	3	12	10	1.00	0.12	5,830	4,780	18
5	77	3	10	10	1.02	0.12	5,330	4,370	18
6	71	7	10	12	0.59	0.11	5,380	4,570	15
7	73	7	9	11	0.58	0.08	6,150	5,660	8
8	73	7	12	8	0.66	0.14	5,850	5,030	14
9	75	7	9	9	0.63	0.10	7,140	6,350	11

Claims

1. A core of a noise filter comprising a coiled thin strip of an amorphous magnetic alloy, characterised in that said alloy essentially consists of a first component which is Fe and Mo, a second component which is at least one selected from the group consisting of Si and Al, and a third component which is at least one selected from the group consisting of B, C, and Al, said first, second and third components being contained in an amount falling within an area defined by a curve Y and on the line of said curve Y and falling outside the curve X shown in Fig. 3, said alloy having the Mo content of up to 7%, and exhibiting a permeability (μ_2) of approximately 4,000 or more measured at 100 kHz and a magnetic field of 0.16A/m (2 mOe), a residual flux density (Br) of 0.3T (3 kG) or less determined in a BH curve measured at a frequency of 2 kHz and a maximum applied magnetic field of 160A/m (2 Oe), and a magnetic flux density (B_2) of from 0.5 to 1.1T (5 kG to 11 kG) measured at 160A/m (2Oe).

2. A core according to claim 1, wherein the Mo content is 3% or more.

3. A core according to claim 1 or claim 2, said core having from 0 to -10% of a pulse-resistance deterioration percentage which is defined by the equation:

$$\frac{\mu e \begin{pmatrix}\text{after application of}\\ \text{a magnetic field of}\\ \text{320A/m (4 Oe)}\end{pmatrix} - \mu e \begin{pmatrix}\text{demag-}\\ \text{netization}\end{pmatrix}}{\mu e\ (\text{demagnetization})} \times 100(\%)$$

wherein μe is the permeability at 100 kHz and 0.16A/m (2 mOe).

Fig. 1

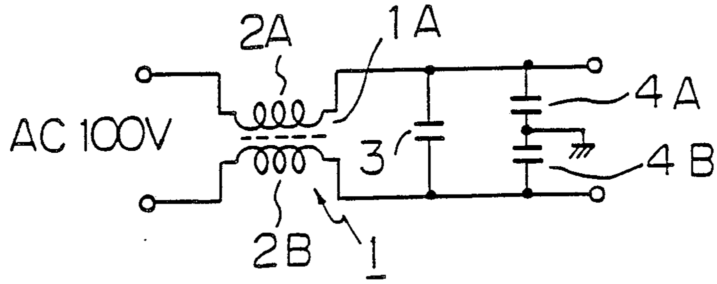

2A
1A
AC 100V
3
4A
4B
2B
1

Fig. 2

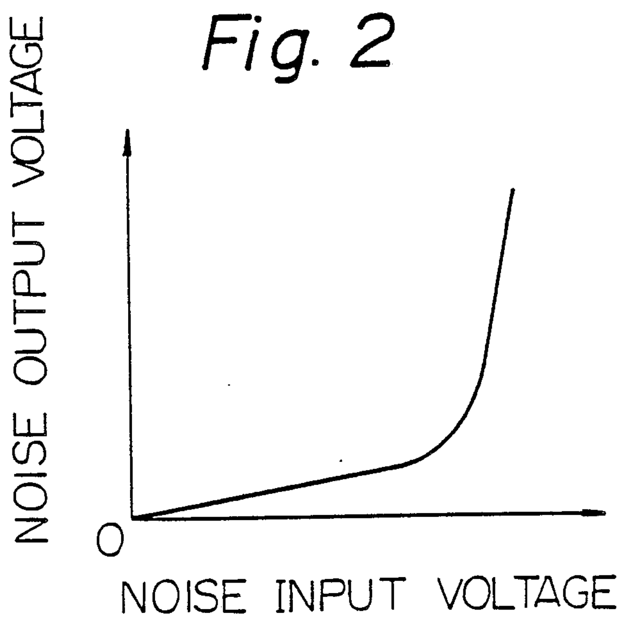

NOISE OUTPUT VOLTAGE
0
NOISE INPUT VOLTAGE

Fig. 3

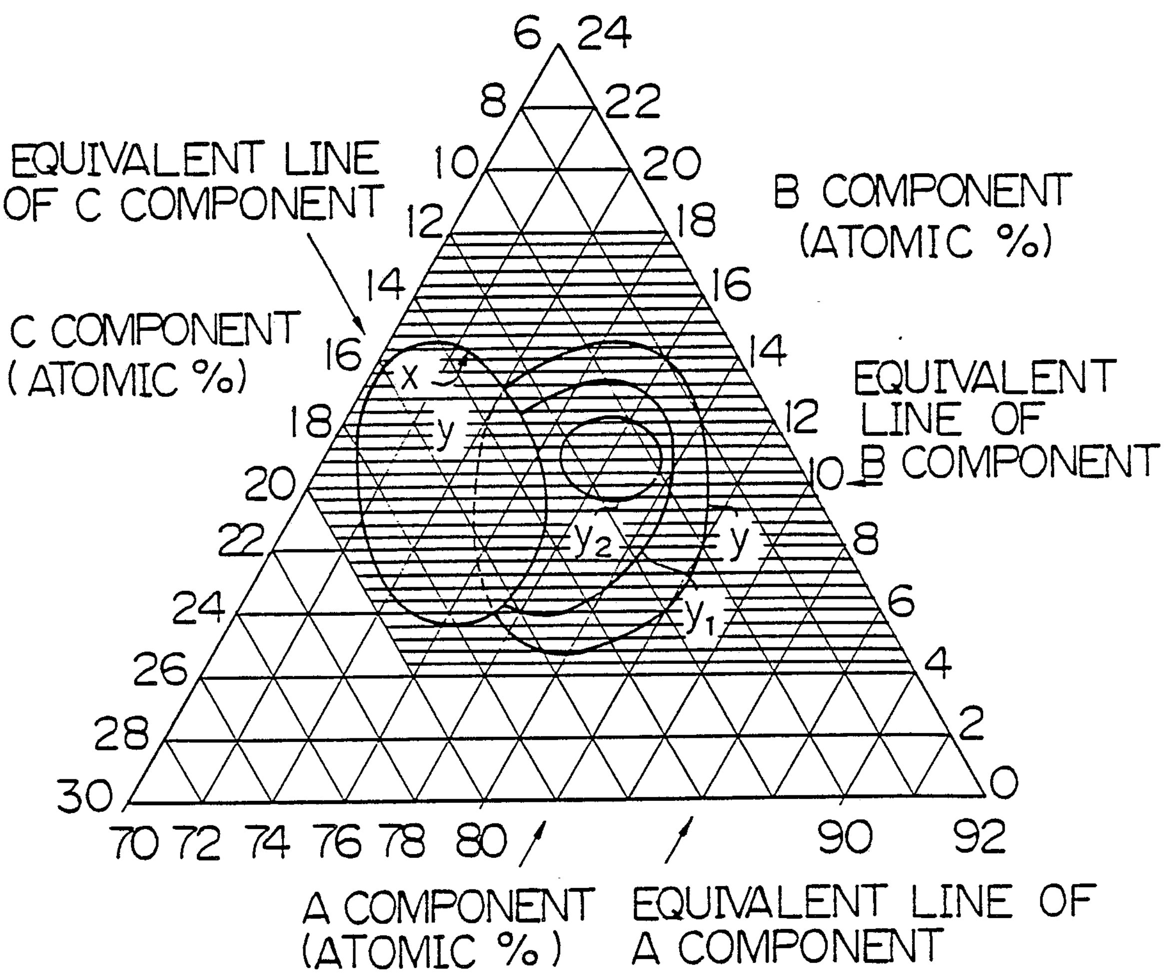

EQUIVALENT LINE OF C COMPONENT
C COMPONENT (ATOMIC %)
B COMPONENT (ATOMIC %)
EQUIVALENT LINE OF B COMPONENT
A COMPONENT (ATOMIC %)
EQUIVALENT LINE OF A COMPONENT
x
y
y_2
y_1
6 8 10 12 14 16 18 20 22 24 26 28 30
24 22 20 18 16 14 12 10 8 6 4 2 0
70 72 74 76 78 80 90 92

Fig. 4

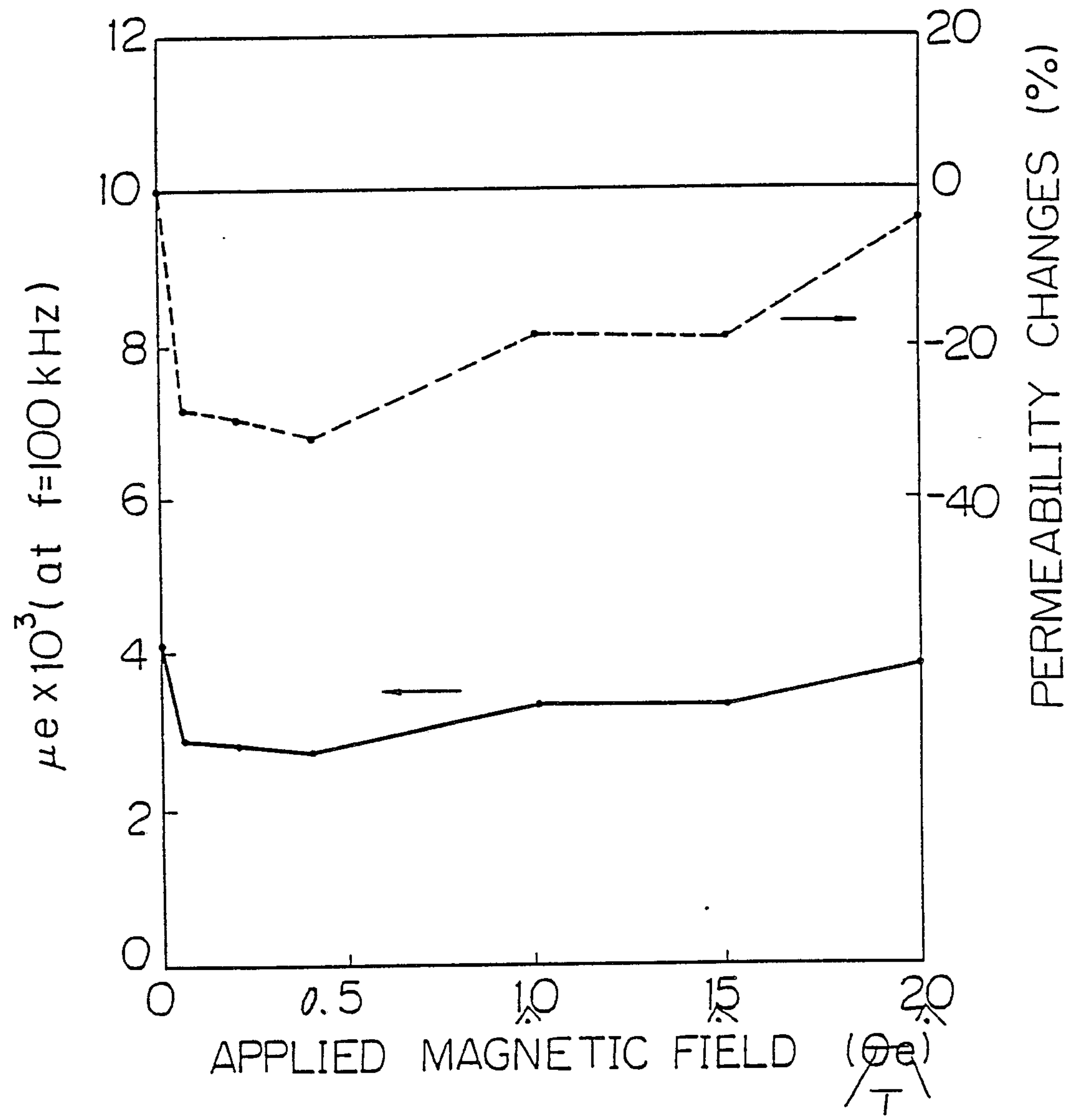
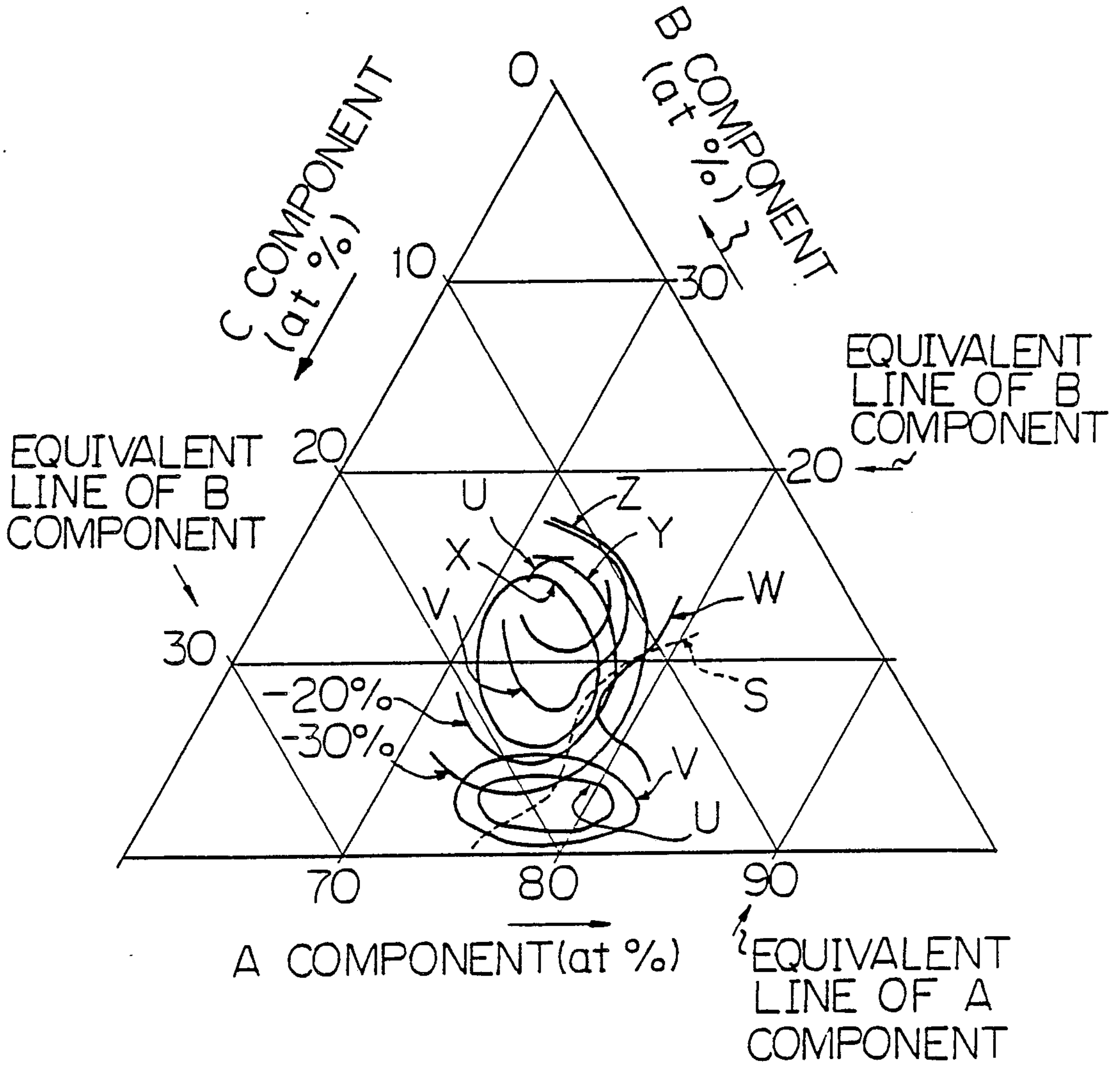
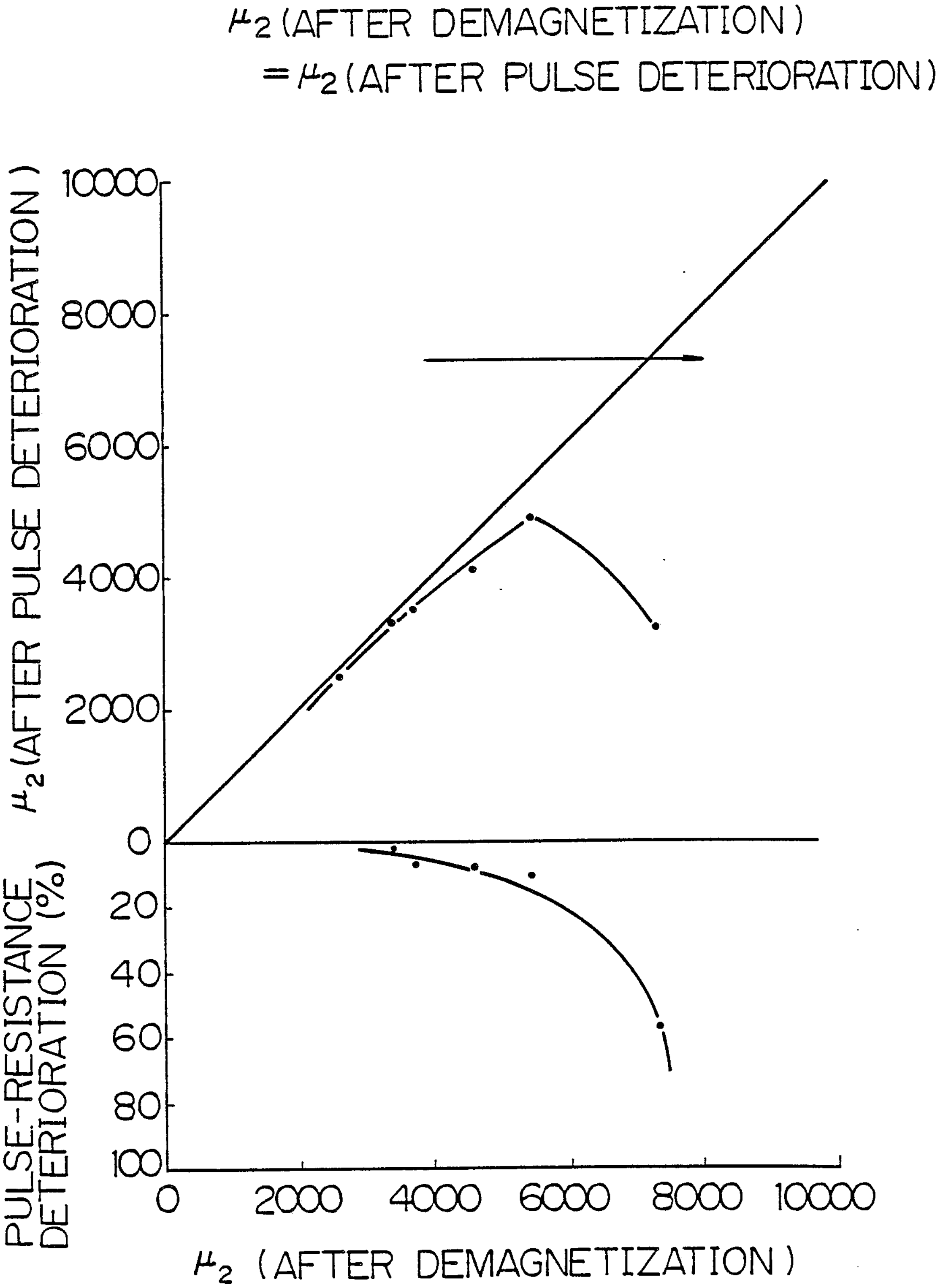

12
10
8
6
4
2
0
20
0
-20
-40
μe x10³ (at f=100 kHz)
PERMEABILITY CHANGES (%)
0
0.5
1.0
1.5
2.0
APPLIED MAGNETIC FIELD (Oe)
T

Fig. 5



0
10
20
30
70
80
90
C COMPONENT (at %)
B COMPONENT (at %)
30
20
EQUIVALENT LINE OF B COMPONENT
EQUIVALENT LINE OF B COMPONENT
U
Z
Y
X
V
W
S
-20%
-30%
V
U
A COMPONENT(at %)
EQUIVALENT LINE OF A COMPONENT

Fig. 6



μ2 (AFTER DEMAGNETIZATION) = μ2 (AFTER PULSE DETERIORATION)
μ2 (AFTER PULSE DETERIORATION)
10000
8000
6000
4000
2000
0
PULSE-RESISTANCE DETERIORATION (%)
20
40
60
80
100
0
2000
4000
6000
8000
10000
μ2 (AFTER DEMAGNETIZATION)