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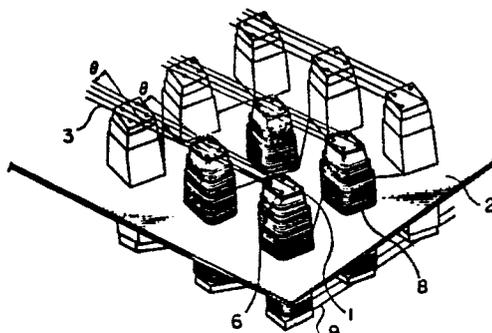
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54 **Semi-hard magnetic material for a reed switch and process for producing the same.**

57 Due to an Mo addition, to a known, Co-Fe-Nb semi-hard magnetic material, the coercive force is enhanced without causing deterioration of the cold workability of the semi-hard magnetic material. In addition, the energy product, the residual flux density and the fullness factor are high according to the semi-hard magnetic material of the present invention. Such material is particularly suited for reed pieces of reed switches, which are mounted in a four wire crosspoint switch.

Fig. 5



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SEMI-HARD MAGNETIC MATERIAL FOR A REED SWITCH
AND PROCESS FOR PRODUCING THE SAME

The present invention relates to semi-hard magnetic materials, which are suited for reed pieces of
5 a self-holding type reed switch, as well as a process for producing the semi-hard magnetic materials. Such materials should possess a hysteresis loop shape and residual magnetization property suited for application
10 in a self-holding type reed switch. Specifically, the semi-hard magnetic materials utilized in a reed switch should preferably possess the following properties.

1. Both saturated magnetic flux density (Bs) and residual magnetic flux density (Br) are high.
2. The square hysteresis loop exhibits a high
15 squareness ratio (Br/Bs) and a high "fullness factor". The term "fullness factor" used herein is represented by the formula:

$$\sqrt{(BH)_{\max}/Br \cdot H_c}$$

wherein (BH)_{max} is the maximum magnetic energy product and
20 H_c is coercive force.

3. The coercive force (H_c) is usually in the range between 10 and 50 Oe. The coercive force should be more than 50 Oe for application of the semi-hard magnetic materials to reed switches where mutual demagnetization,
25 explained hereinafter, is severe.

4. Plastic workability is excellent, i.e. these materials are capable of being easily cold worked into any desired shape or size such as, for example, a fine wire rod having a diameter as small as less than 1 mm.

5. The plating-or soldering-property is excellent, i.e. a surface layer of the semi-hard magnetic materials used for forming a reed switch can be reliably produced by the plating-or soldering-process.

6. When the semi-hard magnetic materials are exposed to a high temperature at the time of sealing the reed pieces having the above mentioned surface layer in a glass capsule of the reed switch, the magnetic properties of the reed pieces are not deteriorated by the increase of temperature.

When the reed switches are used in a four-wire crosspoint switch matrix of an electronic switching system, mutual demagnetization occurs between the four reed switches. As a result of the demagnetization, the coercive force and the squareness ratio of the semi-hard magnetic materials must be higher than in the reed-switches used in a two-wire crosspoint switch of an electronic switching system.

In U.S. Patent NO. 3,989,557, filed by the present Applicant, there is described a process for producing semi-hard magnetic material, wherein an alloy material comprising from 73 to 93% of cobalt, from 1 to 5% of niobium and iron in balance is subjected to (1) a process annealing at a temperature of 900° or higher, and subsequently, (2) a final cold working at a reduction of area of 75% or higher. The same U.S. patent also describes a process for producing a semi-hard magnetic material, wherein the alloy material, which is cold worked as stated above, is further subjected to ageing at a temperature of 950°C and higher. The semi-hard magnetic material, in the U.S. Patent mentioned above, however, is disadvantageous in the fact that the cold working property thereof is deteriorated by the increase of the niobium content in the range of from 1 to 5%, although the coercive force of the

semi-hard material is increased by such increase of niobium. In addition, deterioration of cold-workability is particularly remarkable when an attempt is made to increase niobium to more than 5%.

5 The alloy material of the U.S. Patent mentioned above may contain, for example, tantalum, titanium, vanadium, zirconium, molybdenum, chromium, tungsten and the like. The amount of these metals used in addition to niobium is usually such that the ratio by weight of these metals to
10 niobium is below 30/70. These metals form intermetallic compounds in the same a manner as niobium forms the intermetallic compounds, according to the description of U.S. Patent No. 3,989,557.

 The present Applicant proposed in the U.S. Patent
15 No. 3,983,916 an improved process for removing the deterioration of the cold workability, wherein an alloy material consisting essentially of from 73 to 93% of cobalt, from 3 to 7% of niobium and iron in balance is subjected to (1) a solution treatment, i.e. a heating at a temperature of
20 1000°C or higher followed by a rapid cooling through at least the temperature range between 800°C and 500°C, then, (2) a cold working at a reduction area of 75% or more, and subsequently, (3) an ageing at a temperature in the range
25 further in detail the improved process mentioned above and realized that this process involves the following problem, although the cold workability of the semi-hard magnetic material is in fact enhanced to some extent by the improved process. First, unless the bar or wire of the semi-hard
30 magnetic is carefully drawn in the cold drawing process, the bar or wire is liable to rupture. Second, the cold workability of the semi-hard magnetic material is seriously degraded, to such an extent that the cold working cannot be practiced industrially, when an attempt is made to
35 provide the material with a coercive force higher than 40 Oe. In the semi-hard magnetic material mentioned above and containing 3 to 7% of niobium, the Nb content and Fe

content must be increased to 5% or higher and 18% or higher, respectively, with the result that the coercive force is increased more than 40 Oe, but the cold workability is deteriorated. It is, therefore, practically impossible
5 to obtain from the Co-Fe-Nb alloy material, a semi-hard magnetic material having a coercive force of from 40 to 70 Oe and which is suited for the reed switches to be mounted in a four-wire crosspoint switch matrix of an electronic switching system.

10 A semi-hard magnetic material having a high coercive force is available under the name of VACUZET 655, which is sold by the VACUUMSCHMELZE Company, in Federal Republic of Germany. This semi-hard magnetic material comprises 30% iron 10.6% nickel, 1.2% aluminum, 2.4% titanium and cobalt
15 in balance. Since the magnetic properties of this semi-hard magnetic material are unstable, with the result that, for example, the coercive force is reduced by heat, the material is not suitable for reed pieces, which are sealed on enclosed in a glass capsule of a reed switch. In addition,
20 since the semi-hard magnetic material of VACUZET 655 includes aluminum as well as titanium, the plating-and soldering-properties of the material are not superior to those of the Co-Fe-Nb alloy.

It is, therefore, an object of the present invention
25 to provide a semi-hard magnetic material for reed pieces of a reed switch, which possess the properties 1 through 6, mentioned above, and specifically, a high coercive force and an excellent cold workability.

It is another object of the present invention to
30 improve a semi-hard magnetic material for reed pieces of a reed switch, containing mainly cobalt, and additionally iron and niobium, as well as one additive element which can form an intermetallic compound, so that the cold workability is not deteriorated with an enhancement of the coercive force.

35 It is further object of the present invention to provide a semi-hard magnetic material suited for the reed pieces of reed switches, which are mounted in each crosspoint of the

four wire type crosspoint in an electronic exchange system.

It is also an object of the present invention to prevent the rupture of the reed pieces during the cold working of the reed pieces of a reed switch and to enhance
5 the coercive force of the produced reed pieces.

In accordance with the present invention, there is provided a semi-hard magnetic material for a reed piece of a reed switch, said material containing (a) a major proportion of cobalt and iron, which forms a matrix of said
10 material having a face centred cubic lattice, (b) additionally niobium, which niobium is precipitated in said matrix as intermetallic compounds and provides said material with the required coercive force, and (c) one element, which is added in a predetermined amount with respect to said niobium,
15 characterised in that said one element is molybdenum and is present in said material in an amount of not less than 2% by weight so that said matrix is composed of said face centred cubic lattice and a body centred cubic lattice, and due to the composition of said matrix, the coercive force
20 is increased to a value of not less than 35 Oe, preferably from 40 to 70 Oe, more preferably from 60 to 70 Oe, and the components of said material are present in the following ranges by weight:

iron from 12 to 18%, preferably from 15 to 18%;
25 niobium from 2 to 4%;
molybdenum from 2 to 5%;
and the balance essentially cobalt, thereby providing said material with a residual magnetization flux density of not less than 11 kG, preferably 13 kG, and a fullness factor
30 of not less than approximately 0.80.

The present invention also consists, according to another of its aspects in a process for producing a reed piece of a reed switch from a semi-hard magnetic material containing a major proportion of cobalt and iron, and additionally
35 niobium and one element which is added in a predetermined amount with respect to said niobium, the process comprising the steps of solution-treating said material, cold working

said solution-treated material at a predetermined reduction area, ageing said cold worked material, and enclosing said aged material in a glass capsule of said reed switch, characterised in that molybdenum is selected as said one
5 element in an amount of from 2 to 5% by weight and the iron content is adjusted to an amount in the range of from 12 to 18%, preferably from 15 to 18%, by weight, and the niobium content to an amount in the range of from 2 to 4%
10 by weight, said cold working is performed at a reduction of area of at least 90%, and, due to said molybdenum selection, (a) maintaining the hardness of said cold worked material at a value not exceeding 450 Vickers Pyramid Number, (b) preventing the decomposition of the cobalt matrix phases of the face centred cubic lattice
15 into two different kinds of phases during said cold working, and (c) preventing the rupture of said material during said cold working; said cold worked material is aged at a temperature of from 600 to 750°C, preferably from 650 to 700°C, thereby decomposing said cobalt matrix phases
20 into (a) the phases of intermetallic compounds precipitated in the matrix of said aged material, (b) the original matrix phases of said face centred cubic lattice and (c) the new matrix phases of a body centred cubic lattice; and the semi-hard magnetic alloy
25 is provided with a coercive force not less than 35 Oe, preferably from 40 to 70 Oe, more preferably from 60 to 70 Oe, a residual magnetisation flux density of not less than 11 kG, preferably 13 kG, and a fullness factor of not less than approximately 0.80.

30 The basic component of the semi-hard magnetic material according to the present invention is cobalt, which is contained therein in an amount of from 73 to 93%, preferably from 75 to 81%. When the cobalt content is less than 73%, the alloy material is so hard that the
35 workability thereof is deteriorated. As a result, both the squareness ratio and the fullness factor of the semi-hard magnetic material is disadvantageously reduced.

The alloy material according to the present invention exhibits at the solution treated state a face centred

cubic lattice, because this alloy material mainly contains cobalt and iron. However, when the cobalt content is less than 72%, a part of the alloy material crystals having the face centered cubic lattice is transformed into a body
5 centered cubic lattice during the cold working, with the result that the plastic workability of the cobalt based alloy material is reduced. When the cobalt content exceeds 93%, the workability of the alloy material is also reduced. This is because, a part of the alloy material crystals
10 having the face centered cubic lattice is transformed into a hexagonal close packed lattice, with the result that the plastic workability of the cobalt based alloy material is reduced. In addition, when the cobalt content exceeds 93%, the contents of molybdenum, iron and niobium are
15 relatively reduced, and thus, the magnetic properties of the semi-hard magnetic materials are disadvantageously degraded.

The niobium provides, in combination with molybdenum, the semi-hard magnetic material with the required coercive
20 force. When the niobium content is less than 2%, the coercive force is too low. On the other hand, when the niobium content exceeds 4%, the workability of the cobalt based alloy material is degraded. With an increase of the niobium content, intermetallic compounds containing niobium
25 tend not to be dissolved, and thus, remain in the cobalt matrix after the solution treatment of the cobalt based alloy material.

The iron provides the semi-hard magnetic material with the required, coercive force, saturation flux density
30 and residual magnetization. When the iron content is less than 12%, the coercive force, saturation flux density and residual magnetization are too low. When the iron content exceeds 18%, the cold workability of the cobalt based alloy material is reduced. The iron content is therefore
35 from 12 to 18%.

If the semi-hard magnetic material consists only of cobalt, iron and niobium, the cold workability thereof is

deteriorated when an attempt is made to increase the coercive force thereof by adjusting the niobium content. The feature of molybdenum resides in the fact that the coercive force is enhanced but the cold workability is not
5 deteriorated substantially. The molybdenum content of 2% or more is essential for sharply increasing the coercive force. When the molybdenum content exceeds 5%, the residual magnetization is however, lowered.

The process for producing the semi-hard magnetic
10 material according to the present invention includes the conventional steps of melting the raw materials for obtaining the alloy material, casting the melt into an ingot, hot-working the ingot, solution-treating the hot-worked alloy material, cold working, and subsequently, ageing the alloy
15 material. In the melting step, the conventional raw materials, such as an electrolytic cobalt, an electrolytic iron, a ferromolybdenum metal and a ferroniobium metal, are melted in a high frequency, induction furnace, preferably in a vacuum, high frequency, induction furnace. The
20 obtained melt is cast into a mold to produce an ingot, and the ingot is subjected to a homogenizing annealing. The ingot is then worked by a hot swaging machine, a cold swaging machine and a cold drawing machine, thereby producing a wire, a tape or a small bar. Any conventional process
25 for producing the wire etc., can be employed in producing the semi-finished product of semi-hard magnetic material.

The semi-finished product mentioned above is heated at a temperature of from 1050 to 1200°C, preferably from 1050 to 1150°C, and should subsequently be rapidly cooled.
30 The semi-finished product may then be subjected to a peeling by the dies, if necessary.

The process according to the present invention is characterized in that: (1) the cold working is performed at a reduction of area of at least 90%, and, due to the
35 molybdenum selection, (a) the hardness of the cold worked material is maintained at a value not exceeding approximately 450 in Vickers, (b) the decomposition of a cobalt rich

phase of a face centered cubic lattice into two different phases is prevented during the cold working, and (c) the rupture of the material during the cold working is prevented, and; (2) the cold worked material is aged at a temperature
5 of from 600 to 700°C, and by the ageing, the cobalt-rich matrix phases are decomposed into (a) the phases of inter-metallic compounds precipitated in the matrix of the aged material, (b) the original matrix phases of the face centered cubic lattice, and (c) the new matrix phases of a
10 body centered cubic lattice, and also, the semi-hard magnetic alloy is provided with a coercive force not less than 35 Oe, preferably from 40 to 70 Oe, more preferably from 60 to 70 Oe, a residual magnetization flux density of not less than 13 kG and a fullness factor of not less than
15 approximately 0.80.

The semi-hard magnetic material according to the present invention, which consists of the Co-Fe-Nb-Mo alloy, can be used for the reed pieces of a reed switch, on which pieces a surface coating, for example a rhodium plating,
20 must be applied. Since this semi-hard magnetic material contains neither titanium nor aluminum, the surface coating is uniform and exhibits a high adhesive strength.

The surface coating process includes the following steps. In the preparatory step prior to the applying step
25 of the coating, the reed pieces, which were previously aged for example at 650°C, are boiled in a 5% caustic alkaline solution at a temperature of 100°C for about 20 minutes, or subjected to an electrolytic polishing, thereby removing an oxide film composed mainly of niobium oxide.
30 In the step of forming an underlying layer, the underlying layer, such as a gold striking layer, is deposited on the reed pieces, so as to increase the bonding strength of the desired coating to the reed pieces. In the step of forming the coating, a lower, coating metallic layer, such as a
35 tin layer, may be firstly formed on the underlying layer to a thickness of approximately 0.5 micron, and subsequently, the rhodium plating layer is formed to a thickness of from

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2.0 to 4.0 microns.

The present invention is explained in detail hereinafter with reference to the drawings, wherein:

Fig. 1 is a graph indicating the change of resistivity upon an ageing temperature of Co-15%Fe-4%Nb-x%Mo alloy materials;

Fig. 2 is a graph indicating the relationship of the hardness after drawing with regard to the contents of additional elements added to several cobalt-based alloys;

Fig. 3 is a graph indicating the relationship of the hardness after drawing with regard to the coercive force of two cobalt-based alloys;

Fig. 4 is a general view of a four wire cross-point switch;

Fig. 5 is a partially enlarged view of Fig. 1;

Fig. 6 is a crosspoint, in which the semi-hard magnetic material according to the present invention is used;

Figs. 7A, B and C are graphs indicating the change of the coercive force, the residual flux density and the squareness ratio, respectively, as a function of the aging temperature of Co-15%Fe-4%Nb-x%Mo alloys;

Figs. 8A and B are graphs indicating the change in residual flux density and coercive force, respectively, of the alloy materials of Fig. 7, as a function of the molybdenum content of the alloy;

Figs. 9A, B and C are graphs with regard to Co-18%Fe-3%Nb-x%Mo alloys similar to Figs. 7A, B and C, respectively;

Figs. 10A and B are graphs with regard to the Co-18%Fe-3%Nb-x%Mo alloys, similar to Figs. 8A and B, respectively;

Figs. 11A, B and C are graphs with regard to Co-x%Fe-4%Nb-3%Mo alloys, similar to Figs. 7A, B and C, respectively, and;

Figs. 12A and B are graphs indicating the

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changes in residual flux density and coercive force, respectively, of the alloy materials of Fig. 11, with regard to the iron content of these alloy materials.

The semi-hard magnetic material according to the present invention is characterized, as compared with that consisting of Co-Fe-Nb, by exhibiting a high coercive force not less than 35 Oe, preferably from 40 to 70 Oe, more preferably from 60 to 70 Oe, a residual magnetization flux density of not less than 13 kG and a fullness factor of not less than approximately 0.80. In addition the energy product $(BH)_{\max}$ ranges advantageously from 0.3 to 0.6 M G·Oe.

A measurement of the resistivity and an X-ray diffractometry was carried out with regard to the alloy materials of Co-15%Fe-4%Nb-2~5%Mo, which were firstly formed in the form of a coil having a 2 mm diameter and, then, drawn to a size of 0.6 mm after being solution treated at 1100°C. The drawn coil was subjected to ageing at a temperature up to 1000°C and, then, resistivity measurement and X-ray diffractometry were carried out. The results of such measurement and X-ray diffractometry are shown in Fig. 1.

The following facts will be apparent from Fig. 1.

- (1) The decrease of resistivity starts from 500°C.
- (2) The resistivity is minimum at a temperature of from 650 to 700°C.
- (3) The resistivity is increased from a temperature higher than 700°C.
- (4) The alloy materials exhibit at a drawing state (A.D.) a crystal structure of a face centered cubic (FCC) lattice with a lattice constant (a) of 3.56 angstroms.
- (5) The face centered cubic phases of the alloy material at the drawing state are decomposed into the new phases of the body centered cubic (BCC) lattice and precipitates (PPT), as well as the original face centered cubic (FCC) phases, while the resistivity is decreased during the decomposition.
- (6) Only the face centered cubic (FCC) phases are present at a temperature of 800°C and higher.

It was proven by the X-ray diffractometry of the alloy materials that the face centered cubic phases and the body centered cubic phases are a solid solution of cobalt, and the iron is dissolved in the solid solution.

5 The composition of the precipitated phases are not elucidated but are believed to be the intermetallic compounds of Co_3Nb and Co_3Mo .

From the facts revealed from Fig. 1, it will be apparent that several features of the present invention reside in the structure of the alloy materials. The increase of coercive force by ageing at a temperature of from 600 to 750°C is caused not only by a precipitation of the intermetallic compounds into the cobalt matrix, as in the case of the known, Co-Fe-Nb alloy, but also by a decomposition of the cobalt matrix into the FCC phases and ECC phases. Such decomposition of the cobalt matrix into two kinds of phases is believed to cause the remarkable increase of the coercive force, which increase is achieved when the molybdenum is added in an amount of at least 2%.
20 When the matrix of any metallic material is composed of the two kinds of mixture phases, the cold workability thereof is impaired thereby. In addition, the decomposition of the matrix is liable to occur even during the cold drawing in the case of the known Co-Fe-Nb alloy material.
25 However according to one of the features of the invention, the cobalt matrix is not decomposed due to the Mo addition during the cold working, and thus the cold workability of the alloy materials is not impaired advantageously.

In Fig. 2, the hardness after drawing is shown with regard to the several cobalt-based alloys. The lines - Δ - and - \odot - represent the alloy of Co-15%Fe-2%Nb-x%Mo and the alloy of Co-15%Fe-4%Nb-x%Mo, according to the present invention, respectively. The line - \ominus - represents the alloy of Co-12%Fe-x%Ti, the line -- \odot -- represents the alloy of Co-12%Fe-x%Nb, and the line - \oplus - represents the alloy of Co-11%Fe-5%Ti-x%Mo. All the alloys were cold drawn at a reduction of area of 90%. From Fig. 2, the

influence of the additional element, i.e. molybdenum, niobium or titanium, on the work hardening of Co-Fe alloys is apparent.

The molybdenum content exerts substantially no
5 influence on the hardness of the Co-Fe alloy materials
(c.f. the lines - Δ -, - \circ - and - \odot -). In the alloys
represented by these three lines, the alloy of Co-11%Fe-
-5%Ti-x%Mo has the highest hardness, while the other two
10 alloys have an advantageously low hardness of not exceeding
450 in Vickers. When the titanium- or niobium-content is
increased, the hardness is also proportionally increased
(the line - \odot - or - \odot -).

In Table I, below, the cold workability, the coercive
force (H_c in Oe) and the saturation flux density (B_{100} in
15 kG) are shown with regard to the known, Co-Fe-Nb alloys
disclosed in U.S. Patent No. 3,989,557. These alloys were
produced using the same procedure as in Example 1, illus-
trated hereinbelow. Since the difficulty in the workability
cannot be quantitatively expressed, it is expressed in the
20 three levels A, B and C, wherein the level A indicates
that the alloy material could be worked into a wire having
diameter of 0.6 mm (reduction of area of 91%), the level B
indicates that the wire was frequently ruptured during the
drawing to the size of 0.6 mm, and the level C indicates
25 that the 0.6 mm wire could not be produced by the drawing.
The magnetic properties in Table I are those of the wires
having a diameter of 0.6 mm and aged at 700°C. However,
with regard to the wires of level C, the magnetic properties
of the actually produced wires were measured and then
30 calibrated, in a manner as if the change of the magnetic
properties occurred due to the cold drawing of the wires up
to 91% of the reduction of area.

Table I

Nb (%)	Fe (%)					
	0	9	12	15	18	21
7	-	-	C		-	-
			Hc 48			
			B ₁₀₀ 11			
6			A		B	
			Hc 36	Hc 42		
			B ₁₀₀ 13.6	B ₁₀₀ 14		
5	-	-	A		B	
			Hc 35	Hc 36	C	
			B ₁₀₀ 14.2	B ₁₀₀ -	39.5	
4	A		A		A	
	Hc 27.4	Hc 26.0	Hc 28	Hc 34	Hc 36	Hc 37
	B ₁₀₀ -	B ₁₀₀ -	B ₁₀₀ 15.5	B ₁₀₀ 15.8	B ₁₀₀ 16.0	B ₁₀₀ -
3	A		A		A	
	Hc 17.2	Hc 18.8	Hc 22	Hc 24	Hc 27	Hc 28
	B ₁₀₀ -	B ₁₀₀ -	B ₁₀₀ 15.8	B ₁₀₀ 15.8	B ₁₀₀ 16.0	B ₁₀₀ 17.1

It is apparent from Table I, that the cold workability of the alloy materials exhibiting a coercive force more than 36 Oe is B or C. The cold workability is deteriorated with an increase in the niobium and iron contents. Although
 25 either the high coercive force or the excellent cold workability must be sacrificed in the known alloy materials consisting of cobalt, iron and niobium, both the required, coercive force and cold workability can be achieved by the addition of molybdenum to this alloy material. According
 30 to one of the features of the present invention, the rupture of the wire during the cold drawing is considerably decreased in the present invention as compared with that in the cold drawing of the known alloy material of Co-Fe-Nb. The alloy material according to the present invention can
 35 be drawn at a reduction of area of at least 90% without the wire rupturing. Although the wire according to the known alloy of Co-Fe-Nb is broken into more than three

pieces, the wire according to the present invention is not broken during drawing, even if both wires are drawn under the same drawing conditions.

The hardness after cold drawing is the result of
5 the work hardening and is a factor which influences the cold workability of any metallic material. The relationship between the cold workability and the coercive force of the cobalt based alloy materials is readily seen in Fig. 3. In Fig. 3, the line - \odot - represents the known alloy
10 material of Co-12%Fe-x%Nb, which is cold drawn at a reduction of area of 90% (except for 65% of the alloy containing 6%Nb) and which is aged at 700°C for the period of 1 hour. The alloy material of Co-12%Fe-6%Nb could not be cold drawn at a reduction of area of 90%. The line - \circ -
15 represents the alloy materials according to the present invention, which consists of Co-15%Fe-4%Nb-x%Nb. These alloy materials were drawn at a reduction of area of 90% and the hardness of the alloy materials after the cold drawing was measured. The cold drawn alloy materials were
20 then aged at 650°C for the period of 1 hour. The known alloy materials exhibit the increase of coercive force with an increase in the hardness after drawing, i.e. a deterioration of the cold workability. In other words, due to the precipitation of intermetallic compounds containing
25 niobium, the coercive force is increased, while the intermetallic compounds containing niobium, which are left undissolved in the cobalt matrix, reduce or impair the cold workability of the known alloy of Co-Fe-Nb. On the other hand, in the alloy materials according to
30 the present invention, the coercive force is advantageously increased from 35 to 75 Oe, while the hardness after drawing is kept essentially constant. This fact means that the amount of the intermetallic compounds, which are supposed to contain molybdenum, in addition to niobium,
35 is not changed regardless of the increase of the coercive force. The difference between the two lines in Fig. 3 implies, therefore, that in the alloy materials of the

present invention, the increased coercive force in the range from 35 to 70 Oe is caused mainly due to the decomposition of the cobalt matrix into the new body centered cubic (BCC) phases and the original face centered cubic (FCC) phases, explained in connection with Fig. 1. In other words, the precipitation of the intermetallic compounds does not act a major role to such increase of the coercive force.

Referring to Fig. 4 a coil form 1 contains a plurality of reed switches which are used as crosspoint switches, and outside of each 1, a driving coil 8 which drives the above-mentioned reed switch 1 is wound. A magnetic shunt plate 2 is composed of magnetic material and provides a plurality of holes for arranging the above-mentioned coil forms 1 in matrix array. Horizontal and vertical multiple connecting wires 3 and 9 shown in Fig. 5, connect the lead terminals 6 of the reed switches held in the coil forms 1 with the output terminals of the circuits of the speech path. Said multiple connecting wires 3 and 9 are composed of high permeability magnetic material and are capable of relieving the prominent demagnetizing effect between reed switches. Such demagnetizing phenomenon is frequently produced when the reed switch is miniaturized.

As shown in Fig. 5, four reed switches are inserted in the respective coil forms 1, so as not to lie on the same line with respect to the longitudinal directions of the respective multiple connecting wires 3 and 9, and connected to said respective multiple connecting wires 3 and 9. Thus, the multiple connecting wires 3 and 9 are respectively arranged on the same plane in parallel, with a substantially equal distance between adjacent connecting lines.

Fig. 6 shows the relation between the coil form 1 and the reed switches 13-15 which are contained in the bobbin 1. Referring to Fig. 6, four reed switches 13, 14, 15 and 16 are contained in the wire coil form 1, and the lead ends 6 of these reed switches are arranged in row and column direction as shown in Fig. 5, and connected with the

multiple connection wires.

In the crosspoint switches as shown in Figs. 4, 5 and 6, the hysteresis loop of the semi-hard magnetic materials of the reed switches are distorted by the mutual demagnetization effect, in such a manner that the energy product $(BH)_{\max}$ of the hysteresis loop is decreased. However, since the semi-hard magnetic material according to the present invention exhibits a high coercive force, it is advantageously used for the reed switches of four wire crosspoint switching matrix.

The present invention is explained more in detail in connection with Examples.

Example 1

Electrolytic cobalt, electrolytic iron, ferroniobium metal and ferromolybdenum metal were charged in an aluminous crucible and melted under vacuum by a high frequency induction furnace. The obtained melt was cast to produce an ingot having a diameter of 40 mm and a weight of approximately 3.2 kg. The ingot was homogenized at 1200°C for 5 hours and subsequently worked to a wire of 2 mm in diameter by using a hot swaging machine, cold swaging machine and a wire drawing machine. This wire of 2 mm in diameter was heated at 1100°C for 30 to 60 minutes to carry out the solution treatment, and directly after the heating quenched in water. The so treated wire of 2.0 mm in diameter was cold drawn to the size of 0.6 mm in diameter, and the reduction of area during the cold drawing amounted to 91%. The wire could be cold drawn without occurrence of rupturing. The cold workability was excellent. The cold drawn wire was subjected to an ageing at a temperature lower than 1000°C for one hour. The so produced semi-hard magnetic material contained 15% of iron 4% of niobium, from 2 to 5% of molybdenum and cobalt in the balance.

The measurement results of coercive force (H_c), the residual flux density (B_r), and the squareness ratio (B_r/B_s , B_s designates the saturation flux density) are shown in Figs. 7A, B and C.

The following facts will be apparent from Figs. 7 A, B and C. When the aging temperature is adjusted from 600 to 700°C, preferably from 650 to 660°C, (1) the coercive force is 40 Oe or more, preferably from 50 Oe or more, (2) the squareness ratio ranges from 92 to 95%, and (3) residual magnetization ranges from 11 to 14 kG. Accordingly, several properties required for the semi-hard magnetic materials are satisfied by adjusting the ageing temperature. The molybdenum content should be not more than 5%, so as to provide the semi-hard magnetic material with high residual flux density.

The residual flux density and coercive force measured in the present Example are shown in Figs. 8 A and B, respectively, in dependence upon the molybdenum content. As is clear from Fig. 8 B, the increase of the coercive force with the increase of molybdenum content is ten or more times larger at the molybdenum content of 2% or more than at the molybdenum content of less than 2%. This fact well coincides with the difference in the crystallographic structure of the aged Co-Fe alloy materials, between the alloy materials containing 2% or more of molybdenum and those containing no molybdenum. Such difference is explained in detail in connection with Fig. 1. It can therefore be believed that the crystallographic change of the alloy materials containing less than 2% of molybdenum is similar to that of the known, Co-Fe-Nb alloy.

Example 2

The cobalt-based, semi-hard magnetic material containing 18% of iron, 3% of niobium and from 2 to 5% of molybdenum was produced by the procedure of Example 1.

In Figs. 9 A, B and C similar to Figs. 7A, B and C, respectively, almost same measured results of the coercive force, residual flux density and squareness ratio as in those of Figs. 7A, B and C, respectively, are obtained, except for the following. The coercive force and residual flux density in Figs. 9A and B, respectively are slightly higher than in those of Figs. 7A and B. The squareness

ratio in Fig. 9C.

The influence of molybdenum on the residual flux density and coercive force as seen from Figs. 10A and B, respectively, is different from that as seen from Figs. 8A and B in the following points. In Fig. 10A, the decrease of the residual flux density with the increase of the molybdenum content is advantageously mitigated. In Fig. 10B, the coercive force of the aged alloy materials is higher than that of the aged alloy materials in Fig. 8B containing the same amount as in Fig. 10B. These differences are advantageous from the point of view of magnetic properties, and are caused by lower niobium and higher iron content of the alloy materials in Fig. 10 than in those in Fig. 8.

15 Example 3

The cobalt-based, semi-hard magnetic material containing from 12 to 18% of iron, 4% of niobium and 3% of molybdenum was produced by the procedure of Example 1.

20 Figs. 11A, B and C are graphs similar to Figs. 7A, B and C, respectively.

When the alloy materials containing 18% and 15% of iron are compared with the alloy material containing 12% of iron, the latter exhibits the inferior, coercive force and squareness ratio to those of the former. The iron content is therefore preferably not less than 15%, from the point of view of magnetic properties.

It is clear from Fig. 12, that although the coercive force proportionally increases with the iron content, the residual magnetization is left almost unchanged.

30 The squareness ratio of the alloy materials produced in the present Example ranged from 90 to 95%.

Example 4

The semi-hard magnetic materials having three compositions as shown in Table II were produced by the procedure of Example 1. The measurement results of the magnetic properties are illustrated in Table II.

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Table II

Alloy Composition (wt %)	Coercive Force H _c (Oe)	Residual Flux Density B _r (KG)	Squareness Ratio B _r /B _s	Energy Product (B×H) _{max}	Fullness Factor $\sqrt{\frac{(BH)_{max}}{B_r H_c}}$
Co-15%Fe-4%Nb-3%Mo	42	13.2	0.91	380,000	0.83
Co-15%Fe-4%Nb-4%Mo	61	12.2	0.90	450,000	0.78
Co-15%Fe-4%Nb-5%Mo	72	10.8	0.90	540,000	0.83

- 1 -

CLAIMS

1. A semi-hard magnetic material for a reed piece of a reed switch, said material containing (a) a major proportion of cobalt and iron, which forms a matrix of said material having a face
5 centred cubic lattice, (b) additionally niobium, which niobium is precipitated in said matrix as intermetallic compounds and provides said material with the required coercive force, and (c) one element, which is added in a predetermined
10 amount with respect to said niobium, characterised in that said one element is molybdenum and is present in said material in an amount of not less than 2% by weight so that said matrix is composed of said face centred cubic lattice and a body
15 centred cubic lattice, and due to the composition of said matrix, the coercive force is increased to a value of not less than 35 Oe, preferably from 40 to 70 Oe, more preferably from 60 to 70 Oe, and the components of said material are present in the
20 following ranges by weight:

iron from 12 to 18%, preferably from 15 to 18%;

niobium from 2 to 4%;

molybdenum from 2 to 5%;

and the balance essentially cobalt, thereby providing said material with a residual magnetization flux density of not less than 11 kG, preferably 13 kG, and a fullness factor of not less than approximately 0.80.

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2. A process for producing a reed piece of a reed switch from a semi-hard magnetic material containing a major proportion of cobalt and iron, and additionally niobium and one element which is added in a predetermined amount with respect to said niobium, the process comprising the steps of solution-treating said material, cold working said solution-treated material at a predetermined reduction area, ageing said cold worked material, and enclosing said aged material in a glass capsule of said reed switch, characterised in that molybdenum is selected as said one element in an amount of from 2 to 5% by weight and the iron content is adjusted to an amount in the range of from 12 to 18%, preferably from 15 to 18%, by weight, and the niobium content to an amount in the range of from 2 to 4% by weight, said cold working is performed at a reduction of area of at least 90%, and, due to said molybdenum selection, (a) maintaining the hardness of said cold worked material at a value not exceeding 450 Vickers Pyramid Number, (b) preventing the decomposition of the cobalt matrix phases of the face centred cubic lattice into two different kinds of phases during said cold working, and (c) preventing the rupture of said material during said cold working;

said cold worked material is aged at a temperature of from 600 to 750°C, preferably from 650 to 700°C, thereby decomposing said cobalt matrix phases into (a) the phases of intermetallic compounds .

5 precipitated in the matrix of said aged material, (b) the original matrix phases of said face centred cubic lattice and (c) the new matrix phases of a body centred cubic lattice; and the semi-hard magnetic alloy is provided with a coercive force
10 not less than 35 Oe, preferably from 40 to 70 Oe, more preferably from 60 to 70 Oe, a residual magnetisation flux density of not less than 11 kG, preferably 13 kG, and a fullness factor of not less than approximately 0.80.

15 3. A process according to claim 2, characterised in that said solution treatment is performed at a temperature of from 1050 to 1200°C, preferably from 1050 to 1150°C.

20 4. A process according to claim 2 or claim 3, characterised in that said process further comprises applying a metallic coating layer to said aged material.

25 5. The use of a reed piece of a semi-hard magnetic material according to claim 1, for a four wire crosspoint switch.

Fig. 1

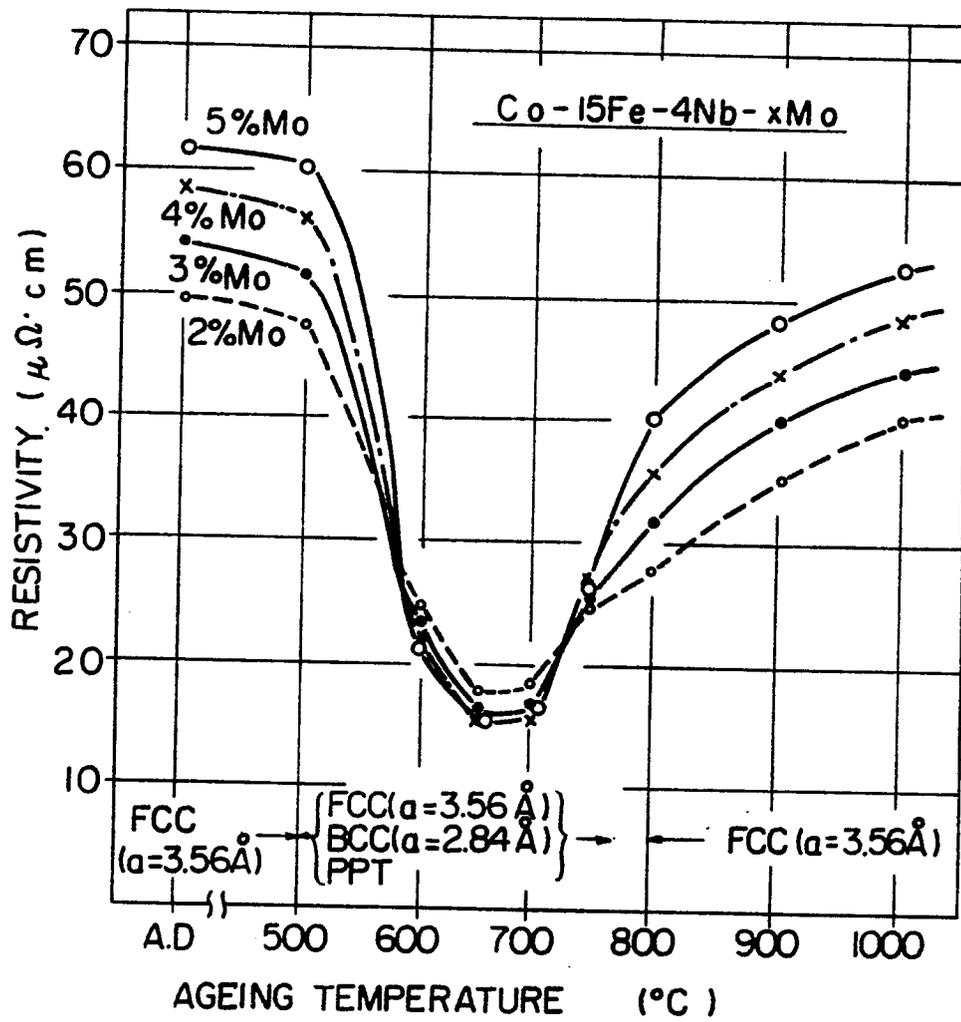


Fig. 2

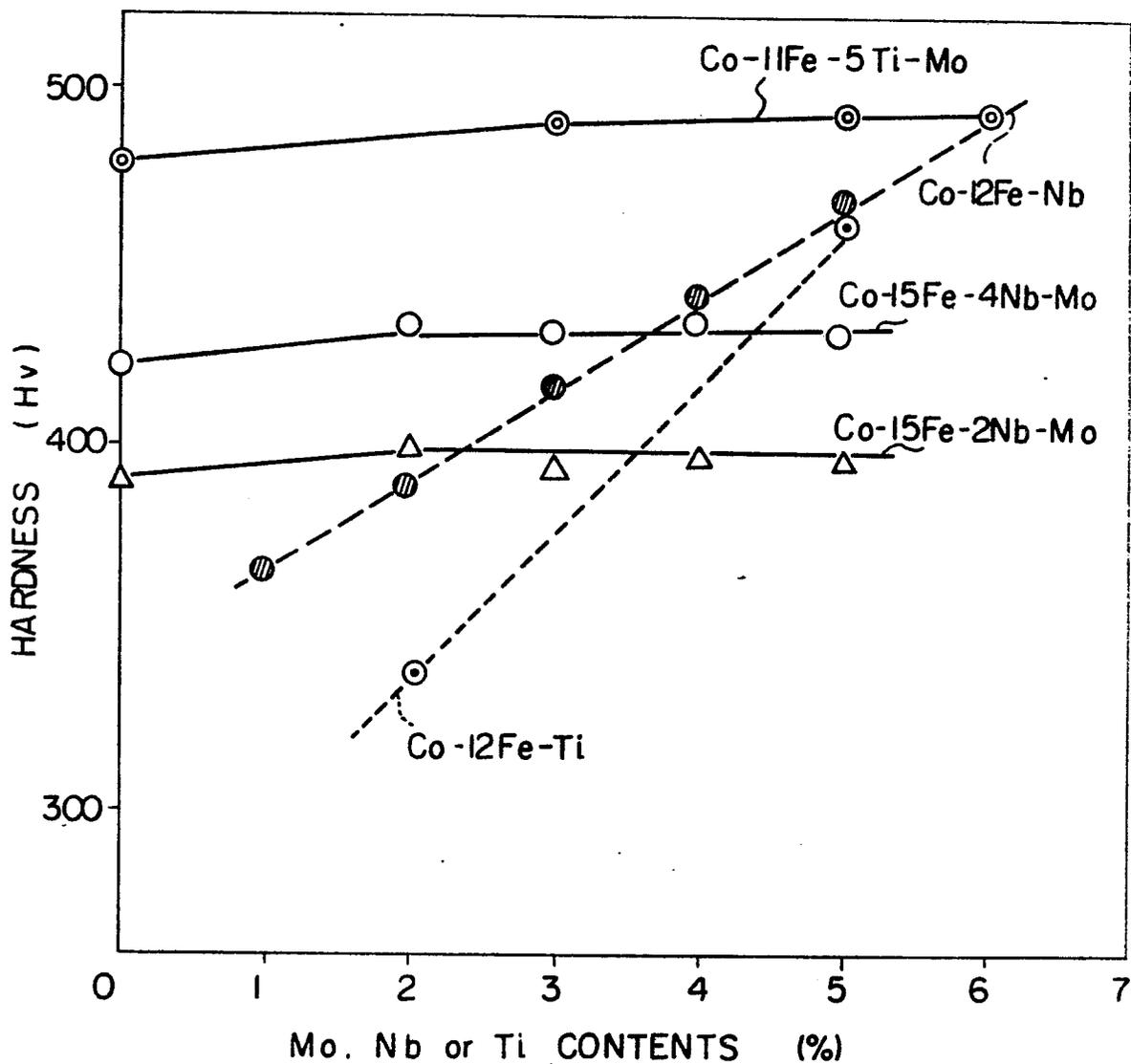


Fig. 3

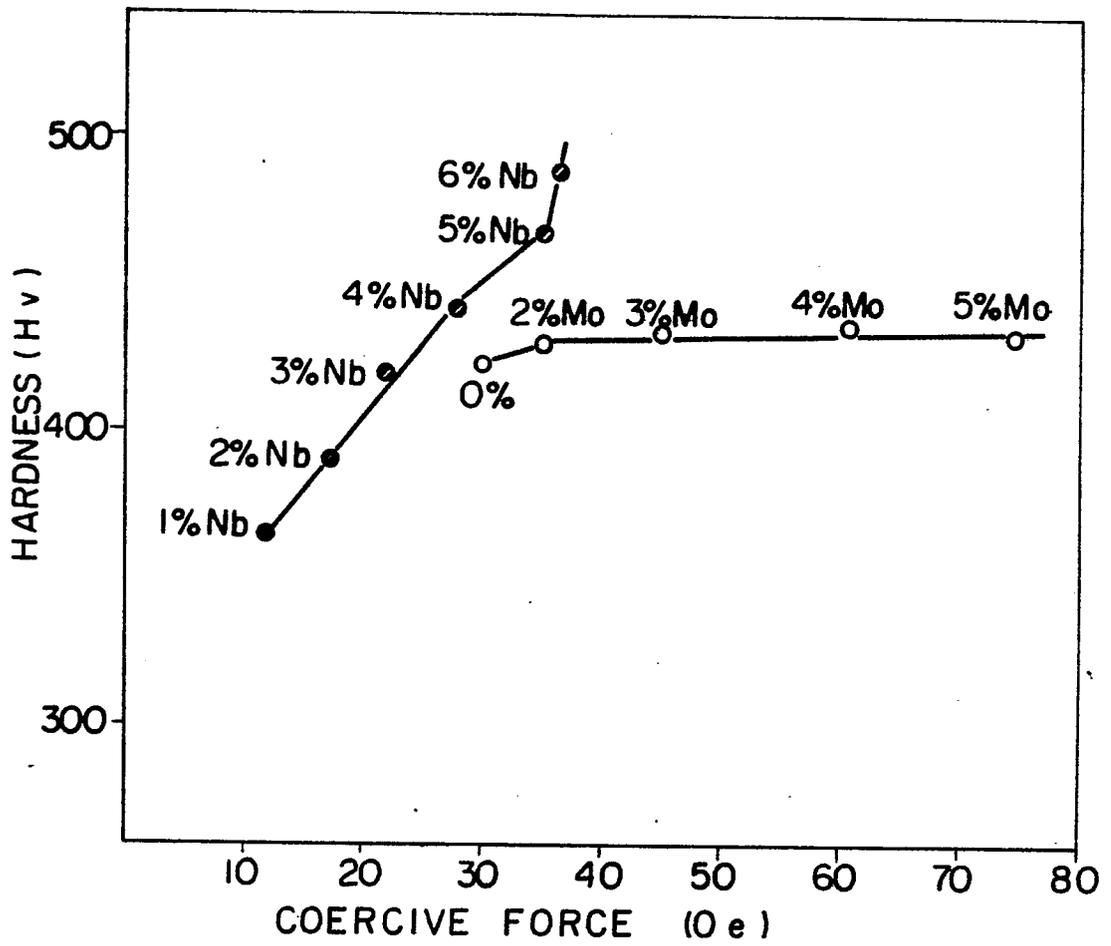


Fig. 4

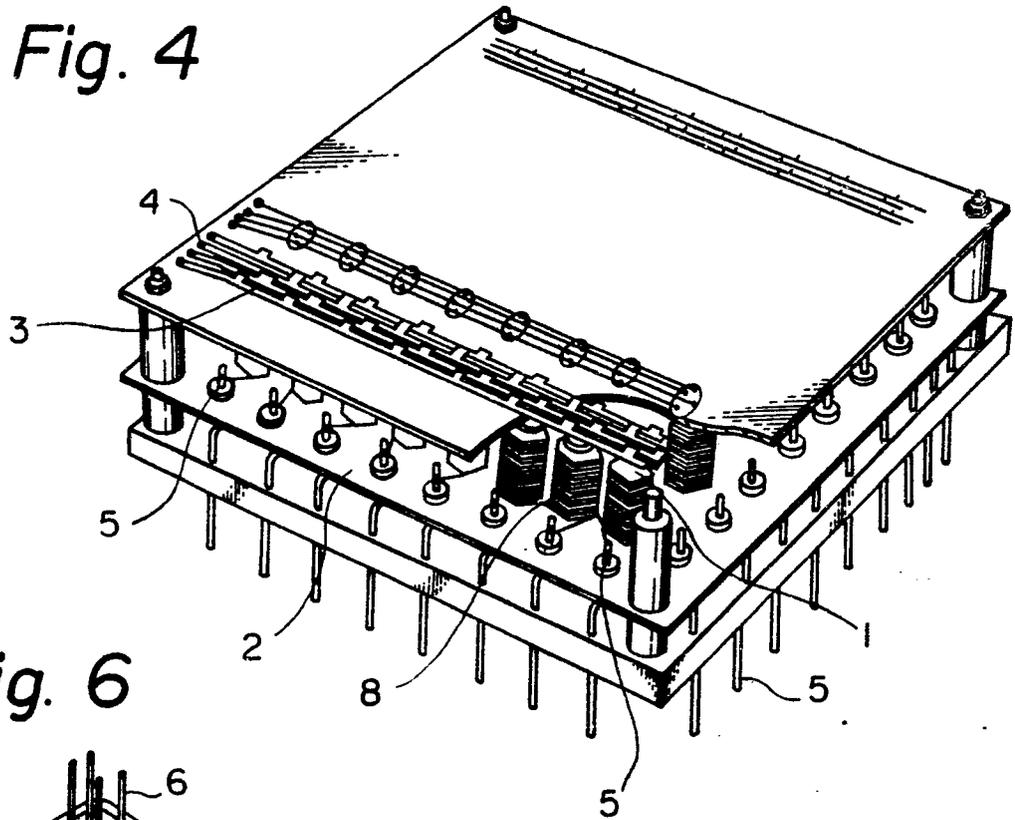


Fig. 6

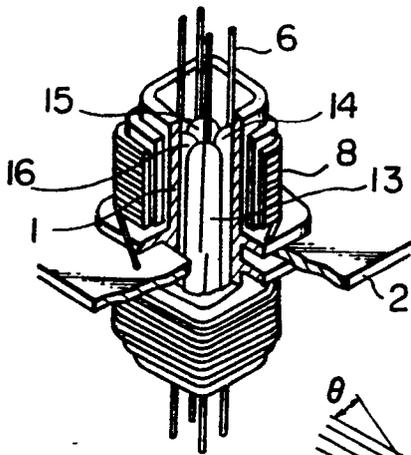


Fig. 5

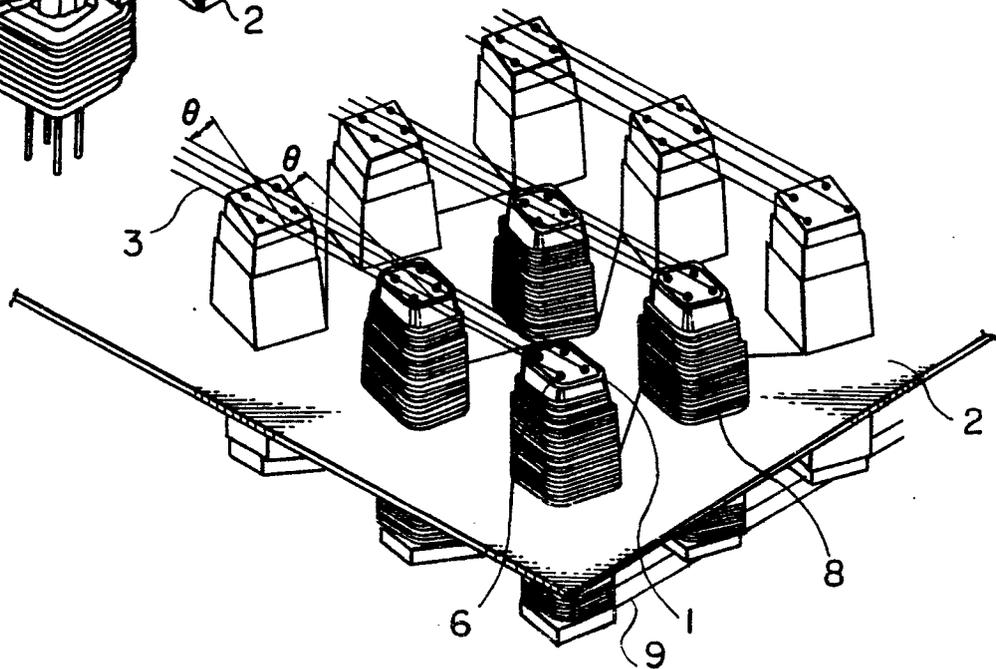


Fig. 4

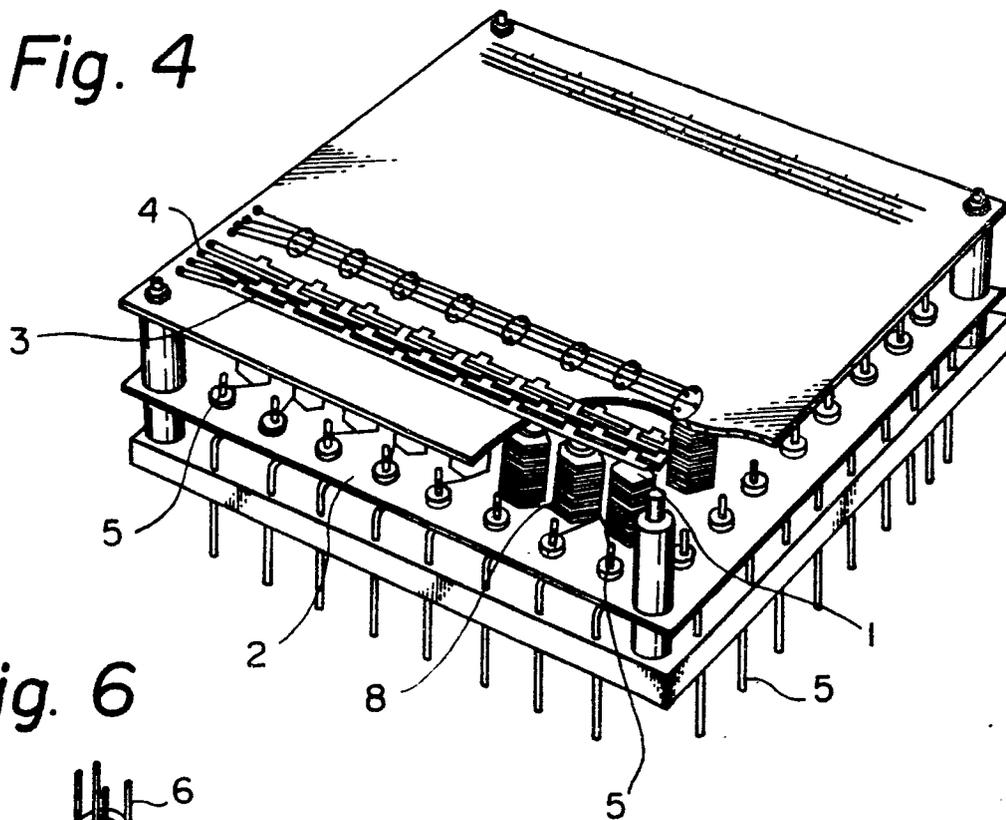


Fig. 6

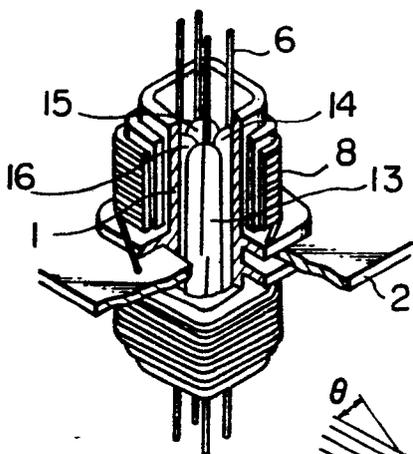


Fig. 5

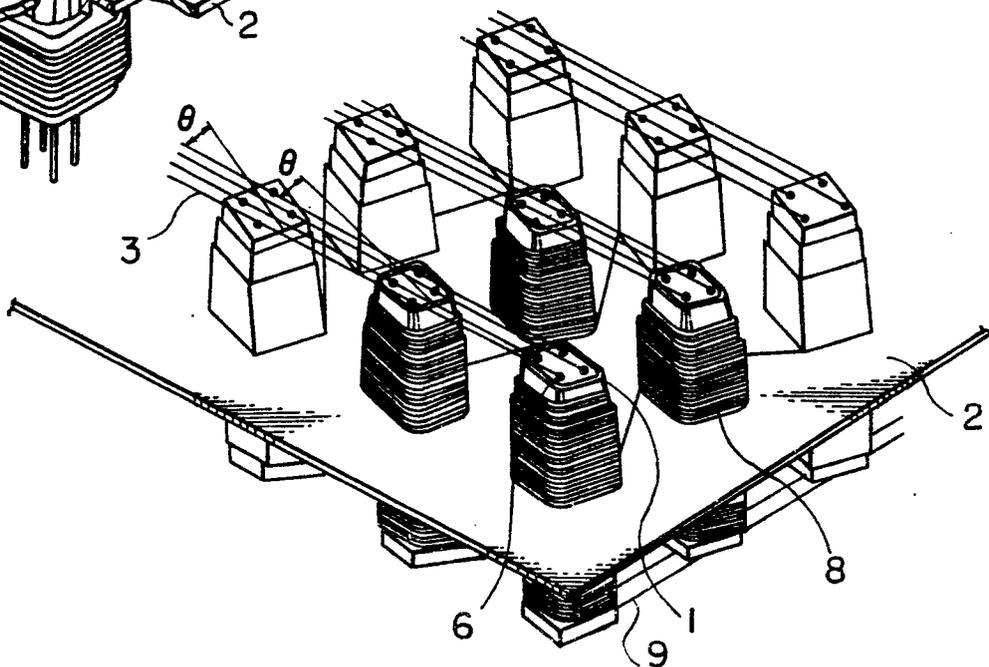


Fig. 7A

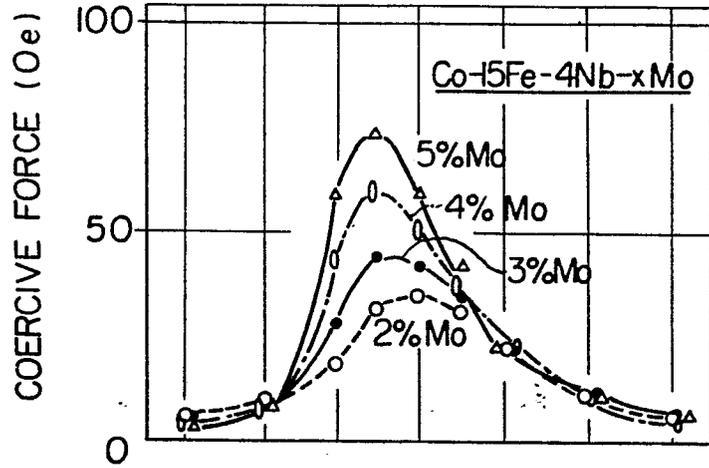


Fig. 7B

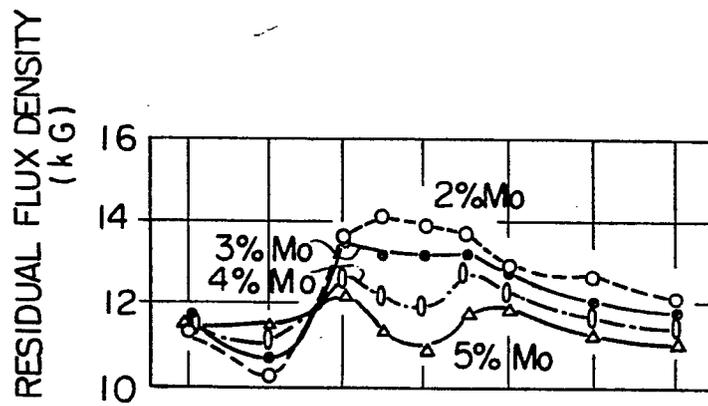


Fig. 7C

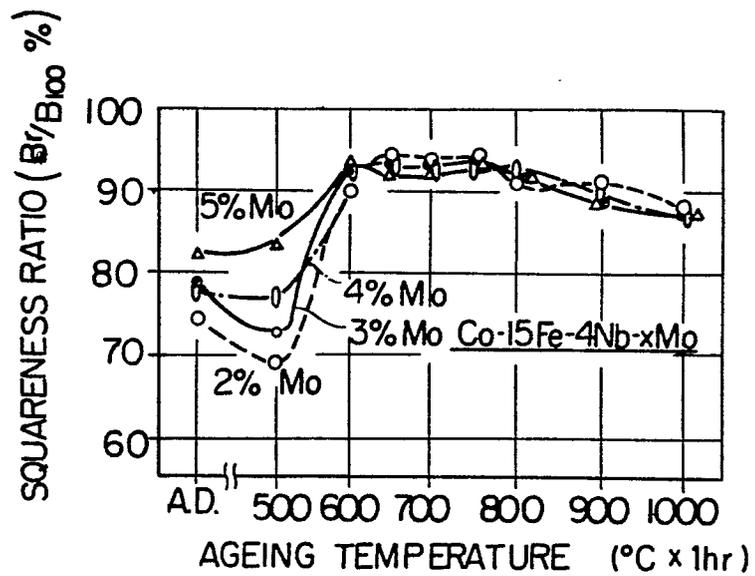


Fig. 8 A

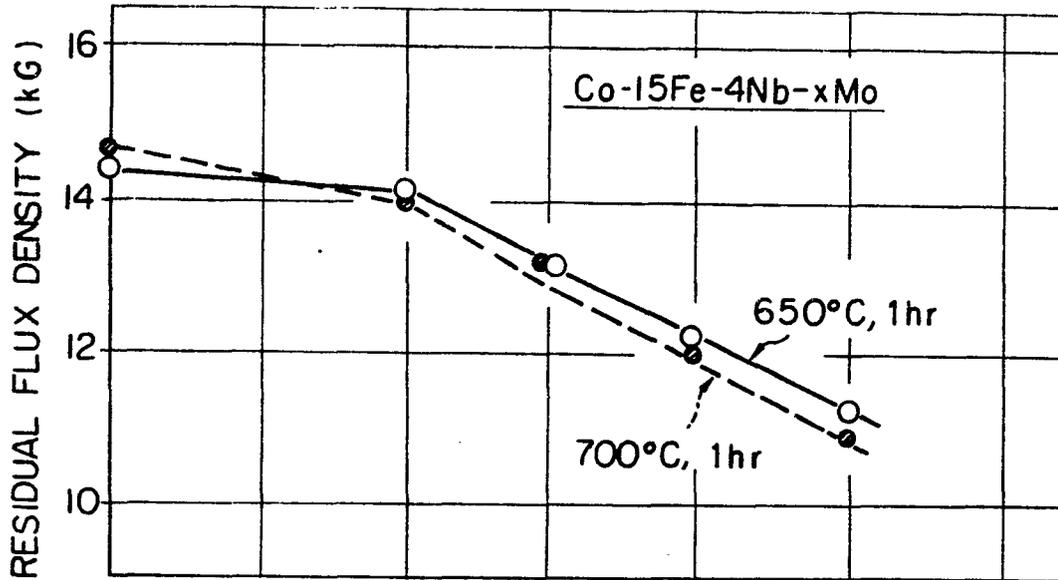


Fig. 8 B

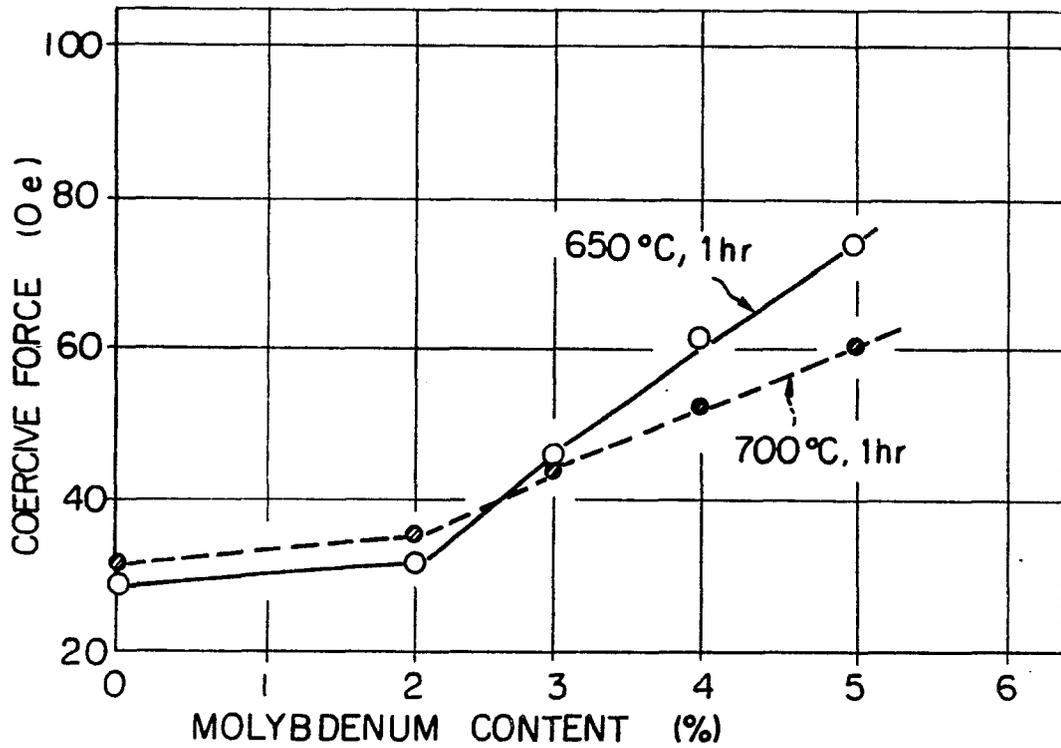


Fig. 9 A

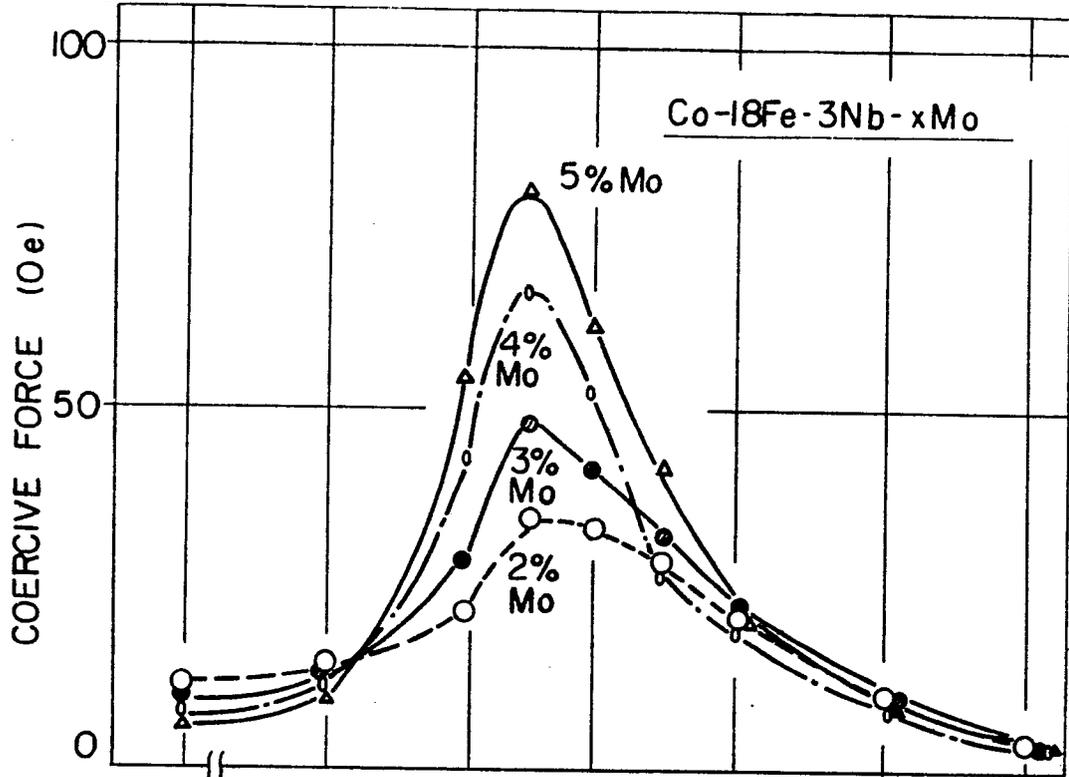


Fig. 9 B

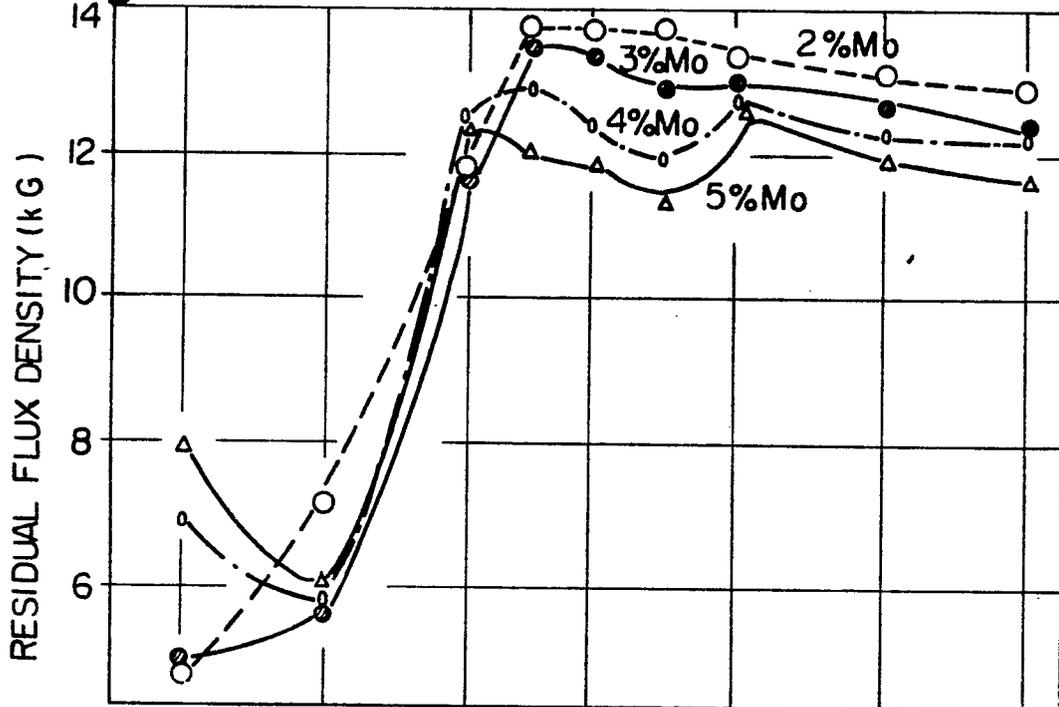


Fig. 9 C

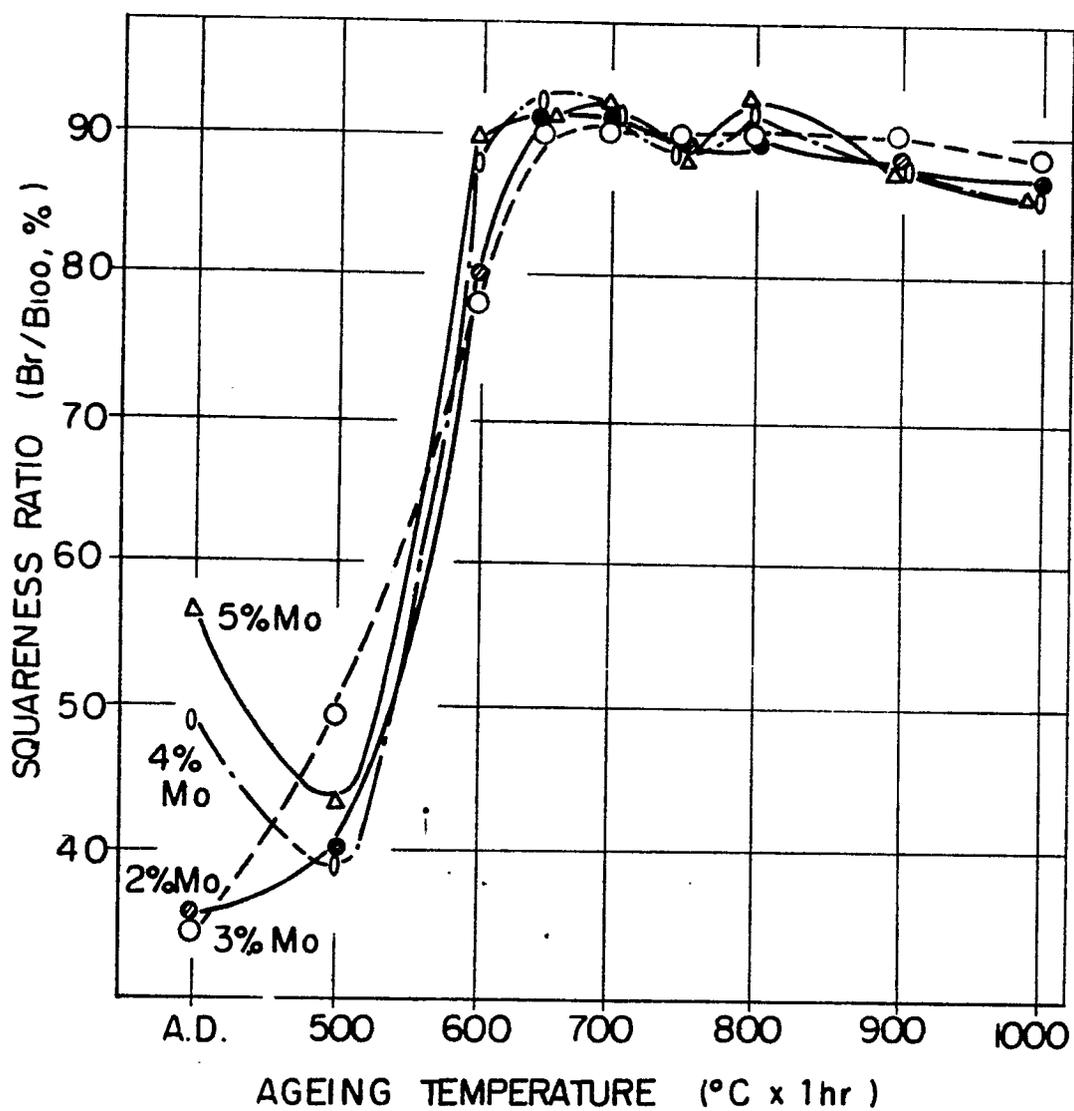


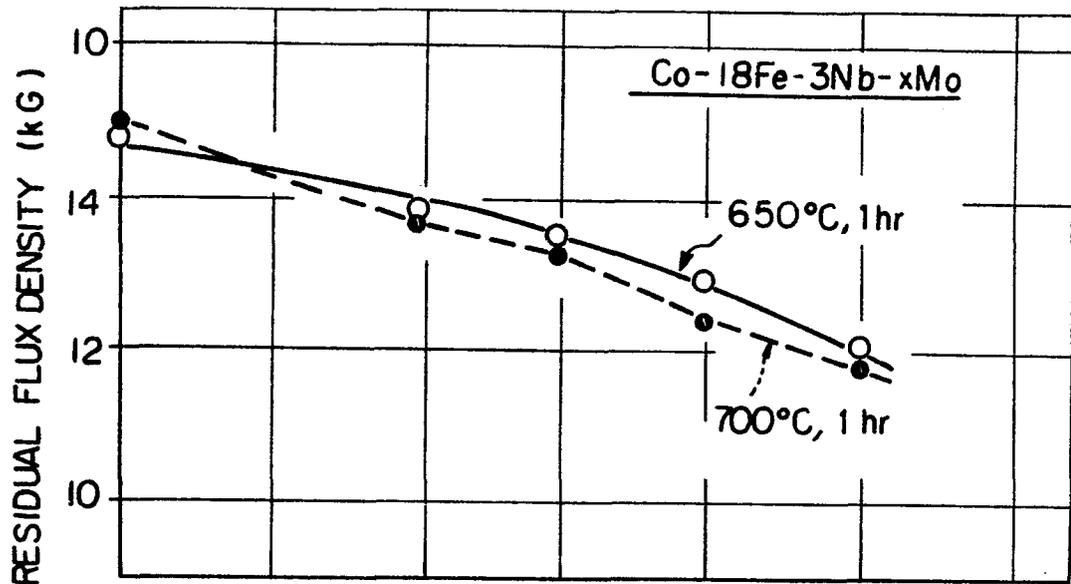
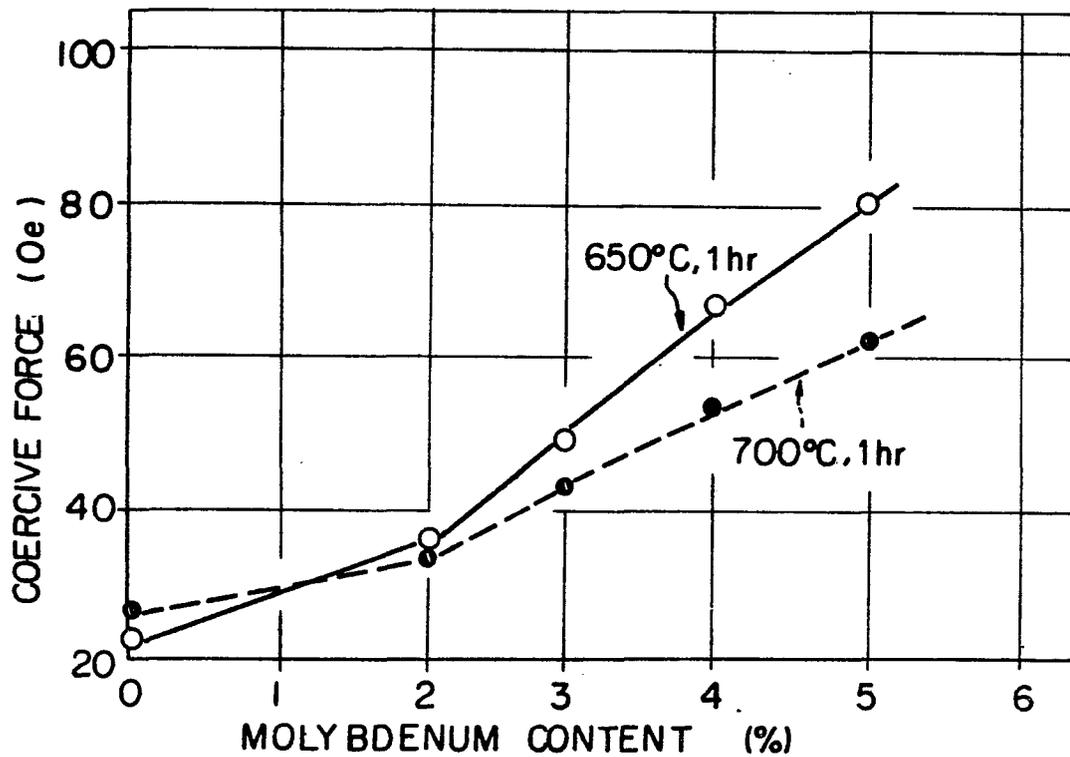
Fig. 10 A*Fig. 10 B*

Fig IIA

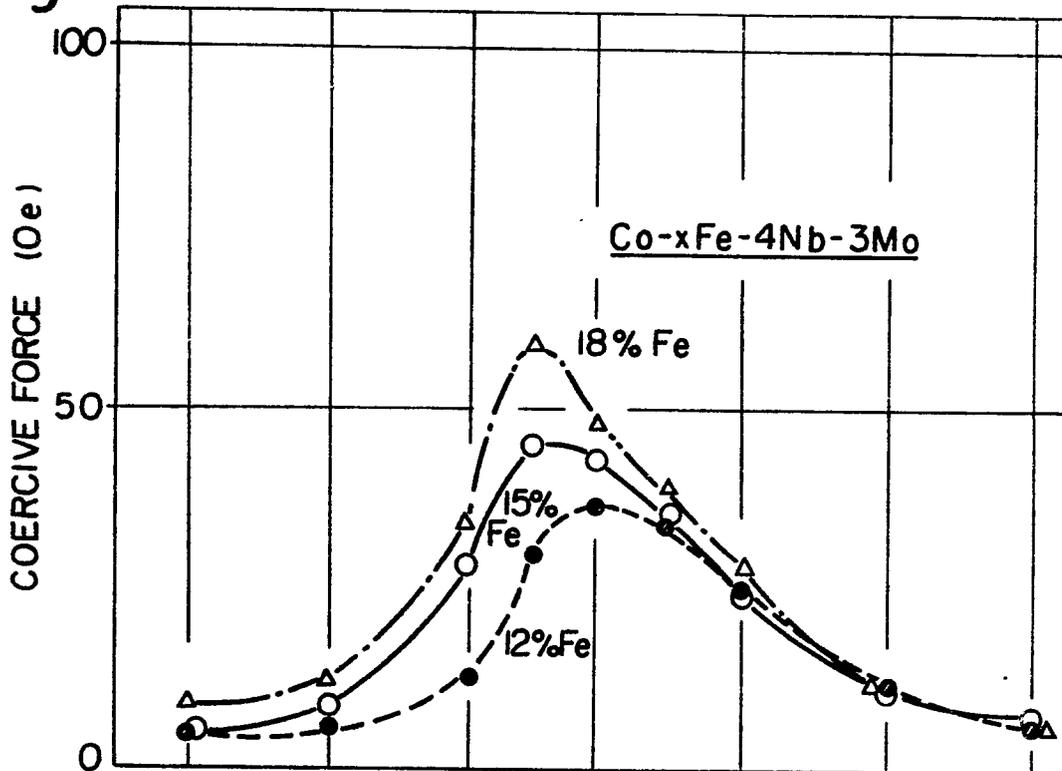


Fig IIB

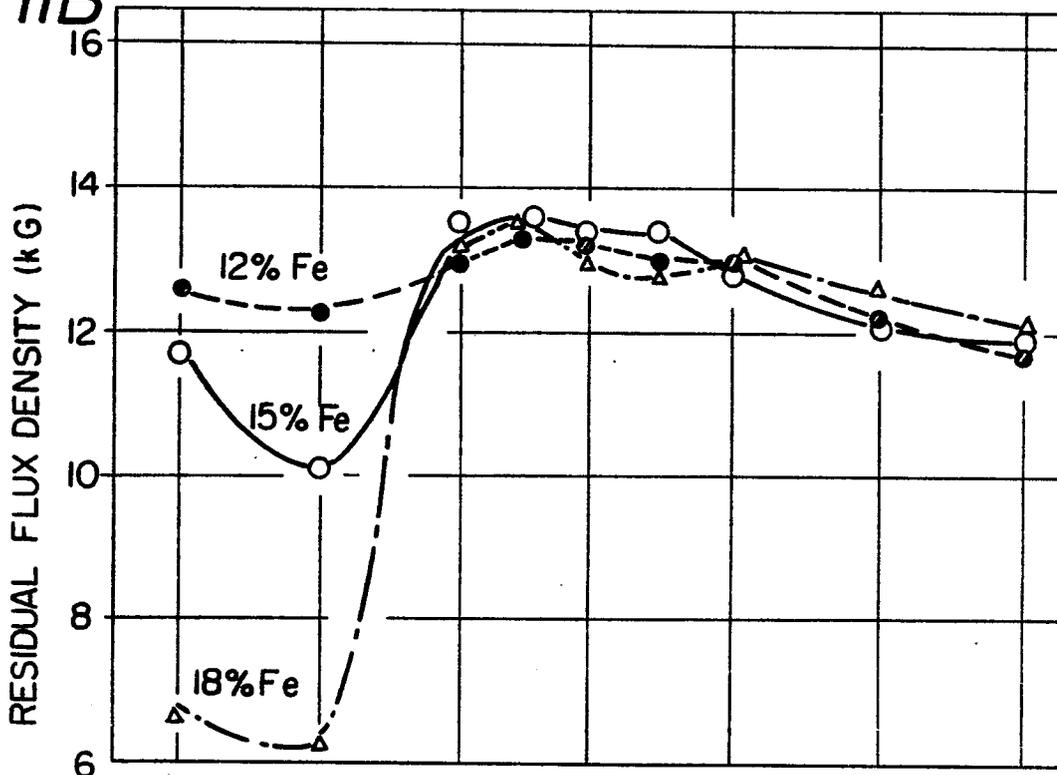


Fig. 11 C

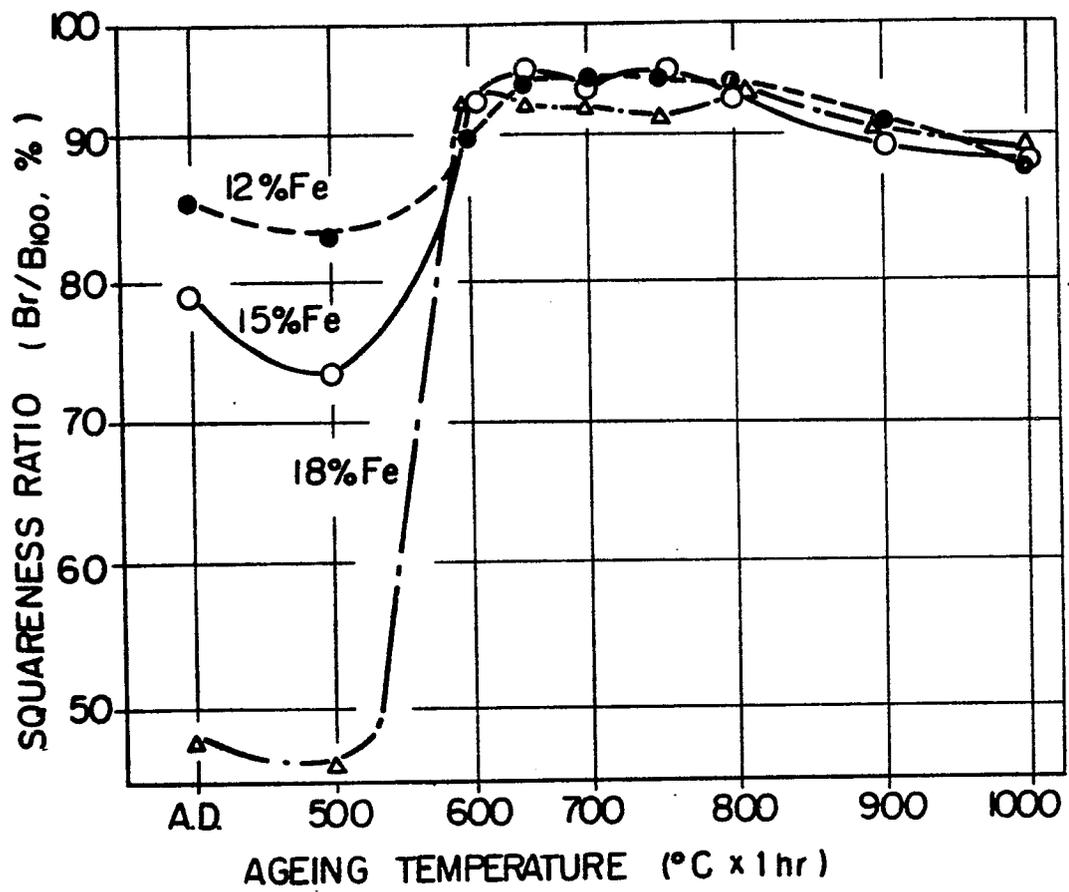
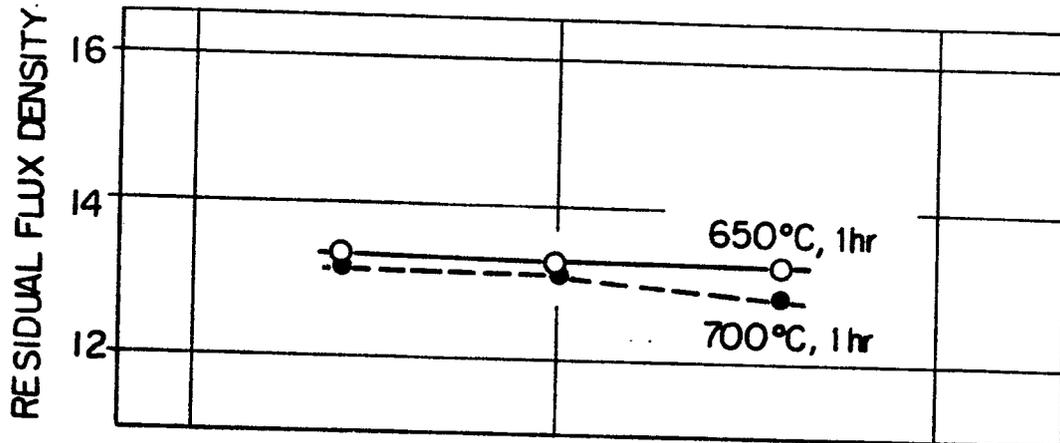
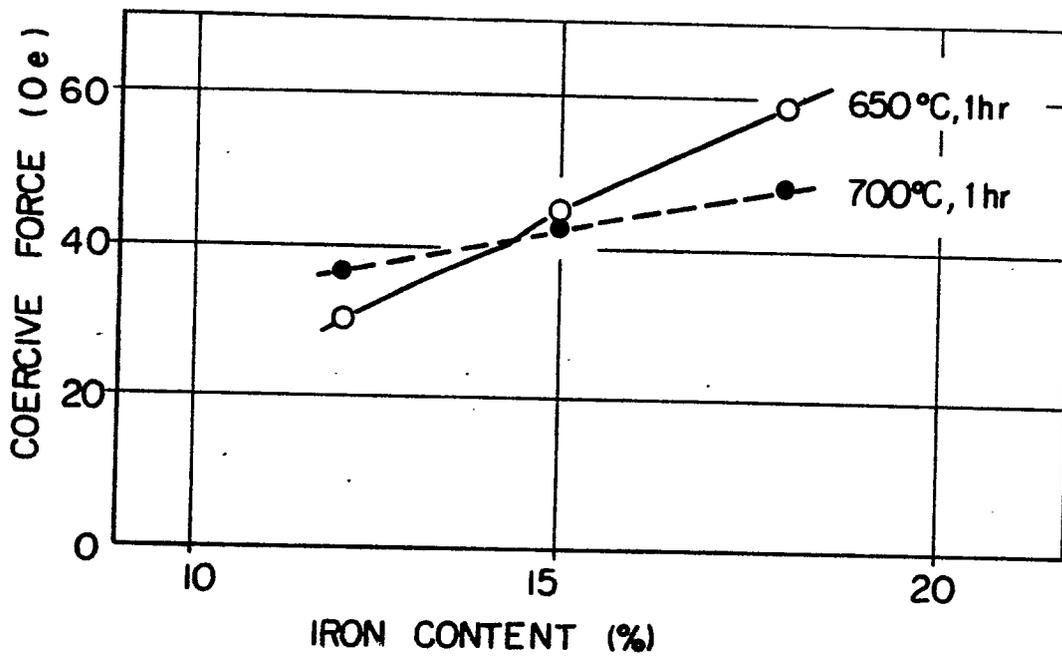


Fig. 12 A*Fig. 12 B*



DOCUMENTS CONSIDERED TO BE RELEVANT		CLASSIFICATION OF THE APPLICATION (Int. Cl. ²)	
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
A	<u>GB - A - 1 118 466</u> (WESTERN ELECTRIC CY.) * Claims 1,2 * ---	1	C 22 C 19/07 H 01 F 1/04 H 01 H 1/02
	<u>FR - A - 2 150 144</u> (FUJITSU LTD.) * Claims 1,2,3 * ---	1,2	
	<u>CH - A - 479 709</u> (MITSUBISHI) * Claim * -----	1	
		TECHNICAL FIELDS SEARCHED (Int. Cl. ²)	
		C 22 C 19/07 C 22 F 1/10 H 01 F 1/04	
		CATEGORY OF CITED DOCUMENTS	
		X: particularly relevant A: technological background O: non-written disclosure P: intermediate document T: theory or principle underlying the invention E: conflicting application D: document cited in the application L: citation for other reasons	
		&: member of the same patent family, corresponding document	
The present search report has been drawn up for all claims			
Place of search	Date of completion of the search	Examiner	
The Hague	28-02-1979	LIPPENS	