United States Patent

[11] 3,624,568

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[21] Appl. No. **83,808**
[22] Filed **Oct. 26, 1970**
[45] Patented **Nov. 30, 1971**

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[54] **MAGNETICALLY ACTUATED SWITCHING DEVICES**
2 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **335/153**
[51] **Int. Cl.** **H01h 51/27**
[50] **Field of Search** 335/151, 152, 153, 154; 148/102; 75/123

[56] **References Cited**
UNITED STATES PATENTS
3,364,449 1/1968 Gould et al. 335/153

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ABSTRACT: The remanent magnetization for cobalt-iron compositions in the category known as "Remendur" is increased by a critical series of processing steps. The most significant departure from conventional processing is in hot working reduction with the alloy maintained at a temperature in which both the α and γ phases are in thermal equilibrium. The alloys are designed for use in magnetically actuated reed switches.

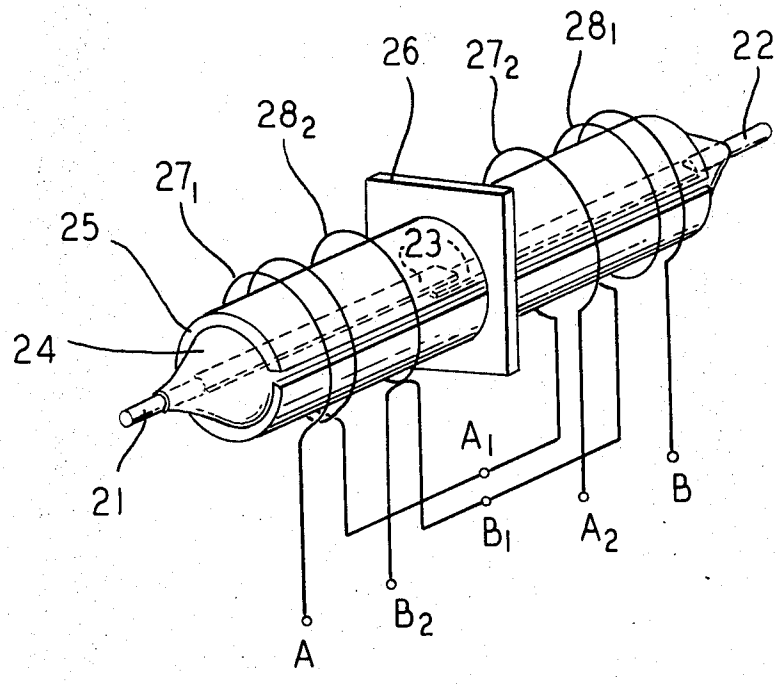


FIG. 2

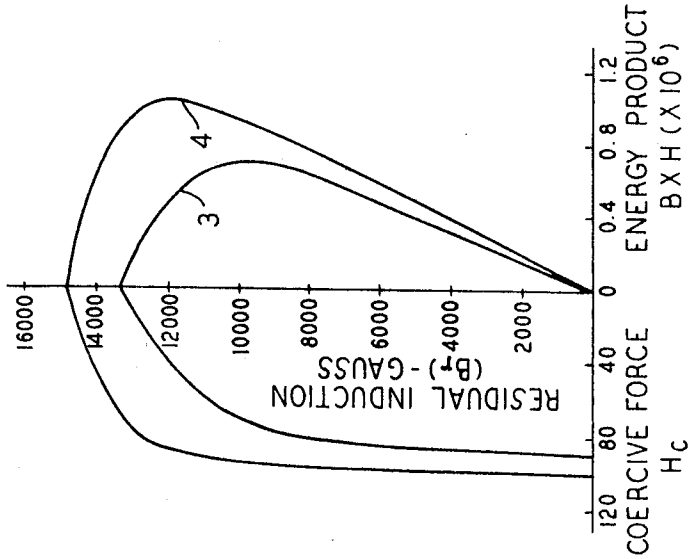
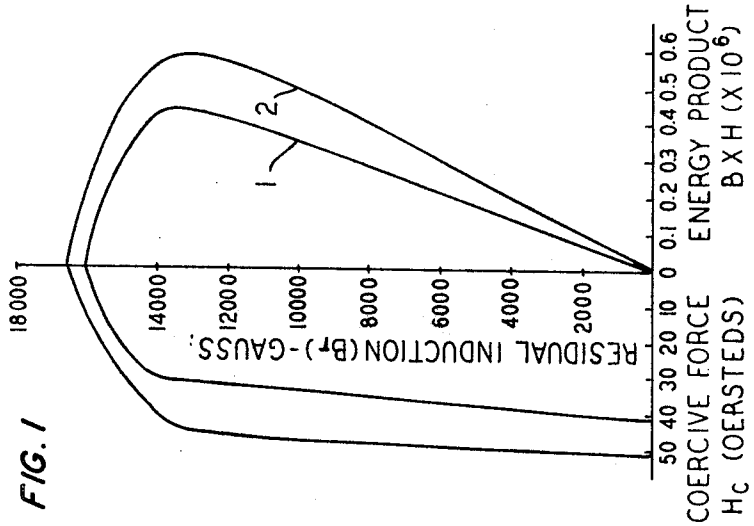


FIG. 1



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FIG. 3

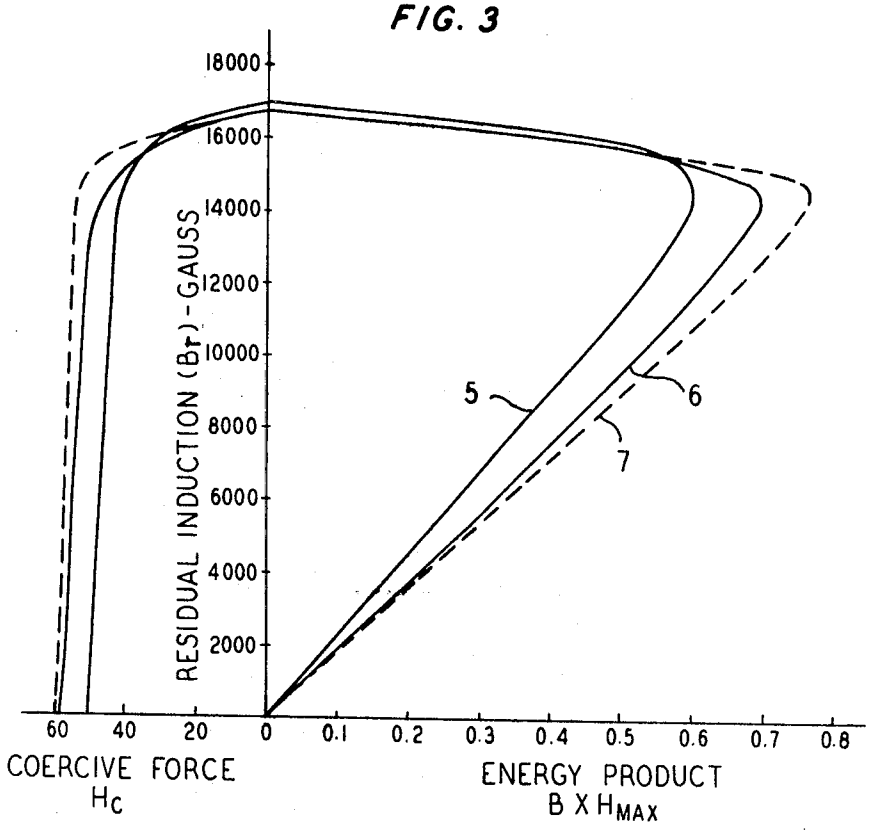

18000
16000
14000
12000
10000
8000
6000
4000
2000
RESIDUAL INDUCTION (Br) - GAUSS
5
6
7
60
40
20
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
COERCIVE FORCE
Hc
ENERGY PRODUCT
B X HMAX

FIG. 4

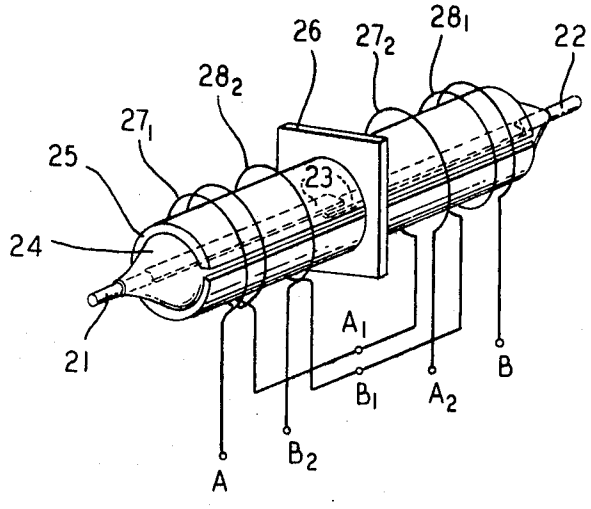

26
27₂
28₁
22
28₂
27₁
25
23
24
21
A₁
B₁
A₂
B
B₂
A

FIG. 5

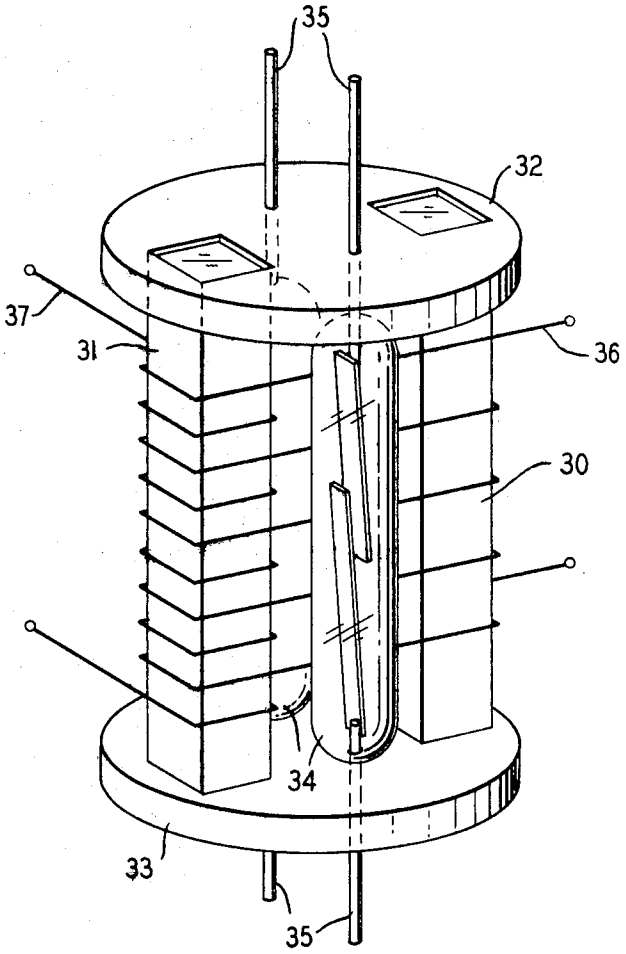
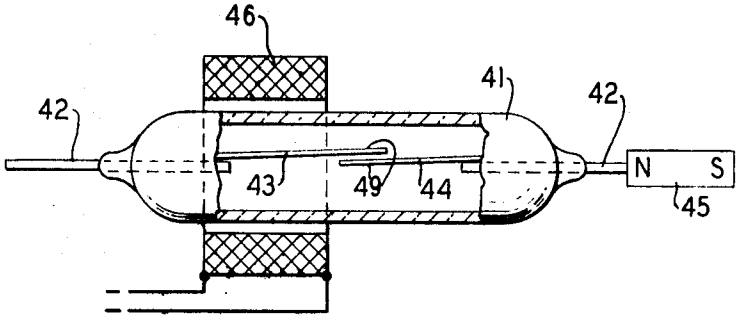


FIG. 6



MAGNETICALLY ACTUATED SWITCHING DEVICES

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention is concerned with magnetically actuated switches utilizing magnetic alloys of cobalt, iron and vanadium. Such compositions, processed appropriate magnetic properties and nominally containing approximately equal parts of cobalt and iron together with a few percent of vanadium, are sometimes referred to as "Remendur."

2. Description of the Prior Art

Telephone systems, in the United States in particular, make large scale use of magnetically actuated switches sometimes known as "ferreeds." Such devices characteristically include at least a pair of sealed metallic contacts which may be switched at speeds appropriate for use in electronic switching systems. Switching is accomplished by changing the magnetization direction of one or more magnetic elements. The closed or opened position is maintained without continuous electrical bias by reason of the remanent magnetization of the magnetic material of which the elements are composed.

While the term "ferreed" takes its name from the prototype device which was a ferrite-actuated reed switch, production models have generally used a metallic alloy. The common alloy nominally contains a few percent of vanadium, remainder approximately equal parts of cobalt and iron. Small additional ingredients may be present to control impurity contents, such as sulfur, or to expedite processing. It is well known that alloys in this compositional range may be magnetically soft (Supermendur), magnetically hard (Vicalloy), or intermediate (Remendur). It is alloys of the latter category which find use in ferreed switch. Such materials are processed in such manner as to develop sufficient remanent magnetization (to maintain closure without power expenditure) and sufficient coercivity to resist demagnetizing fields, while at the same time being sufficiently permeable to permit switching at practical low currents.

Development of appropriate properties requires a series of critical processing steps, and an extensive expenditure both in time and manpower was required before the ferreed reached commercial fruition.

Exemplary ferreed switches now in prevalent use require coercivity of the order of 40 oersteds and remanent magnetization (residual induction—B_r) of the order of about 15,000 gauss (this value for 10-inch samples). Processing to achieve these properties in the desired round or flat section requires a series of successive hot reductions, intermediate anneals, and cold reductions, and finally a partial anneal (U.S. Pat. No. 3,364,449). This final partial anneal is of particular significance. It is carried out at a temperature in which γ-phase material precipitates. This precipitation hardening is responsible, in part, both for the requisite coercivity and remanence.

Continuing development in the field of telephony with a view toward cost reduction has prompted redesign of the ferreed switch. The new designs require magnetic materials having higher coercivity and energy product. Such improved properties will permit proper function of ferreed switches embodying smaller volumes of the magnetic elements. The required properties have never been reported for the otherwise suitable Remendur alloy and do not appear to be attainable by any obvious variation in the now conventional manufacturing procedure.

SUMMARY OF THE INVENTION

A series of critical processing steps, as applied to the fabrication of Remendur stock, results in the properties desired for miniaturized ferreed switches. As described in terms of proposed elements of the order of 0.05-inch diameter and 1.3 inches in length, such processing results in the relevant magnetic properties being increased from typical coercivity and remanence of 40–48 oersteds and 7,000–9,000 gauss, to values of 50–58 oersteds and 11,000–13,000 gauss. This corresponds to an approximate 25 percent increase in energy product.

Compositions of concern are generally conventional and include compositions containing a few percent vanadium, remainder approximately equal parts of cobalt and iron. Additional ingredients included for workability and other purposes associated with alloys in this category may be included also.

Processing, in accordance with the invention, departs in one major respect from the commercial fabrication procedure. At least part of the hot reduction, generally the terminal part prior to cold reduction, is carried out at a temperature to which both the α and γ phases are in thermal equilibrium. In general terms, this working step takes the form of a reduction of the order of at least 10 percent in cross section while operating at a composition-dependent temperature range generally from about 500° C. to about 900° C. Such hot working yields a deformed structure comprising precipitated α phase in a γ matrix. Subsequent cold reduction of this structure and final heat treatment results in material having higher remanence and coercivity.

The alloy systems of the invention are specifically tailored for use in magnetically actuated switches, and the invention is properly described in terms of such switches depending for their operation upon inclusion of one or more elements of the alloy. The switch design, per se, however, represents no fundamental departure from conventional ferreed switches although magnetic element volume may be somewhat reduced. Operational advantages, which naturally flow from incorporation of the alloys, are reliable operation and resistance to accidental switching due to transient electrical fields ordinarily encountered in switching environments.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1, on ordinate units of residual induction in gauss and dual abscissa values of coercive force in oersteds and energy product in gauss-oersteds, is a plot showing the relationship of these parameters. Curves are included for two alloy samples of the same composition, one processed in accordance with conventional procedure and the other processed in accordance with the inventive teaching herein;

FIG. 2, on the same coordinates, is a plot showing the relationship of the same parameters for a different composition herein;

FIG. 3, on the same coordinates, is a plot showing the relationship of these parameters for three samples of the same included composition in which terminal hot reduction was carried out at three different temperatures, only two of which are within the two-phase region;

FIG. 4 is a perspective view of a magnetically actuated switch utilizing magnetic elements in accordance with the inventive teaching;

FIG. 5 is a perspective view of a different type of ferreed also utilizing material of the invention; and

FIG. 6 is a front elevational view, partly in section, of a ferreed structure of still different design in which a reed is itself composed of a magnetic material herein.

DETAILED DESCRIPTION

1. The Drawing

FIG. 1 is plotted from data measured on rod samples of final dimensions 10 inches long by 0.050-inch diameter. Curve 1 represents a sample produced by now conventional processing (see paragraph entitled "Conventional Processing" under section 3 of the Detailed Description). Curve 2 is representative of data taken from several samples in which the fabrication procedure was modified to include a terminal hot reduction step within the two-phase region. In this instance, reduction from three-eighths inch to one-fourth inch was accomplished by hot rolling at about 800° C. With the exception of the dead anneal incorporated in the preparation of the sample from which the data of curve 1 was taken, fabrication was otherwise under identical conditions (see paragraph entitled "Modified Processing" also under section 3 of the Detailed Description).

It is seen that the residual induction was increased from a value of approximately 16,000 gauss to a value of about 16,500 gauss by the modified processing technique. Perhaps more important is the increase coercivity from about 40 oersteds to about 50 oersteds. As noted, the composition treated in FIG. 1 is 48 percent cobalt, 47.5 percent iron, 4.5 percent vanadium, all in weight percent (as are all other compositions reported herein).

FIG. 2 shows the same relationship for an alloy rod 10 - inches by 0.095-inch diameter of 56.4 percent cobalt, 36.6 percent iron, 6 percent vanadium. All three values, i.e., residual induction, coercivity and energy product, are improved by the processing modification. The interdependence of these properties on both cobalt-iron ratio and vanadium content is discussed under section 4, Detailed Description. Curves 3 and 4 are plotted from the data for conventional and modified processing, respectively.

FIG. 3 is included to show the relationship of the three noted parameters to temperature of terminal hot working (i.e., hot working prior to cold reduction). The three curves, denoted 5, 6 and 7, represent three samples of identical composition (48 percent cobalt, 47 percent iron, 5 percent vanadium) processed under identical conditions except that the sample of curves 5, 6 and 7 were terminal hot reduced at 1,000° C., 800° C. and 700° C., respectively. While residual induction shows little change from curve to curve, coercivity and energy product both show significant improvement for successively lower temperature of terminal hot reduction. A characteristic not evident from this figure is the hardness of the hot-rolled material which is increased as temperature of terminal hot working is reduced. This consideration places a lower practical limit on the temperature of this crucial step. Interdependence of this temperature and workability is discussed under section 2 of the Detailed Description.

The device of FIG. 4, the prototype of which is described in U.S. Pat. No. 3,075,059, issued Jan. 22, 1963, is sometimes called the series ferreed. The device depicted includes a pair of magnetizable reeds 21 and 22 constructed of a soft magnetic material enclosed within a glass envelope 24. Overlapping portions of reeds 21 and 22 serve as contact areas 23, which are normally separated. Surrounding envelope 24 there is a split or "C" sleeve 25 of an alloy herein. Disposed about the sleeve, in the vicinity of the contact areas 23 of the reeds 21 and 22, is a shunt plate 26 of a permeable soft magnetic material.

Wound about the sleeve 25 on both sides of the shunt plate 26 are two sets of windings 27_1, 27_2 and 28_1, 28_2, the pair of 27 and 28 windings terminating at A, A_2 and B, B_2, respectively. Each of the windings 27_1 and 28_1 has twice the number of turns of each of the windings 27_2 and 28_2 to permit differential operation, as discussed in U.S. Pat. No. 3,075,059. The A windings are interconnected at terminal A_1 while the B windings are interconnected at terminal B_1.

A complete description of the operation of the device of FIG. 4 or of the other devices herein is not appropriately included in this disclosure and may be obtained by reference to U.S. Pat. No. 3,075,059. Very briefly, switch closure is accomplished by passing current through the windings creating a magnetic path such that flux closure is accomplished through the reeds 21 and 22 at contact areas 23. The remanent field to maintain closure must, of course, be of sufficient strength to overcome the stiffness of the reeds. This condition obtains in the device of FIG. 4 when pulses applied at A and B are such as to produce the same direction of magnetization through the portions of sleeve 25 on either side of shunt 26. Reversing the direction of magnetization of either of the two halves of sleeves 25 results in a flux through shunt 26, so eliminating any substantial flow of flux through either of the reeds.

In device of FIG. 5, two bistable, remanently magnetic members constructed of an alloy herein control two reed switches. The device shown is one type of parallel ferreed.

This device is described in U.S. Pat. No. 2,995,637 issued on Aug. 8, 1961.

The device of FIG. 5 includes a pair of Remendur rods 30 and 31, suspended between a pair of soft magnetic disks 32 and 33. Also suspended between the disks 32 and 33, adjacent to the rods 30 and 31, are two reed switches 34 having individual terminals 35 which protrude through and are electrically insulated from the disks 32 and 33. Reed switches 34 may be identical to that enclosed within tube 24 of FIG. 4. A winding 36 encircles both of the rods 39 and 31. A winding 37 is shown wound about the rod 31 alone.

The arrangement shown provides for a coincident drive to operate the switches 34, but achieves release by current in a single winding. Initially, to prepare the device for use, Remendur rods 30 and 31 are magnetically saturated in the same direction (either up or down in the device as depicted) by passage of a current through winding 36. Since the flux associated with either of the Remendur rods 30 or 31 is opposed by that of the other, the flux of both rods seeks a path through reed switches 34, so accomplishing closure. For the particular embodiment depicted, the remanent magnetization state of rod 30 is now established and will be unaffected by future operation.

In normal operation, switches 34 are released by application of a current to winding 37 with a direction and magnitude such that the remanent magnetization of rod 31 is reversed. This establishes a flux pattern, with the flux in opposite directions in the two rods 30 and 31, and with these rods now defining a closed magnetic circuit, so bypassing switch 34.

Closure is accomplished by coincident drive currents applied simultaneously to windings 36 and 37. Each of these currents is insufficient to reverse the magnetization of rod 31, but the magnetizing force of both coincident currents reverses this state, so restoring the initial flux pattern for closing switches 34. Since only one winding 36 is associated with rod 30, and since the current applied to 36 is, in itself, insufficient to reverse the remanent field, this rod remains unaffected.

The device of FIG. 6 is illustrative of those embodiments in which at least one reed is itself constructed of a remanently magnetic material, as described herein. This figure depicts a reed switch having a glass envelope 41, with terminals 42. A Remendur reed 43 is attached to the left-hand terminal 42. A second reed 44, which may be constructed of a highly permeable soft magnetic material or of an alloy of this invention, is attached to the right-hand terminal 42 so that its free end overlaps the free end of reed 43 to form a contact pair at 49. Also attached to the right-hand terminal 42 is a permanent magnet 45 having a magnetic polarity, as shown. A coil 46 is wound about the envelope 41 on the portion enclosing the reed 43.

Operation of the device is similar to that of those described above, with coil 46 biased in such manner that the magnetization direction of reed 43 corresponds with that of reed 44 (induced by permanent magnet 45) and closure is accomplished. Reversing the direction of magnetization in reed 43 results in two separate flux paths, the one including reed 43, the other, reed 44, in which condition the natural stiffness of the reeds results in release.

2. Definitions

While the terminology used in the description of this invention is not inconsistent with prior art, it is sometimes used in specific context. To avoid ambiguity, the descriptive terminology is briefly discussed:

a. "Squareness Ratio" is the fraction of residual induction divided by saturation magnetization or B_r/B_s. This term is of significance in switching elements since switching speed is related to the slope of the BH characteristic of the hysteresis loop. It is indirectly relevant in that it specifies a value of residual induction, of course, assuming a given saturation magnetization, B_s (which is generally fixed by the composition).

b. "Fullness Factor" BH_{max}/B_rH_c is also a measure of squareness.

c. Residual induction or remanence (B_r) is the flux density remaining in the material after removal of the applied magnetizing force.

d. Coercivity H_c is generally used in its usual context, i.e., that of the minimum applied field required to cause reversal in direction of magnetization. For the geometries discussed, the magnitude of this term is uncomplicated by shape or size effects. In some of the descriptive matter herein, reference is made to a value of B_r for a short element, e.g., 1.3 inches long by 0.050-inch diameter rod. The aspect ratio of such a section is sufficiently small as to result in an increase in the demagnetizing field for the open circuit element. This demagnetizing effect results in a downward shift in the remanence. For example, reduction in length of a 0.050-inch diameter rod from 10 inches to 1.3 inches does not effect its coercivity but does cause a drop in residual induction from 16,500 to 8,000 gauss for the normally processed material. For material processed using a terminal hot-working procedure in accordance with the invention, the drop is considerably smaller, i.e., 16,500 to 11,000 gauss (for 800° C. terminal hot working). Therefore, it is evident that, for a given alloy composition, material used in short sections such as contemplated in devices of the preferred embodiment yields a higher flux output if it is processed in accordance with this invention.

e. "Workability" has reference to the degree of cold reduction which may be attained on conventional apparatus, e.g., drawing, swaging, etc. In its absolute limit, workability is limited by breaking. For many purposes, it is required that the material be cold reduced by at least 60-percent area reduction. Since workability is reduced for a lowered terminal hot working temperature, consideration of this property enters into the determination of a preferred limit for this processing parameter.

f. "Two-Phase Region" has reference to the temperature range over which both the α and γ metallurgical phases of the alloy coexist. This range varies somewhat with cobalt and vanadium composition. However, since, in general, substantial γ phase is desired, there is little interest in operating at the high-temperature end of the region; and since workability is significantly impaired at the low temperature end of the ranges, a preferred temperature range of from 500° C. to 900° C. for the two-phase region is described and this range is generally applicable to the entire range of the alloys herein.

g. "Terminal Hot Working" or "terminal hot reduction" has reference to the most critical step of the processing sequence. It describes that reduction which is carried out in the two-phase region prior to cold reduction. It is generally, although not necessarily, preceded by normal "hot working," and this latter terminology has reference to deformation in the single-phase γ region. Terminal hot working also implies that there be no subsequent hot working, and this implication is accurate to the extent that it precludes further working or, in fact, any treatment in the single-phase γ region (since such treatment results in destruction of the advantageous effects produced during "terminal hot-working"). "Cold Working" alludes to mechanical reduction (generally without heating other than that due to friction) in a sufficiently low-temperature range such that there is little or no change in the relative amounts of α and γ phase material. The purpose of cold working includes the conventional one of introducing strain and thereby improving squareness ratio or fullness factor.

h. "Area Reduction" This is the ratio in terms of reduction in size of cross-sectional area transverse to the working direction. It may be expressed as

$$\frac{A_0 - A_f}{A_0}$$

where A_o is the initial cross-sectional area and A_f is the final cross-sectional area. For round sections, A may be replaced by d^2 (diameter squared).

Other characteristics are of concern for device use. They include temperature coefficient of expansion, plating characteristics, magnetostriction, temperature stability, etc. These properties are known for the Remendur class of alloys and are not significantly altered by the processing modification of the invention.

3. Processing

A. Conventional Processing

Here the usual processing sequence now practiced in the fabrication of Remendur elements for magnetically operated switches, such as the ferreed, is described:

1. A melt is prepared. This requires a temperature of the order of 1,550° C. The material is generally maintained molten for a short period to assure thorough mixing after which it is poured into a mold and solidified to make an ingot.
2. The ingot is heated to (or allowed to cool to) a temperature of about 1,250 C. for hot working.
3. The ingot is hot worked as by swaging or rolling to an appropriate section thickness. This thickness is dictated by several considerations including workability, it being intended that further reduction to ultimate section thickness be carried out by cold working. For comparative purposes, discussion is in terms of hot working, carried out by rolling, to produce a ¼-inch diameter rod. It is well known that such reduction, generally from an ingot diameter of the order of 4 inches, requires successive rolling, reductions and reheatings. This assumes usual commercial apparatus in which heating is not applied during actual reduction.
4. The hot worked ¼-inch diameter rod is dead annealed by heating to a temperature in the single-phase γ region.
5. The rod is quenched to room temperature by immersing in ice brine.
6. The material is then cold worked as by drawing with sufficient working to produce an area reduction of at least 60 percent.
7. Finally, the reduced body is precipitation hardened by heating to a temperature in the two-phase region for a period of the order of from several minutes to several hours. Characteristically such heating is at temperature at the low end of the two-phase region, i.e., at about 600° C. In all processing, heating above a temperature of the order of 350° C. is generally carried out in nonoxidizing atmospheres, e.g., forming gas or hydrogen.

B. Modified Processing

The major change in processing is the elimination of the dead anneal of step 4 under "Conventional Processing." A different procedure is introduced at this point in the processing and so the processing sequence may be described as identical to that set forth in the preceding paragraph but with a new step substituted for dead anneal. Of course, there is no similarity whatever in the function or effect of the old and the new steps. The dead anneal serves to remove any strain due to working while the new step intentionally produces some precipitation hardening. The new step designated 4′ is described:

4′—The temperature of the sample is maintained within the two-phase region (preferably from 700° C. to 850° C.), the upper limit being dictated by the requirement that there be a substantial amount of γ phase produced and the lower limit being dictated by workability considerations during step 6—although any temperature within the two-phase region for the particular alloy composition produces some beneficial effect. "Terminal hot working" is carried out on the sample at this initial temperature to an area reduction of at least 10 percent. While the mechanistic operation is not understood, experiments have established that a significant part of the improvement realized is due to an effect in addition to simple precipitation hardening. This additional effect requires hot

deformation of the two-phase structure to at least 10-percent reduction in area to produce significant improvement in terms of residual induction and/or coercivity. The manner by which this area reduction is brought about is noncritical. Hot rolling, drawing, swaging, etc., are equally efficacious.

While from a processing standpoint it is sometimes convenient to permit the sample to cool from hot working in the single-phase region and then to reheat to within the noted range prior to or during terminal hot working this cooling and reheating is not necessary. The sole requirement is that the material be within the two-phase region during initiation of terminal hot working (of course, at least to the noted required area reduction).

Processing conditions during steps 1 through 3 and 5 through 7 are tailored in accordance with considerations considered applicable by workers in this art. Such considerations take into account final desired characteristics, shape, size, etc. Introduction of the "terminal hot working" of 4', in addition to eliminating the dead anneal of 4, results in an increase in residual induction, coercivity, and energy product for any alloy of the included composition as ordinarily processed to produce a residual induction of at least 12,000 gauss and a coercivity of the order of 20 to 150 oersteds.

As with conventionally processed Remendur, compositions may be varied over relatively large ranges, at least with regard to the major ingredients. The magnetic properties of the final material are extremely sensitive to processing conditions. It is an absolute requirement that the final processing step be a partial anneal following a cold reduction. While there should be no treatment between final cold working and partial anneal, such as to effect magnetic properties, it is at this intermediate stage that the parts are punched and shaped. Where reference is made to directly following working by final anneal, it should be so construed. The cold reduction, which may be effected by rolling, drawing, swaging, etc., must be at least 60-percent area reduction. A preferred figure is 90-percent, such reduction resulting in a fullness ratio of at least 65 percent.

The partial anneal may be carried out over the temperature range of from 400° C. to 675° C. Optimum time of anneal ranges from about one-half hour at 675° C. to about 20 hours at 400° C. Some increase in heating time is permissible, maximum times ranging from 1 hour to 25 hours, the lower value again corresponding with the higher temperature of 675° C. Minimum values may range from one-fourth hour to 15 hours, the lower value corresponding with the higher temperature. Minimum heating time is somewhat dependent on the cross section of the body being treated. Sections adaptable to the devices herein, do not generally exceed 0.05 inch and there are no complications on heating. With appreciably larger sections, it may be necessary to increase heating time to allow for time lag. Heating time should be sufficient to result in heating the innermost portion for the suggested period. Some of the specific examples herein are concerned with elements which were heat treated for from 1 to 3 hours at a temperature of from 550° C. to 575° C., and this range of conditions is to be considered optimum.

Partial anneal, as well as any other treatment involving heating, is desirably carried out in a protective atmosphere over the temperature range down to 350° C. to prevent oxidation of vanadium. In general, air ambient is permissible for processing of thicker sections (60 mils and up). Suitable protective atmospheres are hydrogen, forming gas, argon, helium, nitrogen, etc.

4. Composition

Alloy composition is generally conventional except that use is sometimes made of vanadium content slightly in excess of the usual maximum. For conventional processing, vanadium content in excess of about 5 percent, while it increases workability, reduces residual induction to undesirable levels. For the purposes of this invention, the upper limit is increased to 8 percent. Such increased amounts still have the effects noted but are sometimes required to improve workability for the partially precipitation-hardened material.

The compositions, while basically cobalt, iron and vanadium, may be slightly modified by the addition of other ingredients for well-known purposes. A characteristic composition is 4.5% V, 48% Co, 47.5% Fe, 0.5% Mn (all percentages in this description are in terms of weight percent). The manganese inclusion serves the well-known function of minimizing the deleterious effect of any sulfur inclusion. The amount of manganese is not critical and can be eliminated entirely if precautions are taken to void sulfur inclusions. While amounts as great as 1 percent or more may be used, one-half percent usually suffices, with no further advantage accruing with greater inclusion. It is well known that any of several other elements including cerium, magnesium, beryllium and calcium may be utilized. It is also known that small amounts of various elements including, for example, chromium, zirconium, titanium, nickel, etc., may be incorporated to alter such properties as switching time and resistivity.

Vanadium is included to improve cold-workability of the resultant alloy. The major ingredients, cobalt and iron, are, of course, mainly responsible for the magnetic properties of the alloy. A preferred range on a 100 part basis for the total of these two ingredients is from 45 parts cobalt to 65 parts cobalt, with a broader range extending from 40 to 75 parts of this ingredient. It is seen that considerable freedom exists for increasing cobalt inclusion, and it is this ingredient which is chiefly responsible for increased coercivity and for workability. In general, increasing cobalt content results in decreasing saturation and remanence; however, such values are generally adequate for devices of the type primarily of concern at cobalt levels far above the maximum inclusion indicated. The value of the fullness ratio increases for increasing cobalt from a value of about 62 percent at 40 parts to about 80 percent for 50 parts. The ratio decreased slightly for greater cobalt inclusion and is at a value of about 75 percent for 75 parts. For uses herein, a value of 60 percent is considered a preferred minimum.

Vanadium content ranges from 2 percent up to about 8 percent. While the entire range is usable vanadium content is somewhat dependent on cobalt content, with the low values being preferred for greater cobalt inclusion. Vanadium inclusion improves workability, increases resistivity, improves fullness ratio, and increases coercivity.

What is claimed is:

1. Device comprising a magnetic circuit including a pair of normally open switch contacts of a magnetic material together with at least two separately magnetizable portions, each of said portions having a magnetic fullness ratio of at least 50 percent and each of said portions consisting essentially of an alloy containing from 40 to 75 parts by weight cobalt, 25 to 60 parts by weight iron, and 2 to 8 parts by weight vanadium, said body portions having been produced by a series of processing steps terminating in a cold reduction of at least 60 percent followed by a partial anneal within the range of from 400° to 675° C. for a time period of from one-fourth to 25 hours, characterized in that the said cold reduction is preceded by a hot deformation resulting in a cross-sectional area reduction of at least 10 percent, said deformation being carried out within a temperature range defining the two-phase region for the said alloy within which both α and γ phases are in thermal equilibrium.

2. Device of claim 1 in which said hot deformation is initiated with the said material at a temperature within the range of from 600° C. to 900° C.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,624,568 Dated November 30, 1971

Inventor(s) Karl M. Olsen and Raymond C. Stoffers

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

Col. 1, line 7, after "processed" the words --so as to have-- should be inserted;

line 33, after "in" first occurrence, insert --the--.

Col. 3, line 9, after "10 inches" the word --long-- should be inserted;

line 69, after "flux" insert the word --path--.

Col. 4, line 27, after "these" insert --two--.

Col. 8, line 38, after "ratio" the word "decreased" should read --decreases--.

Signed and sealed this 6th day of June 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
U.S. GOVERNMENT PRINTING OFFICE 1969 O—366-334