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METHOD OF MAKING SINGLE CRYSTAL CORES OF A FERRITE
INCLUDING COBALT AND CORES SO MADE
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FIG. 1

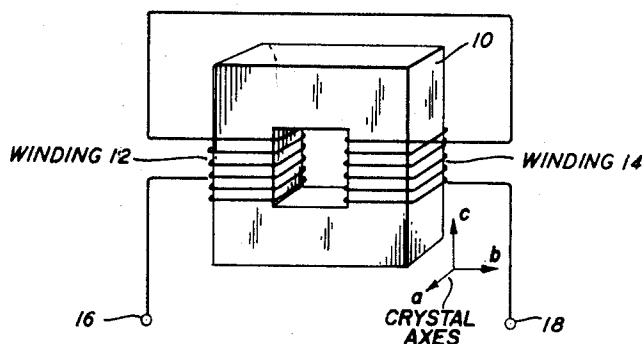
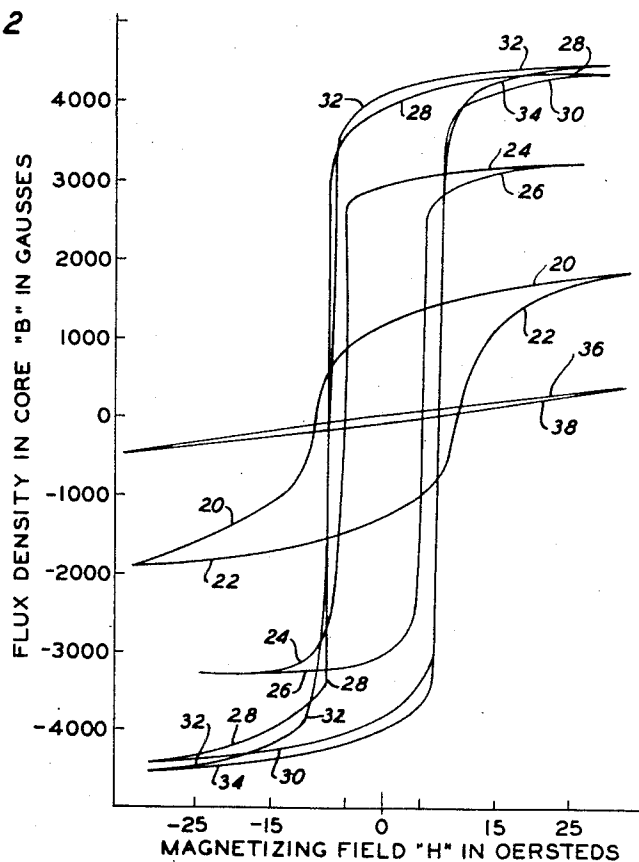


FIG. 2



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METHOD OF MAKING SINGLE CRYSTAL CORES OF A FERRITE INCLUDING COBALT AND CORES SO MADE

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2 Claims. (Cl. 336—218)

The present invention relates to methods of producing magnetic cores for inductance coils, which cores have either vertically elongated, rectangular, hysteresis loops or flat, lenticular, small-area, hysteresis loops and to inductance coils employing said cores. More particularly, it relates to methods of cutting inductance coil cores from single crystals of those ferrites which include a component of cobalt of from one to thirty percent by weight, and treating said cores to alter their hysteresis loops in either of the above mentioned manners and to inductance coils having said treated cores.

In general, any ferrite including from one to thirty percent by weight of cobalt will exhibit the characteristics described hereinbelow irrespective of whether other non-ferrous metallic components are present in the particular ferrite or not. For example, cobalt zinc ferrite conforming to the formula $\text{Co}_{0.32}\text{Zn}_{0.22}\text{Fe}_{2.2}\text{O}_4$ exhibits the characteristics, to be described in more detail hereinunder, to a marked degree. On the other hand, other ferrites including no cobalt such, for example, as manganese zinc ferrite, give virtually negligible results.

For the purposes of this application the phrase "a ferrite including cobalt" shall be understood to mean any and all ferrites having from one to thirty percent by weight of cobalt as a constituent of the ferrite, irrespective of whether other non-ferrous metallic components are present in the particular ferrite or not.

In accordance with the conventional manner of presenting the hysteresis loop of a magnetic material the values of the magnetic field "H" in oersteds are displayed horizontally and the resulting values of the flux density B in the material are displayed vertically. This conventional presentation is assumed for the purpose of description throughout this application and in the appended claims.

Magnetic materials having vertically elongated substantially rectangular hysteresis loops are, as is well known to those skilled in the art, of substantial value for use in switching arrangements and as information storage devices. Conversely, magnetic materials having a small-area, substantially flat, hysteresis loop are of substantial value in instances where a core material of low hysteresis loss and virtually constant permeability over a wide range of magnetic field strength is desired as, for example, for "loading coil" cores and the like, where a virtually constant inductance over a wide range of magnetic field strengths is desired.

The principal object of the invention is to provide a new and convenient method of producing magnetic core elements having either vertically elongated, rectangular, hysteresis loops or small-area, lenticular hysteresis loops.

Another object is to provide inductance coil cores of a ferrite including cobalt, said cores having vertically elongated, substantially rectangular, hysteresis loops.

A further object is to provide core elements of a ferrite including cobalt, said core elements being suitable for fabricating into elements having desirable properties for

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use as information storage devices and in switching arrangements.

A still further object is to provide inductance coil cores of a ferrite including cobalt, said cores having small-area, lenticular, hysteresis loops.

Other and further objects will become apparent during the course of the following detailed description illustrating applications of the general methods of the invention, and from the appended claims.

In the accompanying drawings:

Fig. 1 shows, by way of specific example, a hollow square core of cobalt zinc ferrite which can be employed in demonstrating the modification of the magnetic properties of the material in accordance with the principles of the present invention; and

Fig. 2 shows, by way of illustration, the hysteresis loop of the core of Fig. 1 before treatment and a plurality of modifications of the hysteresis loop of the core of Fig. 1 after being subjected to a like plurality of differing treatments, in accordance with the principles of the present invention, respectively.

In general ferrites of the class designated by the above defined phrase "a ferrite including cobalt" (i.e., any and all ferrites having from one to thirty percent of cobalt by weight, irrespective of whether other non-ferrous metallic components are present or not), have a cubic crystalline structure representable by the three mutually orthogonally related crystal axes *a*, *b*, and *c*, the unit length along each axis being the edge of the unit cube.

Cores of the present invention, as illustrated by the specific example 10 shown in Fig. 1, are cut from a single crystal of the particular "ferrite including cobalt" and may be cut with the front and rear surfaces parallel to any one of the three planes defined as including any two of the above mentioned three crystal axes *a*, *b*, and *c*. The cut must, furthermore, be made so that one of the two pairs of parallel legs of the square core 10 is parallel to one crystal axis and the other pair of parallel legs is parallel to the other crystal axis, of the two axes selected to determine the plane with which the front and rear surfaces of the core 10 of Fig. 1 are to be parallel.

The particular core 10 of Fig. 1 has front and rear faces 0.146" square with a central opening 0.062" square and a thickness front to rear of 0.030". The cross-sectional shape of the legs need not be rectangular but can be round or ovoid, if desired, so long as the orientations with respect to the axes of the crystal from which the core is cut are as described above.

It should be particularly noted also that the core need not necessarily be square but can alternatively be of any rectangular shape which can be conveniently cut from a single crystal with the orientations given above.

Windings, such as 12 and 14, of insulated conductive wire are placed on one or more of the legs of the core 10 and connected in series aiding to terminals 16 and 18.

Curve 20, 22 of Fig. 2 shows the hysteresis loop of the core 10 of Fig. 1 before being subjected to any treatment in accordance with the principles of the present invention.

If the core 10 of Fig. 1 is subjected to a unidirectional magnetic field of from two to twenty oersteds or more by passing a suitable continuous current through its windings 12 and 14 and heated to a temperature of from 120 to 140 degrees centigrade or more and maintained under said magnetic field and at said temperature for from a few seconds to an hour or more and thereafter cooled to room temperature while still maintaining said field, a pronounced "squaring" of the "corners" of its hysteresis loop, as well as a vertical elongation of the loop, will be found to have been effected, as illustrated, by way of example, by curves 24, 26; 28, 30 and 32, 34 of Fig. 2, the specific magnetic field strength, tempera-

ture and time of treatment being as given below for these particular curves, respectively. Cobalt zinc ferrite of the formula given hereinabove was employed in these tests.

Curve	Magnetic Field Strength, oersteds	Temperature, ° C.	Treatment Time
24, 26	2	400	15 minutes.
28, 30	20	190	16 hours.
32, 34	10	400	15 minutes.

There is no advantage to using a temperature greater than the Curie temperature of the ferrite being treated, since above the Curie temperature, magnetic substances become non-magnetic. For the class of ferrites (as defined above) of interest in connection with the present invention the Curie temperature is in the range of 300 to 500 degrees centigrade. The cobalt zinc ferrite mentioned hereinabove has, by way of specific example, a Curie temperature of 450 degrees centigrade.

In general the nearer the temperature approaches the Curie temperature the shorter the time required for treatment in accordance with the present invention, a limit in the order of several seconds being sufficient at temperatures closely approaching the Curie temperature. At lower temperatures a longer time is required, about fifteen minutes being adequate at 400 degrees centigrade and proportionately longer times being advisable at still lower temperatures.

In other tests, comparable hysteresis loops to those of the three curves just described were obtained at magnetic annealing temperatures as low as 140 degrees centigrade. In general, magnetic fields higher than twenty oersteds and/or temperatures higher than 400 degrees centigrade, do not produce any perceptible further elongation of the loop or "squaring" of the corners of the rectangular hysteresis loop. The process is completely reversible, i.e., the original hysteresis loop curve 20, 22 of Fig. 2 is obtained again if the treated core 10 is heated to 400 degrees centigrade in the absence of any appreciable magnetic field and then cooled to room temperature.

Conversely, when a magnetic field is applied perpendicularly to the front and rear faces of the core 10 by external magnetizing means, while the core 10 is heated to a temperature in the order of from 120 to 400 degrees centigrade, or more, the field and temperature being maintained for a time interval depending upon the temperature used as described above, a very flat hysteresis loop as illustrated for example by curve 36, 38 of Fig. 2 is obtained upon cooling to room temperature with the field still maintained, and testing thereafter.

In the last stated instance, heating of the core 10, after completion of the prescribed treatment, to a temperature in the order of 400 degrees centigrade with substantially no magnetic field applied and thereafter cooling

to room temperature restores the element to a normal hysteresis loop for the material as illustrated by curve 20, 22 of Fig. 2. This, of course, demonstrates that the last stated process is also reversible.

Similar metallic ferrites containing no cobalt, such as, for example, manganese zinc ferrite, exhibited no corresponding changes in the character of their respective hysteresis loops when subjected to the above described processes using fields up to twenty oersteds, or more, at temperatures in the range between 120 degrees centigrade and 400 degrees centigrade, or more.

Numerous and varied other related methods, applications and arrangements in accordance with the principles of the present invention can be readily devised by those skilled in the art without departing from the spirit and scope of said principles.

What is claimed is:

1. The method of producing a magnetic core which comprises cutting a hollow rectangular core element from a single crystal of the ferrite $\text{Co}_{0.32}\text{Zn}_{0.22}\text{Fe}_{2.2}\text{O}_4$, the front and rear surfaces of the element being parallel to a plane defined by two crystallographic axes of the single crystal, each of the longitudinal axes of the four portions of the hollow rectangular element being parallel to one of the two axes of the crystal, magnetizing the element with a unidirectional magnetic field induced within the element as a closed magnetic path, heating the element to a temperature between 120 degrees centigrade and the Curie temperature of the ferrite, maintaining the magnetization and the temperature simultaneously for a predetermined time interval, and cooling the element to room temperature while maintaining the magnetizing field.

2. A hollow rectangular magnetic core element of the ferrite $\text{Co}_{0.32}\text{Zn}_{0.22}\text{Fe}_{2.2}\text{O}_4$ cut from a single crystal and having the front and rear surfaces of the core parallel to a plane defined by two crystallographic axes of the single crystal, each of the longitudinal axes of the four portions of the hollow rectangular element being parallel to one of the two axes of the crystal, said core having been magnetically annealed to have a substantially rectangular hysteresis loop.

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