Jan. 3, 1961 E. D. O'BRIAN ET AL 2,966,704

PROCESS OF MAKING A FERRITE MAGNETIC DEVICE

Filed Jan. 22, 1957

FIG. 1.

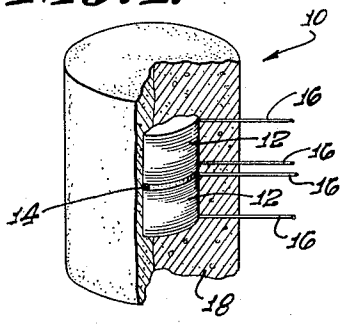


FIG. 2.

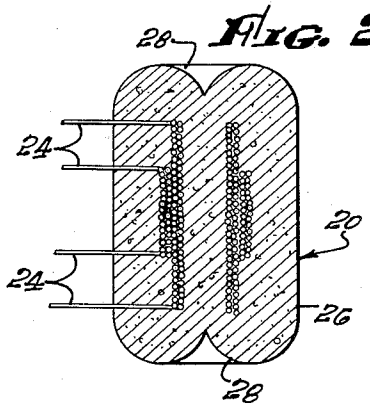


FIG. 3.

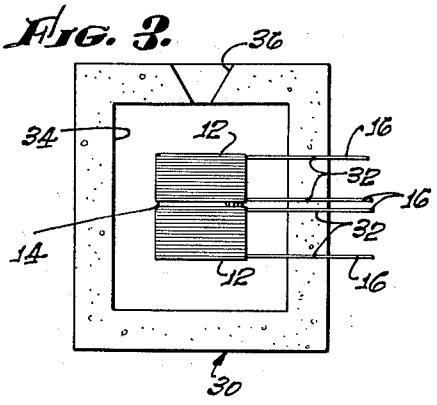


FIG. 4.

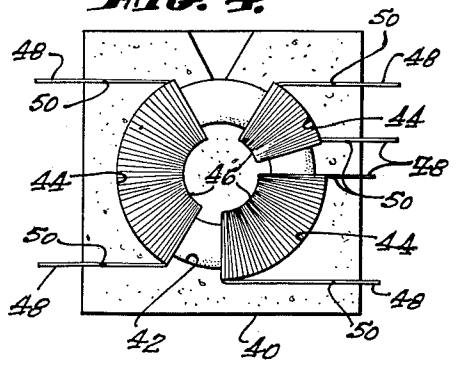


FIG. 5.

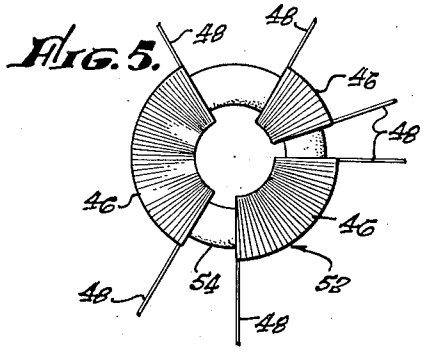
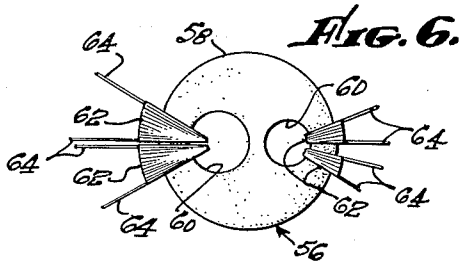


FIG. 6.



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PROCESS OF MAKING A FERRITE MAGNETIC DEVICE

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5 Claims. (Cl. 18—59)

This invention relates to new and improved processes for manufacturing improved electrical devices.

A large number of different electrical devices have been developed which are designed so that a current may flow through a conductor in order to induce magnetic flux within a ferromagnetic core located with respect to the conductor. Such electrical devices frequently include more than one conductor, and the conductors utilized may be of virtually any desired shape such as, for example, the shape of a coil. It is considered virtually impossible to specify in a comparatively brief patent specification the precise nature of all such devices. Various miniature inductors, saturable core reactors, transformers, magnet-memory and switching devices, multi-appertured core control devices and the like are examples of devices of this category.

As the electronic industry progresses there appears to be a very decided need for extremely small, light weight, reliable devices of the category broadly indicated in the preceding paragraph. In order to meet this need, a number of structures have been developed in which a ferromagnetic core is first formed to a desired shape and configuration, and then various conductors are wound upon it with essentially a sewing type of action. Practically all of these devices are sufficiently small so that they cannot be satisfactorily wound on conventional core winding machines or the like. Essentially hand winding operations as indicated herein are relatively expensive. Further, problems frequently arise from a lack of adequate control of the winding operation.

It is a broad object of this invention to provide electrical devices utilizing at least one conductor and an associated ferromagnetic core which are not subject to various limitations and disadvantages of the foregoing and various related types of constructions of similar devices. Another object of this invention is to provide processes for manufacturing such electrical devices, which processes involve the steps of preforming a conductor to a desired shape, and then creating a ferromagnetic core in a desired configuration and position with respect to the conductor. Other objects of this invention are to provide relatively inexpensive light weight electrical devices of the broad category indicated which are extremely reliable in operation.

Still further objects of this invention as well as many advantages of it will be full apparent to those skilled in the art to which the invention itself pertains from a detailed consideration of the remainder of this description including the appended claims and the accompanying drawing in which:

Fig. 1 is a perspective view, partially in section, of an electrical device of this invention;

Fig. 2 is a side elevational view in section of another electrical device of this invention;

Figs. 3 and 4 are diagrammatic side elevational views indicating steps in forming electrical devices of the present invention; and

Figs. 5 and 6 are top elevational views of further electrical devices formed in accordance with the teachings of this invention.

In all figures of the drawing like numerals are used to designate like parts wherever convenient for purposes of illustration and explanation. It is to be understood that the accompanying drawing is not to be taken as limiting this invention in any respect. Obviously the basic features of this invention can be applied to a wide variety of other electrical devices besides those of the specific category illustrated. Further, the processes of this invention can be utilized in other manners besides the specific manner shown.

As an aid to understanding the invention it may be stated in essentially summary form that it concerns electrical devices each of which includes at least one conductor formed to any desired predetermined shape and a ferromagnetic solid core located so as to engage the conductor means employed and firmly hold said conductor means in position. It may also be stated in essentially summary form that the invention concerns processes for making devices of this category, which processes involve the steps of preforming the conductor means utilized, locating a composition with respect to the conductor means so that this composition has approximately the shape desired in a final electrical device and then treating this composition so as to create a solid, ferromagnetic structure.

The actual nature of the invention itself is best more fully explained by referring directly to the accompanying drawing. In Fig. 1 there is shown an auto-transformer **10** formed in accordance with this invention so as to include coils **12** which may, if desired, be separated by an inert steatite spacer **14**; conventional leads **16** extend from these coils **12** out through a body **18** of a ferromagnetic ceramic composition. It will be noted from an examination of Fig. 1 that this body **18** completely encloses the two coils **12** and goes down the centers of these two coils. It is to be also specifically noted that the material within the body **18** makes direct contact against or with the coils **12**.

In Fig. 2 of the drawing there is shown another transformer **20** similar to the transformer **10** which has also been formed in accordance with this invention. This transformer **20** includes concentric coils **22** located against one another, although they may be separated by a non-conductive, nonmagnetic member (not shown). From these coils there project leads **24**, and the coils **22** are enclosed within a body **26** of a ferromagnetic ceramic material. It is to be noted that the ends **28** of the body **26** are curved so as to follow approximately the shape of the flux path within the body in order to save as much material and weight as possible. The coils **22** are, in this construction, also held by direct engagement with the material within the body **26**.

Constructions such as are shown in Figs. 1 and 2 of the drawing may be easily created by a procedure such as is partially indicated in diagrammatic form in Fig. 3 of the drawings. In forming devices of this nature a complete mold **30** which preferably consists of two bilaterally symmetrical half-shell molds, only one of which is shown, are placed together so that leads such as the leads **16** pass within grooves **32** in the molds **30**, in order to support coils such as the coils **12**, within a cavity **34** within this mold. An appropriate inert spacer, such as for example, the steatite spacer **14** may be held by the two coils **12** by friction or an adhesive. It is noted that these coils are prewound in a known manner.

After the mold **30** has been assembled as indicated a fluid suspension of finely divided particles, capable of being heated so as to form a solid ferromagnetic mass may be cast into the cavity **34** through an entrance **36** so as to surround and engage the coils **12** substantially

as indicated in Fig. 1 of the drawing. Next this composition may be "set up" as with use of heat so as to form a solid ferromagnetic body such as the body **18**.

In one preferred method of carrying out a process of the present invention the mold utilized is formed of a porous material, such as for example, plaster of Paris. The liquid composition cast through the entrance **36** into the cavity **34** essentially is filtered out by the walls of the mold **30** so that primarily solid particles remain within the cavity **34**. If desired, pressure can be applied to the interior of the cavity **34** so as to aid in this operation, and if desired moderate heat such as for example, heat up to about 100° C. can be applied so as to aid in the removal of liquid. After all such liquid has been removed, an essentially solid construction is obtained which, in some cases, can be used directly as the desired product.

In order to obtain the optimum physical and magnetic properties, it is normally preferred to form a body such as the body **18** within a device of this invention so that this body consists almost entirely of a solid ferromagnetic ceramic composition, such as for example, a known ferrite composition. Such ferrite compositions are well known at this present time. Reference is made to the article "Methods of Preparation and Crystal Chemistry of Ferrites," by Fresh, appearing in Proceedings of the IRE, October, 1956 issue, page 1303. Liquid suspension of such ferrites may be created for use with this invention utilizing either water or various known organic liquids such as for example, petroleum liquids such as kerosene as the liquid or carrier phase. Petroleum liquids are frequently preferred for this purpose inasmuch as their use eliminates any problem of hydration of the particles placed within the mold **30**.

Obviously the liquid compositions cast may contain virtually any desired percentage of finely divided particles. It is considered best at the present time to follow conventional ceramic practices as to the percentage of solids, particle sizes, etc. The finely divided particles used may be merely oxide or other mixtures capable of being fired together so as to produce ferrites. Preferably, however, these finely divided particles used consist of presintered ferrites which have been ground in the suspending liquid to the desired size. Such presintered materials are preferred because they exhibit less shrinkage in subsequent firing. The suspensions cast may contain, in accordance with known practice, various minor amounts of volatile binders, fluxing agents, wetting agents and the like. Suitable binders are carboxymethylcellulose, various plant hydrocolloids, or the like. Such binders serve to maintain the intermediate product removed from a mold such as the mold **30** in a desired shape until after the firing or sintering operation. Fluxing agents may be employed to aid in the sintering operation.

The sintering operation itself may be carried out at temperatures of from about 450° to 1300° C. in the presence of various known gases. Since the sintering and cooling procedures employed are well known, they will not be specifically discussed herein. When a mold has been used which is capable of withstanding the sintering conditions, the sintering may be carried out in many cases without removing the intermediate product referred to above from the mold. In such cases temporary binders such as are referred to above may, of course, be omitted. It is important that the conductors used in a device of this invention be capable of withstanding sintering operation itself.

For certain sintering operations those skilled in the art to which this invention pertains will choose wires of aluminum, or various aluminum copper alloys or the like which may be covered as by anodizing with an adherent oxide insulating film prior to use. It is also possible to form the conductors utilized out of appropriate wires which have been covered with films of volatile material loaded with various inert, non-conductive particles. As an example of this the conductors utilized may be formed out of a high temperature copper wire coated with polytetrafluorethylene films containing silica or other inorganic particles. During sintering such films will decompose leaving comparatively little ash or residue which would tend to cause shorts between the turns of a coil; also the inorganic particles remaining after sintering will serve to separate the individual turns of the coils from one another. Other similar expedients can, of course, be employed.

If desired, the mold **30** may be altered as indicated in Fig. 4 of the drawing so as to be used in creating slightly different electrical devices falling within the scope of this invention. In Fig. 4 of the drawing, there is shown a modified mold **40** formed of similar material to the material used for the mold **30** so as to be composed of two bilaterally symmetrical half-shell sections which are adapted to fit together so as to define an internal cavity having essentially the shape of a closed loop or ring. Around this cavity in the mold **40** there are formed enlarged grooves **44** which are adapted to contain coils **46** from which there project leads **48** extending out through comparatively small grooves **50** in the mold **40**.

The process in forming devices of this invention with molds such as the mold **40** is substantially identical with the procedure discussed above and, hence, will not be specifically gone over. With this type of construction the coils **46** are held in place by direct engagement with the mold; hence, comparatively stiff leads are not required. With the molds **30** on many cases it may be necessary to artificially stiffen the leads shown as by the use of inert ceramic rods or the like. No such expedients are required with a mold such as the mold **40**. The coils **46** used with this mold can give a curved configuration as shown or can be of a cylindrical variety. In either event they can be wound on a conventional type of winding equipment. If curved, they may be bent to the shape of the mold during the insertion therein.

As a result of the use of a mold such as the mold **40** it is possible to derive a transformer type of construction **52** such as is shown in Fig. 5 of the drawing. This construction consists of essentially a doughnut shape core **54** surrounded by various coils **46** from which there project leads **48**. It is also possible to use this type of mold to produce a multi-apertured control device **56** which includes a core **58** having several apertures **60** located therein. Various coils may be located on the core **58** as shown, and leads **64** extend from these coils **62**.

With devices such as the devices **52** and **56**, the coils are at all times exposed so as to permit their being worked on if required. When coils are located as illustrated in Figs. 5 and 6 they may be readily impregnated with various known materials or they may even be anodized by known processes. Any of the devices falling within the scope of this invention can, of course, be encapsulated in accordance with known process with various protective resin coatings such as, for example epoxy resin films or the like.

The constructions of this invention herein shown and described all utilize cores which consist entirely of a ferromagnetic material such as, for example, a nickel-zinc ferrite or the like. Because of the fact that they do not contain various non-magnetic binders and the like effectively magnetic properties are inherent within them, and weight can be saved through their use. Further, none of these constructions require winding conductors on an already formed core. Obviously the basic principles of this invention can be employed with a wide variety of different diverse constructions designed for different electrical purposes. The equivalent of a multi-apertured control device such as is illustrated in Fig. 6 of the drawing can be formed in the manner of the constructions shown in Figs. 1 and 2 by locating coils in a

concentric manner with respect to one another so that they are separated from one another. Since a number of modifications and adaptations of this category can be made within the scope of this invention, the invention itself is to be considered as being limited only by the appended claims.

We claim:

1. A method for manufacturing a magnetic device which comprises: forming electrical conductor means into a desired shape; placing said conductor means into a desired position within a porous mold; filling said mold with a suspension of a finely divided non permanent magnetic ceramic composition capable of being sintered so as to form a solid ferromagnetic mass in a liquid carrier; removing said carrier from said mold through the pores within said mold; and sintering said composition and said conductor means so as to form a solid mass of said ferromagnetic material, said mass and said conductor being located directly against one another.

2. A method as defined in claim 1 wherein a solid body is formed within said mold by the removal of said liquid carrier from said mold and wherein said body is removed from said mold prior to said sintering step.

3. A method for manufacturing a magnetic device which comprises: placing preformed electrical conductor means into a porous mold; filling said mold with a suspension of a finely divided ceramic composition containing presintered, ground non permanent magnetic ferromagnetic ferrite particles dispersed within a liquid carrier, said ferrite particles engaging said conductor means within said mold and filling said mold, removing said liquid carrier from said mold through the pores in said mold in all directions so as to form a body comprising said particles and said conductor means within said mold; removing said body from said mold; and sintering said body so as to form a solid magnetic device in which said conductor means are in direct engagement with a solid ferromagnetic ferrite body.

4. A method as defined in claim 1 wherein during said forming operation said electrical conductor means comprises a wire, and wherein said wire is formed into the shape of a coil.

5. A method as defined in claim 3 wherein said electrical conductor is a wire and wherein said preformed electrical conductor is a coil formed of a wire.

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