

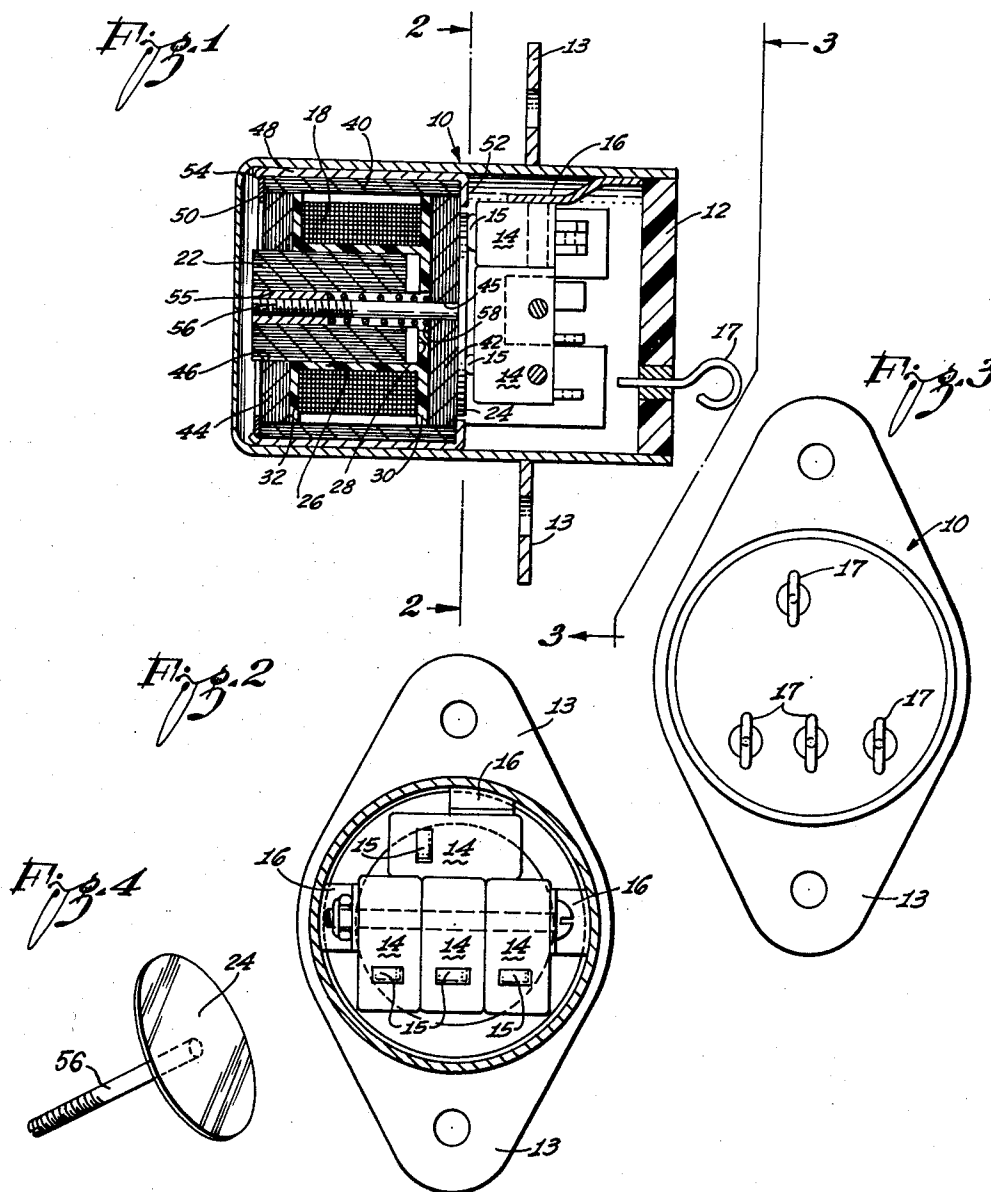
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ELECTROMAGNETIC ACTUATOR AND METHOD OF MAKING SAME

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ELECTROMAGNETIC ACTUATOR AND METHOD OF MAKING SAME

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This invention relates to electromagnetic actuators such as relays and solenoids and, more particularly, relates to such a device for use on aircraft where the available current is 115 volt 400 cycle A.C. current. The invention is specifically directed to the problem of reducing the size, and especially the weight, of such a device.

For the purpose of simplifying the invention and teaching the principles involved, the present disclosure is directed to what is termed a four-pole double-throw power transfer relay capable of exerting an actuating force on the order of 3½ pounds. The description of this particular embodiment of the invention will provide adequate guidance for those skilled in the art who may have occasion to apply the same principles to other specific purposes. All of the prevalent types of aircraft relays for use with 400 cycle current are provided with rectifiers and typically are further provided with magnetic shielding, the magnetic shielding usually being provided by encasing the relay in a housing made of magnetic steel. Rectification of the A.C. current is necessary because the core losses rise rapidly with increase in the frequency, and these losses have heretofore become intolerable at 400 c.p.s. The problem is made more difficult, moreover, because a nominal frequency of 400 c.p.s. means in practice as high as 480 c.p.s. and, in some instances, above 500 c.p.s.

The present invention is based in large part on the discovery that, if certain critical requirements are met, an efficient and exceptionally lightweight relay may be designed for highly successful use in a 115 volt 400 cycle circuit without the necessity of rectifying the current. The elimination of rectifiers not only reduces weight and cost but also increases reliability. The invention is based in further part of the concept of constructing such a relay with what may be termed a closed core structure, which effectively confines the magnetic field and thus makes it unnecessary to provide an external ferromagnetic shield. Instead, the relay is encased in a lightweight non-magnetic metal such as aluminum. A relay constructed in accord with these teachings will occupy only a fraction of the volume required for a conventional 400 cycle relay, will save about one-fifth or less of the space, and will be correspondingly lightweight.

One requirement for a successful embodiment of such a relay is that the core material have a higher magnetic saturation point than the silicon steels that are ordinarily used. Conventional core material, such as 3% silicon steel, has an induction saturation point of approximately 20,000 gauss. The required higher saturation point may be provided, for example, by an appropriately processed, grain-oriented alloy containing at least 49% iron and at least 49% cobalt. Such an alloy is sold by Allegheny Ludlum Steel Corporation under the trade name "Permendur." "Vanadium Permendur," containing approximately 2% vanadium, is preferred. The manner in which such an alloy is processed for grain orientation is well known. The required heat treatment for removing impurities is also well known, and this service may be supplied by Metallurgical Consultants, Inc., 8100 E. Slauson, Montebello, California. The requirements for annealing 2V Permendur are as follows:

- (1) Must be in pure hydrogen atmosphere at all times. Dew point of hydrogen must be less than 40° F.

- (2) Soak at 1375°-1425° F. for 1½ to 2 hours.
- (3) Furnace cool at rate not to exceed 150° F. per hr. to 700° F.
- (4) Retort can then be removed from oven provided that cooling rate does not exceed 150° F. per hr. Hydrogen atmosphere and cooling rate must prevail to 150° F.

A second requirement is that the core structure of the relay be made of thin laminations of a particular thickness. Thickness is critical and must not depart substantially from 0.004 inch $\pm$ 0.001 inch.

With further reference to the requirements for a successful embodiment of the relay, it has been found that the described core structure must be tightly compacted for necessary intimate metal-to-metal contact between the laminated jacket and the two laminated end washers. As will be explained, this requirement may be met by suitably encasing the jacket and end washers under permanent compression.

In the preferred embodiment of the relay, both the circumferential jacket of the core structure and the armature inside the core structure are of generally circular cross section. In this regard, a further requirement for success is that both the jacket and the armature be of spiral or tape-wound laminated construction.

In the preferred practice of the invention, the coil of the relay is wound on a suitable bobbin, and the bobbin is enclosed by a core structure comprising a circumferential laminated jacket and two laminated end washers. An important feature of the invention is that, with such a core structure forming closed magnetic flux paths, external shielding becomes unnecessary, and a relay may be fabricated with a thin aluminum housing at considerable saving in weight in comparison with conventional relays.

The features and advantages of the invention may be understood from the following detailed description and the accompanying drawing.

In the drawing, which is to be regarded as merely illustrative:

FIG. 1 is a longitudinal sectional view of the presently preferred embodiment of the relay;

FIG. 2 is a transverse section taken along the line 2-2 and showing the four switches that are included in the relay construction;

FIG. 3 is a front end elevation of the relay as seen along the line 3-3 of FIG. 1; and

FIG. 4 is a perspective view of a pressure plate that is operated by the armature of the relay for the purpose of actuating the switches.

The selected embodiment of the relay shown in FIGS. 1-4 is hermetically enclosed in a suitable housing, which, in this instance, comprises a cup-shaped aluminum shell 10 closed by an end wall 12 of suitable plastic material. The aluminum shell is provided in the usual manner with apertured mounting flanges or ears 13.

Since this particular relay is a four-pole, double-throw relay, the housing encloses four single-pole, double-throw switches 14 of a well-known snap-acting type, each of which has an operating button or plunger 15. The four switches 14 are rigidly mounted in the aluminum shell 10 by suitable bracket means 16. Mounted in the end wall 12 is a plurality of electrical terminal elements 17 which are connected to the switches by suitable wires (not shown).

The relay proper comprises a coil 18 and an axial armature 22 which carries a pressure plate 24 for depressing the operating buttons 15 of the switches 14. The coil 18 is wound on a bobbin of suitable plastic material which has a cylindrical wall 26, an end wall 28, and two radial end flanges 30 and 32.

For successful operation of the relay, it is essential

that the core structure be a laminated structure of an alloy having an induction saturation point substantially above the 20,000 gauss saturation point of a conventional grain-oriented 3% silicon alloy. The previously mentioned alloy comprising at least 49% cobalt and 49% iron satisfies this requirement, since it has a saturation induction point on the order of 24,000 gauss. In the preferred practice of the invention, "Vanadium Permen-
dur," supplied by Allegheny Ludlum Steel Corporation, Pittsburgh, Pennsylvania, is used, which alloy contains approximately 49% each of cobalt and iron, with about 2% vanadium. For successful operation of the relay on 115 volt, 400 cycle, alternating current without the use of rectification, the specified alloy must have a thickness of 0.004 inch $\pm$ 0.001 inch. As heretofore indicated, it is further essential that the laminated core structure and the laminated armature both be tape wound.

The core structure comprises a laminated circumferential jacket 40, a laminated pole face washer 42, and a laminated end washer 44. The pole face washer 42 is formed with an axial aperture 45 and comprises a stack of thin disks of the selected alloy. The end washer 44 has a large axial aperture 45 to clear the armature 22 and, in like manner, comprises a stack of thin disks of the selected alloy. The circumferential jacket 40 comprises a thin ribbon of the selected alloy of uniform width which is tape wound, i.e., helically wound upon itself. It is essential that the circumferential jacket 40 be in intimate contact with both the pole face washer 42 and the end washer 44. In the construction shown, the circumferential jacket 40 embraces the two washers 42 and 44, and the whole core assembly is permanently confined under pressure against the enclosed bobbin.

The means for confining the core structure is in the form of an inner casing which is fixedly embraced by the aluminum shell 10. The inner casing comprises an inner cylinder 43 and a cooperating flat ring 50, both of which are made of nonmagnetic metal. The inner cylinder 43 tightly embraces the tap-wound jacket 40 and is formed with a radially inward flange 52 at one of its ends, which flange not only overhangs the end of the jacket 40 but also overhangs a circumferential marginal portion of the pole face washer 42. The flat ring 50 extends over the second end of the circumferential jacket 40 and additionally overlies a circumferential marginal portion of the end washer 44. The end of the inner cylinder 43 is turned inwardly, as indicated at 54, into engagement with the outer surface of the flat ring 50. In the assembly procedure, the core structure is axially compressed against the end flange 52 of the inner cylinder 43, and then the opposite end of the inner cylinder is swaged inwardly into engagement with the flat ring 50 to hold the core assembly under permanent axial compression. Thus the bobbin and the two washers 42 and 44 constitute an axial assembly which is permanently held under axial compression between the flange 52 and the ring 50 of the inner casing. This construction insures and maintains intimate and adequate metal-to-metal contact between the jacket 40 and the two washers 42 and 44.

The armature 22 is wound onto a short tube 55 and is fixedly bonded to the tube. The interior of the short tube 55 is screw-threaded for engagement with the screw thread of an axial rod 56, which axial rod carries the previously mounted pressure plate 24. A suitable coil spring 58 surrounds the axial rod 56 in compression between the pole face washer 42 and the short tube 55 to bias the armature to the left, as viewed in FIG. 1, the limit position of the armature being determined by abutment of the pressure plate 24 against the outer side of the pole face washer 42, as may be seen in FIG. 1. The threaded end of the axial rod 56 inside the short tube 55 is provided with a socket or is otherwise formed for engagement by a screw driver or other tool to permit rotational adjustment of the axial rod in the assembly procedure. Con-

sidering the pressure plate 24 as part of the armature, the screw-threaded adjustment of the axial rod 56 changes the effective length of the armature and thus adjusts the armature correctly for operation of the four switches 14.

The fact that the laminated core structure forms closed paths for the magnetic flux, with the laminated metal components of the core structure maintained under permanent axial compression for maximum metal-to-metal contact, makes it unnecessary to employ a housing of steel or other magnetic material for a shielding purpose. In effect, the core structure is self-shielding and thus makes it possible to use aluminum and/or plastic for the housing with substantial saving in weight.

My description in specific detail of the selected embodiment of the invention will suggest various changes, substitutions, and other departures from my disclosure within the spirit and scope of the appended claims.

I claim:

1. An electromagnetic actuator for operation by 320-480 cycle A.C. current without rectification, having:
 - a bobbin;
 - a coil embracing the bobbin;
 - a core structure comprising laminated end washers at the two ends respectively of the bobbin and a laminated spirally wound jacket surrounding the coil and the bobbin;
 - an armature inside the bobbin of spirally wound laminated construction,
 - said core structure and armature being made of grain-oriented alloy having an induction saturation point substantially above 20,000 gauss, the laminations of the alloy being of a thickness on the order of 0.003 inch to 0.005 inch; and
 - a casing enclosing the core structure and confining the core structure under pressure against the bobbin.
2. An electromagnetic actuator as set forth in claim 1, in which said alloy contains at least approximately 49% each of iron and cobalt.
3. An electromagnetic actuator as set forth in claim 2, in which the remainder of the alloy is essentially vanadium.
4. An electromagnetic actuator for operation by 320-480 cycle A.C. current without rectification, having:
 - a bobbin;
 - a coil embracing the bobbin;
 - a core structure comprising laminated face washers at the opposite ends of the bobbin and a laminated jacket surrounding the coil and the bobbin;
 - an armature inside the bobbin;
 - said packet and said armature being spirally wound,
 - said core structure and armature being made of grain-oriented alloy having an induction saturation point substantially above 20,000 gauss, the laminations of the alloy being of a thickness on the order of 0.003 inch to 0.005 inch; and
 - a casing enclosing the core structure and compressing the core structure axially against the opposite ends of the bobbin, said casing comprising a shell embracing the jacket and a cooperating end member, the shell having a radially inward flange at one of its ends engaging one end of the core structure, the end member engaging the other end of the core structure, the other end of the shell being turned radially inward in confining engagement with the outer side of the end member.
5. An electromagnetic actuator for operation by 320-480 cycle A.C. current without rectification, having:
 - a bobbin;
 - a coil embracing the bobbin;
 - a core structure comprising laminated face washers at the opposite ends of the bobbin and a laminated armature inside the bobbin,
 - said jacket and said armature being spirally wound,
 - said core structure and armature being made of grain-oriented alloy having an induction saturation point

5

- substantially above 20,000 gauss, the laminations of the alloy being of a thickness on the order of 0.003 inch to 0.005 inch; and
- a casing enclosing the core structure in a snug manner and compressing the core structure axially against the opposite ends of the bobbin.
6. An electromagnetic actuator as set forth in claim 5, in which said casing is preloaded to maintain the core structure under axial compression.
7. An electromagnetic actuator for operations by 320-480 cycle A.C. current without rectification, having:
- a bobbin with radial flanges at its opposite ends;
 - a coil embracing the bobbin inside the diameter of the radial flanges;
 - a laminated armature mounted for axial movement inside the bobbin;
 - two stacks of disks lying against the opposite ends of the bobbin against the radial flanges thereof, all of the disks being of substantially the diameter as the radial flanges of the bobbin, at least one of the two stacks having an axial opening to accommodate axial movement of the armature;
 - a tape of uniform width equal to the axial dimension of the bobbin plus the axial dimensions of the two stacks of disks, the tape being spirally wound around the bobbin and the two stacks of disks to form a jacket confining the two stacks of disks;
 - the laminations of the armature as well as the disks and the tape being made of a grain-oriented alloy having an induction saturation point substantially above 20,000 gauss and being of a thickness on the order of 0.003 inch to 0.005 inch;
 - a cylindrical casing embracing the jacket and holding the jacket in intimate contact with the circumferential edges of the flanges of the bobbin and with the confined stacks of disks, said casing having radially inward flanges at its opposite ends overlapping circumferential margins of the two stacks and co-operating to compress the two stacks against the two ends of the bobbin.
8. A combination as set forth in claim 7 in which the casing comprises a cylindrical member with an integral radially inward flange at one end and a circular member embraced by the other end of the cylindrical member,

6

said other end of the cylindrical member being deformed inwardly into overhanging engagement with the outer face of the circular member.

9. A method of fabricating a core for an electromagnetic actuator, characterized by the steps of:
- winding a coil on a bobbin having radial flanges;
 - placing two stacks of thin disks of ferromagnetic material of substantially the same diameter as the bobbin flat against the opposite ends of the bobbin to form therewith an axial assembly;
 - winding around the axial assembly a ferromagnetic tape of uniform width substantially equal to the axial dimension of the axial assembly to form a laminated jacket embracing the axial assembly in intimate contact with the two stacks of disks;
 - placing a circular member against the one end of the axial assembly;
 - forming a cylindrical casing of an inside diameter substantially equal to the outside diameter of the axial assembly with an integral radially inward flange at one end of the cylindrical casing;
 - telescoping the cylindrical casing over the axial assembly and the circular member with the inward flange of the cylindrical casing abutting the other end of the axial assembly;
 - placing the circular member together with the axial assembly and the inward flange of the cylindrical casing under axial compression; and
 - while the axial compression is maintained, deforming the other end of the cylindrical casing inward into overhanging engagement with the circular member to make the axial compression permanent.

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LARAMIE E. ASKIN, *Primary Examiner.*