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MAGNETOSTRICTIVE RELAY

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Fig. 1.

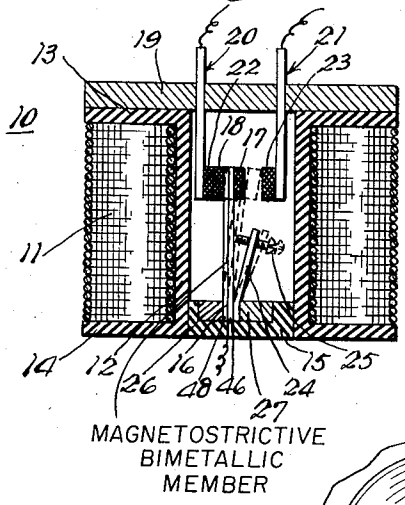


Fig. 2.

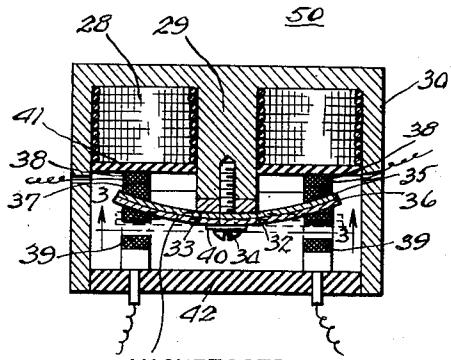


Fig. 3.

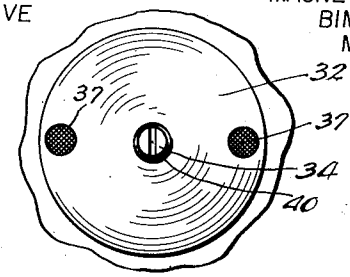


Fig. 4.

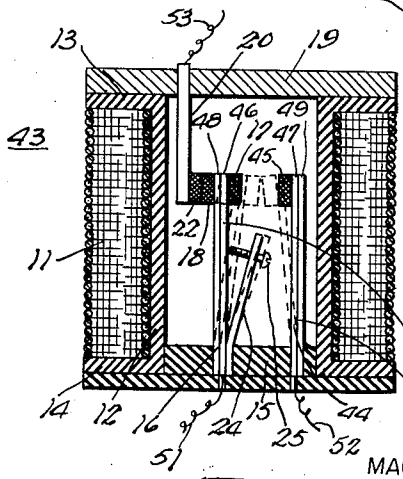
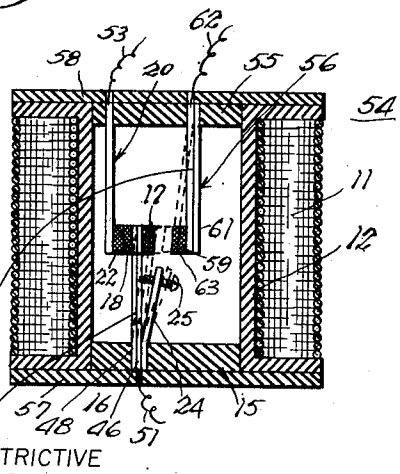


Fig. 5.



MAGNETOSTRICTIVE BIMETALLIC MEMBER

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MAGNETOSTRICTIVE RELAY

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4 Claims. (Cl. 200—87)

This invention relates to circuit control devices, and more particularly to electrical switches which are actuated by the influence of an electromagnetic field.

It is an object of this invention to utilize the magnetostrictive properties of magnetic materials in an improved switch mechanism which will be characterized by rapid, positive operation.

Magnetic circuit control switches heretofore known in the art have generally utilized only the principle of magnetic attraction to cause the motion necessary to complete a circuit. In order to build a switch actuated by magnetic attraction which will operate on small current or power requirements, it is necessary that it have extremely small contacts and a delicate mechanism which is fragile and readily damaged by vibration or rough use. To build a relay or magnetic switch with the durable construction necessary for most mobile uses requires a heavy armature and contact assembly and consequently a large power input to the actuating coil for positive operation. One of the results of this power requirement is usually a slow operating relay actuated by marginal power.

Accordingly, it is an object of this invention to employ the magnetostrictive principle in an electromagnetic switch which will be durable in all types of service but still capable of rapid operation with low power input.

It is a further object of this invention to increase the speed of operation of electromagnetic switches by utilizing a bimetallic sheet material in which the two constituent metals have coefficients of magnetostrictive elongation of opposite sign.

Another object of this invention is to make an improved relay which utilizes both the principles of magnetic attraction and magnetostriction in a manner which will cause more rapid, positive action of the control elements on a smaller power requirement than heretofore.

An additional object of this invention is to create a relay which will be useful over a wider range of frequencies than heretofore known. The customary relay is designed for operation on the normal power frequencies and will be unsatisfactory at higher frequencies as a result of excessive iron losses. A device constructed following the teaching of this invention will reduce this disadvantage without loss of sensitivity or speed of operation. Such a relay is ideally suited for aircraft uses where the power sources usually supply a voltage of higher frequency to conserve weight.

It is an additional object of this invention to provide a magnetostrictive circuit control device which will be compensated for changes in ambient temperature which might otherwise produce erratic control characteristics.

Further and additional objects of the invention will appear from the description, accompanying drawings, and appended claims.

The magnetostrictive phenomenon is a magneto-mechanical effect wherein the physical dimensions of certain materials are changed for a change in the magnetic

flux present in the material. It has been observed that pure nickel contracts in a magnetic field, pure iron first elongates and then contracts and many alloys such as iron-nickel or iron-cobalt alloys elongate in a field.

In carrying out this invention, the principle of magnetostriction is utilized by bonding two metal strips together, one having a positive coefficient of magnetostriction and the second a negative coefficient of magnetostriction, that is, one elongates and the second contracts in a magnetic field, and thus a bimetal is formed which will assume an arcuate shape in a magnetic field.

In carrying out this invention in one form, a relatively long narrow strip of magnetostrictive bimetallic sheet material is provided. More specifically, a bimetallic strip is secured as a cantilever beam within a hollow coil of insulated wire. A resilient magnetic strip is mounted at the opposite end of the coil with its free end within the coil and positioned relative to the free end of the bimetallic strip. Upon energizing the coil, the magnetostrictive character of the bimetal will cause it to assume an arcuate shape and move toward the second strip of magnetic material. This motion will be augmented by the magnetic attraction of the two free ends which will have assumed opposite magnetic polarities. Thus the additive character of the magnetostrictive effect and the magnetic attraction will produce a quick action on less power than was heretofore possible. It has been found that the ratio of thickness of the two sheet materials composing the bimetallic member should be close to unity for maximum displacement of the free end of the bimetallic members. It has also been found that the thickness of the bimetallic member determines its over-all displacement, and a thickness should be chosen of the minimum required for rigidity sufficient to prevent erratic operation.

Another form of this invention utilizes a concave disc of two magnetostrictive materials having magnetostrictive coefficients of opposite sign. This disc is mounted on the core of an electromagnetic device in such a manner that a radial magnetic field is created in the disc when the electromagnet is energized. When flux density due to this field becomes sufficient, a sudden snapping motion is produced in the disc causing it to distort from the concave to a convex position. This sudden snapping motion is used to close a pair of electrical contacts which are supported in a position relative to the disc. As long as the electromagnet is energized, the disc will remain in its distorted position producing a firm, positive contact of low impedance. Immediately upon de-energizing the electromagnet, the disc will snap back to its original undistorted position providing a quick, positive circuit break which will minimize contact arcing and consequent burning, pitting and general contact deterioration.

For a more complete understanding of the invention, reference should now be made to the accompanying drawings wherein:

Figure 1 is a front elevation in section illustrating one embodiment of the invention;

Fig. 2 shows a second embodiment of the invention, also illustrated in section, which utilizes a disc type of magnetostrictive element;

Fig. 3 is a partial section taken along line 3—3 of Fig. 2 and shows the contact orientation on the bimetallic disc;

Fig. 4 shows another embodiment of the invention, also in section, which is characterized by increased sensitivity resulting from the use of two bimetallic strips; and

Fig. 5 is a front elevation in section of an embodiment utilizing the combination of two bimetallic elements and the principles of magnetic attraction.

Referring now to the drawings and more particularly to Fig. 1, **10** indicates a relay constructed in accordance with this invention. A coil **11** is wound on a hollow insulating core **12** having end members **13** and **14**. Fixed at one end of this hollow insulating core is a supporting disc **15** of insulating material adapted to rigidly support bimetallic member **16**. Bimetallic member **16** is composed of two metals having magnetostrictive coefficients of opposite sign such as nickel and iron-cobalt. Metal **46** has a negative magnetostrictive coefficient such as nickel and metal **48**, bonded thereto, has a positive coefficient such as iron-cobalt alloy so that the member will assume an arcuate shape when in a magnetic field. It has been found that by bonding together a strip of nickel and a strip of an iron-cobalt alloy having the same thermal coefficient as nickel, a bimetallic element results which will be responsive to changes in magnetic field but will show little effect due to changes in ambient temperature. A desirable alloy for this purpose is one composed of 60% iron and 40% cobalt. Upon the free end of bimetallic member **16**, two contact members **17** and **18**, preferably of precious metal, are attached.

Coil **11** is closed at its other end by a disc **19**, also of insulating material. Secured in disc **19** are contact member **20** having contact **22** secured thereto and contact member **21** with contact **23** fixed thereto. Contact member **20** provides a normally closed circuit with the bimetallic contact member **16** through contacts **18** and **22** while contact member **21** provides a normally open circuit with respect to contact member **16**. In this embodiment contact member **20** is made of a material which is nonmagnetic such as copper or brass, while contact member **21** is composed of some magnetic material such as soft iron. Secured in supporting disc **15** is a spring member **24** having an adjusting screw **25** threaded into its free end. This spring **24** is adapted to tension bimetallic member **16** to determine the current in coil **11** which will be sufficient to cause the motion necessary to complete a circuit through contacts **17** and **23**. Also inserted in supporting disc **15** are two metallic inserts **26** and **27**. These inserts are chosen according to their thermal coefficients of expansion so that any thermal effects which do exist in the bimetallic member **16** can be compensated for by expansion or contraction of metallic inserts **26** and **27**. This results in a lateral motion of bimetallic member **16** in the base **15**, and compensates for thermal distortion in the bimetal. The manner in which this relay operates will now be briefly described.

The normal position for bimetallic member **16** is in contact with normally closed contact member **20** through contacts **18** and **22**. When current of sufficient magnitude flows in coil **11**, the bimetallic member will assume an arcuate shape as indicated by the dotted lines of Fig. 1 which will cause contacts **22** and **18** to disengage and contact **17** to approach contact **23**. As contact member **21** and the bimetallic member **16** are both composed of magnetic materials under the influence of a magnetic field resulting from the current in coil **11**, member **21** will assume a magnetic polarity at its free end and bimetallic member **16** will assume an opposite magnetic polarity at its free end. These members will therefore be magnetically attracted which will augment the motion of contact **17** toward contact **23** resulting from the magnetostrictive distortion of bimetallic member **16** caused by the magnetic field in the hollow core. As the magnetostrictive effect is almost instantaneous this motion and consequently the relay's operating characteristics will be very rapid and positive. Adjusting screw **25** can be turned to adjust spring **24** and thus determine at what current in coil **11** contact **17** will engage contact **23**.

Another embodiment of the invention based on the same principle uses a disc-shaped moving element. This embodiment of the invention is illustrated in Figs. 2 and 3 and has the characteristic of very rapid, positive operation resulting from a snap action. In the relay **50**, an electromagnetic coil **28** of insulated wire is wound upon an iron core **29** and enclosed in a soft iron case **30**. Core **29** and case **30** provide a low reluctance magnetic path for the flux resulting from current in coil **28**. Mounted on the open end of core **29** is a bimetallic disc **32** displaced from the core **29** by an insulating spacer **33** and secured thereto by attaching means such as screw **34**. Screw **34** is electrically insulated from disc **32** by an insulator **40**. The bimetallic disc **32** is composed of metals having magnetostrictive coefficients of opposite sign as described above. In this embodiment, metal **35** is an iron-cobalt alloy and member **36** is composed of nickel. As shown in Fig. 3, electrical contacts **37**, preferably of precious metal, are secured to the periphery of disc **32**. These contacts **37** are adapted to engage normally closed contacts **38** or normally open contacts **39**. Normally closed contacts **38** are mounted upon insulating spacer **41** and normally open contacts **39** are secured in a base **42** of a nonmagnetic and electrically insulating material which also acts as a closure for the soft iron case **30**, thus sealing the entire structure.

The manner in which this embodiment operates is similar to the embodiment of Fig. 1. When a current flows in coil **28**, a magnetic field is induced in core **29** which traverses bimetallic element **32** and the soft iron case **30**. The flux in disc **32** causes an elongation of the iron-cobalt alloy **35** and a contraction of the nickel element **36**. When the flux in disc **32** reaches some predetermined magnitude, a sudden inversion of the disc is caused so that instead of its normal concave shape it will now assume a convex configuration at the same time completing a circuit through contacts **37—37** and **39—39**.

An embodiment similar to that shown in Fig. 1 is indicated by numeral **43** of Fig. 4. This embodiment is characterized by greater sensitivity resulting from the multiplied motion of two bimetallic strips. Here, coil **11** is wound on a hollow insulating core **12** having end members **13** and **14**. Secured in an insulating supporting disc **15** are two bimetallic members **16** and **44**. Bimetallic member **16** has spring **24** and adjusting screw **25** associated therewith as in the embodiment of Fig. 1. Secured to bimetallic member **16** are contacts **17** and **18**, and secured to bimetallic member **44** is contact **45**. An insulating end closure member **19** is secured to the other end of coil **11** and supports contact member **20** having contact **22** secured thereto. The bimetallic members **16** and **44** are so oriented that under the influence of a magnetic field, their effects will be additive, thus increasing the sensitivity of the relay. In order that this additive character exists, metal elements **46** and **47** are the elements having the negative magnetostrictive coefficient such as nickel, and elements **48** and **49** have the positive coefficient such as the iron-cobalt alloy. Thus, when a magnetic field is present in the hollow core, bimetallic members **16** and **44** will assume arcuate shapes as illustrated by the dotted lines in Fig. 4. This will complete an electrical circuit between conductors **51** and **52** through bimetallic member **16**, contact **17**, contact **45**, and bimetallic member **44**, and open the normally closed electrical circuit between conductors **51** and **53**.

In Fig. 5, the advantages of magnetic attraction described above in conjunction with Fig. 1 are utilized while at the same time gaining the advantages of two bimetallic elements illustrated in the embodiment of Fig. 4. Relay **54** consists of a coil of insulated wire **11** wound upon a hollow insulating core **12** as in the previous embodiments. One end of the hollow core is closed by an insulating supporting disc **15** which has imbedded therein a bimetallic member **16** having contacts **17** and **18** secured thereto and a resilient adjusting means **24** with adjusting screw **25** threaded thereto. The other end of the hollow insulating core **12** is closed by insulating disc **55** which supports an additional bimetallic member **56** having contact **63** fixed to the free end thereof. Disc **55** also supports a nonmagnetic contact member **20** having a contact **22** secured thereto. This whole unit is then

sealed by end closures 57 and 58. Fig. 5 shows this embodiment in the unactuated position, which means that no current is flowing in coil 11. When current flows in coil 11, a magnetic field is induced within the core 12 and the bimetallic elements 16 and 56 are distorted thereby. Bimetallic element 16 consists of metal 48 having a positive magnetostrictive coefficient and metal 46 having a negative magnetostrictive coefficient. Bimetallic member 56 is composed of metallic strip 59 having a negative magnetostrictive coefficient and 61 having a positive magnetostrictive coefficient. Therefore, as the magnetic flux within hollow core 12 increases, the bimetallic members 16 and 56 will assume the positions shown by the dotted lines in Fig. 5. This will open a circuit between conductors 51 and 53 and will complete a circuit between conductors 51 and 62 through bimetallic member 16, contact 17, contact 63, and bimetallic member 56. Again, this motion will be practically instantaneous as the magnetostrictive effect is a substantially instantaneous phenomenon and will therefore characterize this relay by rapid, positive operation. Additionally, as both members 56 and 16 are of magnetic materials, they will more positively engage one another as a result of the magnetic attraction which the free ends thereof possess when a field is present within core 12. It will thus be seen that a relay has been provided which will combine the advantages of several known magnetic phenomenon. The magnetostrictive effect on a bimetallic element and the magnetic attraction of contact members within a magnetic field have been combined to give an improved quick-acting relay.

Other modifications and embodiments of this invention will be immediately apparent to one skilled in the art. Many various contact arrangements become immediately apparent as well as the possibility of improved operation by the addition of various iron flux paths to reduce the over-all reluctance of the magnetic path. The normally closed contacts may also be of a magnetic material to give a quick break. As the bimetallic contact member under the influence of a magnetic field moves away from the normally closed contact member, the magnetic attraction would tend to maintain the closure until the magnetic force is insufficient and at that point the contacts will disengage very rapidly. Also, it is possible to utilize other magnetic materials besides the nickel and iron-cobalt alloy mentioned herein without departing from the invention. It also might be desired to completely evacuate the structure of this invention or to impregnate it with some electrically inert atmosphere.

Thus, this invention provides a relay which will be extremely rapid in operation and have contact closure which is positive and free from "chatter." The relay will be responsive to voltages over a wide range of frequency and will not be detrimentally affected by changes in ambient temperature.

Without further elaboration, the foregoing will so fully explain the gist of our invention that others may, by applying current knowledge, readily adapt the same for use under varying conditions of service, without eliminating certain features, which may properly be said to constitute the essential items of novelty involved, which items are intended to be defined and secured to us by the following claims.

We claim:

1. A control device for controlling electric circuits comprising a contact member composed of two elongated magnetostrictive strips having different coefficients of elongation and bonded together so that said member will assume a deformed position when in a magnetic field, a resilient contact member composed of magnetically attractable material, said contact member and resilient contact member being mounted as cantilever beams having free ends supported in overlapping spaced relation, and means for longitudinally magnetizing said

contact member and resilient contact member to effect actuation thereof due to the combined magnetostrictive deformation of said contact member and the attractive force between said contact member and said resilient contact member.

2. A control device for controlling electric circuits comprising a contact member composed of two elongated magnetostrictive strips having different coefficients of elongation and bonded together so that said member will assume a deformed position when in a magnetic field, a resilient contact member composed of magnetically attractable material, said contact member and resilient contact member being mounted as cantilever beams having free ends supported in overlapping spaced relation, and an elongate hollow coil of insulated conducting material surrounding said contact member and resilient contact member creating a magnetic flux in said contact member and resilient member to effect actuation thereof due to the combined magnetostrictive deformation of said contact member and the attractive force between said contact member and resilient contact member.

3. A control device for controlling electric circuits comprising a contact member composed of two elongated magnetostrictive strips having different coefficients of elongation and bonded together so that said member will assume a deformed position when in a magnetic field, a resilient contact member composed of magnetically attractable material, said contact member and resilient contact member being mounted as cantilever beams having free ends supported in overlapping spaced relation, means for longitudinally magnetizing said contact member and resilient contact member to effect actuation thereof due to the combined magnetostrictive deformation of said contact member and the attractive force between said resilient contact member and said contact member, and tensioning means for said contact members whereby the magnetic field required for actuation of the control device may be predetermined.

4. A control device for controlling electric circuits comprising a contact member composed of two elongated magnetostrictive strips having different coefficients of elongation and bonded together so that said member will assume a deformed position when in a magnetic field, a resilient contact member composed of magnetically attractable material, said contact member and resilient contact member being mounted as cantilever beams having free ends supported in overlapping spaced relation, an elongate hollow coil of insulated conducting material surrounding said resilient contact member and said contact member creating a magnetic flux in said contact member and resilient member to effect actuation thereof due to the combined magnetostrictive deformation of said contact member and the attractive force between said contact member and said resilient contact member, and tensioning means for said contact members whereby the magnetic flux required for actuation of the control device may be predetermined.

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