Dec. 2, 1952 J. HAGEN 2,620,466

ELECTROMAGNETIC CONTROL DEVICE

Filed May 31, 1950

FIG. 1

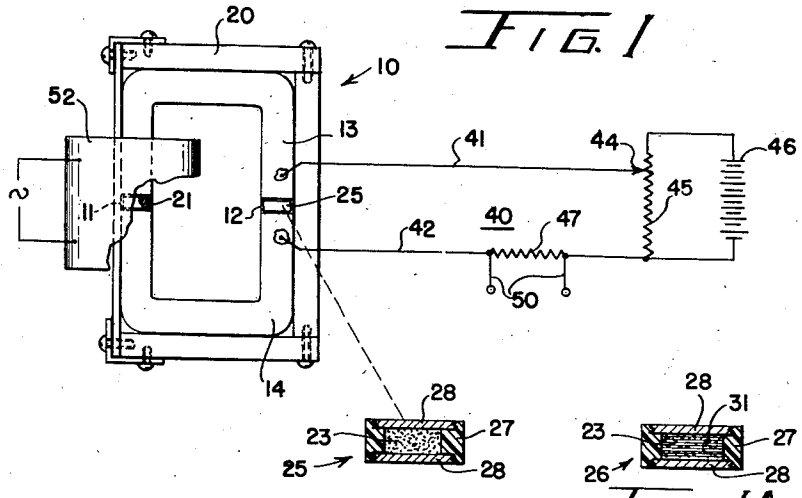


FIG. 1A

FIG. 2

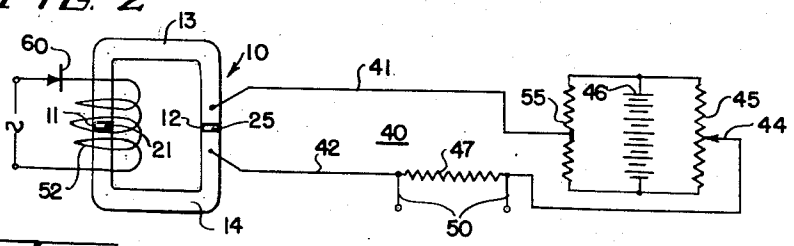


FIG. 3

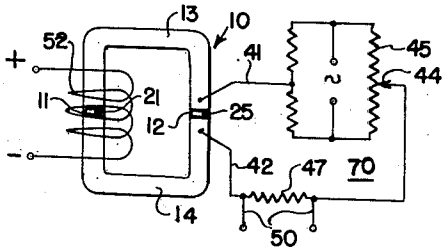
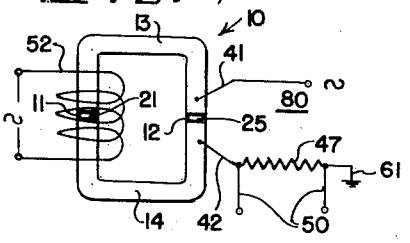


FIG. 4



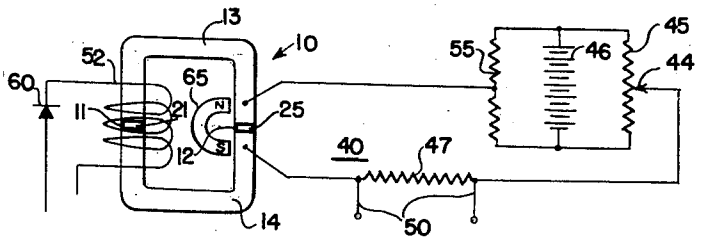


FIG. 5

Inventor
JERRY HAGEN

By

George H. Fisher

Attorney

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ELECTROMAGNETIC CONTROL DEVICE

Jerry Hagen, Minneapolis, Minn., assignor to Minneapolis-Honeywell Regulator Company, Minneapolis, Minn., a corporation of Delaware

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7 Claims. (Cl. 323—94)

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My invention relates to electromagnetic type of control devices and particularly to devices of this general type having electrical signal outputs and employing magnetic fluids as a portion of a magnetic circuit.

The use of magnetic fluids in control devices is a relatively recent advancement in science which has heretofore been applied primarily to the field of clutches and similar devices wherein the magnetic properties of the magnetic fluid alone have been utilized. In the present invention not only the magnetic properties of the fluid are utilized but also its property of electrical conductivity. This new magnetic device comprises a magnetic core structure having a plurality of air gaps therein within one of which is located a quantity of magnetic fluid. The fluid therein is connected in a series relationship with a load circuit supplied by a signal for energizing the same. A control or energizing winding on the core structure selectively and variably magnetizes the core structure and the fluid in the gap making it conductive to amplify, modulate, or otherwise modify the signal supplied to the load circuit.

It is therefore an object of this invention to provide a new and novel electromagnetic control device utilizing the variable resistance properties of a magnetic fluid for varying an electrical signal output of the device.

It is also an object of this invention to provide a device of the magnetic fluid type which is capable of modulating, amplifying or otherwise modifying electrical signals.

Another object of this invention is to provide in a device of this type a means for retaining the magnetic fluid in an air gap of a magnetic core structure.

A further object of this invention is to provide a device of this type with an improved means for holding the magnetic fluid distributed in the air gap of the magnetic core structure of the device.

Still another object of this invention is to provide in a device of this type means for substantially eliminating residual magnetism in the core structure and its effect upon the magnetic fluid in the air gap.

It is further an object of this invention to provide in a device of this type a means for inserting a bias or saturating flux in the core structure of the device to increase its sensitivity.

These and other objects of this invention will become apparent from a reading of the attached description together with the drawings wherein:

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Figure 1 is a schematic disclosure of the magnetic control device of the subject invention shown as a modulator for a D. C. signal in a load circuit connected to the device,

Figure 1A shows in section another arrangement of a container to be positioned in the air gap of the core structure of the device shown in Figure 1 the container positioning a magnetic fluid in the respective air gap of the core structure of the device,

Figures 2, 3 and 4 are schematic disclosures of the same magnetic control device utilizing different arrangements of controlling and load signals connected to the device, and

Figure 5 is another modification of the magnetic control device which discloses the use of a biasing magnet in the magnetic circuit of the device.

My invention, which is shown schematically in the drawings, comprises a magnetic core structure 10 having a plurality of air gaps 11, 12 therein. For simplicity, the core structure is shown as a pair of U-shaped core members 13 and 14 of magnetic material positioned with their bifurcated extremities in near abutting relationship to define the gaps 11, 12 therebetween. A frame 20 of nonmagnetic and nonelectrically conductive material holds the core members 13, 14 in assembled and spaced relationship. It is to be understood that this structure is intended to be illustrative only and that the shape and arrangement of the core members 13, 14 and the frame 20 together with the location of the gaps 11 and 12 may be varied within the scope of the teaching and operation of this device as will become apparent as this disclosure proceeds.

The core members 13, 14 at air gap 11 may be separated by a block of electrical insulating material, the block being indicated at 21, which block will aid in the spacing of the core members and will also prohibit an electric circuit between the members at this point. However, the air gap 11 alone may be employed as an electrical insulator when the core members 13, 14 are spaced apart by means of the frame 20.

Within gap 12 formed by core members 13, 14 of core structure 10 is positioned a quantity of a magnetic fluid indicated at 23, the magnetic fluid being composed of a plurality of magnetic particles suspended in a liquid having an oil base. The fluid 23 may be positioned or held in gap 12 by any suitable means but the magnetic or iron particles within the gap 12 must be the only electrical conductor across the gap between the core members 13, 14. I have found that con-

tainers such as is shown at 25 and 26 in Figure 1 and 1A respectively are highly advantageous for housing the magnetic fluid and spacing the core members 13, 14.

Container 25 which is shown in Figure 1 is formed of a plastic or insulating tube 27 into the ends of which copper or iron or other electrical or magnetic material end plates 28 are threaded. Tube 27 has a shoulder or ridge portion 30 on its inner surface which spaces the end plate 28 with respect to the tube 27. The magnetic fluid 23 is added to the container 25 before assembly of the plates 28 on the tube 27 is completed. The container is so positioned between the extremities of core members 13, 14 forming the gap 12 that the end plates abut the core members and are in magnetic and electrical contact therewith. When iron is used as the material in the end plates 28, these end plates act as a mere continuation of the core members which abut the container 25. Copper or other electrical or nonmagnetic materials are used in the end plates 28 to cut down the effect of residual magnetism in the core structure 10 in a well known manner.

Container 26 which is shown in Figure 1A is similar to the container 25 disclosed in Figure 1 and either may be substituted in the core structure 10 shown in Figure 1 or in any of the core structures in the figures later to be described. The container 26 differs from container 25 in that a plurality of layers of cloth 31 or other woven or fibrous nonmagnetic and nonelectrically conductive material is placed in the spacing or opening within the container and in contact with the magnetic fluid 23. This cloth or fabric acts as a wick and tends to distribute the magnetic fluid uniformly within the opening of the container 26 and between the end plates 28 thereof. Such an arrangement tends to guard against settling of the magnetic particles within the fluid which under ideal circumstances remains in suspension in the oil base at all times.

As noted above, the magnetic fluid 23 in gap 12 is also utilized as an electrical conductor connecting the core members 13, 14 forming the gap in an electrical circuit 40 to be described below. Connected to the core members 13, 14 adjacent the air gap 12 are a pair of conductors 41 and 42 which lead to the electrical circuit 40 and which is adapted to be connected to an external load, this circuit also being adapted to be energized by a signal source of variable magnitude and phase as will become evident as this disclosure proceeds. In Figure 1, the load or electrical circuit 40 includes the magnetic fluid 23 in gap 12, conductor 41, a wiper 44 of a potential divider apparatus the winding 45 of which is connected in a series relationship with a D. C. battery source 46. This electrical load circuit is completed from winding 45 through a load resistor 47 and conductor 42 to the fluid 23 in gap 12. A pair of output terminals 50 are connected across the load resistor 47 to supply the external load (not shown) with the voltage drop across the resistor 47. Depending upon the type of load employed, the load resistor 47 may or may not be included in the load circuit 40. Variations in the signal impressed on load circuit 40 may be had by varying the position of wiper 44 on winding 45.

It is also to be understood that where the core structure 10 is supplied with only one air gap then the conductors to the electrical circuit are to be placed directly in contact with the magnetic fluid, such as being located within the container holding the same and electrically insulated from the core structure. In this manner the electric circuit can be only completed through the magnetic fluid.

The core structure 10 also includes a controlling winding 52 which winding is positioned on the core structure to be common to both of the magnetic members 13, 14 such that when the winding is energized the portions of the members 13, 14 adjacent gap 12 will be energized with opposite magnetic polarities. In Figure 1, an A. C. energizing source is adapted to be connected to the winding 52 which acts as a controlling or magnetizing winding for the core structure 10. The alternating flux set up in core structure 10 due to the energization of coil 52 from the A. C. source magnetizes the core members 13, 14 and hence the magnetic fluid 23 in gap 12 with alternating magnetic polarities thereby causing the magnetic particles in the fluid to align and disalign with each reversed or alternation of current flow providing simultaneously an electrical conductor across the gap 12. As the particles in the fluid align under the influence of the magnetic field the resistance of the conductor formed thereby decreases permitting increased current flow in the load circuit 40 connected in series therewith. In this manner a chopped or pulsed or modulated direct current signal will flow into the load circuit 40 and the voltage drop across the resistor 47 takes on a modulated wave form which will be impressed across the output terminals 50.

In Figure 2 is shown another embodiment of the invention utilizing the same core structure 10 as that employed in connection with Figure 1 and discussed above. For simplicity the details of the core structure 10 and the frame 20 which positions the same are omitted in the discussion and in the drawings but it is to be understood that they are to be included with this embodiment. In Figure 2 there is shown the core members 13, 14 with the air gaps 11 and 12 formed therebetween, the controlling winding 52 mounted on the core structure 10 and the container 25 positioned in air gap 12 to house the magnetic fluid 23. This embodiment utilizes a somewhat different type of D. C. signal supply which is adapted to be connected to the load circuit 40 and in series with the fluid 23 in gap 12. This D. C. signal source comprises a bridge type of supply which includes a tapped resistor 55 connected to the conductor 41 and in parallel with the potentiometer winding 45 whose wiper 44 is connected to the load resistor 47. The D. C. battery source 46 is connected across the input diagonal to the bridge, and the conductors 41, 42 through load resistor 47 to the output diagonals of the bridge. With this arrangement, the load signal across the gap is reversible in polarity and variable in magnitude depending upon the position of wiper 44 with respect to the tap of resistor 55. Energizing winding 52 is similarly adapted to be connected to an A. C. source but a half wave rectifier 60 is included in this energization circuit to modify the controlling current in a manner to be later described. The pulsed A. C. supplied to the energizing winding due to the half wave rectifier 60 causes a pulsed unidirectional flux flow in the magnetic core structure 10 and variable unidirectional magnetic polarities across the gap 12. This pulsed magnetization similarly magnetizes the particles in the magnetic fluid 23 to make and break the load circuit at the air gap 12. The output across the

load resistor 47 or at the terminals 50 will thereby be a modulated D. C. of the same frequency as the frequency of the A. C. input to coil 52.

The disclosure of Figure 3 also employs the same magnetic core structure as that shown in the device of Figure 1, hence the details of that portion of the circuit will be omitted here. The load circuit 70 connected in series with gap 12 and across the load terminals 50 is substantially the same as the load circuit 40 employed in connection with Figure 2 except that the signal source is energized by an alternating current source of power. Similarly the energizing or controlling winding 52 on the core structure 10 is adapted to be energized by a selectively variable D. C. source of power. The output of this circuit is an amplification of the A. C. supply or signal impressed on the load circuit 40 depending upon the variation in magnitude of the energizing current supplied to winding 52.

In Figure 4 there is shown another embodiment of this device in which the core structure is similar to the embodiments described above. For this reason the details of the core structure are omitted here. This particular embodiment acts as a mixer or modifier of alternating load signals. The load resistor 47 and magnetic fluid 23 are connected in series with an alternating current source of power omitting any bridge arrangement. This arrangement provides an output circuit which includes the conductor 41 connected to the alternating source, core member 13, the magnetic fluid 23 in gap 12, core member 14, conductor 42, and load resistor 47 to a ground connection 61 for the return side of the A. C. source. The output terminals or load terminals 50 are as before connected across the load resistor 47 but the load resistor 47 may be omitted if desired. The alternating signal impressed on this load circuit 80 and across the resistor 47 will be modified by the frequency of the A. C. supply energizing coil 52 mounted on core structure 10. As is apparent from the drawing, the alternating magnetization of core structure 10 due to the magnetization of the magnetic particles of fluid 23 makes or breaks the electrical conductor formed at the air gap 12 permitting current to flow in the load circuit 80 only during periods when the load circuit is completed.

The disclosure of Figure 5 is another embodiment substantially the same as that disclosed in Figure 2 employing a bridge type D. C. signal load circuit 40 and a rectified controlling input to the winding 52 mounted on core structure 10. This disclosure varies from the disclosure of Figure 2 in that it includes a U-shaped permanent magnet 65 the extremities of which are positioned adjacent the core members 13, 14 bridging the gap 12 in which the magnetic fluid 23 is located. A magnetic flux created by the permanent magnet 65 overcomes the initial permeability of the magnetic circuit formed by core structure 10 and magnetic fluid 23 tending to saturate this portion of the magnetic circuit and increase the sensitivity of the device. The pulsating current flow in coil 52 is in such a direction as to be additive with the permanent magnet flux in aligning the particles of the magnetic fluid. The permanent magnet also serves an additional purpose in that its strength is chosen to keep the magnetic particles partially aligned in the air gap 12 thereby aiding in keeping the particles distributed in the air gap and in suspension in the fluid.

Magnet 65 further operates in the same manner as rectifier 60 in that its unidirectional flux aids and opposes the alternating flux from an unrectified A. C. input to coil 52 such that the load current will have the same frequency as the controlling input signal. Therefore magnet 65 may sometimes be used to replace rectifier 60.

Numerous objects and advantages of my invention have been set forth above in the foregoing description together with details of structure and function of the invention and the novel features thereof are pointed out in the appended claims. These disclosures, however, are intended to be illustrative only and I may make changes in details (especially in matters of shape, size and arrangement of parts) within the principle of the invention to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed.

I claim as my invention:

1. In a device of the class described, a magnetic core structure having a pair of fixed air gaps therein, a container of electrically insulating material having electrically conductive end plates positioned in one of said air gaps with said end plates abutting said core structure a plurality of magnetic particles suspended in a fluid and positioned in said container, means included in said container adapted to hold said magnetic particles in a dispersed relationship, electrical circuit means adapted to be energized from an adjustable source of power and including an output circuit, said electrical circuit means being connected in series with said one of said air gaps, and means for magnetizing said magnetic core structure such that portions of said structure on either side of said one of said air gaps are polarized with magnetic polarities of varying magnitudes.

2. In a device of the class described, a magnetic core structure having a pair of fixed air gaps therein, a container of electrically insulating material having electrically conductive end plates positioned in one of said air gaps with said end plates abutting said core structure, a plurality of layers of nonmagnetic and nonelectrically conductive fibrous material positioned in said container, a plurality of magnetic particles suspended in a fluid and positioned in said container being held in a dispersed relationship by said fibrous means, electrical circuit means adapted to be energized from an adjustable source of power and including an output circuit, said electrical circuit means being connected in series with said one of said air gaps and means for magnetizing said magnetic core structure such that portions of said structure on either side of said one of said air gaps are polarized with magnetic polarities of varying magnitudes.

3. In a device of the class described, a magnetic core structure having a plurality of fixed air gaps therein, a plurality of magnetic particles suspended in a fluid and positioned in one of said air gaps, electrical circuit means connected in a series relationship with said one of said air gaps and having output terminals adapted to be connected to an external load, means mounted on said core structure for magnetizing said core structure such that portions of said structure on either side of said one of said air gaps are polarized with magnetic polarities of varying magnitudes, and a magnetic biasing means of predetermined polarity and magnitude positioned adjacent said portions of said core structure forming said one of said air gaps.

4. In a device of the class described, a mag-

netic core structure having a plurality of fixed air gaps therein, a plurality of magnetic particles suspended in a fluid and positioned in one of said air gaps, electrical circuit means connected in series relationship with said one of said air gaps and having output terminals adapted to be connected to an external load, means mounted on said core structure for magnetizing said core structure such that portions of said structure on either side of said one of said air gaps are polarized with magnetic polarities of varying magnitudes, and a U-shaped permanent magnet of fixed polarity and magnitude positioned adjacent said portions of said core structure forming said one of said air gaps.

5. In a device of the class described, a magnetic core structure having a plurality of fixed air gaps therein, a plurality of magnetic particles suspended in a fluid and positioned in one of said air gaps, electrical circuit means connected in a series relationship with said one of said air gaps and having output terminals adapted to be connected to an external load, means mounted on said core structure for magnetizing said core structure such that portions of said structure on either side of said one of said air gaps are polarized with magnetic polarities of varying magnitudes, and a permanent magnet with opposite polarity extremities abutting said portion of said core structure adjacent said one of said air gaps.

6. In a device of the class described, a magnetic core structure having at least one air gap therein, a plurality of magnetic particles suspended in a fluid positioned in said air gap, electrical circuit means including an output resistor adapted to be energized from an adjustable

source of power, said circuit being connected to said magnetic particles in said air gap, means mounted on said core structure adapted to energize said core structure and thereby magnetize said particles in said air gap, and a magnetic biasing means of predetermined polarity and magnitude positioned adjacent to portions of said core structure forming said air gap.

7. In a device of the class described, a magnetic core structure having a pair of air gaps therein, a container of electrically insulating material having electrically conductive end plates positioned in one of said air gaps with said end plates abutting said core structure, a plurality of magnetic particles suspended in a fluid and positioned in said container, electric circuit means adapted to be energized from an adjustable source of power and including an output circuit, said electrical circuit means being connected in series with said one of said air gaps, winding means mounted on said core structure adapted to be energized by a rectified alternating current signal, and a U-shaped permanent magnet of fixed plurality and magnitude positioned adjacent said portions of said core structure forming said one of said air gaps.

JERRY HAGEN.

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