

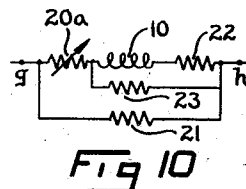
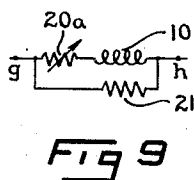
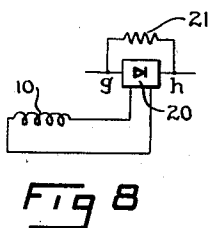
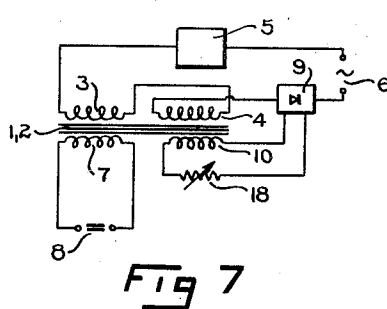
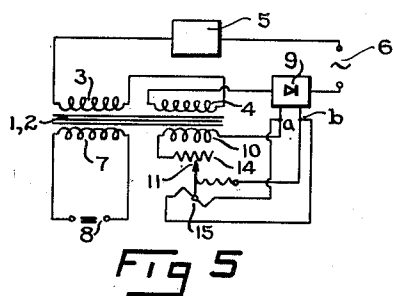
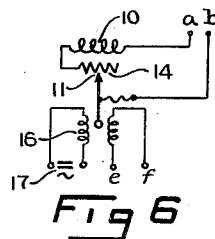
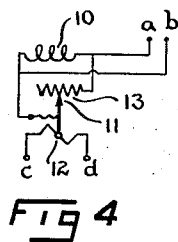
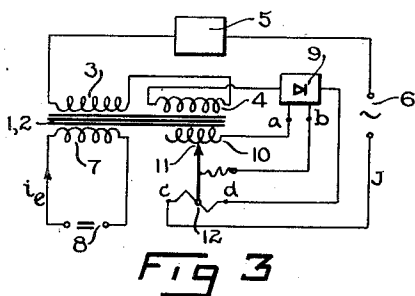
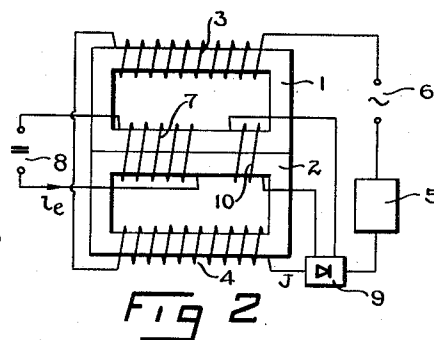
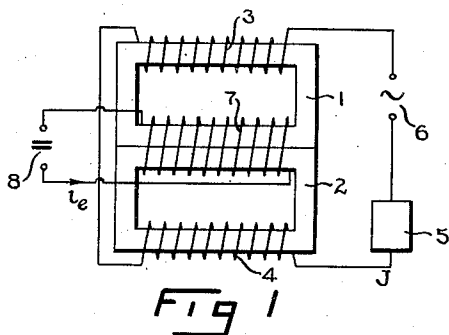
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POWER AMPLIFIER

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2,287,754

POWER AMPLIFIER

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8 Claims. (Cl. 171-242)

This invention relates to an arrangement for adjusting an organ, particularly a control surface or the like in airplanes or seagoing vessels.

In the copending application Serial No. 290,968, filed August 19, 1939, is described an arrangement for automatically adjusting an organ, particularly a control surface in airplanes or seagoing vessels in accordance with instruments capable of being loaded only to a slight extent, particularly with directional indicators, such as compasses, gyro-indicators etc.

According to the above copending application the electrical magnitude transmitted by said instruments is transmitted to a magnetic amplifier arrangement connected to a feed back circuit and is amplified by the amplifier arrangement in such a manner that the output energy which the amplifier supplies to the current consuming device, for instance, to an electrical directional drive, has such a value as to bring about an adjustment of the organ.

The present invention relates to an improvement in the novel magnetic amplifier provided in the arrangement according to the above copending application. The invention is based on the fact that means are provided in the feed back circuit of the magnetic amplifier so as to influence the amplification factor and that these means are capable of being controlled in accordance with the electrical magnitudes of the output energy.

Further details of the invention will be apparent from the following description taken in connection with the accompanying drawing, in which

Figs. 1 and 2 show diagrammatically the magnetic amplifier described in the above copending application.

Fig. 3 shows an embodiment for carrying out the inventive idea with the aid of the feed back controllable by influencing the effective number of turns of the feed back winding.

Fig. 4 shows a further embodiment with a parallel resistance for the feed back winding, controllable by means of the output alternating current.

Fig. 5 shows another embodiment with a resistance lying in series with the feed back and controllable in accordance with the rectified current serving for the feed back.

Fig. 6 shows an embodiment with a resistance regulable by means of a double instrument.

Fig. 7 shows an embodiment with a non-linear resistance serving to control the feed back.

Fig. 8 shows an embodiment with a resistance combination serving to control the feed back.

Fig. 9 shows a modification of the arrangement with a resistance combination shown in Fig. 8.

Fig. 10 shows a connection in diagrammatic form of an arrangement with resistance combinations serving to control the feed back.

Before proceeding with the description of the invention the operation of the novel magnetic amplifier disclosed in the above copending application is hereinafter briefly repeated with reference to Figs. 1 and 2.

In Fig. 1, 1 and 2 denote cores consisting of a material of high magnetic permeability, for instance, of an iron-nickel alloy. The two cores are provided each with a winding 3 and 4 respectively. The two windings 3 and 4 are arranged in series and in series with the current consuming device 5 energized by the alternating current source 6. In the windings and therefore in the current consuming device 5 flows an alternating current J whose magnitude depends upon the alternating-current resistance of the windings. The magnitude of this resistance depends upon the permeability of the two cores in accordance with the working point on the magnetization curve. On the two cores is arranged a common winding 7 which is traversed by the direct current i_d supplied by an impulse transmitter (not shown). The two windings 3 and 4 are so wound that the voltages induced in the winding 7 by the current flowing in the windings 3 and 4 annul each other. The direct current flowing in the winding 7 produces in both cores magnetic fluxes which displace the working point on the magnetization curve. By displacing the working point the permeability changes according to the magnetization curve and therefore changes the alternating-current resistance of the windings 3 and 4. The alternating-current resistance of these windings depends therefore upon the direct current i_d flowing in the winding 7 and varies with the direct current.

If the output current is plotted against the input current in a diagram for an arrangement according to Fig. 1 without consuming device, the inclination of the tangent on this curve in the working point is to be considered as the steepness of the magnetic amplifier. The amplification factor of the arrangement depends upon this steepness.

In the arrangement according to the above copending application an increase of the amplification factor is attained by the fact that the alternating current flowing in the windings 3

and 4 is rectified and is rendered effective in the sense of a self-amplification by the feed back by supplying the alternating current to an additional winding which is allotted to the two cores in the same manner as the winding 7 of Fig. 1. The effect of this feed back will now be briefly explained with reference to Fig. 2 in connection with the disclosure of the above copending application. In Fig. 2 the same parts are denoted by the same reference numerals as in Fig. 1. 1 and 2 denote the cores consisting of a material of high magnetic permeability, 3 and 4 the windings arranged on these cores and traversed by the alternating current, 5 the current consuming device and 6 the power source. 7 designates the winding traversed by the direct current supplied by the directional indicator 8. The alternating current flowing in the windings 3 and 4 traverses a rectifier arrangement 9. The current rectified with the aid of this rectifier arrangement is supplied to the additional winding 10 which is allotted to the cores 1 and 2 in the same manner as the winding 7. Consequently, a periodically variable current whose effect may be attributed to the effect of a direct current flows in the winding 10. The current in this winding displaces the working point on the magnetization curve and therefore varies the permeability of the cores 1 and 2 as well as the alternating-current resistance of the windings 3 and 4 in the same manner as above described for the effect of the current i_e flowing in the winding 7. Depending upon the direction of flow of the current in the rectifier arrangement 9 and upon the direction of the current flowing in the winding 7 the current in the winding 10 produces in the cores 1 and 2 magnetic fluxes which have both either the same or opposite direction as the fluxes which are produced by the current i_e in the winding 7, i. e., the fluxes may be either added or subtracted. It is first assumed that $i_e=0$. The current J flowing in the windings 3 and 4 and in the current consuming device 5 is denoted in this case by J_0 and the current j flowing in the winding 10 is denoted by j_0 correspondingly to the zero current J_0 . The working point on the magnetization curve of the cores 1 and 2 is determined by the currents J_0 and j_0 . If a current i_e flows in the winding 7 in the direction that the magnetic fluxes in the cores produced thereby have the same direction as the fluxes which are produced by j , the working point on the magnetization curve is shifted by the effect of the current i_e so as to reduce the permeability of the cores and therefore the alternating-current resistance of the two windings 3 and 4. With decreasing alternating-current resistance J increases, which in turn brings about an increase of j . To the increase of j corresponds an increase of the flux in the cores produced by this current, which increase causes a further decrease of the permeability, therefore a further decrease of the alternating-current resistances of the windings 3 and 4 as well as a further increase of the current J . Consequently, the current j causes an increase in the effect of the input current i_e in the form of a self-amplification and therefore an increase in the amplification factor.

In this arrangement the feed back is constant. The magnitude of the feed back and therefore the amplification factor cannot assume any high value for the following reason. The resistance of the two windings 3 and 4 retains always a definite value also in case the winding 7 is de-

energized, i. e. an alternating current flows in this arrangement also in this zero position. This zero current J_0 produces a magnetic bias and thereby decreases the initial permeability as well as the initial resistance of the windings 3 and 4. This means an undesirable increase in the zero current with increasing number of turns of the winding 10 with respect to an arrangement without feed back and at the same time a restriction of the controllable resistance range of the windings 3 and 4, since the smallest resistance value which these windings may assume is the value for which the two cores 1 and 2 are completely saturated. Upon these two moments depends the selection of the magnitude of the constant feed back.

According to the present invention the steepness of the characteristic and therefore the amplification factor of the arrangement are capable of being influenced by the fact that means are provided in the feed back circuit for automatically controlling the feed back and that these means are controllable in accordance with the electrical magnitudes of the output energy.

A practical embodiment of the invention is shown in Fig. 3. In this figure 1 and 2 denote the two cores, 3 and 4 the windings traversed by the alternating current J , 5 the current consuming device, 6 the alternating-current source, 7 the winding traversed by the input current i_e and 8 the impulse transmitter supplying the input current. The feed back winding 10 is directly connected on the one hand to the rectifier arrangement 9 and on the other hand through a slide contact 11. The slide contact 11 is operated by a device 12 which operates according to this embodiment in the form of a measuring mechanism and is traversed by the output alternating current J . The slide contact causes, depending upon its position, more or less turns of the feed back winding 10 to be traversed by the rectified alternating current so as to increase more or less the feed back. In this case the arrangement may be so designed that for the zero value J_0 of the output current no or only a few turns are inserted in the circuit, that with increasing current J the number of the turns inserted increases and that for the maximum value of this current the desired greatest number of feed back windings lie in the feed back circuit.

The effect of the feed back may be reduced to a minimum for the zero value J_0 of the output current J which means that the alternating current J_0 flowing in the arrangement may be reduced to a value as is desired for an arrangement without feed back. In this manner at the same time the complete controllable resistance range or the windings 3 and 4 is maintained as in the case of an arrangement without feed back.

In the embodiment shown in Fig. 4 the arrangement of the parts 1 to 9 is the same as in Fig. 3 and therefore it is not shown in this figure. In Fig. 4 the feed back winding 10 is connected to the points a and b of Fig. 3 and the number of turns of the winding 10 is so chosen that for the maximum value of the output current J the desired maximum feed back is attained. Parallel to this feed back winding is connected a resistance 13 whose effective magnitude is controllable with the aid of the slide contact 11 operated by the device 12. The device 12 is inserted with the terminals c , d in the circuit of the output alternating current J as in the embodiment shown in Fig. 3. In this case the arrangement is, for instance, so designed that for the maximum

value J the slide contact 11 lies on the free end of the resistance 13 which is so chosen that it is practically ineffective in this case as a shunt for the winding 10, whereas for the zero value J_0 of the output alternating current J the slide contact 11 lies on the opposite end of the resistance 13 and the winding 10 is thus practically short circuited and therefore the feed back is ineffective.

Instead of the output alternating current J also a current derived from the current J may be used to operate the measuring mechanism which actuates the slide contact. In the embodiment shown in Fig. 5 in which the same parts are denoted by the same numerals as in the preceding figures a direct-current measuring mechanism 15 is provided which is connected to the points a, b of Fig. 4 and lies in parallel relation to the series connection consisting of the feed back winding 10 and a variable resistance 14. The resistance 14 lies as mentioned above in series with the feed back winding 10 and is chosen in this case in such a manner that it attains its maximum value for the zero value J_0 of the output alternating current and the desired minimum value for the greatest value of the current J . The measuring mechanism 15 may, of course, also be series-connected with the winding 10 and the resistance 14, i. e., it may directly be operated by the current serving for the feed back.

The control of the feed back may be effected as already mentioned above directly in accordance with the output alternating current or indirectly in accordance with the latter by means of a current derived from the output alternating current. According to the invention also an additional impulse transmitter may be provided, by means of which the feed back is controllable by the current supplied by this additional impulse transmitter alone or together with the output alternating current. Such an embodiment is shown in Fig. 6, in which 16 denotes a double device which is operated on the one hand by the output alternating current and on the other hand by an additional current i_2 of an additional impulse transmitter provided as indicated at 17.

In the embodiment according to Fig. 5 the regulable resistance 14 presents a variable resistance whose magnitude depends upon the output alternating current J . This dependence is brought about in this embodiment by the electrical mechanical method. In Fig. 7 is shown an embodiment in which this dependence of the series resistance for the feed back winding upon the output alternating current of the arrangement is brought about by the electrical method only. In series with the winding 10 is connected the non-linear voltage-responsive resistance 18, for instance, a semi-conductor, a semi-conductor combination with blocking layers or the like which is so chosen that according to its resistance-current characteristic the feed back is controlled in the like manner as described above in accordance with the feed back current and therefore with the output current. The non-linear resistance may also be connected in parallel to the feed back winding 10 in the manner as shown in Fig. 2, in which case depending upon the desired purpose the resistance characteristic is correspondingly chosen. If the regulation of the feed back should be effected in a manner corresponding to the operation of the arrangement according to Fig. 4, a current conductor, for instance, an incandescent lamp, may be employed as a current-responsive resistance, whose

resistance is small for small currents and with increasing current intensity increases in such a manner that for small voltages applied to the terminals a and b this non-linear resistance forms a small shunt to the feed back winding so that only a very small fraction of the current supplied by the rectifier arrangement is employed for the feed back, whereas upon the occurrence of high voltages at the terminals a and b the non-linear resistance assumes a great value so that the main portion of the direct current supplied by the arrangement 9 flows through the winding 10.

A particularly advantageous embodiment of the invention is shown in Fig. 8, in which the rectifier arrangement 20 included in the feed back circuit is formed in a known manner by non-linear resistances. A resistance 21 which may be a non-linear or linear resistance is connected to the alternating-current input terminals $g-h$ of this rectifier arrangement. To explain the operation reference may be had to Fig. 9 which shows a modification of the arrangement as shown in Fig. 8. In Fig. 9, 10 denotes the feed back winding, 20a a non-linear resistance as a substitute for the rectifier arrangement. Parallel to the series-connected winding 10, resistance 20a is arranged the resistance 21 which may be a non-linear or linear resistance. If a relatively low voltage is applied to the terminals $g-h$ and if a selenium rectifier is employed, for instance for the rectification, the momentary value of the resistance 20a is great, whereas if a relatively high voltage is applied to the terminals $g-h$ the momentary value of this resistance is small. If, for instance, a linear resistance is employed as a parallel resistance 21, it may, for instance, be so dimensioned, that it is small as compared to the resistance of the series-connection consisting of the winding 10 and the resistance 20a for low voltages applied to the terminals $g-h$ (i. e. for small output alternating current J , for which the resistance 20a assumes a great value). In this case only a small fraction of the rectified alternating current flows in the feed back winding 10. If, however, the output alternating current is large a high voltage occurs at the terminals $g-h$, the momentary value of the resistance 20a is small and therefore the resistance of the series connection winding 10—resistance 20 is small with respect to the resistance 21.

By means of the resistance 21 it is at the same time possible to equalize in a simple manner the non-uniformities which occur in the case of mass production, for instance, owing to the non-uniformities of the material, for instance, of the core material which presents in the case of highly permeable materials great fluctuations as to the permeability.

By the choice of this resistance, particularly if this resistance is a non-linear resistance, and of the non-linear resistance 20a it is further possible to influence the characteristic of the amplifier—relation between output current and input current—and to adapt it to a great extent to the corresponding purpose. In this case it is, of course, possible to use the invention in a manner other than the above-described, for instance, in such a manner, that in contradistinction to the embodiments previously described the feed back is kept large for small output alternating currents and small for large output alternating currents.

The resistance 21 may, of course, also be regu-

lated by hand or by a particular impulse transmitter, for instance, in a manner described in the preceding embodiments by auxiliary measuring mechanisms.

A further advantageous modification of the arrangement shown in Fig. 8 is illustrated in Fig. 10, in which is shown an arrangement, in which a combination of resistances or a plurality of such resistance combinations as shown in Fig. 9 are provided for the control of the feed back. In Fig. 10, 10 denotes the feed back winding and 22 a resistance series-connected thereto. A resistance 23 is parallel connected to the series connection of the parts 10 and 22. This arrangement represents a resistance combination which is series-connected with the resistance 20a shown as spare resistance for the rectifier arrangement 20 and a parallel resistance 21 is allotted to the series connection which consists of the resistance 20a and of the resistance combination formed of the parts 10, 22 and 23. The resistances 21, 22, 23 may be non-linear or linear resistances by means of which it is possible to adapt the characteristic of the amplifier to any desired purpose.

What is claimed is:

1. A magnetic amplifier comprising a magnetizable core carrying a pair of windings connected in series opposed relation, a source of alternating current connected to energize said pair of windings, means for rectifying the output current of said windings, a direct current input circuit including a third winding on said core whereby during current flow in said third winding the permeability of said core is decreased thus causing an increase in the output current of said pair of windings, a feed back circuit comprising a fourth winding for said core electrically connected to the output of said rectifying means for aiding the effect of the third winding in additionally decreasing the permeability of said core in accordance with the output current of said pair of windings, and control means in said feed back circuit traversed by the output current of said rectifying means for modifying the effect of said fourth winding on said core.

2. A magnetic amplifier comprising a magnetizable core carrying a pair of windings connected in series opposed relation, a source of alternating current connected to energize said pair of windings, means for rectifying the output current of said windings, a direct current input circuit including a third winding on said core whereby during current flow in said third winding the permeability of said core is decreased thus causing an increase in the output current of said pair of windings, a feed back winding on said core electrically connected to the output of said rectifying means for aiding the effect of the third winding in additionally decreasing the permeability of said core in accordance with the output current of said pair of windings, and control means traversed by the output current of said rectifying means for automatically modifying the effect of said feed back winding on said core.

3. A magnetic amplifier comprising a magnetizable core carrying a pair of windings connected in series opposed relation, a source of alternating current connected to energize said pair of windings, means for rectifying the output current of said windings, a direct current input circuit including a third winding on said core whereby during current flow in said third winding the reactance and output current of

said pair of windings is varied, a feed back coil on said core electrically connected with the output of said rectifying means for modifying the reactance of said pair of windings, and means for selecting the effective value of said feed back coil in accordance with the current output of said pair of windings.

4. A magnetic amplifier comprising a magnetizable core carrying a pair of windings connected in series opposed relation, a source of alternating current connected to energize said pair of windings, means for rectifying the output current of said windings, a direct current input circuit including a third winding on said core whereby during current flow in said third winding the reactance and output current of said pair of windings is varied, a feed back coil on said core electrically connected with the output of said rectifying means for modifying the reactance of said pair of windings, and means including a slidable contact engaging said feed back coil for selecting the effective value of said coil in accordance with the current output of said pair of windings.

5. A magnetic amplifier comprising a magnetizable core carrying a pair of windings connected in series opposed relation, a source of alternating current connected to energize said pair of windings, means for rectifying the output current of said windings, a direct current input circuit including a third winding on said core whereby during current flow in said third winding the reactance and output current of said pair of windings is varied, a feed back coil on said core electrically connected with the output of said rectifying means for modifying the reactance of said pair of windings, and means including a resistance in circuit with said coil for controlling the effective value of said coil in accordance with a current derived from the output current of said pair of windings.

6. A magnetic amplifier comprising a magnetizable core carrying a pair of windings connected in series opposed relation, a source of alternating current connected to energize said pair of windings, means for rectifying the output current of said windings, a direct current input circuit including a third winding on said core whereby during current flow in said third winding the reactance and output current of said pair of windings is varied, a feed back coil on said core electrically connected with the output of said rectifying means for modifying the reactance of said pair of windings, a resistor in circuit with said coil, and means including a slidable contact engaging said resistor for controlling the effective value of said coil as a function of the output current of said pair of windings.

7. A magnetic amplifier comprising a magnetizable core carrying a pair of windings connected in series opposed relation, a source of alternating current connected to energize said pair of windings, means for rectifying the output current of said windings, a direct current input circuit including a third winding on said core whereby during current flow in said third winding the reactance and output current of said pair of windings is varied, a feed back coil on said core electrically connected with the output of said rectifying means for modifying the reactance of said pair of windings, and means defining a non-linear resistance in circuit with said coil for controlling current flow in said coil in accordance with the output current of said pair of windings.

8. A magnetic amplifier comprising a magnetizable core carrying a pair of windings connected in series opposed relation, a source of alternating current connected to energize said pair of windings, means for rectifying the output current of said windings, a direct current input circuit including a third winding on said core whereby during current flow in said third winding the reactance and output current of

said pair of windings is varied, a feed back coil on said core electrically connected with the output of said rectifying means for modifying the reactance of said pair of windings, and non-linear resistance means in series with said coil whereby current flow in said coil is controlled in accordance with the output current of said pair of windings.

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