

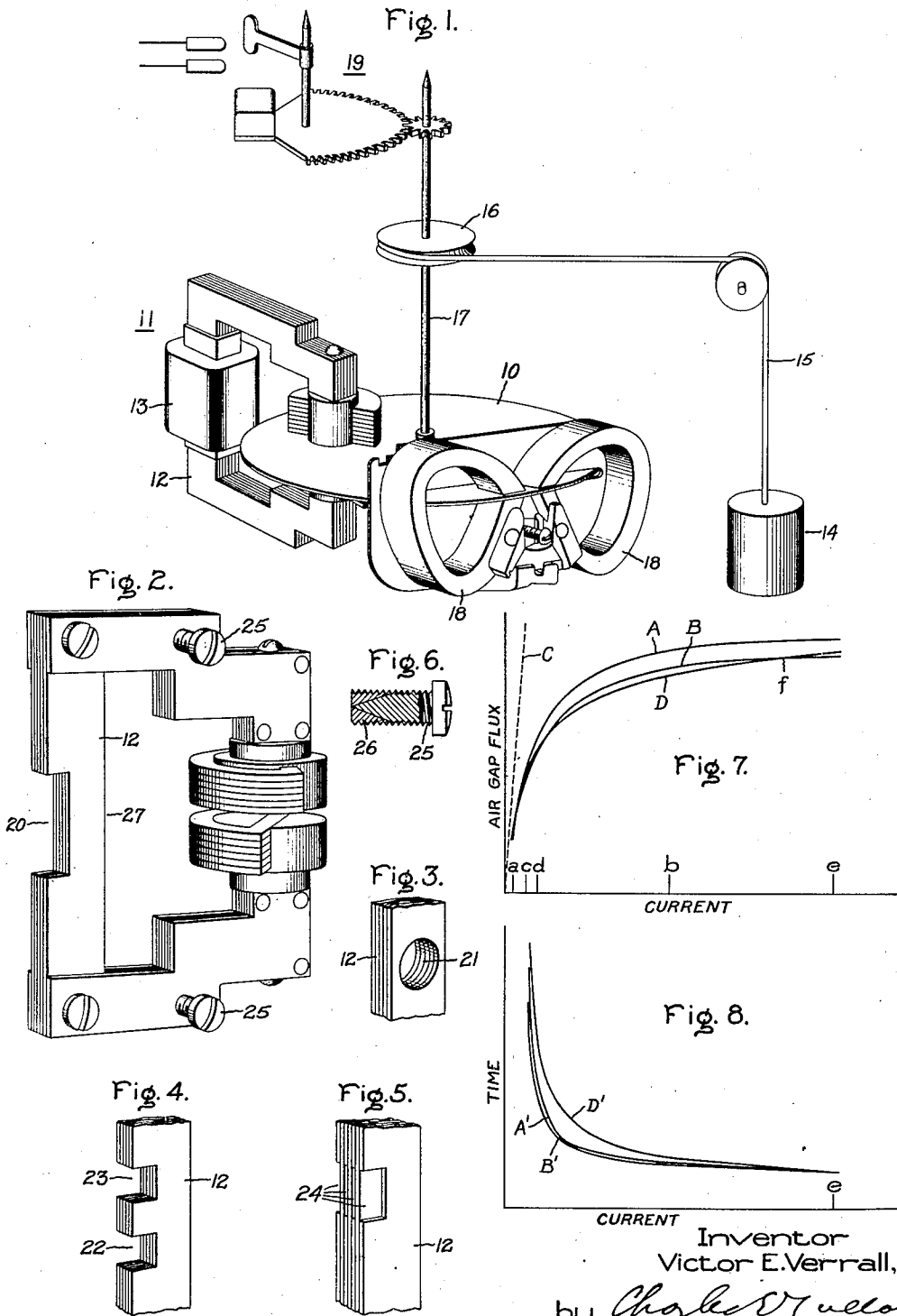
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V. E. VERRALL

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ELECTRORESPONSIVE DEVICE

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Inventor
Victor E. Verrall,
by *Charles V. Tulla*
His Attorney.

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ELECTRORESPONSIVE DEVICE

Victor E. Verrall, Fort Wayne, Ind., assignor to
General Electric Company, a Corporation of
New York

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My invention relates to improvements in electroresponsive devices and more particularly to improvements in time element relays whose movable member is actuated in accordance with the flux across a fixed air gap and an object of my invention is to provide an improved arrangement for controlling the flux across the air gap relatively to the current energization of the relay whereby to control the time-current characteristic of the relay. Other objects of my invention will appear hereinafter.

In the manufacture, sale and use of time element relays it is sometimes necessary to vary the time-current characteristic either in whole or in part. Thus, it is frequently necessary to match the time-current characteristic of a relay with the time-current characteristic of one or more relays already installed. The installed relays may be of the same or a different make. Also for different applications of the same relay different time-current characteristics may be desirable. Moreover, in the manufacture of relays which should have a given time-current characteristic there are encountered variations in the properties of the materials used, such as differences in the magnetic properties of the iron employed, etc. Such differences, even though they may be comparatively small, tend to prevent uniformity in the operating characteristics of the relays and their effects should be capable of elimination. In accordance with my invention I provide an improved electromagnetic construction for so controlling the flux distribution in the electromagnetic structure of the relay as to provide the desired flexibility in the control of the time-current characteristic.

My invention will be better understood from the following description when considered in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

In the accompanying drawing, Fig. 1 illustrates in perspective a time element relay embodying my invention; Fig. 2 illustrates in perspective to an enlarged scale the core of the electromagnetic driving element of the relay shown in Fig. 1, the energizing winding being omitted in order more clearly to illustrate the magnetic structure; Figs. 3, 4 and 5 are part details illustrating modifications of my invention; Fig. 6 illustrates in a partly sectional elevation a part used in another embodiment of my invention; and Figs. 7 and 8 are curves explanatory of my invention.

For the purpose of illustrating my invention,

I have shown in Fig. 1 a time element relay comprising a movable current conducting member, such as a disk 10, which is movable in the air gap of a shaded-pole type of electromagnetic actuating means or motor element 11. This element has a magnetic core 12 and an energizing winding or coil 13 which may be connected to be energized in accordance with the current or voltage of a circuit, or as otherwise desired. As shown, the motor element 11 tends to turn the disk 10 against the uniform bias or restraint provided by a weight 14 mounted on a flexible element 15. This flexible element, which may be a cord or chain, is arranged to be wound on a pulley 16 fixed to the disk spindle 17, as the disk is rotated by the motor element 11. Variable retarding or damping means, such as adjustably positioned permanent drag magnets 18, are provided to obtain the desired time delay action. Suitable circuit controlling or contact means 19 may be provided, as shown.

In order to control the air gap flux-current characteristic of the motor element 11 and thereby the time-current characteristic of the relay, I arrange in accordance with my invention to have the electromagnetic core 12 locally reduced in area. This may be done by providing the core 12 with a flux control opening which may take any one or more of several forms, examples of which are illustrated in Figs. 2 to 5 inclusive. Thus as shown in Fig. 2, the opening takes the form of a rectangular notch 20, while in Fig. 3 the opening is a circular hole 21. Where special effects are desired two or more openings, such as notches 22, 23 may be arranged in series as shown in Fig. 4, and may be of different proportions to provide different local saturations. Instead of having an opening clear through the core 12, alternate laminations of the core may be provided with openings such as notches 24, as shown in Fig. 5. It will be apparent that, with the rectangular notch, the length of the notch and the reduction in area of the core may be effected each independently of the other whereas in the circular opening these two features are interdependent.

Further, in accordance with my invention, I may provide reduced area portions of a variable character, especially where small changes are desired. Such an arrangement, as shown in Fig. 2, may take the form of an adjustably positioned magnetic member or insert as for example a screw 25 threaded into the core 12 transversely to the flux path. Where a micrometric control is desired, and especially in thin cores and cores

of small cross-section, the magnetic insert 25 may, as shown in Fig. 6, be tapered and provided with a cap 26 of non-magnetic material to provide an engaging surface with the core opening.

5 The direct effect of locally reducing the area of the core 12 is a change in the air gap flux-current characteristic. The construction of the relay shown is, however, such that a change in this characteristic causes a corresponding
10 change in the time-current characteristic because the net disk torque at the disk speeds encountered in practice increases with increase in flux across the air gap. In other words, the damping effect of this flux is small in comparison
15 with the damping effect of the drag magnets 18.

For a further understanding of my invention, reference will be had to Figs. 7 and 8 whose curves afford a general explanation of the action of the flux control opening and why this opening
20 effects, in the shape of the air gap flux-current characteristic, a change which cannot be obtained by changing the cross-section of the core generally, for example, by merely removing one or more laminations from the core. The curves
25 shown in Figs. 7 and 8 are drawn from data based on having the opening in the winding leg substantially centrally disposed with respect to the winding 13. This I now consider to be the most effective arrangement, but other locations
30 of the opening with respect to the winding give effects determined by the same principles of flux distribution as will appear hereinafter.

In Fig. 7 the curve A is for a magnet having a given number of laminations, but no flux control opening. The bending over of this curve as the
35 current is increased is explained mainly by the rapid increase in the reluctance of the iron path as the flux density increases in its various parts. If the iron were of infinite permeability, all of
40 the magnetomotive force would be concentrated across the air gap and the flux would be as shown by the straight broken line C. Even at a low value of current such as a , the permeability of the iron path is such that with the winding
45 positioned on the core leg opposite the air gap, only part of the flux goes across the air gap, and the curve has a smaller slope than curve C. With further increase in current, the increase in flux is such that the iron path approaches saturation and its reluctance increases in the manner
50 characteristic of the particular kind of iron used. The fraction of the total magnetomotive force appearing across the air gap is thus decreased and the curve bends over as shown. For currents above the value b , the reluctance of the iron path has become so high that the increase in flux across the air gap is mainly due to the share of the total leakage flux passing the air gap by virtue of its position and area. The air gap flux-current characteristic is, therefore, approximately a straight line of small slope.

With the cross-section throughout the length of the iron path uniformly reduced as by removing a lamination for example, the curve B is
65 obtained. The area of the air gap is the same as before. Each state in the change of reluctance of the iron path as a whole now occurs at a lower air gap flux. Moreover, since the air gap reluctance is unchanged and constitutes a considerable part of the total reluctance at all times, the same flux density is now obtained at
70 a lower current than in the case of the curve A. Each stage occurs at about the same relative flux as before because all parts of the iron

path are reduced by the same amount. Consequently, the new air gap flux-current characteristic should be obtained approximately by shifting curve A downward and to the left which
fits curve B in a general way.

Curve D shows the air gap flux-current characteristic when the cross-section of the core of the magnet of curve A is reduced a given percentage over a given length in the middle of the winding leg, as shown for example in Fig. 2. From a current value a to a current value c , the permeability of the reduced iron section is not decreased much from that of the corresponding unreduced section. Also the reduced section is only a fraction of the total flux path so that the air gap flux is nearly the same as for curve A. The flux density in the reduced section 27 is greater at a given current for these same reasons and the increasingly rapid change in permeability, which occurs as the flux density increases with increase in current beyond the value c , causes the air gap flux-curve to bend over more rapidly than the curve A. This effect is accentuated by the location of the reduced section in the center of the winding 13 where it carries the leakage flux as well as the air gap flux. When the current increases to the value d , the permeability of the section 27 is sufficiently low to reduce the air gap flux as much as when the entire iron path was reduced in cross-section, as previously mentioned, and as the current further increases the reduction is greater than it was when the entire path was reduced. As the current increases and saturation in the section 27 is approached, an increased percentage of the coil flux crosses the air gap formed by the opening 20 and the air gap flux-current curve ceases to bend away from the curve A so rapidly. When saturation in this section is fairly complete, the effect is very much that of an air gap of the length of the opening 20 as far as further increase in flux is concerned. The flux density in the iron except in section 27 is less than for the case of curve B, and the effect of a change in permeability is less also because of the opening 20 so that the air gap flux-current curve has a less rapid change in slope for the higher currents than does curve B and crosses it at f before the current attains the value e .

The flux control opening in the electromagnet is thus a means for making use of rapid change in the permeability of the iron as the flux density changes by arranging to have the flux density in a part of the iron path greater than the rest with the object of limiting the air gap flux over a certain range of current value. This range is determined by the dimensions and location of the opening. Thus, a deeper opening will increase the flux density in the section 27 at low current values and cause the air gap flux-current curve to bend over sooner. After saturation of the section which will, of course, occur at a lower current than with a shallower opening, the curve will continue at higher currents with about the same slope as before because the flux density in the remainder of the iron will be only slightly less than with a shallower opening. Therefore, a deeper opening changes the slope in the flux-current curve for the low range of current values principally. The longer opening introduces a greater reluctance in the magnetic path for a given decrease in permeability in the saturating section. The flux density at low currents will not be much different

than with a shorter opening. Therefore, the flux-current curve will start bending over at about the same time but will bend more and continue to do so until saturation of the section which occurs at a higher current value than before. Therefore, a longer opening changes the slope of the flux current curve for the middle and lower range of current values principally. The flux crossing the opening 20 decreases the effect of saturation in the section 27 and prolongs it somewhat also by increasing the flux density in the rest of the iron while the section 27 is approaching saturation. When the opening is made deeper, this effect tends to counteract the principal effect. It can be utilized more effectively by applying pole pieces to the end faces of the opening.

The time current curves for the relay shown in Fig. 1 using the three magnets whose flux current curves are discussed above are indicated in Fig. 8 by corresponding letters A', B' and D'. The definite time part of the curves, that is the portion of the characteristic to the extreme right at *e* where the currents are large, was made nearly the same in each case by suitable adjustment of the damping magnets. These time curves show even more clearly than the flux curve that with the flux control opening, the change in values can be restricted more or less to a given range of current values and a greater change in curve shape obtained than by simply changing the cross-section of the iron or the number of laminations. Thus, it will be observed that the time current curves A' and B' differ substantially inappreciably throughout their whole range whereas the time current curve D' differs materially from either of the curves A', B' through a considerable portion of its range although there is substantial agreement of all three in their initial and final points. It will be further observed from Fig. 8 that the curve D' resulting from the flux control opening feature gives a greater time selectivity characteristic than does either of the curves A', B'.

Openings in other locations along the magnetic circuit afford a different control of the air gap flux current characteristic and of the time-current characteristic than does the opening centrally located with respect to the coil. The effect of a given opening is determined by the size and shape of the opening and the size and shape of the parallel reduced section of the magnet and the consequent relative increase in flux density in part of the magnetic circuit and resulting change of reluctance as current changes, also by the location of the opening and the resulting relative distribution of the total coil flux between the air gap and the various leakage paths. Some of this leakage flux may pass through the movable member or disk at points adjacent to the main air gap flux and thereby produce forces upon the disk which depend upon the amount and phase-relation of the leakage and air gap fluxes as determined by the size, shape, and location of the opening. Since these forces may be arranged as desired to either aid or oppose the forces produced by the air gap flux, the opening thereby provides a further and different control of the time-current characteristic than it provides by reason of its limitation of the air gap flux.

The effectiveness of this control can be increased by applying auxiliary magnetic pole

pieces to concentrate the leakage flux on the desired part of the disk and locating the flux control opening in the magnetic circuit between these poles and the main air gap. The openings shown in Fig. 2 with adjustable screws 25 provide a control of the time-current characteristic both by means of their limitation of the air gap flux and by means of their effect upon the relative amount of leakage flux as above described.

While I have shown my invention in considerable detail, I do not desire to be limited to the exact arrangements shown, but seek to cover in the appended claims all those modifications that fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A time element relay including a rotatably mounted induction disk and actuating means therefor including a shaded pole electromagnet having an air gap in which said disk is movable and an energizing winding centrally disposed on the core of the electromagnet, the core of said electromagnet being provided with a flux control opening centrally disposed with respect to said winding for locally increasing the flux density and causing the reluctance of said core to change in a predetermined manner as the current in said winding changes whereby to control the time-current characteristic of the relay over a predetermined range of current values.

2. A relay including a movable current conducting member and actuating means therefor including an electromagnet having an air gap in which said member is movable and an energizing winding disposed on the core of the electromagnet, the core of said magnet being provided with a flux control opening centrally disposed with respect to said winding for locally increasing the flux density and causing the reluctance of said core to change in a predetermined manner as the current in said winding is changed whereby to limit the air gap flux over a predetermined range of current values dependent on the dimensions and the location of the opening.

3. A time element electroresponsive device including a movable current conducting member and actuating means therefor including an electromagnet having an air gap in which said member is movable and an energizing winding disposed on the core of said electromagnet, the core of said electromagnet having a local reduction in area centrally disposed with respect to said winding for increasing the flux density and causing the reluctance of said core to change in a predetermined manner as the current energization of the electromagnet is changed whereby to control the time-current characteristic of the device over a predetermined range of current values.

4. An electromagnetic device including a movable member and actuating means therefor including an electromagnet having an air gap, the core of said electromagnet being locally reduced in area for increasing the flux density and causing the reluctance of said core to change in a predetermined manner as the current energization of the electromagnet is changed whereby to limit the air gap flux over a predetermined range of current values dependent on the location and proportioning of the reduction in area and adjustably positioned means for varying the reduction in area.

5. An electromagnetic device including a mov-

- able member and actuating means therefor including an electromagnet having an air gap, the core of said electromagnet being provided with a plurality of local reductions in area for increasing the flux density and causing the reluctance of said core to change in a predetermined manner as the current energization of the electromagnet is changed whereby to limit the air gap flux over a predetermined range of current values dependent on the location and proportioning of the reductions in area and magnetic means adjustably positioned in said core for varying at least one of the reductions in area.
6. A relay including a movable current conducting member, actuating means therefor including a shaded pole electromagnet having an air gap in which said member is movable, the core of said electromagnet being provided with a flux control opening for locally increasing the flux density and causing the reluctance of said core to change in a predetermined manner as the current energization of the electromagnet is changed and magnetic means adjustably positioned in said opening for varying the effect thereof.
7. An electromagnetic device including a movable member, and actuating means therefor including an electromagnet having an air gap, the core of said electro-magnet having a plurality of local reductions in area for increasing the flux density and causing the reluctance of said core to change in a predetermined manner as the current energization of the electromagnet is changed and magnetic means for varying the amount of one of the reductions in area.
8. An electromagnetic device including a movable current conducting member and actuating means therefor including a magnetic core having an air gap in which said member is movable and an energizing winding on said core, the core of said electromagnet being provided with a flux control opening centrally disposed with respect to said winding for locally increasing the flux density and causing the reluctance of said core to change in a predetermined manner as the current energization of the electromagnet is changed whereby to limit the air gap flux over a predetermined range of current values and with another flux control opening intermediate said gap and said winding for increasing the flux density and causing the reluctance of said core to change in a predetermined manner as the current in said winding is changed whereby to control the relation between the air gap flux and the leakage flux crossing said current conducting member.
9. A time element relay including a rotatably mounted induction disk and actuating means therefor including a shaded pole electromagnet having an air gap in which said disk is movable and an energizing winding centrally disposed on the core of said electromagnet, said core being provided with a flux control opening centrally disposed with respect to said winding for locally increasing the flux density and causing the reluctance of the core to vary in a predetermined manner as the current energization of the electromagnet is changed whereby to limit the air gap flux over a predetermined range in current values and with another flux control opening disposed intermediate said gap and said one flux control opening for locally increasing the flux density and causing the reluctance of the core to change in a predetermined manner with the current in the winding whereby to control the relation between the air gap flux and the leakage flux crossing the disk.
10. An electromagnetic device including a movable member and actuating means therefor including an electromagnet having a core provided with an energizing winding and an air gap in which said member is movable, the core of said electromagnet being provided with a plurality of flux control openings for locally increasing the flux density and causing the reluctance of said core to change in a predetermined manner as the current in said winding is changed whereby to limit the air gap flux over a predetermined range of current values dependent on the dimensions and locations of the openings, one of said openings being centrally disposed with respect to said winding and another of said openings being intermediate said air gap and said one opening and magnetic means for varying the extent of said other opening.
11. A time element relay including a rotatably mounted induction disk and actuating means therefor including an electromagnet having a core provided with an energizing winding centrally disposed thereon and an air gap in which said disk is movable, the core of said electromagnet being provided with a plurality of flux control openings for locally increasing the flux density and causing the reluctance of said core to change in a predetermined manner as the current in said winding changes whereby to control the time current characteristic of the relay over a predetermined range of current values, one of said openings being centrally disposed with respect to said winding and others of said openings being intermediate said air gap and said one opening, there being at least one of said other openings on each side of the air gap and magnetic means adjustably positioned in said other openings for varying the extent thereof.

VICTOR E. VERRALL.

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