Oct. 31, 1950 R. B. SHANCK 2,528,088

ELECTROMAGNETIC RELAY

Filed May 28, 1947

FIG. 1

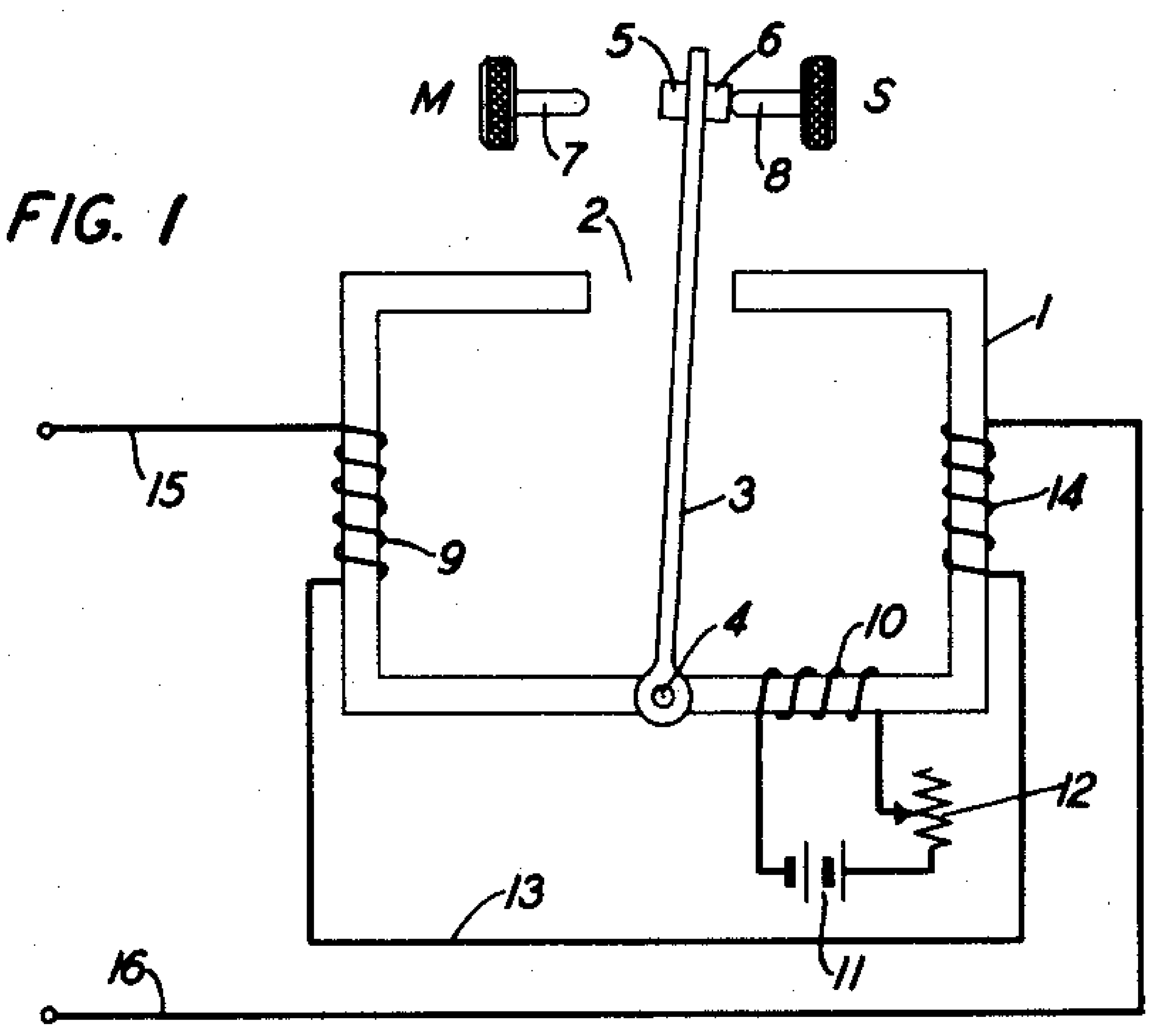
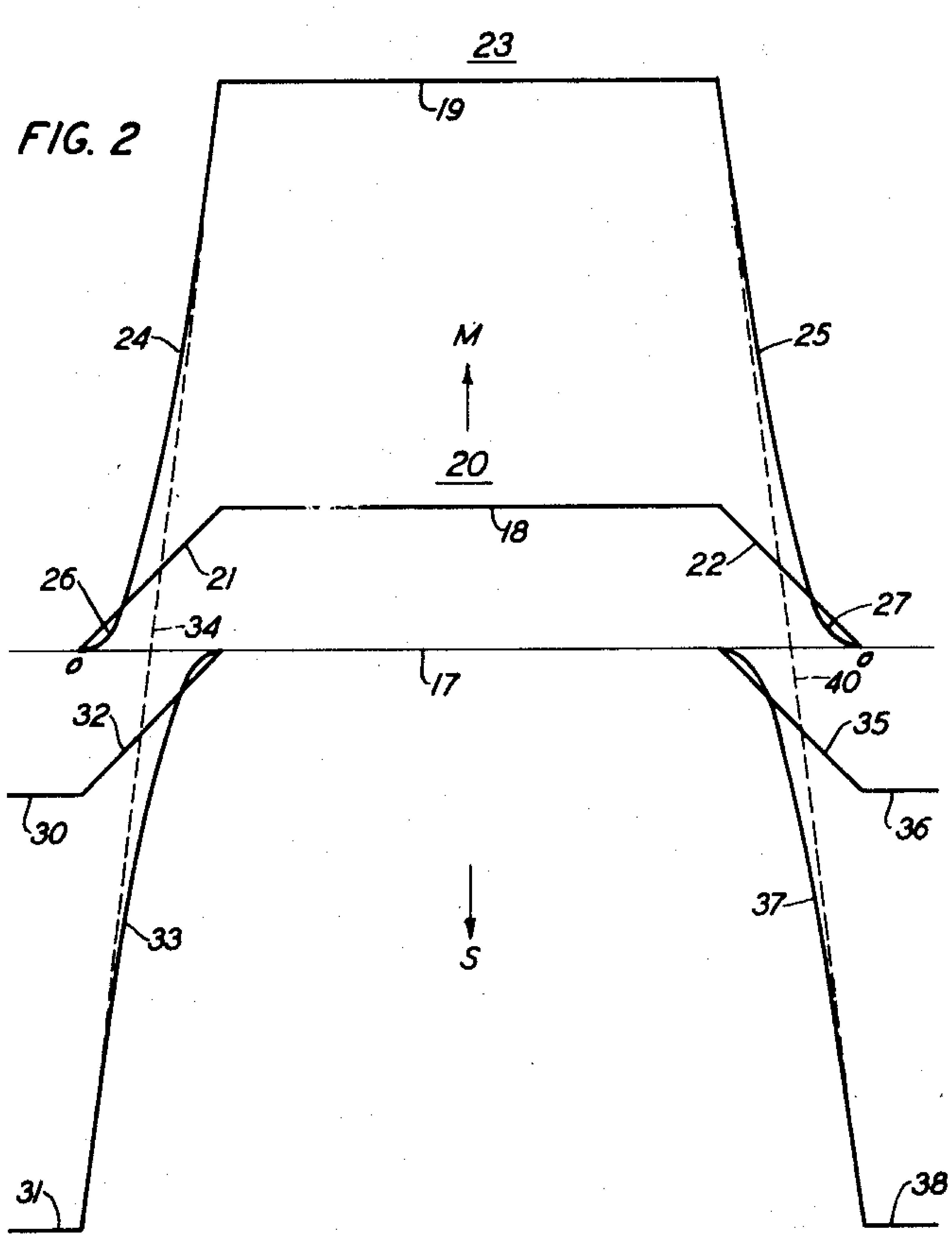


FIG. 2



INVENTOR
R. B. SHANCK

BY John E. Cassidy

ATTORNEY

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ELECTROMAGNETIC RELAY

Roy B. Shanck, Douglaston, N. Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

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This invention relates to magnetic relays or switches in electrical systems and more particularly is an improved magnetic relay or switch of the neutral type which affords symmetrical operating characteristics about the operating point on the current wave hitherto obtainable only by means of the more expensive polar relay.

An object of this invention is the improvement of magnetic relays or switches.

A more particular object of this invention is the provision of a magnetic relay or switch of the neutral type which affords symmetrical operating characteristics about the operating point on the current wave.

Another object of the invention is to provide a neutral relay, the operating characteristic of which closely approximates the more expensive polar relay.

In the operation of the ordinary neutral relay no current is supplied to the relay for the normal unoperated condition. To operate the relay a circuit is closed. Current in the operating winding starts to build up from zero. The force exerted on the armature is proportional to the square of the current in the operating winding. During the early stages of operation while the current is relatively low the operating force, proportional to the square of the low current, will be relatively small. During the latter stages the operating force proportional to the square of the relatively high current will be relatively great. The force on the armature does not increase uniformly. The armature of the ordinary neutral relay is spring biased to one of its two positions. The time required to build up an operating force sufficient to actuate the armature from its normal to its operated position will be longer than that required to reduce the operating force to its release value due to the non-symmetrical shape of the force curve about the operate and release points for theh armature. Further for different rates of build-up and decay of the operate current curve, the operate and release times of the relay will be changed. To obtain a particular response within the limits of the relay it is necessary to adjust the relay for different wave shapes.

Polar relays operating to alternate positions in response to pulses of current of opposite polarity are presently available which afford symmetrical operating characteristics but they are relatively expensive, costing several times as much as a neutral relay.

The foregoing difficulty of lack of symmetrical operation in neutral relays is obviated in the relay of the present invention. The manner in

which this is achieved will become apparent from the following description when read with reference to the associated drawing which discloses a preferred embodiment in which the invention may be incorporated. It is to be understood, however, that the invention may be incorporated in other forms than that in which it is presently embodied which will be apparent to those skilled in the art.

In the drawing:

Fig. 1 shows a diagrammatic plan view illustrating the relationship of the essential elements necessary to an understanding of the relay of the present invention, comprising a magnetizable core, armature, contacts, line connections, line winding, biasing winding and circuit therefor, and counter biasing winding, in which view other relay parts, not necessary to an understanding of the invention, are omitted; and

Fig. 2 is a graph illustrating the operation of the relay.

In the following description it will be assumed that the relay is so disposed that the operate and release forces are unaffected by gravity.

In Fig. 1 a magnetizable core 1, which may, for instance, be rectangular and of soft iron, is provided with a gap 2. An armature 3 hinged in any convenient manner such as by the pin 4 at the middle of the base of core 1 projects through the gap 2. Contacts 5 and 6, affixed to the armature 3, abut opposed contacts 7 and 8 as the armature 3 is actuated under the influence of the magnetic field.

Wound on the left limb of the magnetic core 1 is an operating winding 9. Wound on the base of the right-hand portion of the magnetic core 1 is a biasing winding 10. The current in the biasing winding, which may be supplied for instance from a battery 11, may be adjusted by means of variable resistance 12, so that the winding 10 produces the same magnetomotive force as the current in the winding 9 when the latter carries the full steady-state direct current. Connected in series with the operating winding 9 by means of conductor 13 is a winding 14 wound on the right-hand limb of core 1. Winding 14 has the same number of turns as operating winding 9 and produces a magnetomotive force of such magnitude and direction as to exactly nullify that of the bias winding 10 when the full steady-state operating current is applied to the relay through the conductors 15 and 16. When no current is supplied through conductors 15 and 16 to windings 9 and 14 the effect of the current in the biasing winding 10 actuates the armature 3 to the right to close contacts 6 and 8. When full steady-state direct current is supplied through conductors 15 and 16 the effect of the current in the counter-biasing winding 14 neutralizes the effect of the biasing current and the effect of the current in winding 9 actuates the armature 3 to the left to close contacts 5 and 7.

It is pointed out that windings 10 and 14 on the right-hand magnetic branch are shown in their respective positions in Fig. 1 for reasons of clarity in illustration. The windings in practice would ordinarily be wound in parallel turns as a single unit to obtain the closest coupling. It is further pointed out that although the relay or switch is intended for general use, it will probably find its widest application as a telegraph relay in which case the full current and no current conditions above-referred to may be marking and spacing signals applied to the relay.

The manner in which symmetry is obtained may be understood from the following and reference to Fig. 2.

In Fig. 2, distances parallel to the horizontal base or abscissae 17 from left to right may be considered to represent time starting at 0 which represents the start of an operate and release or a marking and spacing cycle of the relay per Fig. 1. Distances in the vertical direction above and below the abscissae represent the magnitudes of the quantities represented by the particular curves. Curve 20 represents current in the operating winding 9. Curve 23, shown by the full lines, represents the operating force resulting from the current 20 and the ordinate of the curve 23 at each point thereon is proportional to the square of the vertical distance measured on curve 20 in vertical alignment therewith, since the force developed at each instant by the winding 9 is proportional to the square of the current in winding 9 at the instant.

Curves 20 and 23 taken together and disregarding the other portions of Fig. 2 illustrate the operation of an ordinary neutral relay. Such a relay might be represented by the relay of Fig. 1 if windings 10 and 14 were omitted and armature 2 were actuated by a spring which normally maintained contacts 6 and 8 closed and in which relay the armature 3 were actuated to close contacts 5 and 7 in response to current in winding 9. Assuming such a relay, the build-up of the current in winding 9 may be represented by line 21 starting at zero time and sloping upward to the right. The steady-state condition of constant magnitude may be represented by line 18 parallel to the horizontal axis and the decay of the current following opening of the circuit 15—16 may be represented by the line 22 sloping downward to the right again to zero. The corresponding force developed will be represented by lines 24, 19 and 25 respectively for the build-up, steady-state and decay conditions.

The concave curvatures 26 and 27 at the left-hand and right-hand portions of the force curve near the base thereof is characteristic of any curve having an expression $Y=KX^2$ corresponding to $f=Ki^2$ where f is the force, i is current at any instant, and K is a constant.

The armature 3 of the assumed neutral relay will be operated toward the left at some point in the rising current curve 21 at which the corresponding magnitude of the force thereby developed as represented on the force curve by a point on portion 24 in vertical alignment therewith, overcomes the spring tension holding the armature to the right. On the decay of the current the armature 3 will be actuated to the right by the spring tension when the force of the spring overcomes the force represented by some point on curve 25 in vertical alignment with a point on curve 22 representing the corresponding current.

The horizontal distance between the operate and release points on curves 24 and 25 measures the time during which contacts 5—7 are closed, which, when the relay is used in telegraphy, corresponds to a marking interval. For current waves of differing slopes, assuming a constant biasing spring tension, the operate and release points on the force curves will vary. The less steep the slopes of lines 21 and 22, the more pronounced the variation in the duration of the closed interval. If the assumed neutral relay is to be used to transmit, receive or repeat telegraph signals, for instance, where it is important that the duration of the marking and spacing intervals be faithfully reproduced, and that these intervals remain constant for current waves having differing slopes, it is necessary to change the tension of the biasing spring continually as the wave shape of the signal changes.

The relay of the present invention overcomes the foregoing difficulty in the following manner.

The magnitude of the current in the biasing winding 10 is represented by the vertical distance from the horizontal axis 17 to the horizontal portion 30 of the curve just below the horizontal axis at the left. It is shown below the horizontal axis since its effect is opposite to that of the current in winding 9. During the interval just prior to the arrival of a current pulse over circuit 15—16 the only current in the relay is the biasing current in winding 10 which is constant. This is indicated by section 30 which is horizontal indicating biasing current of constant magnitude. This generates a uniform force indicated by the horizontal portion 31 of the corresponding force curve, shown also below the horizontal axis, since it opposes the force generated in winding 9. This condition continues until the start of reception of the incoming signal at point 0.

The effect of the incoming signal in winding 9 will be as described above for the assumed neutral relay as shown by curves 20 and 23. The effect of the winding 14 is to modify the effect of the biasing winding 10 and the current and force curves of the two windings 14 and 10 have been combined in the current and force curves shown in full lines in the lower portion of Fig. 2. As the current in winding 14 builds up along line 32, which is parallel to line 21, since the current in windings 14 and 9 is identical, the effect is the same as though the current in the biasing winding 10 were being reduced to zero at the same rate at which the current in winding 9 increases. The corresponding force curve 33 of the decline of the force generated by windings 10 and 14 is similar to that of the increase of force in winding 10 but inverted in magnitude and time.

The net force resulting from the effect of all three windings may be obtained by subtracting the ordinates of the curve 33, as measured from the horizontal axis 17 downward, from the corresponding ordinates of curve 24 as measured upwardly from the same axis. This net force is indicated by the dotted line 34. Where line 34 crosses the horizontal axis 17 the net force of all three windings is zero. Above and below this point of zero force the line 34 is symmetrical being of substantially uniform slope. The net force curve is substantially a straight line as the tendency toward deviation from a straight line is substantially due to variations from substantial linearity in the concave portions of the two curves from which the net force curve is derived. Near the horizontal axis where the departure from substantial linearity is significant, the magnitudes of the ordinates of each of the original curves are small, whereas the magnitudes of the ordinates of the force curve on the opposite side of the horizontal axis at such points is a maximum. The resulting variaitons from linearity will therefore be small throughout the entire curve 34.

On release the operation will be as indicated by the portion of the curves on the right-hand side of Fig. 2 where the decline in the current in winding 9 is represented by line 22, the corresponding decline in the force generated by winding 9 is represented by line 25, the change in net current in the windings 10 and 14 combined is represented by line 35, the final constant current in the biasing winding by line 36, corresponding to line 30, the decline in the combined force exerted by windings 10 and 14 is represented by line 37 and the final net force by winding 10 alone is represented by line 38 which corresponds to line 31. The resultant force of the three windings during the decay of the current in the line 15—16 is indicated by the dotted line 40 which is also symmetrical about the horizontal axis representing zero force and is substantially straight.

It is particularly pointed out that in the case of a relay such as that shown in Fig. 2 when disposed so that the forces required to move the armature in each direction are not unbalanced by gravity, forces of the same magnitude above and below the horizontal axis will be required to actuate the armature in the two directions, respectively. The total duration of any closure of contacts 5 and 7 will be measured by the horizontal distance between some point on curve 34 above the horizontal axis and a point in a corresponding position on curve 40 below the horizontal axis. Whatever the position of the operating point on the upper portion of curve 34, the distances measured horizontally to the corresponding point on the lower portion of curve 40 will be equal whatever the slope of the current curve as long as the wave shapes are the same for build-up and decay. The duration of the closure of contacts 5—7, or of all possible marking intervals, will be unaffected by variations in the slope of the current wave for build-up and decay. It is therefore unnecessary to adjust the relay of the present invention for signal curves of differing slopes as is the case in the ordinary neutral relay.

In the foregoing explanation a straight line characteristic has been assumed for current build-up and decay for reasons of simplicity and clarity. It will be found that analysis of the action of the relay with other wave shapes, as for instance a sine wave, will yield the same conclusions.

As an illustration of another configuration, having the advantage of eliminating magnetic coupling between the two branches of the magnetic path, the core might be formed of two U-shaped elements arranged substantially as a W and having a horizontal armature pivoted at the center of the armature and at the top of the junction of the middle legs of the core.

It is pointed out that the biasing effected through the circuit connected to winding 10 may

be effected by a permanent magnet or other means.

It will be obvious that other configurations are possible for the magnetic structure of the relay and some of these may be preferable as regards reduction of magnetic coupling between the part subjected only to magnetomotive force resulting from flow of line current and the part in which the magnetomotive force results from currents in the baising winding and a line winding.

What is claimed is:

1. A neutral electromagnetic relay, contacts on said relay, a line connected to said relay, said relay responsive to current and no-current pulses impressed on said relay through said line, said current pulses of substantially uniform duration but differing in their rates of build-up and decay for different pulses at various times, and means included in said relay comprising a line winding, biasing means of constant unchanging force and effect, independent of the transitions between said pulses and a counter-biasing winding all cooperating to provide constant duration of closure of said contacts notwithstanding said differing rates, to preclude the necessity for adjusting said relay, said line winding, said counter-biasing winding and said line all being connected in series, the effect of current in said counter-biasing winding opposing the effect of said biasing means, and equalling the effect of said biasing means when said current pulse is at full amplitude, said line winding and said counter biasing winding of such relative sizes and so disposed as to produce equal and aiding effects.

2. A relay in accordance with claim 1, said relay having a substantially U-shaped core, an armature having one end secured at the middle of the base of said core, said armature having a free end projecting through the opening between the arms of said core, said line winding mounted on said core to one side of said armature and said biasing means and said counter-biasing winding both mounted on said core on the opposite side of said armature from said line winding.

3. A neutral relay subject to the application of current and no-current pulses of substantially constant duration but of differing rates of build-up and decay, said relay including means for automatically compensating for said differing rates, so as to afford operated intervals of uniform duration, to preclude the necessity for adjustments, said means comprising an operating winding and a counter-biasing winding, each of an equal number of turns, said windings connected in series and in series with an operating circuit, and a biasing means of constant unchanging force and effect, independent of said current no-current pulses, said biasing means arranged to produce continuously at all times a force equal to and opposite from the force generated by said counter-biasing winding when an applied operating wave is at full amplitude.

4. A neutral relay having an armature actuable to a first and a second position in response to current and no-current pulses applied to said relay, a magnetizable path in said relay comprising a first and a second arm interconnected by a base, said armature having a pivoted end at the middle of said base and a free end projecting between said arms, biasing means on said relay imposing a constant unchanging biasing force at all times on said armature, said means actuating said armature to said first position in response to a no-current pulse, a counter-biasing winding on said first arm connected in series with an

equal operating winding on said second arm, said armature actuable to said second position in response to a current pulse in said operating and counter-biasing winding, said counter-biasing winding proportioned and directed to substantially neutralize said biasing means in response to said current pulse at full magnitude, and said operating winding proportioned and directed to develop a force substantially equal to and opposite from that of said biasing means in response to said current pulse at full magnitude.

5. A neutral relay having a substantially U-shaped magnetizable core, an armature hinged at the middle of the base of said core, a free end on said armature actuable between a first and a second contact, a first magnetizing coil on a first arm of said core, a second magnetizing coil on a second arm of said core, on the opposite side of said armature from said first arm, said windings connected in series, an operating line on which current no-current signal pulses are imposed connected in series with said windings, said windings of equal size and producing when magnetized equal magnetomotive forces, a biasing element on said relay, independent of said line, said element tending to actuate said armature toward said first contact with a uniform constant unvarying biasing force at all times, said biasing force equal and opposed to that developed by said second winding when a current pulse in said second winding is at full amplitude, said armature actuable in response to said current pulse to engage said first contact.

6. A neutral relay having a first and a second magnetizing winding connected together in series and in series with an operating circuit, on which circuit current, no-current signal impulses are impressed, an armature on said relay, a biasing winding on said relay, a source of direct-current voltage local to said relay and independent of said operating circuit connected at all times to said biasing winding, said armature having a free end actuable to engage a first contact on said relay under the influence of said biasing winding in response to a no-current pulse, said first and said second windings of equal size, to produce equal electromotive forces when energized by a current pulse, said first winding disposed on said relay so as to actuate said armature to engage a second contact on said relay, opposed to said first contact, in response to a current pulse, said second winding at full current amplitude having a number of ampere turns equal to the ampere turns of said biasing winding, said second winding disposed on said relay so as to neutralize the effect of said biasing winding when said current pulse is at full amplitude.

7. A circuit through which direct current, current, no-current signal pulses are impressed, a neutral relay, said relay comprising a magnetizable core having a first and a second arm, an operating magnetizing winding on said first arm, a counter biasing magnetizing winding on said second arm, said windings connected in series and in series with said circuit, said windings of an equal number of turns and producing equal magnetomotive forces in said arms, each of said forces increasing from zero magnitude to a magnitude F as said current signal pulse rises from zero magnitude to full magnitude, an armature secured to said core and having a free end projecting through an opening between said arms, said armature actuable between a first and a second contact on said relay opposed to said free end of said armature, a biasing winding on said second arm, said biasing winding connected at all times to a source of direct current voltage individual to said biasing winding and independent of said circuit, said biasing winding producing at all times a constant magnetomotive force equal to said force F, said armature actuable to engage said first contact in response to said force F produced by said biasing winding at a first time during the reception of a no-current pulse, said counter biasing winding wound oppositely from said biasing winding so that its magnetomotive force opposes the force of said biasing winding, the magnetomotive forces of said biasing winding and of said counter biasing winding neutralizing each other when said current pulse is at full amplitude, said operating winding wound in a direction to actuate said armature to engage said second contact as the magnitude of the current rises during the reception of a current pulse.

8. The method of operation of a neutral relay to afford closed contact intervals of uniform duration in response to current signal pulses in a circuit from which said relay receives current, no-current signal pulses, in which circuit the current signal pulses are of uniform duration and amplitude but of differing rates of current increase and of current decay, at different times, which method comprises: (1) applying a constant uniform biasing first force of magnitude F tending to actuate an armature on said relay toward a first position at all times; (2) generating at a first time two other forces simultaneously, one of which forces rises from zero to magnitude F and is so applied as to counter said biasing force and the other of which forces rises from zero to magnitude F at the same rate as said counter biasing force and is so applied as to actuate said armature toward a second position, opposite from said first position; (3) reducing at a second time, said two other forces simultaneously, and each at the same rate, said rate the inverse of said generating rate, from magnitude F to zero, while said armature is actuated to said first position under the influence of said biasing force.

ROY B. SHANCK.

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