

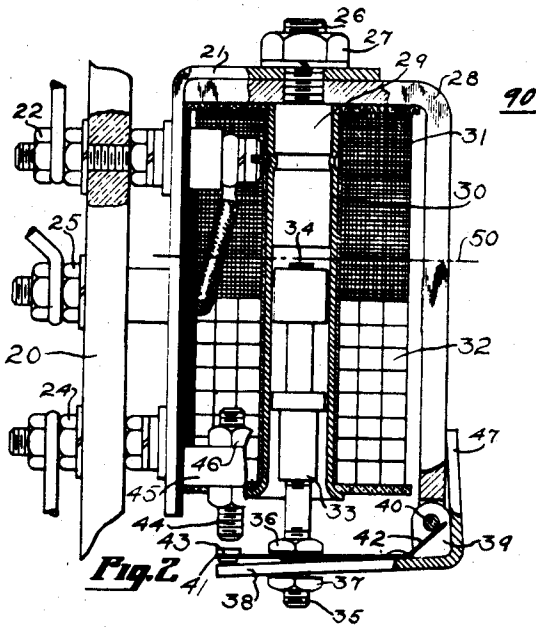
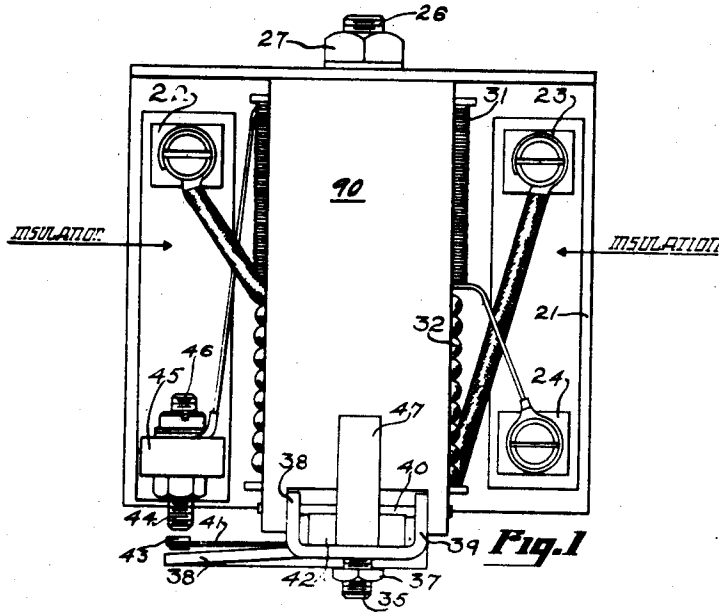
Aug. 24, 1926.

J. C. FEDERLE
ELECTRICAL APPARATUS

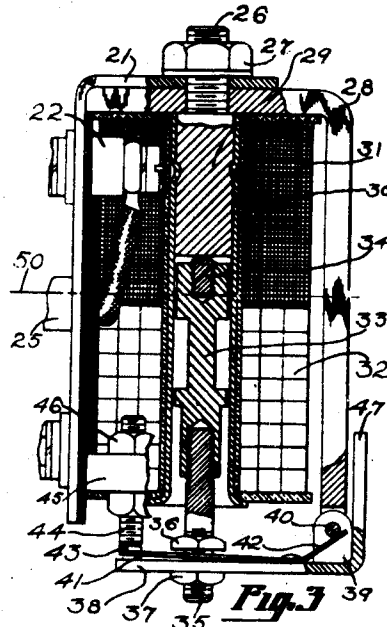
Filed Oct. 3, 1922

2 Sheets-Sheet 1

1,597,650



Witnesses
George Wallace
Warren Schmieding



Inventor
Joseph C. Federle
By
J. Ralph Zehr
his Attorney

Aug. 24, 1926.

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J. C. FEDERLE
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2 Sheets-Sheet 2

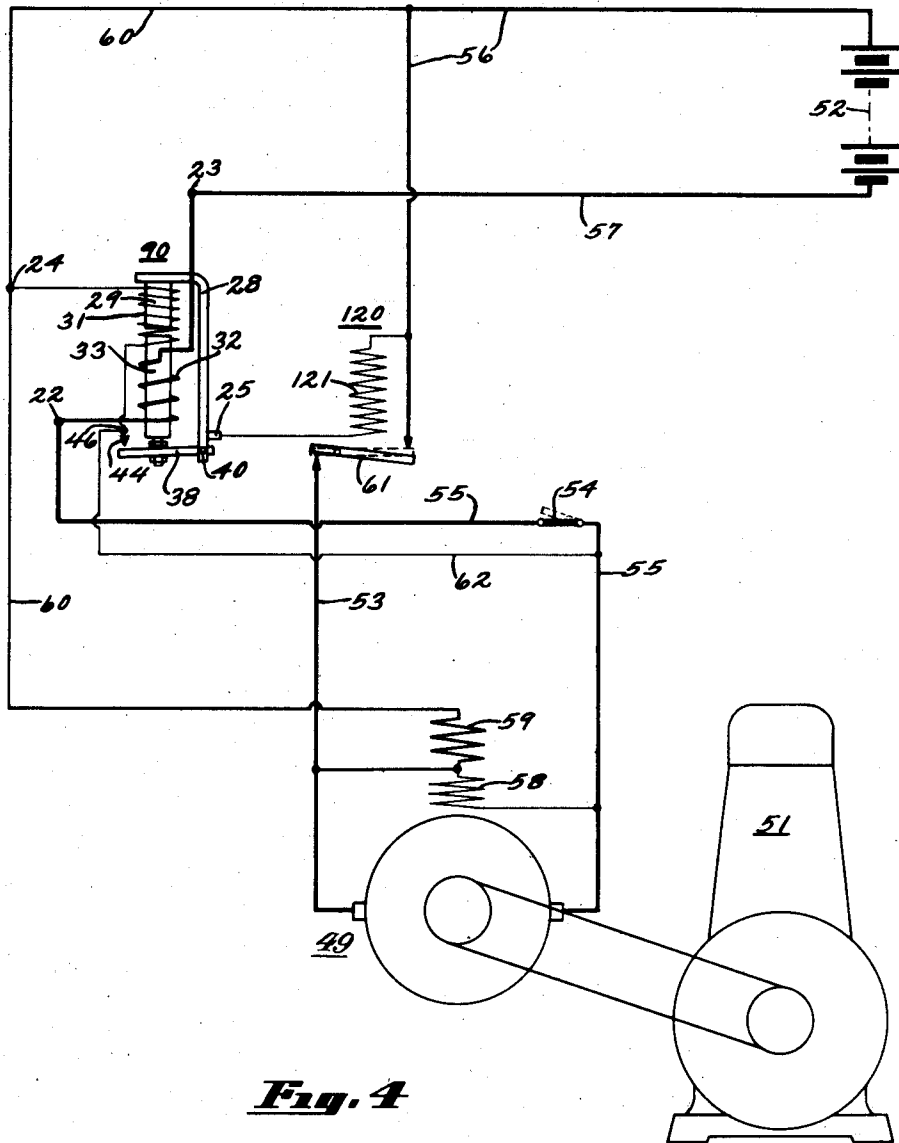


Fig. 4

Witnesses
Geo. C. Passco.
Lloyd M. Keighley.

Inventor
Joseph C. Federle
By J. Ralph Dehn
his Attorney

UNITED STATES PATENT OFFICE.

JOSEPH C. FEDERLE, OF DAYTON, OHIO, ASSIGNOR TO DELCO-LIGHT COMPANY, OF DAYTON, OHIO, A CORPORATION OF DELAWARE.

ELECTRICAL APPARATUS.

Application filed October 3, 1922. Serial No. 592,155.

This invention relates to electro-magnetically controlled circuit making devices or relays which control a circuit in accordance with the amount and direction of current flow through the relay.

It is an object of the invention to provide an improved relay which will respond to current flowing in a certain direction and in excess of a predetermined amount to control a circuit to open or close the same, but when this current flowing in this same direction decreases to a certain value below the first mentioned predetermined value, the relay will function to control the circuit in the opposite sense; and it is an aim of the invention to reduce to the minimum the difference between these two current values.

A further object is to provide a relay which will function, in case the direction of current flow is reversed, to maintain the circuit in the same condition as created by the aforesaid decreasing of the current to the second mentioned value.

Other and further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings, wherein a preferred embodiment of one form of the present invention is clearly shown.

In the drawings:—

Figs. 1 and 2 are front and side views, respectively, of the relay with the relay contacts open;

Fig. 2 being partly in section longitudinally of the relay magnets;

Fig. 3 is a view similar to Fig. 2, but showing the relay contacts closed; and

Fig. 4 is a diagram of a battery charging system showing an application of the present invention.

The relay 90 is mounted upon an instrument panel 20 of non-conducting material which supports a magnetizable bracket 21, this bracket being attached to panel 20 by terminals 22, 23, and 24 which are all insulated from bracket 21, and by a terminal 25 which is electrically connected with bracket 21. Bracket 21 is attached by a bolt 26 and nut 27 with magnet frame 28. The head 29 of bolt 26 serves as a magnet core and supports a non-magnetizable tube 30 which supports a magnet winding 31 of a large number of turns of fine wire and a magnet

windings 32 of fewer turns of coarse wire. The head 29 terminates above the lower end of magnet winding 31. The tube 30 provides a guide for a magnetizable plunger 33 carrying a non-magnetizable plug 34 and connected with non-magnetizable rod 35 carrying nuts 36 and 37. Rod 35 passes through lever 38 which is included between nuts 36 and 37, and 38 is provided with ears 39 having pivotal connection with frame 28 by a rod 40.

41 is a leaf spring attached to lever 38 and having an end thereof bent up as at 42 to engage the rod 40. Spring 41 is apertured to receive rod 35, and carries contact 43 which engages contact 44 adjustably connected with block 45 to which is attached terminal 46.

Lever 38 has a portion 47 thereof extending along the frame 28 to serve as a stop limiting the downward movement of lever 38 and of plunger 33. The range of movement of plunger 33 is limited so that the upper end of plunger 33 will always be above the upper end of coil 32 and partly within the coil 31 for a purpose to be described.

Coil 31 is connected between terminals 46 and 24, and coil 32 is connected between terminals 22 and 23.

The present invention is particularly applicable to battery charging systems such as that illustrated and described in the copending application of Charles F. Kettering and Joseph C. Federle, Serial No. 589,991, filed September 23, 1922. While the present invention is susceptible of various other applications, this particular use will serve as an example to explain its operation more clearly. Such a system comprises an engine driven dynamo operable as a generator to charge the battery, or as a motor to crank the engine. The dynamo is commonly provided with series field and shunt field windings, which are employed cumulatively when the dynamo operates as a motor in order to give a high starting torque for engine cranking, but when the engine becomes self-operative to drive the dynamo as a generator, the series field winding is short circuited or otherwise rendered inoperative so that the generator has shunt characteristics. The present invention may be employed as a reverse current relay in such a system to

short circuit the series field winding when the engine becomes self-operative whereby the generator will function with shunt characteristics to charge the battery.

Referring to Fig. 4 which shows the elements of a battery charging system such as described in the aforesaid copending application, 49 indicates a dynamo which may be driven as a generator by engine 51 and connected in circuit with storage battery 52 to charge the latter. The charging circuit is in heavy lines as follows: From the positive pole of generator 49 through wire 55, series winding 32 of relay 90, wire 57, battery 52, wire 56, switch 61, and wire 53 back to the negative pole of the generator 49. The dynamo is provided with shunt field and series field windings 58 and 59, respectively, but it will be observed that when the dynamo is operating as a generator and the above mentioned charging circuit is closed, the wire 53, switch 61, and wire 56 serve to short circuit the series field 59 and wire 60, causing the generator to operate with shunt characteristics.

The manner of cranking the engine and putting the system into operation will now be briefly described. When it is desired to start the engine 51 the switch 54 is closed thereby connecting the dynamo 49 with the battery 52 through the following cranking circuit as shown in Fig. 4: Battery 52, wire 57, series winding 32 of relay 90, wire 55, dynamo 49 which will now function as a motor, shunt and series field windings 58 and 59, respectively, and wire 60 back to the negative side of battery 52. Closing the switch 54 also connects the shunt winding 31 of the relay 90 across the battery and dynamo line through a circuit including wire 62 and shunt winding 31 to the terminal 24 on wire 60. During this cranking operation the lever 38 of relay 90 is in unattracted or down position, but when the engine becomes self-operative and the dynamo 49 begins to function as a generator, the lever 38 is attracted and a circuit is closed through winding 121 of load switch 120 with the result that the armature 61 is attracted or raised to close the charging circuit above described and to short circuit the series winding 59 whereby the generator which started to function as a differential compound generator is changed to a simple shunt generator. The circuit through winding 121 to terminate the cranking or starting function and to commence the charging function, is closed through contacts 43 and 44 of the relay 90.

The change from a differential compound generator to a simple shunt generator is attended with an immediate rise in voltage as is well understood by those skilled in the art, consequently, the engine being self-operative, it is not necessary nor

desirable to delay connecting up the charging circuit until the generator speed has increased sufficiently to cause a reversal of the current in the series relay winding 32. It is preferable to make the change before the cranking current through the winding 32 has fallen to zero, and at a generator speed which will immediately result in charging the battery when the generator characteristics are changed from differential compound to simple shunt, as already explained.

Therefore the relay is constructed to change the characteristic of the dynamo from differential to shunt while yet there is some discharge from the battery. Assume that it is desirable to have the contacts 43 and 44 closed for the purpose of changing the generator characteristics when the battery discharge to the dynamo falls to 5 amperes and that these contacts should remain closed for all smaller values of discharge current down to zero as well as for all values of charging current, that is, current from the generator to the battery. On the other hand, it is desirable that the contacts 43 and 44 should remain open at all times during the cranking operation, so that the dynamo operating as a motor may have series characteristics and consequently high starting torque. This cranking current may attain as high a value as 70 amperes when the cranking circuit is first closed and then fall to a lower value which, for example, may be as low as 14 amperes, the current values depending on how easy it is to start the engine cranking and then to continue to turn the engine over.

It is also desirable to have contacts 43 and 44 reopen whenever for any reason the dynamo ceases to charge the battery and the battery discharges to the dynamo. It will be obvious from the characteristics of the relay 90, if the contacts 43 and 44 close when the discharge current falls to 5 amperes, that it will require a larger discharge current to reopen the contacts 43 and 44, but such discharge current must at the same time be less than the minimum cranking current of 14 amperes, for otherwise if the battery discharge were to attain to 14 amperes before contacts 43 and 44 opened, then, under the most favorable cranking conditions, the battery might continue to discharge into the dynamo to operate it as a motor until the battery were discharged. On being opened the relay contacts, as disclosed in the copending application referred to, cooperate with other circuits to cause the dynamo to be disconnected from the battery to prevent further discharge. For the understanding of the present invention it is not necessary to go into further detail. But it is important to note that it is desirable to cause the con-

tacts 43 and 44 to reopen when this battery discharge value is as near as possible to that lower discharge value (5 amperes in the example given) at which these contacts close.

In the example given the following conditions are imposed on the relay 90—(minus values denote battery discharge):

Contacts 43 and 44 must close at minus 5 amperes and remain closed from minus 5 to zero and for all plus values must reopen for minus values of current but little in excess of minus 5 amperes and must remain open for all larger minus values.

To accomplish all this, coil 31 is constructed so that if the potential across its terminals is 32 volts, for example, the magnetism produced by it will be more than enough to overcome the attraction of gravity. It is found satisfactory to construct coil 31 so that it will provide 207 ampere turns of magnetism when the voltage is 32. Coil 31 may be called the plunger actuating coil, and, within the limits of "cut in" and "cut out" current values in coil 32 the voltage across coil 31 will be practically constant. Hence coil 31 will exert a substantially constant pull on the plunger 33.

Coil 32 may be called the modifying coil since it determines when coil 31 shall close or open the contacts 43, 44 by attracting the plunger 33 or releasing it.

In the conventional reverse current relay, the series coil is usually wound around and is co-extensive with the length of the shunt coil. If such an arrangement of the coils were employed in the present relay, the turns in the series coil would need to be limited so that its ampere turns, when the maximum cranking current is passing through it, would not be sufficient to cause the field of the series coil to be strong enough to attract the plunger to close the relay contacts.

However in the present invention the series coil 32 is placed immediately below the shunt coil 31 and below the upper end of the plunger 33 with beneficial results enabling the difference between the "cut in" and "cut out" current values of the relay producing the upward and downward movements of the plunger respectively, to be made much smaller than possible if the conventional arrangement of relay windings were followed. Since coil 32 is below coil 31 and below the upper end of plunger 33, coil 32 will always tend to move the plunger 33 downwardly, when the field produced by coil 32 opposes that produced by coil 31, therefore no concern may be given to limiting the turns of coil 32 simply because the cranking current may reach a high value such as 70 amperes.

In the present relay, when the coil 31 is opposing the coil 32, that is, assuming the

northseeking poles of the coils are opposing one another, the tendency for the flux produced by winding 31 will be to pass down through the core 29, across the air space to the bracket 21 and frame 28, returning to the bolt 26. In a similar manner, the flux due to the coil 32 will pass upwardly through plunger 33 across the air space to the bracket 21 and frame 28, then downwardly through the bracket 21 and frame 28 and through the air space to the lower end of plunger 32. There is thus a very strong leakage field from the core 29 and plunger 33 to the magnetic bracket 21 and frame 28. Since a movable plunger will always tend to place itself inside the solenoid so that the total flux passing through this solenoid is a maximum, plunger 33 which includes a portion extending above the coil 32, will tend to move downwardly when the flux of coil 32 opposes that of coil 31 and this occurs in spite of the fact that there is theoretically a resultant magnetic motive force due to the magnetic motive force of coil 32 less that of coil 31, tending to send flux around the complete magnetic circuit.

It has been found satisfactory to use 18 turns in the coil 32, and it has been observed that when minus 5 amperes flow in coil 32, the field of coil 31 is strong enough to attract the plunger 33 to cut in contacts 43 and 44. It has been observed that when between minus 7 and minus 8 (about minus 7.8) amperes flow in coil 32, the plunger 33 will be released to cut out the contacts 43 and 44. Therefore the differential is but 2.8 amperes or about 50 ampere turns.

Even if the differential were 50 ampere turns in both the present invention and in the conventional relay, it is apparent that the differential in amperes alone must always be greater in case of the conventional relay, because the number of turns is limited, as stated. For example, suppose coil 32 were around the coil 31 as in the conventional relay, then if coil 31 develops 207 ampere turns, and coil 32 develops but 90 ampere turns of opposing magnetism, then the resultant is 117 ampere turns which we will assume to be sufficient to attract the plunger. Now suppose that coil 32 were to develop more than 324 ampere turns of opposing magnetism, as it might easily do with a high cranking current, the resultant would also be 117 ampere turns of opposing magnetism which would likewise cause the plunger 33 to be attracted towards the core 29. Hence, if coil 32 of the conventional relay is to carry as much as minus 70 amperes of current, then the turns must be limited to approximately 4.6. The differential being 50 ampere turns, the differential in amperes would be $50/4.6$ or about 11.5 amperes. From the statement of the problem it is evi-

dent that such a large differential in current will render the conventional type of relay unsuited for the present purpose.

In a relay of the conventional type having 5 coils of the same electrical dimensions as the present invention it has been observed that the differential in ampere turns cannot be made as low as 50. It has been observed that if the "cut in" value is about minus 5 10 amperes, the "cut out" value will be about minus 15 or 16 amperes which is more than the minimum current required to keep the dynamo running as a motor to crank the engine. Therefore it is believed that the low 15 differential possible in the present invention is the result of placing the shunt and series coils end to end.

As long as the series coil 32 of the present invention carries minus (battery discharge) 20 current the fields of coils 31 and 32 are opposing, that is, their magnetic fields are tending to repel one another because like poles are adjacent. It is believed that each field tends to crowd the other away from a 25 zone of influence upon the upper end of the plunger. Observation tends to indicate that as the field of coil 32 weakens the field of coil 31 is crowded less above its lower end; and that as the field of coil 32 increases the 30 field of coil 31 is crowded above from its lower end. A study by means of iron filings of the flux paths of the two coils seems to indicate that there is a line of separation of the flux paths of these coils above the upper 35 end of the coil 32 when this coil carries minus 5 amperes or more of battery discharge current. This line is indicated by the line 50 in Figs. 2 and 3. The flux path of the field of coil 32 tends to stay below 40 this line and the flux path of the other field above this line. Line 50 may be called the parting line since it denotes a line of separation when the fields are repelling one another. The line 50 in Fig. 2 indicates approximately the location of this parting line 45 when coil 32 is producing a relatively strong field opposing the field of coil 31. The line 50 in Fig. 3 indicates approximately the position of this parting line when the opposing field of coil 32 is relatively weak. 50

As the minus current in coil 32 increases this line appears to move closer to the core 29, and vice versa as the minus current approaches zero. Therefore it is believed that 55 as the current in coil 32 changes from minus 5 to minus 7.8 amperes in the example given, the ability of coil 32 to pull the plunger 33 down is caused by extending the field of coil 32 and at the same time crowding the 60 flux of the field of coil 31 away from a zone of attracting influence upon the plunger 33. It is believed that as the parting line 50 is moved from the position shown in Fig. 3 to the higher position shown in Fig. 2, the effectiveness of the turns in coil 31 located be-

low line 50 is reduced. By reason of the immediate presence of the repelling field of coil 32, the flux of these turns of coil 31 are not permitted to link up with the main flux path of coil 31. 70

To summarize, it is believed that the small differential between the "cut in" and "cut out" current values of the relay has been brought about by so locating the shunt and series coils that for all minus (battery discharge) 75 current values the series coil will always pull the plunger away from the shunt coil. Therefore more turns can be employed in the series coil than if conventional constructions were followed. The 80 shunt and series coils are arranged so that one field may crowd the other and that a line or zone of separation will occur adjacent the end of the plunger which may be common to both fields, with the result that 85 a relatively small differential in ampere turns is the result. Since this differential is relatively small and the number of turns in the series coil is relatively large for reasons stated, than in the equation, amperes dif- 90 ferential equals the fraction

$$\frac{\text{ampere turns of differential}}{\text{number of turns}}$$

this quotient has been reduced in the present 95 invention by decreasing the numerator and increasing the denominator of the fraction.

When the current in coil 32 is reversed, as during battery charging, then coils 31 and 32 act cumulatively and produce a field tend- 100 ing to hold the plunger 33 in upper position.

A lost motion connection has been provided between plunger 33 and lever 38 so that slight fluctuations in current will not produce intermittent separation of contacts 105 33 and 34. If the plunger rises from the position shown in Fig. 2 until the clearance between lever 38 and nut 37 is taken up, or falls from the position shown in Fig. 3 until nut 36 rests on spring 41, the plunger 110 will complete its movements in these respective directions, and the closing or opening of the contacts will be quick and positive.

While the form of mechanism herein 115 shown and described constitutes a preferred embodiment of one form of invention, it is to be understood that other forms might be adopted and various changes and alterations made in the shape, size, and proportion of the elements therein without departing from the spirit and scope of the invention. 120

What is claimed is as follows:—

1. In a relay, the combination with a movable magnetizable member; of a magnet 125 tending to move said member in a certain direction; and an electromagnet tending to move the member in another direction when current flows in a certain direction in said electromagnet, but tending to move the mem- 130

ber in the first mentioned direction when current flow is reversed.

2. In a relay, the combination with a movable magnetizable member; of magnet for attracting the member toward it; an electromagnet surrounding the movable member and capable of producing a field repelling the field of the first magnet and thereupon tending to attract the member away from the first magnet, but upon reversal of current producing a field which cooperates with the field of the first magnet so as to produce attraction of the member toward the first magnet.

3. In a relay, the combination with a magnet and an electromagnet which are juxtaposed so that their fields will repel each other when current flows in the electromagnet in a certain direction and so that their fields will be linked into a common field when current flows in the electromagnet in the opposite direction; and a movable magnetizable member normally decentered with respect to the common field in a direction away from the first magnet and normally decentered with respect to the field of the electromagnet in a direction toward the field produced by the first magnet.

4. In a relay, the combination with a coaxial juxtaposed magnet coil having repellent fields when current flows in one of the coils in a certain direction and a common field when current is reversed in said coil; and a movable magnetizable member surrounded by the coil in which direction of current is reversed and normally decentered with respect to the common field and normally decentered with respect to the field of the last mentioned coil in the direction of the other coil.

5. In a relay, the combination with coaxial juxtaposed magnet coils, one for providing a substantially constant field strength and the other a field of variable strength, the fields of the coils being repellent when current flows in the second coil in a certain direction and the fields being united into a common field when current flow in the second coil is reversed; and a movable magnetizable member surrounded by the second coil and normally decentered with respect to the common field in a direction away from the first coil and normally decentered with respect to the field of the second coil in a direction toward the first coil.

6. In a relay, the combination with coaxial juxtaposed magnet coils, one for providing a substantially constant field

strength and the other a field of variable strength, the fields of the coils being repellent when current flows in the second coil in a certain direction and the fields being united into a common field when current flow in the second coil is reversed; a magnetizable core within the first magnet and having its end nearest the second coil spaced from the second coil; and a movable magnetizable member surrounded by the second coil and having a portion normally within the first coil but spaced from said core, the member being normally decentered with respect to the common field in a direction away from the core and normally decentered with respect to the field of the second coil in a direction toward the core.

7. In a relay, the combination with a movable magnetizable member; of a magnet tending to move said member in one direction; and an electromagnet for modifying the effect of the first magnet so that when current flowing in the electromagnet exceeds a certain value the member will be moved magnetically in the opposite direction, and when the current flowing in the electromagnet falls below a certain value the member will be moved magnetically toward the first magnet.

8. In a relay, the combination with a movable magnetizable member; of a magnet tending to move said member in one direction; and an electromagnet for modifying the effect of the first magnet so that when current flowing in the electromagnet exceeds a certain relatively low value the member will be moved magnetically in the opposite direction, and when the current flowing in the electromagnet falls below a certain value slightly less than the first mentioned value, the member will be moved magnetically toward the first magnet.

9. In a relay the combination with a movable magnetizable member; of a magnet tending to move said member toward said magnet, and an electromagnet for modifying the effect of the first magnet so that when current flowing in a certain direction in the electromagnet exceeds a certain value the member will be moved magnetically away from the first magnet, and when the current in the electromagnet falls below a certain value or is reversed the member will move toward the first magnet.

In testimony whereof I hereto affix my signature.

JOSEPH C. FEDERLE.