Sept. 20, 1938. E. W. BOEHNE 2,130,871

HIGH SPEED TRIPPING SYSTEM

Filed Aug. 4, 1936 2 Sheets-Sheet 1

Fig. 1.

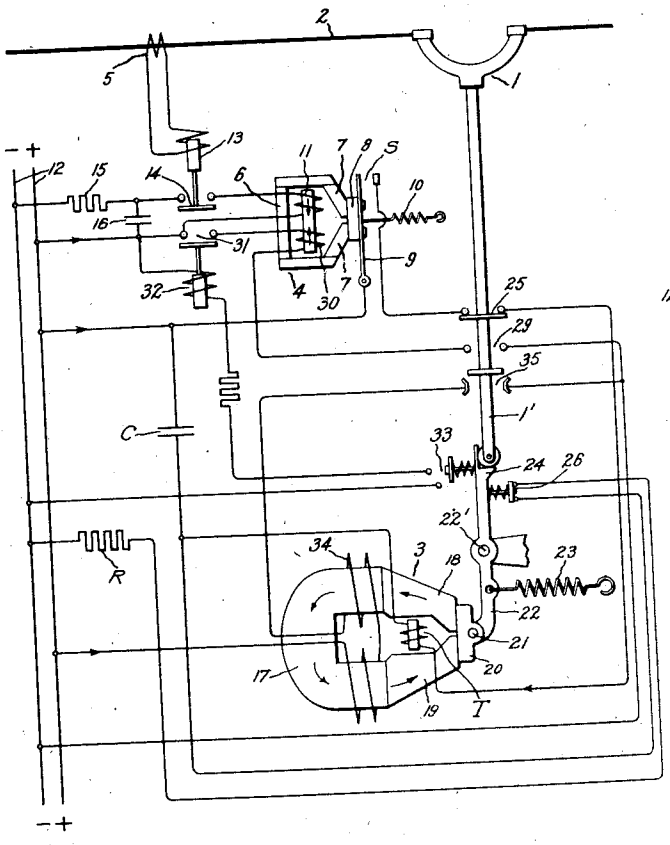


Fig. 2.

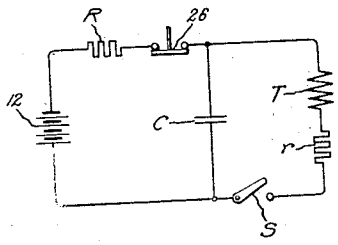


Fig. 9.

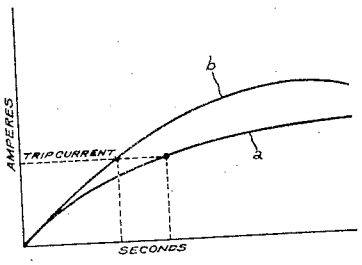


Fig. 3.

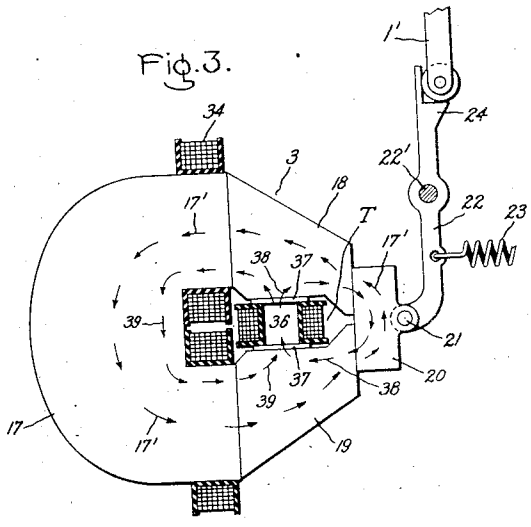
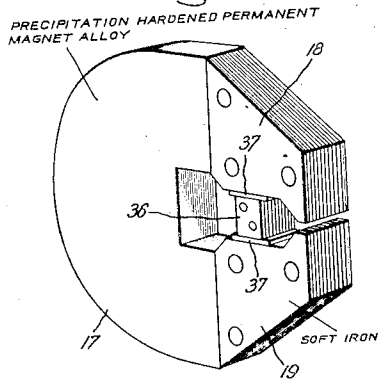


Fig. 4.



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Fig. 7.

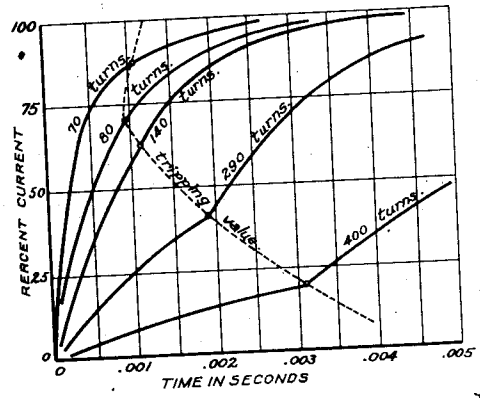


Fig. 5.

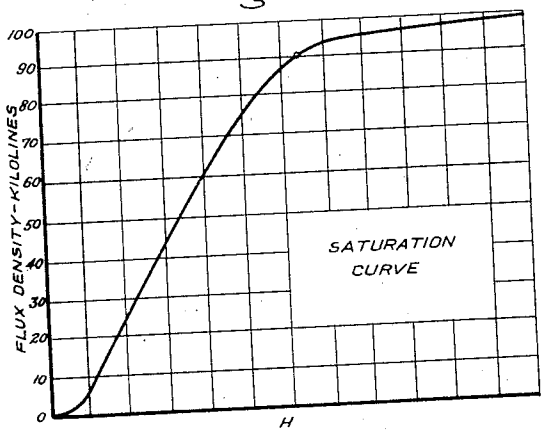


Fig. 8.

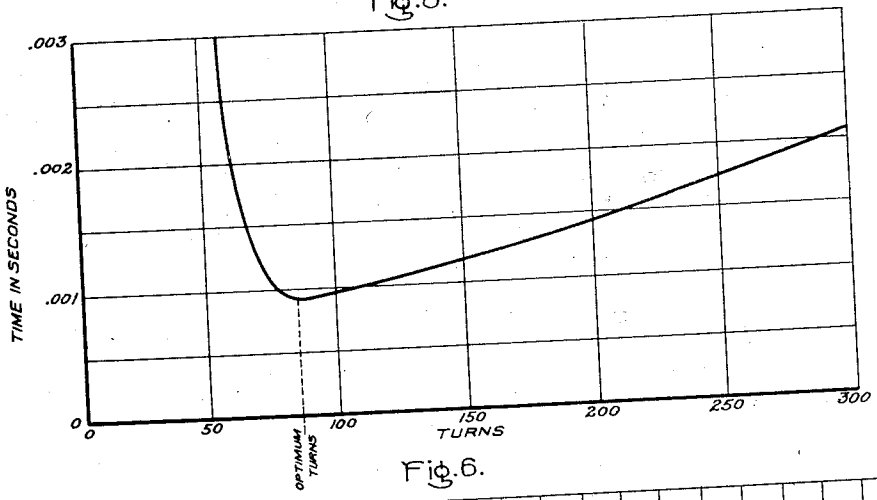
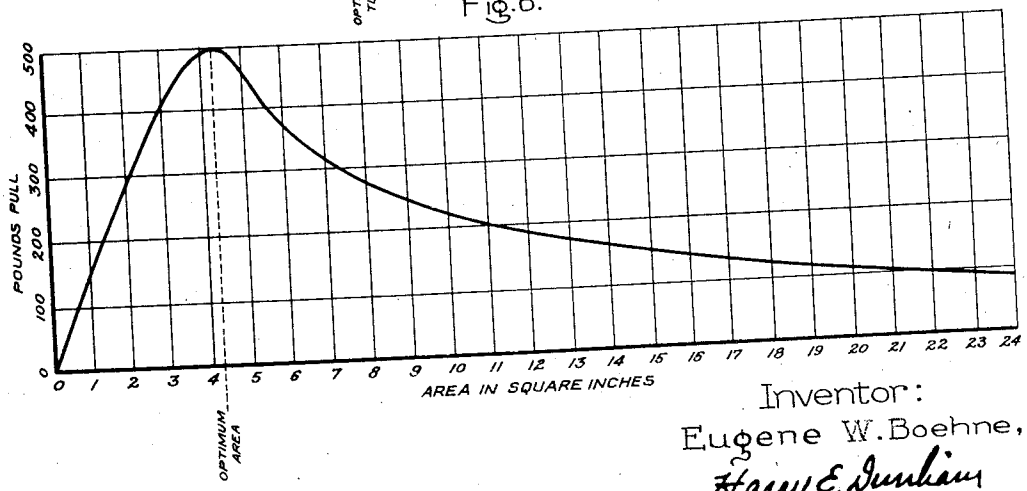


Fig. 6.



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2,130,871

UNITED STATES PATENT OFFICE

2,130,871

HIGH SPEED TRIPPING SYSTEM

Eugene W. Boehne, Yeadon, Pa., assignor to General Electric Company, a corporation of New York

Application August 4, 1936, Serial No. 94,220

11 Claims. (Cl. 175—294)

My invention relates to high speed releasing devices, such as for example those applied to the tripping mechanism of an electric circuit breaker for initiating high speed opening of the breaker. The control of many other high speed operations, such as the quick automatic application of breakers to rotating equipment is also contemplated.

In high tension power systems operating at commercial frequencies, the duty of quickly isolating a fault, such as a short circuit for example, falls upon the circuit breakers controlling the affected part of the system. It is, therefore, essential that the circuit breaker completely clear the circuit within a few cycles at the most in order that the stability of the system shall not be upset. The operation of a high tension oil circuit breaker for example to clear the circuit may be divided into several stages; namely, disengagement of the tripping or releasing mechanism in response to a fault condition, initiation of opening movement of the breaker contact structure in response to release thereof, and opening movement of the contacts coincident with the arc-interrupting operation. The present invention is primarily concerned with the first stage of operation, the last two stages relating more specifically to the circuit breaker and its operating mechanism.

A principal object of my invention, therefore, is the provision of an improved high speed tripping or releasing device which is effective appreciably to reduce the tripping time over that heretofore attained.

My invention will be more fully set forth in the following description referring to the accompanying drawings, and the features of novelty which characterize my invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

Referring to the drawings, Fig. 1 is a partly diagrammatic view of a circuit breaker operating system embodying the present invention; Fig. 2 is a simplified circuit diagram of circuit constants involved in Fig. 1; Fig. 3 is a view of the tripping magnet generally shown in Fig. 1; Fig. 4 is a perspective view illustrating the structure of the magnet shown by Fig. 3, and Figs. 5–9, inclusive, are graphs relating to the tripping magnet and circuit design factors. The circuit breaker operating system illustrated by Fig. 1 comprises an electric circuit breaker generally indicated at 1 for the high tension power circuit 2, the circuit breaker being controlled by a tripping magnet 3, which is in turn controlled by a relay 4 and current transformer 5. The operation in general is similar to the conventional method of tripping the breaker, that is in response to a fault condition in the high tension power line 2, such as a short circuit for example, the current transformer 5 causes energization of the relay 4, which in turn energizes the tripping or releasing means 3 for opening the breaker 1.

The operation and arrangement of the relay system which comprises no part of the present invention are specifically described and claimed in my copending application for control devices and systems, Serial No. 94,219, filed concurrently herewith and assigned to the same assignee as the present invention.

The relay 4 comprises a permanent magnet 6 having soft iron pole pieces 7 and a coacting armature 8 carried on a pivoted contact arm 9. The operation of the armature 8 controls the contacts of the relay switch indicated at S. The magnetomotive force produced by the permanent magnet 6 normally maintains the armature 8 in the closed magnetic circuit position shown against the bias of spring 10. When this magnetomotive force is overcome by the spring 10, the relay switch S is closed. For the purpose of controlling release of the armature 8, a solenoid or tripping coil 11 is related to the magnetic circuit above described so that energization of said coil from the direct current control source 12 causes release of the armature 8 and closing of the relay switch S. To this end the current transformer 5 causes in response to predetermined current in the line 2 actuation of the solenoid 13 for closing the control circuit at 14. The relay control circuit also includes a current limiting series resistance 15 and a capacitance 16 connected across the coil 11 when the contacts at 14 are closed. It will, therefore, be apparent from the above description that predetermined energization of the current transformer 5 is effective to cause actuation of the relay 4 and closing of the relay switch S.

The tripping or releasing device 3, which is controlled by the relay 4, also includes a permanent magnet 17, soft iron pole pieces 18 and 19 and an armature 20 of similar material. The armature 20 is carried at 21 by a latch member 22 pivoted at 22' and biased by a tension spring 23 away from the magnet. The latch 22 is provided at its opposite end with an abutment 24 arranged to engage and hold as generally indicated, the operating rod 1' of the circuit breaker in the closed circuit position. Normally, the magnetomotive force produced by the permanent magnet 17 is effective to hold the armature 20

in the closed magnetic circuit position against the bias of spring 23.

The tripping magnet 3, as in the case of relay 4 includes a tripping solenoid or coil T which is arranged when energized from the control source 12 to produce a flux in the magnetic circuit of the magnet opposing that produced by the permanent magnet in that portion of the magnetic circuit including the soft iron armature 20. This relationship is such that energization of the trip coil T so weakens the holding force at the armature 20 that the armature spring 23 rotates the latch 22 in a counterclockwise direction, thereby releasing the breaker operating rod 1' and permitting opening of the breaker. This general type of tripping device commonly known as the "flux-shifting" type, is shown for example by Tritle Reissue Patent No. 15,441 of August 29, 1922.

Energization of the trip coil T may be effected when the breaker 1 is closed by closing the relay switch S. The control circuit so established includes the control source 12, relay switch S, auxiliary switch 25, which is controlled by the breaker 1 and assumes similar circuit controlling positions thereto, magnet trip coil T, auxiliary switch 26 which is controlled by the latch 22 so that it is closed in the holding position of the latch and vice versa, and series resistance R which is chosen, in a manner hereinafter described, in accordance with the characteristics of the tripping circuit. A capacitance C, which also is chosen in accordance with the desired characteristics of the tripping circuit, is connected across the trip coil T when the relay switch S is closed, as diagrammatically illustrated by Fig. 2.

Immediately upon release of the latch 22 in response to a tripping impulse, the latch controlled auxiliary switch 26 is opened, instantly deenergizing the trip coil T. Also, the circuit breaker in moving to open circuit position causes opening of the auxiliary switch 25, which is also in series with the relay switch S. The latch controlled auxiliary switch 26 operates considerably faster than the breaker controlled auxiliary switch 25, the latter serving more as a back-up switch for insuring that the circuit of the trip coil is open when the breaker is open.

The breaker also controls auxiliary switch contacts at 29 included in the control circuit of the resetting coil 30 of the relay 4. Likewise included in the circuit of the resetting coil 30 are contacts indicated at 31 controlled by a solenoid 32 which is in turn energized from the control source 12 through another auxiliary latch controlled switch at 33. Accordingly, release of the latch 22 causes closing of the auxiliary switch at 33, energizing of the solenoid 32 and closing of the control circuit at 31. Therefore, when the cricuit at 29 is also closed the resetting coil 30 is energized from control source 12, thereby attracting the armature 8 to the holding position shown. In this position the relay switch S is open.

If desired, the permanent magnet 17 may be provided with an exciting coil 34 which is but momentarily energized from the control source 12 by the breaker controlled auxiliary switch at 35. That is, in moving to the closed circuit position the breaker rod 1' causes momentary closing of the exciting coil circuit at 35 so that the permanent magnet is recharged, so to speak, to its original magnetomotive force.

The resetting of the latch 22 when the circuit breaker is to be reclosed can be accomplished in any suitable manner, such as by a mechanical connection (not shown) operatively interconnecting the breaker closing mechanism (also not shown) and the latch 22. Since the relay 4 is immediately reset after the circuit opening operation, the magnet trip coil T cannot again be energized prior to another actuation of the relay 4. The latch 22 can also be manually tripped if desired.

Referring more particularly to the tripping device 3, the permanent magnet portion 17 is preferably composed of a magnetic alloy comprising a precipitation hardened product, basically an iron-nickel-aluminum alloy, and specifically a nickel-iron-aluminum and cobalt alloy of the character described and claimed in Rudner Patents 1,947,274 and 1,968,569. This magnetic alloy has certain highly desirable qualities for a permanent magnet material, such as for example magnetomotive force greatly in excess of that of ordinary permanent magnets. The pole pieces 18 and 19, referring to Figs. 3 and 4, are composed of soft iron laminations, and are designed so as to collect the flux produced by the permanent magnet and concenerate it at that portion of the magnetic circuit including the soft iron armature 20. The flux produced by the permanent magnet 17 in the closed magnetic circuit including the armature 20 can be generally designated by the flux arrows 17'.

The trip coil T, which includes a soft iron laminated core 36 spaced by non-magnetic members 37 from the pole pieces 18 and 19, is positioned in shunt with respect to the aforesaid magnetic circuit so that when the coil T is energized from the control source 12 the flux produced thereby tends to take two paths, namely the path including the armature 20 indicated by the flux arrows 38, and a path through the permanent magnet indicated by the flux arrows 39. Therefore, the flux produced by the coil T is in the same direction as the main flux in the magnetic circuit including the permanent magnet thereby having a magnetizing effect on the permanent magnet, and in the opposite direction in that part of the circuit including the armature 20. Accordingly, the holding flux at the armature 20 is weakened a predetermined extent so that the spring 23 is effective to pull the armature away from the magnet.

In designing the magnetic path of the magnet including the armature 20, the force required to move the latch 22 is primarily taken into account. In the present instance, wherein the latch is used for tripping a large high tension power breaker, the spring 23 is designed for a pull of approximately 300 pounds. Accordingly, in the holding position the magnet must exert a pull in excess of this, such as 500 pounds for example. Knowing the required pull at the armature, the magnetomotive force and the size of the permanent magnet are chosen and the optimum area of the armature for maximum pull determined in accordance with known design (Figs. 5 and 6).

Since the magnetomotive force of the permanent magnet material is definitely known, the soft iron laminated pole pieces 18 and 19 are designed to collect the flux from the inherently low density area at the abutting surface of the magnetic alloy and concentrate it at a comparatively small high density area at the armature. This is determined by the formula $F=.014B^2A$, where F is the force in pounds, A is the armature area in square inches and B is the flux density in kilolines per square inch. Fig. 5 is the B—H or

saturation curve for the armature metal. Knowing the most efficient point for operation on the saturation curve, the optimum area of the armature for maximum force may readily be computed. Fig. 6 illustrates the relationship between effective armature pull and the area of the armature.

Heretofore tripping magnets of the character in question utilized an electromagnet energized from a direct current source rather than a permanent magnet, hence soft iron comprised the main, if not the entire part, of the magnetic circuit including the armature. In accordance with the present invention, part of the magnetic circuit including the ineffective path of the trip coil flux has comparatively high reluctance so that the tripping flux is concentrated at the armature where it is most effective. Since the division of tripping flux between its two paths 38 and 39 (Fig. 3) depends on the reluctance of these paths, it will be seen that a high reluctance path through the permanent magnet and a comparatively low reluctance path through the armature 20 are desirable. This is accomplished by using the precipitation hardened magnetic alloy of the character above described for the permanent magnet since this alloy has a permeance of 2 as compared with 1 for air and 1000 to 2000 for iron. This practically amounts to an open circuit for that part of the trip coil flux 39.

Referring again to Fig. 3, it will therefore be apparent that the flux indicated at 39 would be weak as compared with the magnet "bucking" flux at 38. This insures faster building up of the bucking flux in the armature to a tripping value. Also the soft iron laminated pole pieces 18 and 19, which are particularly designed for low losses form for the trip coil flux 38 a path permitting a high rate of flux build-up.

The most marked increase in tripping speed over prior devices of this character is obtained, however, by design of the trip coil T. Heretofore a comparatively large number of ampere turns of the trip coil were considered not only desirable but essential for effective tripping on the assumption that a large tripping flux was most effective. For example, in a well known commercial form of tripping device using a direct current electromagnet having a magneto-motive force of the degree in question, the trip coil is designed for approximately 500 turns. I have found that by appreciably reducing the number of turns a predetermined amount and by inserting in the trip coil circuit externally of the trip coil a compensating non-inductive resistance, the flux required for tripping builds up in the armature at a much higher rate. In other words, the armature 20 is released by the spring 23 in much shorter time when the trip coil is designed in accordance with my invention since the bucking flux at 38 more quickly reaches a value counteracting the main magnet flux.

Figs. 7 and 8 illustrate graphically the improved operation when the trip coil is designed in accordance with my invention. The value H, or number of ampere turns in terms of force required to trip the armature is readily known i. e. the difference between the magnet pull and the spring pull or approximately 200 pounds. With a given source of direct current voltage and a fixed magnitude of ultimate trip coil current, I have found that by properly relating noninductive external resistance to a reduced number of turns there results not only a new value of ultimate current for tripping but also a great decrease in tripping time until the optimum number of turns is reached as graphically illustrated by Fig. 7.

It will be noted from this graph that for a trip coil of the usual number of turns, such as from 400 to 500 for example, the tripping current, although being a small part of the ultimate trip coil current, nevertheless requires approximately .003 second in order to bring the tripping flux up to its effective value. The coil having eighty turns, however, although requiring a higher percentage of the ultimate trip coil current to produce tripping, is effective to cause tripping of the armature in less than .001 second. It will, therefore, be apparent that tripping speed may be appreciably increased by properly relating the factors above referred to.

The relationship between the tripping time and the number of turns of the trip coil T is graphically illustrated by Fig. 8 which clearly shows that the tripping time for a given ultimate maximum current is increased if the number of turns of the trip coil is decreased or increased with respect to the optimum value, this value being approximately eighty turns in the present instance.

This is in decided contrast to prior practice wherein it was assumed that greater tripping flux would produce high speed tripping and wherein it was customary to include practically all of the current limiting resistance in the trip coil itself. A detailed analysis of the electrical conditions involved in this high speed tripping is believed to be unnecessary for a complete understanding of the present invention, other than to point out that the inductance of the trip coil is reduced by the reduction in the number of coils, and this decreased inductance is connected in series with an external non-inductive resistance for fixing the ultimate trip coil current.

It may be noted at this point that the latch controlled auxiliary switch 26, which operates practically instantly on tripping, limits the trip coil current to approximately its tripping value, that is about 70 per cent of the ultimate value as indicated by Fig. 7.

Although the above described tripping device is several times faster than any other releasing or tripping device known to me, the tripping operation may be even further speeded up by connecting a capacitance C across the trip coil as diagrammatically illustrated by Fig. 2. The capacitance C is connected on the coil side of the auxiliary switch 26 and on the supply side of the relay switch S. Accordingly, when the auxiliary switch 26 is opened in accordance with a tripping operation to interrupt the trip coil current, the capacitance prevents a high inductive surge by acting as a reservoir for the stored energy in the coil T.

When the breaker is closed, the auxiliary switch 26 is closed and the relay switch open so that closing of the switch S not only completes the trip coil and battery circuit but also completes a shunt circuit including the capacitance C and the trip coil. Since the capacitance remains charged at the voltage of the source or battery 12 when the switch S is open, closing of this switch causes a rapid discharge through the trip coil, thereby increasing the rate of building up of the tripping current. That is, the capacitance in shunt with the direct current source acts as a transient "booster" in speeding up energization of the trip coil.

The improved operation due to the capacitance C can be understood from the following analysis.

When the new steady value of the current is reached,

$$I=\frac{E}{R+r}$$

where r is the internal resistance of the trip coil. The voltage across the condenser will have dropped from

$$E \text{ to } \frac{E(r)}{(R+r)}$$

and therefore the charge reduced from

$$Q_1(=CE) \text{ to } Q_2\left(=\frac{(r)CE}{(R+r)}\right)$$

This difference in charge, or

$$Q_1-Q_2=CE\frac{(R)}{(R+r)}$$

or

$$\int_0^t i\,dt$$

results in much faster building up of the trip coil current, which in turn results in a decided improvement in tripping speed. It also follows that for best use of the capacitance, the ratio

$$\frac{R}{r}$$

should be comparatively large.

The effect of the capacitance C in the present instance is graphically illustrated by Fig. 9 wherein curve "a" represents the circuit of Fig. 2 without capacitance and curve "b" represents the circuit as shown. It will be noted that the current reaches the tripping value on curve b in appreciably less time than in the case of curve a.

It should also be noted that the optimum number of turns of the tripping coil is still further reduced when the capacitance is included in the control circuit, as compared with the circuit without the capacitance.

It shall be understood, of course, that the above described improvements in the trip coil circuit can be applied generally to a tripping magnet, regardless of whether the magnetomotive force is supplied by an electromagnet or permanent magnet. Also the relay 4 is preferably similarly designed so that closing of the relay switch S takes place practically instantly in response to a fault condition.

It should be understood that my invention is not limited to specific details of construction and arrangement thereof herein illustrated, and that changes and modifications may occur to one skilled in the art without departing from the spirit of my invention.

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

1. A high speed releasing device comprising means forming a magnetic circuit including a relatively movable armature, biasing means for causing relative movement of said armature and said magnetic circuit, a source of magnetomotive force normally holding said armature and circuit in closed magnetic circuit position against said bias, a tripping coil having a magnetic path related to said magnetic circuit so as to produce a flux in that part of the magnetic circuit including said armature opposing that produced by said magnetomotive force, the number of turns of said coil being related to the impedance of the circuit externally of said coil for effecting an optimum with respect to the rate of the building up of said tripping flux in said armature and means for controlling energization of said tripping coil.

2. A high speed releasing device comprising means forming a magnetic circuit including a relatively movable armature, biasing means for effecting relative movement between said magnetic circuit and armature, a source of magnetomotive force normally holding said magnetic circuit and armature in closed magnetic circuit position against said bias, a tripping coil positioned adjacent said magnetic circuit for producing a flux in that part of the magnetic circuit including said armature opposing that produced by said magnetomotive force for effecting release of said armature, the number of turns of said coil being related to the resistance of the coil circuit externally of said coil for effecting an optimum with respect to the rate of building up of said tripping flux in said armature, and means for controlling energization of said tripping coil.

3. A high speed tripping magnet comprising a source of magnetomotive force for producing in a magnetic circuit a holding flux, a tripping coil having a magnetic path including a part of said magnetic circuit for producing a tripping flux opposing said holding flux in the said part of the magnetic circuit, and a control circuit for energizing said tripping coil, the number of turns of said tripping coil being related to the constants of the circuit of the tripping coil to effect an optimum with respect to the rate of building up of said tripping flux to the tripping value.

4. A high speed tripping magnet comprising a source of magnetomotive force for producing in a magnetic circuit a holding flux, a tripping coil magnetically related to said circuit for producing a tripping flux opposing said flux in a part of the magnetic circuit, a control circuit for energizing said tripping coil, and a capacitance in said control circuit arranged to be connected across said tripping coil when said coil is energized for increasing the rate of building up of said tripping flux to the tripping value, the number of turns of said tripping coil being related to the constants of the circuit of the tripping coil to effect an optimum with respect to the rate of building up of said tripping flux to the tripping value.

5. A high speed releasing device comprising means forming a magnetic circuit including a relatively movable armature, biasing means for effecting relative movement of said magnetic circuit and armature, a source of magnetomotive force normally holding said magnetic circuit and armature in closed magnetic circuit position against said bias, a tripping coil having a magnetic path related to said magnetic circuit so as to produce a flux in that part of the magnetic circuit including said armature opposing that produced by said magnetomotive force for releasing the armature with respect to said magnetic circuit, a control circuit having a source of electromotive force for energizing said tripping coil including a normally charged capacitance arranged to be connected in shunt with said tripping coil when said control circuit is closed, said capacitance thereby discharging through said coil so as to increase the rate of the building up of said tripping flux in said armature, said capacitance by reason of said shunt relationship also serving to absorb the stored energy of said coil when said shunt circuit is disconnected from said source.

6. A high speed tripping magnet comprising a permanent magnet portion and a relatively movable tripping armature normally held in closed magnetic circuit position, means con-

trolled by said tripping armature movable between two positions, an armature releasing coil having a magnetic path related to the magnetic circuit including said armature, a charging coil for said permanent magnet portion, and a switch controlling the circuit of said charging coil arranged to be momentarily closed in accordance with the tripping operation of said armature.

7. A high speed tripping magnet having a magnetic circuit including a relatively movable armature normally held in closed magnetic circuit position by the magnetomotive force of said magnet, means biasing said armature towards open magnetic circuit position, an armature releasing coil having a magnetic path related to the magnetic circuit of said magnet, and an auxiliary switch controlled by said armature for instantly deenergizing said releasing coil in accordance with the release of said armature.

8. A high speed magnet having a magnetic circuit including a relatively movable armature normally held in closed magnetic circuit position by the magnetomotive force of said magnet, means biasing said armature towards open magnetic circuit position, an armature releasing coil having a magnetic path related to the magnetic circuit of said magnet, and a control circuit for said coil including a source of direct current, a non-inductive resistance, a normally open control switch, and a capacitance connected in shunt with said source of direct current and non-inductive resistance, said capacitance being so related to the ohmic resistance of said tripping coil and said non-inductive resistance that closing of said control switch causes an initial discharge from said condenser to said trip coil so as to increase the rate of build-up of the tripping flux of said coil to the tripping value.

9. A high speed releasing magnet of the flux-shifting type comprising a source of magnetomotive force for establishing a holding flux, a tripping coil for establishing a releasing flux, a source of electromotive force for energizing said tripping coil, a capacitance arranged to be connected in shunt with both said source of electromotive force and tripping coil, a non-inductive resistance of appreciable value in the connection between said source of electromotive force and said capacitance, and a control switch adapted to connect said capacitance in shunt with said trip coil for discharging said capacitance through said coil substantially coincident with energization of said coil by said electromotive force, said switch also establishing a circuit whereby said capacitance subsequently absorbs the inductive energy of said coil.

10. A high speed releasing magnet of the flux-shifting type comprising a source of magnetomotive force for establishing a holding flux, a tripping coil for establishing a releasing flux, a source of electromotive force for energizing said tripping coil, a capacitance normally connected in shunt with said source of electromotive force, a normally closed control switch and a non-inductive resistance of appreciable value being included in said shunt connection, and a second normally open control switch for connecting said source of electromotive force in series with said tripping coil and also said capacitance in shunt therewith for causing discharge of said capacitance through said tripping coil substantially coincident with energization of said coil by said source of electromotive force.

11. A high speed releasing magnet of the flux-shifting type comprising a source of magnetomotive force for establishing a holding flux, a tripping coil for establishing a releasing flux, a source of electromotive force for energizing said tripping coil, and a capacitance arranged to be connected in the tripping coil circuit in shunt with both said source of electromotive force and tripping coil, the circuit constant ratio

$$\frac{R}{r}$$

being comparatively large where R is the non-inductance resistance of that part of the circuit including the capacitance and source of electromotive force, and r is the non-inductive resistance of the tripping coil.

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