

[54] ELECTROMAGNETIC SWITCH

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[58] Field of Search..... 335/236, 239, 240, 335/281

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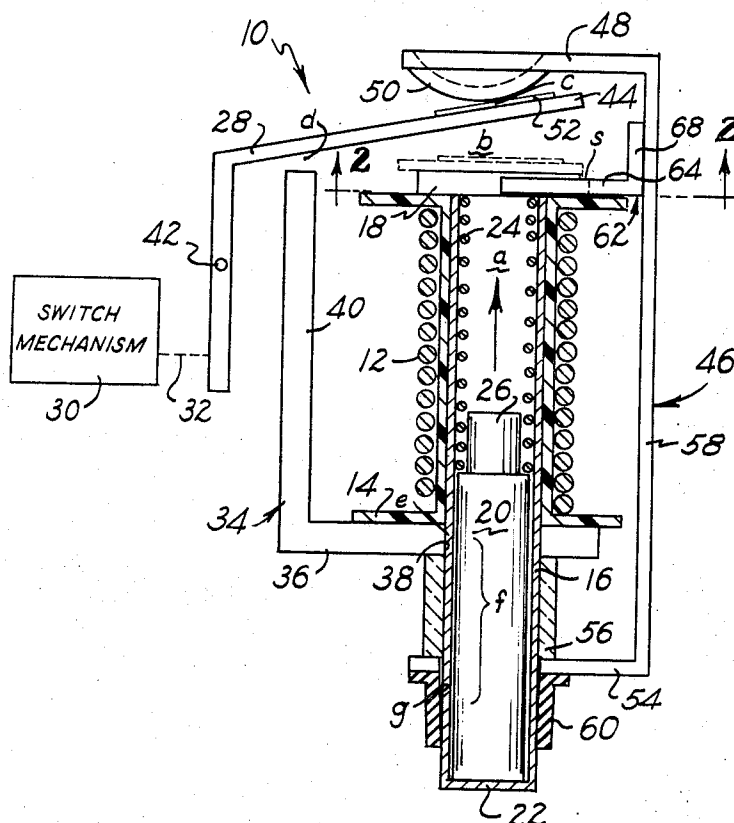
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[57] ABSTRACT

An electromagnetic switch having a flux producing solenoid and a movable armature attractable to the solenoid upon the occurrence of a predetermined current level and duration is provided with flux path means in the form of members of low reluctance arranged so that the flux circuit comprises a plurality of loops, each loop having one or more reluctances which are variable and dependent upon the position of a movable core located within the solenoid and the position of the armature. The arrangement is such that increased pulse resistance is obtained without substantially effecting the operation of the switch upon sustained overloads of a predetermined amount and duration.

10 Claims, 3 Drawing Figures



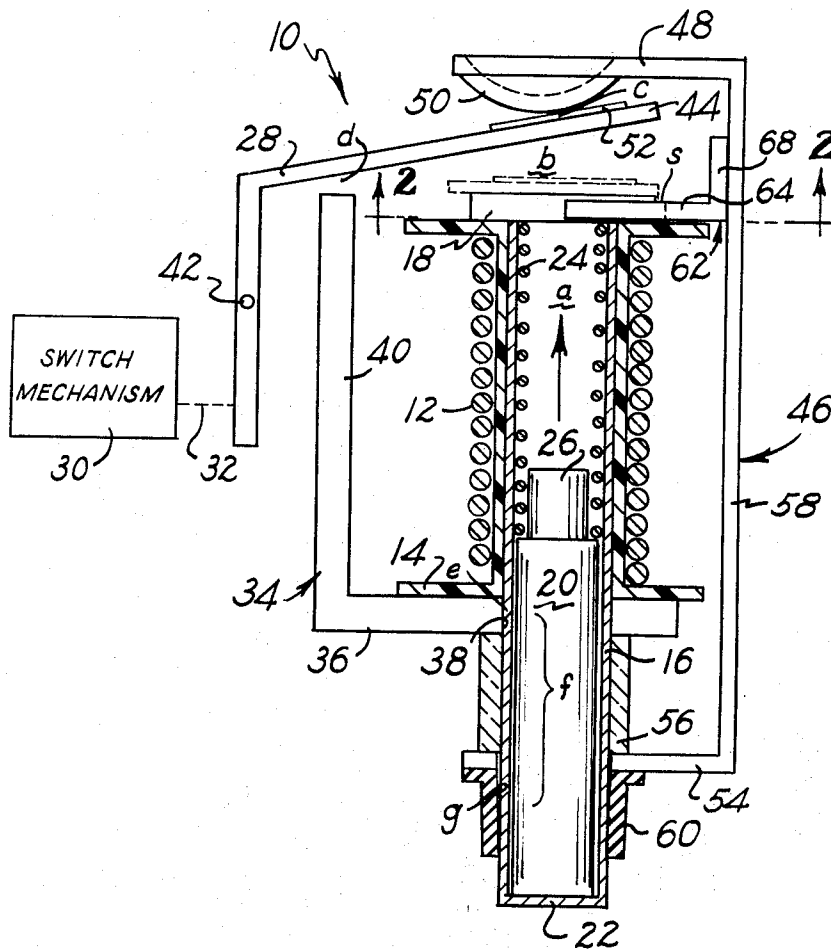


Fig. 1.

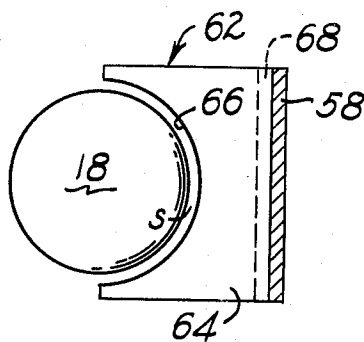


Fig. 2.

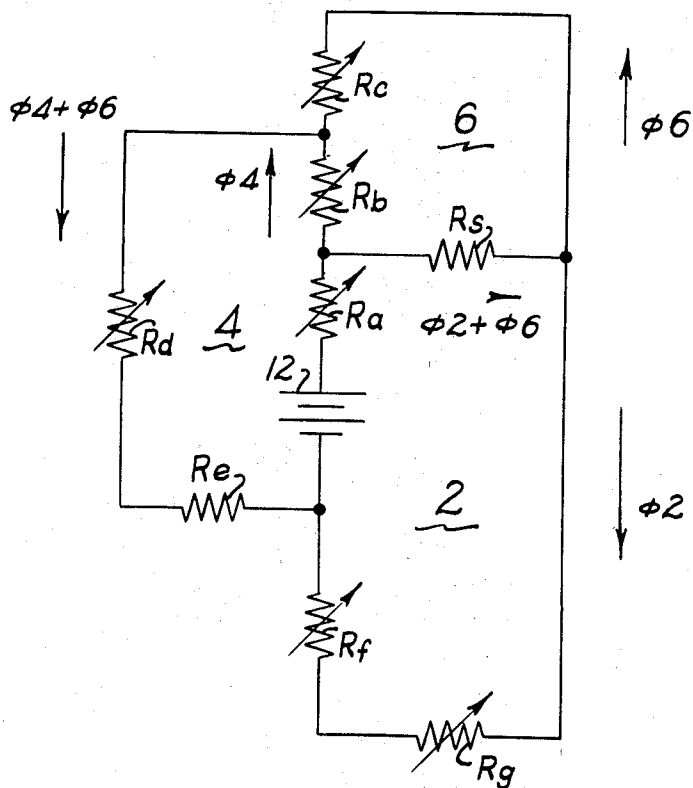


Fig. 3.

ELECTROMAGNETIC SWITCH

This invention relates to electromagnetic switches, and more particularly to a time delay circuit breaker which will allow predetermined transients to pass through the breaker without causing the breaker to trip.

A switch of this type having a solenoid and movable time delay core movably disposed therein is the subject matter of copending and coassigned application Ser. No. 134,997 filed Apr. 19, 1971. In that application the switch is provided with an auxiliary backframe against which the clapper of the armature tripping mechanism rests when the circuit breaker is in the "on" position, this backframe provides an alternate path for the generated magnetic flux. With time delay core down, this path has a smaller total air gap than does the normal tripping flux circuit in the main frame and therefore has a lower total reluctance. When an inrush occurs the magnetic flux generated by the solenoid takes the path of least reluctance which is through the auxiliary frame to complete the flux circuit. The circuit breaker thus withstands the high inrush without tripping. However during sustained overload conditions the core of the solenoid picks up to switch the path of least magnetic reluctance from the auxiliary backframe to the main-frame hereby pulling the clapper down and tripping the circuit breaker. While such a switch is preferred for many applications it has been found that in certain situations it is desirable to pass even larger transients or pulses without substantially effecting the circuit breaking function on normal sustained overloads. In recent years, for instance, computer companies have been emphasizing reduction in size in the design of new generation computers. This emphasis has lead to increased use of high density, ferromagnetic power supplies and distribution transformers. A characteristic of this type of supply is its high inrush or turn-on current spike in the order of 18 times nominal ampere rating. In order to start such equipment it is necessary to pass this pulse of short duration without causing the circuit breaker to trip.

Briefly, in accordance with the present invention the structure of the switch comprises magnetic members arranged so that a flux circuit is formed with three loops each including one or more variable reluctances. The reluctances are in effect switched between high and low values by the movement of a movable core within the flux producing solenoid and the armature. A magnetic bias is applied to the armature by flux passing through one loop during pulses which are to be passed through the switch while some of the additional flux caused by the pulses is diverted into another loop; however upon a sustained overload essentially all the flux passes through the third loop which includes the working gap of the magnetic switch, that is the gap between the clapper and the pole piece of the solenoid. This is accomplished by opening one loop with core pickup and opening and shunting another loop with the closing of the clapper.

Thus among the several objects of the invention may be noted the provision of an electromagnetic switch which is insensitive to pulses of given level and duration. Another object is the provision of such a switch in which essentially all of the flux developed is applied to the clapper during sustained overloads to achieve optimum circuit breaking operation.

Yet another object is the provision of such apparatus which is reliable yet relatively inexpensive, apparatus which is readily calibrated, has few moving parts to maximize longevity and apparatus which can be used with essentially any electromagnetic device having a movable armature. Another object of this invention is the provision of a new and improved magnetic circuit breaker assembly for the protection of electrical circuits and components against sustained overloads and short circuits especially one in which the flux generated is efficiently used both to actuate the circuit breaker and to obviate nuisance tripping. Other objects and features will be in part apparent and in part pointed out hereinafter.

The invention accordingly comprises the elements and combinations of elements, steps and sequence of steps, features of construction and manipulation, and arrangements of parts, all of which will be exemplified in the structures and methods hereinafter described, and the scope of the application of which will be indicated in the appended claims.

In the accompanying drawings in which the preferred embodiment of the invention is illustrated:

FIG. 1 is an elevational view, partly in cross section and partly schematic of the preferred embodiment of the invention;

FIG. 2 is a cross sectional view taken on lines 2-2 of FIG. 1; and

FIG. 3 is an analog flux circuit diagram of the FIG. 1 embodiment.

As stated above, a problem which is commonly associated with electromagnetic switches, particularly when they are used as circuit breakers, is that of nuisance tripping of the device. This refers to interruption of a circuit upon occurrence of a high overload of duration sufficiently short that it is not detrimental to the particular load being protected. An example of a common type of momentary overload is the occurrence of high amplitude transients of relatively short duration occasioned by the switching on an electric power supply. It is desirable in such instances to provide some means to prevent tripping of such a circuit breaker until the overload exists for some predetermined interval of time related to the specific amount of overload. A typical electromagnetic circuit breaker is provided with a time delay mechanism such as a dashpot mechanism in which a core moves through a fluid-filled dashpot chamber. The desired time delay is obtained by retarding movement of the core through the fluid chamber. When the core approaches the pole piece the flux density is increased sufficiently to attract the armature and cause it to pivot toward the pole piece thus tripping the breaker. However, this type of time delay mechanism may not prevent tripping due to the high amplitude transients mentioned above which occur when a power supply is switched on, even though the inrush lasts for a period of time less than that required for movement of the core to the pole piece. The magnitude of this type of overload is sufficiently large to substantially instantaneously attract the armature of the circuit breaker's operating mechanism thereby tripping the breaker and frustrating the function of the time delay.

Various attempts have been made to prevent this type of nuisance tripping including the provision of shunt paths in which a portion of the flux developed by the solenoid is shunted away from the armature. Such schemes provided in prior art devices however have

been inherently inefficient since a significant portion of the flux produced is shunted away from the armature and is in effect, wasted and result in a device which is less sensitive to sustained overloads and has less force available for desired tripping. Further, such devices frequently require additional moving parts for the shunt mechanism adding to the expense of the apparatus and introducing maintenance and reliability problems.

The preferred embodiment of the present invention eliminates the nuisance tripping problem yet obviates the disadvantage of the prior art. Device 10 comprises flux producing means in the form of solenoid 12 preferably wound on a nonmagnetic bobbin 14. A dashpot mechanism comprising a thin-walled elongated tube 16 preferably of brass or other suitable nonmagnetic material, closed at its upper end by a cover or cap 18 secured to the tube, is telescopically received within solenoid 12. Cover 18 is magnetizable and constitutes a pole piece of a circuit breaker, relay or the like. The lower end of the tube 16 is closed by any conventional stopper means or formed integrally with the side walls as indicated in the Figure, as by drawing. An elongated armature core 20 located in tube 16 is shorter than the tube and movable axially therein. Core 20 is made of iron, steel or other suitable magnetizable material.

A hydraulic fluid or other suitable fluid may be inserted and fill substantially the portion of tube 16 not occupied by core 20. The fluid is forced from one end of the tube to the other around the periphery of the core when core 20 is moved in the tube. Passage around the periphery constitutes a restriction which limits the rate of fluid flow from one end of tube 16 to the other end thereof, thereby retarding the rate of movement of the core 20 and providing a desired time delay for sustained overloads. It will be understood that a fluid passage can be provided by other means, such as by grooves or other shaped formations in the inner surface of tube 16 or in the outer surface of core 20 or by a passage through the core.

The bottom end 22 of tube 16 projects from the solenoid and the core is biased against closed end 22 (the position shown in the drawings) by a return coil spring 24 (preferably nonmagnetic) which reacts from the inner surface of cover 18 against the upper end of core 20. Spring 24 is kept axially aligned in tube 16 by reduced diameter portion 26 on core 104.

Passage of current through solenoid 12 creates a magnetic field in and around the solenoid and within the tube 16 which attracts core 20 toward the upper portion of tube 16 and into a central portion of the solenoid. When the core 20 reaches a central portion of the solenoid, the reluctance of the magnetic circuit is reduced due to the presence of the magnetizable core and there is a resulting increase in the strength of the magnetic field initially created by passing current through the solenoid. This increase in the magnetic field attracts armature 28 and is used to operate a switch mechanism 30 through linkage 32.

The solenoid assembly is mounted in a first generally L-shaped frame 34 formed of magnetizable material having a bottom solenoid supporting arm 36 provided with a tube receiving aperture 38 in the distal portion thereof so that the bottom of the solenoid is contiguous with arm 36, and an upstanding arm 40. Armature 28 adjacent arm 40 is pivotably mounted at 42 and has a distal free portion or clapper 44 adapted to move toward and away from pole piece 18. Armature 28 is

normally biased into the position shown in solid lines in the nonactuated condition either through the linkage mechanism 32 or by a separate spring, for instance a spring located at pivot 42.

A second frame 46 of magnetizable material is generally U-shaped and encompasses frame 34, armature 28 and solenoid 12. Frame 46 has a first leg 48 located on the side of the armature portion 44 removed from the solenoid and is preferably provided with a dimple 50. Shim 52 is also shown on the face of clapper 44 which comes into engagement with dimple 50. A second leg 54 is spaced from the bottom of the solenoid and interposed supporting arm 36 by a cylindrical spacer 56 of nonmagnetic material. Leg 54 is provided with aperture 56 which receives the bottom portion of tube 16. In order to minimize the reluctance between leg 54 and core 20 a sleeve 60 of magnetic material may be placed about tube 16 in contact with leg 54.

Legs 48 and 54 of the second frame are connected by a right leg 58. Attached to leg 58 is a magnetic member 62 formed of a suitable magnetic materials such as steel. As seen in FIG. 2 member 62 has a bottom plate 64 formed with a recess 66 to form a radial gap between plate 64 and pole piece 18. Member 62 is attached to leg 58 in any convenient manner as by welding upstanding plate 68 thereto.

Certain gaps are designed into the structure to effect the desired operation. Neglecting leakage reluctances and any reluctance associated with the iron of the circuit, a description of the designed reluctance follows. When the core is in the unactuated or down position shown in FIG. 1 gap *a* exists between core 20 and pole piece 18. A working gap *b* is that space between pole piece 18 and clapper 44 while gap *c* is between clapper 44 and dimple 50 including shim 52. Gap *d* is between armature 28 and arm 40 of frame 34, while the gap between arm 36 of frame 34 and core 20 is identified by *e*. The gap between arm 36 of frame 34 and the bottom leg 54 of frame 46 is represented by *f*. Gap *g* is located between core 20 and the combination of leg 54 and sleeve 60. Finally the radial gap between plate 64 and pole piece 18 is identified by *s*.

The above structure forms in effect three flux loops 2, 4, 6 as indicated in FIG. 3. FIG. 3 is an analog circuit showing the several gaps as fixed or variable reluctances *R*. Loop 2 comprises flux generator 12 (ampere turns), variable reluctance *R_a*, fixed reluctance *R_s*, variable reluctance *R_g* and variable reluctance *R_f*. Loop 4 comprises the flux generator 12, variable reluctance *R_a*, variable reluctance *R_b*, variable reluctance *R_d* and fixed reluctance *R_e*. Loop 6 comprises fixed reluctance *R_s* and variable reluctance *R_c* and *R_b*. Thus reluctance *R_s* is common to loops 2 and 6.

Operation of the FIG. 2 embodiment follows. When either no electric current or insufficient electric current passes through solenoid 12 to move core 20 upwardly, spring 24 maintains the core at the bottom of tube 16 even if the device is in a position other than shown in FIG. 2 (e.g., askew or upside down). As a circuit breaker, the device is calibrated so that the core will not move upwardly until a predetermined overload occurs (magnitude and duration of the overload being inversely proportional). As explained above when the core moves to a central position in the solenoid, the electromagnetic force on armature 28 tending to attract it to the pole piece becomes strong enough to cause the armature to pivot to the dashed line position.

This in turn causes the circuit breaker switch mechanism 30 to trip or break the circuit through linkage 32.

The variable reluctances vary in response to the position of armature 28 and core 20. Thus the operation of the device 10 will be explained for three sets of conditions, firstly with core 20 down and armature portion or clapper 44 up, both of which are shown in solid lines in FIG. 1; secondly with core 20 up and clapper 44 up; and thirdly with core 20 up and clapper 44 down. Under the first condition it will be seen that reluctance R_f is minimal approaching zero and thus a considerable portion of the total flux ϕ_t is diverted around the working gap b circulating as ϕ_6 in loop 2. Since reluctance R_c is also low with clapper 44 up additional flux ϕ_6 is shunted around the working gap b through gap c . This reduces flux in the working gap but also produces a magnetic bias on clapper 44 by flux ϕ_6 . This magnetic bias, along with the spring bias helps to resist movement of clapper 44 under high current pulse excitation.

Under the second condition reluctance R_a becomes minimal approaching zero however ϕ_2 becomes quite small since reluctance R_f becomes very large due to the introduction of an air gap because of the displacement of core 20. This in effect opens loop 2. The circuit can then be considered as a two loop circuit made up of loops 4 and 6. The values of reluctances R_s and R_c as well as the shape of the projection 50 on bracket 46 are designed to result in such a division of flux between the working gap b and gap c that device 10 will trip at the proper current level. Considerably more total flux and thus higher levels of ϕ_2 and ϕ_4 are produced in this second condition than in the first because of the elimination of high reluctance R_a with concomitant increases in the magnetic forces.

Under the third condition loop 2 again can be considered to be open and the circuit to have two loops as clapper 44 starts down and finally as a single loop 4 when clapper 44 completes its travel. As clapper moves from an extremity at projection 50 to its opposite extremity at pole piece 18 reluctance R_c increases while reluctances R_b and R_d decrease. Therefore, the desirable condition of maximizing the amount of flux ϕ_4 through the working gap is attained along with the highest possible force levels for the particular magnetic circuit parameters.

Once the clapper 44 starts its downward motion in normal operation as the result of an overload it is critical that the auxiliary magnetic circuit (loops 2 and 6) used to obtain resistance to short, high level pulses be negated as much as possible. This must be done to insure that adequate flux levels are provided in working gap c to produce maximum clapper forces necessary for reliable performance of the circuit breaking function. Device 10 accomplishes this optimum performance by opening loop 2 with pickup of core 20; by opening loop 6 with the closing of clapper 44 (clapper 44 contacting pole piece 18); and by shunting loop 6 with the closing of the clapper. Thus through the use of the movable core and clapper as flux switching means along with a flux circuit comprising three loops an improved circuit breaker is provided in which increased pulse resistance is obtained while at the same time maintaining essentially all of the flux through the working gap during a sustained overload to enable the circuit breaker to complete its unlatching function.

It has been found that a device made in accordance with the invention has greatly improved pulse resis-

tance. For example such a breaker passed three cycles of 400 hertz current of 20 times rated current (i.e., peak of current pulse 20 times the RMS breaker rating) compared to eight times rated current for a conventional time delay circuit breaker.

As many changes could be made in the above constructions without departure from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings, shall be interpreted as illustrative and not in a limiting sense, and it is also intended that the appended claims shall cover all such equivalent variations as come within the true spirit of the invention.

It is to be understood that the invention is not limited in its application to the details of construction and arrangement of parts illustrated in the accompanying drawings, since the invention is capable of other embodiments and of being practiced or carried out in various ways. Also, it is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation.

I claim:

1. An electromagnetic switch having improved pulse resistance comprising a flux producing solenoid having first and second ends, a pole piece disposed at the first end of the solenoid, an armature having a clapper portion movable toward and away from the pole piece, a core of magnetic material movably mounted within the solenoid, means forming a flux path having three loops, the flux path forming means including a main frame of magnetic material having a first arm contiguous to the second end of the solenoid, the main frame having a second arm adjacent a portion of the armature, an auxiliary frame of magnetic material having a first leg near the second end of the solenoid but spaced from the first leg of the main frame, the auxiliary frame having a second leg near the first end of the solenoid but spaced from the pole piece, the clapper movable between the pole piece and the second leg of the auxiliary frame, and a member of magnetic material disposed adjacent the pole piece but spaced therefrom.

2. A switch according to claim 1 in which the member of magnetic material disposed adjacent the pole piece is supported on the auxiliary frame.

3. A switch according to claim 1 in which the member of magnetic material is common to two of the three loops.

4. A switch according to claim 1 in which the core is movable between two extremities, in one extremity it extends at least between the first arm of the main frame and the first leg of the auxiliary frame and thus results in relatively low reluctance therebetween while in the other extremity the core does not extend between the first arm of the main bracket and the first leg of the auxiliary bracket resulting relatively high reluctance therebetween.

5. A switch according to claim 1 in which upon passage of current through the solenoid a magnetic bias is applied from the second leg of the auxiliary frame to the clapper when the clapper is contiguous to the second leg of the auxiliary frame.

6. A switch according to claim 5 in which movement of the clapper to the pole piece effectively opens one of the flux loops by creating a relatively high reluctance between the clapper and the second leg of the auxiliary frame.

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7. A switch according to claim 6 in which the movement of the clapper to the pole piece also shunts flux from the second leg of the auxiliary frame through the third frame.

8. A switch according to claim 1 in which a portion of the member of magnetic material is coplanar with the pole piece.

9. A switch according to claim 1 in which the member of magnetic material is formed of a plate having a recess therein, the pole piece received in the recess.

10. A switch according to claim 9 in which the recess is semi-circular and is disposed adjacent the pole piece leaving a radial gap therebetween.

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