Oct. 17, 1944. G. O. WILMS ET AL 2,360,750

MAGNETIC ACTUATOR

Filed Sept. 12, 1942 2 Sheets-Sheet 1

Fig. 1

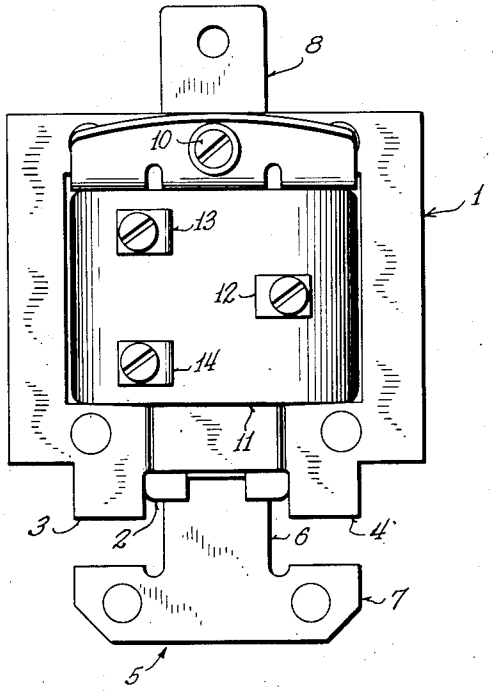
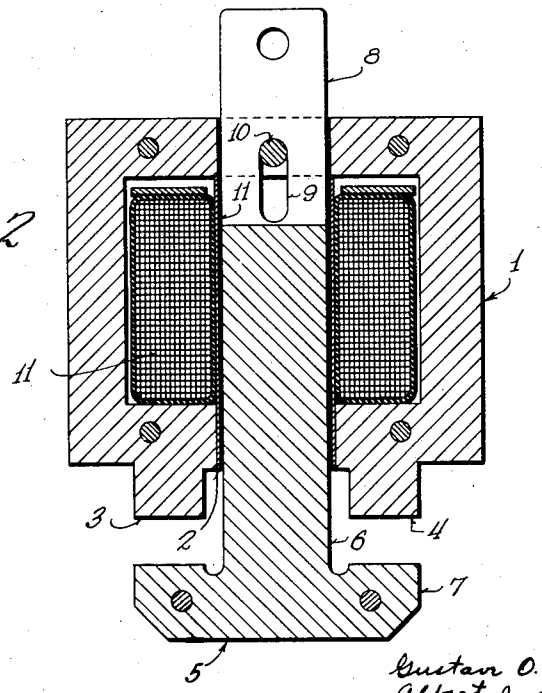


Fig. 2



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Fig. 3

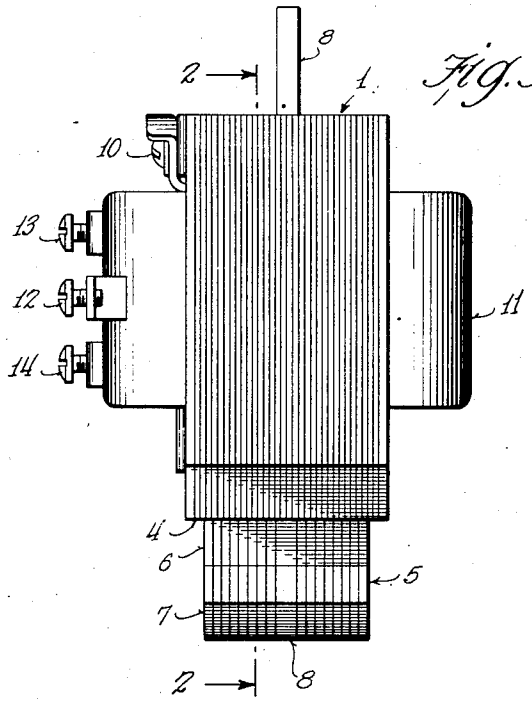
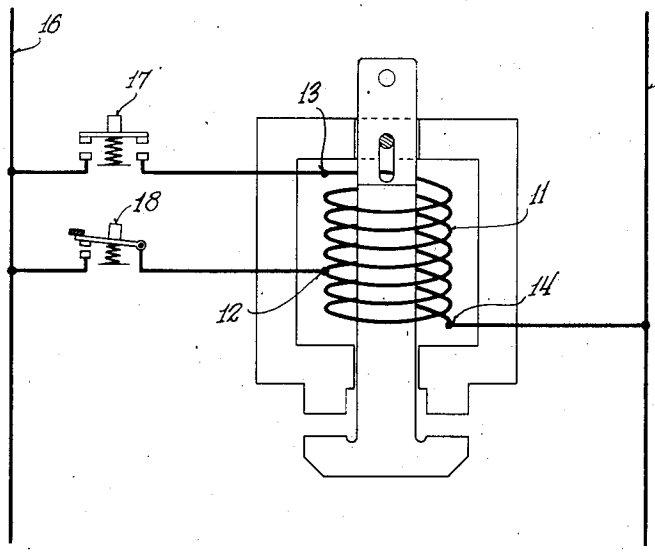


Fig. 4



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MAGNETIC ACTUATOR

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Application September 12, 1942, Serial No. 458,104

10 Claims. (Cl. 175—335)

This invention relates to electromagnets and resides in a specialized form of the same in which applied alternating current causes the magnet parts to be attracted to one another against a separating force and to be permanently magnetized so that they stay in attracted position after termination of the current. Magnets having such properties by reason of an armature controlled repeat action switch have been described in our co-pending application, Serial No. 315,040, filed January 22, 1940, now Patent No. 2,297,339 dated September 29, 1942, for Electromagnetically operated devices. The present application constitutes a continuation in part of the aforesaid application, Serial No. 315,040; the present application being concerned with the provision of limits for the properties of the permanently magnetizable part and the coil, within which limits a magnet can be constructed which will close on alternating current and stay closed after termination of the current without the necessity for a repeat action switch.

A residual magnetic holding force in an electromagnet has heretofore been produced by others by entirely different means. The advantage of such a magnet lies in the fact that it consumes no energy when reposing in closed position and it is free of the annoying hum which is often experienced with current held alternating current magnets. To obtain this result others have heretofore found it necessary to apply direct current to the magnet coil, unless as disclosed and claimed in our co-pending application, Serial No. 315,040, an automatic repeat action is provided for, which on the basis of statistical theory reduces positive retention to a certainty when alternating current is employed.

The object of the present invention is to obtain the results obtained by our aforesaid co-pending application with alternating current and without need to resort to automatic repeat action. This is accomplished by the invention herein disclosed, by causing the permanently magnetizable part of the magnet to become sufficiently magnetized during a single half cycle that it does not become demagnetized to the releasing point until a substantial part of the succeeding reverse cycle has taken place by which time circuit conditions reach a state in which interruption of the current by separation of the switch contacts is postponed to the end of the current cycle by the arc which becomes established thus assuring remagnetization. These results are obtained through this invention by laminating the hard, permanently magnetizable part of the magnet and by using a coil which draws a current large enough to serve the specific purpose desired.

In the drawings, forming a part hereof, there is set forth by way of illustration and not of limitation one specific embodiment of a magnet constructed in accordance with this invention. In these drawings:

Fig. 1 is a front elevation of a magnet of this invention shown in open position,

Fig. 2 is a sectional view in front elevation of the magnet shown in Fig. 1, viewed through the plane 2—2, indicated in Fig. 3,

Fig. 3 is a side view in elevation of the magnet shown in Fig. 1, and,

Fig. 4 is a wiring diagram of the magnet.

Referring now to Figs. 1, 2 and 3, a magnet is shown furnished with a roughly rectangular yoke 1, composed of laminations held together by rivets engaging appropriate side plates. As appears more clearly in Fig. 2, the lower side of the yoke 1, is provided with an opening which receives a square tubular guiding sleeve 2. On opposite sides of the opening in which the sleeve 2 is received the laminations extend downwardly to form the pole face portions 3 and 4.

The laminations of the yoke 1 are preferably made up of electrical sheet such as transformer iron, for example annealed low carbon steel containing approximately 3 to 4 percent of silicon, but any soft magnetic material is suitable for the purpose and all such materials are referred to herein as "soft steel." The thickness of the laminations should be such as to minimize eddy current losses. For most suitable materials the thickness should be in the neighborhood of number 24 to number 30 U. S. standard sheet gage. The guiding sleeve 2 which serves a purely mechanical purpose should be composed of non-magnetic material and should be divided vertically with one or more slots, not shown, to minimize eddy currents.

Positioned to slide within the sleeve 2 is an inverted T shaped armature 5 comprising a vertical tongue 6 and a transverse head 7. The armature 5 is made up of laminations secured to the opposite sides of a center lamination 8. The center lamination 8 is heavier than the rest and is preferably composed of non-magnetic material such as stainless steel. The center lamination 8 also extends upwardly beyond the others through a slot in the upper side of the yoke 1 to a position above the yoke 1 where it is accessible for attachment to a switch or other instrumentality to be actuated by the magnet.

As shown more clearly in Fig. 2, the lamination 8 is pierced by an elongated slot 9 in proper position to receive the bolt 10 which is put in place after the armature has been inserted within the sleeve 2. In this way the sleeve 2 is secured in place and the armature 5 is held within the limits of travel intended, but is nevertheless free to move from the open position shown in the drawings, to the closed position in which the head 7 is in sealing engagement with the pole faces 3 and 4.

The armature 5 as shown is gravity biased to open position, the whole of the weight of the armature being active to cause a separating force between the yoke and armature. If desired the magnet may be employed in other than vertical position in which event biasing means other than or in addition to gravity may be employed.

The material of which the laminations of the armature 5, other than the center lamination 8, is made, may be any suitable permanent magnet alloy, as for example chromium, tungsten or cobalt steel, properly hardened and heat treated so as to be capable of high residual flux and high coercive force as compared with the materials previously mentioned in connection with the yoke 1. Such materials are herein referred to as "hard steels" and they are what is called permanently magnetizable.

The active or magnetic laminations of the armature 5 should be thin enough to permit effective flux penetration that is thin enough to minimize eddy current losses and the demagnetizing effect of eddy currents. In selecting the thickness of the laminations it is useful to be guided by the depth of penetration of flux at the frequency for which the magnet is intended to operate as determined by the Steinmetz formula.

Surrounding the sleeve 2, and the path of travel of the armature tongue 6, is a coil 11 positioned as shown. The coil 11 is provided with end terminals 13 and 14 and center tap 12 to permit connection of the same in circuit as shown in Fig. 4.

In Fig. 4 line lead 15, is shown connected to end terminal 14 while line lead 16 is shown connected through normally open stop button 17 with end terminal 13 and through normally open start button 18 with mid tap 12. The portion of the coil 11 between the mid tap 12 and the terminal 14 is the magnetizing coil capable of producing a high magnetomotive force. The entire coil 11 between the end terminals 13 and 14 constitutes the opening coil. Because of the larger number of turns in the opening coil the impedance is largely increased, the increase being roughly in proportion to the second power of the ratio of the number of turns. As a result the net ampere turns is much less than that of the closing portion of the coil and the weaker alternating flux thus produced is effective for demagnetizing the magnet parts when it is desired to open the magnet. If desired the resistance of the part of the coil between the taps 12 and 13 may be increased to adjust the demagnetizing effect to the value desired or such increased resistance may be provided externally if more convenient.

The problem of obtaining satisfactory operation of a magnet of the type here involved does not arise during the time when the operator is pushing the closing button but at the instant he releases it. As long as the current is applied to the coil the magnet functions much the same as any other alternating current magnet, with magnetization, demagnetization and remagnetization intervals following in such rapid succession that a sufficient net holding force results. The problem therefore is one of precluding the termination of coil current by release of the closing button during one of the intervals when demagnetization due to reverse magnetization produces inadequate holding force.

In a magnet constructed in accordance with this invention as contrasted with one otherwise similar but having a solid hard steel part, a much larger proportion of the permanently magnetizable part is accessible to the magnetizing effect of the alternating flux and the necessary magnetomotive force to cause substantially all of the material to follow a hysteresis loop extending close to saturation can be imposed without difficulty. By way of contrast a solid armature made of a typical hard steel permits a depth of flux penetration which is so limited that much of the material cannot be brought into action at all with any reasonable amount of magnetomotive force that can be imposed. The net residual holding force which can be developed by alternating flux in a solid material by any practically attainable alternating magnetomotive force is therefore materially reduced and the inadequate holding force intervals of the cycle are greatly extended.

With the armature properly laminated alternating magnetization is sufficient so that inadequate holding force intervals of the cycle produced by reverse magnetization are reduced and commence a considerable interval of time after reversal of current occurs. To obtain the result desired it is necessary to avoid the commencement of the inadequate holding force interval prior to the point in the cycle at which an arc, which will persist until the cycle current is again zero, can be relied upon to occur upon separation of the coil circuit contacts. By increasing the current in the coil circuit, the point of commencement of an arc, which will persist until zero cycle current, can be advanced. By lamination of the armature the moments of commencement of the inadequate holding force intervals can be delayed. By combining these two effects in accordance with this invention; that is, by using a laminated armature and by employing a coil whose characteristics are proportioned to the characteristics of the current source so that enough current is drawn, formation of an arc upon separation of the coil circuit contacts will occur and such arc will persist until the cycle current again becomes zero whenever the contacts are separated during an interval of inadequate holding force produced by reverse magnetization. In fact such an arc will occur in the magnet of this invention even when the coil circuit contacts are separated somewhat in advance of the inadequate holding force interval so that a margin of safety is provided which ensures positive operation under all circumstances.

In order that the coil draw the current required with the magnet at or near closed position, it has been found that it should have not more than about 175 turns for each volt of intended applied voltage divided by the frequency when the magnet part extending through the coil has an effective cross-sectional area of 1 sq. in. For convenience this area is referred to as armature area. For magnets of larger armature area the number of turns in the coil should be proportioned roughly inversely to the armature area. Taking into account these relationships it is convenient to express the minimum number of turns which can be used in a given case by

using the words "armature area turns per applied frequency volt." Hereinafter when the words "not more than 175 armature area turns per frequency volt" are employed, they are intended to express the following mathematical relationship:

$$\text{Number of turns} < \frac{175 \times \text{intended applied voltage}}{\text{armature area in square inches} \times \text{frequency}}$$

A coil whose resistance is within normal limits, and when wound in accordance with the above limitations, will produce the required initiation of an arc which persists until the cycle current is zero when the coil circuit contacts are separated during an inadequate holding force interval, providing the intended voltage is applied and a laminated gravity biased armature is employed. With the armature biased to a greater or lesser extent the coil may be proportioned to the current source characteristics accordingly.

The magnet of this invention therefore is one in which a portion of the magnetic circuit is composed of hard steel which is laminated or otherwise subdivided to electrically isolate the several mechanically united elements and in which a coil is employed which is proportioned in keeping with the electrical source so that sufficient current is drawn to facilitate the formation and maintenance of a cycle completing arc when the contacts controlling the coil current are separated during or substantially prior to the beginning of an inadequate holding force interval. In fulfilling these conditions it is helpful to limit the amount of separation of the contacts of the starting button 18. For this reason a stop is shown in Fig. 4 and it has been found that it is desirable to limit the degree of separation of the contacts by means of such a stop to a distance of about $\frac{1}{32}$ inch to $\frac{1}{8}$ inch with a separation of $\frac{1}{16}$ inch being preferred. However, the speed with which significant changes take place at a frequency of 60 cycles is so great that any ordinary button may be employed at such a frequency without losing the benefits and advantages of this invention because the time involved during release of the button is usually sufficiently small to keep the effective separation within the limits desired.

While this invention has herein been described by reference to a specific instance of its embodiment, it is not intended that the protection to be afforded hereby shall be unnecessarily limited by such specific instance. The intention is that the protection to be granted hereunder shall extend to the full limit of the inventive advance disclosed herein as defined by the claims hereto appended.

We claim:

1. In a self maintaining electromagnet adapted for operation on alternating current, the combination comprising a soft steel yoke, an armature relatively movable with respect to said yoke and composed of electrically isolated mechanically united elements of hard steel, means permitting a separating force to be exerted between said yoke and armature, a coil positioned to apply flux to said armature having not more than 175 cross-sectional area turns per frequency volt of intended applied operating voltage, and a supply circuit for said coil containing a single pair of normally open contacts.

2. In a self maintaining electromagnet adapted for operation on alternating current, the combination comprising a soft steel yoke, an armature relatively movable with respect to said yoke and biased therefrom and composed of hard steel electrically subdivided to permit substantially complete flux penetration, said yoke and armature forming a substantially closed flux path in closed position, a coil interlinking said flux path having not more than 175 cross-sectional area turns per frequency volt of intended applied operating voltage, and a supply circuit for said coil containing a single pair of normally open contacts.

3. In a self maintaining electromagnet adapted for operation on alternating current, the combination comprising a yoke, an armature relatively movable to and from a closed position with said yoke and forming therewith in closed position a flux path capable of residual magnetism, said yoke and armature each being composed of electrically isolated mechanically united magnetic elements, means permitting a separating force to be exerted between said yoke and armature, a coil positioned to apply flux to said armature having not more than 175 cross-sectional area turns per frequency volt of intended applied operating voltage, and a supply circuit for said coil containing a single pair of normally open contacts.

4. In a self maintaining electromagnet adapted for operation on alternating current, the combination comprising a yoke, an armature relatively movable to and from a closed position with said yoke and biased therefrom and forming therewith in closed position a flux path capable of residual magnetism, said yoke and armature each being composed of a magnetic material electrically subdivided to permit complete flux penetration, said yoke and armature forming a substantially closed flux path in closed position, and a coil interlinking said flux path having not more than 175 cross-sectional area turns per frequency volt of intended applied operating voltage, and a supply circuit for said coil containing a single pair of normally open contacts.

5. In a self maintaining electromagnet adapted for operation on alternating current, the combination comprising a yoke, an armature relatively movable to and from a closed position with said yoke and forming therewith in closed position a flux path capable of residual magnetism, said yoke and armature each being composed of a plurality of electrically isolated mechanically united elements which do not exceed in thickness the double depth of flux penetration at the frequency at which said magnet is intended to operate, means permitting a predetermined separating force to be exerted between said yoke and armature, a coil interlinking said flux path having not more than 175 cross-sectional area turns per frequency volt of intended applied operating voltage, a supply circuit for said coil containing a single pair of normally open contacts, and means for demagnetizing said yoke and armature sufficiently to cause said magnet to open.

6. In an electromagnet adapted for operation on alternating current, the combination comprising a laminated soft steel yoke the laminations of which do not exceed in thickness the approximate double depth of penetration of alternating flux at the frequency at which said magnet is intended to operate, an armature composed of laminated hard steel capable of residual magnetism the laminations of which do not exceed in thickness the approximate double depth of penetration of alternating flux at the frequency at which said magnet is intended to operate, said yoke and armature forming a substan-

tially closed flux path in closed position, means permitting a separating force to be exerted between said yoke and armature, a coil interlinking said flux path having not more than 175 cross-sectional area turns per frequency volt of intended applied operating voltage, a supply circuit for said coil containing a single pair of normally open contacts, and means for demagnetizing said yoke and armature sufficiently to cause said magnet to open.

7. In a self maintaining electromagnet adapted for operating on alternating current, the combination comprising a yoke, an armature relatively movable to and from a closed position with said yoke and forming therewith in closed position a flux path capable of residual magnetism, said yoke and armature each being composed of a plurality of electrically isolated mechanically united elements which do not exceed in thickness the double depth of flux penetration at the frequency at which said magnet is intended to operate, means permitting a predetermined separating force to be exerted between said yoke and armature, a coil interlinking said flux path having not more than about 175 cross-sectional area turns per frequency volt of intended applied operating voltage, a supply circuit containing a single switch having a pair of normally open contacts separable by about $\frac{1}{32}$ to $\frac{1}{8}$ inch connected to said coil for admitting and interrupting current passing therethrough, and means for demagnetizing said yoke and armature sufficiently to cause said magnet to open.

8. In an electromagnet adapted for operation on alternating current, the combination comprising a laminated soft steel yoke the laminations of which do not exceed in thickness the approximate double depth of penetration of alternating flux at the frequency at which said magnet is intended to operate, an armature composed of laminated hard steel capable of residual magnetism the laminations of which do not exceed in thickness the approximate double depth of penetration of alternating flux at the frequency at which said magnet is intended to operate, said yoke and armature forming a substantially closed flux path in closed position, means permitting a separating force to be exerted between said yoke and armature, a coil interlinking said flux path having not more than about 175 cross-sectional area turns per frequency volt of intended applied operating voltage, a supply circuit containing a single switch having a pair of contacts separable by about $\frac{1}{32}$ to $\frac{1}{8}$ inch connected to said coil for admitting and interrupting current passing therethrough, and means for demagnetizing said yoke and armature sufficiently to cause said magnet to open.

9. In a self maintaining alternating current magnet the combination comprising a source of alternating current, supply connections extending from said source, a pair of normally open contacts in said supply connections for interrupting the same, a yoke, an armature relatively movable with respect to said yoke and biased therefrom and electrically subdivided to facilitate flux penetration, said yoke and armature forming a substantially closed flux path in closed position capable of residual magnetism, and a coil interlinking said flux path connected to said supply connections and having characteristics so correlated with the characteristics of said source of alternating current that an arc will form which will persist until zero cycle current whenever said contacts are allowed to separate during a cycle interval of inadequate holding force between said yoke and armature caused by reverse magnetization.

10. In a self maintaining alternating current magnet the combination comprising a source of alternating current, supply connections extending from said source, a pair of normally open contacts in said supply connections for interrupting the same, a yoke, an armature relatively movable with respect to said yoke and biased therefrom and electrically subdivided to facilitate flux penetration, said yoke and armature forming a substantially closed flux path in closed position capable of residual magnetism, and a coil interlinking said flux path connected to said supply connections and having the number of turns thereof so proportioned to the characteristics of said source that an arc will form which will persist until zero cycle current whenever said contacts are allowed to separate during a cycle interval of inadequate holding force between said yoke and armature caused by reverse magnetization.

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