July 11, 1967 F. W. KUSSY 3,330,994

ELECTROMAGNET

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FIG. 1.

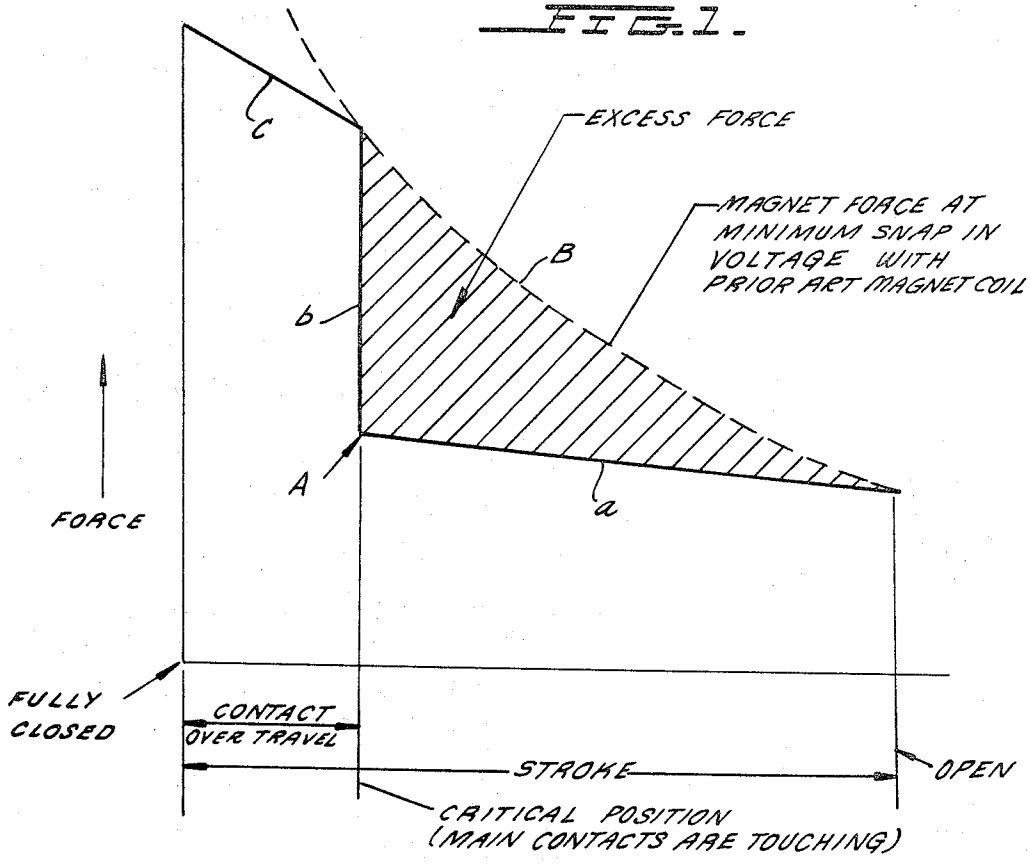


FIG. 2.

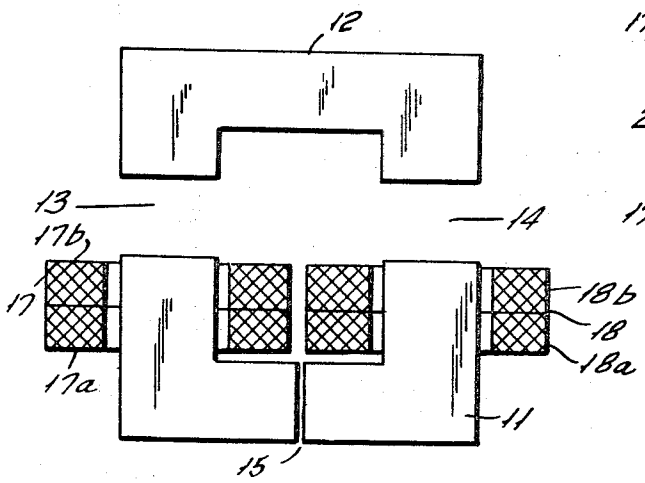
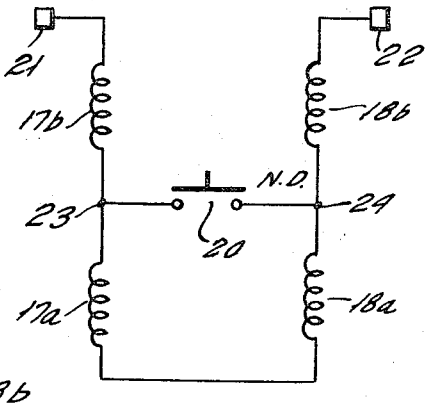


FIG. 2A.



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FIG. 3

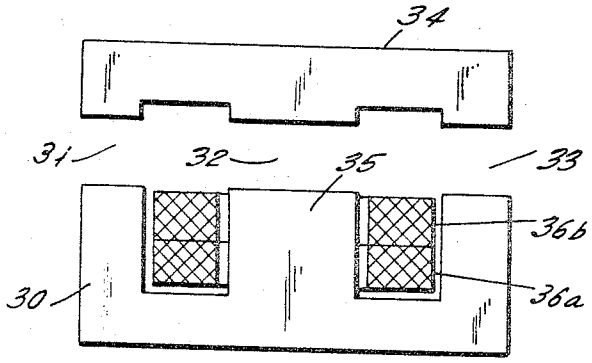
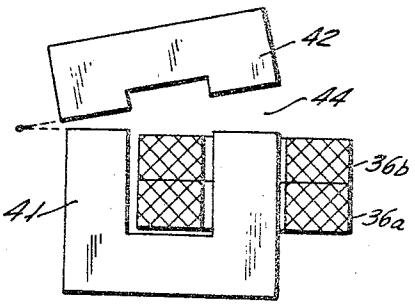


FIG. 3B



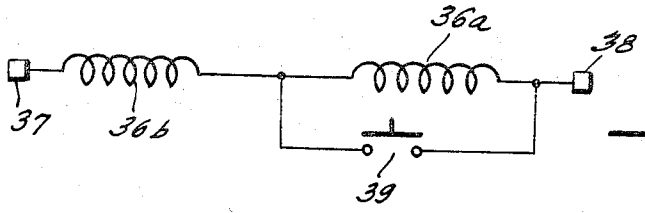


FIG. 3A

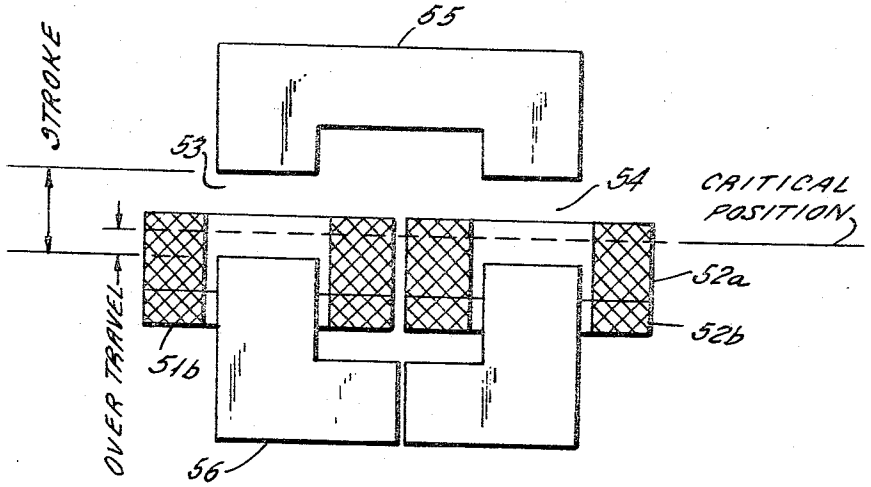


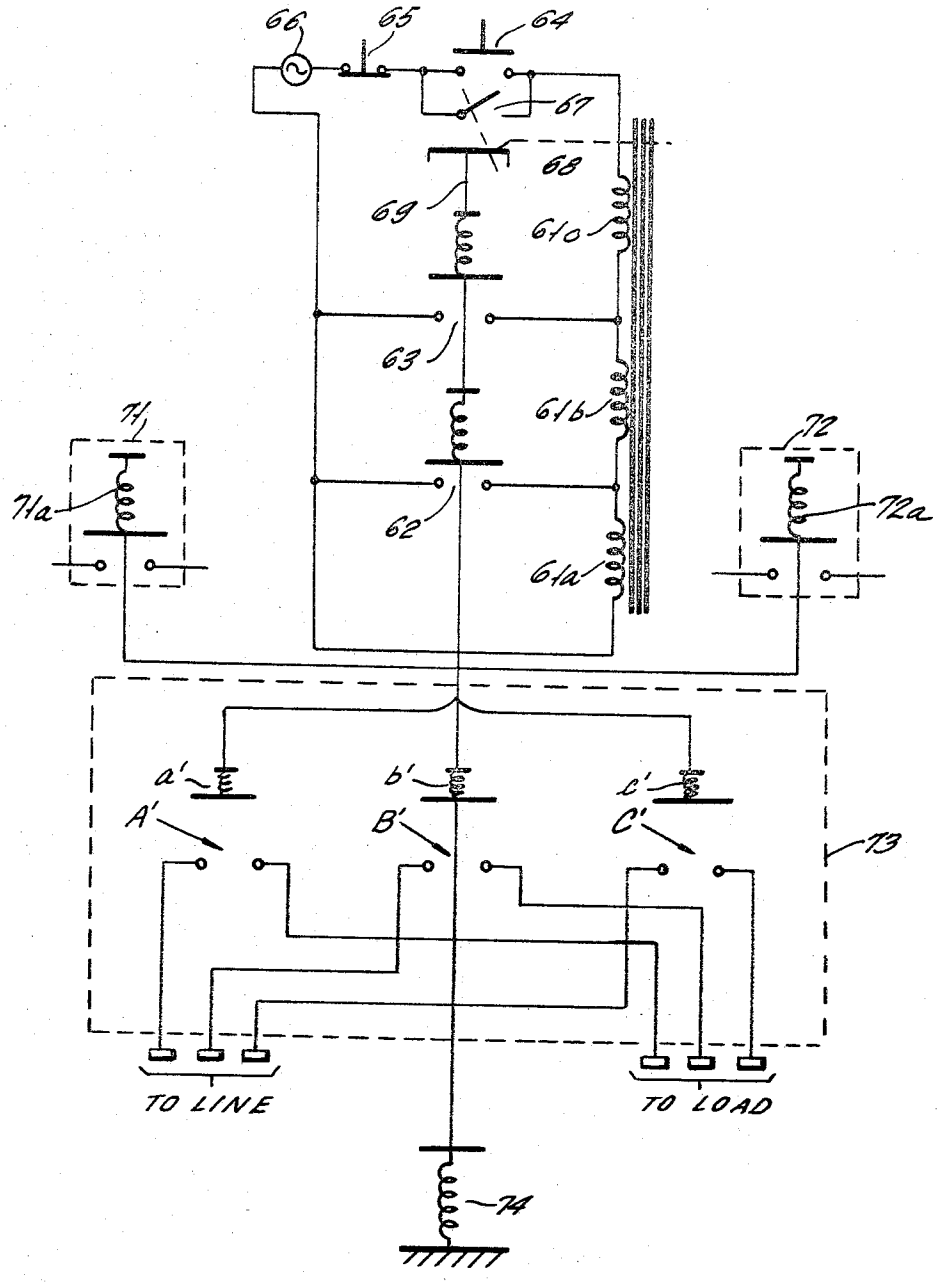
FIG. 4

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FIG. 5.



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ABSTRACT OF THE DISCLOSURE

An A.C. electromagnetic contactor is provided with switch means for shorting a portion of the magnet operating coil at a point in the closing stroke just before initial contact engagement takes place. Shorting a portion of the operating coil without reducing the energizing voltage causes an increase in flux generated by the coil resulting in an abrupt increase in closing force at a point in the closing stroke where there is an abrupt increase in force required for closing. The reduced flux in the fully open position prevents force buildup sufficient to bring about contact engagement under low voltage conditions.

This invention relates to electromagnets for actuating electrical switches and the like, and is directed particularly to an A.C. excited electromagnetic contactor having a short operating stroke.

The Cataldo et al. copending U.S. application (D–305) Ser. No. 189,915, filed Apr. 24, 1962, entitled, Electromagnetic Contactor, and assigned to the assignee of the instant invention, discloses a construction for a contactor which is closed upon actuation of an electromagnet. During the closing stroke for contactors of this type the magnet armature must initially overcome the force of return springs and at a point before the end of the closing stroke must overcome the combined forces of return springs and contact pressure springs. This point, hereinafter referred to as the "critical" position, is at the armature position corresponding to the point where the main contacts of the contactor make initial engagement. Thus, electromagnets for contactors should exert a high force at the moment the main contacts engage but in the fully open position of the magnet the force exerted thereby should be relatively low.

In constructions of the prior art this characteristic was extremely difficult to obtain especially in view of the fact that contactor operation must also take place down to a predetermined voltage below rated voltage, and that for voltages below this predetermined voltage the contactor should not be stalled in the critical position. Adding to the problem was the fact that in the construction of electromagnetic contactors the air gap between the armature and the stationary magnet frame is relatively small and in cases of large size contactors the magnet pole faces are relatively large.

Large magnets of the prior art have a force-air gap characteristic which is fairly flat between the open and critical positions so that the desired force in the critical position can only be obtained by having a large mechanical load acting upon the armature in the open position thereof. In order to overcome such a large mechanical load a still larger magnet is required with this larger magnet having a relatively high power loss in the closed position thereof.

Further, contactor magnets of the prior art have force characteristics which differ materially from the force characteristics of the load presented by the contactors. In particular, the prior art magnet exerted a much greater force in the portion of the stroke prior to contact engagement than was necessary to overcome the force of the return springs. This excess force caused high acceleration of the main movable contacts before engagement with

the main stationary contacts resulting in high impact on contact engagement with excessive contact wear. The prior art attempted to reduce excessive contact wear on impact by providing linkage constructions which were not only complicated but themselves were subjected to wear.

It is desirable to utilize a small control transformer for operation of large electromagnetic contactors. In most cases the size of this control transformer is not determined by the required volt amperes of the closed magnet but by the permitted voltage drop to the open magnet since industry standards require that an electromagnetic contactor with a control transformer must pull in at a predetermined voltage below rated voltage. Typical electromagnet constructions have an in-rush current which is 8 to 10 times as large as the holding current and in the open position of the magnet, have a high power factor. These latter two conditions impose severe limitations upon the size of the required control transformer.

In order to overcome these disadvantages of the prior art the instant invention provides an electromagnet in which there is a plurality of coil sections and a switching means to deactivate certain of these sections at predetermined positions of the magnet closing stroke. In a typical construction the magnet coil is provided with two sections which are connected in series in the open position of the magnet, and just prior to reaching the critical position during the closing stroke one of these coil sections is deactivated by placing a short circuit across this coil section. Since the coil is excited by alternating current of constant voltage the ampere turns thereof for the same excitation voltage increases as the number of coil turns decreases. With the construction of the instant invention, during the initial portion of the closing stroke, when only the force of the return springs must be overcome, the electromagnet exerts a relatively low force and during the remaining portion of the closing stroke the reduced number of coil turns enables the electromagnet to exert a much larger force to overcome the combined forces of the return springs and contact pressure springs. Further, since in the open position the required ampere turns are small a relatively control transformer can be used.

With this type of coil switching arrangement the power factor in the open position of the magnet can be made relatively small by choosing wire of relatively low resistance for the coil section which is shorted. If the power factor of the open magnet is low a still smaller control transformer can be used to control a large magnet.

It will be shown that by extending the concepts of the instant invention a coil having three or more sections with associated shorting switches may be arranged to produce superior operation when the load imposed on the electromagnet has two or more abrupt increases during the course of the closing stroke. Such conditions arise when the contactor is provided with a plurality of auxiliary switches whose contacts engage at a point in the magnet closing stroke prior to engagement of the main contacts. Under such conditions one coil section would be shorted just prior to engagement of the auxiliary switch contacts and a second section would be shorted just prior to engagement of the main contacts.

Accordingly, a primary object of the instant invention is to provide a novel construction for an electromagnet.

Another object is to provide a novel construction for an electromagnetically operated contactor in which the force-air gap characteristic of the magnet is similar to the forces encountered by the magnet during the force of the closing stroke.

Still another object is to provide an electromagnetically operated contactor in which there is a novel means provided for achieving an abrupt increase in magnet force during the course of the closing stroke.

A further object is to provide a novel construction for the electromagnet of a contactor which enables the control transformer to be of reduced size.

These as well as further objects of this invention shall become readily apparent after reading the following description of the accompanying drawings in which:

FIGURE 1 is a diagram which compares the force-stroke characteristic of a prior art electromagnet with the force encountered by the magnet during the closing stroke thereof when operating a contactor.

FIGURE 2 is a schematic of a magnet frame having two working gaps and a double section coil associated with each of the gaps.

FIGURE 2A is an electrical schematic showing the coil sections of FIGURE 2 connected in circuit with a shorting switch in accordance with the teachings of the instant invention.

FIGURE 3 is a schematic of a magnet frame having three working gaps and a single double section coil.

FIGURE 3A is an electrical schematic showing the coil sections of FIGURE 3 and a shorting switch interconnected in accordance with the teachings of the instant invention.

FIGURE 3B is a schematic showing the double section coil of FIGURE 3 utilized with a magnet frame having two working gaps.

FIGURE 4 is a schematic showing a modification of the electromagnet illustrated in FIGURE 1.

FIGURE 5 is a schematic illustrating a contactor and auxiliary switches operated by an electromagnet having three section coils.

Now referring to the figures. FIGURE 2 illustrates a magnet frame consisting of U-shaped stationary portion or yoke **11** and inverted U-shaped armature **12** with working gaps **13, 14** between the confronting ends of the arms of yoke **11** and armature **12**, and additional fixed gap **15** in yoke **11**. As is well known to the art, fixed gap **15** is provided in order to aid demagnetization when coils **17, 18**, magnet **11, 12** is deactivated.

Coils **17, 18** are multi-turn units which surround the arms of frame portion **11** in a region of working gaps **13, 14** respectively. Coil **17** is provided with two multi-turn sections **17***a*, **17***b* while coil **18** is provided with two multi-turn sections **18***a*, **18***b*.

The electrical connections between the coil sections is shown in FIGURE 2A. More particularly, the coil sections are arranged in a series circuit extending between terminals **21, 22** in the following order: section **17***b*, section **17***a*, section **18***a*, and section **18***b*. Normally open shorting switch **20** is connected from juncture **23** between coil sections **17***a*, **17***b*, to juncture **24** between coil sections **18***a*, **18***b*.

In a manner well known to the art, armature **12** is connected for operation of the main contacts of a contactor. Shorting switch **20** is arranged to be closed just before the armature reaches its critical position, the critical position being that position of the armature corresponding to the position of the contactor main contacts as they are initially brough into engagement.

The solid line A in the diagram of FIGURE 1 illustrates the force which an electromagnet must overcome in operating a typical contactor. That is, the portion (*a*) of line A shows that in the operation of the closing stroke prior to engagement of the main contacts of the contactor the force to be overcome increases very gradually. Then, at the critical position there is an abrupt increase in the force to be overcome as indicated by the vertical section (*b*) of line A. The gradual increase in force shown in portion (*a*) is due to the fact that the return spring for the electromagnet armature is being compressed. It is noted that this force would be constant with a gravity drop out contactor. The abrupt increase as shown in section (*b*) is brought about by the sudden encounter with the force exerted by the contact pressure springs. These springs

exert an increasing pressure during the contact overtravel portion at the end of the closing stroke as indicated in section (*c*) of line A.

The dotted line B shows that prior art magnet coils produced a magnet force which increases gradually during the course of the closing stroke. The shaded area of FIGURE 1, between curves A and B, shows that prior to contact engagement prior art magnet coil constructions produced a magnet force much greater than required throughout the entire region between the fully open position and the critical position for the magnet armature.

The magnet construction shown schematically in FIGURE 2A is such that with armature **12** in the fully open position all four coil sections are active. These coil sections may readily be designed to produce a force characteristic extending substantially parallel to section (*a*) of line A in FIGURE 1. At a position of armature **12** just prior to engagement of the contactor main contacts, switch **20** is closed thereby placing a short across coil sections **17***a*, **18***a* and thereby deactivating the latter sections. The reduced number of coil turns now appearing between terminals **21, 22** provides an increased value of ampere-turns since the coils are provided with an A.C. excitation. Hence, the flux in working gaps **13, 14** will increase abruptly and the force acting upon armature **12** will step to a point above section (*c*) of line A at the critical position and extend above section (*c*) to the fully closed position.

FIGURE 3 shows a magnet frame having an E-shaped stationary portion **30** providing three working gaps **31–33** between the legs of stationary portion **30** and armature **34**. The center leg **35** of magnet frame portion **30** is surrounded by a coil having two sections **36***a*, **36***b*.

As shown in FIGURE 3A, coil sections **36***a*, **36***b* are connected in series between terminals **37, 38** with normally open shorting switch **39** connected across coil section **36***a*. The operation of the magnet embodiment illustrated in FIGURE 3 is the same as the mode of operation for the embodiment illustrated in FIGURE 2. That is, shorting switch **39** is arranged to close just prior to engagement of the contactor main contacts, thereby increasing the number of ampere-turns, resulting in an abrupt increase in the force exerted in the magnet just prior to engagement of the main contacts of the contactor.

FIGURE 3B illustrates coil sections **36***a*, **36***b* mounted to one leg of U-shaped stationary section **41** on a magnet frame having an inverted U-shaped armature **42** with the frame having two working gaps **43, 44**. The electrical connections and operation for the embodiments of FIGURES 3 and 3*b* are identical.

The embodiment of FIGURE 4 is similar to that of FIGURE 2 except that the coil sections **51***a*, **52***a* which remain active during the entire closing stroke encompass a portion of the working gaps **53, 54**. It is well known that leakage flux is reduced in a magnetic circuit by surrounding the air gap thereof by the magnet coil, and that by reducing leakage the magnet force is increased. In prior art magnets of this type the force air gap characteristic is even flatter than for a magnet in which no portion of the air gap is surrounded by the coil. That is, magnet force in this type of magnet increases very little as the gap closes. Thus, with this type of magnet the force in the open position would have to be much greater than the force exerted by the return springs in order for the magnet to exert a sufficient force at the critical position.

With the arrangement shown in FIGURE 4 this disadvantage of the prior art is overcome. More particularly, the coil sections **51***b*, **52***b*, which become shorted when the armature reaches the critical position, is located remote from the working gaps **53, 54**. In the open position the arms of armature **55** are outside coil sections **51***a*, **52***a* and a relatively low force is produced in the fully open position. This force increases gradually as armature **55** moves toward the stationary portion **56** of the magnet frame. By the time armature **55** is in the critical position,

the magnet pole faces are surrounded by coil sections **51***a*, **52***a* and leakage flux is considerably smaller than for the fully open position of armature **55**. This produces the desired steep characteristic at the critical position.

In the case of a contactor operated in conjunction with a plurality of auxiliary switches the magnet coil may be divided into three or more sections as shown in FIGURE 5. For example, as illustrated in FIGURE 5 the magnet coil is divided into three sections **61***a*, **61***b*, **61***c* with normally open switch **62** arranged for shorting section **61***a* and normally open switch **63** arranged for shorting sections **61***a* and **61***b*. The three sections **61***a*–**61***c* are connected in series through normally open start control switch **64** and a normally closed stop control **65** to a single phase A.C. energizing source **66**. Holding contact **67** is connected in parallel with the start button **64**. The magnet armature **68** is connected to contact carrier **69** which carries the bridging contacts and contact pressure springs for shorting switches **62**, **63** as well as the bridging contacts of auxiliary switches **71**, **72** and the bridging contacts for all three phases A'–C' of contactor **73**.

When start control **64** is closed, all three coil sections **61***a*–**61***c* are energized and armature **68** is caused to move downward against the force of return spring **74**. At a point just prior to the closing of auxiliary switches **71**, **72** shorting switch **62** closes thereby deactivating coil section **61***a* and increasing the current through coil sections **61***b*, **61***c*. This abruptly increases the closing force on armature **68**. This abrupt increase is required because of added load imposed by contact pressure springs **71***a*, **72***a* as the contacts of auxiliary switches **71**, **72** are brought into engagement. Thereafter, at a position just before the engagement of the main contacts of contactor **73**, shorting switch **63** closes so that both coil sections **61***a* and **61***b* are deactivated and there is another abrupt increase in the closing force acting on armature **68**. This last abrupt increase in armature force is necessary in order to overcome the further load imposed by the contact pressure springs *a'*, *b'*, *c'* of contactor **73** as the main contacts thereof are brought into engagement.

It should now be obvious that by choosing various ratings between the number of turns of each of the coil sections it is possible to obtain a desirable force air gap characteristic for the magnet to avoid stalling in one or more critical positions. Further, by adjusting the position of the armature at which the shorting switch closes, an abrupt increase in magnet forces may be obtained at the desired armature position under all tolerance conditions. It is noted that a clapper type armature may also be operated in this same manner.

Accordingly, it is seen that this invention provides a novel A.C. energized electro-magnet whose force stroke characteristic may be matched more closely with load characteristics than is possible to achieve with any economical construction of the prior art.

Although there has been described a preferred embodiment of this novel invention, many variations and modifications will now be apparent to those skilled in the art. Therefore, this invention is to be limited, not by the specific disclosure herein, but only by the appending claims.

The embodiments of the invention in which an exclusive privilege or property is claimed are defined as follows.

I claim:

1. In combination, an A.C. electromagnet including a magnetic frame and a current carrying coil which when energized generates magnetic flux in said frame, said frame including a yoke and a relatively movable armature separable from said yoke to form a working gap, first means biasing said armature to an open position wherein said gap is fully open, said armature being movable toward said yoke to a closed position by magnetic flux resulting from current flow through said coil; second means producing a force acting upon said armature in the direction of said first means after said armature reaches a critical position while moving toward said closed position, said armature prior to reaching said critical position being free of said force generated by said second means, and additional means for causing an abrupt increase in flux generated by said coil when said armature in moving toward said closed position reaches a predetermined position intermediate said open and said critical positions, said predetermined position being in the vicinity of said critical position, said abrupt increase in flux generated by said coil producing an abrupt increase in force directing said armature toward said yoke.

2. The combination as set forth in claim **1** in which the abrupt increase in flux generated by said coil is produced with the same voltage applied to said coil as in the open position of the armature.

3. The combination as set forth in claim **2** in which the voltage is single phase.

4. The combination as set forth in claim **1** in which the additional means is a normally open switch which when closed places a short circuit across one section of said coil.

5. The combination as set forth in claim **10** in which the coil is provided with another section which surround only a part of said gap, said part being adjacent to said yoke, said armature having a portion thereof extending into said another section when said armature is in said critical position.

6. The combination as set forth in claim **5** in which said one section is disposed remote from said gap.

7. In combination, an A.C. electromagnet including a magnetic frame and a current carrying coil which when energized generates magnetic flux in said frame, said frame including a yoke and a relatively movable armature separable from said yoke to form a working gap, first means biasing said armature to an open position wherein said gap is fully open, said armature being movable toward said yoke to a closed position by magnetic flux resulting from current flow through said coil; a plurality of additional means each applying an addition force acting upon said armature in the direction of said first means, each of said additional forces being applied abruptly to said armature at individual predetermined positions thereof as said armature moves toward said closed position, said armature prior to reaching the respective individual predetermined positions being free of the particular one of said additional forces applied at the respective individual predetermined positions, and further means for causing abrupt increases in flux generated by said coil, each of said increases in flux generated occurring just prior to said armature reaching particular predetermined positions in moving toward said closed position, individual ones of said additional forces being applied to said armature in moving toward said closed position at individual ones of said predetermined positions, each of said abrupt increases in flux generated producing abrupt increases in force directing said armature toward said yoke.

8. The combination as set forth in claim **7** in which the application of said additional forces increase armature loading as said armature moves toward said closed position.

9. The combination as set forth in claim **8** in which opening springs of a multi-phase contactor constitute the means biasing the armature to the open position, said contactor having a plurality of sets of main contacts and a first set of contact pressure spring means for said main contacts, auxiliary switch means operated by said armature, said auxiliary switch means including separable contact means and a second set of contact pressure spring means for said separable contact means, said sets of contact spring means constituting said additional means.

10. In combination, an A.C. electromagnet including a magnetic frame and a current carrying coil which when energized generates magnetic flux in said frame, said frame including a yoke and a relatively movable armature separable from said yoke to form a working gap, first means biasing said armature to an open position wherein said

gap is fully open, said armature being movable toward said yoke to a closed position by magnetic flux resulting from current flow through said coil; second means producing a force acting upon said armature in the direction of said first means after said armature reaches a critical position while moving toward said closed position, and additional means for causing an abrupt increase in flux generated by said coil when said armature is in a position intermediate said open and said critical positions, said additional means including a normally open switch which when closed places a short circuit across one section of said coil.

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