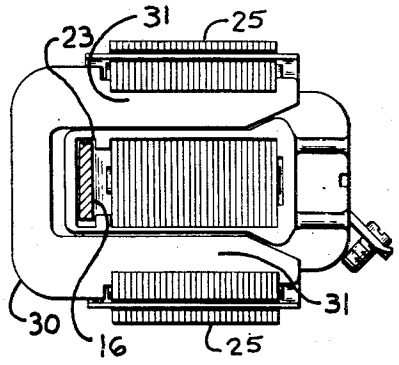
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ELECTROMAGNETIC APPARATUS

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Fig. 2



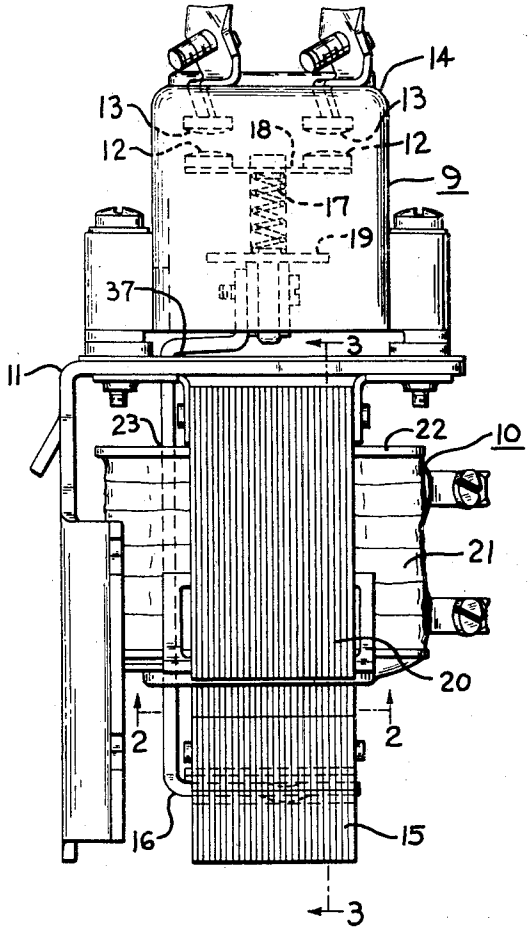


Fig. 1

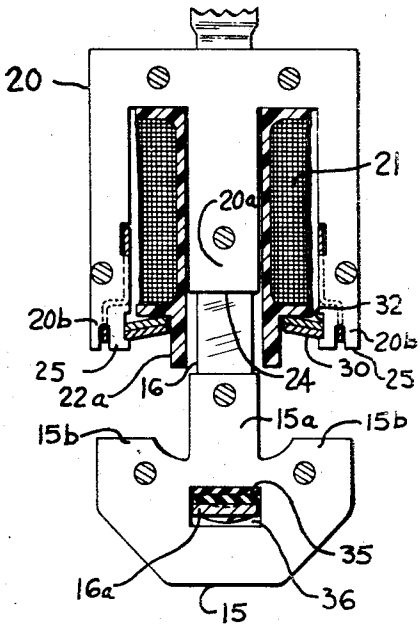


Fig. 3

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ELECTROMAGNETIC APPARATUS

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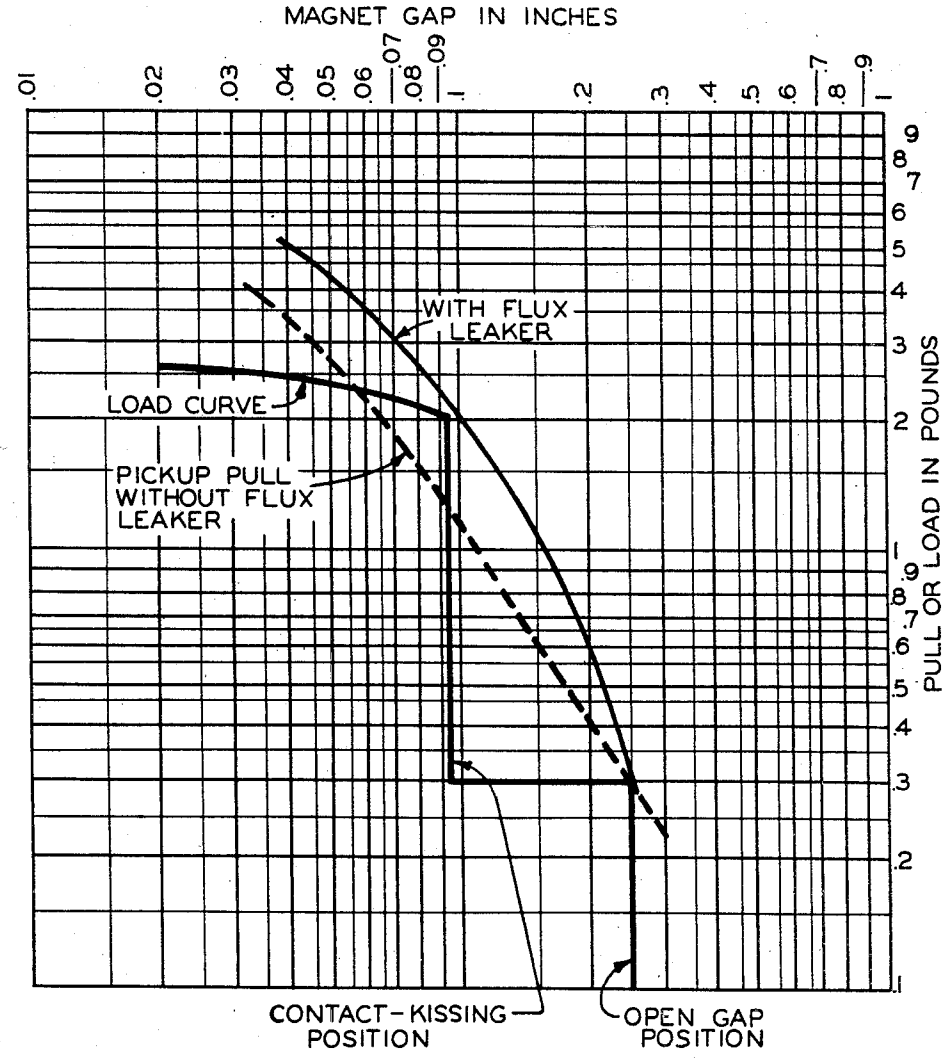


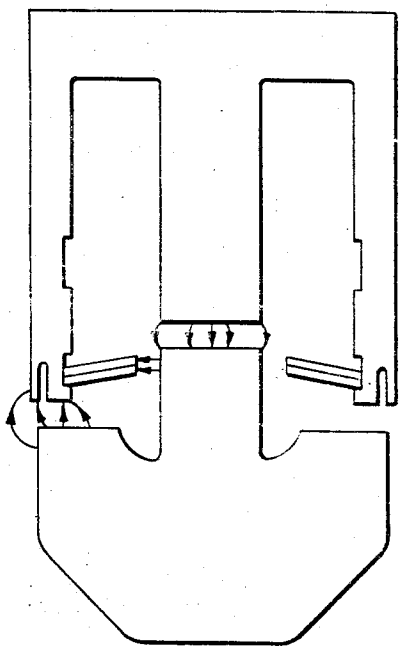
Fig. 4

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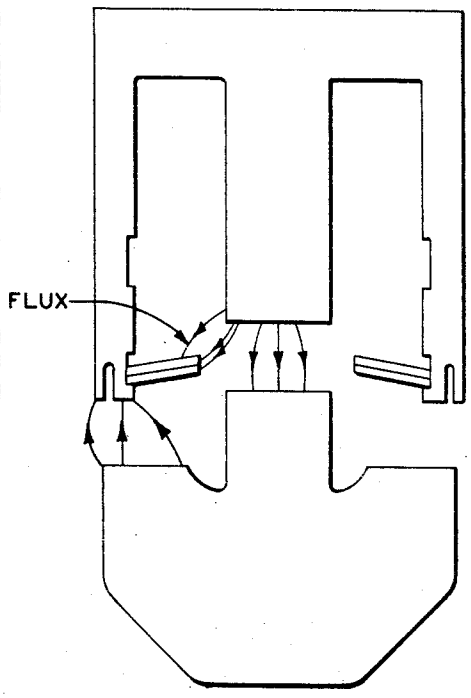
ELECTROMAGNETIC APPARATUS

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KISS POSITION

Fig. 5



OPEN GAP POSITION

Fig. 6

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ELECTROMAGNETIC APPARATUS

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Application June 1, 1955, Serial No. 512,364

14 Claims. (Cl. 200—87)

My invention relates to an electromagnetically operated apparatus and, more particularly, to apparatus employing electromagnets or solenoids to open and close sets of contacts in electric control circuits.

Such electromagnetically operated apparatus normally includes a magnetic core, a coil for energizing the core and a magnetic armature mechanically arranged to close several sets of contacts during its movement toward the magnetic core when the core is energized. One difficulty encountered in such apparatus, especially where a small electromagnet is called upon to provide sufficient force tightly to close several sets of contacts, is that at certain sub-rated voltage levels the electromagnet may have sufficient magnetic attraction or "pull" to overcome the dead weight of the armature assembly and move it to a lightly-kissing contact position but may have insufficient magnetic attraction to close the contacts with enough force to provide good electrical connection therethrough. Because of the alternating current nature of the electromagnet excitation, these lightly-kissing contacts vibrate and chatter against one another thereby producing arcing and burning at the contacts. This same chattering condition has also been found to occur where the voltage level of a previously energized coil decreases until the armature drops out to this "contact-kissing" position or when the armature rebounds after drop-out to this "contact-kissing" position.

In order to overcome these difficulties it is highly desirable that the electromagnet be designed so that any level of electrical energy sufficient to cause the armature to move from its open-gap position to its "contact-kissing" position be likewise sufficient to drive the armature into its full "contact-closing" or closed-gap position against the additional mechanical loading of the contact assembly during contact closure. Conversely, any electrical energy level insufficient to maintain contact closure should likewise be insufficient to hold the armature during drop-out in any position above its open-gap position. These conditions are met when the electromagnet is designed so that the magnetic attraction or "pull" on the armature increases or decreases at an unusually rapid rate as the gap between the magnet core and armature is varied. Electromagnets having this steep pull-versus-magnetic-gap characteristic have heretofore been either unattainable or quite expensive with the result that manufacturers have generally adopted the expedient of utilizing an electromagnet larger than that required by electrical design considerations.

Accordingly, one object of the invention is to provide economical magnetically operated contact-closing apparatus in which vibration and chatter of the contacts is virtually eliminated regardless of the energy level at which the electromagnet is operated.

Another object is to provide an economical electromagnet having an unusually steep magnetic-pull-versus-magnet-gap characteristic.

A further object is to provide an electromagnet construction in which rebound of the armature to the "contact-kissing" position is substantially reduced.

In general, in accord with the invention, an electromagnetically operated apparatus is provided in which the magnet core has a pair of spaced poles, a magnetic armature assembly is supported for movement relative to at least one of the poles and magnetic means are provided which form a leakage path for magnetic flux between the poles. This magnetic flux leakage means is located so as to divert a substantial percentage of the generated flux away from the armature when the armature is in its open-gap position. However, as the armature moves toward its "contact-kissing" position, the armature provides a more favorable path for the magnetic flux than the leakage path so that a greater proportion of the total flux is employed to "pull" the armature as the gap between the armature and magnet core is decreased. As a consequence, the normal pull exerted upon the armature by the magnet when the armature is in its open-gap position is considerably lessened while the pull exerted on the armature in the "contact-kissing" position is virtually unaffected by this magnetic flux leakage means, and any flux level sufficient to begin closure of the armature is likewise sufficient to drive the armature through its "contact-kissing" position into its "contact-closing" position.

In accord with another feature of the invention, the magnetic members providing the magnetic flux leakage path between the magnet poles are also employed securely to position the coil of the electromagnet upon the magnet core.

In accord with a further feature of the invention the possibility of armature rebound to its "contact-kissing" position is minimized by the insertion of loosely fitting flat shims between the armature and the strap connecting the armature to the movable contacts thereby to provide a novel shock absorbent backstop for the electromagnet.

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, together with further objects and advantages thereof may be easily understood by referring to the following description taken in connection with the accompanying drawings.

In the drawings,

Figure 1 is a side view of an electromagnetically operated contact embodying the invention.

Figure 2 is a front cross-sectional view of the electromagnet in the contactor of Figure 1.

Figure 3 is a cross section taken along the lines 3—3 of Figure 1.

Figure 4 is a graph of the pull-versus-magnet-gap characteristic of the electromagnetically operated apparatus of Figure 1 in relation to the load curve of such apparatus, and

Figure 5 is a schematic diagram of the electromagnet showing the flux path in the "contact-kissing" position of its armature.

Figure 6 is a schematic diagram of the electromagnet showing the flux path in the open-gap position of its armature.

Referring now to Figure 1, the invention is shown in one form embodied in a contactor **9** comprising an electromagnet **10** supported on a frame **11** and arranged upon energization to close sets of movable contacts **12** against stationary contacts **13** embedded within an insulating terminal block **14**. Electromagnet **10** operates contacts **12** through an armature assembly which includes a vertically reciprocating armature **15** connected to contacts **12** through a metal plunger or strap **16**. A resilient contact mounting mechanism is actuated by strap **16** and

includes a plurality of springs 17 inserted between the contact supporting bars 18 and a movable insulating bar or platform 19. Electromagnet 10 also comprises a magnet core 20 having a central leg 20*a* and a pair of outer legs 20*b* terminating in poles 24 and 25 and built up from laminations of generally E-shaped cross section, as best seen in Figure 3. An energizing coil 21 encircles the central leg 20*a* and pole 24 of magnet core 20. Coil 21 is wound on a coil form 22 having a central rectangular aperture 23 which accommodates the central leg 20*a* of magnet core 20 as well as the central or plunger portion 15*a* of T-shaped armature 15. The connecting strap 16 between armature 15 and contact-carrying platform 19 is also vertically slidable within the central aperture 23 of coil form 22. The outer portions 15*b* of armature 15 overlie the outer poles 25 of the outer legs 20*b* of magnet core 20 and are magnetically attracted thereto when coil 21 is energized. Central plunger portion 15*a* of armature 15 is likewise aligned and spaced from the central pole 24 of central leg 20*a* of core 20 and is magnetically attracted thereto upon energization of coil 21 with even greater force than that provided by the outer poles 25. Upon energization, armature 15 moves from its open-gap position illustrated in Figures 1 and 2 to an intermediate contact-kissing position in which contacts 12 lightly engage contacts 13, and then continues to move against the additional force of springs 17 to its closed-gap position in which armature inner and outer portions 15*a* and 15*b* come into contact with the inner and outer poles 24 and 25 respectively of magnet core 20.

In accord with the invention, magnetic means in the form of magnetic members such as U-shaped steel plates 30 are provided for diverting a substantial percentage of the magnetic flux generated at the poles 24 and 25 of magnet core 20 toward each other and away from the magnetic armature 15 when the armature is in its open-gap position. The free end portions 31 of plates 30 are seated as a press fit within notches 32 along the inner sides of outer core legs 20*b* adjacent poles 25 and extend transversely toward central neck portion 22*a* of coil form 22. Plates 30 thus bridge or shunt a substantial portion of the air gap between the inner pole 24 and the outer poles 25 of the magnetic core 20. They also serve to hold the coil assembly on the central leg 20*a* of core 20. The percentage of the generated magnetic flux shunted between these magnet poles is, of course, dependent upon the air gap distance between the central pole 24 and the inserted magnetic plates 30 as compared to the distance from each pole 24 and 25 to the confronting magnetic surfaces 15*a* and 15*b* of armature 15. When armature 15 is in its open-gap position, the distance between the armature and each magnet pole 24 and 25 is about equal to or larger than the air gap between central pole 24 and each portion 31 of magnetic plates 30. The open-position gap between each magnet pole 24 and 25 and the overlying portions 15*a* and 15*b* of armature 15 is preferably also larger than the gap between each leg portion 31 of magnetic plates 30 and the central portion 15*a* of the armature. However, as the gap between the armature and magnet core 20 is decreased, for example, to the intermediate contact-kissing position, the magnet-to-armature gaps are considerably smaller than the pole-shunting gaps between central pole 24 and these magnetic plates. This phenomenon is diagrammatically illustrated in Figures 5 and 6. As a consequence, the magnetic pull on the armature 15 is considerably lessened when the armature is in its open-gap position but is substantially unaffected by this leakage flux as the armature approaches its closed-gap position.

The resulting increase in the steepness of the slope of the magnetic-pull-versus-gap characteristic of a typical electromagnet embodying the invention is illustrated in Figure 4. In Figure 4 the load curve of the contactor 9 is illustrated together with a dashed pull-versus-magnet-gap characteristic curve without the magnetic plates 30 or "flux leaker" as compared with a solid line curve of the pull-versus-magnet-gap characteristic with the magnetic plates 30 or "flux leaker." From the load curve it will be noted that the electromagnet requires a pull of 0.3 pound to begin to move the armature assembly toward the closed position and that it requires a pull of about 2.0 pounds to move the armature assembly beyond its contact-kissing position toward its closed-gap position. Without the magnetic plates 30, there is an energy level, as indicated by the dashed curve A, at which sufficient pull is developed by the magnet to overcome the armature load of 0.3 pound and move the armature assembly to the contact-kissing position, but thereafter, insufficient pull is developed to overcome the 2.0 pound load required to move the armature beyond its contact-kissing position to its closed-gap position. Consequently, the armature merely hangs and vibrates at the contact-kissing position causing arcing and burning of the contacts 12 and 13.

When the magnetic plates 30 are employed, however, any excitation energy level sufficient even barely to overcome the dead weight the 0.3 pound load of the armature, as illustrated by the solid curve B, is sufficient to also overcome the additional 2.0 pound contact load after the armature has reached its contact-kissing position thereby to drive the armature to its fully closed position. Consequently, with magnetic plates 30 there is no energy level condition of the electromagnet in which the armature will remain hung at its contact-kissing position. The electromagnet either will not begin to lift the armature, or if it does not begin to lift the armature, it will drive it completely to its closed-gap position. Conversely, once the armature is fully closed, any energy level insufficient to hold the armature in its closed position will also be insufficient to hold the armature in its contact-kissing position since the dead weight of the armature will exceed the pull of the electromagnet as the armature drops out. It will be appreciated that a slightly higher energy level is required to overcome the 0.3 pound dead weight load of the armature assembly with the magnetic plates 30 than without them. However, the energy levels represented by both the dashed curve A and the solid curve B are considerably below the rated or recommended energy level for operating the electromagnet. It is only when unforeseen electrical conditions or disturbances cause the energy level to drop to the levels illustrated by these curves that the problem of contact chatter arises.

In accord with a further aspect of the invention the possibility of contact vibration and chatter is further minimized by providing a construction which reduces the rebound of the armature after it has dropped open. Even with the flux leaking magnetic plates 30, it had been found at certain low excitation energy levels of coil 21 that armature rebound after drop-out could cause the armature to return to its contact-kissing position where it would hang and chatter. In order to reduce this rebound a plurality of metal or hard fiber shims 35 are inserted within transverse hole 36 of armature 15 above the transverse arm extension 16*a* of plunger 16. The shims are inserted as a loose fit with considerable play between them and the walls of the armature defining the central hole 36. In this way the loose shims act as a shock absorber when the armature 15 strikes against the plunger arm 16*a* after the plunger comes to rest as a result of striking supporting frame 11 at point 37.

Although I have described above one embodiment of the invention, many modifications may be made. For example, a single thicker magnetic member may be used to replace the two thin magnetic plates 30. Also, each U-shaped magnetic plate 30 may be replaced by two separate rectangular plates each held adjacent a respective one of the outer poles 25 of magnet 20. It is to be under-

stood, therefore, that I intend by the appended claims to cover all such modifications as fall within the true spirit and scope of the invention.

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

1. Electromagnetically operated apparatus comprising a pair of electrical contacts, an electromagnet including a magnetic core having a pair of spaced magnetic poles and an armature movable between open- and closed-gap positions relative to said poles, said armature being mechanically connected to one of said contacts for moving it into tight engagement with the other contact when the armature is in its closed-gap position, and magnetic shunting means extending between said poles with only a small air gap therebetween for diverting sufficient magnetic flux away from said armature when said armature is in said open-gap position that any flux level within said core sufficient to move said armature is also sufficient to drive said armature to its closed-gap position against the additional load of said contact engagement.

2. Electromagnetically operated apparatus comprising a pair of electrical contacts, an electromagnet including a magnetic core having a pair of spaced poles, a coil assembly surrounding said core and a magnetic armature movable between open and closed positions relative to at least one of said poles, said armature being mechanically connected to one of said contacts for moving it into tight engagement with the other contact when the electromagnet is energized, and magnetic shunting members contacting the core adjacent one of said poles and extending toward the other of said poles to reduce the air gap therebetween and to divert magnetic flux away from said armature when said armature is in its open position, said magnetic shunting members overlying said coil assembly and holding said assembly on said core.

3. Electromagnetically operated apparatus comprising a pair of electrical contacts, an electromagnet including a magnetic core having a pair of spaced poles and a magnetic armature having an aperture therein and movable between open- and closed-gap positions relative to at least one of said poles, means connecting said armature with one of said contacts for moving it into and beyond a lightly-kissing contact position into tight frictional engagement with the other contact when said armature is in its closed-gap position, said connecting means including a connecting rod and a plurality of shims inserted as loose fits within said armature aperture to reduce rebound to said contact-kissing position, and magnetic shunting members contacting said core adjacent one of said poles and extending toward the other pole to provide a small air gap therebetween to divert sufficient flux away from said armature when in said open-gap position that any flux level effecting movement of said armature also drives said armature beyond said contact-kissing position.

4. Electromagnetically operated apparatus comprising a pair of electrical contacts, an electromagnet including a magnetic core having a pair of spaced outer poles and an inner pole intermediate said outer poles and an armature movable between open- and closed-gap positions relative to said inner pole, said armature being mechanically connected to one of said contacts for moving it into tight frictional engagement with the other contact when the armature is in its closed-gap position, and magnetic shunting members contacting said core adjacent said outer poles and extending toward said inner pole to provide a small air gap therebetween to divert sufficient magnetic flux away from said armature when in its open-gap position that any flux level effecting movement of said armature also drives said armature to its closed-gap position against the additional load of said contact engagement.

5. Electromagnetically operated apparatus comprising a pair of electrical contacts, an electromagnet including a magnetic core of E-shaped cross section, a coil assembly surrounding the central leg of said E-shaped core, and an armature of generally T-shaped cross section movable between open- and closed-gap positions, relative to said core, said armature being mechanically connected to one of said contacts for moving it into tight engagement with the other contact when the armature is in its closed-gap position, and magnetic shunting members contacting the outer legs of said E-shaped core overlying said core assembly and extending toward the central leg of said core to provide a small air gap therebetween about equal to the gap between said central leg and said armature when said armature is in its open-gap position.

6. Electromagnetically operated apparatus comprising a magnet core having a pair of spaced outer legs terminating in outer poles and an inner leg intermediate said outer legs terminating in an inner pole, a magnetic armature supported for reciprocating movement in the space between said outer legs between open- and closed-gap positions relative to said inner pole, and magnetic members contacting said outer legs adjacent their poles and extending toward said inner pole to reduce the magnetic air gap and provide a flux leakage path between said poles for diverting a substantial percentage of magnetic flux generated in said core away from said armature when the armature is in its open-gap position.

7. Electromagnetic apparatus of claim 6 wherein the air gap between said magnetic members and said inner pole of said core is no greater than the gap between said inner pole and said armature when the armature is in its open-gap position.

8. Electromagnetic apparatus comprising a magnetic core having spaced generaly parallel legs terminating in magnetic poles, a coil assembly surrounding one of said legs and extending beyond its pole, a magnetic armature having a portion supported for reciprocating movement within said coil assembly extension between open- and closed-gap positions relative to the coil-surrounded pole, and magnetic shunting means contacting the other leg of said core and extending toward said coil-surrounded pole above said coil assembly to reduce the air gap between said poles and divert a substantial percentage of magnetic flux away from said armature when said armature is in its open-gap position.

9. The electromagnetic apparatus of claim 8 wherein the magnetic shunting means comprises a magnetic plate inserted as a tight fit between said core leg and said coil assembly thereby firmly to clamp said coil assembly in position around the other leg.

10. A magnetic core having a pair of spaced generally parallel legs terminating in magnetic poles, a coil for energizing said core located in the space between said legs, a magnetic armature having outer portions overlying said poles and an inner portion supported for reciprocating movement within said coil and magnetic shunting members contacting the legs of said core adjacent their poles and extending toward the central portion of said armature to provide air gaps therebetween substantially less than the air gaps between said poles and said outer portions of said armature when said armature is in its open-gap position.

11. The electromagnetic apparatus of claim 10 wherein the magnetic shunting members overlie the coil and help hold the coil on said core.

12. Electromagnetic apparatus comprising a magnetic core having a pair of outer legs and a central leg to form a core having a generally E-shaped cross section, the central leg terminating short of the outer legs, a coil assembly surrounding the central leg, a magnetic armature having the outer portions overlying said outer core legs and a central portion overlying said inner core leg and movable between open- and closed-gap positions relative to said legs, and at least one magnetic shunting member contacting an outer leg of said core and extending toward the central portion of said armature above said coil assembly.

13. The electromagnetic apparatus of claim 12 wherein the armature has an aperture formed therein and

the apparatus also comprises a rigid strap inserted as a loose fit within said aperture and movable within said armature, means to arrest movement of said strap to stop said armature in its open-gap position and a plurality of flat shims inserted within said aperture as a loose fit between said strap and the wall of said armature defining said aperture thereby to help absorb the shock of armature drop out to its open-gap position.

14. Electromagnetically operated apparatus comprising a magnet core having a pair of spaced outer legs terminating in outer poles and an inner leg intermediate said outer legs terminating in an inner pole, a magnetic armature supported for reciprocating movement in the space between said outer legs between open- and closed-gap positions relative to said inner pole, and a U-shaped magnetic member having its respective free ends each contacting a respective outer leg adjacent to its pole and extending transversely towards said inner pole to reduce the magnetic air gap and provide a flux leakage path between said poles for diverting a substantial percentage of magnetic flux generated in said core away from said armature when said armature is in its open-gap position.

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