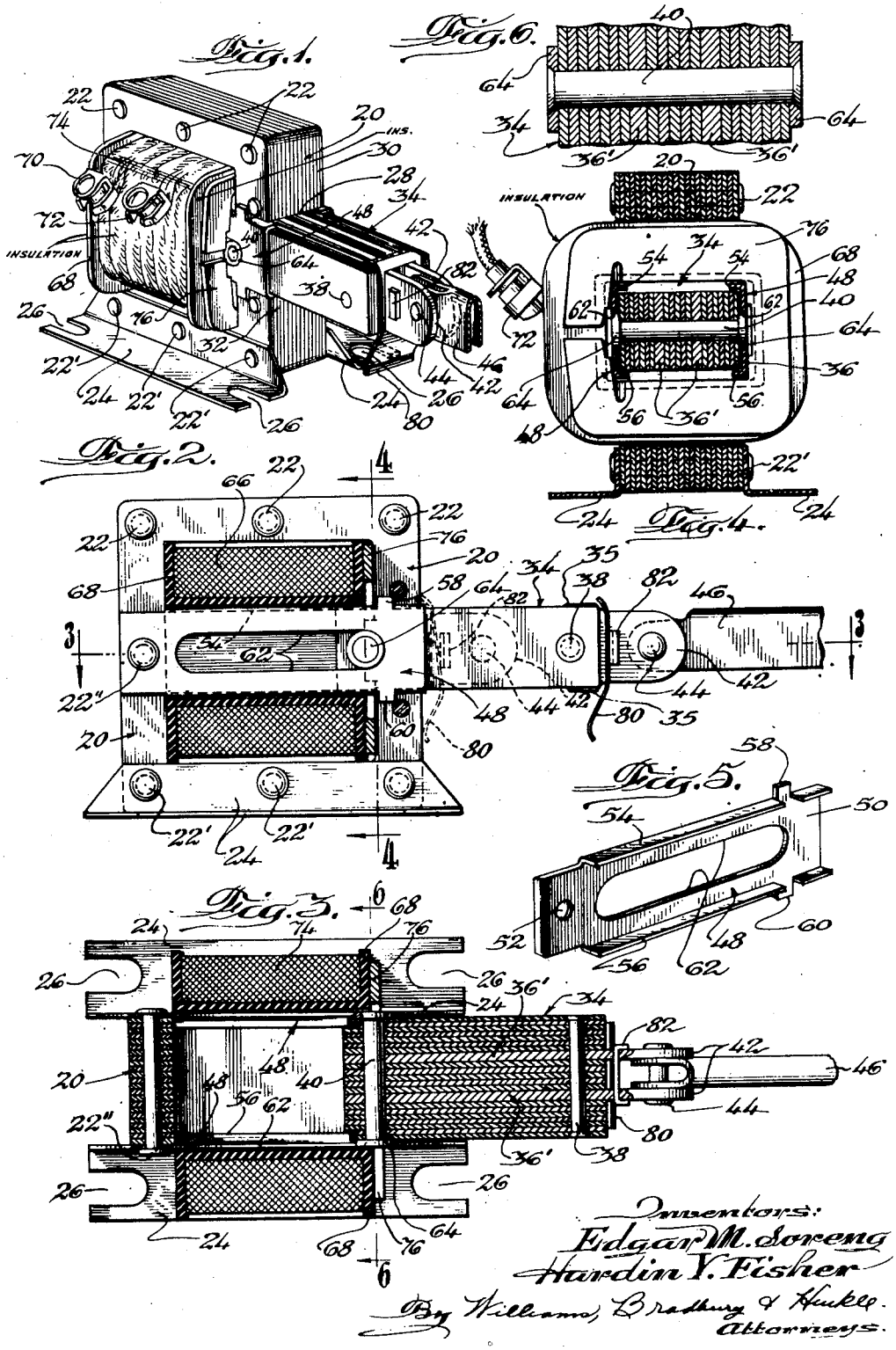
Aug. 23, 1949. E. M. SORENG ET AL 2,480,057

SOLENOID WITH PLUNGER

Filed June 5, 1944 3 Sheets-Sheet 1



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SOLENOID WITH PLUNGER

Filed June 5, 1944 3 Sheets-Sheet 2

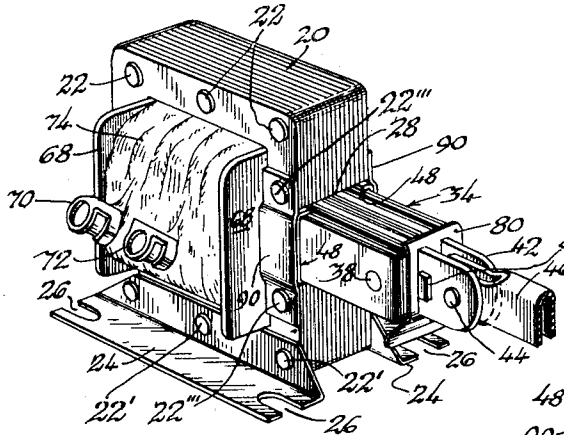


Fig. 7.

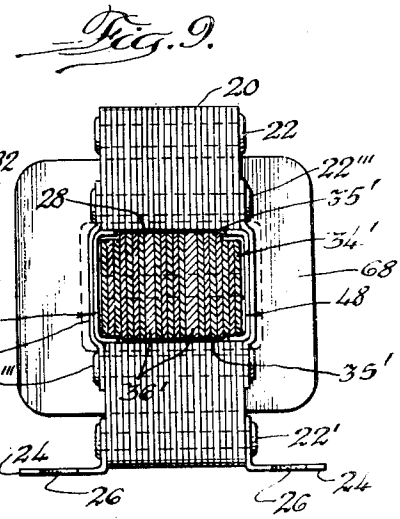


Fig. 9.

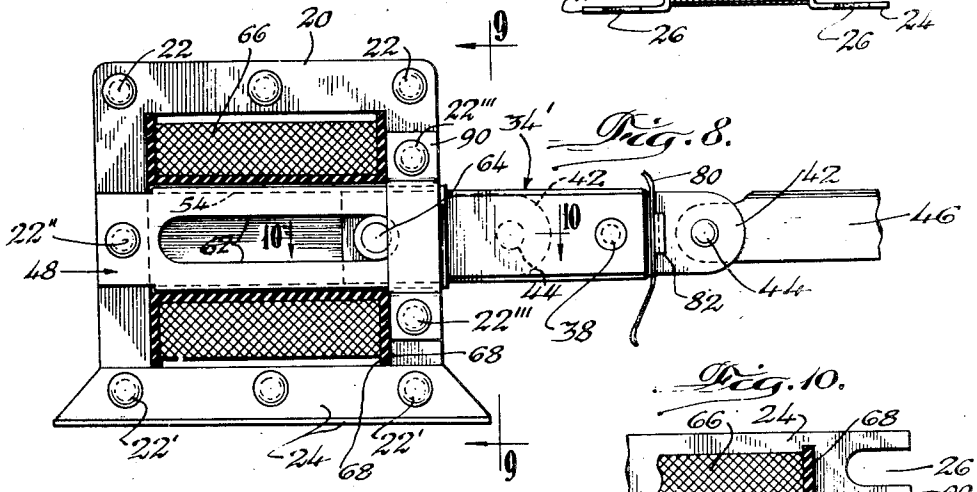


Fig. 8.

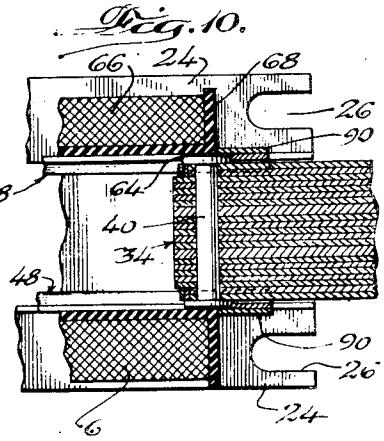


Fig. 10.

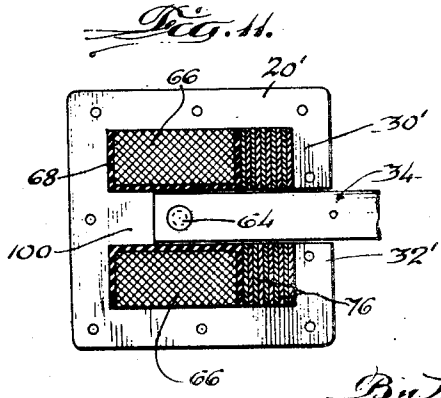


Fig. 11.

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Filed June 5, 1944 3 Sheets-Sheet 3

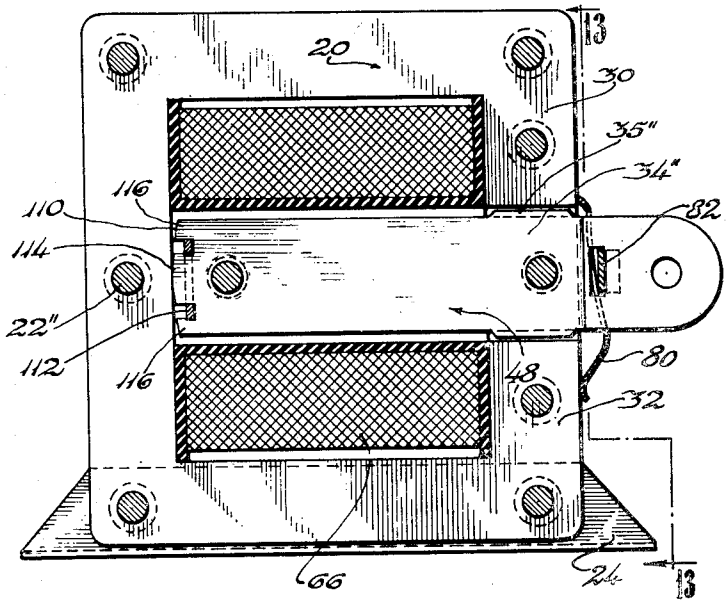
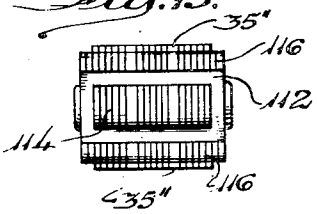


Fig. 12.

Fig. 15.



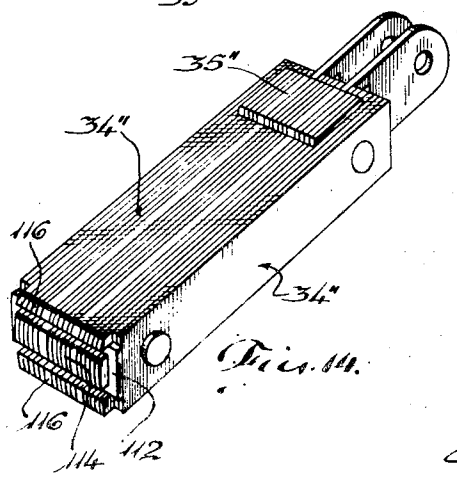
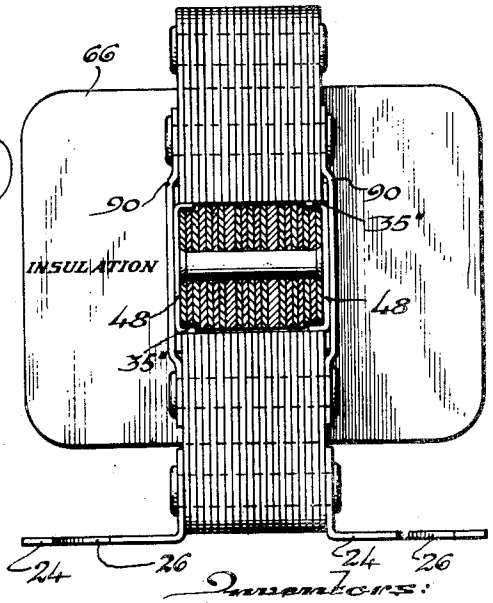


Fig. 14.

Fig. 13.



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UNITED STATES PATENT OFFICE

2,480,057

SOLENOID WITH PLUNGER

Edgar M. Soreng, Skokie, and Hardin Y. Fisher, Hillside, Ill., assignors to Soreng Manufacturing Corporation, a corporation of Illinois

Application June 5, 1944, Serial No. 538,832

9 Claims. (Cl. 175—341)

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Our invention relates to solenoids and is more particularly concerned with, but not limited to, solenoids of the type which are manufactured in large quantities by mass production methods.

An object of our invention is to provide a solenoid having improved operating characteristics.

Another object of our invention is to provide a new and improved solenoid having a reduced number of parts.

Another object of our invention is to provide a new and improved solenoid which may be assembled more simply and easily than the solenoids heretofore known.

Another object of our invention is to provide a solenoid having improved means for guiding and limiting travel of the solenoid plunger.

Another object of our invention is to provide a new and improved solenoid which can be manufactured more cheaply than the solenoids of the prior art.

Another object of our invention is to provide a new and improved solenoid which is more compact and efficient than the solenoids heretofore known.

Another object of our invention is to provide a new and improved solenoid which exerts a more uniform pull on the solenoid plunger throughout its entire range of travel.

Another object of our invention is to provide a new and improved solenoid which is quieter and less subject to vibration than the solenoids heretofore known.

Another object of our invention is to provide a new and improved solenoid which is less subject to heating than the solenoids heretofore in use.

Other objects and advantages will become apparent as the description proceeds.

In the drawings,

Fig. 1 is a perspective view of a preferred form of solenoid embodying our invention;

Fig. 2 is a vertical sectional view of the solenoid shown in Fig. 1;

Fig. 3 is a horizontal sectional view taken on the line 3—3 of Fig. 2;

Fig. 4 is a transverse vertical sectional view taken on the line 4—4 of Fig. 2;

Fig. 5 is a perspective view of one of the plunger guides;

Fig. 6 is a partial transverse sectional view through the plunger and is taken on the line 6—6 of Fig. 3;

Fig. 7 is a perspective view similar to Fig. 1 but showing a solenoid embodying a modified form of our invention;

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Fig. 8 is a vertical longitudinal sectional view through the solenoid of Fig. 7;

Fig. 9 is a transverse sectional view taken on the line 9—9 of Fig. 8;

Fig. 10 is a partial horizontal sectional view taken on the line 10—10 of Fig. 8;

Fig. 11 is a vertical longitudinal sectional view of a solenoid embodying still another modification of our invention;

Fig. 12 is a longitudinal, vertical, sectional view of a further form of our invention;

Fig. 13 is an end view partly in section, taken on the irregular line 13—13 of Fig. 12;

Fig. 14 is a perspective view of the plunger of this embodiment; and

Fig. 15 is a rear end view of this plunger.

Referring particularly to Figs. 1 to 6, inclusive, it will be seen that this form of our invention comprises a generally rectangular frame 20 illustrated as being of laminated construction and formed of a multiplicity of similar strips of magnetic material secured together by rivets or any other suitable fastening means indicated generally by reference character 22. The frame has a pair of angular brackets 24 secured thereto by rivets 22' which also serve to hold together the individual laminations of which the frame 20 is composed. The brackets 24 are of angular construction and are provided with notches 26 whereby the solenoid may be readily attached by means of screws, bolts or similar fastening means to any suitable support.

The forward portion of the frame as viewed in Fig. 1, has a rectangular opening 28 located between opposing end portions 30 and 32 of the frame 20. A plunger 34 is slidably mounted in the opening 28. This plunger is preferably formed of a multiplicity of strips 36 secured together by rivets 38 and 40. Two of the plunger strips indicated by the reference character 36' are preferably made somewhat heavier than the remaining strips and have forwardly projecting ends 42 adapted to receive a pin 44 for connecting the plunger to the mechanism to be operated thereby, such, for example, as the link 46.

Movement of the plunger 34 relative to the frame 20 is guided by a pair of channel shaped guides 48. One of these guides is shown in perspective in Fig. 5 and since both guides are identical, the construction of these guides is best indicated by this figure. Each guide is formed from sheet metal and comprises a web or body portion 50 provided at one end with a hole 52 whereby the two guides may be attached to the frame 20 by the rivet 22'' which also serves to

hold together the laminations of which the frame is composed. The edges of the sheet metal strip forming the guides are bent over as indicated at 54 and 56 to provide laterally projecting flanges which serve as rails between which the edges of the plunger are confined. The continuity of the flanges 54 and 56 is interrupted by ears 58 and 60 which lie in the same plane as the main body or web 50 of the guide.

Each guide is provided with a centrally located slot 62 adapted to receive one of the enlarged disc-like heads 64 of the rearmost rivet 40 of the plunger 34. Outward movement of the plunger is limited by engagement of the disc-like heads 64 with the forward ends of the guide slots 62. In assembled position the forward portions of the flanges 54 and 56 are located between the end portions 30 and 32 of the frame 20. Ears 58 and 60 overlap these end portions, as clearly shown in Figs. 1 and 2, and thereby prevent the forward ends of the guides 48 from being pressed inwardly against the sides of the plunger 34.

The central portions of the guides 48 are surrounded by an electrical coil 66 comprising many turns of wire carried by a spool 68 formed of any suitable insulating material. The coil is provided with terminals 70 and 72 and is covered with insulating material 74. While the terminals of the coil 66 may be constructed and arranged in any suitable manner, for some purposes it is advisable to construct and arrange these terminals in the manner disclosed and claimed in the co-pending application of Edgar M. Soreng, Ser. No. 515,673, filed December 27, 1943 issued August 12, 1947 as Patent No. 2,425,443.

The coil 66 and its supporting spool 68 are slightly shorter than the opening in the rectangular frame 20 and a split spacer ring 76 is located between the forward end of the spool 68 and the end portions 30 and 32 of the frame 20. This spacer ring prevents separation of the forward ends of the guides 48 and holds the ears 58 and 60 of these guides firmly pressed against the sides of the end portions 30 and 32 of the magnetic frame 20. The spacer rings 76 are preferably formed of steel or other suitable magnetic and resilient material whereas the guides 48 are composed of brass or other suitable non-magnetic material.

An important feature of our invention lies in the compactness and superior tractive effort of our solenoid. In this connection, particular attention is directed to the fact that the only parts enclosed within the coil are the plunger 34 and the two guides 48. These guides engage directly the sides of the main frame 20, and the space between the guides is occupied by the rectangular cross section of the plunger except for such clearance as is necessary to permit the plunger to slide freely in these guides. The entire mass of the plunger including the two rivets 38 and 40 is preferably formed of magnetic material and a portion of the forward end of the plunger which is out of vertical alignment with the flanges of the guides is made of increased height as is clearly shown at 35 in Figs. 2 and 4.

In this manner the magnetic mass of the plunger is a maximum for any given size of coil and the magnetic gaps between this plunger and the coil are of minimum size whereby a maximum pull is exerted by the plunger. While we have shown the electrical coil 66 as supported on a non-magnetic spool 68, it may in some instances be desirable to eliminate this spool in order to have the coil even closer to the plunger. Even where it is inadvisable completely to eliminate this spool, the spool can be made much thinner than illustrated in the drawings to minimize the magnetic gap between the coil and the plunger.

In some constructions it is desirable to provide means for reducing vibration of the outer end of the plunger and cushioning inward movement of the plunger as it approaches engagement with the rear wall of the frame 20. We have accordingly mounted on the end of the plunger 34 a bent plate 80 formed of resilient material. This plate is secured in place by a short length of metallic ribbon 82 which extends through slots in projecting ends 42 of the heaviest plunger strips. The ends of the ribbon 82 are bent over as clearly indicated in Figs. 1 and 2 to prevent displacement of this ribbon from these slots.

In Figs. 7, 8, 9 and 10 of the drawings we have illustrated a modified form of our invention wherein the spacer ring 76 is eliminated and strips 90 are provided to prevent separation of the forward ends of the guides 48. These strips 90 are secured to the main frame 20 by rivets 22''' and serve to strengthen the frame 20 adjacent the opening 28 in which the plunger slides. The strips 90 lie outside of the path of rivet heads 64 and are not engaged by these rivet heads which do not project laterally beyond the guides 48 as is clearly shown in Figs. 8 and 10.

In the embodiment of Figs. 7 to 10, inclusive, the electrical coil 66 may occupy the entire opening within the frame 20 and this coil fits closely about the uninterrupted magnetic mass of the plunger 34' as clearly shown in Fig. 9. In this embodiment of our invention we have shown an alternative and interchangeable form of plunger in which the portion 35' of increased height extends the entire length of the plunger further to increase the magnetic mass thereof. Except for the extent of the increased height portion of the plunger and the means for preventing separation of the forward ends of the guides 48, this embodiment is the same as the previous embodiment.

In Fig. 11, we have somewhat diagrammatically illustrated a third form of our invention which is particularly designed to provide a more uniform pull on the plunger 34 throughout its entire range of movement. In this form of our invention the main frame 20' is preferably composed of laminations having inwardly extending projections 100 in alignment with the plunger 34 and constituting one pole of the magnet formed by the main frame. This pole 100 is surrounded by a part of the electrical coil 66 and the remaining portion of this coil surrounds the inner end of the plunger 34 when the latter is at or near the innermost portion of its stroke. The plunger 34 may be identical in construction with the plunger of the previous embodiment of Fig. 1 and is provided with a rivet having heads 64 adapted to engage in slots in the guides 48 as described in connection with previous embodiments although such guides are not shown in detail in the diagrammatic view of Fig. 11.

The space between the end portions 30' and 32' of the main frame and the pole portion 100 must be at least as great as the length of the coil 66 in order to permit insertion of this coil in the frame 20'. After the coil 66 has been inserted and moved to its pole surrounding position as shown in Fig. 11, the space between the right hand end of this coil and the end portions 30' and 32' of the main frame is filled with spacer rings 76 which may be identical with the spacer

ring of the first embodiment and which serve effectively to prevent separation of the forward ends of the guides 48. These spacer rings are preferably of steel or other suitable magnetic material so that the electrical coil 66 is closely surrounded by magnetic material to provide a powerful and highly efficient solenoid.

The solenoid shown in Figs. 12 to 15, inclusive, utilizes a laminated main frame 20 which may be identical with that shown in the first embodiment of our invention. This solenoid is also provided with guides 48 attached at their rear ends to the main frame by a rivet 22'' and having their forward ends held against separation by strips 90 like those described more particularly in connection with the embodiment of Figs. 7 to 10, inclusive. The guides 48 are surrounded by the electrical coil 66 which, in this embodiment, fills the entire space between these guides and the various portions of the main frame.

This solenoid is provided with a plunger 34'' formed of laminated strips as in the previous embodiments. The forward end of this plunger has a portion 35'' of greater height than the remainder of the plunger and when the plunger is in its innermost position as shown in Fig. 12, the portion 35'' is located between the end portions 30 and 32 of the frame 20. The portion 35'' is of substantially the same length as the frame ends, as most clearly shown in Fig. 12.

Referring particularly to Figs. 13, 14 and 15, it will be seen that the portion 35'' does not extend across the entire width of the plunger but is confined to that portion of the plunger which is out of vertical alignment with the inturned flanges of the guides 48. In the particular embodiment shown, the three outer laminations on each side of the plunger do not have portions of increased height, whereas the remainder of the plunger laminations do have such portions. The portion 35'' extends above and below the main body of the plunger an amount slightly less than the thickness of the guides 48, so that this portion is never in contact with the end portions 30 and 32 of the frame 20 and there is always an air gap therebetween. In the embodiment of Figs. 12 to 14, the upper and lower ends of the portion 35'' are of the same area, whereas in the previous embodiments this is not true.

The air gap between the portion 35'' of the plunger and the end portions of the generally C-shaped frame is enough to prevent the plunger from sticking due to residual magnetism, yet the extra magnetic material in this portion of the magnetic circuit greatly reduces the reluctance of the magnetic circuit of the solenoid when the plunger is in the closed or rearward position. This reduced reluctance reduces the magnetizing current and thereby reduces the I^2R loss of the coil. This reduces the heating of the solenoid where a reduction in heating is most beneficial. This permits the solenoid to be operated at a high flux density to give a large pull for a relatively small solenoid but keeps the heating of the coil to a low value and avoids trouble due to residual magnetism resulting from operating the solenoid at a high flux density.

When the plunger is in the retracted position shown in Fig. 12, the left hand or inner end of the plunger engages the frame 20. This end of the plunger is circular ground, using a large radius whose curvature is exaggerated in the drawing. This curvature is most clearly indicated by the reference character 110 in Fig. 12 of the drawings. This end of the plunger is provided with a shading coil 112 and the portion of the plunger which actually touches the frame 20 is the part 114 which is surrounded by the shading coil. This gives the portion of the magnetic circuit enclosed by the shading coil less reluctance than the unshaded portion due to the fact that the unshaded portion has a very small air gap at this point between the frame 20 and the unshaded end portions 116 of the plunger.

When the alternating current is changing so that the magnetism is decreasing and approaching zero, the magnetism in the unshaded portion will die out first due to this added reluctance and to the current flowing in the shading coil. The flux in the shaded portion of the magnetic circuit will be the last to pass through zero, which gives a maximum rate of change of flux in this portion of the magnetic circuit as the flux, due to changes in the current in the coil, passes through zero. This maximum rate of change of flux in the shaded portion as the flux is passing through zero induces a maximum voltage in the shading coil. This provides current in the shading coil to produce the maximum amount of shading flux at the instant it is needed, i. e., when the main flux is passing through zero. The solenoid of this embodiment remains quiet when holding a load almost equal to the load required to pull the plunger away from its sealed position in which its curved end engages the frame 20. This solenoid also remains quiet when the outer end of the plunger is rocked up and down within the limit permitted by the clearance between it and the guides 48 because the inner end of the plunger is circular and a slight movement of the outer or forward end of the plunger does not break contact between the rounded end of the plunger and the frame 20. The primary function of the biasing spring 80 at the forward or outer end of the plunger is to prevent vibration of this end of the plunger.

The solenoids disclosed in the drawing are preferably provided with laminated main frames and plungers since these solenoids are intended to be used with alternating currents. Likewise in Fig. 11 a plurality of spacer rings 76 is preferably used in lieu of a single broad spacer ring. While our invention is particularly adapted for alternating current solenoids, it is not limited to such use but may be incorporated in solenoids designed for operation with direct current.

While we have illustrated and described only four embodiments of our invention, it is to be understood that our invention may assume numerous other forms and includes all modifications, variations and equivalents coming within the appended claims.

We claim:

1. A solenoid of the class described, comprising a generally rectangular laminated frame of magnetic material having spaced end portions forming a plunger-receiving opening therebetween, said frame being also provided with a coil-receiving opening, an electrical coil located in said coil-receiving opening, said coil having a central opening in alignment with said plunger-receiving opening and likewise adapted to receive a part of a plunger therein, a pair of guides having rearward ends riveted to a portion of said frame opposite said plunger-receiving opening, each of said guides having inturned flanges and longitudinally extending slots intermediate said flanges, said guides having forward ends provided with ears adapted to engage opposite sides of the end portions of said frame, a plunger slid-

ably mounted in said guides, said plunger being formed of laminated magnetic material held together by a rivet having heads located in said slots to limit movement of said plunger, said heads having outer surfaces coinciding substantially with the outer surfaces of said guides whereby said coil may closely surround said guides and provide a minimum space between said plunger and said coil, and a split magnetic spacer ring interposed between said coil and frame and surrounding said guides to clamp said ears against said frame.

2. A solenoid of the class described, comprising a generally C-shaped frame having end portions defining a plunger-receiving opening, an electrical coil located in said frame and having a central opening in alignment with said first-named opening, a pair of guides extending through said coil and attached to said frame, said guides having inturned edges forming plunger guiding rails, said guides having longitudinally extending slots, a plunger slidably mounted in said guides, said plunger being of laminated magnetic material, the laminations adjacent said guides being narrower than the other laminations of said plunger whereby minimum air space is provided between said plunger and said coil, and a rivet extending through the laminations of said plunger and having heads located in said slots whereby movement of said plunger is limited by engagement of said heads with the ends of said slots.

3. A solenoid of the class described, comprising a generally rectangular frame of magnetic material having spaced end portions forming a plunger-receiving opening therebetween, said frame being also provided with a coil-receiving opening, an electrical coil located in said coil-receiving opening, said coil having a central opening in alignment with said plunger-receiving opening and likewise adapted to receive a part of a plunger therein, a pair of guides having rearward ends riveted to a portion of said frame opposite said plunger-receiving opening, each of said guides having inturned flanges and longitudinally extending slots intermediate said flanges, a plunger slidably mounted in said guides, said plunger being formed of magnetic material and having heads located in said slots to limit movement of said plunger, said heads having outer surfaces coinciding substantially with the outer surfaces of said guides whereby said coil may closely surround said guides and provide a minimum space between said plunger and said coil, and a split magnetic spacer ring interposed between said coil and frame and surrounding said guides resiliently to clamp the forward ends thereof against the sides of said frame.

4. A solenoid of the class described, comprising a generally C-shaped frame, an electrical coil located in said frame and having a central opening aligned with the opening between the ends of said frame, said electrical coil being adapted for connection to a source of alternating current, a plunger slidable in said openings, means for guiding said plunger therein, said plunger having a rounded end for engaging a part of said frame opposite the opening therein, said plunger having a portion of increased height between the ends of said frame, said portion being of such height as to provide air gaps between said portion and the ends of said frame, said guides permitting limited lateral movement of said plunger whereby a part of the curved end of said plunger has rocking engagement with said frame, a shading coil surrounding said part, and means for reducing vibration of the other end of said plunger.

5. A solenoid of the class described, comprising a generally C-shaped frame, an electrical coil located in said frame and having a central opening aligned with the opening between the ends of said frame, said electrical coil being adapted for connection to a source of alternating current, a plunger slidable in said openings, means for guiding said plunger therein, said plunger having a rounded end for engaging a part of said frame opposite the opening therein, said plunger having a portion of increased height between the ends of said frame, said portion having upper and lower extremities of substantially the same area as the ends of said frame and being of such height as to provide air gaps between said extremities and the ends of said frame, said guides permitting limited lateral movement of said plunger whereby a part of the curved end of said plunger has rocking engagement with said frame, a shading coil surrounding said part, and means for reducing vibration of the other end of said plunger.

6. A solenoid of the class described, comprising a generally C-shaped frame, an electrical coil located in said frame and having a central opening aligned with the opening between the ends of said frame, said electrical coil being adapted for connection to a source of alternating current, a plunger slidable in said openings, means for guiding said plunger therein, said plunger having a rounded end for engaging a part of said frame opposite the opening therein, said plunger having a portion of increased height between the ends of said frame, said portion being of such height as to provide air gaps between said portion and the ends of said frame, said guides permitting limited vertical movement of said plunger whereby a part of the curved end of said plunger has rocking engagement with said frame, a shading coil surrounding said part, and a spring carried by the other end of said plunger and engageable with the ends of said frame to eliminate plunger vibration.

7. A solenoid of the class described comprising a generally C-shaped frame, an electrical coil located in said frame and having a central opening aligned with the opening between the ends of said frame, a pair of channel-shaped guides extending through said coil and spaced apart with the flanges of one guide extending toward the flanges of the other and with the rear end portions of their webs secured, respectively, to opposite faces of the frame, said guides having ears adjacent their forward ends adapted to engage opposite sides of the end portions of said frame, resilient clamping means holding said ears against the frame, said flanges of the guides being directly attached throughout their length to the web portions of the guides and the forward ends of said flanges extending to the outer end of said opening between the ends of the frame, and a plunger slidably mounted in said guide with its marginal portions embraced by the flanges thereof.

8. A solenoid of the class described comprising a generally C-shaped frame, an electrical coil located in said frame and having a central opening aligned with the opening between the ends of said frame, a pair of channel-shaped guides extending through said coil and spaced apart with the flanges of one guide extending toward the flanges of the other and with the rear end portions of their webs secured, respectively, to opposite faces of the frame, each of said guides having a pair of ears integral with its web extending

in the plane of said web and spaced from the forward end of the guide, said ears bearing against the sides of the two end portions of the frame, resilient clamping means holding said ears against the frame, said flanges of the guides being directly attached throughout their length to the web portions of the guides and the forward ends of said flanges extending to the outer end of said opening between the ends of the frame, and a plunger slidably mounted in said guides with its marginal portions embraced by the flanges thereof.

9. A solenoid of the class described and comprising a frame of magnetic material having spaced end portions forming a plunger-receiving opening between them, an electrical coil in fixed relation to said frame, said coil having an axial opening in alignment with said plunger-receiving opening and also adapted to receive a part of the plunger therein, guide means extending in said opening of the coil, a laminated plunger mounted for reciprocation on said guide means, said plunger having two laminations spaced inwardly of the edges of said plunger which project in their respective planes beyond the ends of the other laminations for connection with an

element to be actuated by the solenoid, a resilient cushion member fitted around said projecting laminations and against the ends of said other laminations, and a retaining element extending transversely through said projecting laminations in spaced relation to the ends of the other laminations with said resilient member disposed between said ends and the retaining element.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,005,857	Lindquist	Oct. 17, 1911
1,696,615	Trombetta	Dec. 25, 1928
2,156,937	Davis	May 2, 1939
2,275,115	Trombetta	Mar. 3, 1942
2,284,011	Oliver	May 26, 1942
2,311,431	Davis	Feb. 16, 1943
2,343,806	Scofield	Mar. 7, 1944
2,356,377	Bowen	Aug. 22, 1944