Sept. 8, 1925.

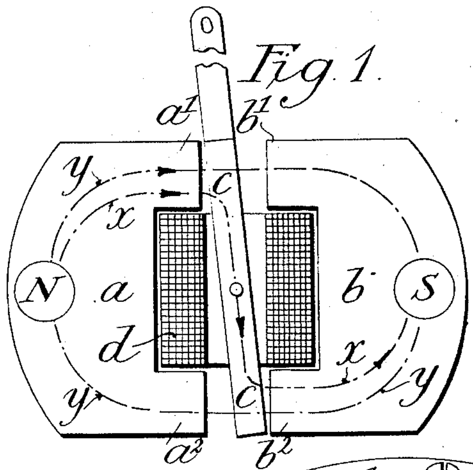
1,552,676

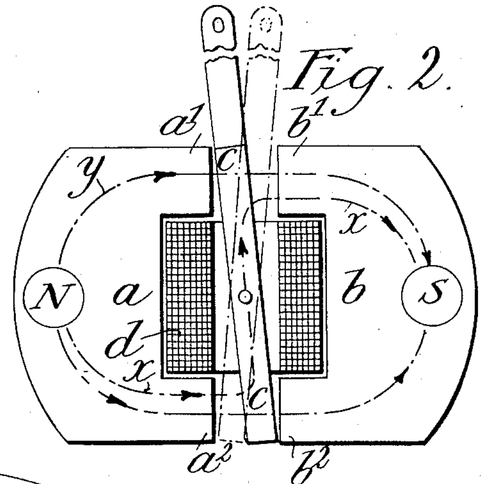
R. E. H. CARPENTER ET AL

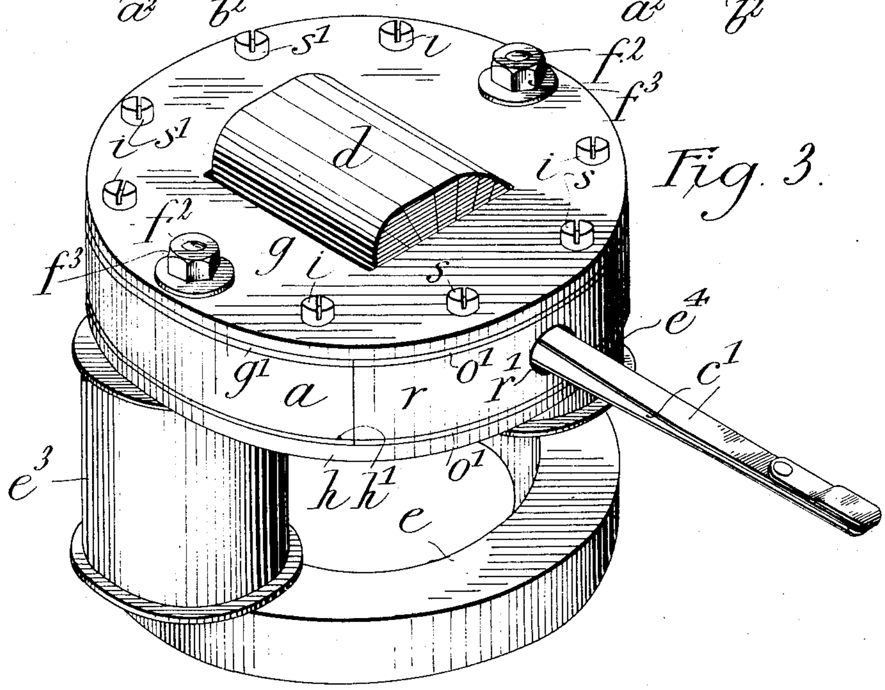
ELECTROMAGNETIC APPARATUS

Filed Sept. 1, 1921

3 Sheets-Sheet 1







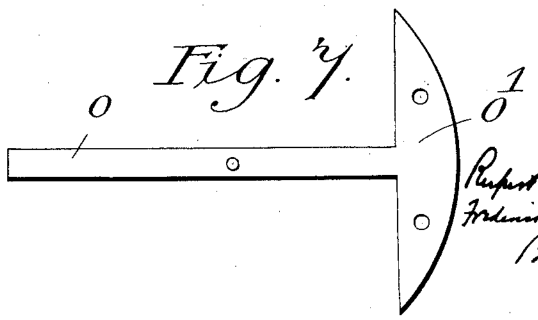


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Fig. 4.

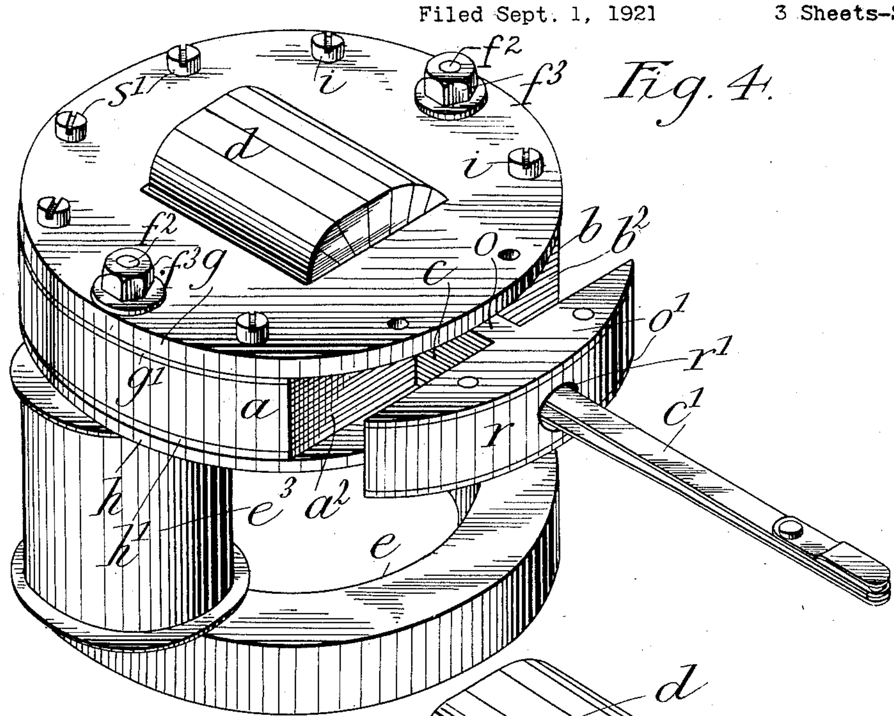

Fig. 5.

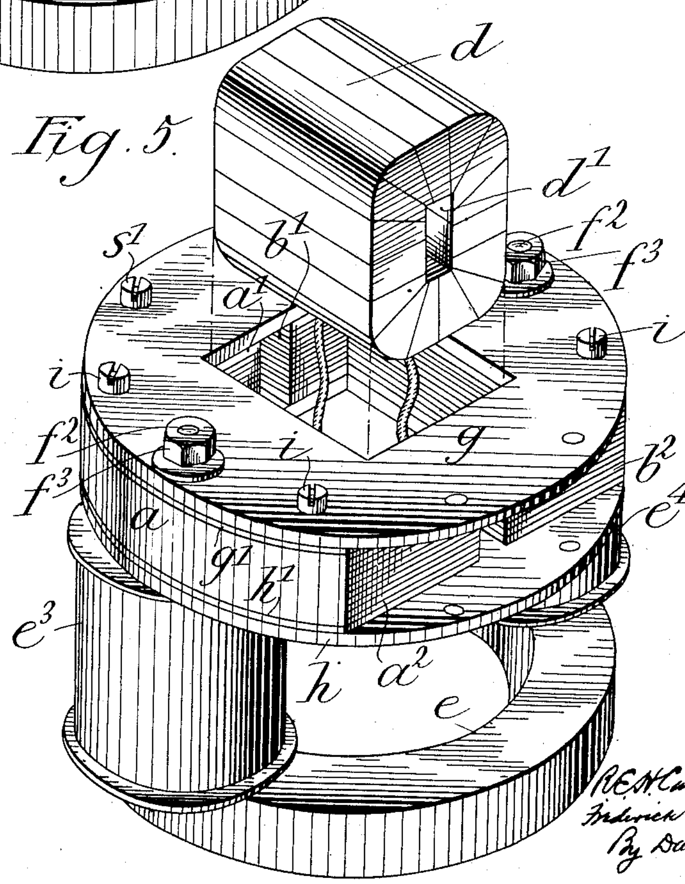

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Fig. 6.

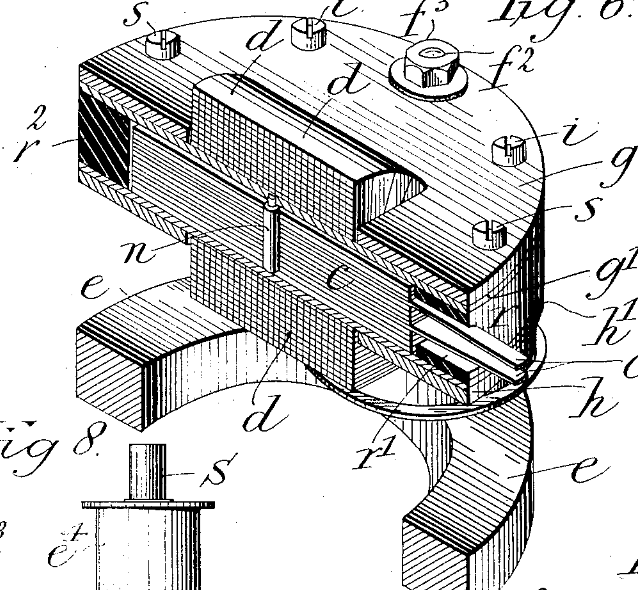


Fig 8.

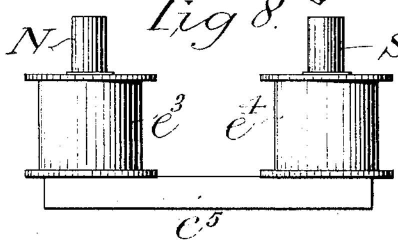


Fig 9.

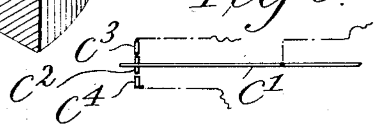
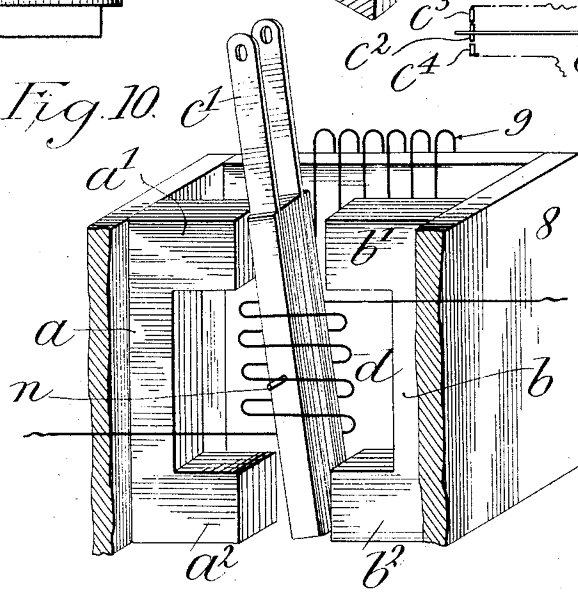


Fig. 10.



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Patented Sept. 8, 1925. **1,552,676**

UNITED STATES PATENT OFFICE.

RUPERT EVAN HOWARD CARPENTER AND FREDERICK GEORGE CREED, OF CROYDON, ENGLAND.

ELECTROMAGNETIC APPARATUS.

Application filed September 1, 1921. Serial No. 497,459.

To all whom it may concern:

Be it known that we, Rupert Evan Howard Carpenter and Frederick George Creed, subjects of the King of Great Britain and Ireland, residing, respectively, at Croydon, in the county of Surrey, England, have invented Improvements in or Relating to Electromagnetic Apparatus, of which the following is a specification.

This invention relates to electro-magnetic motor apparatus, adapted for use as a relay, switch or the like, of the kind in which a pivotally supported armature is to a greater or lesser extent arranged in the space between the poles of an otherwise complete single magnetic circuit system such as to produce a unidirectional flux extending transversely of the armature, the movement of which latter is responsive to variation or reversal of flux produced longitudinally of the armature by a coil or coils within which the armature is arranged.

In this connection it has been proposed to employ a magnet designed to cause the flux to thread the armature transversely substantially throughout all of the length thereof that is located between the polar faces in order to eliminate longitudinal flux or residual magnetism in the armature when its energizing circuit is ineffective.

In contradistinction to this the principal object of the present invention is to provide an apparatus of the same general type in which however the transverse flux referred to is practically localized to polar faces beyond the extremities of the armature energizing coil or coils and so dimensioned that the effect of varying or reversing the longitudinal flux of the armature by varying or reversing the magneto motive force applied to such armature is to produce a redistribution of the transverse flux in the pole pieces of the magnet with small hysteresis and eddy-current loss in the latter. The polar faces referred to are those of projections from a pair of massive pole pieces designed so that the reluctance of the said pole pieces and polar projections is small compared with that of the armature, and an easy path is provided for the varying flux in order to reduce the magneto motive force necessary to effect the variations.

A further object of the invention is to simplify the construction of such an apparatus whilst preserving the principal characteristic.

In the accompanying drawings, Figs. 1 and 2 are diagrammatic views illustating apparatus according to the invention. Figs. 3 and 4 are perspective views showing, somewhat diagrammatically, one constructional arrangement of apparatus embodying the invention, some of the parts in Fig. 4 being partly withdrawn. Fig. 5 is a similar view to Fig. 4, showing another part of the apparatus partly removed and other parts wholly removed. Fig. 6 shows in perspective, a vertical section through the apparatus. Fig. 7 shows in plan, one of the pivot plates for the armature. Fig. 8 shows, diagrammatically, a modification. Fig. 9 is a detail view showing a further modification. Fig. 10 shows diagrammatically, a modified construction of electro-magnetic apparatus with armature and controlling coil.

Broadly, an electro-magnetic apparatus according to the invention, comprises, as shown in Figs. 1 and 2, two oppositely arranged permanently polarized pole pieces *a* and *b* having polar projections a^1, a^2 and b^1, b^2 arranged to form two pairs thereof with an air gap between the projections of each pair, the terminal face of each polar projection being flat and co-equal in area with the cross section of the projection so that the gap between each pair of polar projections a^1, b^1 and a^2, b^2 has parallel sides and has a cross sectional area throughout its length equal to that of the polar projections, for the purpose hereinbefore mentioned An armature *c* of good magnetic material is mounted to oscillate in the air gaps between the pairs a^1, b^1 and a^2, b^2 of polar projections, and a coil *d* (or coils) hereinafter called the controlling coil, is arranged in the space between the pole pieces *a b* independently of the armature *c* and adapted to magnetize the armature, and the current through which can be reversed or varied in value from time to time by any suitable means so as either to reverse the polarity of the armature, or to vary the magnetic strength of the armature. The arrangement is such that the pole pieces *a*, *b* with their polar projections a^1, a^2 and b^1, b^2 and the armature *c*, form two paths for the magnetic flux between the pole pieces, one direct through the air gaps between the oppositely arranged pairs of polar projections and the other indirect through the armature from one or other polar projection of one pair, to the opposite and diagonally arranged polar projection of the other pair. As a consequence of this construction, when the armature is at rest in one inclined position, say that shown in Fig. 1, between one polar projection a^1 of one pair thereof and the opposite diagonally arranged polar projection b^2 of the other pair, some of the magnetic flux between the pole pieces will pass through the armature c, as indicated by the arrows x, and some across the air gaps, as indicated by the arrows y, and the armature will be held over in the said inclined position, even though the current passed through the controlling coil d, for causing the armature to assume the said inclined position, has been cut off. On setting up a current in the opposite direction through the controlling coil d, or on varying the strength of the current passed through the coil, the polarity of the armature c, will be reversed, or the magnetic strength of the armature will be varied, with the result that the magnetic flux through the armature will be reversed, as shown in Fig. 2, or varied, and the armature then caused to turn into or towards its opposite inclined position so that some of the magnetic flux will then flow through the armature between the opposite diagonally arranged pair of polar projections a^2, b^1, either in the opposite direction, as indicated, or to a different extent, and the armature will be moved into or towards the opposite inclined position to that shown in Fig. 1 and be held in the new position, shown in dotted lines in Fig. 2. When the flux through the armature is not completely reversed, spring bias may be used to effect the required movement of the armature. Thus, the polarity of the armature may be reversed alternately, or the strength of the magnetic flux in the armature may be increased and reduced alternately without reversing its polarity. It will therefore be understood that in each case a change in the current flow in the controlling coil will produce a change in the direction or in the amount of the magnetic flux passing through the armature c and hence a change in the forces acting upon the armature. The movements of the armature will in each case take place in a prompt and dead beat manner and with any desired power, according to the strength of the current passed through the controlling coil, to suit the purpose for which the apparatus is to be used.

The pole pieces a and b, which may be of soft iron, or of other good magnetic material, may be magnetized, as by a permanent magnet, or by a magnetizing coil or coils other than the controlling coil d associated with the armature c used for magnetizing such armature, and traversed by a continuous current or they may be magnetized in both of these ways.

Electro-magnetic apparatus embodying the invention can be constructed in various forms.

In the arrangement, shown in Figs. 3 to 7 inclusive, the two pole pieces a and b, formed of laminated sheets of good magnetic material of channel or horse shoe shape, are mounted upon and secured to two diametrically arranged polar projections N. S (Figs. 1 and 2) extending upwardly from diametrically arranged portions of an annular shaped permanent magnet e in a direction parallel to the axis of the magnet, the two polar projections forming opposite consequent poles which may in some cases and as shown, be further magnetized by coils e^3, e^4 traversed by current passing continuously through them. In the latter case, the permanent magnet e may, as shown in Fig. 8, be replaced by a soft iron bridge or connecting piece e^5, or pieces. c is the armature mounted, as hereinbefore described, to oscillate in the air gaps between the associated pairs of polar projections a^1 b^1 and a^2 b^2 of the two pole pieces a and b. d is the coil for controlling the armature. It is supported free from the armature and in a stationary manner, within the rectangular space between the pole pieces a and b and the two pairs of polar projections a^1, b^1 and a^2, b^2 thereon.

In the particular example shown, the two groups of laminations forming the two pole pieces a and b are clamped between circular plates g and h and packing plates g^1, h^1 by screws i so as to form a single unit. Each magnet pole N or S extends through a hole in each group of laminations forming the pole piece a or b and its clamping and packing plates g, h and g^1, h^1 and terminates in a screw threaded end f^2 for the reception of a nut f^3. The arrangement is such that by placing the two pole pieces a and b with their clamping and packing plates g, h and g^1, h^1 as a unit over the two magnet poles N S and screwing up the nuts f^3, the said units can be fixed in a readily removable manner to the said magnet poles. The armature c is made, as shown in Fig. 6, of laminated iron strips riveted together, some of the strips being extended, as shown at c^1, to form a tongue, and a hole being formed through all of them for a pivot pin n. The armature thus made is pivoted on the pin n, between upper and lower pivot plates o of non-magnetic metal, each of the shape shown in Fig. 7. The enlarged segmental shaped ends o^1 of the said plates are spaced apart by a correspondingly shaped distance piece r (Fig. 4) of insulating material inserted between them and formed with a hole r^1 through which the tongue c^1 of the armature c freely extends. The combined armature c, pivot plates o and distance piece r form a single unit that can be readily placed in position by passing it through the gap left between the clamping and packing plates g g^1 and h h^1 (Figs. 4 and 5), the armature c with its pivot plates o extending between the pairs of polar projections a^1, b^1 and a^2, b^2, the segmental shaped ends o^1 of the pivot plates o and distance piece r finally filling, as shown in Fig. 3, the gap between the adjacent portions of the clamping and packing plates g, g^1 and h, h^1 to which they are fixed by screws s. As will be seen, the arrangement is such that the said unit can, by removing the screws s and loosening corresponding opposite screws s^1, be readily removed, when desired, without interfering with any other part of the apparatus. A similar shaped distance piece r^2 (Fig. 6) is fixed in the oppositely arranged gap between the clamping and packing plates to complete the circular formation of the associated parts.

The controlling coil d is made of the shape shown in Fig. 5 with an opening d^1 for the armature and is inserted in place through rectangular shaped openings in the said clamping and packing plates g h and g^1, h^1 (Fig. 5) and the rectangular shaped space between the pole pieces a and b and polar projections a^1, b^1 and a^2, b^2 before the armature c with its pivot plates is inserted in place. The coil is held in position by the pivot plates when these are inserted through the opening d^1 in the coil. The said coil can therefore be readily removed, when desired, after first withdrawing the armature c with its pivot plates. The tongue c^1 of the armature can be used to operate a switch, valve or other device by the movements of the armature under the action of the controlling coil d, the apparatus acting as a motor. Or the tongue c^1 could, if desired and as shown in Fig. 9, form or carry a movable contact c^2 working between stationary contacts c^3 and c^4 to adapt the apparatus to act as an electric relay.

As will be seen, by the construction described, the cross sectional area of the flux path provided by the iron pole-pieces a and b with their polar projections and air gaps is large compared with that of the armature c so that the flux density of the oscillating component of the flux in the pole pieces and polar projections will be small compared with that in the armature. It follows that the magnetic reluctance of the pole pieces and polar projections to the varying component of the flux is small compared with that of the armature, and that the hysteresis and eddy current losses in the pole pieces and polar projections are also small compared with those in the armature. Further, this result is achieved without in any way increasing the length of the turns of the controlling coil d, or coils, as would be the case were such coil or coils to embrace one or more of the polar projections. It will further be seen that the construction is such that it is an easy matter to make the reluctance of the air gaps, and the flux density in the air gaps, of any value desired for the purpose for which the apparatus is designed, by suitably choosing the area of the faces of the polar projections and making the length of the armature to accord. These features are of considerable practical importance in electro-magnetic apparatus of the kind referred to.

Instead of supporting the controlling coil d in position by the pivot plates o of the armature c, as hereinbefore described, the said coil, or coils, may be otherwise supported. Thus, the said controlling coil, or coils, may be fixed within the space or recess between the two pairs of polar projections and the armature be carried by a spindle that extends through it and through the coil, or between the coils, if two coils are used, and into externally arranged bearings.

In the modified construction shown in Fig. 10, the electro-magnetic apparatus comprises a hollow magnetic structure 8 of square or rectangular shape in plan, provided with a polarizing coil 9, or coils, and having two internal oppositely arranged laminated pole pieces a and b shaped as described to form two opposite pairs of polar projections a^1, a^2 and b^1, b^2 with intervening air gaps in which a laminated armature c of good magnetic material is mounted to oscillate, as hereinbefore described, the controlling coil d (or coils) for the armature being supported within the central intermediate space or recess between the two pairs of polar projections. The pivot pin n for the armature is carried in side bearings not shown. One or each end c^1 of the armature may be arranged to open and close an electric circuit, or to operate a switch or other device, as may be desired, and as hereinbefore described.

What we claim is:—

1. Electromagnetic apparatus of the kind herein referred to, comprising a pair of oppositely and constantly polarized pole pieces, an armature pivoted therebetween and an armature energizing winding encircling the armature adjacent to its pivot, the said pole pieces being provided with polar projections adapted to produce a flux transverse to the armature localized to regions beyond the extremities of the armature energizing winding and each having a flat terminal face coequal in area with the cross section of the polar projection, said pole pieces with their polar projections being so dimensioned that the effect of altering the condition of the flux of the armature through the agency of the winding aforesaid is to produce a redis-

tribution in the transverse flux with small hysteresis and eddy-current loss in the pole pieces, substantially as described.

2. Electromagnetic apparatus of the kind herein referred to, comprising a pair of massive pole pieces each having a pair of lateral polar projections with flat terminal faces each co-equal in area with the cross section of the corresponding polar projection, the projections of one pole piece being opposite the projections of the other pole piece, leaving a relatively large space intermediate of two narrower spaces which have parallel sides, an armature extending into all these spaces aforesaid, a pivot for said armature adjacent to the centre of the larger space, a winding in said larger space encircling a portion of the armature and the pivot aforesaid, and a constantly polarized yoke connecting the pole pieces, the massive pole pieces being such that the reluctance thereof and of the polar projections is small compared with that of the armature, as and for the purpose specified.

3. Electromagnetic apparatus of the kind herein referred to, comprising an annular member and a pair of limbs extending therefrom in a direction parallel to the axis of the said member, the whole being magnetized so that the limbs are of constant opposite polarity, pole pieces connected to said limbs, an armature pivoted therebetween and an armature energizing winding encircling the armature adjacent to its pivot, the said pole pieces having projections adapted to produce a flux transverse to the armature localized to regions beyond the extremities of the armature energizing winding, substantially as described.

4. Electro-magnetic apparatus of the kind herein referred to, comprising a field magnet having a pair of polar limbs, a pair of pierced clamping plates, means for securing said plates to the limbs aforesaid, laminæ between said plates constituting massive pole pieces for the limbs each having polar projections, a movable armature arranged to be influenced by said polar projections and a winding entering the piercings in the plates associated with the armature, pole pieces and projections so as to enable the flux condition to be altered to produce armature movement, substantially as described.

5. Electro-magnetic apparatus of the kind herein referred to, comprising an annular member, a pair of limbs extending therefrom in a direction parallel to the axis of the said member, a winding on each limb adapted to maintain the limbs of constant opposite polarity, a pair of pierced clamping plates, means for securing said plates to the limbs aforesaid, laminæ between said plates constituting massive pole pieces for the limbs each having polar projections, a movable armature arranged to be influenced by said polar projections and a winding entering the piercings in the plates associated with the armature, pole pieces and projections so as to enable the flux condition to be altered to produce armature movement, substantially as described.

6. In electro-magnetic apparatus of the kind herein referred to, a pair of parallel magnetic limbs, pole pieces carried by said limbs and each provided with polar projections having flat terminal faces each coequal in area with the cross section of the respective polar projections so that the gaps between the pairs of polar projections are each of similar cross sectional area throughout its length, an armature extending through the gaps between said pole projections, a pivot for said armature and means for holding said pivot parallel to the limbs aforesaid, substantially as described.

7. In electromagnetic apparatus of the kind herein referred to, an annular member, a pair of limbs extending therefrom in a direction parallel to the axis of the said member, pole pieces carried by said limbs, an armature associated with said pole pieces, a pivot for said armature and means for holding said pivot parallel to the axis of the annular member, substantially as described.

8. In electromagnetic apparatus of the kind herein referred to, a pair of pierced plates, laminæ constituting pole pieces disposed between the plates, means for clamping the plates together, a coil adapted to be inserted through either pierced plate so that it occupies a position between the pole pieces with its axis parallel to the planes of the plates, an armature, a pivot therefor and a pivot carrier adapted to be inserted between the plates and pole pieces in order to hold the coil in position, substantially as described.

9. An annular member, a pair of limbs extending therefrom in a direction parallel to the axis of the said member, a pair of pierced plates, laminæ constituting pole pieces disposed between the plates, means for attaching the plates and laminæ to the limbs aforesaid, a coil adapted to be inserted through either pierced plate so that it occupies a position between the pole pieces with its axis parallel to the planes of the plates, an armature, a pivot therefor and a pivot carrier, adapted to be inserted between the plates and pole pieces, holding the axis of the pivot coincident with the axis of the annular member, substantially as described.

Signed at London, England, this 16th day of August 1921 by Rupert Evan Howard Carpenter; signed at Paris, France, by Frederick George Creed this 19th day of August, 1921.

RUPERT EVAN HOWARD CARPENTER.
FREDERICK GEORGE CREED.