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R. M. LEIPPE

2,813,252

MAGNETIC SHUNT STRUCTURE FOR INDUCTION METERS

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Fig. 1.

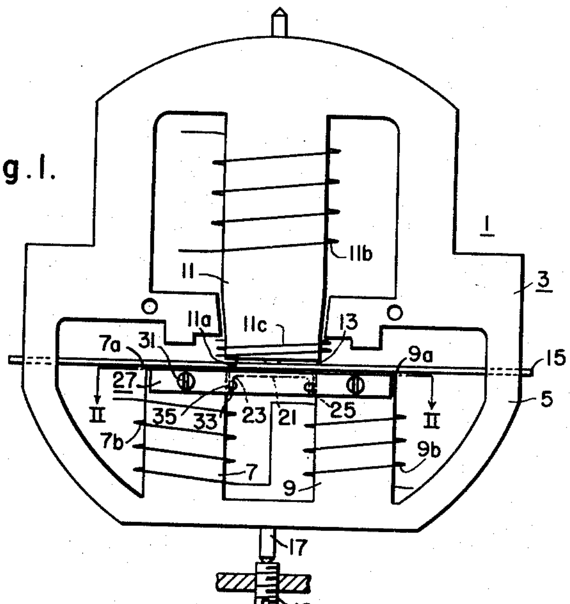


Fig. 2.

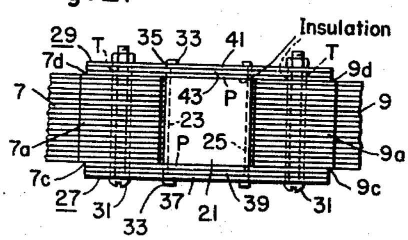


Fig. 3.

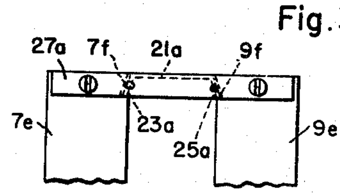


Fig. 4.

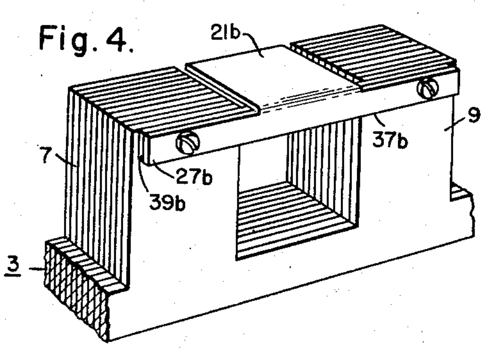
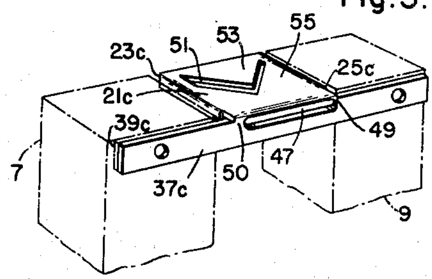


Fig. 5.



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MAGNETIC SHUNT STRUCTURE FOR INDUCTION METERS

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This invention relates to electromagnets and it has particular relation to electromagnets suitable for incorporation in alternating current induction instruments.

Alternating current induction instruments are employed in various fields. For example, they may be employed as measuring instruments, integrating meters and relays. Although the invention may be incorporated in all of these instruments, it will be discussed with particular reference to an alternating current induction watt-hour meter.

The electromagnet commonly employed for induction watt-hour meters includes a magnetic structure having an air gap. The magnetic structure comprises two spaced parallel current pole pieces which are effective when energized for directing current magnetic flux into the air gap.

In order to improve the performance of induction watt-hour meters, it is the practice to position a magnetic shunt between the pole pieces for the purpose of diverting magnetic flux away from the air gap. A magnetic shunt generally is wedged between the pole pieces and the pole pieces have pole tips extending towards each other beneath the magnetic shunt.

In the conventional prior art structure care must be exercised in wedging the magnetic shunt in its mounted position if damage to the associated pole pieces or distortion thereof is to be avoided. Furthermore, the pole tips ordinarily employed make it difficult to install form wound current windings through the air gap and over the current pole pieces. A prior art magnetic shunt is disclosed in the Barnes Patent 2,177,274.

In accordance with the invention, the magnetic shunt for the watt-hour meter is mounted on one or more bridge units which engage the sides of the current pole pieces. The bridge units not only support the magnetic shunt, but may constitute additional shunts between the pole pieces. These shunts may be designed to saturate successively as the energization of the current windings increases. In addition, the bridge units provide a support for the current pole pieces and maintain accurate spacing thereof. If desired, the main magnetic shunt and one or more of the bridge units may be combined in an integral structure. This integral structure may be slitted, if desired, to provide any desired number of substantially independent magnetic shunt paths between the current pole pieces.

In a preferred embodiment of the invention, the magnetic shunt has flanges adjacent and parallel to the associated pole pieces for the purpose of decreasing the magnetic reluctance between the magnetic shunt and the pole pieces. This permits an increase in the spacing between the magnetic shunt and the pole pieces.

It is therefor an object of the invention to provide an improved magnetic shunt assembly for electromagnets.

It is a further object of the invention to provide an electromagnet for induction instruments having a magnetic shunt positioned between spaced current pole pieces and having one or more bridging units secured to the pole pieces and supporting the magnetic shunt.

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It is also an object of the invention to provide an electromagnet as set forth in the preceding paragraph, wherein one or more of the bridge units constitute additional magnetic shunts for current magnetic flux.

It is a still further object of the invention to provide an electromagnet having a magnetic shunt positioned between current magnetic pole pieces and having a bridging unit extending between the pole pieces, the bridging unit being integrally connected to the magnetic shunt.

It is another object of the invention to provide an electromagnet as set forth in the preceding paragraph, wherein the integral bridging unit and magnetic shunt are divided by openings into a plurality of magnetic shunt paths designed to saturate successively as the energization of the current pole pieces increases.

Other objects of the invention will be apparent from the following description taken in conjunction with the accompanying drawing, in which

Figure 1 is a view in side elevation of an induction instrument embodying the invention;

Fig. 2 is a view taken along the line II—II of Fig. 1;

Fig. 3 is a view in side elevation with parts broken away of a modified form of the invention;

Fig. 4 is a view in perspective with parts broken away showing a modified magnetic shunt assembly positioned between pole pieces of an electromagnet; and

Fig. 5 is a view in perspective with parts broken away showing a modified form of the shunt assembly illustrated in Fig. 4.

Referring to the drawing, Fig. 1 shows an induction watt-hour meter suitable for measuring power in a single phase alternating current circuit. The meter includes an electromagnet **1** comprising a magnetic structure **3**. The magnetic structure has a continuous magnetic rim **5** and two parallel spaced current pole pieces **7** and **9** projecting inwardly from the rim **5**. The magnetic structure also includes a voltage pole piece **11** which projects inwardly from the rim. The current pole pieces have pole faces *7a* and *9a* which are disposed substantially in a common plane and which are spaced from the pole face *11a* of the voltage pole piece to provide an air gap therebetween. The complete magnetic structure may be constructed of a plurality of laminations of soft magnetic iron.

Current windings *7b* and *9b* respectively surround the current pole pieces **7** and **9** for directing when energized a current magnetic flux through the pole pieces **7** and **9** and the associated air gap **13**. A voltage winding *11b* surrounds the voltage pole piece for directing when energized a voltage magnetic flux into the air gap **13**. A conventional closed quadrature or lagging loop *11c* surrounds the voltage pole piece adjacent the pole face *11a*.

When the windings are energized the voltage and current magnetic flux established in the air gap are displaced in time and in space to provide a resultant shifting magnetic field. An electroconductive armature or disc **15** is positioned in the air gap **13** and is secured to a shaft **17** which is mounted for rotation in suitable bearings **19**. A permanent magnet (not shown) is conventionally employed for opposing rotation of the electroconductive armature with a force which varies in accordance with the rate of rotation of the armature. It will be understood that the electroconductive armature **15** rotates in accordance with the power of an alternating current circuit from which the watt-hour meter is energized and that the revolutions may be counted by a suitable register (not shown) to integrate the energy supplied by the associated electrical circuit.

In order to improve the performance of the watt-hour meter a main magnetic shunt **21** is positioned between the current pole pieces 7 and 9 adjacent the pole faces thereof. The shunt 21 may be constructed of a suitable soft magnetic material such as cold-rolled steel and is designed to saturate as the energization of the current windings 7*b* and 9*b* increases. As will be understood in the art, such a magnetic shunt increases the accuracy of the watt-hour meter. Preferably the magnetic shunt has flanges 23 and 25 which are adjacent and parallel to the respective pole pieces 7 and 9. These flanges decrease the magnetic reluctance between the shunt and the pole pieces and permits the provision of a larger gap between the magnetic shunt and each of the current pole pieces. They also stiffen the shunt mechanically.

The magnetic shunt 21 is mounted on one or more bridge units. In the embodiment of Figs. 1 and 2 two bridge units 27 and 29 are employed. The bridge unit 27 extends between the current pole pieces and engages corresponding sides 7*c* and 9*c* of the current pole pieces. Similarly, the bridge unit 29 engages corresponding sides 7*d* and 9*d* of the current pole pieces. It will be noted that the current pole piece 7 is positioned between first ends of the bridge units, whereas the pole piece 9 is positioned between second ends of the bridge units. The bridge units may be secured to the current pole pieces in any suitable manner, as by means of bolts 31. If desired, insulation may be provided for breaking up the conductive paths for circulating or "sneak" currents in the shunt assembly. Thus the bolts 31 may be located within suitable insulating bushings T or insulating tubes which insulate the bolts from the current pole pieces and from the bridge units. In addition, insulation P may be interposed between each bridge unit and the associated current pole pieces 7 and 9. The insulation T and P may be constructed of any suitable material such as fish paper or fiber.

The magnetic shunt 21 is secured to the bridge units in any suitable manner. In the specific embodiment of Figs. 1 and 2 the magnetic shunt 21 has four lips 33 which project through small openings 35 in the bridge units. If desired, the projecting ends of the lips may be bent over the bridge units to secure the magnetic shunt to the bridge units.

It will be noted that the bridge units not only mount the magnetic shunt but they assist in maintaining accurate spacing of the current pole pieces. The two bridge units and the shunt constitute in effect a balanced and rigid girder uniting the free ends of the pole pieces. Furthermore, no pole tips extend from the current pole pieces into the space between the pole pieces. Consequently, preformed current windings may be introduced through the air gap 13 and lowered over the current pole pieces without interference from such pole tips.

Either one or both of the bridge units may be designed as an additional magnetic shunt. For example, the bridge unit 27 may include a strip 37 of soft magnetic material which is spaced from the current pole pieces by means of a non-magnetic spacer 39. The spacer conveniently may be constructed of brass. Under such circumstances, bolts 31 also may be constructed of a suitable non-magnetic material such as brass. In a similar manner, the bridge unit 29 may include a soft magnetic strip 41 and a non-magnetic spacer 43. Consequently, the main magnetic shunt 21 and the two bridge units provide three individual shunts which may be proportioned to saturate successively as the energization of the current windings 7*b* and 9*b* increase. In this way, any desired load compensation for the watt-hour meter may be provided. The lips 33 may be sufficiently small that they do not interfere with the individual operations of the various magnetic shunts. That is, the lips 33 may saturate before sufficient magnetic flux flows to saturate any of the magnetic shunts.

If the non-magnetic spacers 39 and 43 are formed of an electrical insulating material, effective insulation for the strips 37 and 41 is provided without utilization of the insulation P. Also if the bridge units are secured by insulating bolts or rivets, such as plastic rivets in place of the bolts 31, the insulating tubes T are not required to break up the conductive paths.

In the embodiment of Fig. 3 a magnetic structure is employed which is similar to that of Figs. 1 and 2 except that the current pole pieces 7*e* and 9*e* have notches 7*f* and 9*f* for reception of a magnetic shunt 21*a*. The magnetic shunt 21*a* has flanges 23*a* and 25*a*. The magnetic shunt 21*a* is similar to the magnetic shunt 21 of Figs. 1 and 2 except that the flanges 23*a* and 25*a* are inclined outwardly for reception in the notches 7*f* and 9*f* of the associated current pole pieces. The magnetic shunt 21*a* may be mounted on one or more bridge units which are similar to the bridge units 27 and 29 of Fig. 2. For example, in Fig. 3 the bridge unit 27*a* corresponds to the bridge unit 27 of Figs. 1 and 2 and is similarly constructed.

In Fig. 4 the magnetic structure 3 has associated therewith a magnetic shunt 21*b* which corresponds to the magnetic shunt 21 of Figs. 1 and 2. In addition, the magnetic structure 3 of Fig. 4 has a bridge unit 27*b* which includes a magnetic strip 37*b* and a spacer 39*b* which corresponds to the magnetic strips 37 and the spacer 39 of Figs. 1 and 2 except that the magnetic strip 37*b* is constructed integrally with the magnetic shunt 21*b*. Conveniently, the strip and the magnetic shunt may be punched from a sheet of cold-rolled steel and the shunt and strip thereafter may be bent into transverse planes as illustrated in Fig. 4. The magnetic shunt 21*b* consequently is in an effective position wherein it shunts magnetic flux equally from all of the laminations in the pole pieces 7 and 9. The spacer 39*b* may be made thick enough to prevent appreciable magnetic flux from entering the shunt therethrough. Alternatively the thickness of the spacer 39*b* may be selected to permit some of the magnetic flux to enter the magnetic shunt therethrough.

In the embodiment of Fig. 5 a magnetic strip 37*c* and a magnetic shunt 21*c* correspond to the strip 37*b* and the shunt 21*b* of Fig. 4 and are similarly constructed in an integral manner. The strip 37*c* is spaced from the current pole pieces 7 and 9 (shown dotted in Fig. 5) by means of a non-magnetic spacer 39*c* and is secured to the pole pieces by means of non-magnetic bolts not shown. The magnetic shunt 21*c* has flanges 23*c* and 25*c* which correspond respectively to the flanges 23 and 25 of Fig. 1 and are provided for a similar purpose.

If it is desired to employ progressively saturated shunts, the shunt assembly of Fig. 5 may be divided into a plurality of independently operating shunt portions. For example, a slit 47 may be provided for restricting the connection between the main shunt 21*c* and the magnetic strip 37*c* to two small integral connections 49 and 50. Strip 37*c* and the main shunt 21*c* thus operate substantially as independent shunt portions and may be designed to saturate successively as the energization of the associated current windings is increased. It will be understood that the connections 49 and 50 are sufficiently small to saturate well in advance of saturation of either the main shunt 21*c* or the strip 37*c* and have such a small magnetic flux carrying capacity that they do not materially affect the performance of the shunt assembly.

The main magnetic shunt 21*c* similarly may be divided into a plurality of substantially independent shunt portions. For example, a slit 51 may be provided which divides the magnetic shunt 21*c* into two parts 53 and 55. The connections between these parts may be made so small that they have no material effect on the performance of the shunt assembly but are employed primarily as mechanical connections between the parts. The shunt assembly of Fig. 5 consequently provides three substantially independent shunt parts, each of which may be designed to saturate at a different value of energization of the associated current windings.

The shunt assemblies of Figs. 4 and 5 are simple in construction, low in cost and sturdy.

The strips **37**, **41**, **37*b***, **37*c*** have large pick-up areas adjacent the current pole pieces. Similarly the flanges **23**, **25**, **23*a***, **25*a***, **23*c***, **25*c*** provide large pick-up areas adjacent the current pole pieces. The large pick up areas increase the total compensation obtainable from the shunt assembly.

Although the invention has been described with reference to certain specific embodiments thereof, numerous modifications falling within the spirit and scope of the invention are possible.

I claim as my invention:

1. An induction instrument including a magnetic structure having an air gap, said magnetic structure comprising a pair of parallel, spaced current pole pieces having pole faces substantially in a common plane adjacent the air gap, current windings on the current pole pieces for establishing when energized a current magnetic field in the air gap, said magnetic structure including voltage means effective when energized for producing a voltage magnetic field in the air gap which is displaced in time and space from the current magnetic field to establish a resultant shifting magnetic field in the air gap, and an electro-conductive armature mounted in the air gap for rotation by the magnetic field, in combination with a shunt assembly comprising a bridge unit extending between the pole pieces adjacent the pole faces and having spaced portions engaging respectively corresponding sides of the pole pieces, and a magnetic shunt intermediate the pole pieces for shunting magnetic flux away from the air gap, said shunt being saturable within the range of energization of the current windings, said magnetic shunt being secured to the pole pieces only through the bridge unit, the bridge unit comprising a magnetic bridge member extending between the pole pieces adjacent the pole faces, said magnetic bridge member saturating at an energization of the current windings different from the energization required to saturate the magnetic shunt.

2. In an electromagnet, a magnetic structure having an air gap, said magnetic structure including a pair of pole pieces having pole faces disposed substantially in a common plane adjacent said air gap, winding means for establishing a magnetomotive force between said pole faces to produce a magnetic field in the air gap, and a shunt assembly for shunting magnetic flux produced by the magnetomotive force away from the air gap, said shunt assembly comprising first and second magnetic shunt members connected to each other for mechanical support with each of said shunt members being effective for shunting magnetic flux between the pole pieces away from the air gap, said first shunt member being positioned substantially intermediate said pole pieces and defining a first plane parallel to said common plane, said second shunt member defining a second plane substantially transverse to said first plane and extending adjacent to and across corresponding sides of said pole pieces to present a substantial area to said pole pieces, said shunt members being proportioned to saturate at different energizations of said winding means.

3. In an electromagnet, a magnetic structure having an air gap, said magnetic structure including a pair of pole pieces having pole faces disposed substantially in a common plane adjacent said air gap, winding means for establishing a magnetomotive force between said pole faces to produce a magnetic field in the air gap, and a shunt assembly for shunting magnetic flux produced by the magnetomotive force away from the air gap, said shunt assembly comprising first and second magnetic shunt members connected to each other for mechanical support with each of said shunt members being effective for shunting magnetic flux between the pole pieces away from the air gap, said first shunt member being positioned substantially intermediate said pole pieces and defining a first plane parallel to said common plane, said second shunt

member defining a second plane substantially transverse to said first plane and extending adjacent to and across corresponding sides of said pole pieces to present a substantial area to said pole pieces, and electrical insulation insulating the shunt members from the pole pieces, said shunt members being designed to saturate for different energizations of said winding means.

4. In an electromagnet, a magnetic structure having an air gap, said magnetic structure including a pair of pole pieces having pole faces disposed substantially in a common plane adjacent said air gap, winding means for establishing a magnetomotive force between said pole faces to produce a magnetic field in the air gap, and a shunt assembly for shunting magnetic flux produced by the magnetomotive force away from the air gap, said shunt assembly comprising first and second magnetic shunt members integrally connected to each other to provide an integral and homogeneous shunt assembly, each of said shunt members being effective for shunting magnetic flux between the pole pieces away from the air gap, said first shunt member being positioned substantially intermediate said pole pieces and defining a first plane parallel to said common plane, said second shunt member defining a second plane substantially transverse to said first plane and extending adjacent to and across corresponding sides of said pole pieces to present a substantial area to said pole pieces, and means securing the second shunt member to the pole piece, said first shunt member being connected to the pole pieces only through the second shunt member, said shunt members being designed to saturate for different energizations of said winding means.

5. In an electromagnet, a magnetic structure having an air gap, said magnetic structure including a pair of pole pieces having pole faces disposed substantially in a common plane adjacent said air gap, means for establishing a magnetomotive force between said pole faces to produce a magnetic field in the air gap, and a shunt assembly for shunting magnetic flux produced by the magnetomotive force away from the air gap, said shunt assembly comprising first and second magnetic shunt members integrally connected to each other by integral connectors proportioned to saturate in advance of the shunt members, said first and second shunt members being effective for shunting magnetic flux between the pole pieces away from the air gap and saturating at different values of magnetomotive force between the pole faces, said first shunt member being positioned substantially intermediate said pole pieces and defining a first plane parallel to said common plane, said second shunt member defining a second plane substantially transverse to said first plane and extending adjacent to and across corresponding sides of said pole pieces to present a substantial area to said pole pieces, and means securing the second shunt member to the pole pieces, said first shunt member being connected to the pole pieces only through the second shunt member.

6. In an electromagnet, a magnetic structure having an air gap, the magnetic structure comprising a pair of spaced magnetic pole pieces having pole faces disposed substantially in a common plane adjacent the air gap, energizing means associated with the pole pieces to effect the establishment of a magnetomotive force between the pole faces for producing a magnetic field in the air gap, and a shunt assembly for shunting magnetic flux produced by the magnetomotive force away from the air gap, said shunt assembly comprising first and second magnetic strip members defining first and second planes extending substantially transverse to each other, said first strip member being positioned intermediate said pole pieces substantially in the plane of said pole faces and having a separate flange extending adjacent and parallel to each of the pole pieces for decreasing the magnetic reluctance between the first strip member and the pole pieces, said first strip member having a slit therein defining first and second magnetic shunt members positioned intermediate said pole pieces and connected by a first pair of relatively

narrow integral connectors, said second strip member being integrally connected to said first strip member and having the ends thereof overlapping and secured to corresponding sides of said pole pieces, said second strip member having a slit therein defining a third shunt member bridging said pole pieces and connected to said first and second shunt members by a second pair of relatively narrow integral connectors, said first and second pairs of connectors being proportioned to saturate prior to the saturation of said shunt members, said shunt members being proportioned to saturate at different values of magnetomotive force between the pole faces.

7. In an electromagnet, a magnetic structure having an air gap, said magnetic structure including a pair of pole pieces having pole faces disposed substantially in a common plane adjacent said air gap, winding means for establishing a magnetomotive force between said pole faces to produce a magnetic field in the air gap, and a shunt assembly for shunting magnetic flux produced by the magnetomotive force away from the air gap, said shunt assembly comprising first and second magnetic shunt members connected to each other for mechanical support with each of said shunt members being effective for shunting magnetic flux between the pole pieces away from the air gap, said first shunt member being positioned substantially intermediate said pole pieces and defining a first plane parallel to said common plane, said second shunt member defining a second plane substantially transverse to said first plane and extending adjacent to and across corresponding sides of said pole pieces to present a substantial area to said pole pieces, said shunt members being proportioned to saturate at different values of magnetomotive force between the pole faces produced by energization of the winding means.

8. An induction instrument including a magnetic structure having an air gap, said magnetic structure comprising a pair of parallel, spaced current pole pieces having pole faces substantially in a common plane adjacent the air gap, current windings effective when energized for directing alternating current magnetic flux in series through the current pole pieces and the air gap to establish a current magnetic field in the air gap, said magnetic structure establishing a loop including the current pole pieces in parallel and said air gap, voltage means effective when suitably energized for directing alternating voltage magnetic flux through said loop to produce a voltage magnetic field in the air gap which is displaced in time and space from the current magnetic field to establish a shifting magnetic field in the air gap, and an electroconductive armature mounted in the air gap for rotation by the magnetic field, in combination with a shunt assembly comprising a magnetic shunt member located substantially in the space between the current pole pieces in a plane substantially parallel to the plane of the pole faces, a bridge shunt member extending across the current pole pieces in a plane substantially transverse to said pole faces and having end portions adjacent sides of the current pole pieces in a common plane, means securing the end portions respectively to the pole pieces, said magnetic shunt member extending adjacent the bridge shunt member and being secured thereto, said shunt members being constructed of soft magnetic material proportioned to shunt magnetic flux between the pole pieces and to saturate respectively at different values of energization of the current windings.

9. An induction instrument including a magnetic structure having an air gap, said magnetic structure comprising a pair of parallel, spaced current pole pieces having pole faces substantially in a common plane adjacent the air gap, current windings effective when energized for directing alternating current magnetic flux in series through the current pole pieces and the air gap to establish a current magnetic field in the air gap, said magnetic structure establishing a loop including the current pole pieces in parallel and said air gap, voltage means effective when suitably energized for directing alternating voltage magnetic flux through said loop to produce a voltage magnetic field in the air gap which is displaced in time and space from the current magnetic field to establish a shifting magnetic field in the air gap, and an electroconductive armature mounted in the air gap for rotation by the magnetic field, in combination with a shunt assembly comprising a magnetic shunt member located substantially in the space between the current pole pieces in a plane substantially parallel to the plane of the pole faces, a bridge shunt member extending across the current pole pieces in a plane substantially transverse to said pole faces and having end portions adjacent sides of the current pole pieces in a common plane, means securing the end portions respectively to the pole pieces, said magnetic shunt member extending adjacent the bridge shunt member and being secured thereto, said shunt members being constructed of soft magnetic material proportioned to shunt magnetic flux between the pole pieces and to saturate respectively at different values of energization of the current windings, said shunt members being integral parts of a sheet of soft magnetic material bent to position the shunt members transverse to each other, the connection between said shunt members through the sheet being proportioned to saturate for an energization of the current windings too small to saturate the shunt members.

10. An induction instrument including a magnetic structure having an air gap, said magnetic structure comprising a pair of parallel, spaced current pole pieces having pole faces substantially in a common plane adjacent the air gap, current windings effective when energized for directing alternating current magnetic flux in series through the current pole pieces and the air gap to establish a current magnetic field in the air gap, said magnetic structure establishing a loop including the current pole pieces in parallel and said air gap, voltage means effective when suitably energized for directing alternating voltage magnetic flux through said loop to produce a voltage magnetic field in the air gap which is displaced in time and space from the current magnetic field to establish a shifting magnetic field in the air gap, and an electroconductive armature mounted in the air gap for rotation by the magnetic field, in combination with a shunt assembly comprising a magnetic shunt member located substantially in the space between the current pole pieces in a plane substantially parallel to the plane of the pole faces, a bridge shunt member extending across the current pole pieces in a plane substantially transverse to said pole faces and having end portions adjacent sides of the current pole pieces in a common plane, means securing the end portions respectively to the pole pieces, said magnetic shunt member extending adjacent the bridge shunt member and being secured thereto, said shunt members being constructed of soft magnetic material proportioned to shunt magnetic flux between the pole pieces and to saturate respectively at different values of energization of the current windings, means establishing a non-magnetic spacing between at least one of the end portions and the associated pole piece, the portions of the pole pieces adjacent the first-named shunt member being transverse to the plane of the pole faces over substantial areas to permit substantial movement of the first-named shunt member transverse to said plane without substantial alteration in the magnetic reluctance of the path between the pole pieces through the first-named magnetic shunt.

11. In an electromagnet, a magnetic structure having an air gap, said magnetic structure including a pair of pole pieces having pole faces disposed substantially in a common plane adjacent said air gap, means for establishing a magnetomotive force between said pole faces to produce a magnetic field in the air gap, and a shunt assembly for shunting magnetic flux produced by the magnetomotive force away from the air gap, said shunt assembly comprising a magnetic shunt member positioned

substantially between the pole pieces adjacent and parallel to the pole faces and designed to saturate within the rated range of variations of the magnetomotive force, a bridge unit extending between said pole pieces adjacent the pole faces, said bridge unit having its ends overlapping and secured to sides of said pole pieces located substantially in a common plane, and securing means securing the magnetic shunt member to the bridge unit, the magnetic shunt member having flanges extending adjacent and parallel to sides of said pole pieces to reduce the magnetic reluctance of the gaps between the shunt member and the pole pieces, said flanges extending substantially transverse to said common plane, each of said pole pieces having a uniform cross-sectional area, said bridge unit comprising a magnetic shunt element and said securing means comprising connectors integrally connected to the magnetic shunt element and the shunt member, said connectors being proportioned to saturate substantially before the magnetic shunt member as the magnetomotive force between the pole faces increases.

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