Nov. 11, 1969 R. A. PARNELL 3,478,289

PERMANENT MAGNET ASSEMBLY FOR A LOUDSPEAKER ASSEMBLY

Filed Feb. 12, 1968

Fig. 1

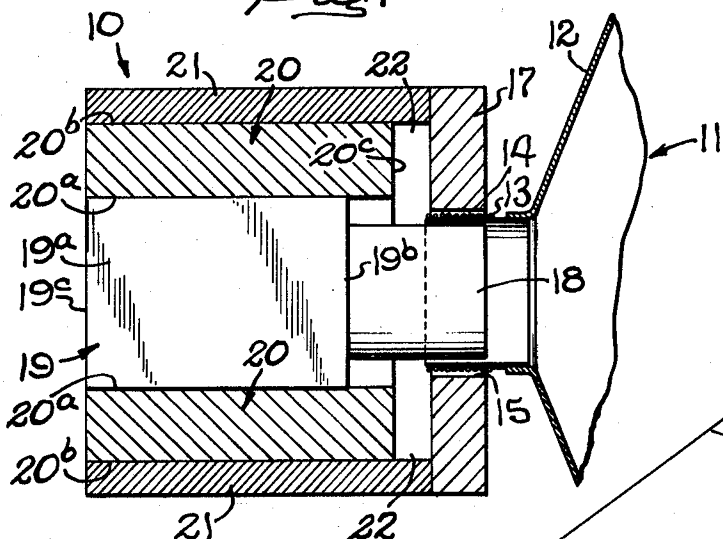


Fig. 2

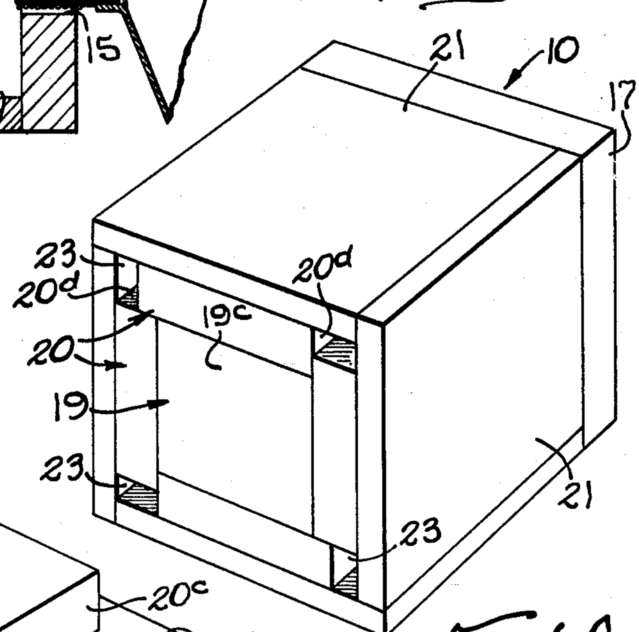


Fig. 3

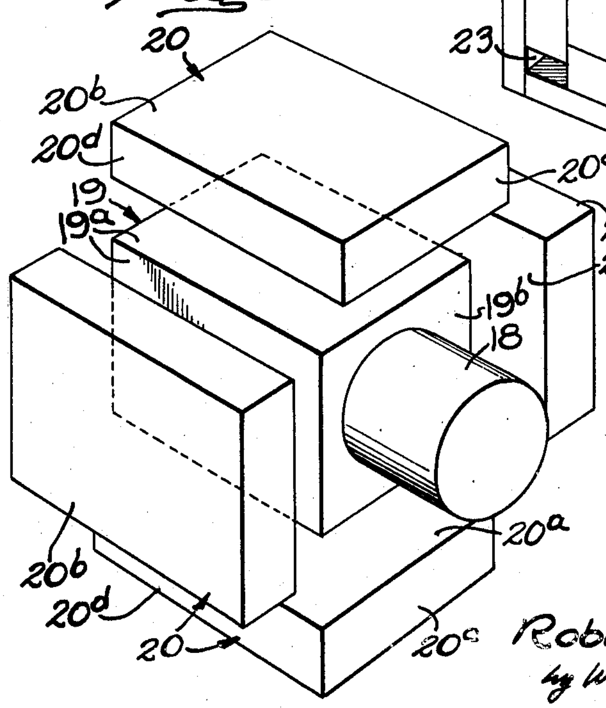
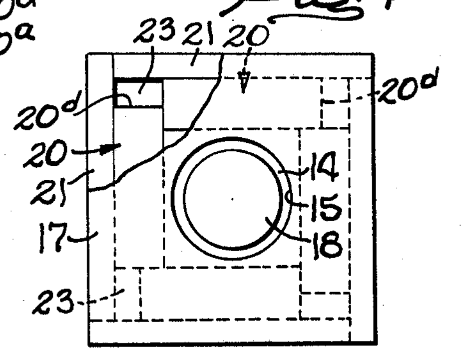


Fig. 4



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PERMANENT MAGNET ASSEMBLY FOR A LOUDSPEAKER ASSEMBLY

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ABSTRACT OF THE DISCLOSURE

A permanent magnet assembly for use in a loudspeaker assembly having a cone diaphragm with a speaker coil disposed in an air gap in the magnet assembly. The latter comprises a cubical block with a cylindrical pole piece bonded to one end to form the core structure, and with four ceramic wafers having like poles disposed against the sides of the block and partially overhanging the pole piece. Four rectangular side plates are disposed against and bonded to the opposite poles to form a case, and a front plate defining the air gap abuts against the front edges of the side plates. The magnets have side edge portions in partially overlapping relation around the block to leave spaces in the four corners of the assembly.

BACKGROUND OF THE INVENTION

This invention relates to permanent magnet assemblies of the type used in electrical-acoustical transducers such as loudspeakers, microphones and the like in which a magnetic field is produced in an air gap for interaction with a current-carrying coil movable in the gap. The quality of performance of such transducers depends upon the density of the magnetic field or flux produced in the air gap, called the gauss, and this density depends upon the total flux produced by the amount and type of magnet material used, and the efficiency of the assembly in concentrating the available flux in the air gap.

Various types of permanent magnet assemblies have been proposed and used, one well-known type utilizing a disk of magnetized ferrite ceramic material sandwiched between two end plates of magnetic material with a pole piece or core affixed to one plate and projecting through the magnet into an opening in the other plate defining the air gap. Another commercial type uses a magnet plug composed of a more expensive Alnico material with one pole of the magnet placed against the crosspiece of a U-shaped metal strap and either the opposite pole or a pole cap thereon disposed in a hole in a front plate spanning the free ends of the legs of the strap, the plate sometimes being formed integrally with the rest of the strap. Still another type that has been proposed in that shown in Patent No. 2,275,880 having a cylindrical sheath magnet disposed around an elongated core rod and surrounded by a cylindrical outer case forming the return path for flux, the air gap being defined in a hole in a front plate around the end of the core. This type of structure has not found wide commercial acceptance, perhaps because the magnet structure is not practical from an economical mass-production standpoint.

SUMMARY OF THE INVENTION

The primary object of the present invention is to provide a new and improved permanent magnet assembly for loudspeakers and related devices in which comparable flux density is obtained with a smaller investment in raw materials, most notably the permanent magnet material required for the assembly, whereby a substantial reduction in cost is achieved. A related object is to obtain optimum utilization of available flux to achieve higher flux densities and better quality of performance with a given amount of magnet material. In addition, these ends are achieved in an assembly of relatively simple and compact construction capable of being mass-produced at low cost with readily available stock requiring a minimum of machine operations and assembly labor. Another important object is to provide a novel assembly of the foregoing character that makes possible the use of inexpensive wafers of ceramic magnet material to obtain flux densities comparable to those obtained in conventional ceramic or Alnico structures but at a substantial saving in the cost of magnet material. In keeping with these objectives, the invention aims to minimize the amount of stray or lost flux in the structure for more efficient utilization of available magnetic flux and optimum flux density in the air gap and to accomplish this while maintaining the conventional gap geometry.

Other objects and advantages of the invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a fragmentary cross-sectional view taken in a longitudinal plane through a loudspeaker assembly and showing a permanent magnet assembly embodying the novel features of the present invention.

FIG. 2 is a perspective view of one end of the magnet assembly.

FIG. 3 is an exploded perspective view of the internal parts of the magnet assembly.

FIG. 4 is an elevational view of the front end, partly broken away for clarity of illustration.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

As shown in the drawings for purposes of illustration, the invention is embodied in a permanent magnet assembly **10** for use with a loudspeaker **11** having a cone diaphragm **12** with a speaker coil **13** disposed within an annular air gap **14** (FIGS. 1 and 4) formed in the front end wall of the magnet assembly, the latter being referred to in the trade as a "speaker pot." As a result of the magnetic field created in the air gap, changes in the electrical signal applied to the coil cause the latter and the cone to vibrate and produce sound.

In this instance, the air gap **14** is defined in the usual manner between the circular wall **15** of a hole in the front wall, herein formed by a rectangular front plate **17** composed of suitable magnetic material such as cold rolled steel or other ferromagnetic material, and the forward end portion of a pole piece **18** projecting coaxially into the hole from behind the front plate and also composed of magnetic material, the pole piece being the front portion of the core structure of the assembly. The dimensions of the hole and the pole piece, as well as the area and volume of the gap, are the subjects of appropriate engineering standards and thus are not concerned with the present invention, which may be applied to different standard gap sizes. To produce the magnetic field in the air gap for interacting with the voice coil **13**, a magnet unit is incorporated in the assembly with a first pole of one polarity in conducting relation with the pole piece **18** to make the latter of the same polarity, and with a second, opposite pole in conducting relation with the front plate **17** through an outer element composed of magnetic material in contact with the front plate. Thus, the assembly forms a magnetic circuit between the opposite poles of the magnet unit for flux created by the unit, which flux passes through the air gap between the pole piece and the front plate.

The density of the field in the air gap **14** depends upon the total available flux produced by the magnet unit and upon the effectiveness of the assembly in confining the flux to the circuit by minimizing leakage or stray flux around the assembly. Thus, the cost of a given permanent magnet assembly is primarily affected by the amount and type of magnet material required to obtain a desired flux density or gauss in the gap, and designs that result in more efficient utilization of magnet material or permit the use of less expensive magnet materials either produce savings in the cost of manufacture or increase the quality of performance obtained with a given amount of material.

In accordance with the present invention, the elements of the permanent magnet assembly are constructed and arranged in a novel manner for optimum utilization of available flux and also for simplicity and economy of fabrication. To these ends, the rear or inner portion of the core structure is formed by a flat-sided body **19** of polygonal cross-section to which the pole piece **18** is secured, either integrally or as a separate piece, to project forwardly from one end of the body into the hole **15** in the front plate **17**, and the magnet unit comprises a plurality of slabs or wafers **20** of permanent magnet material disposed around the body with flat inner sides **20**^{a} of the wafers formed as like poles contacting the body and with opposite poles **20**^{b} facing outwardly away from the body, the wafers extending forwardly beyond the body toward the front plate in spaced relation with the pole piece. Outside the magnet unit is a conducting case having side elements **21** contacting the opposite poles of the wafers and extending forwardly to the front plate thereby to complete the magnetic circuit. Accordingly, the magnet unit is composed of simple and inexpensive magnets that may be composed of ceramic magnet material in a readily available form. In addition, the outer case may be constructed from simple and inexpensive plate stock, and the end result is an assembly that more efficiently utilizes available flux than prior assemblies that have been commercially practical from a manufacturing standpoint.

In this instance, the core body **19** is a cubical block and thus is of rectangular or square cross-section having four flat outer sides **19**^{a} disposed in planes parallel to the longitudinal, front-to-rear axis of the core structure. The pole piece **18** is simply a cylinder of the same magnetic material having a diameter less than the width of the front end face **19**^{b} of the block and affixed to the latter in centered relation to project forwardly in spaced relation with the planes of the four sides. With a two-piece core, economy of mass production is made possible, using lengths of readily available bar stock, but it will be apparent that a single-piece construction can be used in which the front end portion **18** is machined to the desired size and shape.

Four permanent magnet wafers **20** are disposed against the sides of the core body **19** to enclose the latter within the magnet unit, these wafers having flat inner sides **20**^{a} in substantially gap-free contact with the flat sides **19**^{a} of the body, and also having flat outer sides **20**^{b} disposed in parallel planes for contact with the case. The magnet unit thus is arranged with the preferred direction of orientation of the wafers parallel to the general plane of orientation of the flux in the air gap **14**.

As shown most clearly in FIGS. 1 and 2, the rear edges of the wafers **20** preferably are substantially flush with the rear end **19**^{c} of the core body **19** and the forward edges **20**^{c} are spaced forwardly from the front end **19**^{b} of the body whereby the forward portions of the wafer overhang part of the pole piece **18** in spaced relation therewith. Thus, there is voice-coil clearance around the full length of the pole piece, permitting the coil to vibrate freely along the full length. The outer case preferably comprises four flat rectangular plates **21** of magnetic material such as cold rolled steel disposed against the outer sides **20**^{b} of the wafers with the rear edges of the plates flush with the rear edges of the wafers and the front edge portions of the plates extending forwardly beyond the front end of the body for engagement with the front plate **17**. The latter also is a rectangular plate with the hole **15** punched in its center, and either is fitted into the front of the case or is butted against the side plates, herein being shown as abutting against the front edges of the plates.

It will be seen in FIG. 1 that the side plates **21** are longer than the magnet wafers **20** so as to leave a space or clearance gap **22** between the overhanging forward edges **20**^{c} of the magnets and the inner side of the front plate **17**. The overhang of the magnets is important from the standpoint of shielding the pole piece **18** from the case, the two being of opposite polarity so that flux would stray across the intervening space if there were no shielding. On the other hand, the pole piece and the inner sides **20**^{a} of the magnets are of the same polarity so that no flux loss occurs between the overhanging portion of the magnet unit and the pole piece. If, however, the front edges **20**^{c} of the magnets were butted against the front plate, a short circuit would occur in this area and result in localized return paths and flux loss between the magnets and the front plate. Thus, spacing the magnets a preselected distance from the front plate (so that little or no magnetic potential difference exists) is believed to minimize leakage flux within the assembly by obtaining optimum shielding of the pole piece while eliminating the localized return paths through the forward edges of the magnets.

At the same time, the normal pattern of flux lines in the clearance gap **22** around the front edges of the magnets reduces or eliminates the magnetic potential difference around the unshielded portion of the pole piece to minimize flux leakage through the clearance gap to the case. For optimum flux density in the air gap **14**, the width of the clearance gap **22** should be from one-half to two-thirds of the magnet length, that is, the thickness of the wafers between the poles **20**^{a} and **20**^{b}.

A similar phenomenon has been observed with respect to the arrangement of the side edges **20**^{d} of the wafers **20**. Although it would be possible to use wafers of the same width as the contiguous sides **19**^{a} of the body **19**, improved efficiency is obtained if the wafers are made wider than the body by an amount less than the thickness of each wafer, and arranged flush with one adjacent side and partially overhanging the other adjacent side, as shown shown in FIGS. 2 and 4. Thus each wafer abuts along one side edge **20**^{d} against the inner face **20**^{a} of one adjacent wafer and overhangs the corresponding side edge of the other adjacent wafer, while leaving a clearance space at **23** within each corner of the assembly. Again, it has been found that this arrangement avoids or minimizes the localized return paths within the assembly that would result from having one inner pole face **20**^{a} of a wafer in full overlapping contact with the entire edge **20**^{d} of another wafer, forces available flux to flow through the useful circuit rather than leaking between edges of the magnets, and evidently reduces or eliminates magnet potential differences in the clearance spaces **23**. The amount of overlap for optimum flux confinement should be between one-third and two-thirds of the wafer thickness.

As previously suggested, the novel magnet assembly **10** is well suited for mass-production fabricating and assembly operations at low cost. The core structure **18**, **19** may be made by severing short lengths of rectangular and cylindrical bar stock to form the core body and the pole piece while the side plates **21** and the front plate **17** are similarly made from flat stock. The magnet wafers **20** preferably are composed of ferrite ceramic material, so all materials used are relatively inexpensive. Moreover, the assembly operations are extremely simple. In one possible method of assembly, the pole piece is bonded to the core body, the four wafers are bonded to the sides of the body in the proper overlapping relationship, and the side plates are similarly bonded to the outer sides of the magnets. Then the front plate is bonded to the forward edges of the side plates with the pole piece coaxially located in the hole **15**, and the unit is complete. While various adhesive bonding materials may be used, I have found that a thin film of the material sold under the trademark "Loctite" is quite suitable.

It will be noted that only the dimensions of the pole piece **18** and the hole **15** are at all critical. With the overlapping arrangement of the wafers **20** and the side plates **21**, there is ample space to accommodate variations in dimensions, so there is no need for close manufacturing tolerances. In addition, there is no need for mechanical fasteners of any kind, although fasteners may be used instead of an adhesive, if desired.

Flux leakage is minimized in several ways in the assembly described above, by reducing the exposed surface area of the magnet unit, eliminating instances in which surfaces of opposite polarity are in contact with or adjacent to each other, and confining the available flux to the useful circuit defined by the core **18, 19**, the front plate **17**, and the case **21**. In addition, the exposed area of the magnetic circuit element surfaces parallel to the direction of orientation of the permanent magnet material is less than in other commercial structures and this is believed to be responsible for part of the increase in efficiency. Among the most significant factors in the reduction of flux leakage are the shielding of the pole piece **18** from the adjacent portions of the side plates **21**, and the elimination of localized return paths between the magnets and the front plate, both of these protective features being achieved quite simply and practically with the wafer arrangement disclosed.

From the foregoing, it will be seen that the present invention provides a practical permanent magnet assembly **10** in which optimum utilization of magnet material is obtained, and that this is accomplished in an assembly that may be mass-produced with readily available and relatively inexpensive steel and ceramic magnet stock requiring little machining and only simple assembly operations. Thus, the invention provides substantial savings in the cost of magnet material and also in the costs of steel and labor. The result is a compact and simple permanent magnet assembly that compares favorably in performance with the other commercially accepted Alnico and ceramic magnet structures while costing materially less in terms of gauss per dollar.

While a preferred embodiment of the invention has been described in detail, various modifications and variations will suggest themselves to those skilled in the art. For example, instead of a core body **19** of square or rectangular cross-section, a triangular or other polygonal section may be used, with a permanent magnet wafer disposed against each side of the body. Of course, different arrangements of wafers and side plates may be used, including integrally joined plates covering more than one side of the magnet unit, without departing from the scope and spirit of the present invention, as defined by the appended claims.

I claim as my invention:

1. A permanent magnet assembly for use in a loudspeaker structure, said assembly having, in combination, a core structure of magnetic material including a block of rectangular cross-section having flat outwardly facing sides and a cylindrical pole piece projecting forwardly from one end of said block inside the space bounded by the planes of said sides, four wafers of ferrite ceramic permanent magnet material having flat inner sides of like polarity disposed against and covering the sides of said block and having flat outer sides of opposite polarity, said wafers extending forwardly from said one end in spaced overhanging relation with said pole piece and having side edge portions in overlapped relation around said block, four plates of magnetic material having flat inner sides disposed against the outer sides of said wafers and arranged in edge-to-edge relation around the wafers to form a case, said plates having front portions extending forwardly beyond the front edges of said wafers, a front plate composed of magnetic material abutting against said front portions of said plates and having a circular hole into which said pole piece extends to define an annular air gap opening rearwardly into said assembly in alinement with the clearance extending rearwardly to said block around said pole piece, said wafers having front edges spaced rearwardly from said front plate and leaving a clearance gap between the front plate and the magnets, and means securing the parts of said assembly together.

2. A permanent magnet assembly as defined in claim **1** in which said securing means is an adhesive applied between the various parts.

3. A permanent magnet assembly as defined in claim **1** in which said pole piece and said block are separate parts bonded together by an adhesive.

4. A permanent magnet assembly as defined in claim **1** in which said wafers are identical in size and shape.

5. A permanent magnet assembly comprising a core structure of magnetic material having a flat-sided body of rectangular cross-section and a pole piece projecting forwardly from one end of said body within the space bounded by the planes of said sides of said body four permanent magnet wafers disposed against said sides and covering the latter, said wafers having like first poles in flat abutting contact with said sides and opposite second poles facing outwardly away from the core body, an outer case of magnetic material comprising four side plates having inner side surfaces disposed against said second poles and extending forwardly beyond said core body in spaced relation with said pole piece, and a front plate of magnetic material abutting against the forward portions of said side plates and having a hole into which said pole piece projects in spaced relation with the wall of said hole thereby defining an annular air gap around the pole piece.

6. A permanent magnet assembly as defined in claim **5** in which said wafers are of preselected thickness between said poles and extend forwardly beyond said core body in spaced relation with said pole piece and terminate in front edges spaced behind said front plate to leave a preselected clearance gap between the wafers and the front plate, said side plates extending beyond said gap to said front plate.

7. A permanent magnet as defined in claim **6** in which said clearance gap is equal to between one-half and two-thirds of said thickness.

8. A permanent magnet assembly as defined in claim **5** in which said wafers are of preselected thickness and said poles are rectangular in shape and wider than the contiguous side of said core body by an amount equal to between one-third and two-thirds of said thickness, each wafer having one side edge flush with an adjacent side of said body and another side edge in partially overlapping relation with an adjacent wafer.

9. A permanent magnet assembly as defined in claim **5** in which said wafers are bonded by adhesive to said body and said side plates are similarly bonded to said wafers and to said front plate.

10. A permanent magnet assembly as defined by claim **9** in which said pole piece and said core body are separate pieces bonded together by adhesive.

11. A permanent magnet assembly comprising a core structure of magnetic material having a flat-sided body of polygonal cross-section and a pole piece projecting forwardly from one end of said body, a plurality of permanent magnet disposed against and covering the flat sides of said body and having inner flat sides constituting like first poles abutting against said sides and outer opposite poles facing outwardly away from said body, an outer case of magnetic material disposed against said outer poles, said case extending forwardly beyond said body in spaced relation with said pole piece, and a front plate of magnetic material abutting against the forward edge portion of said case and having a hole into which said pole piece projects in spaced relation with the wall of said hole thereby to define an annular air gap around the pole piece, whereby said core structure, said case and said wafers define a flux circuit from said first poles into said core structure and through the latter to said air gap, across the gap to said front plate, through the latter to said case, and thence back to said outer poles.

12. A permanent magnet assembly as defined in claim **11** in which said magnets extend forwardly beyond said body in spaced relation with said pole piece and terminate in edges spaced a preselected distance behind said front plate thereby shielding part of the forwardly extending portion of said case from said pole piece and leaving a clearance gap between said edges and said front plate.

13. A permanent magnet assembly as defined in claim **12** in which said preselected distance is selected to locate said edges so that no magnetic potential difference exists between said edges and said front plate across said clearance gap, and between said pole piece and the clearance gap.

14. A permanent magnet assembly as defined in claim **11** in which said magnets are wafers of a preselected thickness between said poles, and said preselected distance is equal to between one-half and two-thirds of said preselected thickness.

15. A permanent magnet assembly as defined in claim **11** in which each of said magnets is a wafer wider than the contiguous side of said body and arranged with one side edge flush with an adjacent side of the body and the opposite side edge overhanging the other adjacent side of the body whereby each wafer overlaps the side edge of an adjacent wafer and abuts against the first pole of another adjacent wafer.

16. A permanent magnet assembly as defined in claim **15** in which the amount of overlap is less than the thickness of the overlapped wafer, leaving a clearance space between the overlapping edge and said case.

17. A permanent magnet assembly as defined in claim **15** in which said wafers are of a preselected thickness and the amount of overlap is between one-third and two-thirds of said thickness.

18. A permanent magnet assembly as defined in claim **11** in which said magnets are wafers having flat parallel

pole faces and said case comprises a plurality of plates of magnetic material having flat sides abutting against said outer poles and arranged to surround said wafers on all exposed sides of the latter.

19. A permanent magnet assembly as defined in claim **18** including an adhesive holding said side plates, said wafers and said core structure in assembled relation.

20. A permanent magnet assembly comprising a core structure of magnetic material having a core body and a pole piece projecting forwardly therefrom, a magnet unit arranged around said core body and comprising a plurality of permanent magnet wafers having flat inner sides of like polarity abutting against said core body and outer sides of opposite polarity, said wafers being in edge-to-edge relation around said body, a front member of magnetic material having a hole into which said pole piece extends and cooperating with the pole piece to define an air gap, and an outer return element of magnetic material contacting said outer sides and said front member to complete a magnetic circuit between said poles and through said air gap.

21. A permanent magnet assembly as defined in claim **20** in which said core body has flat sides in substantially gap-free contact with the inner sides of said wafers.

22. A permanent magnet assembly as defined in claim **21** in which said wafers have flat outer sides and said return element is a case comprising flat plates arranged in edge-to-edge relation around said magnet unit.

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G. HARRIS, Primary Examiner

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179—117; 335—306