

May 26, 1964

W. J. BRAND ET AL

3,134,933

ADJUSTABLE GAP MAGNET

Filed Aug. 13, 1962

FIG. 1

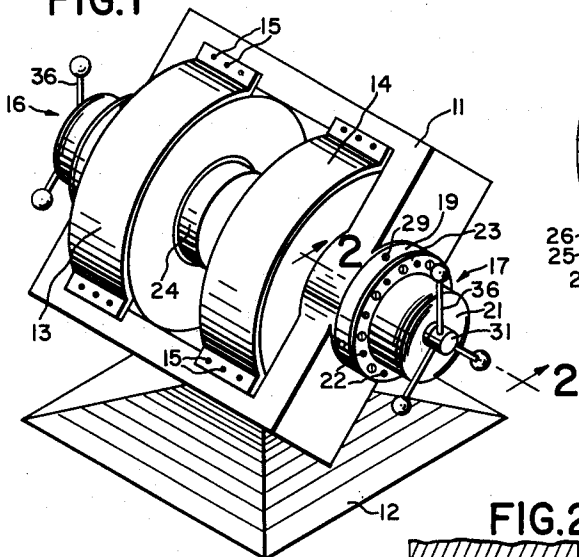


FIG. 3

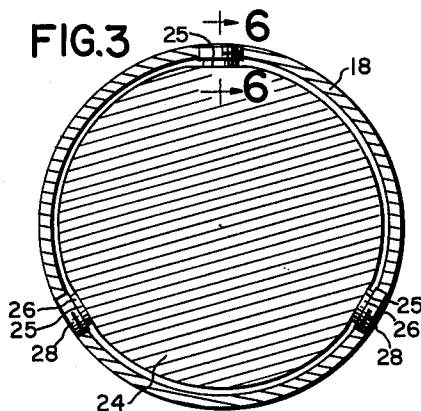


FIG. 5

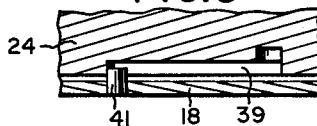


FIG. 2

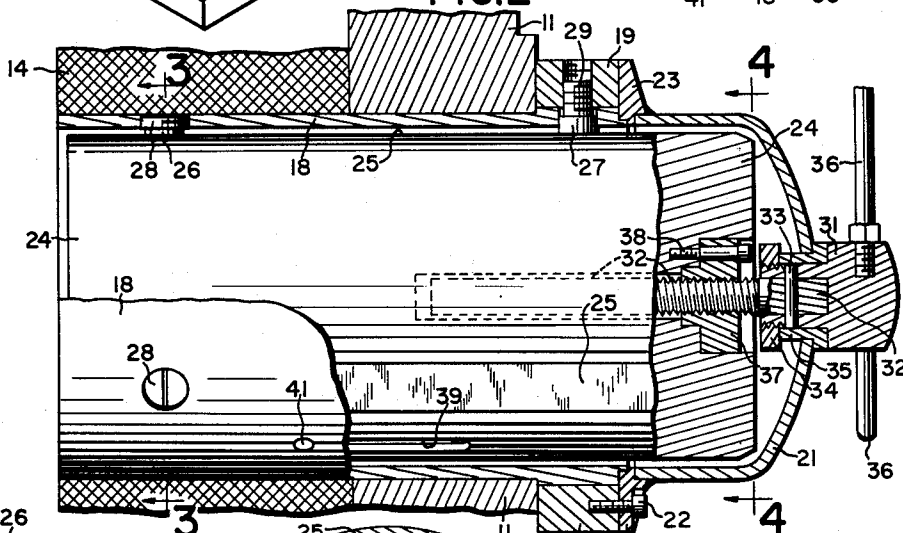


FIG. 4

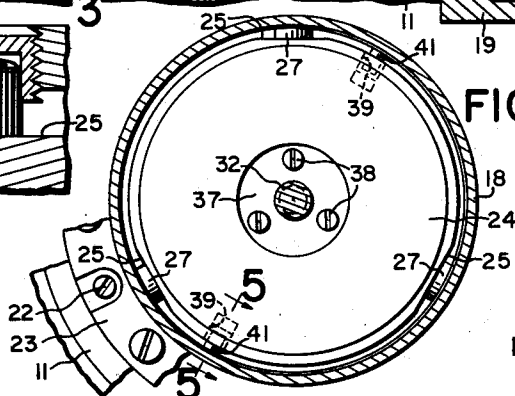
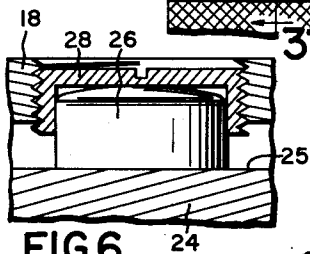


FIG. 6



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ADJUSTABLE GAP MAGNET

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10 Claims. (Cl. 317-158)

The present invention relates in general to magnets and more specifically to novel magnet apparatus which provides for adjustments in the magnet gap spacing while maintaining a high degree of alignment of the pole faces of the magnet whereby the reproducibility of the homogeneity of the magnetic field produced by the magnet may be greatly increased. Such adjustable air gap magnets which produce a highly homogeneous magnetic field are useful in various types of gyromagnetic resonance spectroscopy applications where the resolution obtainable becomes a direct function of the homogeneity of the magnetic field employed.

Heretofore adjustable air gap magnets of the general type discussed herein have been constructed which will give the user an air gap adjustment over several inches or more. It has been extremely difficult, however, to maintain a high degree of reproducibility of magnetic field homogeneity in such magnets since homogeneity and air gap adjustment are not compatible parameters.

The present invention provides a novel magnet apparatus which permits magnet gap spacing adjustments while maintaining a high degree of pole piece alignment and positioning to thereby give reproducible high homogeneity magnetic fields over the range of gap spacing.

The principal object of the present invention, therefore, is to provide a novel adjustable air gap magnet having exceptionally high magnetic field homogeneity over the entire range of gap adjustment.

One feature of the present invention is the provision of a novel mounting arrangement for the sliding pole pieces of an adjustable gap magnet which will give a degree of pole piece alignment and positioning heretofore unattainable.

Another feature of the present invention is the provision of a novel apparatus for imparting longitudinal sliding motion to the pole pieces in a manner which minimizes any radial misaligning forces acting on the pole pieces.

These and other features and advantages of the present invention will be more apparent after a perusal of the following specification taken in connection with the accompanying drawings wherein,

FIG. 1 is a perspective view of an adjustable air gap laboratory electromagnet utilizing the present invention,

FIG. 2 is a view partially cut away and partially in cross section of one of the sliding pole pieces and its associated adjusting and aligning mechanisms,

FIG. 3 is a cross section view of the pole piece of FIG. 2 taken along section line 3-3,

FIG. 4 is a cross section view of the structure of FIG. 2 taken along section line 4-4,

FIG. 5 is a section view taken along section line 5-5 in FIG. 4, and

FIG. 6 is an enlarged view of one of the pole piece pressure pads taken at section line 6-6 in FIG. 3.

Referring now to FIG. 1 there is shown an electromagnet structure which embodies the present invention, said structure including a solid closed rectangular shaped yoke 11 of highly permeable material such as, for example, iron mounted on a base or pedestal 12, preferably in a rotating manner about a vertical axis. A pair of electrical windings 13 and 14 are fixedly secured within the yoke 11 by bolts 15. A pair of adjustable gap pole piece assemblies 16 and 17 are mounted on the yoke 11 and

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extend inwardly toward each other through the sides of the yoke and the associated electrical windings.

One of these pole piece assemblies is more clearly shown in the remaining figures, the other pole piece assembly being of similar construction. The pole piece assembly comprises a hollow cylindrical pole sleeve 18 of steel having an integral flange 19, an end bell 21 being secured over the outer end of the sleeve 18 by means of bolts 22 which extend through an integral flange 23 which mates with flange 19. A cylindrical pole piece 24 is located within the sleeve 18, said pole piece having three equispaced longitudinally directed flat surfaces 25 formed therein. These flat surfaces 25 each slideably engage two associated pressure pads 26 and 27, each pressure pad being disc shaped with a flat inner surface engaging the flat surface 25 and a slightly domed outer surface which engages the flat surface at the inner ends of associated adjusting screws 28 and 29. The pressure pads 26 fit within the cup-shaped adjusting screws 28 which are screwed into associated tapped holes in the sleeve 18. The adjusting screws 29 associated with the pressure pads 27 extend through tapped holes in the flange 19 and may be reached for adjusting after complete assembly of the magnet.

The adjusting mechanism associated with the pole piece comprises a pole piece driver cap 31 having a bore in its inner end into which a pole piece driver 32 is affixed by means of a dowel pin 33. The inner end of the driver cap 31 is threaded and an internally threaded annular clamp member or nut 34 is screwed thereon to secure the assembly to the bearing member 35 mounted in the end bell 21. The clamp 34 is secured tight enough against the bearing 35 to prevent backlash yet loose enough so that the assembly is permitted to rotate in the bearing 35 in response to rotational motion imparted through the spokes 36. Also, the pole piece driver 32 is slightly undersized relative to the bore in the driver cap 31 to permit a slight amount of radial play along the dowel pin 33.

The inner end of the driver 32 is threaded and is screwed through a collar or nut 37 which is affixed within a bore in the pole piece by means of shoulder screws 38. Because of the shoulder screws and also because the diameter of the screws 38 is made undersized relative to the hole in the collar 37, the collar 37 and associated driver 32 are permitted slight radial play in the pole piece 24.

A pair of keyways 39 are located in the pole piece, keys 41 being secured in the sleeve 18 and extending into the keyways 39 to limit the distance of longitudinal movement of the pole pieces within the sleeve 18 and to prevent rotation of the pole piece in the sleeve 18.

The structural elements of this magnet are made of conventional materials such as steel. The pressure pads 26 and 27 are made of a good bearing material, such as bronze, as are the driver cap 31 and nuts 34 and 37.

During adjustment of the air gap spacing during use, the flat end of the pressure pads 26, 27 is free to follow and align the pole piece ways or flats, the doming configuration of the outer end of the pressure pad permitting a freedom of angular movement of the pad which will compensate for any slight irregularities or dimensional inaccuracies along the pole piece flats.

The forward pressure pads 26 are tightened down by means of the screws 28 to such a degree as to exert a balance of pressure on the three ways or flats 25, this pressure resulting in a slight deformation of the sleeve 18 with a resultant spring loading effect on the pole piece. The adjustment of the forward pads 26 is accomplished before assembly of the pole piece 24 into the yoke 11 and the electrical coils. The three rearward pressure pads 27 are also adjusted so as to exert an equal balancing

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force on the three flats 25. The three adjusting screws 29 are accessible after complete assembly of the magnet apparatus and therefore trimming-up adjustments may be made by means of these screws 29 during use of the magnet.

It is noted that the adjustment screw or driver assembly is arranged in such a manner as to minimize all radial force being transmitted to the pole piece 24 during longitudinal or axial movement of the pole piece and to optimize the repositioning of the pole piece on its axis after movement. This is accomplished by use of the capitated floating nut 37 into which the driver screw 32 is threaded, the driver screw 32 also being mounted in a floating manner by means of the dowel pin 33 in the driver cap 31.

In one electromagnet made in accordance with this invention, the pole piece diameters were 6 inches and the gap spacing was variable from $\frac{1}{2}$ inch to $5\frac{1}{2}$ inches maximum with a field strength variation of up to about 24 kilogauss. As an illustration of the field reproducibility of this magnet, the air gap was set at one inch with a field strength at the center of the air gap of about 6,000 gauss. A plot was made of the field strength at discrete intervals across the air gap from pole face to pole face by means of a very sensitive nuclear magnetic resonance field measuring instrument. After such measurements and plotting were completed, the pole pieces were moved apart a distance of about five inches by rotation of the drivers and were then returned to their original position, i.e., an air gap of one inch. The same measurements and plotting described above were repeated at this time for comparison with the first measurements. It was found that the reproducibility pole cap to pole cap was within 50 milligauss which is one part in 120,000 homogeneity. This was far superior to any results obtained with any prior known adjustable air gap magnet of similar specifications.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, for example, more than three flats 25 could be employed on the pole pieces and/or a different number of pressure pads could be utilized per flat, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An adjustable air gap magnet structure comprising a yoke, a pair of electrical coil assemblies secured on said yoke, and a pair of pole piece assemblies mounted on said yoke and extending toward each other through associated ones of said electrical coil assemblies to form an air gap therebetween, each pole piece assembly comprising a cylindrical pole piece having a plurality of longitudinally directed, spaced-apart flat surfaces on the outer surface thereof, a hollow cylindrical sleeve in which said cylindrical pole piece is slideably mounted, a plurality of pressure pads secured in said sleeve, the inner ends of said pads extending into sliding contact with associated ones of the flat surfaces on said pole piece, and adjustable means mounted on said sleeve and engaging the outer ends of said pressure pads and exerting an inwardly directed pressure thereon whereby said pressure pads are tensioned against the flat surfaces of the said pole piece to maintain said slideable pole piece aligned within said yoke and coil assemblies.

2. An adjustable air gap magnet as claimed in claim 1 wherein at least three longitudinal flat surfaces are located on the outer surface of each of said pole pieces, each flat surface having at least two spaced-apart pressure pads slideably engaged therewith.

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3. An adjustable air gap magnet as claimed in claim 2 wherein said pressure pads have a substantially flat inner surface slideably engaging the associated flat surface on said pole piece and a domed outer surface engaging said adjustable means mounted on said sleeve.

4. An adjustable air gap magnet as claimed in claim 1 wherein said pressure pads have a substantially flat inner surface slideably engaging the associated flat surface on said pole piece and a domed outer surface engaging said adjustable means mounted on said sleeve.

5. An adjustable air gap magnet structure comprising a yoke, a pair of electrical coil assemblies secured on said yoke, and a pair of pole piece assemblies mounted on said yoke and extending toward each other through associated ones of said electrical coil assemblies to form an air gap therebetween, each pole piece assembly comprising a cylindrical pole piece having a plurality of longitudinally directed, spaced-apart flat surfaces on the outer surface thereof, a hollow cylindrical sleeve in which said cylindrical pole piece is slideably mounted, a plurality of pressure pads secured in said sleeve, the inner ends of said pads extending into sliding contact with associated ones of the flat surfaces on said pole piece, adjustable means mounted on said sleeve engaging the outer ends of said pressure pads and exerting an inwardly directed pressure thereon whereby said pressure pads are tensioned against the flat surfaces of the said pole piece to maintain said slideably pole piece aligned with said yoke and coil assemblies, and adjustable means at the outer end of said pole piece assembly for slideably moving said pole piece in said sleeve.

6. An adjustable air gap magnet as claimed in claim 5 wherein at least three longitudinal flat surfaces are located on the outer surface of each of said pole pieces, each flat surface having at least two spaced-apart pressure pads slideably engaged therewith.

7. An adjustable air gap magnet as claimed in claim 6 wherein said pressure pads have a substantially flat inner surface slideably engaging the associated flat surface on said pole piece and a domed outer surface engaging said adjustable means mounted on said sleeve.

8. An adjustable air gap magnet as claimed in claim 5 wherein said adjustable means at the outer end of said pole piece assembly comprises an internally threaded collar secured to said pole piece, an externally threaded driver screwed into said collar, rotation of said driver imparting longitudinal sliding motion to said pole piece through said collar, and means for rotating said driver.

9. An adjustable air gap magnet as claimed in claim 8 wherein said means for rotating said driver comprises a driver cap rotatably mounted on said pole piece assembly, and means for coupling said driver to said driver cap whereby a slight play exists between said driver and driver cap in a direction normal to the axis of said driver.

10. An adjustable air gap magnet as claimed in claim 9 wherein said driver extends into a bore in said driver cap, said bore being slightly larger than said driver to permit play therebetween, and a pin extending through said driver and coupling it to said driver cap.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,134,933

May 26, 1964

William J. Brand et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 3, line 18, after "inch" insert -- minimum --;
column 4, line 28, for "with" read -- within --.

Signed and sealed this 2nd day of March 1965.

(SEAL)

Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents

UNITED STATES PATENT OFFICE
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