

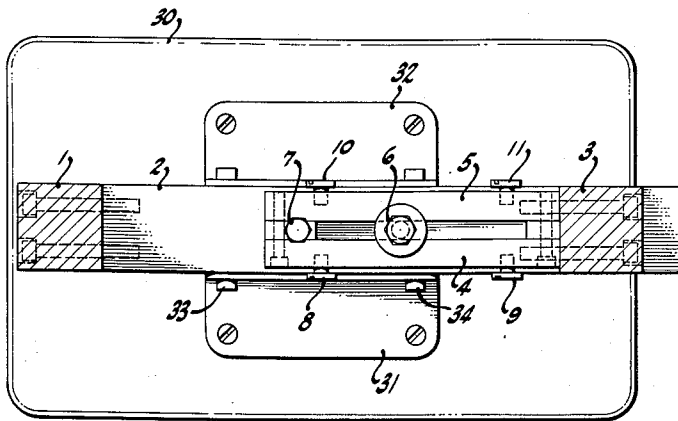
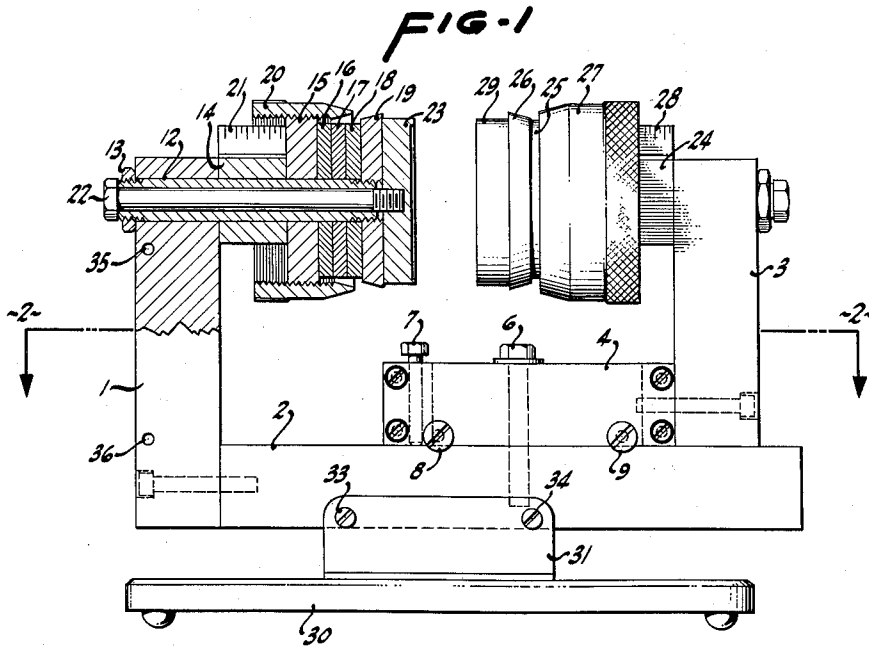
Jan. 23, 1962

N. T. SEATON

3,018,422

VARIABLE-FIELD PERMANENT MAGNET

Filed Nov. 16, 1959



INVENTOR.
NORMAN T. SEATON

BY

Lippincott & Ralls
ATTORNEYS

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3,018,422

VARIABLE-FIELD PERMANENT MAGNET
Norman T. Seaton, 2230 Prince St., Berkeley, Calif.
Filed Nov. 16, 1959, Ser. No. 853,342
5 Claims. (Cl. 317—201)

This invention relates to permanent magnets especially useful in scientific laboratories for such purposes as nuclear resonance experiments, beta-ray spectrometers, mass spectrometers, bending or deflection of charged particles, illustration of physical laws, and the like. Among the objects of the invention are to provide an exceptionally versatile, high-quality, permanent magnet having a continuously variable magnetic field intensity over a 20:1 range, having graduated scales to permit repeatable field settings, having easily changed pole faces and a variable gap, having a large magnetomotive force supplied by permanent magnets of a material exhibiting virtually no hysteresis effects, having provisions for vertical or horizontal mounting, selectively, and so constructed that pole faces and gap settings can be readily changed without difficulty.

Briefly stated, a preferred form of the magnet comprises two permanently, longitudinally magnetized cylinders of sintered ceramic, ferromagnetic material mounted upon a generally C-shaped, soft-iron yoke. The yoke comprises two L-shaped portions each composed of a leg and a back at right angles to each other, with the two backs connected together in parallel, sliding relation. Pole pieces are attached to the inner ends of the permanently magnetized cylinders, and the magnetic field intensity between the pole faces is adjusted by means of ferromagnetic sleeves mounted in longitudinally adjustable, coaxial relation to the magnetized cylinders.

The invention may be better understood from the following detailed description and the accompanying drawings.

FIG. 1 of the drawings is a side elevation, partly in section, of a variable-field, permanent magnet embodying this invention;

FIG. 2 is a section taken along the line 2—2 of FIG. 1.

Referring to the drawings, one portion of the yoke comprises a straight leg 1 and a straight back 2 fastened together by any suitable means, e.g., screws. Another portion of the yoke comprises a straight leg 3 and a straight back 4, 5 similarly fastened together. The last-mentioned back preferably consists of two parallel, side-by-side parts 4 and 5, as is best shown in FIG. 2, with a slot between them for purposes that will appear as the description proceeds. The back 2 and the back 4, 5 are mounted in parallel, sliding relation, so that the legs 1 and 3 are substantially parallel and adjustably spaced from each other. The screw 6, which extends through the slot between parts 4 and 5 into a threaded hole in back 2, can be tightened to hold the two backs firmly in place relative to each other when the desired setting has been achieved. Parts 4 and 5 may be non-magnetic.

Screw 7 extends through a threaded hole in back 4, 5 and rests against the upper surface of back 2, so that the parts 4, 5 and the thereto attached leg 3 may be tilted slightly by adjustment of screw 7. Screws 8 and 9 extend into threaded holes in part 4 and screws 10 and 11 extend into threaded holes in part 5; the heads of all four last-mentioned screws engage sides of back 2, as illustrated, for adjusting the alinement of back 4, 5 with back 2. As will subsequently become apparent, screws 7, 8, 9, 10, and 11 provide means for accurately adjusting the alinement of the pole faces of the magnet.

A non-magnetic, e.g., bronze, tube 12 extends through a hole at the upper end of leg 1 inward toward leg 3, as shown in FIG. 1. A similar tube (not visible in the drawing) extends inward from leg 3 in axial alinement

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with tube 12. Each end of tube 12 is provided with exterior threads, and a nut 13 engaging the outer end of tube 12 holds it in position relative to leg 1.

The yoke is extended inward slightly from the upper end of leg 1 by a short block 14 of soft iron provided with an axial bore receiving the tube 12, block 14 being mounted upon tube 12 and thereby held in position. A disc 15 of ferromagnetic material, e.g., soft iron, likewise has an axial bore receiving tube 12, whereby the disc 15 is mounted upon the tube 12 and thereby held in position adjacent to the block 14 and in magnetic connection with the soft-iron yoke. External threads are provided on the outer edge of disc 15 for reasons that will subsequently appear.

Next, there is a cylinder of permanently, longitudinally magnetized, ferromagnetic ceramic material, e.g., barium ferrite, preferably made up from a stack of sintered ceramic disks 16, 17, and 18, as shown. This cylinder also is provided with an axial bore receiving tube 12, whereby the permanently magnetized cylinder is held in place on the sleeve adjacent to the disc. Another ferromagnetic disc 19, e.g., of soft iron, has an internal threaded bore mating with the threads at the inner end of tube 12. Thus, when disc 19 is screwed onto the end of tube 12, all of the parts 14—18 are held securely in place between leg 1 and disc 19.

For adjusting the magnetic field intensity between the pole pieces hereinafter described, a shunt is provided for diverting an adjustable portion of the magnetic flux provided by the permanently magnetized cylinder 16—18. This shunt takes the form of an internal threaded, ferromagnetic sleeve 20, e.g., of soft iron, which is in mating screw engagement with the external threads upon the outer edge of disc 15, as shown. Thus, sleeve 20 is mounted in longitudinally adjustable, coaxial relation to the permanently magnetized cylinder 16—18.

A portion of the magnetic flux provided by the magnetized cylinder passes from disc 15 into the ferromagnetic sleeve 20 and across the air gap between the inner end of sleeve 20 and the disc 19 to the other end of the magnetized cylinder. The size of the air gap is obviously adjusted by turning sleeve 20, which causes it to move longitudinally of the magnetized ceramic cylinder because of the screw thread engagement with disc 15. As the gap is decreased, a larger and larger proportion of the magnet flux is thus diverted, and when the gap is completely closed, the permanent magnet is essentially short-circuited. The edge of the disc 19 and the inner end of sleeve 20 are tapered, as shown to minimize the torque required to rotate sleeve 20 when it is close to mating engagement with disc 19.

A small scale 21 is attached to the block 14, as shown, to provide an accurate physical indication of the position of the shunt sleeve 20. By this means field settings can be accurately repeated without reference to past history, the ceramic material employed for the permanent magnet exhibiting virtually no hysteresis effects.

It is frequently desirable to use a variety of pole pieces for various purposes: for example, pole pieces of relatively large diameter, and having a shimmed edge as illustrated, may be desirable in certain cases for providing a relatively flat or uniform magnetic field between the pole faces. Small-diameter pole pieces may be desirable when a higher intensity at the center of the magnetic field is required. Also, pole pieces having faces of particular shapes may be desired for special purposes. The present invention makes removal and substitution of pole pieces especially simple and convenient. A non-magnetic, e.g., bronze, bolt 22 extends through tube 12, as shown. The pole face 23 screws onto the end of bolt 22. Hence the pole piece can be removed and replaced quite simply without any other disassembly of the magnet structure what-

soever. Furthermore, when removing and replacing pole pieces, adjusting magnet gaps, etc., the permanent magnets are easily shorted out by moving sleeve 20 over the magnet cylinders into contact with disc 19, thus completely shorting out the magnet and reducing the magnetic field between the pole faces to a very small value.

An identical magnet structure is mounted upon the other leg 3. Block 24 corresponds to block 14, disc 25 corresponds to disc 18, disc 26 corresponds to disc 19, sleeve 27 corresponds to sleeve 20, scale 28 corresponds to scale 21, and pole piece 29 corresponds to pole piece 23. Both of the two permanently, longitudinally magnetized cylinders, adjacent to respective ones of the two pole pieces, are thus connected in series within the magnetic circuit, and are magnetized in series aiding relation to provide an intense magnetic field between the pole pieces 23 and 29 when the sleeves 20 and 27 are moved outward for diverting a minimum amount of the flux provided by the two magnetized cylinders.

A wooden base 30 is provided with two brackets 31 and 32 for supporting the magnetic structure. Screws 33 and 34 pass through the two brackets 31 and 32 and through two holes in back 2 of the yoke when the horizontal mounting illustrated is to be employed. For vertical mounting, screws 33 and 34 are removed and the magnetic circuit is turned 90° whereupon the screws 33 and 34 are replaced, but in this instance pass through holes 35 and 36 in leg 1 of the magnet yoke.

What is claimed is:

1. An adjustable-field permanent magnet comprising a pair of spaced-apart pole pieces, a permanently, longitudinally magnetized cylinder, magnetic circuit means connecting said pole pieces to opposite ends of said cylinder, whereby a magnetic field is provided between said pole pieces, and a sleeve of ferromagnetic material mounted in longitudinally adjustable, coaxial, flux shunting relation to said cylinder and separated therefrom by a variable length airgap controllable through said longitudinal sleeve adjustment, whereby an adjustable proportion of the magnetic flux provided by said longitudinally magnetized cylinder passes through said sleeve for adjustably diminishing the magnetic field between said pole pieces.

2. An adjustable-field permanent magnet comprising two permanently, longitudinally magnetized cylinders, axially aligned and spaced apart so that their inner ends face toward each other and their outer ends face away from each other, a C-shaped yoke extending between and magnetically connecting together the outer ends of said cylinders, two spaced-apart pole pieces, one mounted adjacent to the inner end of one of said cylinders and the other mounted adjacent to the inner end of the other cylinder, and two sleeves of ferromagnetic material, one mounted in longitudinally adjustable, coaxial, flux shunting relation to one of said cylinders and separated therefrom by a

variable length airgap controllable through said longitudinal sleeve adjustment, the other sleeve mounted in a similar manner relative to the other cylinder, whereby an adjustable proportion of the magnetic flux provided by each said longitudinally magnetized cylinder passes through each said respective sleeve for adjusting the intensity of the magnetic field between said pole pieces.

3. An adjustable-field permanent magnet as described in claim 2 wherein said C-shaped magnetic yoke comprises two L-shaped portions each composed of a leg and a back, means connecting said two backs together in parallel, sliding relation, said legs being parallel and adjustably spaced; and additionally comprising means mounting said cylinders, in axially aligned, adjustably spaced relation to each other, between and upon respective ones of said two parallel legs.

4. An adjustable-field permanent magnet comprising a C-shaped magnetic yoke comprising two L-shaped portions each composed of a leg and a back, means connecting said backs together in parallel, sliding relation, said legs being parallel and adjustably spaced, two axially aligned, non-magnetic tubes attached to and extending inward toward each other from respective ones of said legs, two discs having an externally threaded outer edge and having a central bore receiving a respective one of said non-magnetic tubes, said externally threaded discs being mounted upon said tubes in magnetic connection with respective ones of said legs, two permanently, longitudinally magnetized cylinders, each having an axial bore receiving a respective one of said non-magnetic tubes, said cylinders being mounted upon said tubes between and adjacent to respective ones of said externally threaded discs, two internally threaded sleeves of ferromagnetic material in mating screw engagement with respective ones of said externally threaded discs, said internally threaded sleeves thereby being in longitudinally adjustable, coaxial relation to respective ones of said longitudinally magnetized cylinders, two additional ferromagnetic discs mounted upon respective ones of said tubes between and adjacent to respective ones of said cylinders, two non-magnetic screws extending inward through respective ones of said tubes, and two removable pole pieces attached to the inner ends of respective ones of said screws.

5. The adjustable field permanent magnet described in claim 2, wherein each said sleeve engages its respective cylinder at one end and coaxially surrounds said cylinder to be separated from the other end by a variable length airgap controllable through said longitudinal sleeve adjustment.

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