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2,812,203

PERMANENT MAGNET HOLDING ARRANGEMENT

Filed May 21, 1956

2 Sheets-Sheet 1

Fig. 1

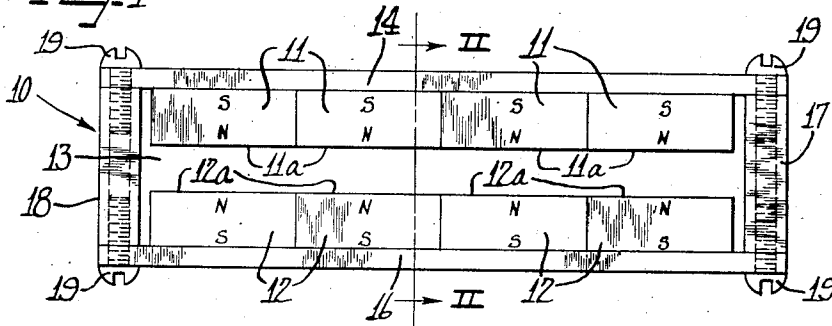


Fig. 2

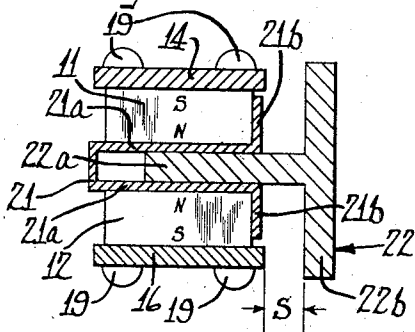


Fig. 3

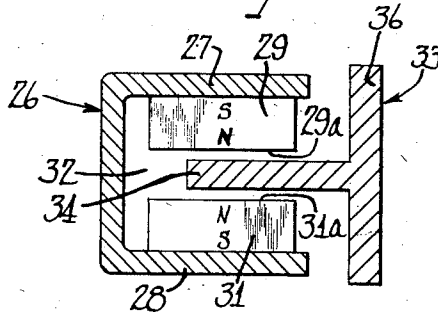


Fig. 4

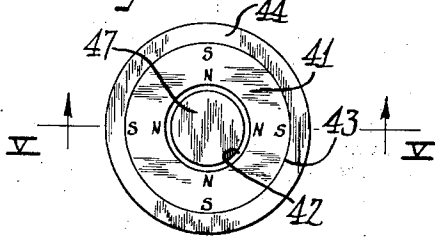
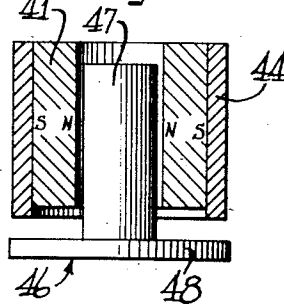


Fig. 5



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2 Sheets-Sheet 2

Fig-6

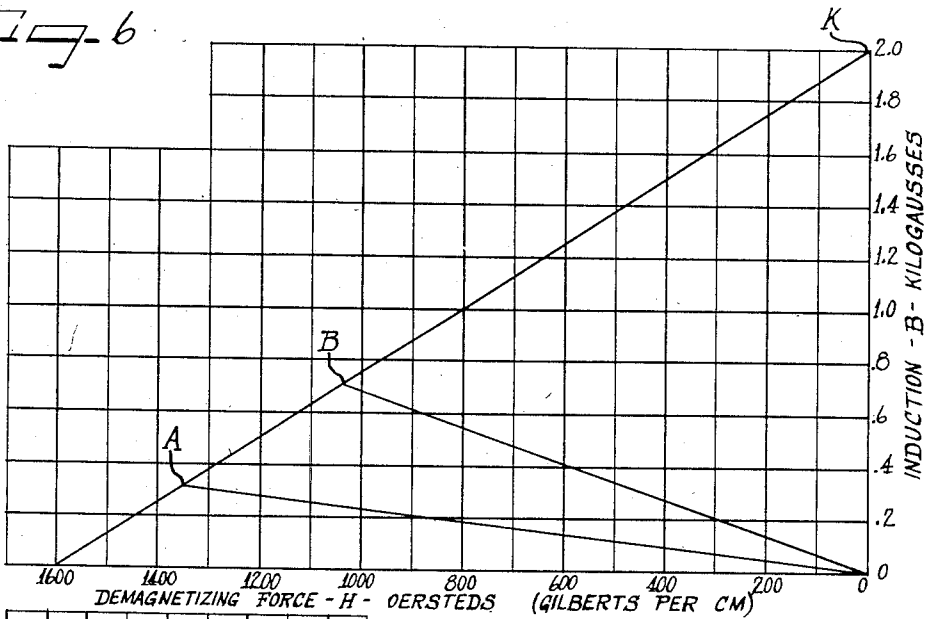
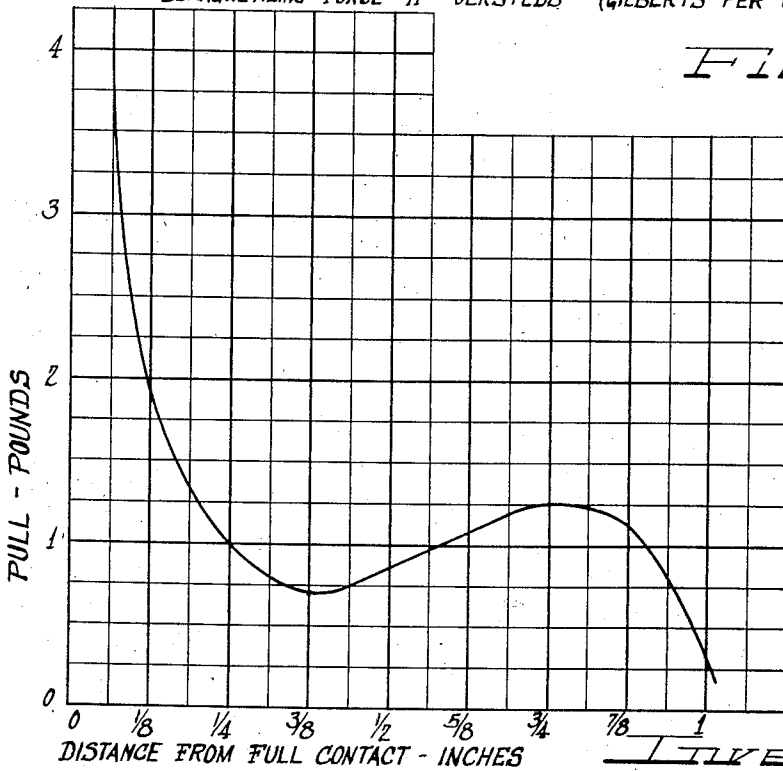


Fig-7



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1

2,812,203

**PERMANENT MAGNET HOLDING ARRANGEMENT**

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9 Claims. (Cl. 292—251.5)

The present invention deals with improved permanent magnet holding assemblies.

In recent years, one of the biggest developments in the field of permanent magnets has been the development of the ceramic-type magnet of the mixed ferrite type which has highly improved magnetic properties. These ferrite materials are electrical non-conductors, hard, and much lighter in weight than magnets made of metallic alloys. The ceramic ferrites are very resistant to demagnetization and evidence very low eddy current losses. The permanent magnet materials have very high coercive force values and high maximum energy products. Because of these various characteristics, the magnets can be incorporated into structures which require a large magnetic area but a relatively short magnetic length. The magnetic holding assemblies of the present invention take advantage of these various improved characteristics of the ceramic-type magnets and provide a highly efficient, light-weight permanent magnet holding assembly. Magnetic assemblies of this type can be included in refrigerator door latch structures or other structures requiring compact and efficient holding mechanisms.

An object of the invention is to provide an improved permanent magnet holding assembly of high efficiency.

Another object of the invention is to provide a magnetic holding assembly in a circuit which has low leakage permeances, thereby increasing the total potential energy available from the magnets.

Another object of the invention is to provide an efficient holding assembly by the use of ceramic-type permanent magnets of large area and short magnetic length.

Another object of the present invention is to provide a permanent magnet holding assembly and armature having controllable pull characteristics.

The present invention can best be described in conjunction with the attached sheets of drawings which illustrate several embodiments thereof.

In the drawings:

Figure 1 is a view in elevation of a permanent magnet holding assembly according to the present invention, with portions thereof removed to illustrate the structure more clearly.

Figure 2 is a cross-sectional view taken substantially along line II—II of Figure 1, illustrating the magnet assembly and its cooperation with the armature;

Figure 3 is a cross-sectional view partly in elevation of a modified form of the magnetic holding assembly and armature;

Figure 4 is a plan view of a still further modified form of the invention, illustrating the magnet holding assembly with the armature removed;

Figure 5 is a cross-sectional view taken substantially along the line V—V of Figure 4;

Figure 6 is a graph representing a typical demagnetization curve for a ceramic-type ferrite; and

Figure 7 is a graph of the pull characteristics of the arrangement shown in Figure 1, the distance from the full contact position of the armature being indicated as

2

the abscissae, and the pull in pounds exerted on the armature being plotted as the ordinates.

As shown on the drawings:

In Figure 1 reference numeral 10 indicates generally a permanent magnet holding assembly according to the present invention. The permanent magnet assembly 10 includes a plurality of wafer-type flat ceramic magnets 11 of relatively large area but relatively short magnetic length. Preferably these magnets are of the barium ferrite type having the empirical formula  $BaFe_{12}O_{19}$ . These materials have a coercive force of about 1600 oersteds and a residual induction of approximately 2000 gauss after the application of an applied field of 10,000 oersteds.

As indicated in Figures 1 and 2, the magnets 11 are aligned to provide inner faces 11a having a common magnetic polarity which, in the illustrated instance, is a north pole.

Spaced from the magnets 11 is another series of magnets 12 having corresponding inner faces 12a confronting the faces 11a of the magnets 11. The magnetic orientation of the magnets 12 is such as to provide faces 12a of the same magnetic orientation as the faces 11a, that is, all of the confronting pole surfaces in the illustrated embodiment are north poles.

The magnets 11 and 12 are in spaced opposed relation to provide an air gap 13 between the opposed magnets.

The magnets 11 and 12 may be partly supported by their inherent magnetic attraction to a pair of spaced pole pieces 14 and 16 composed of a ferromagnetic material and partly by a suitable adhesive. As best seen in Figure 2, the edges of the pole pieces 14 and 16 extend slightly beyond the corresponding edges of the magnets 11 and 12 to protect the surfaces of the magnets from impact by the armature, and to serve as a seating surface for the armature.

The pole pieces 14 and 16 are secured together into a rigid frame by means of a pair of non-magnetic spacers 17 and 18 disposed at opposite ends of the pole pieces 14 and 16. The spacers 17 and 18 may be composed of a magnetically transparent material such as brass. A plurality of screws 19 secure the pole pieces 14 and 16 to the spacers 17 and 18.

In order to protect the faces of the magnets 11 and 12 from abrasion or impact, it is preferable to include a non-magnetic spacer 21 (Figure 2) in the air gap 13, the spacer 21 having sides 21a received flush against the faces 11a and 12a, and having a marginal portion 21b received against the end faces of the magnets 11 and 12.

The armature 22 composed of ferromagnetic material has a projection 22a received in sliding engagement with the spacer 21, and a headed portion 22b normal to the projection 22a and arranged to abut the pole pieces 14 and 16 to limit the travel of the armature through the air gap provided between the magnets 11 and 12.

In order to understand the operation of the magnetic circuit of the invention, reference is invited to Figure 6 of the drawings which illustrates a demagnetization curve for a barium ferrite material.

It will be seen that with the armature 22 completely separated from the magnets, the magnets will operate at a very low flux density, as indicated by point A on the demagnetization curve. This is because the magnets opposing each other have low leakage permeances, and consequently, the flux in the external circuit and the flux in the magnets is low.

The total potential energy available from the magnets is proportional to the volume of permanent magnet material and the area designated by the lines OAK in Figure 6. It is desirable, therefore, to cause the mag-

net to operate at as low a flux density as possible with the armature 22 away from the influence of the magnets of the holding assembly.

As the armature 22 approaches the magnets, the flux emanating from the faces of the magnets will increase. The flux passes through the air gap and into the projecting portion 22a of the armature, creating considerable pull on the armature as it is first introduced into the magnet holding assembly. This pull is reflected by the pull characteristic curve shown in Figure 7. The latter was derived by measuring the pull in pounds on the armature 22 at various distances from the fully closed position of the armature, these distances being represented by the letter S in Figure 2.

As the reluctance of the magnetic circuit is decreased due to the increasing amount of iron entering the circuit, the average flux density in the magnet will also increase, and the system will operate at a point designated at B in Figure 6. This change in operating points provides somewhat less pull energy on the armature so that, as reflected in Figure 7 of the drawings, the pull on the armature may decrease as the armature moves closer to its fully closed position. However, when the headed portion 22b comes closer and closer to the pole portions 14 and 16, a new low reluctance circuit is established, and the major portion of the pull occurs between the headed portion 22b and the pole pieces 14 and 16. This attractive force reaches a maximum upon direct contact, that is, where the dimension S is zero. In the contact position, practically all the holding force is due to flux between the armature 22 and the pole pieces 14 and 16.

A modified form of the invention is illustrated in Figure 3 of the drawings. In place of the frame structure illustrated in Figures 1 and 2, the frame in this form of the invention consists of a U-shaped frame member 26 composed of ferromagnetic material and having opposed legs 27 and 28. Two or more magnets 29 and 31 are disposed on opposite sides of the frame, leaving an air gap 32 between the confronting faces of the magnets 29 and 31. As in the other embodiment, the confronting faces 29a and 31a have the same magnetic polarity and, consequently, the faces of the magnets 29 and 31 which abut the legs 27 and 28 have the same magnetic polarity.

A cooperating armature 33 having an inwardly projecting portion 34 arranged to be received within the air gap 32 cooperates with the permanent magnet assembly in the same manner as the embodiment described in Figures 1 and 2. The armature 33 also has a headed portion 36 which is arranged to abut the ends of the legs 27 and 28 when the armature 33 is in its fully closed position. Despite the fact that this form of the invention provides a complete circuit of iron between the opposed magnets, the particular arrangement of the magnets reduces the leakage permeance to a minimum.

In the structure illustrated in Figures 4 and 5 of the drawings, the magnetic elements take the form of a single hollow cylindrical permanent magnet 41 which, as indicated in the drawings, is magnetized in a radial direction to provide a north pole at the inner periphery 42 of the magnet and a south pole at the outer periphery 43. The cylindrical permanent magnet 41 is enclosed within a shell 44 composed of a magnetic material such as iron or steel, and, as indicated in Figure 5, the axial length of the shell 44 is slightly larger than the axial length of the magnet 41. A cooperating armature 46, having a cylindrical shank portion 47 received within the axial bore of the magnet 41, also has an end flange portion 48 arranged to abut the end of the shell 44 when the armature 46 is in its fully closed position.

The magnet holding assembly shown in Figures 4 and 5 has the same type of holding characteristics as that shown in the preceding figures. Thus, when the shank portion 47 first approaches the axial bore of the magnet, the flux from the magnet enters the shank portion

of the armature and creates a considerable pull on the armature. As the armature moves closer to the full contact position, the flux density between the armature and the magnetic pole piece provided by the shell 44 increases very substantially, reaching a maximum at the time that the flange portion 48 abuts the ends of the magnetic shell 44.

It will be evident that various modifications can be made to the described structure, such as by changing the shape of the armature or the magnets or the pole pieces, to take advantage of the improved characteristics of the magnetic circuits herein provided.

I claim as my invention:

1. A permanent magnet assembly comprising means defining opposed portions of the same magnetic polarity separated by an air gap and remote portions of the same magnetic polarity but different from the polarity of the said opposed portions, a magnetic pole piece associated with said remote portions, and a magnetic armature having a portion arranged to be received in said air gap and another portion arranged to abut said pole piece at the fully closed position of said armature.

2. A permanent magnet assembly comprising a pair of flat magnets in spaced opposed relation, said magnets being magnetized along their thickness dimension and providing opposed confronting faces of the same magnetic polarity separated by an air gap, a pair of pole pieces associated with said magnets at the faces of said magnets opposite to said confronting faces, and a magnetic armature having a portion arranged to be received in said air gap and another portion arranged to span said pole pieces at the fully closed position of said armature.

3. A permanent magnet assembly comprising a pair of flat magnets in spaced opposed relation, said magnets being magnetized along their thickness dimension and providing opposed confronting faces of the same magnetic polarity separated by an air gap, a pair of pole pieces associated with said magnets at the faces of said magnets opposite to said confronting faces, and a magnetic armature having a portion arranged to be received in said air gap and another portion normal to said first-named portion arranged to span said pole pieces at the closed position of said armature.

4. A permanent magnet assembly comprising a pair of flat permanent magnets in spaced opposed relation, said magnets having a relatively large area but a relatively short magnetic length in their thickness dimension, said magnets providing opposed confronting faces of the same magnetic polarity separated by an air gap, a pair of pole pieces associated with said magnets at the faces of said magnets opposite to said confronting faces, and a magnetic armature having a portion arranged to be received in said air gap and another portion arranged to span said pole pieces at the closed position of said armature.

5. A magnet assembly comprising a pair of flat barium ferrite magnets in spaced opposed relation, said magnets being magnetized along their thickness dimension and providing opposed confronting faces of the same magnetic polarity separated by an air gap, a pair of pole pieces associated with said magnets at the faces of said magnets opposite to said confronting faces, and a magnetic armature having a portion arranged to be received in said air gap and another portion arranged to span said pole pieces at the closed position of said armature.

6. A permanent magnet assembly comprising a plurality of flat permanent magnets disposed in opposed spaced relation and separated by an air gap, said magnets being arranged to provide surfaces of the same magnetic polarity at the sides of said magnets confronting said air gap, a pair of ferromagnetic pole pieces adjoining said magnets at the surfaces thereof remote from said air gap, a pair of non-magnetic spacers at opposite ends of said pole pieces securing said pole pieces together into a rigid

5

frame, and an armature having a projection arranged to be received in said air gap and a headed portion arranged to abut said pole pieces in the fully closed position of said armature.

7. A permanent magnet assembly comprising a plurality of flat permanent magnets disposed in opposed spaced relation and separated by an air gap, said magnets being arranged to provide surfaces of the same magnetic polarity at the sides of said magnets confronting said air gap, a non-magnetic spacer disposed against said confronting sides, a pair of ferromagnetic pole pieces adjoining said magnets at the surfaces thereof remote from said air gap, a pair of non-magnetic spacers at opposite ends of said pole pieces securing said pole pieces together into a rigid frame, and an armature having a projection arranged to be received in said air gap and a headed portion arranged to abut said pole pieces in fully closed position of said armature.

8. A permanent magnet assembly comprising a generally U-shaped ferromagnetic frame member, a pair of flat permanent magnets disposed adjacent the legs of said frame member, said magnets being spaced by an air gap and having surfaces of the same magnetic polarity

6

confronting said air gap, and an armature having a projecting portion arranged to be received in said air gap and having a portion extending normal to said projecting portion arranged in closed position of said armature to abut the ends of the legs of said frame member.

9. A permanent magnet assembly comprising a hollow cylindrical permanent magnet magnetized in its radial direction, a hollow cylindrical ferromagnetic shell surrounding said magnet, and a headed armature having a shank portion arranged to be received axially of said magnet and having a headed portion arranged to abut said shell at the closed position of said armature.

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