

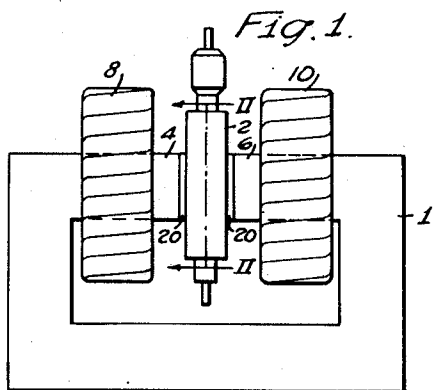
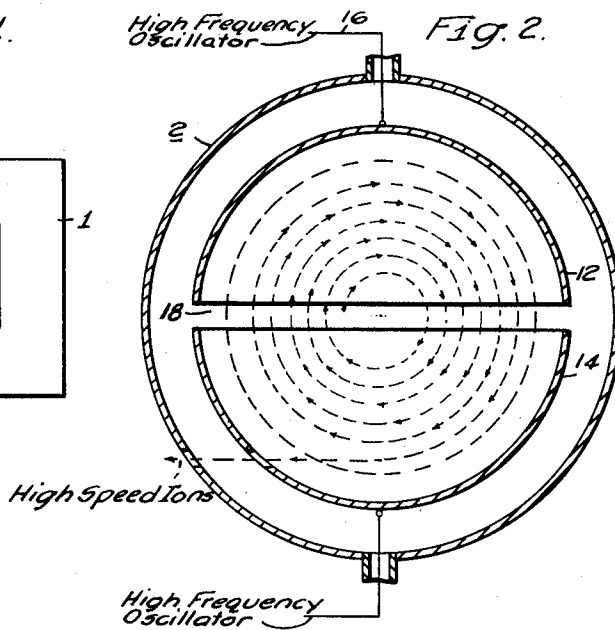
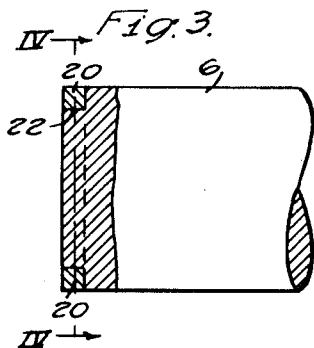
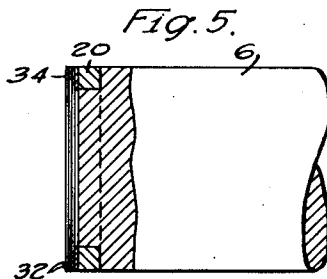
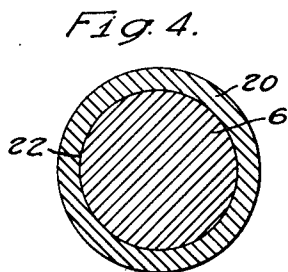
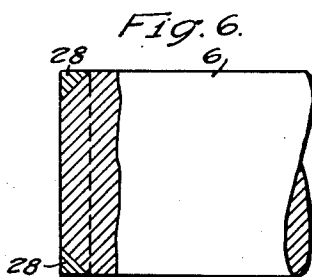
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2,597,476

ELECTROMAGNET

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WITNESSES:

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ELECTROMAGNET

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10 Claims. (Cl. 175—21)

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This invention relates to magnetic structures and more particularly to electromagnets for producing relatively strong magnetic fields.

In some applications of electromagnets, it is desirable to obtain substantially uniform flux density over as much of the area of the pole face of the magnet as possible. This uniformity of flux density is particularly desirable in magnets used in electrical apparatus for the acceleration of electrical charges as for example in cyclotrons. It is also desirable in magnetrons. Cyclotrons are used for high power X-ray work and nuclear physics investigations. One form of such apparatus is disclosed in Patent Number 1,948,384, issued to E. O. Lawrence, February 20, 1934.

In this type of apparatus a large electromagnet is used to produce a high density magnetic field over a relatively small air gap which, coupled with a high frequency electric field, produces high speed acceleration of ions in an enclosed space between the poles of the gap. It has been found that the flux density of the magnetic field should, for proper operation, be maintained substantially at the magnitude which it has at the center of the magnet over as large an area as practicable. In regions where the flux density drops below 96% of its magnitude at the center, the beam of electric charges tends to become defocused and develops an excessively large cross sectional area and the energy of the charges becomes distributed over an excessively wide range. It has also been found that the flux density of the magnetic field in this type of apparatus does drop below 96% of its value at the center in a large area adjacent to the outer edge of the pole faces when constructed in accordance with knowledge available prior to this invention of which I am aware.

In order to overcome the effect of this area of low flux density, it has been necessary, heretofore, to construct magnets of relatively large size, for apparatus for accelerating electric charges, in order that sufficient uniformity of flux density near the center of the pole piece could be utilized to produce the desired results. This expedient has resulted in an increase in the cost of the magnet. Since a portion of the magnetic field produced by such a large magnet is unusable, it has also reduced the efficiency of the apparatus.

An object of this invention is to provide a magnetic structure that will produce a useful magnetic field over a larger area of the pole

face of the magnet than has been available heretofore.

A further object of the present invention is to provide a magnetic structure which produces a substantially uniform flux density over a large area of the pole piece of a magnet.

A still further object of this invention is to provide an electromagnet for cyclotrons, or other apparatus that will produce a substantially uniform flux density at the face of the pole pieces at less expense than heretofore has been considered practicable.

Other objects and advantages will appear upon consideration of the detailed description of the invention below which will be best understood when read in connection with the attached drawing, wherein:

Figure 1 is a somewhat schematic elevational view of a cyclotron embodying a magnet constructed in accordance with this invention;

Fig. 2 is an enlarged sectional view of the electrode structure shown in Figure 1 taken substantially at the line II—II;

Fig. 3 is an enlarged fragmentary view, partly in section, of one of the pole pieces;

Fig. 4 is a cross-sectional view of one of the pole pieces taken substantially along line IV—IV of Fig. 3;

Fig. 5 is an enlarged fragmentary view similar to Fig. 3, but showing a modification of the invention; and

Fig. 6 is an enlarged fragmentary view similar to Fig. 3, but showing another modification of my invention.

In accordance with my invention, I provide an electromagnet for a cyclotron, or other apparatus, with a combination of ferro-magnetic materials, at least one of which has a high saturation flux density to produce a uniform flux density over the pole face. A material of high saturation flux density which is used in the preferred practice of my invention is that disclosed in copending application Serial No. 706,583, filed October 30, 1946, now Patent No. 2,442,219, granted May 25, 1948 to James K. Stanley, and assigned to Westinghouse Electric Corporation. Another material is described in Patent No. 2,292,191, granted August 4, 1942, to Weldon H. Brandt and Walter R. Woodward, and assigned to Westinghouse Electric Corporation.

Referring now to the drawing, there is shown at Figure 1, one type of apparatus used for the acceleration of electric charges, comprised of a magnet 1, with pole pieces 4 and 6, and energizing coils 8 and 10. Between said pole pieces is a

casing 2, enclosing electrodes, not shown in this figure.

At Fig. 2 is shown an enlarged sectional view of the electrodes inside casing 2, of Figure 1, taken substantially at the line II—II. An oscillating electric field is established through hollow electrodes 12 and 14 when energized by a high frequency electric circuit 16. Ions are released by suitable apparatus (not shown) in the diametral region 18 between the electrodes, and attracted to the interior of the electrode having the opposite charge. The pole pieces 4 and 6 arranged on opposite sides of electrodes 12 and 14 produce a uniform magnetic field, the lines of force of which extend transversely to the electrodes 12 and 14 and normal to the plane of the electric field between the electrodes.

The electric field described above causes the ions to move in a curved path in a plurality of revolutions within the space of the electrodes 12 and 14 in such manner that its path forms substantially a spiral of increasing radius, the particle being continually deflected by the action of the magnetic field thereon so as to revolve around the axis or center of the field, and the period of half revolution is determined by the strength of the magnetic field.

For removing and utilizing the accelerated charges, tangential electrodes (not shown) similar to the electrodes 40 and 41 of the system disclosed in the Lawrence Patent No. 1,948,384 may be included in the system.

A detailed description of the action of the multiple acceleration of ions is not considered necessary herein. For such a description reference may be made to the E. O. Lawrence Patent No. 1,948,384.

Referring now to the drawing, Figs. 3 and 4 show an enlarged fragmental view of one of the pole pieces 6. In the pole piece shown in this view, a ring 20 of rectangular cross section and of ferrous-magnetic material of high saturation flux density is inserted in a recess 22 cut out in the original pole piece. The ring 20 may be of any high saturation flux density ferrous-magnetic material, but should preferably be of the material described in the said copending application to James K. Stanley or in Patent 2,292,191. A typical cyclotron magnet in accordance with my invention has pole pieces 6 of nine inch diameter and a double symmetrical yoke. The rings 20 inserted in the poles have an inside diameter of seven inches (an outside diameter of nine inches) and a thickness (depth) of one-half inch. The rings are composed of a material which is composed of 20% to 35% cobalt, $\frac{1}{2}$ % to 3% vanadium, remainder substantially all iron, the material having been heat treated at from 550° C. to 800° C. as disclosed in said Brandt et al. Patent No. 2,292,191. The composite structure of this magnet has a relatively small pole area but the field which it produces is relatively uniform radially. Other alloys which may be used in the practice of my invention have a higher content of cobalt—approximately 50% in one case.

A homogeneous electromagnet of the same dimensions as the magnet 6 has a useful radius of 79% of the true radius. The useful radius of the pole piece of the composite magnet is 86% of the true radius. Since the output energy of the magnet of a cyclotron varies as the square of the useful radius, the net gain in useful energy realized as a result of this invention amounts to about 15%.

I have found that the flux distribution can be improved by building up the ring 20 above the surface of the remainder of the magnet 6. This object can be accomplished by securing to the ring, ring shaped strips 32, of high saturation material (shimming). The strips may be so distributed that near the outer rim the build up 34 is higher than near the inner rim of the ring 20.

In the magnet shown in Fig. 6, the ring 28 is of triangular cross section. In this arrangement the added material increases in thickness as its radius from the center of the pole piece increases. By proper selection of the cross section of the ring, the saturation flux density of the pole piece may be maintained proportionately to (or equal to) the reduction of the flux density of the material of the main body of the pole piece.

My invention may be practiced not only with the material described herein, but with other ferrous-magnetic materials that have saturation flux densities higher than the saturation flux density of the main structure of the pole piece of a magnet.

As shown in Figs. 1, 3, 4 and 5, and described hereinabove, elements are included which experimentally and practically operate efficiently in the manner indicated. However, it is apparent that modifications may be made of the apparatus, and elements thereof, which are equivalent in their functioning. For example, the ferro-magnetic material with high saturation flux density, may be fitted on pole pieces in the shape of rings with rectangular cross section, or with angular cross-section, and of any width to provide increase of flux density at the point on a magnet of a cyclotron, or other magnet, where the flux density would normally drop below 96% of its value at the center of the pole piece. Also, the material may be fitted on pole pieces of any shape. Hence, the disclosed system is primarily illustrative, the limits of the invention being defined by the claims as hereto appended.

I claim as my invention:

1. A magnetic structure comprising a magnet having a composite pole piece, the peripheral portion of said pole piece in the region of the pole face being formed of a magnetic material having sufficiently higher saturation flux density than that of the remainder of said pole piece that substantially uniform flux density may be maintained across said pole face, said peripheral portion in the region of said pole face being built up so that it projects beyond said pole face, the build up increasing with increasing radial distance from the center.

2. A magnetic structure comprising a magnet having a composite pole piece, the peripheral portion of said pole piece in the region of the pole face being formed of a magnetic material having sufficiently higher saturation flux density than that of the main portion of said pole piece that substantially uniform flux density may be maintained across said pole face, said peripheral portion in the region of said pole face being built up of laminated rings of said magnetic material so that it projects axially beyond said main portion, the build up increasing with increasing radial distance from the center.

3. A magnetic core structure, comprising a main portion made of material having a predetermined saturation flux density and of configuration to form opposing pole pieces, the cross section of said main portion being reduced in the region of said pole piece extremities, and an auxiliary ring portion made of material hav-

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ing sufficiently higher saturation flux density than that of said main portion that substantially uniform flux density may be maintained across the face of said pole piece, said auxiliary portion being of configuration to fit onto the reduced cross-section part of said main portion and having a periphery which conforms to that of the non-reduced cross-section part of said main portion.

4. A magnet having a composite pole piece, the portion of said pole piece in the region of the periphery of the pole face being composed of a magnetic material of sufficiently higher saturation flux density than that of the magnetic material composing the remainder of said pole piece that substantially uniform flux density may be maintained across said pole face.

5. A magnet having a composite pole piece, the portion of said pole piece in the region of the periphery of the pole face being composed of a ring of magnetic material of sufficiently higher saturation flux density than that of the magnetic material composing the remainder of said pole piece that substantially uniform flux density may be maintained across said pole face.

6. A magnet having a pole piece of uniform cross section in which a portion forming a ring in the region of the face and periphery of the pole piece is composed of a magnetic material having a saturation flux density sufficiently higher than that of the magnetic material of which the remainder of the said pole piece is composed that substantially uniform flux density may be maintained across said pole face.

7. A magnet having a pole piece of uniform cross section in which a portion forming a ring in the region of the face and periphery of the pole piece is composed of a ferrous-magnetic material having sufficiently higher saturation flux density than that of the ferrous-magnetic material of which the remainder of the said pole piece is composed that substantially uniform flux density may be maintained across said pole face.

8. An electromagnet for a cyclotron including a magnetic core structure having a composite pole piece, a portion of said pole piece which is

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common to the pole face and the pole periphery in the region of the pole face forming a ring, being composed of an iron-cobalt alloy containing 20% to 30% cobalt, the remainder of said core structure being composed of a magnetic material having sufficiently lower saturation flux density that substantially uniform flux density may be maintained across said pole face.

9. An electromagnet for a cyclotron including a magnetic core structure having a composite pole piece, a portion of said pole piece which is common to the pole face and the pole periphery in the region of the pole face forming a ring, being composed of an iron-cobalt alloy containing 20% to 30% cobalt, $\frac{1}{2}$ % to 3% vanadium, $\frac{1}{4}$ % to 1% manganese, the remainder of said core structure being composed of a magnetic material having sufficiently lower saturation flux density that substantially uniform flux density may be maintained across said pole face.

10. An electromagnet comprising a core of magnetic material having a pole provided with a recessed edge extending around the entire face of the pole, and a member of magnetic material having sufficiently higher saturation flux density than that of said core and pole material disposed in and filling said recess that substantially uniform flux density may be maintained across said pole face.

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REFERENCES CITED

The following references are of record in the file of this patent:

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Number	Name	Date
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1,948,384	Lawrence	Feb. 20, 1934
1,956,279	Godsey, Jr.	Apr. 24, 1934
2,141,890	Weis	Dec. 27, 1938
2,245,373	Weis	June 10, 1941
2,292,191	Brandt et al.	Aug. 4, 1942
2,297,305	Kerst	Sept. 29, 1942
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