Jan. 13, 1970 A. F. ISRAELSON ET AL 3,489,280

MAGNETIC SEPARATOR HAVING FIELD SHAPING POLES

Filed Feb. 3, 1966 2 Sheets-Sheet 1

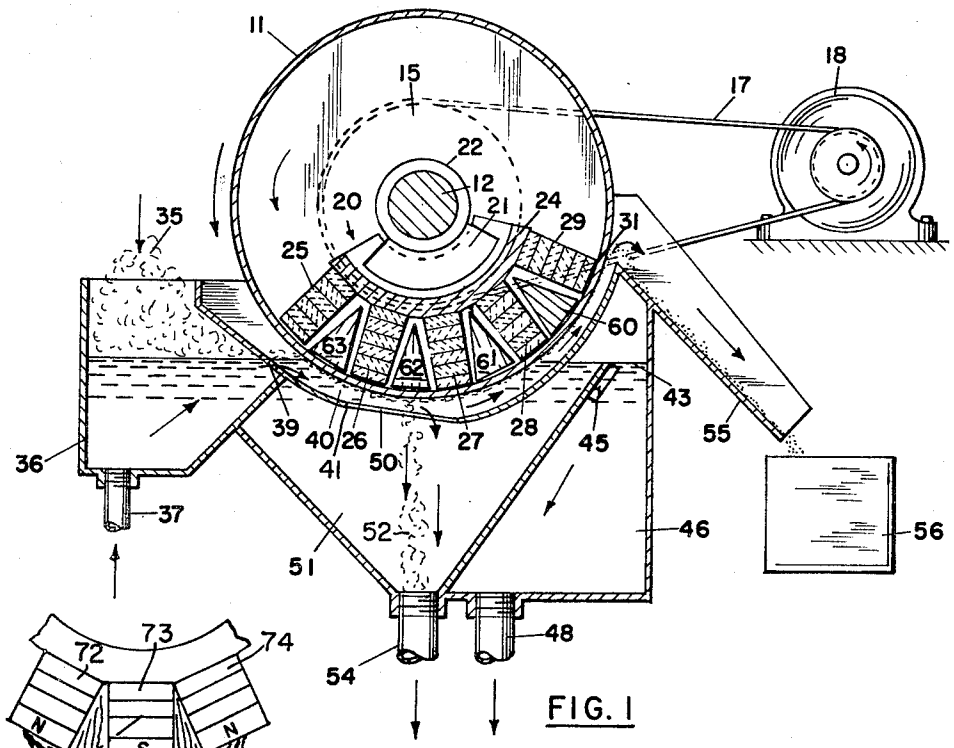


FIG. 1

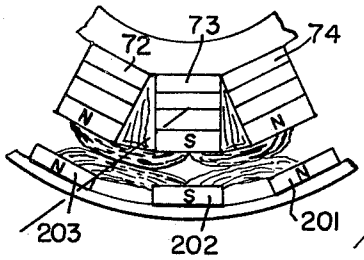


FIG. 6

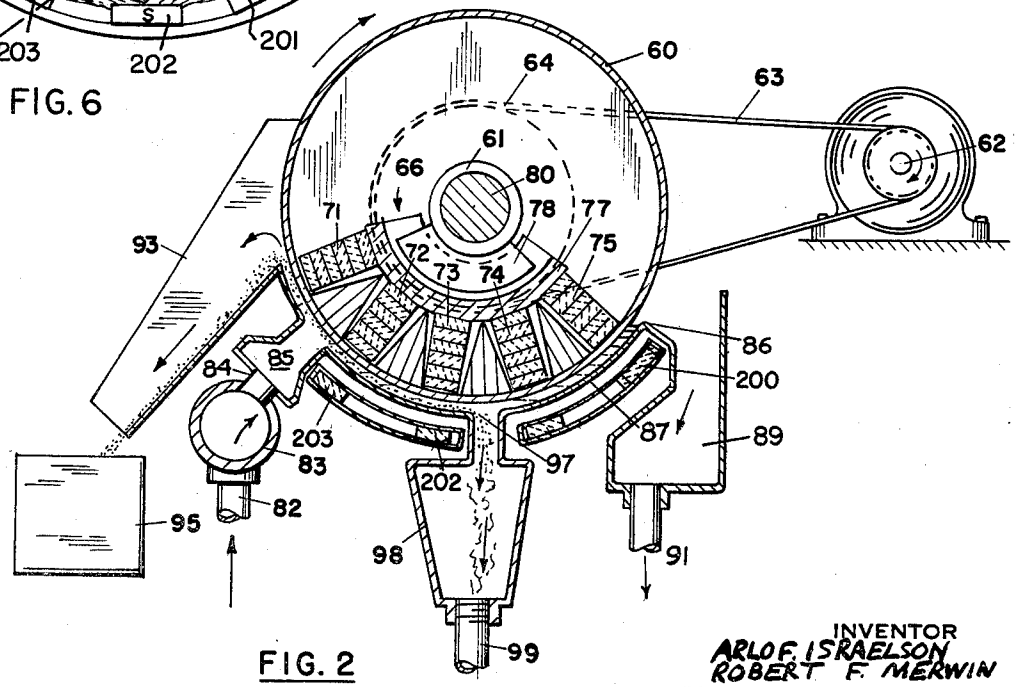


FIG. 2

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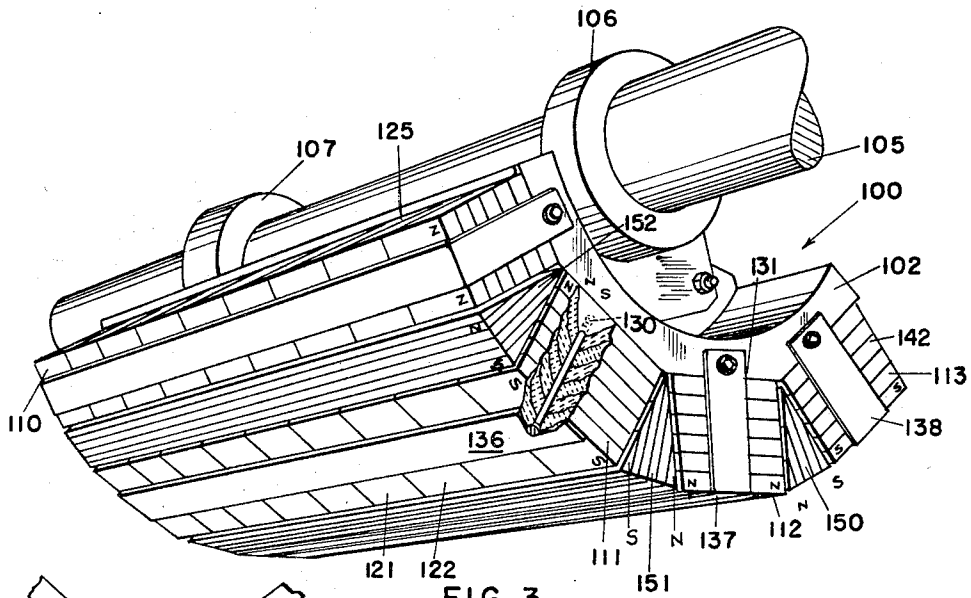


FIG. 3

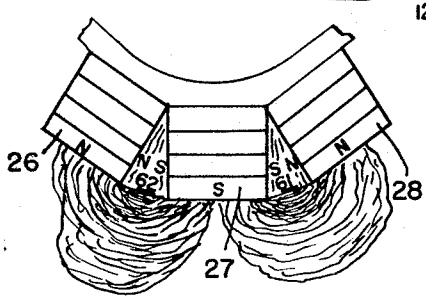


FIG. 5

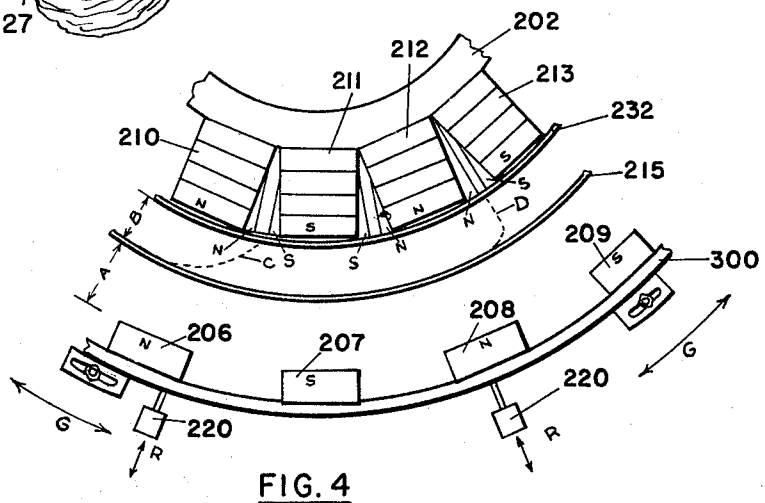
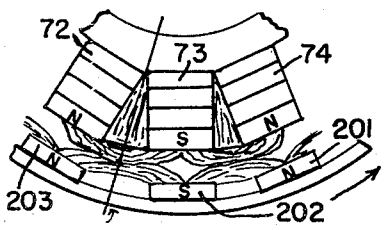


FIG. 4

FIG. 7



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United States Patent Office 3,489,280
Patented Jan. 13, 1970

3,489,280

MAGNETIC SEPARATOR HAVING FIELD SHAPING POLES

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Filed Feb. 3, 1966, Ser. No. 524,782
Int. Cl. B03c 1/14
U.S. Cl. 209—223 6 Claims

This invention relates generally to magnetic separators and more particularly to drum type magnetic separators for separating magnetic material from nonmagnetic material in wet or dry form.

In the fields of magnetic separators many different types of magnetic separators have been developed and are currently in use to recover and concentrate ferromagnetic materials.

Some of these separators are powered by electromagnets; however, since the advent of the ceramic permanent magnets, it has become economically practical to use magnetic separators powered by these materials.

Improvements in these separators have been hampered by specifications that were established, based upon the design of the first successful electromagnetic separators. Originally, it was considered practical and advisable to measure the fields in magnetic drum separators, at a distance of two inches from the rotating drum shell. Then an average of these measurements was taken and drums were classified by these averages. For example: 650 gauss drum, 750 gauss drum, and so forth. As time has passed, users have specified higher and higher flux densities, until more recently specifications are being written, in some cases, for drums with a 1200 gauss rating.

In the meantime, magnet designers have been somewhat frustrated by the insistence of users that the two-inch gauss line must be observed, when it is an established fact that magnetic field gradient is more important than overall flux density. In other words, the force of magnetic attraction varies as the product of the field intensity and the field gradient. Which is to say that if there are two magnetic drums, each with a flux density of 3000 gauss at the shell surface, but, as a result of design ingenuity, one drum has a flux density of 1200 gauss at two inches . . . the other with 1200 gauss at one inch then the latter would attract magnetic particles with much greater force.

Disregard of this proven principle is especially wasteful when it is recognized that throughout the mining industry the slurries to be separated are never more than three-quarter inch or one inch deep adjacent to the face of the magnetic drum separator.

To design and build permanent magnetic drum separators, incorporating the very desirable high gradient field configuration and with ample magnetic intensity, has been considered difficult and excessively expensive. With conventional designs and existing permanent magnetic materials so much ordinary permanent magnetic material had to be used to compensate for flux leakage that space was not available within the drums and, if the newer high strength materials were used, costs would be prohibitive.

Apparatuses of the magnetic type for separating or segregating magnetisable and nonmagnetisable materials from a mixture or stream of such materials are well known. An example of such a separator is shown in Patent No. 3,168,464. Applicant has discovered that by placing repelling magnets between the magnetic poles of a drum separator such as shown in the said patent, that the fields of magnetic force from the magnetic poles are reshaped and strengthened in such a manner that a more powerful and more effective magnetic force is exerted on the particles being separated therefore a much more efficient separating is accomplished.

It is accordingly, an object of the invention to provide an improved magnetic separator.

Another object of the invention is to provide an improved magnetic separator which is simple in construction, economical to manufacture and simple as well as efficient to use.

Another object of the invention is to provide a magnetic separator made of spaced permanent magnets having interpoles of repelling magnets spaced therebetween and means to direct a stream of materials to be separated past the said poles.

Another object of the invention is to provide an improved magnetic separator having circumferentially spaced permanent magnets and a second set of circumferentially spaced permanent magnets spaced on a larger radius and facing the poles of the first permanent magnets with the like polarity of said second set of magnets repelling the polarity of said first set with means to direct a stream of materials to be separated between the first and second permanent magnets.

With the above and other objects in view, the present invention consists of the combination and arrangement of parts hereinafter more fully described, illustrated in the accompanying drawings and more particularly pointed out in the appended claims, it being understood that changes may be made in form, size, porportions, and minor details of construction without departing from the spirit or sacrificing any of the advantages of the invention.

In the drawings:

FIG. 1 is a longitudinal cross sectional view of a magnetic separator according to the invention showing repelling magnets inserted between poles of main magnets.

FIG. 2 is a view similar to FIG. 1 of another embodiment of the invention showing additional poles (repelling magnets) spaced on the opposite side of a path for a stream of material to be separated.

FIG. 3 is an isometric view of a magnetic assembly similar to the one shown in FIG. 1.

FIG. 4 is an enlarged view of four main poles with three repelling poles of the magnetic assembly and four outer bucking magnets in operative relation to each other.

FIG. 5 is a view of a magnetic assembly showing the field shape which would occur with the magnetic arrangement shown in FIG. 1.

FIG. 6 is a view of an assembly showing the magnetic field shape which would occur with the magnetic arrangement shown in FIG. 2.

FIG. 7 is a view of the field arrangement which would occur if the adjustable magnets were moved to the relation relatives to the poles shown in FIG. 4.

Now with more particular reference to the drawings. The drawings illustrate drum-type magnetic separators employing permanent magnets, according to the invention. The drum-type magnetic separators, according to the drawing, have been constructed specifically for recovering or separating magnetizable materials, for example in iron ore purification in concentrators or for use in second flow processes, for example for removing from coal finally ground iron magnetite. It is to be understood the permanent magnet, according to the invention, is also applicable to attractors other than separators.

The magnetic separators illustrated in the drawing are of the wet-drum type. It is to be understood, however, that permanent magnet separators, according to the invention, can be constructed as dry systems. FIG. 1 illustrates a con-current wet-drum separator comprising a drum or cylindrical shell **11** made of non-magnetic, non-magnetizable metallic material and mounted for rotation about a stationary shaft **12** on bearings, not shown, supported on a framework, not shown.

The cylindrical shell **11** is rotatably driven counter-

clockwise, for example, by a sprocket wheel **15** which is in turn rotatably driven through a chain drive **17** illustrated diagramatically from an electric motor **18**. The sprocket is suitably secured to one of the end plates, not shown, of the drum or shell.

The shell **11** has an exterior surface that forms a material conveyor operative as hereinafter described. A fixed permanent magnet described generally by the reference numeral **20** is mounted on the shaft **12** concentrically with the cylindrical shell **11** and interiorly thereof. The magnet comprises support members **21** provided with a hub **22** supporting a back plate **24** preferably having high magnetic permeability. Multiple pole assemblies **25–29** of alternate polarity are mounted angularly spaced on the back plate **24**. These poles extend axially in the cylindrical shell or drum **11**. Repelling magnets **60, 61, 62** and **63** are placed between poles **25–29** as shown. The repelling magnets have a polarity such that the poles of the repelling magnets are adjacent like poles of the magnets **25–29**. The repelling magnets practically eliminate flux leakage because of their repelling force that forces the leakage field back into the magnets **25–29**. The permanent magnet **20** construction details will be hereinafter described completely. The outermost end faces of the poles are spaced radially inwardly of the inner surfaces of the rotatably driven shell **11**, for example, about one-eighth of an inch or one-sixteenth or even three-eighths or larger clearance depending upon the size of the separator so that an air gap **31** is formed between the pole end faces and the shell interior surfaces.

Provision is made externally of the cylindrical shell **11** for delivering a slurry or mixture of material comprising magnetizable material and non-magnetizable material to be separated by the attraction of the magnetizable material to the outer conveyor surface of the cylindrical shell **11** by the strong high-gradient type magnetic field developed by a permanent magnet **20**. The material to be separated designated **35** is delivered to a chamber **36** extending longitudinally of the cylindrical shell. Water is fed into the chamber **36** through a conduit **37** so that a slurry is formed and delivered through an elongated opening **39** in the chamber **36** into a second chamber **40** formed between the drum **11** and plate **41**. The water delivered through the inlet conduit **37** is held at a level **43** by suitably controlling the delivery rate and the height of a plate **45** that defines an overflow chamber **46** so that the excess water flows through an overflow outlet conduit **48**.

The material **35** moves along between the shell exterior surface and the plate **41** in contact with the shell, and in the same direction as the shell rotation, so that the magnetizable material therein is attracted to the outer surface of the shell or drum and held in position thereon. As the drum rotates the material is agitated by the magnet **20**, since the successive fields formed by the assemblies are of alternate polarity, it can readily be appreciated carrying the material through a series of alternating polarity magnetic fields associated with the permanent magnet will rotate the magnetizable materials on the surface of the shell thereby permitting the non-magnetic material or tailings to fall clear of the conveyor outer surface of the shell. The non-magnetic tailings are discharged through an opening **50** into a chamber **51** and are designated generally by the reference number **52**. The tailings entering the chamber **51** are discharged from this chamber through an outlet conduit **54**. The magnetic material remains attracted to the outer surface of the shell until it comes into a position past the pole **29** so that the permanent magnet **20** is no longer effective and the magnetic material falls off, or it may be scraped by a scraper, not shown, into a discharge chute **55** from which it may be discharged, for example, to a container **56** as magnetic concentrate.

In the drawings FIG. 2 illustrates a wet-drum separator in which a rotatably driven cylindrical shell or drum **60** is mounted for rotation on a stationary shaft **61** and is driven clockwise at a suitable preselected speed by an electric motor **62** through a chain drive **63** cooperative with a sprocket wheel **64** mounted on an end plate of the drum, not shown. The apparatus is provided with a permanent magnet **66** mounted on the shaft **61** in a stationary position and concentric with the shell **60**. The permanent magnet comprises multiple pole assemblies **71–75** of alternate polarity secured to a magnetizable back plate **77** mounted depending from support plates **78** having hub **80** circumferentially of the shaft **61**. The permanent magnet **66** functions in a manner similar to the magnet **20** heretofore described.

In the embodiment of the apparatus illustrated in FIG. 2 the slurry of material to be separated is provided through a supply or inlet pipe **82** to an elongated chamber **83** and fed through a delivery opening, for example a pipe **84**, into a distribution chamber **85**. The slurry in the chamber **85** is maintained at a level **86** by the baffle or spill-over plate **87** and the controlled rate of feed and any excess of overflow water enters another chamber **89** and is discharged to an overflow outlet pipe **91**.

In this type of apparatus the magnetic material is attracted to the strongest fields by the magnetic pole assembly **72** nearest the opening into the distribution chamber and is then agitated as the material is carried into the field of opposite polarity developed by the magnetic assembly **71** and is discharged as magnetic concentrate through a discharge chute **93** into a suitable container illustrated diagrammatically at **95**. The material entering the distribution chamber **85** also flows through the chamber in the direction of the pole assembly **73** where further refining or attraction of magnetizable material takes place and the non-magnetic tailings are discharged through an opening **97** into a chamber **98** and out through a tailings discharge outlet pipe **99**.

The fixed permanent magnets **20, 66** heretofore generally described are constructed according to either of two constructions of permanent magnet assemblies to be hereinafter described and in which like reference numerals denote similar parts. According to the invention, the permanent magnets are constructed generally in the manner of the construction of a permanent magnet **100** illustrated in FIG. 3. The magnet **100** comprises an arcuate back plate **102** made, for example of steel and supported on support plates, for example the support plate, axially spaced on a shaft **105** and provided with hubs **106, 107** through which a stationary shaft **105** passes.

The permanent magnet **100** comprises a plurality of pole assemblies **110–113** of alternate polarity. The even numbered pole assemblies **110, 112** may be considered to be of north magnetic polarity and the odd numbered pole assemblies **111, 113** may be considered to be of south magnetic polarity. Each pole is formed by an assembly of a plurality of stacks of ceramic permanent magnet material arranged axially on the magnet. For example, the pole **111** comprises nine stacks, two of which are designated with reference numerals, for example the stacks **121, 122**. Each stack is made up of magnetic units **125**. Each magnetic unit is in the form of a magnetic slab having a greater length and width dimension than thickness. The magnetic units are preferably made of a magnetic ceramic material and have major opposite faces defining their thickness dimension and arranged within each stack with their major faces in an intimate face-to-face relationship. The stacks are arranged contiguous to each other with the magnetic units in end-to-end abutting realtionship. The magnetic units in the stacks are of equal thickness so the stacks on each pole are of equal height. The units **125** in each stack are magnetized permanently in the same direction and in the direction of their thickness dimension which corresponds to magnetization in a direction substantially normal to the opposite faces defining the thickness dimension of the unit.

The successive stacks in each pole assembly are arranged in a row as illustrated in FIG. 3 and are secured to the steel back plate which has high magnetic permea-

bility and is provided with flats, for example the flats **130, 131** extending longitudinally of the plate on which the innermost magnetic units **125** have their faces in intimate contact therewith. These flats are spaced angularly on the arcuate back plate and are on equidistant radii from the axis of rotation of the shaft. The flats need not have the same width when the pole pieces have different widths. In the illustrations in FIGS. 1 and 2 the pole pieces or magnetic units have the same width in all the poles. The outer units are, therefore, concentric and equally spaced radially inwardly from the inner surfaces of a cylindrical shell with which they are mounted concentrically.

The repelling magnets **150, 151** and **152** are disposed between the magnetic units, The repelling magnets are polarized laterally as shown.

In the embodiment of the invention shown in FIG. 4, the main poles **210, 211, 212** and **213** are fixed to the back bar **202** which is made of magnetic material and may be held stationary in the same manner as in the other embodiments of the invention. A rotating drum **232** may be driven in the manner as the drum in the preceding embodiments are driven. A stationary baffle or housing **215** is fixed generally concentric to the rotating drum **232** and spaced outward from the rotating drum a distance indicated at B. This distance is determined by the magnetic field characteristic desired in the space between drum **232** and housing **215**.

The bucking magnets **206, 207, 208** and **209** are fixed to a back bar **300** which is made of magnetic material. The bucking magnets and back bar are held in spaced relation to the fixed baffle **215**. The bucking magnets and back bar **300** are rotatably adjustable and may also be adjusted toward and away from the main magnets by means of the adjusting members **220**, to permit shaping and increasing or decreasing the gradient and strength of the magnetic field in the space between drum **232** and baffle **215**. The stationary baffle **215** is fixed a distance B from the rotating drum and the faces of the bucking magnets will be adjusted to have a distance A of a suitable magnitude to give the proper bucking effect on the field resulting from the main magnets. In the embodiment of FIGURE 4, Dimension B must be less than A so the ferromagnetic particles will be attracted to the main poles, rather than to bucking magnets. Also in the embodiment of FIG. 4; the bucking magnets are rotatably adjustable so that the field pattern of the main magnets can be adjusted to attract particles so they will move toward the main magnets either in the path illustrated in C or D, or any intermediate path, depending upon the characteristics of the materials being separated. Where the particles to be attracted are weakly magnetic, path C is preferable over D because the direction of attraction is such that more time is permitted to overcome the inertia of the moving particles. In path D the particles must change direction rather abruptly, so there is a greater chance that some weakly magnetic particles could get past the magnets. The outside repelling magnets cause a significant increase in flux density at the surface of the drum shell with realtively low flux densities in adjacent areas. It is the rather abrupt change within a short distance that is called high gradient and is so important for the attraction of magnetic particles.

The adjustment of the repelling magnets closer to or further from the main magnets is important because it permits adjustment of the field strength to accommodate variations in characteristics of ore deposits. With some ores, if the magnets are too strong, they may remove undesirable frictions.

The foregoing specification sets forth the invention in its preferred practical form, but it is understood that the structure shown is capable of modification within a range of equivalents without departing from the invention which is to be understood is broadly novel as is commensurate with the appended claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A magnetic separator comprising:
a back bar,
spaced permanent main magnets fixed to said back bar, and said magnets having a face spaced from said back bar,
said main magnets each having a magnetic pole adjacent its said face of opposite polarity from the pole of the main magnet adjacent thereto,
repelling magnets disposed between said main magnets,
means to direct a stream containing nonmagnetic material and magnetic material in close proximity to said faces of said magnets and through magnetic fields produced by said main magnets, whereby said magnetic material is separated from said nonmagnetic material,
said repelling magnets each having a magnetic pole at each side thereof of like polarity to the pole of the main magnet at said face thereof, whereby the leakage field of said main magnets is repelling and reinforces the normal field which is forced outward toward said stream of material,
a plurality of bucking magnets being disposed in an arcuate pattern outside of said main magnets with one pole of each said bucking magnet directly opposite and facing a like pole of said main magnet.

2. The separator recited in calim **1** wherein:
said means to direct said materials into close proximity to said faces of said magnets comprises a hollow drum,
a part of said drum extending between said main magnets and said bucking magnets,
a stationary housing disposed between said drum and said bucking magnets,
said stationary housing and said drum defining a flow path for said materials.

3. The separator recited in claim **2** wherein:
means is provided for adjusting said bucking magnets rotatably in relation to said main magnets whereby the effect of said of said bucking magnets on the field of said main magnets is altered.

4. The separator recited in claim **3** wherein:
means is provided for moving said bucking magnets toward and away from said main magnets whereby the magnetic field may be made stronger or weaker.

5. The separator recited in claim **4** wherein:
one said bucking magnet is disposed adjacent each said main pole.

6. The separator recited in claim **5** wherein:
means is provided for adjusting said bucking magnets toward and away from said main magnets and to adjust rotatably in relation to said main magnets whereby the effect of said bucking magnets on the field of said main magnets is altered.

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U.S. Cl. X.R.

209—232; 210—222