

April 19, 1966

E. A. LAURILA

3,246,753

HIGH-INTENSITY MAGNETIC SEPARATOR

Filed Jan. 15, 1964

4 Sheets-Sheet 1

Fig. 1

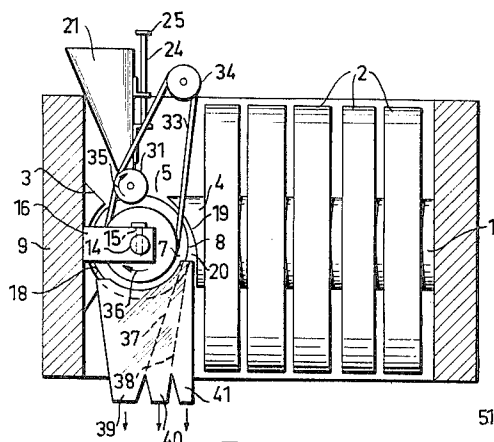


Fig. 7

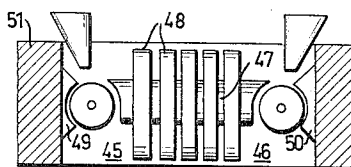


Fig. 8

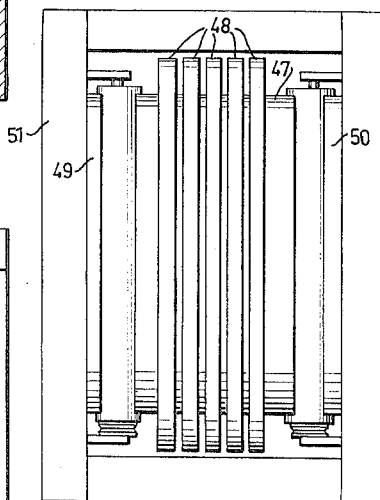


Fig. 2

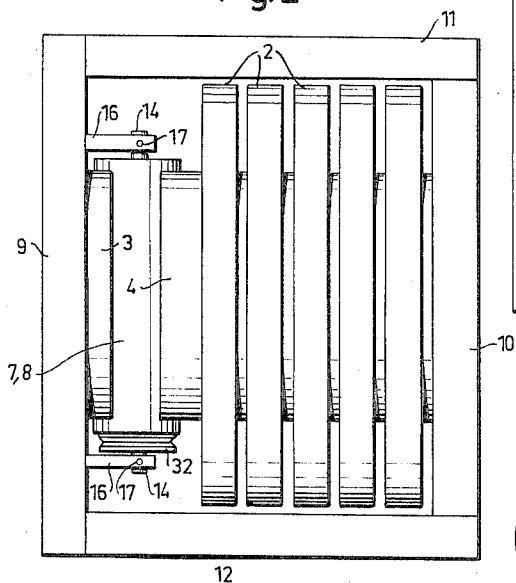
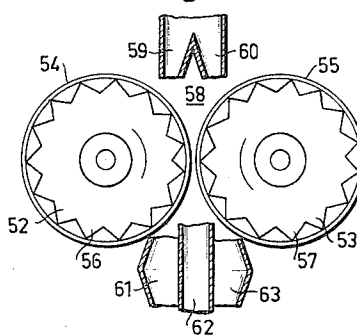


Fig. 9



ERKKI AUKUSTI LAURILA INVENTOR

BY ERIC V. MANNSON

ATTORNEY

April 19, 1966

E. A. LAURILA

3,246,753

HIGH-INTENSITY MAGNETIC SEPARATOR

Filed Jan. 15, 1964

4 Sheets-Sheet 2

Fig. 3

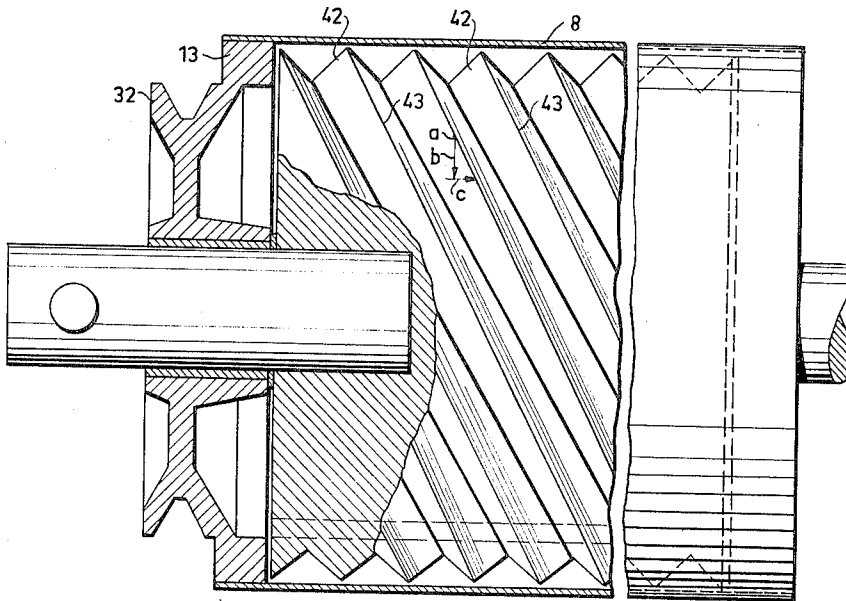


Fig. 4

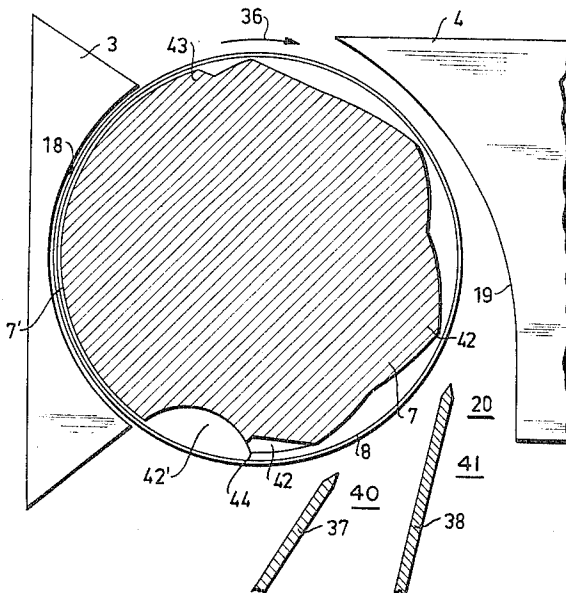
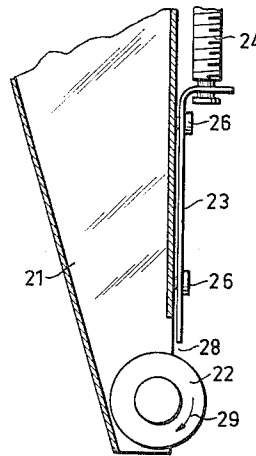


Fig. 6



INVENTOR

ERKKI AUKUSTI LAURILA

BY ERIC Y. MUNSON

ATTORNEY

April 19, 1966

E. A. LAURILA

3,246,753

HIGH-INTENSITY MAGNETIC SEPARATOR

Filed Jan. 15, 1964

4 Sheets-Sheet 3

Fig. 4a

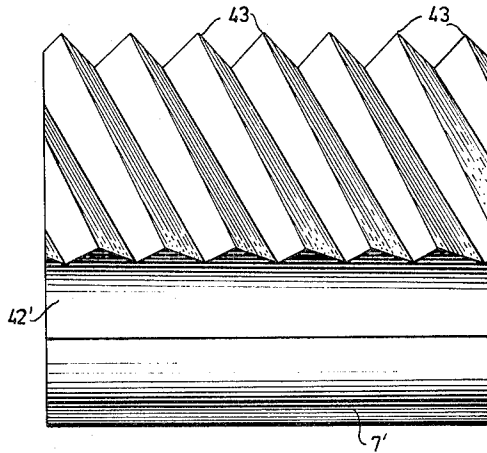
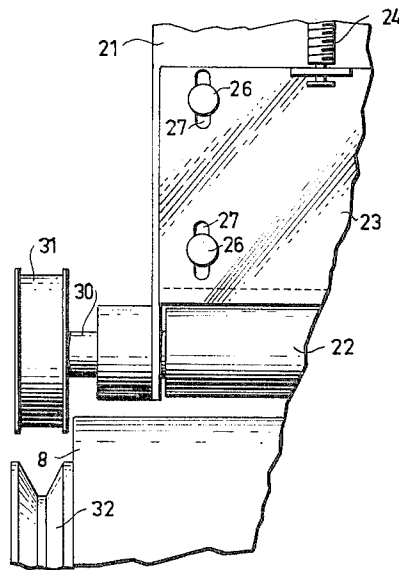


Fig. 5



INVENTOR

ERKKI AUKUSTI LAURILA

BY ERIC J. MUNSON

ATTORNEY

April 19, 1966

E. A. LAURILA

3,246,753

HIGH-INTENSITY MAGNETIC SEPARATOR

Filed Jan. 15, 1964

4 Sheets-Sheet 4

Fig.10

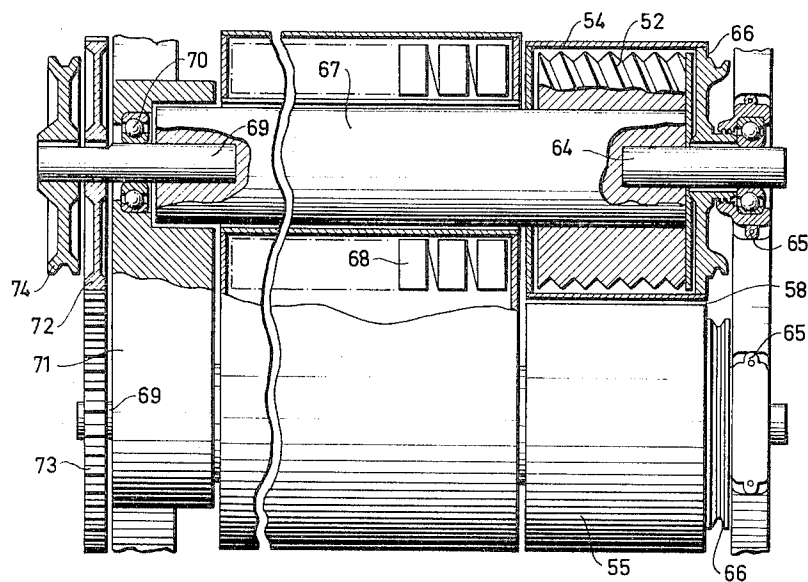
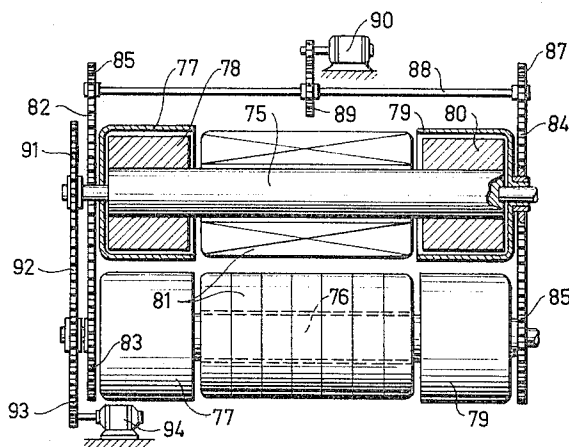


Fig.11



INVENTOR

ERIKI AUKUSTI LAURILA

BY ERIC J. MANSON

ATTORNEY

1

3,246,753

HIGH-INTENSITY MAGNETIC SEPARATOR

Erkki Aukusti Laurila, Helsinki, Finland, assignor to Sala Maskinfabriks Aktiebolag, Sala, Sweden, a corporation of Sweden

Filed Jan. 15, 1964, Ser. No. 337,937

2 Claims. (Cl. 209-219)

This invention relates to high-intensity separators for the separation of ores, particularly weakly magnetic ores. The application is a continuation-in-part of my co-pending patent application Serial No. 97,789 filed on March 23, 1961, and now abandoned, and claiming priority from the Swedish patent application No. 3,155/60, filed on March 30, 1960.

For the separation of weakly magnetic ores high-intensity separators of various kinds are used. Since the magnetic attraction is proportional to the product of the intensity of the field and the gradient thereof, both the intensity of the field and the gradient thereof should be as high as possible to obtain the desired separation in a separator for weakly magnetic ores. For this reason, electromagnets are most suitable in such separators, and the requirements are satisfied only by the use of magnetic circuits which are closed as much as possible. Therefrom it follows that the magnetic field to be used for the separation should be positioned in an air gap in a magnetic circuit, that is, between two magnet poles of opposite polarity. By suitable construction of the magnet poles limiting the air gap it is possible for the gradient to have substantially the same direction in every part of the air gap. The separation takes place while the particles of the ore are caused to move through the air gap. Certain devices are used to render possible such movement. In the most common types of magnetic separators a rotary iron cylinder is provided in the air gap which cylinder forms a secondary magnet pole in which the magnetic particles are attracted and transported through the air gap, whereas the nonmagnetic particles are separated from the feed.

The most serious inconvenience in the many various separator constructions devised in accordance with the above principle consists in that the magnetic particles which are attracted toward the surface of the cylinder are retained on this surface without moving relative to the cylinder as they travel through the air gap. Non-magnetic particles are often enclosed between the magnetic particles. In view of this fact separation of both kinds of particles is made difficult, resulting in inferior concentrates leaving the separator. For this reason, high-intensity separators of the type indicated cannot be used for treatment of pulverized material. Since, on the other hand, large-sized particles cannot be fed into the separator on account of the fact that the dimensions of the air gap are too small, especially at the place of the maximum attraction, the field of application of these separators is very limited as regards the grain size of the material. Generally, the grain size is between 0.012 and 0.12 inch.

Another known type of magnetic separator comprises crossed strips for the transport of the material through the air gap. In these and other analogous separators the material to be separated travels through a magnetic field with upwardly directed force of attraction. In this case, the particles are drawn upwards toward strips, rotating disks or the like members by means of which they are carried along. In case of pulverized material, these separators have a somewhat better ability of separation than the previously named separators, but they have a low capacity and cannot be used for the separation of very weakly magnetic material, this being mainly due to the fact that the magnetic field must entirely overcome the

2

influence of gravitation at a comparatively great distance from an overlying magnet pole. In certain connections, these separators are therefore not counted among high-intensity separators in the usual sense of the word.

The object of the present invention is to provide a separator which as regards the intensity of the field is equal in merit to conventional high-intensity separators and, in addition, is suitable for the separation of pulverized and weakly magnetic material.

In its broadest aspect, the invention is characterized by the fact that the separation members for moving the material to be separated through the air gap comprise a body of magnetic material having ridge-like projections and a partition of non-magnetic material, the material to be separated being fed toward said partition which is movable through the air gap in proximity to said projections the top edges of which are facing the partition which is movable substantially transversely of the lines of force of the magnetic field between the poles and adapted to be moved past the ridge-like projections in a manner such as to cause attracted material on the partition to move relative to the partition. The sharp-edged ridges concentrate the magnetic field and the attraction forces at certain very limited areas on the partition opposite the ridges, and as the partition moves relative to the ridges, a rolling movement is imparted to the particles on the partition, resulting in that the non-magnetic material will be freed and can be separated from the feed.

The separation members can be devised in many different ways within the scope of the invention. In order to have the centrifugal forces contribute to the separation, the partition may be a rotary drum and the body consisting of magnetic material may be a roll positioned within the drum and having the projections on its surface in close proximity to the inner surface of the drum which is rotatable about the axis of the roll.

A particularly effective movement of the particles of the material on the surface of the drum can be obtained if the projections extend obliquely with respect to the axial direction of the drum and preferably along helical lines. In this case, the forces which during the movement of the surface of the drum are acting along said surface will have components extending axially of the drum so that the particles will tend to move not only peripherally in planes extending at right angles to the axis of the drum, but also parallel to the axial direction of the drum, the result being an improved release and separation of the non-magnetic material.

In a high-intensity the leakage losses in magnetic circuit must be as small as possible. Thus, it is important to reduce to a minimum the clearances between the pole surface and the drum at the back of the latter and between the adjacent wall of the drum and the body of magnetic material mounted in the drum and being energized through magnetic induction to generate a magnetic separation field between the opposite pole surface and the adjacent side of the drum. For this purpose, according to an aspect of the invention the magnetic body in the drum has a shape adapted to that of the drum and of one of the pole surfaces. In this embodiment the projections or ridges are formed in one part of the peripheral surface of the body only, the other part being smooth located in close proximity of the inner wall surface of the drum which in turn has its outer peripheral wall surface in close proximity of the adjacent pole surface. Preferably, the drum is cylindrical, the latter part of the peripheral surface of the body being cylindrical too. In this case, the body extending in the drum should be stationary, the drum being rotatable and adapted to rotate about an axis concentric with a circular arc along which the adjacent pole surface extends.

It is important that all material to be separated has left the surface of the drum at the point where the drum surface approaches the pole surface located close to the peripheral surface of the drum, i.e. at the back of the drum, since otherwise the retained material could enter the small space between the pole surface and the drum and clog therein with the result that the separator would stop or become destroyed. This may be avoided by providing a groove, in the magnetic body in the transition between the part provided with the projection and the smooth part of the body surface, whereby there is a definite reduction of the magnetic field in advance of pole surface in question.

Further features and advantages of the invention will be apparent from the following description of forms of construction diagrammatically illustrated in the accompanying drawing in which FIG. 1 is a vertical sectional view and FIG. 2 a top view (with the feed members omitted) of a magnetic separator according to a first embodiment of the invention. FIG. 3 is a top view, partly in section, and FIG. 4 a cross-sectional view, both to an enlarged scale, of the separation drum and the thereby enclosed roll of the separator illustrated in FIGS. 1 and 2. FIG. 4a is a bottom view of the magnetic body shown in FIG. 4, FIGS. 5 and 6 are enlarged views of the feed members for the supply of the material to be separated in a magnetic separator according to FIGS. 1 and 2. FIG. 7 is an elevation and FIG. 8 a top view of a second form of construction of magnetic separator. FIG. 9 is an elevation and FIG. 10 a top view, partly in axial section, of a magnetic separator according to a third embodiment of the invention. FIG. 11 is a top view, with the upper part in section, of a further modification.

Referring to FIGS. 1 to 6, numeral 1 denotes the core and numeral 2 the exciting coils of an electromagnet between the poles 3 and 4 of which there is an air gap 5 for the separation members which consist of a body 7 of magnetic material, such as Armco-iron, 30% Co-Steel or the like, and a partition 8 of non-magnetic material, such as stainless steel or glassfibre-reinforced plastic. One pole 3, a south pole, is formed by a pole piece secured to one side 9 of a rectangular frame, the opposite side of which is connected to one end of the core 1. The other end of the core forms the north pole of the electromagnet. The frame also comprises a pair of sides 11, 12 extending between the sides 9 and 10 and forms a closed magnetic circuit together with the core 1, the pole pieces 3, 4 and the body 7 which consist of a magnetic material.

The body 7 has an at least approximately cylindrical main shape and is carried by two axially projecting studs 14 which by means of crosspins 15 are secured to brackets 16 extending inwardly from the side 9 of the frame. The partition 8 is a drum having a cylindrical surface in coaxial relation to the body 7. The drum has end walls 13 (FIG. 3) of aluminium or another non-magnetic material, said end walls being mounted on the stationary journals 14.

The concave surfaces of the pole pieces 3, 4 are facing the drum 8. The surface 18 of one pole piece is located close to and concentrically with respect to the drum and the other surface 19 is located at a greater distance from the drum and is arc-shaped in a manner such that a downwardly widening separation space 20 is formed between the drum and the surface 19.

The grain-shaped or pulverized material to be separated is admitted to the upper side of the drum 8 from a hopper 21 (FIGS. 1, 5 and 6) which at its lower end has a feed roller 22 and on its front side carries a control member in the form of a sliding shutter which by means of a screw 24 and a handwheel 25 is adjustable vertically toward and away from the feed roller. The shutter is guided by means of studs 26 which are secured to the front wall of the hopper and extend through slots 27 in the shutter. Between the lower edge of the shutter and the feed roller 22 there is formed a feed slot 28

which is controllable by means of the screw 24 and through which the material passes as the feed roller 22 rotates in the direction indicated by the arrow 29.

On a journal 30 of the feed roller 22 there is mounted a belt pulley 31, and on the end wall 13 of the drum 8 there is provided a belt pulley 32. A motor 34 drives the drum and the feed roller by means of the pulleys and a belt 33 in the direction indicated by the arrows 35 and 36, that is, clockwise as viewed in FIG. 1.

The lower side of the drum 8 is partly surrounded by the upper portion of a collecting chamber for the separated material. By means of partitions 37 and 38 this chamber is divided into three hopper-like pockets 39, 40 and 41 for collecting concentrates, mixed discharge and tailings, respectively.

As shown in FIGS. 3 and 4, the side of the body 7 which faces the separation space 20 is provided with ridge-like projections 42 which extend helically from a place 43 on the upper side of the body 7 to a place 44 on the lower side thereof. The top edge 43 of the projections 42 is comparatively sharp. The angle between the sides of two adjacent projections may vary and may normally amount to about 90°.

A magnetic field of high intensity can be formed between the body 7 and the pole piece 4 by the use of an electromagnet. By magnetic induction the side of the body 7 that faces the pole piece 4 becomes a magnet pole having a polarity opposite to that of the pole piece 4, that is, a south pole, since according to the example pole 4 is a north pole. The magnetic field is concentrated at the edges 43 of the projections which are in close proximity to the inside of the surrounding drum 8.

Preferably, the body 7 is stationary, i.e. is keyed to the stationary studs 14. This has the advantage that the part of the surface of the body that faces the pole surface 18 may be cylindrical and concentric with said pole surface whereby in turn the space between the peripheral surface of the body 7 and the inner wall of the drum and the space between the outer wall surface of the drum and the surface 18 may be made very small. This is important since otherwise there will be losses of the magnetic force induced in the body 7 and thus a reduction of the capability of separation of the separator. In practice, the clearance between the smooth surface part 7' of the body 7 and the inner wall surface of the drum may be reduced to approximately zero so that the drum may glide in contact with the body surface 7' oil being admitted to the inner of the drum to reduce the friction.

Due to the small clearance between the drum and the pole surface 18 there is a risk for particles from the material being separated to be entrained into the small space and clogging in said space. This risk can be effectively avoided by providing a groove 42' in the body 7, said groove extending in the longitudinal direction of the body from one end thereof to the other as shown in FIG. 4a. The groove is located in the transition between the surface part of the body formed with the projections 42 on one hand and the smooth surface 7' on the other hand. The groove accomplishes a material reduction of the magnetic field strength at the surface of the drum radially opposite said groove, whereby any risk also for strongly magnetic particles to be carried along past the groove is avoided.

The general mode of operation of the separator described is as follows.

Separators of the type in consideration are usually used for the separation of weakly magnetic and comparatively finely crushed ores. Upon rotation of the feed roller 22 the pulverized material to be separated is continuously supplied from the hopper 21 and falls down on the upper side of the drum 8 of non-magnetic material. The drum 8 rotates in the direction indicated by the arrow 36 and carries the material into the magnetic field in the separation space 20. The magnetic particles of the material are attracted by the stationary body 7 and will be re-

5

tained on the outer side of the drum 8. These particles are collected particularly at places opposite the top edges 43 of the projections 42 where the intensity of the field is a maximum. The drum tends to carry each particle *a* (FIG. 3) along a circular arc in a plane extending radially of the drum, that is, in the direction indicated by the arrow *b* in FIG. 3. At the same time, the projection 42 extending obliquely with respect to said plane tends to cause the particle to move along the helical top line 43. Consequently, the movement can be considered to have an axial component *c* with the result that the particle will roll laterally on the outer surface of the drum 8 during its downward movement through the separation space. However, the feed consists of a mixture of magnetic and non-magnetic particles. Due to the described rolling movement of the magnetic particles, the non-magnetic particles which may be enclosed between magnetic particles retained on the drum will be exposed and thrown off the drum under the influence of the centrifugal force and drop through the separation space 20. These tailings are thrown out in the widened lower part of the space 20 and collected in the right hand pocket 41 to the right of the partition 38 (FIG. 4). A mixed discharge containing some magnetic material drops into the intermediate pocket 40 between the partitions 37 and 38. The magnetic material follows along with the drum 8 to the lower side thereof where the magnetic field is too weak to retain the particles against the action of the centrifugal force and gravity. The magnetic particles consequently drop off and are collected in the left-hand pocket 39 as a concentrate. Due to the groove 42' a considerable reduction of the magnetic field is obtained before the drum wall enters the space adjacent the pole surface 18 so that no particles are entrained into said space.

In the embodiment illustrated in FIGS. 7 and 8, the closed magnetic circuit comprises two separator units 45, 46 one on each side of an electromagnetic core 47 with coils 48 and surrounded by a common frame 51 provided with pole pieces 49, 50. Each unit 45 and 46 may be constructed as described with reference to FIGS. 1 to 6. More than two similar units may be provided in a common magnetic circuit.

The rolling movement of the material to be separated can be obtained, in accordance with the invention, by means other than those described above. An example of a suitable device is illustrated in FIG. 9. In this example there are provided two rolls 52 and 53 of magnetic material, such as iron, each of the rolls being surrounded by a drum 54 and 55, respectively, of non-magnetic material, such as stainless steel or plastic. Each roll has projections 56 and 57, respectively, which form a star-shaped pattern and extend axially or helically. Both the rolls and the drums are adapted to rotate. They are coupled to each other in a manner such that the projections 56 on the roll 52 like the teeth of two intermeshing gear wheels are moving in opposite relation to the spaces between the projections on the other roll 53. The axes of rotation of the rolls are parallel to each other, and a separation space 58 is provided between the drums. In this space, the drums are moving downwards, each drum being adapted to rotate in the same direction as the roll enclosed thereby but at another and preferably somewhat higher speed than the drum.

The rolls 52 and 53 are unlike poles of an electromagnet so that a magnetic field of high intensity is formed between them in the separation space 58. The material to be separated falls from upper hoppers 59, 60 onto the drums and is attracted toward the top edges of the projections 56, 57 where the intensity of the magnetic field is a maximum. They are carried along by the drums under rolling movement so as to expose the non-magnetic material which is collected in an intermediate pocket 62, whereas the concentrates are thrown slightly laterally into the pockets 61 and 63.

6

The separator diagrammatically illustrated in FIG. 9 may be constructed as shown in FIG. 10. Here, the end walls of the drums 54, 55 are freely mounted on journals 64 which are carried by anti-friction bearings 65. The end walls form belt pulleys 66 (or may be provided with intermeshing gear wheels of equal diameters) so as to be able to be driven by suitably provided belts in opposite directions and at equal peripheral speeds. The journals 64 are formed on or secured in shafts 67 of larger diameters which serve as electromagnet cores and within the drums carry the star-shaped rolls consisting of soft iron, one of these rolls 52 being shown in section in the upper part of FIG. 10. Exciting coils 68 are provided around the shaft 67. At the end remote from the roll 52 the shaft has secured therein a journal 69 which is mounted in a bearing 70 in a lateral frame 71 of magnetic material, such as Armco-iron. Intermeshing gear wheels 72 and 73 are keyed onto the journals 69. One of the journals 69 also has secured thereon a belt pulley 74. A closed magnetic circuit extends from the roll 52 via one of the shafts 67, the journal 69, the frame part 71, the other journal 69 and the other shaft 67 to the other roll 53 within the drum 55. This circuit comprises an air gap between the rolls 52 and 53 in which gap the cylindrical walls of the drums 54, 55 and the separation space 58 between the drums are positioned.

If one shaft 67, 69 is rotated by means of the belt pulley 74 the other shaft will be driven in the opposite direction by means of the gear wheels 72, 73 which are permanently in mesh with each other. By means of the belt pulleys 66 the drums 54 and 55 are driven at equal speeds and in the same directions as the rolls 52 and 53, respectively, and preferably at a somewhat higher speed than the rolls.

Since the magnetic forces between the rolls may amount to very high values, it may be suitable and advantageous to load the shafts symmetrically by the provision at both ends thereof of separator units consisting of rolls and drums, as diagrammatically illustrated in FIG. 11. Here, the shafts 75 and 76 serving as electromagnetic cores are provided at one end with a separator unit consisting of drums 77 and rolls 78, and at the other end with a separator unit consisting of drums 79 and rolls 80. The shafts have individual exciting coils 81. The drums 77 as well as the drums 79 are coupled to each other for rotation in opposite directions and at equal peripheral speeds, such as by means of pairs of gear wheels 82, 83 and 84, 85 respectively. These gear wheels are driven by gear wheels 86, 87 mounted on a shaft 88 provided with a gear wheel 89 which is driven by a motor 90. The shafts 75, 76 and the appertaining rolls 78, 80 are commonly driven by means of gear wheels 91 and 92, the gear wheel 92 meshing with a pinion 93 on the shaft of a motor 94.

The separator illustrated in FIG. 11 is arranged symmetrically with respect to a central plane extending at right angles to the shafts 75, 76. The attractive forces in the magnetic field between the rolls 78 at one end of the shafts are equal to the attractive forces between the rolls 80 at the other end of the shafts, resulting in a uniform load on the shafts.

The invention is not limited to the forms of construction illustrated. In order to facilitate the rolling movement of the material on the surface of the drum in the case of axially extending parallel projections, the axis of rotation of the drum may be inclined or vertical so that the force of gravity has a component parallel to the axis of rotation.

What is claimed is:

1. A high-intensity magnetic separator for the separation of pulverized ores and similar material comprising an electromagnet forming a magnetic circuit having a gap between opposite poles and a magnetic field in said gap, a stationary body of magnetic material and a drum both mounted in said gap with the body extending axially

in the drum, said body having a substantially cylindrical main shape and ridge-like projections extending helically around only a part of the circumference thereof and said drum being rotatable in the gap with its inner circumference in the proximity of said projections, a further part of the peripheral surface of the body being smooth and a groove being formed in the surface of the body, said groove separating the smooth part from the part having the projections.

2. A high-intensity magnetic separator for the separation of pulverized ores and similar material comprising spaced magnetic pole pieces forming a magnetic field in the space therebetween, means above said space for feeding material to be separated, a drum of non-magnetic material mounted for rotation about its axis in said space, one pole piece having a concave surface in close proximity to and concentric with the drum, the other pole piece having an arcuate surface spaced at a greater distance from the drum than the spacing between the first pole piece and the drum and forming a downwardly widening passage for the material being separated, a substantially cylindrical body of magnetic material having ridge-like projections extending helically around part of the circumferential surface thereof, another part of said surface being smooth and the transition between said surface parts being located at the lower side of the body and being formed by a groove extending longitudinally of the body from one end thereof to the other, the body be-

ing mounted in the drum with its projection in close proximity of the inner wall thereof, means to rotate the drum relatively to the body to move magnetic particles of the material being separated with and in relation to the drum, and means in said passage and below the drum for receiving concentrate separated from weakly magnetic material and tailings.

References Cited by the Examiner

UNITED STATES PATENTS

284,620	9/1882	Buchanan	209—219
411,899	10/1889	Moffatt	209—219 XR
449,610	3/1891	Moffatt	209—219
639,062	12/1899	Kreuser	209—219
832,827	10/1906	Wait	209—219
910,664	1/1909	Green	209—219
1,529,970	3/1925	Ullrich.	
1,958,521	5/1934	Payne	209—219
1,965,441	7/1934	Tyden	209—219
2,766,888	10/1956	Queneau	209—219
2,862,619	12/1958	Stearns	209—219 XR
3,024,910	3/1962	Palasvirta	209—219

FOREIGN PATENTS

1,012,872	8/1957	Germany.
-----------	--------	----------

HARRY B. THORNTON, *Primary Examiner.*