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**Lee et al.**

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[54] **HIGH INTENSITY MAGNETIC SORTER**


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[51] **Int. Cl.**[2] .............................................. **B03C 1/22**

[58] **Field of Search** ........... 209/223, 219, 214, 232, 209/213, 230, 228



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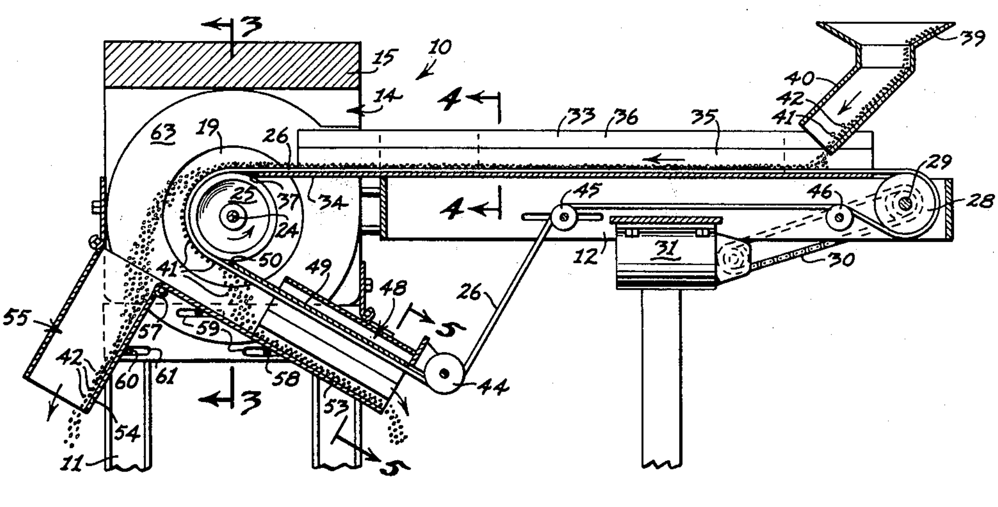
[57] **ABSTRACT**

A high intensity magnetic sorter in which a mixture of feebly magnetic particles and non-magnetic particles are fed to the top portion of a rotary wheel rotable about a horizontal axis and influenced by an intense magnetic field creating field gradients increasing radially toward the wheel for attracting the magnetic particles toward the wheel, and deflector plates for guiding the separated non-magnetic particles and magnetic particles from the rotating wheel to separate deposit stations.

**2 Claims, 5 Drawing Figures**

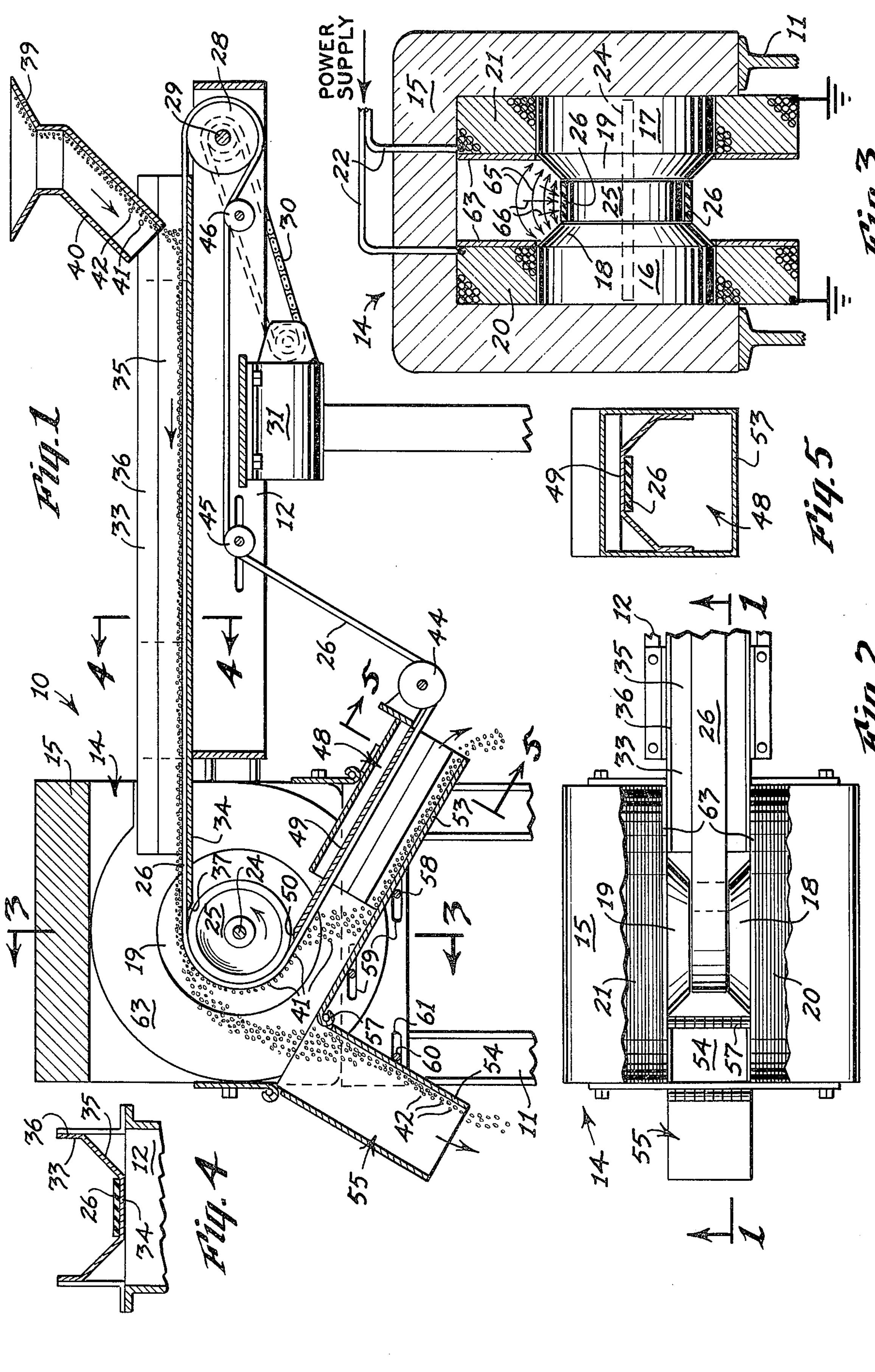



Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

# HIGH INTENSITY MAGNETIC SORTER

## BACKGROUND OF THE INVENTION

This invention relates to a magnetic sorter, and more particularly to a high intensity magnetic sorter for feebly magnetic materials and non-magnetic materials.

It is known in the art to provide a pulley having bar magnets in the periphery thereof for attracting magnetic materials carried by an endless belt around the pulley, so that magnetic particles are separated from non-magnetic particles fed around the pulley. The non-magnetic particles drop from the pulley by gravity, while the magnetic particles are held by magnetism against the pulley until they are diverted away from the magnetic influence of the pulley.

Such prior art magnetic pulleys produce low-order fields of magnetism, which are more than adequate for separating ferromagnetic particles, such as iron, cobalt or nickel, from non-magnetic particles. However, such fields created by simple bar magnets are totally inadequate for separating feebly or weakly magnetic particles from non-magnetic particles. The magnetic fields created by the bar magnet not only move with the pulley, but also produce non-uniform fields circumferentially of the pulley. The magnetic forces of greatest strength are concentrated at the intermittently spaced bar magnets to attract magnetic particles in bunches to the rim of the conventional magnetic pulleys.

## SUMMARY OF THE INVENTION

It is therefore an object of this invention to provide a rotary sorter wheel or pulley, at least a portion of the outer rim of which is under the influence of an intense stationary magnetic field, circumferentially uniform around the wheel, and having high field gradients for producing strong magnetic forces radially toward the wheel. Feebly magnetic particles fed to the periphery of the wheel are thus magnetically attracted to the wheel, while non-magnetic particles drop from the wheel by gravity.

This intense magnetic field is created by stationary electromagnets larger than conventional electromagnets and energized by currents of high amperage. The iron cores of the large electromagnet are spaced on opposite sides of the wheel and are provided with specially shaped pole tips, which not only transmit the high intensity magnetic field, but also produce magnetic field gradients of high values increasing radially inward toward the wheel so that the most intense part of the field is closely adjacent to the outer rim of the wheel. The resultant, radially inward, magnetic forces are thus strong enough to attract the feebly magnetic particles against the rim of the rotating wheel.

As the particles are carried around the rim of the wheel from a feeding position on top of the wheel, the non-magnetic particles are thrown off the wheel by centrifugal force and drop by gravity through an appropriate chute to a deposit station. The magnetic particles, being attracted to the rim of the wheel are carried around toward the bottom of the wheel. The magnetic particles are physically separated from the rim of the wheel by a deflector plate, and preferably by an endless belt trained around the wheel and over the deflector plate, to remove the magnetized particles from the influence of the magnetic field and magnetic field gradients. When the gravitational force and the centrifugal force exceed the magnetic attractive force, the feebly



magnetic particles also drop by gravity to a second deposit station substantially spaced from the first deposit station of the non-magnetic particles.

By virtue of the strength of the magnetic field and field gradients, particles may be fed more rapidly to the wheel, such as by the endless belt, to produce a more rapid separation rate, and thereby improve production.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a vertical sectional elevation of the sorter made in accordance with this invention, taken along the line **1—1** of FIG. **2;**

FIG. **2** is a fragmentary top plan view of the portion of the sorter including the sorter wheel and magnet, with portions broken away;

FIG. **3** is a slightly enlarged section taken along the line **3—3** of FIG. **1,** with the deflector plates removed;

FIG. **4** is an enlarged fragmentary section taken along the line **4—4** of FIG. **1;** and

FIG. **5** is an enlarged section taken along the line **5—5** of FIG. **1.**

## DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings in more detail, FIG. **1** discloses the paramagnetic sorting apparatus **10,** including a sorter frame **11** and a conveyer frame **12,** both of which are stationary, and which may be connected to each other.

Mounted upon the sorter frame **11** is a large C-shaped electromagnet **14** having a C-shaped, or inverted U-shaped, flux return piece **15** made from highly permeable magnetic material, preferably iron. Fixed to, or forming an integral part of, the opposed inner surfaces of the legs of the return piece **15** are a pair of cylindrical iron cores **16** and **17,** having respective pole tips **18** and **19,** terminating in opposed pole faces defining an air gap. Surrounding the cores **16** and **17** are coils **20** and **21** of electrical conductors, supplied with current of high amperage through power supply leads **22,** from any convenient source of high voltage electricity, not shown.

Mounted for rotary movement upon a shaft **24,** preferably co-axially of the cylindrical cores **16** and **17** and within the air gap between the pole tips **18** and **19,** is a sorter wheel or head pulley **25,** made of non-magnetic material. Trained around the head pulley **25** is an endless belt **26** of uniform width substantially equal to the width of the head pulley **25** and also substantially spanning the air gap between the pole tips **18** and **19.** The endless belt **26** is also trained about the driven tail pulley **28** rotatably mounted upon driven shaft **29** at the rear end of the conveyor frame **12.** Shaft **29** is driven through the sprocket and chain transmission **30** from a variable speed motor **31,** for moving the endless belt **26** in the direction of the arrow disclosed in FIG. **1.**

Supported upon the conveyor frame **12** is a channel-shaped trough **33,** having the configuration, best disclosed in FIG. **4.** The trough **33** has a flat bottom wall **34** of substantially the same width as the endless belt **26,** to support belt **26** as it moves over the top surface of the bottom wall **34.** The bottom portions **35** of the side walls diverge upward and terminate in the straight vertical upper side wall portions **36.** The bottom wall **34** extends forward to terminate in a front edge **37** closely adjacent to the surface of the head pulley **25,** to permit the endless belt **26** to feed tangentially over the outer rim of the head pulley **25.** Trough **33** is disclosed as being horizontal, but of course may decline toward the head pulley **25** at other angles, if desired.

Mounted above the rear portion of the trough **33**, by means not shown, is a hopper **39** having a discharge spout **40**, for discharging a mixture of feebly magnetic particles **41** and non-magnetic particles **42** upon the conveyor belt **26**.

The return leg of the endless belt **26** is trained about the idler pulleys **44**, **45** and **46**, so that the belt **26** makes an almost 180° degree wrap about the head pulley **25**, and is provided with a greater than 180° degree wrap about the tail pulley **28**.

A portion of the return leg of the endless belt **26** between the bottom of the head pulley **25** and idler pulley **44** is supported by an inverted return trough **48** fixed upon the sorter frame **11**. As is best disclosed in FIG. **5**, the return trough **48** has a channel-shape similar to the feed trough **33**. The top wall **49** of the return trough **48** terminates in an edge **50** spaced quite close to the rim of the head pulley **25** to provide a substantially straight support for the return portion of the endless belt **26**, particularly while the magnetic particles are still under the influence of the magnetic field around the head pulley **25**.

A deflector plate **53** is mounted on the frame **11** below the return trough **48** in such a manner that it may form with the return trough **48** a discharge chute for the magnetic material **41**.

Another deflector plate **54** is mounted upon the sorter frame **11** for directing the non-magnetic particles **42**, dropping by gravity from the belt **26**, to a deposit station (not shown) spaced from the deposit station for the magnetic material **41**. The deflector plate **54** may form one wall of a discharge chute **55**.

The deflector plates **53** and **54** may be supported in any desired manner upon the sorter frame **11**, but are preferably so mounted that they may be shifted to different positions for catching and diverting the respective streams of magnetic particles **41** and non-magnetic particles **42**. As disclosed in FIG. **1**, the diverter plates **53** and **54** are connected to each other by a piano hinge **57** for pivotal movement relative to each other and to the frame **11**. Plate **53** may also be provided with bolts **58** for limited movement in slots **59**, while the plate **54** may be provided with a bolt **60** for limited movement in the corresponding slot **61**.

Ring-shaped shields **63** are mounted against the inner surfaces of the coils **20** and **21** to protect them from the particles fed by the endless belt **26** to the sorter wheel **25** and also to prevent the accumulation of dirt and dust upon the coils **20** and **21**.

In the construction of the sorter apparatus **10**, the return flux piece **15**, cores **16** and **17** and their respective pole tips **18** and **19** are made of solid iron. The sorter frame **11** is preferably made of steel for strength, and may also provide an alternate flux path for the cores **16** and **17**.

The head pulley **25**, troughs **33** and **48**, deflector plates **53** and **54**, and discharge chute **55**, are preferably made of non-magnetic metals, such as stainless steel. The coil shields **63** are preferably made of non-magnetic metal, such as aluminum.

The structure and location of pole tips **18** and **19** are extremely important to the successful function of this invention. As disclosed in the drawings, the pole tips **18** and **19** have frusto-conical shapes and are mirror images of each other. The inner surface of each pole tip **18** and **19** is circular and substantially equal to the di-



ameter of the sorter wheel **25**, or to the sum of the diameter of the sorter wheel **25** and twice the thickness of the endless conveyor belt **26**.

As best disclosed in FIG. **3**, the magnetic field lines **65** form an arcuate pattern between the adjacent upwardly diverging frusto-conical surfaces of the pole tips **18** and **19** and uniformly around the pulley **25**. Accordingly, there is the greatest concentration of magnetic field lines closest to the belt **26** engaging the rim of the pulley **25**. Proceeding radially outward from the sorter wheel **25**, the field lines **65** become less and less concentrated, that is, farther and farther apart, so that magnetic field gradients result which increase in value radially toward the wheel **25**. Thus, magnetic forces, illustrated by the force lines **66** in FIG. **3**, are produced normal to the field lines **65**, so that there is a strong magnetic force generally radially inward toward the wheel **25**. Because of the arcuate pattern of the field lines **65**, the lines of force toward the edges of the wheel **25** are directly laterally inward. The greater the magnitude of the field gradients, the greater strength of the magnetic forces.

If the diameter of the sorter wheel **25** is less than the diameter of the parallel inner faces of the pole tips **18** and **19**, no significant gradients exist between the parallel face surfaces of the pole tips **18** and **19** because the magnetic field is of nearly equal concentration and therefore there is almost no change in the magnetic field in this area. Accordingly, the greatest magnetic forces produced by the gradients between the converging surfaces of the pole tips **18** and **19** would be substantially above the belt **26**. Such an arrangement would constitute an inefficient utilization of the magnetic field gradients for the separation of the feebly magnetic particles **41**.

If the diameter of the wheel **25** were greater than the diameter of the inner pole faces, then the greatest value of the magnetic gradients and the resultant magnetic forces would be created somewhere in the body of the pulley or wheel **25** radially inward from the belt **26**, which would not only waste magnetic energy, but would create weaker magnetic forces than those in the pole and wheel arrangement of FIG. **3**, all the current and magnetic values otherwise being equal.

In the actual commercial operation of the sorter apparatus **10**, weakly magnetic particles **41** in the form of ferro-phosphorus particles have been separated from non-magnetic slag. In this commercial apparatus, a maximum magnetic field of 15 kilogauss was created producing field gradients of approximately 1 kilogauss per centimeter (2.54 kilogauss per inch). Feebly magnetic particles of ferro-phosphorous from small fines up to particles approximately 4 inch in diameter were readily separated. Moreover, it was immaterial whether the magnetic and non-magnetic particles were wet or dry. The width of the belt **26** in the commercial apparatus **10** is 3¾ inches and the linear velocity of the belt was approximately 3 to 5 feet per second. Under such conditions, separated products have been obtained as pure as **98–99%**.

More intense apparatus **10** may be used in which the magnet **14** develops fields as high as **30** kilogauss, gradients of 1–2 kilogauss per centimeter, and utilizing belt speeds of 8 feet per second.

With such a high intensity magnetic field and such strong magnetic field gradients, the speed of the belt may be greater than when it is moving through a much smaller magnetic field, with weaker field gradients, to increase the production of separating non-magnetic and magnetic materials. The location of the deflector plates **53** and **54** is adjusted according to the strength of the magnetic field across the sorter wheel **25** and also depending upon the linear speed of the belt **26.** The location of the deflector plate **54** also may depend upon the size of the non-magnetic particles **42,** as well as the speed of the belt **26.**

In the operation of the apparatus **10,** the mixture of magnetic particles **41** and non-magnetic particles **42** are fed from the hopper **39** down through the discharge chute **40** upon the forwardly moving conveyor belt **26.** As the particles approach the rotating sorter wheel **25** they come under the influence of the magnetic field, first passing through the weak field gradients and then gradually through the stronger field gradients, as that portion of the belt **26** supporting the particles engages the rapidly rotating sorter wheel **25.** As the belt **26** continues around the wheel **25,** the non-magnetic particles **42** are thrown off by centrifugal force in a parabolic trajectory and dropped by gravity, as illustrated in FIG. **1,** into the first discharge chute **55,** where the non-magnetic particles **42** are dropped to any convenient deposit station or receptacle, not shown.

On the other hand, the magnetic particles **41,** under the influence of the high intensity magnetic field **65,** are held upon the moving belt **26** with a circumferentially uniform magnetic attractive force, as the belt moves around the forward portion of, and toward the bottom of, the wheel **25.** Because of the circumferential uniformity of the field gradients, the magnetic field may remain stationary while the sorter wheel **25** and belt **26** rotate.

Because of the strong magnetic forces acting upon the feebly magnetic particles **41,** the wall **49** of the trough **48** becomes mandatory to prevent this portion of the belt **26** from sagging upward. After the belt **26** passes the front edge **50** of the top plate **49** and continues to move along the plate **49,** the magnetic particles **41** are gradually removed from the influence of the magnetic field until they reach a point where the force of gravity is greater than the magnetic attraction, and the particles **41** drop upon the deflector plate **53** and are carried by gravity to a second deposit station, such as a receptacle or another conveyor, not shown. The belt **26,** after discharging all of the particles, passes sequentially around the idler pulleys **44,** pulleys **45** and **46,** and around the tail pulley **28,** to receive another charge of particles **41** and **42** from the discharge chute **40.**

The magnetic fields and magnetic field gradients generated by the C-shaped magnet **14** are each approximately 10 times the fields and gradients employed in conventional magnetic pulleys. For the reasons previously discussed, the belt speed is also much faster than belt speeds for conventional magnetic pulley separaters.

The C-shaped magnetic flux piece **15** is made of solid iron and has a uniform width as illustrated in FIGS. **1** and **2,** to provide a continuous flux return path. The C-shaped magnetic flux return piece **15** also has an advantage over an entirely closed return flux piece, such as a hollow housing or drum configuration, since the entire bottom portion of the magnet **14** is open for discharge of the particles. The open bottom is also an advantage for maintenance of the head pulley **25** and the interior of the magnet **14.**

The particular channel-shaped trough **33** is designed to conform to the cross sectional shape of the particle feed path around the head pulley **25** and between the frusto-conical surfaces of the pole tips **18** and **19** and the coil shields **63,** revealed in FIG. **3.** Thus the trough and pole tips provide continuity of shape for feeding the particles from the trough **33** upon the sorter wheel **25.** The shape of the trough **33** is also designed to minimize clogging of the belt **26.** If the side walls of the trough **33** were vertical so that the trough had an exact U-shape, all the material deposited in the trough would bear down upon the belt **26.** However, the particular channel configuration, illustrated in FIG. **4,** of the trough **33** permits the belt **26** to directly support only a portion of the material deposited in the trough. The portions of material along the sides of the trough are supported by the declining walls **35,** which also assist in feeding particles from the sides of the trough **33** down upon the belt **26** as the belt **26** progresses through the trough **33.**

As illustrated in FIG. **3,** all of the magnetic force lines **66** tend to force the magnetic particles **41** toward the center of the belt **26,** thus tending to keep most of the magnetic particles away from the pole tips **18** and **19** for more efficient movement of the magnetic particles, and also to minimize wear of the magnetic particles against the pole tips **18** and **19.** Furthermore, the magnetic forcing of the particles to the center of the belt **26** also minimizes the chances of magnetic particles jamming between the belt **26** and the pole faces **18** and **19.** Sealed spacer elements, not shown, may be fitted between the pole tip faces and the pulley **25** to minimize particles falling into the air gap and jamming the head pulley **25.**

The angle which the frusto-conical surfaces of the pole tips **18** and **19** makes with the flat pole tip face, or the direction of particle feeding, is preferably 30°–60° for relatively large size magnetic particles **41,** as opposed to finely divided particles, such as powder or fines. The angle the frusto-conical pole tip surfaces disclosed in FIG. **3** is 45°. This angle is determined by the general size of the input particles, and particularly the size of the magnetic material **41.** For very small size magnetic particles **41,** such as fines, truncated pole tips are not needed. Cylindrical pole tips would suffice, provided the diameter of the opposed pole faces are substantially equal to the diameter of the sorter wheel **25.** Furthermore, the feed trough **33** might have a pure U-shaped channel cross section.

Since there are no particles traveling around the back side of the head pulley **25,** that is between the wall edges **37** and **50,** no magnetic field is needed in this area. Hence, the magnet cores **16** and **17** and the pole tips **18** and **19** do not have to be completely cylindrical, but may be segments of cylinders opposing each other only along the path of the particles **41** and **42** around the head pulley **25.**

What is claimed is:

**1.** A high intensity magnetic sorting apparatus for the separation of feebly magnetic materials from non-magnetic materials comprising:

a. a sorter wheel having a circumferential rim portion of uniform width,

b. a frame supporting said wheel for rotary movement about a horizontal axis and said rim portion for movement in an operative feed path for said magnetic materials,

c. drive means rotating said wheel,

d. an electromagnet stationarily mounted on said frame, and having pole tips spaced on opposite sides of said wheel,
e. said pole tips having inner faces spaced apart on opposite sides of said rim portion a distance slightly greater than the width of said rim portion,
f. each of said pole faces comprising at least a circular segment coaxial of said wheel, having a diameter substantially equal to the diameter of said wheel, and extending circumferentially parallel to, and at least the length of, said operative feed path,
g. said pole tips being shaped to create a magnetic field, when said electromagnet is energized, across said rim portion to produce magnetic field gradients increasing radially inward toward the exterior periphery of said rim portion, and to produce maximum field gradients immediately adjacent the exterior periphery of said rim portion,
h. endless belt means carried circumferentially around said sorter wheel coinciding with said operative feed path for feeding a mixture of feebly magnetic particles and non-magnetic particles in a path toward said wheel and substantially tangent to said rim portion, so that said particles are carried around said rim portion within said magnetic field and said feebly magnetic particles are magnetically attracted toward the exterior periphery of said rim portion by the magnetic force produced by said increasing gradients, so that said feebly magnetic particles move along said operative feed path around said wheel rim portion,
i. means for energizing said electromagnet,
j. means for receiving the non-magnetic material dropping by gravity from said rotary wheel, and
k. means for removing the feebly magnetic particles from said wheel at the end of said operative feed path comprising a portion of said belt means and a chute having a top wall projecting tangentially from the bottom portion of said wheel at the end of said operative feed path, said belt means being guided away from said wheel through said chute and beneath said top wall.

**2.** The invention according to claim **1** in which the pole tip surfaces are at least the segments of the frustum of a cone converging toward said inner pole faces.

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