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Smith et al.

[11] **3,901,795**

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[54] **METHOD AND APPARATUS FOR SEPARATING MAGNETIC AND NON-MAGNETIC SUBSTANCES**

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[51] **Int. Cl.**[2] **B03C 1/30**

[58] **Field of Search** ..... 209/39, 214, 216, 218, 209/223 A, 223 R, 232

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Attorney, Agent, or Firm—Diller, Brown, Ramik & Wight

[57] **ABSTRACT**

This disclosure relates to novel apparatus for and methods of separating magnetic and non-magnetic materials by conveying the same on a first of two spaced conveyors toward a magnetic separator which draws the magnetic material and deposits the same upon the second conveyor whereas the non-magnetic material drops by gravity in the gap between the conveyors. Any minor amounts of the non-magnetic material deposited upon the second conveyor are removed by a blast of air which directs the latter material toward and into the gap as well as impinges the same upon the periphery of a rotating roller from which such minor amounts of non-magnetic material are deposited into the gap between the conveyors.

32 Claims, 6 Drawing Figures

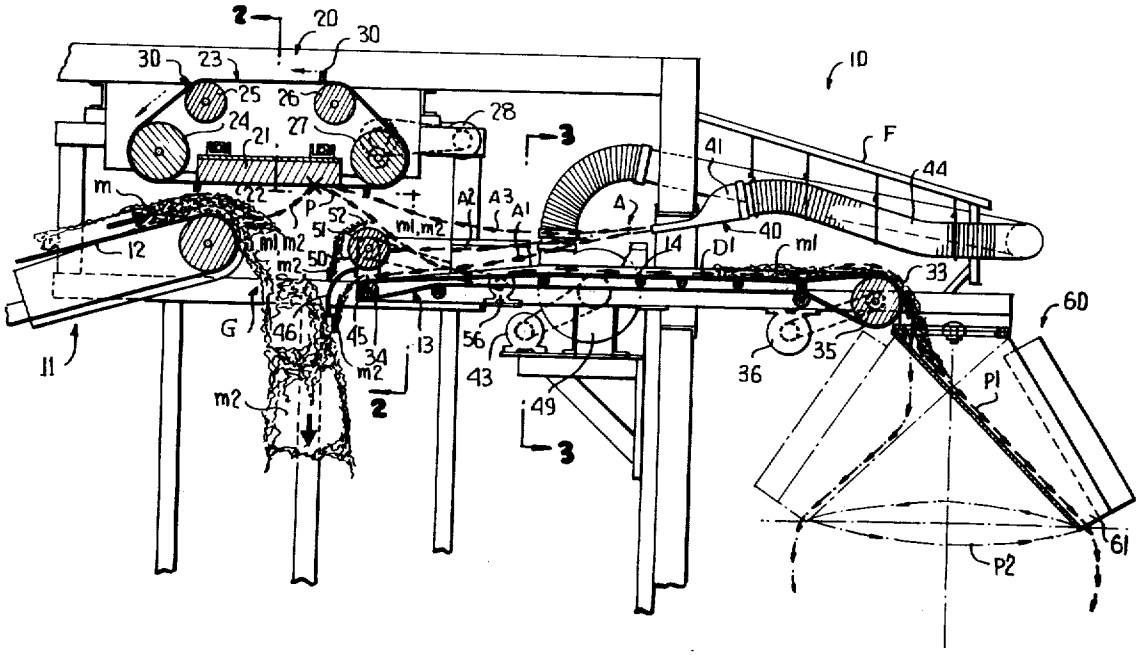


FIG.1

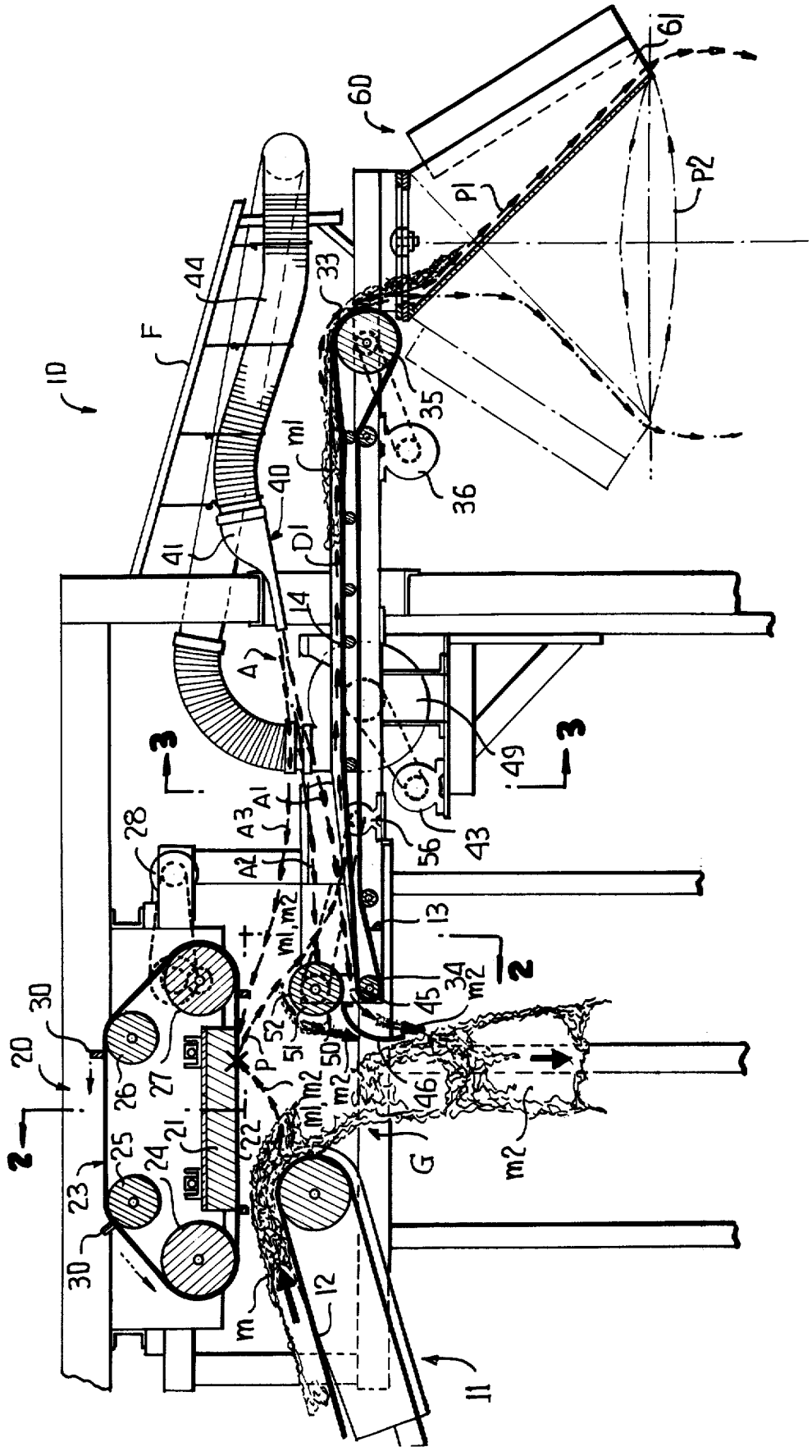

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51
52
56
60
61
F
G
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P1
P2
m
m1
m2
A1
A2
A3
A4
D1
2
3

FIG.3

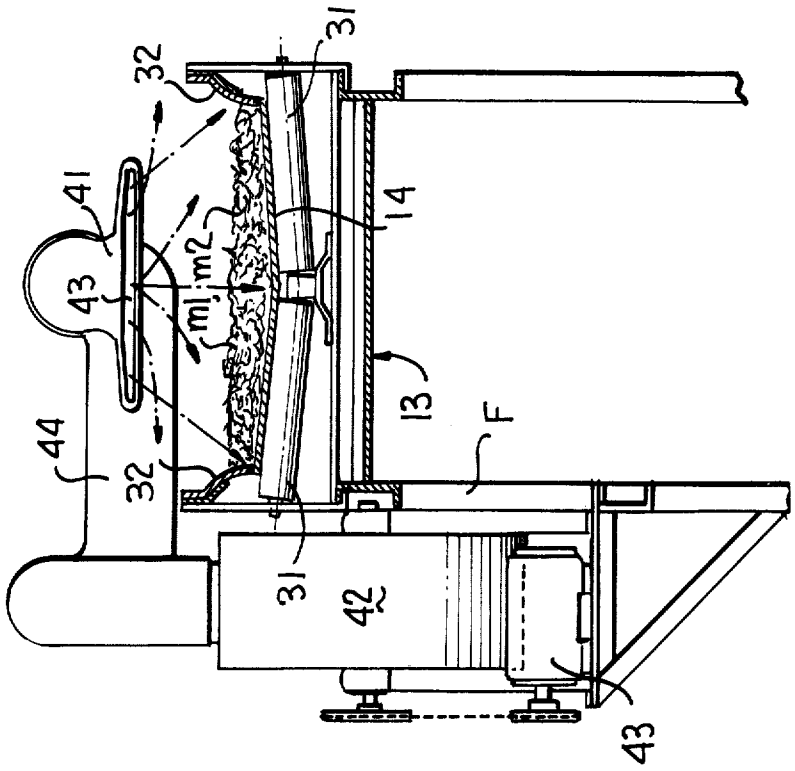
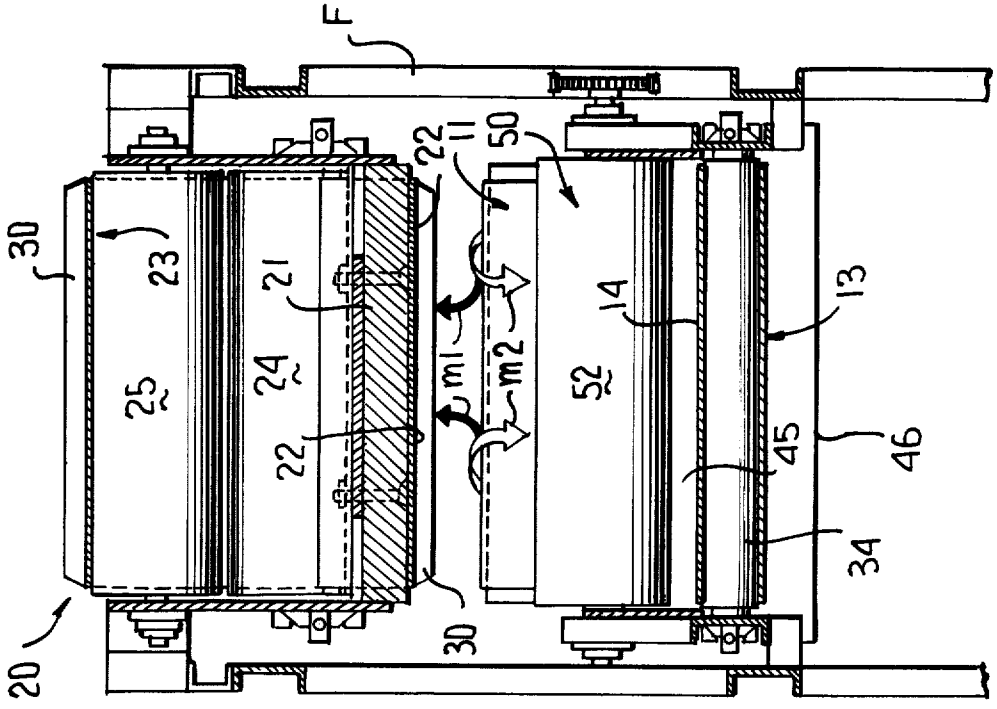

31
32
41
14
43
m2
m1
13
F
44
32
31
42
43

FIG.2


F
22
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23
21
14
13
25
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m1
m2
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22
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46
34
30
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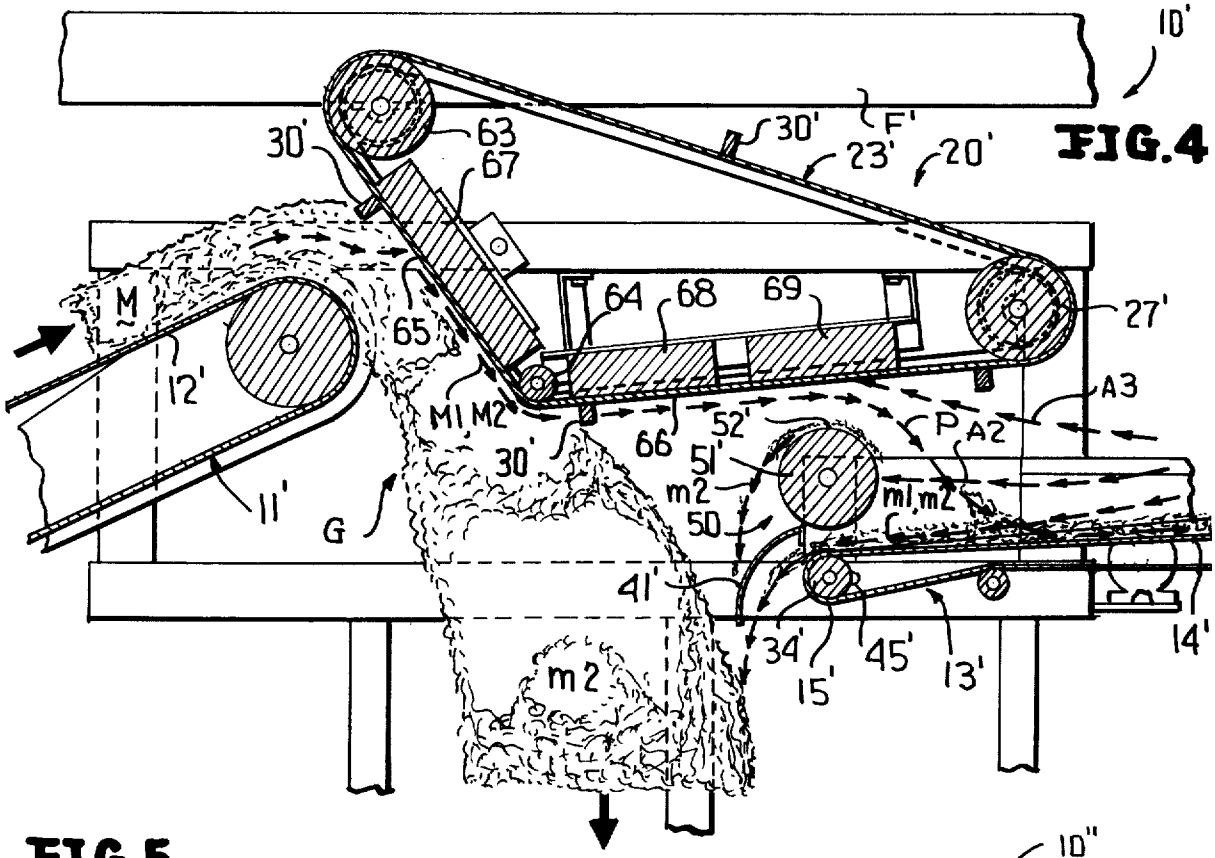
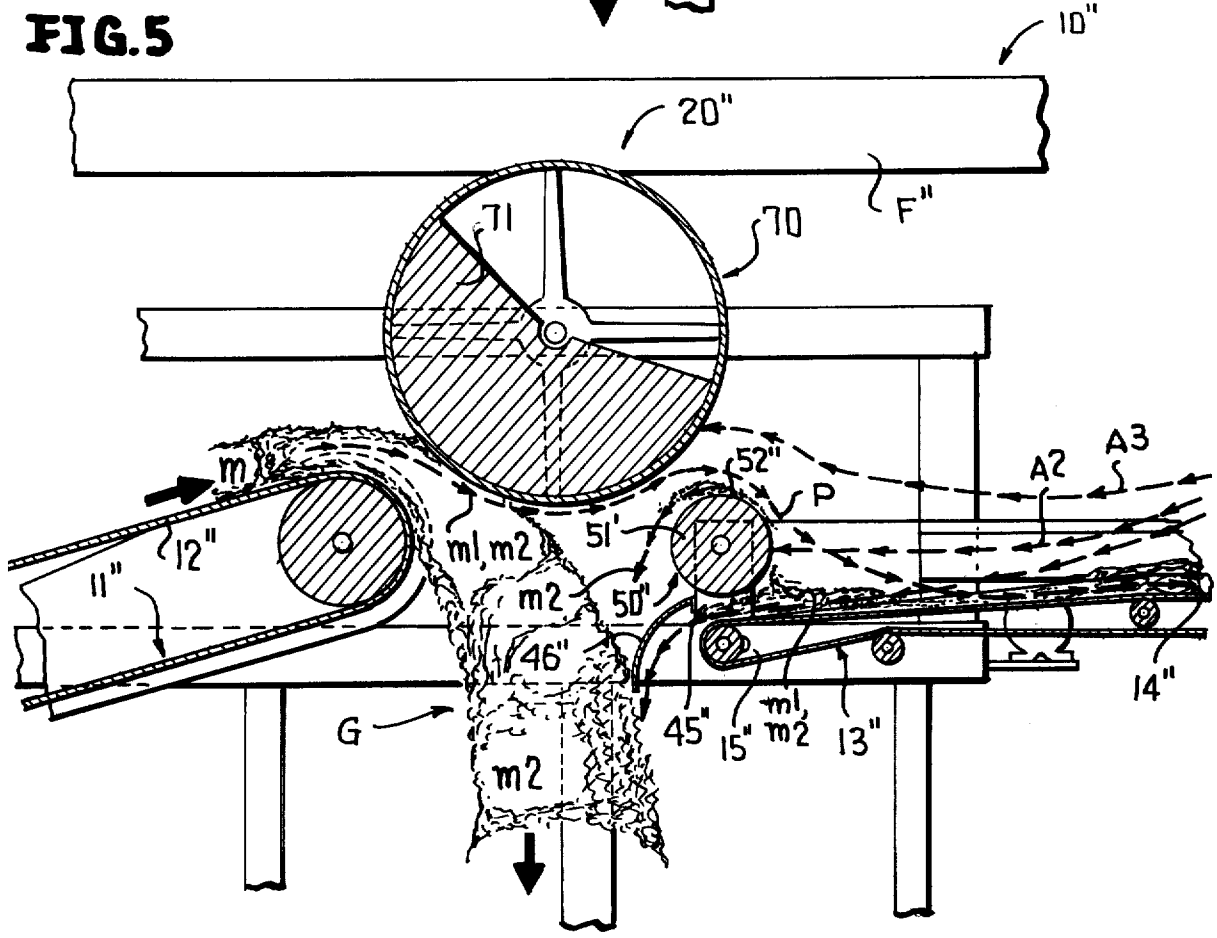

10'
30'
63
67
30'
F'
23'
20'
M
65
64
68
69
27'
12'
M1 M2
66
52'
A3
P
A2
30'
51'
m2
m1,m2
11'
G
50
41'
34'
45'
13'
14'
15'
m2

FIG.4

FIG.5


10"
20"
F"
71
70
m
52"
A2
A3
P
12"
51'
m1,m2
11"
m2
50"
46"
14"
G
45"
15"
m1,
m2
13"
m2

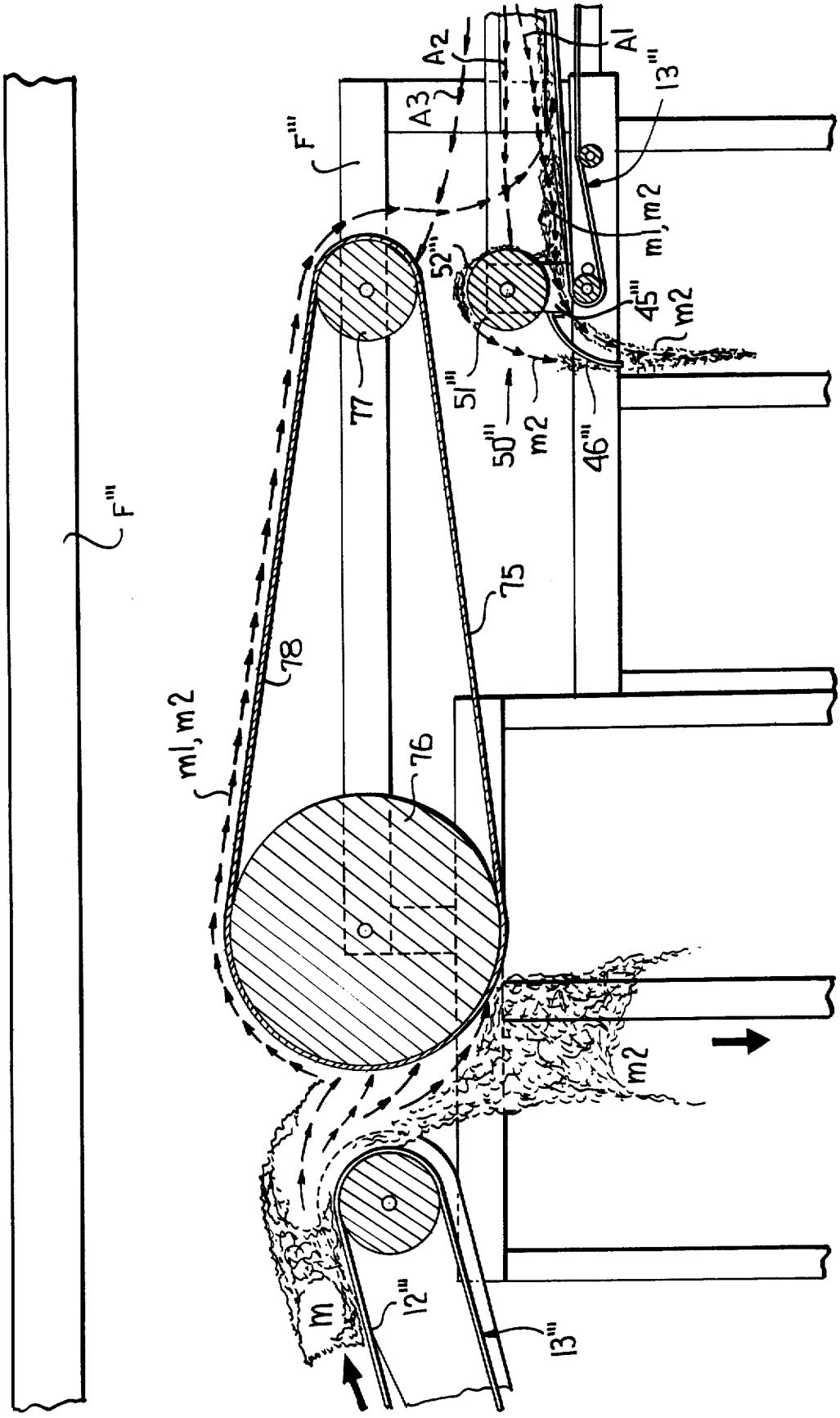


FIG.6

METHOD AND APPARATUS FOR SEPARATING MAGNETIC AND NON-MAGNETIC SUBSTANCES

The present invention is directed primarily to the field of solid waste disposal in which there is a growing trend toward the use of refuse shredding, pulverizing or other forms of presizing or prereducing equipment to condition the waste prior to further processing or complete disposal. The objectives of refuse presizing as related to solid waste management are multi-faceted and may include preparing the waste material as suitable feed for use as supplementary fuel, particularly in coal-fired boilers; minimizing health and esthetic problems often associated with municipal refuse handling such as blowing paper, odor, fly and rodent propagation, etc.; improving refuse placement and compactability in sanitary land fills; reducing the need for costly daily cover in such land fills; preparing the material as suitable feed for refuse disposal by pyrolysis; fuel bed or vortex incineration; and preparing the material for physical and chemical segregation into useful byproducts, such as chemical fiber.

This basic change in municipal solid waste handling practice is occurring as a result of the concentrated national effort (beginning in **1965**) to improve solid waste management in the United States, reduce environmental problems associated with current operations, and conserve national resources through reclamation and use of waste materials where economically feasible.

Refuse shredding or presizing is a basic step for improving the material handling characteristics of municipal refuse and other solid waste. Shredding converts a difficult and objectionable heterogeneous material into something approaching a semi-fluid of even and small size distribution which is readily transportable and easily handled by automatic machines; smaller material is more readily rendered homogeneous and the material is highly desirable from the standpoint of waste material reclamation and reuse.

In keeping with the foregoing, a primary object of this invention is to provide novel apparatus for and methods of rendering heterogeneous materials homogeneous following a presizing operation, and particularly doing so by separating ferromagnetic or magnetic materials from non-magnetic material.

In keeping with a further object of this invention, the novel apparatus for achieving magnetic-nonmagnetic separation includes first and second in-line but spaced conveyors, the first of which has a flight carrying presized refuse containing magnetic and non-magnetic components, means are provided for removing the magnetic material and delivering tne same to the second conveyor along with minor amounts of the non-magnetic material, and second means for removing the minor amounts from the second conveyor, the second removing means being a source of moving air directed above and along the second conveyor in a direction toward the first conveyor whereby the minor amounts of non-magnetic material are blown off the entrance end of the second conveyor.

A further object of this invention is to provide novel apparatus of the type heretofore described wherein the second removing means further includes a rotating roll adjacent the entrance end portion of the second conveyor having a surface against which will impinge the blown material, and the roll is appropriately rotated to deliver the thus impinged material into the gap between the conveyors.

Still another object of this invention is to provide novel apparatus of the type immediately heretofore set forth wherein the roll is spaced above the second conveyor and portions of the blown material pass through the gap or throat between the entrance end of the second conveyor and the roll into the gap.

Though the primary objects of this invention are concerned with the separation of magnetic and non-magnetic material, a further object is that of providing novel apparatus for and a method of separating heavy and light materials irrespective of their magnetic and-/or non-magnetic characteristics by providing a conveyor having entrance and exit end portions, the conveyor having a flight movable in a first direction from the entrance end portion to the exit end portion, means for depositing heavy and light material upon the flight at the entrance end portion whereby the same will move toward the exit end portion, means for removing the light material from the flight, the removing means including means for directing air above and along the flight in a second direction opposite the first direction whereby the light material will be blown toward the entrance end portion, the removing means further including means at the entrance end portion against which will impinge a portion of the blown light material, and means for moving the last-mentioned means in the second direction whereby the impinged and blown light material will be moved in the second direction and thus separated from the heavy material moved in the first direction by the flight.

Another more specific object of this invention is to provide novel apparatus for and a method of separating light and heavy material in the manner immediately set forth heretofore wherein the last-mentioned means is a rotating roll having surface means possessing an affinity for holding thereupon the blown light material.

In keeping with another object of this invention there is provided a novel method of separating relatively heavy and light materials by depositing the same upon a surface moving in a first direction between first and second positions, directing air above and along the material opposite the first direction whereby the light material will be blown in a second direction, collecting the light material thus blown, and thereafter further conveying the collected light material in the second direction by at least partial rotary motion.

With the above and other objects in view that will hereinafter appear, the nature of the invention will be more clearly understood by reference to the following detailed description, the appended claimed subject matter, and the several views illustrated in the accompanying drawing.

IN THE DRAWINGS

FIG. **1** is a side elevational view illustrating a novel apparatus constructed in accordance with this invention for separating materials, and illustrates first and second conveyors having a gap therebetween spanned by a magnetic separator, means for directing air toward an entrance end portion of the second conveyor, and a rotating roll adjacent the entrance end portion.

FIG. **2** is an enlarged sectional view taken generally along the line **2—2** of FIG. **1**, and illustrates by the headed arrows the manner in which magnetic and non-magnetic materials are separated, as viewed in the upstream direction of material movement.

FIG. 3 is an enlarged sectional view taken generally along line 3—3 of FIG. 1, and illustrates details of the nozzle, a blower, and side skirts of the second conveyor.

FIG. 4 is a fragmentary sectional view of another apparatus, and illustrates details of the magnetic separator.

FIG. 5 is a fragmentary sectional view similar to FIG. 4, and again illustrates details of another magnetic separator.

FIG. 6 is a fragmentary sectional view similar to FIGS. 4 and 5, and again illustrates details of another magnetic separator.

Referring first to FIG. 1 of the drawings, an apparatus 10 for separating magnetically attractive (ferromagnetic) material from magnetically non-attractive (nonmagnetic) materials includes first means 11 for conveying the materials along a first path from left-to-right. The heterogeneous or admixed magnetic and nonmagnetic material is generally designated by the reference numeral M. Prior to being deposited upon an upper flight 12 of the conveyor 11 the material M is preferably shredded, presized or otherwise reduced into a relatively small size such as to approach a semi-fluid or light-weight condition which may be readily handled, transported and, of course, processed by the apparatus 10.

Second conveyor means, generally designated by the reference numeral 13 is provided contiguous and inline to the conveyor 11. The second conveyor 13 likewise includes an upper flight 14 which moves material M1 from left-to-right. The material M1 is substantially composed of magnetic material although minor amounts of nonmagnetic material may be initially admixed therewith adjacent an entrance end portion 15 of the conveyor 13. For the most part the nonmagnetic material M2 drops by gravity through a gap G between the conveyors 11, 13 while the magnetic material M1 and the minor amount of the nonmagnetic material M2 is conveyed across the gap G by magnetic separating means 20.

The magnetic separating means 20 includes a permanent or electromagnet 21 suitably supported within the framework F of the apparatus 10, in the manner clearly apparent from FIG. 2. A lower surface (FIG. 2) of the magnet 21 lies in a generally horizontal plane and a lower flight 22 of a conveyor 23 moves thereacross from left-to-right, as viewed in FIG. 1. The conveyor belt 23 is entrained about a plurality of suitably conventionally journalled pulleys 24 through 27, the latter of which is driven counter-clockwise, as viewed in FIG. 1, by gearing from an electric motor 28. Preferably, though not necessarily, the conveyor 23 includes a plurality of cleats or pushers 30 which assure that the magnetic material M1 and the minor amount of nonmagnetic material M2 attracted to the flight 22 will be moved thereby and subsequently deposited upon the entrance end portion 15 of the conveyor 13. As an alternate construction the conveyor belt 23 may simply be a pair of spaced chains spanned by the pushers 30 whereupon the magnetic material M1 attracted from the material M will impinge against the lower surface of the magnet 21 and will be pushed therefrom by the pushers 30, along with any minor amounts of the material M2, and thus will likewise be deposited upon the end portion 15 of the second conveyor 13.

The second conveyor 13 is generally of a trough-like configuration (FIG. 3) and the upper flight 14 is supported in the configuration best illustrated in FIG. 3 by a plurality of support rollers 31 suitably journaled for rotation in the machine frame F. A pair of skirts 32 constructed of flexible material are likewise conventionally secured to the frame F and with the upper flight 14 define a generally U-shaped configuration defining a trough T in which the material M1 is conveyed from the entrance end portion 15 to an exit end portion 33 of the conveyor 13. The conveyor 13 is entrained about a conventionally journaled pulley 34 and another pulley 35 (FIG. 1), the latter of which is rotated in a clockwise direction by an electric motor 34 and an appropriate conventional pulley and drive belt arrangement.

Means generally designated by the reference numerals 40 and 50 are provided for removing the minor amount of magnetic material M2 from the material M1, M2 on the flight 14 of the conveyor 13 as the latter moves from left-to-right or in a direction D1 of FIG. 1. The means 40 includes a nozzle 41 having a generally rectangular orifice 42 (FIG. 3) which is positioned above the upper flight 14 of the conveyor 13 and the material M1, M2 thereupon. A conventional fan (not shown) of a blower 49 is rotated or driven from an electric motor 43 through suitable conventional pulleys and a drive belt (unnumbered) with the air being conducted to the nozzle 41 by an appropriate flexible conduit 44 suspendingly supported from the frame F in a conventional manner. Preferably the nozzle 41 may be adjustably supported from the frame F to increase or decrease the height thereof, as well as the angulation relative to the horizontal, to achieve a desired flow path of the air as it is emitted from the orifice 43, it being noted that the reference character A indicates generally the flow path of the air when the nozzle 41 is in the position shown in FIG. 1. It is also to be noted that the skirts 32, 32 in addition to precluding the materials M1, M2 from falling off the sides of the upper flight 14 of the conveyor 13 also serve as a guide for the air path A and confines the same generally between the skirts 32, 32. The purpose of the blast of air A is to blow the minor amounts of the material M2 from the materials M1 and M2 deposited at the entrance end portion 15 into the gap G thereby commingling with the materials M2 dropped directly from the conveyor 11 into the gap whereupon only the magnetic material M1 departs the end portion 33 of the conveyor 13. Essentially, the material M is shredded municipal refuse which may, for example, include pieces of iron, ferromagnetic alloys, nickel, cloth, paper, string, etc. Though the magnetic separator 20 will remove substantially all magnetic material M1 from the material M there is a tendency for cloth, paper, string, or other pieces of non-magnetic material to cling to the separated material and thus be deposited upon the end portion 15 of the conveyor 13. However, due to the air blast A minor amounts of the material M2 will be blown into the gap G in one of two ways or impinged against a surface 51 of the removing means 50. The air path or air stream A may be viewed as being composed of a plurality of different streams which for purposes of description have been broken down into simply three streams A1, A2, and A3.

The stream A1 indicates that portion of the over-all air stream A lying closest to the material upon the upper flight 14 and that which tends to move along

toward and through a throat or opening **45** between the end portion **15** of the conveyor **13** and the roll **51**. Thus any of the lighter material M2 contacted by the stream of air A1 will follow this same path and will be directed into the gap G preferably though not necessarily with the assistance of a baffle **46** spanning the width of the conveyor.

The stream of air A3 indicates that portion of the over-all air stream A which tends to be deflected upwardly by the material upon the upper run **14**, the roll **51** itself, and the particular position of the nozzle **41** relative to the horizontal. The stream A3 therefore will blow material M2 into the gap G during such time as it is being carried along with the material M1 from a point X along a path P until it passes the periphery of the roll **51**. Thus while travelling along the path P between the time the materials M1, M2 leave the flight **22** of the conveyor **23** and the time the material M1, M2 reaches the conveyor **13** a portion of the latter will be blown by the air stream A3 into the gap G.

The air stream A2 designates a midportion of the main stream A which will blow the material M2 against a periphery or surface **52** of the roll **50** and cause the same to impinge thereagainst. The roll **51** is rotated counter-clockwise as viewed in FIG. **1** by an electric motor and a suitable pulley and drive belt arrangement. Thus cloth, string, and other non-metallic or nonmagnetic material impinged against the surface **52** will rotate therewith counter-clockwise and upon approaching the gap G the same will drop therefrom by gravity or may be wiped therefrom by the upper portion (unnumbered) of the baffle **46** which can be positioned in close intimate relationship to the surface **52**. Preferably the surface **52** may be cloth or the roll **51** may be simply a bristle brush thus having a great affinity for such loose material to adhere thereto.

Since the metallic material M1 leaving the end portion **33** of the conveyor **13** has a high angle of repose and, therefore, does not spread easily a discharge chute **60** is mounted for rotation in a conventional manner adjacent the end portion **33** of the conveyor **13**. The chute **60** is of a generally U-shaped configuration in cross section gradually decreasing in size toward a discharge end **61** thereof. Thus as material follows the path P1 upon the rotation of the chute **60** in a conventional manner a Path P2 of a generally circular shape is circumscribed thus more evenly distributing the magnetic material M1 in a storage area, bin, trailer or the like. Thus the apparatus **10** separates the heterogeneous mass of refuse M into homogeneous magnetic material M1 and homogeneous nonmagnetic material M2.

Referring to FIG. **4** of the drawings, a portion of a machine **10'** is illustrated which is substantially similar to the machine **10** and those elements identical thereto bear like reference characters although primed. The machine **10'** differs from the machine **10** in the particular configuration of the conveyor belt **23'** of the separator **20'**. Instead of being entrained about pulleys which impart a generally polygonal configuration to the conveyor belt, as illustrated in cross section in FIG. **1**, the conveyor belt **23'** is entrained about the pulley **27'** which is the drive pulley and two idle pulleys **63, 64** positioned to impart generally a triangular configuration to the conveyor belt **23'**, as viewed in cross section. Thus the material M is first attracted to the surface of the conveyor belt **23'** at a flight **65** which moves downwardly and away from the conveyor **11'**, rounds the roller **64** and thereafter continues along a generally horizontal flight **66** for subsequent deposit upon the conveyor **13'**. In addition, attached to the frame F' are a plurality of permanent magnets **67, 68** and **69** having alternate poles adjacent each other. This configuration of the conveyor **23'** and particularly the angulation between the flights **65, 66** results in the efficient separation of the materials M1, M2 and a lesser carry-over of the minor amounts of the materials M2 upon the conveyor **13'**.

Referring to FIG. **5** of the drawings the apparatus **10''** likewise is similar to the apparatuses **10** and **10'** and thus like elements have been similarly identified except for the double priming thereof. In this embodiment the magnetic separator **20''** is a drum **70** appropriately mounted for rotation in the frame F'' and driven by conventional means (not shown) for rotation in a counter-clockwise direction as viewed in FIG. **5**. A permanent magnet core **71** is conventionally supported in stationary or fixed relationship to the frame F'' with the drum **70** simply rotating thereabout. Thus, the material M1 is attracted to the rotating drum **70** and is conveyed along a generally arcuate path prior to being moved out of the influence of the magnet **71** and deposited upon the conveyor **13''**.

Referring to FIG. **6** of the drawings, another machine **10'''** is once again identical to the machines **10, 10'** and **10''** except for details of the magnetic separator **20'''** and thus like elements have been triple primed. In keeping with the construction of the separator **20'''** a belt **75** thereof is entrained about a pair of pulleys **76, 77** journalled appropriately in the frame F''' with the latter pulley **77** being rotated clockwise through a suitable drive mechanism (not shown). Thus the pulley **76** is likewise rotated in the same clockwise direction. The pulley **76** is further constructed as a permanent magnet or may constitute a permanent magnet secured internally of a conventional pulley. Thus in either event the magnetic core or magnetic pulley **76** is rotated clockwise and thus material M1 and minor amounts of the material M2 attracted thereto is carried clockwise by the conveyor **75** over an upper flight **78** prior to discharge upon the conveyor **13'''**.

While preferred forms and arrangements of parts have been shown in illustrating the invention, it is to be clearly understood that various changes in details and arrangement of parts may be made without departing from the spirit and scope of this disclosure.

We claim:

1. Apparatus for separating magnetically attractive and magnetically nonattractive materials comprising first means for conveying said materials along a first path, second means excluding magnetic means contiguous said first conveying means for conveying said materials along a second predetermined path generally inline with said first path, said first and second conveying means move said materials along said respective first and second paths in the generally same direction, magnetic means between said first and second conveying means for removing said magnetically attractive material along with minor amounts of said magnetically nonattractive material from said first conveying means and depositing the same upon said second conveying means, and second means for removing said minor amounts from said second conveying means.

2. The apparatus as defined in claim 1 wherein said first and second conveying means are in spaced relationship to each other defining therebetween a gap into which is deposited said magnetically nonattractive material except for said minor amounts.

3. The apparatus as defined in claim 2 wherein said second removing means includes a source of moving air directed against said minor amounts of magnetically nonattractive material and toward said gap whereby the last-mentioned material is blown from said second conveying means into said gap.

4. The apparatus as defined in claim 2 wherein said first removing means includes third means for conveying said magnetically attractive material and said minor amounts of magnetically nonattractive material from said first conveying means across said gap to said second conveying means.

5. The apparatus as defined in claim 4 wherein said second conveying means has entrance and exit end portions, said removed magnetically attractive material and minor amounts of magnetically nonattractive material is deposited at said entrance end portion and thus is conveyed toward said exit end portion, and said second removing means includes means at said entrance end portion for directing a portion of said minor amounts of magnetically nonattractive material toward said first conveying means and into said gap.

6. The apparatus as defined in claim 5 including conveying means in said gap for receiving thereupon said magnetically nonattractive material and conveying the same therefrom.

7. The apparatus as defined in claim 5 wherein said directing means is a source of moving air directed against said minor amounts of magnetically nonattractive material.

8. The apparatus as defined in claim 5 wherein said directing means is a conveyor moving toward said first conveying means.

9. The apparatus as defined in claim 5 wherein said directing means is defined by a source of moving air directed against said minor amounts of magnetically nonattractive material and a conveyor moving toward said first conveying means.

10. The apparatus as defined in claim 9 wherein said last-mentioned conveyor includes surface means having an affinity for holding thereupon said magnetically nonattractive material.

11. The apparatus as defined in claim 1 wherein said second removing means includes a source of moving air directed against said minor amounts of magnetically nonattractive material whereby the latter is blown from said second conveying means.

12. The apparatus as defined in claim 1 wherein said first removing means includes third means for conveying said magnetically attractive material and said minor amounts of magnetically nonattractive material from said first conveying means to said second conveying means.

13. The apparatus as defined in claim 1 wherein said first removing means includes means for magnetically attracting said magnetically attractive material.

14. The apparatus as defined in claim 13 wherein said attracting means is a magnet and said first removing means further includes third means partially entraining said magnet for conveying said magnetically attractive material and said minor amounts of magnetically nonattractive material from said first conveying means to said second conveying means.

15. The apparatus as defined in claim 1 wherein said second conveying means has entrance and exit end portions, said removed magnetically attractive material and minor amounts of magnetically nonattractive material is deposited at said entrance end portion and thus is conveyed toward said exit end portion, and said second removing means includes means at said entrance end portion for directing a portion of said minor amounts of magnetically nonattractive material toward said first conveying means.

16. The apparatus as defined in claim 15 wherein said directing means is a source of moving air directed against said minor amounts of magnetically nonattractive material.

17. The apparatus as defined in claim 15 wherein said directing means is a conveyor moving toward said first conveying means.

18. The apparatus as defined in claim 15 wherein said directing means is defined by a source of moving air directed against said minor amounts of magnetically nonattractive material and a conveyor moving toward said first conveying means.

19. The apparatus as defined in claim 1 wherein said second conveying means has entrance and exit end portions, said removed magnetically attractive material and minor amounts of magnetically nonattractive material is deposited at said entrance end portion and thus is conveyed toward said exit end portion, said second removing means includes means at said entrance end portion for directing a portion of said minor amounts of magnetically nonattractive material toward said first conveying means, and said second removing means further includes a source of moving air directed against said minor amounts of magnetically nonattractive material whereby a portion thereof is blown from said second conveying means.

20. The apparatus as defined in claim 1 wherein said second conveying means has entrance and exit end portions, said removed magnetically attractive material and minor amounts of magnetically nonattractive material is deposited at said entrance end portion and thus is conveyed toward said exit end portion, said second removing means includes means at said entrance end portion for directing a portion of said minor amounts of magnetically nonattractive material toward said first conveying means, and said second removing means further includes a source of moving air directed against said minor amounts of magnetically nonattractive material and toward said entrnace end portion directing means whereby a portion thereof is blown from said second conveying means upon said entrance end portion directing means and directed by the latter from said second conveying means.

21. The apparatus as defined in claim 1 wherein said second conveying means has entrance and exit end portions, said removed magnetically attractive material and minor amounts of magnetically nonattractive material is deposited at said entrance end portion and thus is conveyed toward said exit end portion, said second removing means includes means at said entrance end portion for directing a portion of said minor amounts of magnetically nonattractive material toward said first conveying means, and said second removing means further includes a source of moving air directed against said minor amounts of magnetically nonattractive ma-

terial and toward said entrance end portion directing means whereby a portion thereof is blown from said second conveying means upon said entrance end portion directing means and directed by the latter from said second conveying means and said entrance end portion directing means is spaced above said entrance end portion whereby a portion of said minor amounts of magnetically nonattractive material is blown under said entrance end portion directing means and from said second conveying means.

22. The apparatus as defined in claim **21** wherein said directing means is a conveyor moving toward said first conveying means.

23. The apparatus as defined in claim **21** wherein said directing means is a conveyor moving toward said first conveying means, and said conveyor includes surface means having an affinity for holding thereupon said minor amounts of magnetically nonattractive material.

24. The apparatus as defined in claim **1** wherein said second conveying means has entrance and exit end portions, said removed magnetically attractive material and minor amounts of magnetically nonattractive material is deposited at said entrance end portion and thus is conveyed toward said exit end portion, and said second removing means includes means at said entrance end portion for directing a portion of said minor amounts of magnetically nonattractive material toward said first conveying means and said directing means includes surface means having an affinity for holding thereupon said last-mentioned portion of material.

25. The apparatus as defined in claim **1** wherein said second means includes surface means having an affinity for holding thereupon said minor amounts of nonattractable material, and means for rotating said surface means opposite to the direction of travel of said first conveying means.

26. The apparatus as defined in claim **1** wherein said magnetic means is an electromagnetic.

27. The apparatus as defined in claim **1** wherein said magnetic means is a roll permanent magnetic.

28. The apparatus as defined in claim **1** wherein said magnetic means is a flat permanent magnetic.

29. The apparatus as defined in claim **1** wherein said magnetic means is an electromagnetic and a roll permanent magnetic.

30. The apparatus as defined in claim **1** wherein said magnetic means is a roll permanent magnetic and a flat permanent magnetic.

31. The apparatus as defined in claim **30** wherein said magnetic means further includes an electromagnetic.

32. A method of separating relatively heavy and light material comprising the steps of performing a magnetic separation on the heavy and light material, depositing the magnetically separated heavy and light material upon a surface at a first position, moving the deposited material toward a second position in a first direction, directing air above and along the material in a second direction opposite the first direction whereby the light material will be blown in the second direction, collecting the light material thus blown, and thereafter further conveying the collected light material in the second direction.

* * * * *