

**Oct. 31, 1961**

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**3,006,472**

## MAGNETIC SEPARATOR AND METHOD OF SEPARATING MATERIALS

Filed Nov. 12. 1957

2 Sheets-Sheet 1

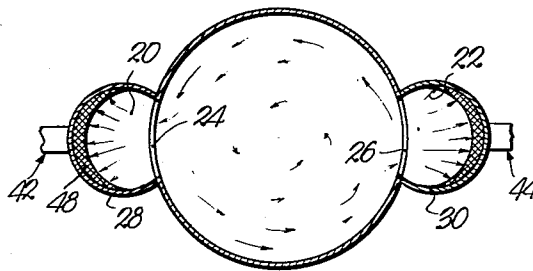
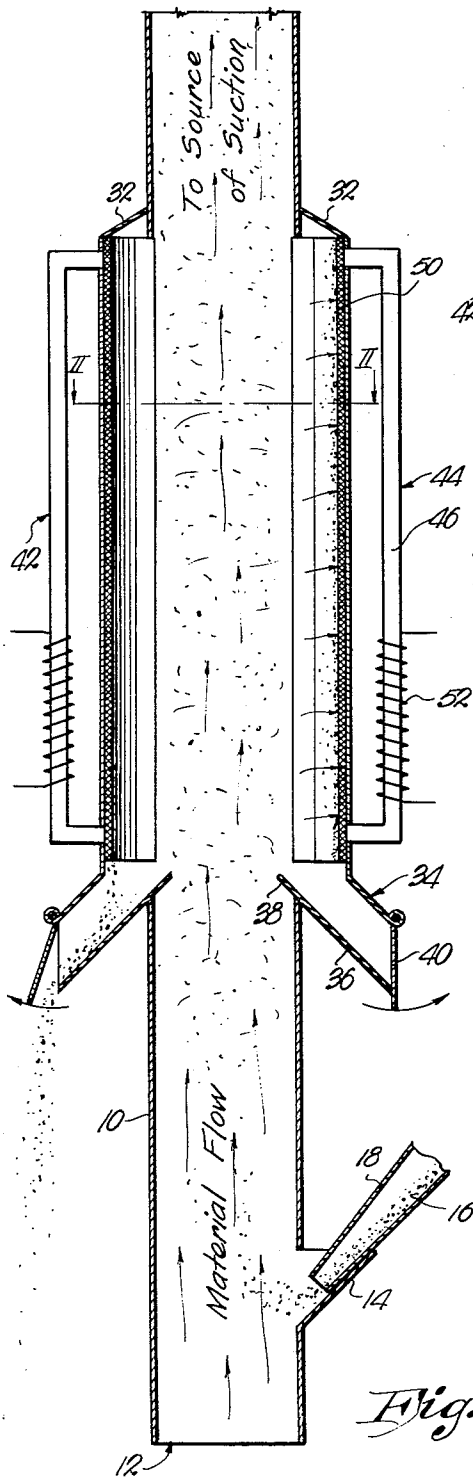


*Fig. 2.*

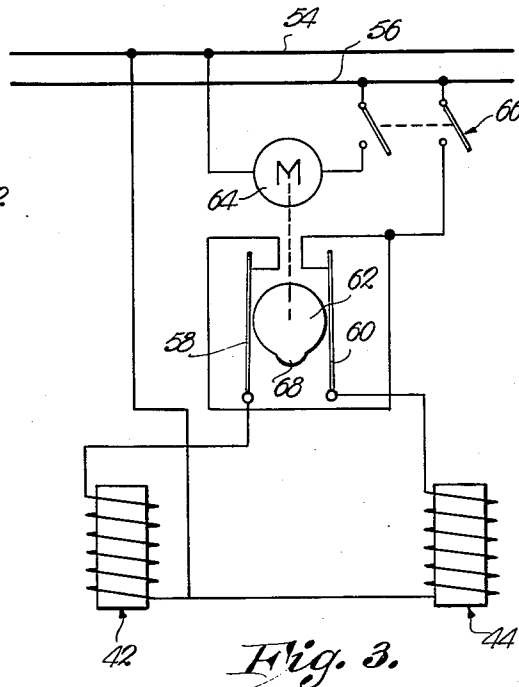


*Fig. 3.*

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2 Sheets-Sheet 2

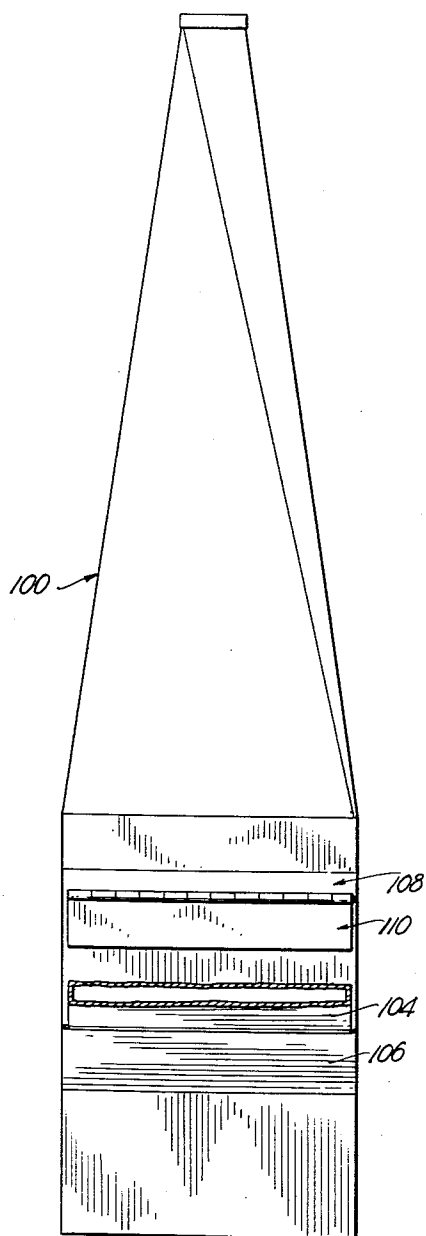


Fig. 4.

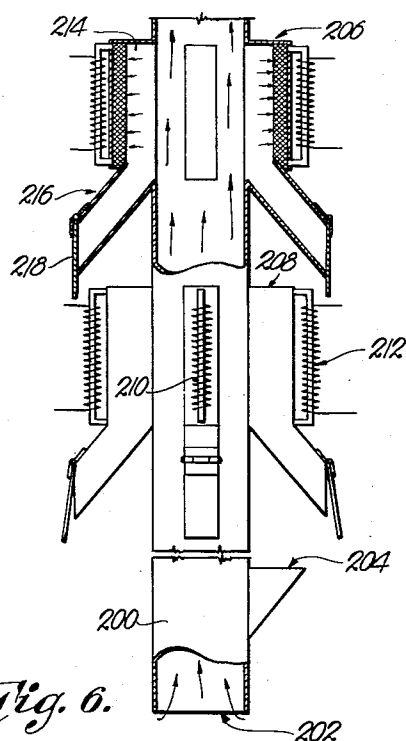


Fig. 6.

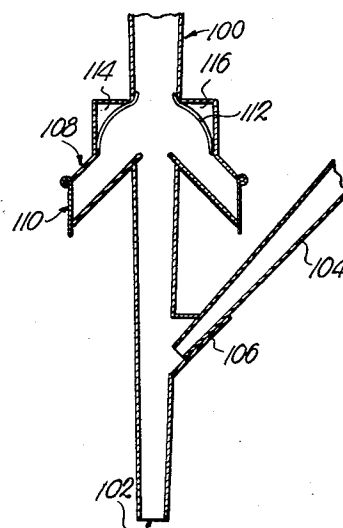
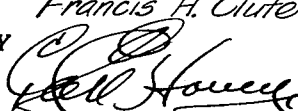


Fig. 5.

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## MAGNETIC SEPARATOR AND METHOD OF SEPARATING MATERIALS

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Filed Nov. 12, 1957, Ser. No. 695,744

7 Claims. (Cl. 209—214)

This invention relates to the field of magnetic segregation, and has for its principal object the presentation of an improved system differing essentially from those heretofore known by virtue of the fact that it contemplates the automatic separation of substances from materials, the collection of the removed substances, and the ultimate direction of the collected substances to a point of use or packaging, all automatically and for the most part, without operator attention.

It is realized of course, that the field of magnetic segregation, especially in the preparation of ore, is, in its broad sense, highly developed. In the processes heretofore known by me, the more valuable minerals are separated from the waste material and from each other by the use of magnets and in the usual type of segregator, it becomes an easy matter to separate the non-magnetic from the magnetic, and the weakly magnetic from the strongly magnetic by weakening or strengthening the magnetic field.

While such broad principles are employed in part in the apparatus forming the subject matter of the instant invention and in carrying out the novel method herein-after described, no satisfactory means has heretofore been developed for conveying the materials through the magnetic fields, nor has any suitable means been suggested for quickly and easily directing the separated substances to points of use or packaging. In conventional ore separators, a belt conveyor is employed to carry the ores below a magnet and the latter in turn raises the magnetic ore to another belt at right angles to the first.

It has been found that when apparatus of the aforementioned nature is employed in the art of magnetic segregation, such belts, revolving wheels or other contrivances, fail to effect proper separation because of inherent defects including not only the adverse results emanating from the existence of static electricity, but tendency of the materials to channel and, therefore, not be adequately and fully attracted toward the source of magnetic energy as is desired.

Accordingly, while magnetic separators have obviously been widely used in separating iron from matters, such as iron filings from those of brass; scraps of nails or wire from wheat, etc.; and iron particles from ore in powder, there has, to my knowledge, never heretofore been developed a satisfactory apparatus or method capable of segregating substances other than the metallics which are clearly capable of being attracted by a magnetic body.

The instant invention finds its basis in the early comprehensive classification of all substances into magnetics and diamagnetics, coupled with the growth of scientific investigations since that time and the present state of knowledge regarding magnetism. Therefore, the term "magnetic substances" as herein used is intended to include any and all substances susceptible to the action of a magnetic body, e.g. one having the ability to exert a force on such substances.

In this connection, it has long since been recognized that nearly all materials have an inherent ionization and that all substances may be divided into two general classes, namely, conductors and non-conductors. Furthermore, while electromagnets such as those employed in the instant invention and hereinafter more fully de-

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scribed, are widely used where it is desired to cause a temporary force action, it will become apparent as this specification progresses, that I have employed these instrumentalities in a novel manner and combined the same with structural components, as well as with certain fundamental principles in a way to produce new and advantageous results.

In light of the foregoing, it now becomes apparent that it is not intended that the instant invention be limited to the removal of metallic substances from materials, but contemplates removal of any magnetic substance, for example, seeds, wherein it is desired to present an end product that is free of all foreign matter including those seeds which have for some reason or other, lost all or substantially all, of their germinating characteristics.

The invention is also capable of being logically extended into the color spectrums when the latter is studied objectively from the viewpoint of a wave phenomenon. To the physicist, all visible and invisible emanations are regarded as electromagnetic waves differing essentially in wave length alone. With that in mind, it is manifest that substances having characteristics which cause the same to produce emanations of differing wave lengths and distinguishable for the most part only by differences in color, may be separated through use of the instant invention.

With the above basic understanding of the field to which the instant invention relates and the intended scope thereof, it is now clear that the most important object of the present invention is to provide for better handling of the materials containing the magnetic substances to be removed therefrom, and for improved means of handling the substances themselves after removal and when it is desired to direct the same to a point remote from the magnetic field and the materials initially handled.

Another important object of the present invention is to provide an improved magnetic separator that makes use of an air stream for moving the materials through a magnetic field to thereby not only eliminate the inherent difficulties above referred to with respect to static charges, but to constantly agitate or disperse the materials through the magnetic field many times during the conveying operation to the end that all, or virtually all, of the substances which are to be recovered are, in fact, separated and not permitted to leave the magnetic field with the bulk of the materials being handled.

Another important object of the present invention is to provide apparatus capable of carrying out the method of the instant invention which contemplates the temporary creation of a magnetic field so as to attract the desired substances from the materials, collect the same and ultimately discharge the substances all automatically as the field is alternately created and dissipated or eliminated.

A further object of the present invention is to combine the electromagnetic principles above set forth and the air stream means of material conveyance with a gravity discharge of the removed substances in a direction opposite to, as well as laterally from, the direction of ascent of the material in the air stream itself.

A still further important object of the present invention is to employ all of the principles above set forth in a manner to permit grading, i.e., separate removal of substances from the material differing magnetically, all though employment of spaced, magnetic fields extending into the air stream and having differing intensities, or extent of attraction.

Many additional objects relating not only to the apparatus of the instant invention, but the novel method thereof will be made clear or become apparent as the following

specification progresses, reference being had to the accompanying drawings, wherein:

FIG. 1 is a fragmentary, vertical, cross-sectional view showing a magnetic separator made according to one form of the instant invention and capable of separating materials pursuant to the method contemplated thereby.

FIG. 2 is a fragmentary, cross-sectional view taken on line II-II of Fig. 1.

FIG. 3 is a schematic wiring diagram showing the electrical components of the separator.

FIG. 4 is an elevational view of a modified form of magnetic separator capable of carrying out the aforementioned method.

FIG. 5 is a fragmentary, cross-sectional view taken at right angles to FIG. 4; and

FIG. 6 is a fragmentary, elevational view partially broken away and in section showing another embodiment of the instant invention.

In FIGS. 1-3 of the drawings there is shown a magnetic separator that includes tubular structure consisting essentially of an air flow tube 10, vertically disposed and provided with an air inlet opening 12 in direct communication with the atmosphere and conveniently disposed at, or forming the lowermost open end of tube 10.

As depicted in FIG. 1, the opposite end of tube 10 is coupled with any suitable source of suction not shown, and, therefore, when material to be separated is introduced into the tube 10, it will obviously flow vertically toward the source of suction with the air stream and under influence thereof. To this end there is shown in FIG. 1, an inlet hopper 14 communicating with the tube 10 above the open end 12 thereof, for receiving the material 16 that is directed into hopper 14 by a conduit or the like 18.

In the embodiment shown in FIGS. 1-3 there is provided a pair of opposed chambers 20 and 22 alongside the tube 10 and communicating therewith by virtue of openings 24 and 26 respectively, formed in tube 10. The chambers 20 and 22 are elongated in this embodiment of the invention and disposed in parallelism with the tube 10. They are presented by use of arcuate pipe-like attachments or extensions 28 and 30 respectively, rigidly secured to the outer face of tube 10 as by welding. The upper ends of the extensions 28 are provided with closures 32 joining with tube 10, but each extension 28 and 30 is provided with a laterally and downwardly extending outlet spout 34 at its lowermost end. It is to be preferred that the bottom wall 36 of each spout 34, extend inwardly into the tube 10 presenting baffles 38 tending to deflect the upwardly flowing material 16 inwardly toward the axis of the tube 10, thereby preventing the material 16 from entering the chambers 20 and 22 by the force of the air stream itself.

Each spout 34 is provided with a vertically swingable gate 40 that is normally held closed by force of gravity or other yieldable means operably connected therewith.

Opposed magnetic fields within chambers 20 and 22 and extending into the air stream within tube 10, are created preferably through use of devices 42 and 44 capable of transforming electric energy into magnetic energy. Electromagnetic devices 42 and 44 include cores 46 of soft iron or the like in the usual manner, in engagement at the ends thereof with elongated bars 48 suitably attached to corresponding extensions 28 and 30 therewithin of any desired configuration such as illustrated in FIG. 2.

Manifestly, the bars 48 are made from magnetic material capable of attracting magnetic substances 50 thereto when the separator is placed in use. Electromagnets 42 and 44 include additionally, conventional windings 52 operably coupled in the comparatively low voltage circuit shown by FIG. 3 with primary lines 54 and 56 that are in turn coupled with a source of electric energy not shown. Obviously, conventional magnetic wire, provided with a relatively thin insulating cover, may be employed in producing the coils 52 and the power or "pull" of the electromagnets 42 and 44 will depend upon the current

in amperes, as well as the number of turns (ampere turns) which produce the magnetic lines of force. It is recognized in the instant invention that a reduction of current requires a greater number of turns and that with a "fixed" conductor size, the aforementioned insulation of the conductors has much to do with the winding space required for each electromagnet. The winding space will vary in accordance with the type and amount of insulation necessary to provide adequate protection in the over-all assembly of the separator. Manifestly, by increasing the strength of the current and the number of turns of wire forming a part of the coils 52, the strength of the magnetic field may be increased and with such knowledge the strength may be readily computed.

There is also illustrated in FIG. 3 of the drawings, one type of arrangement that may be employed to alternately energize and de-energize the magnets 42 and 44. It includes switch means 58 and 60 within the circuits for magnets 42 and 44 respectively, and having a rotatable cam of the like 62 located therebetween and driven by a prime mover 64 that is likewise operably coupled with the lines 54 and 56. Upon closing the master switch means 66 to energize the electric motor 64 and close the circuits for the magnets 42 and 44, the cam means 62 will be placed into continuous operation and as node 68 of cam means 62 alternately engages the switches 58 and 60, the circuits for the magnets 42 and 44 will be alternately de-energized. Although, as shown in FIG. 3, both magnets 42 and 44 are normally energized and the circuits therefor are only momentarily de-energized during continuous rotation of the cam means 62, nodal means 68 may be formed in such manner as to at all times maintain one of the magnets de-energized during the alternate energization and de-energization of the two circuits. This fact is mentioned because it is contemplated that either of the magnetic fields shall be of sufficient intensity to remove all of the magnetic substances 50 from the material 16 that are capable of being attracted from the air stream when a field of predetermined intensity is created.

In operation, therefore, material 16 is continuously fed into the tube 10 and is carried upwardly in the air stream to traverse the magnetic field or fields as the case may be. Magnetic substances will move into the chambers 20 and 22 when both magnets 42 and 44 are energized by virtue of the attractive power of the magnetized bars 48 and such substances 50 will collect on the inner faces of the bodies 48 as the remainder of the material continues to rise and flow toward the source of suction.

Air is normally prevented from entering the tube 10 via spouts 34 since the gates 40 are normally closed. However, when the magnets 42 and 44 are de-energized to demagnetize the bodies 48 and thereby eliminate the fields, the substances 50 will fall by gravity into the corresponding spouts 34 and ultimately discharge therefrom as the weight of the substances 50 swing gates 40 to the open position.

Manifestly, the time factor, i.e., the time necessary for bodies 48 to become demagnetized, thereby releasing the substances 50, and the time that is required for the substances 50 to gravitate through spouts 34, will govern the nature of the node 68 and, therefore, the length of time that either of the switches 58 or 60 is held open thereby. It is for this reason that it is hereinabove pointed out that it may be more desirable to only energize one of the magnets at a time and to provide a field intensity such as to not require energization of both magnets in order to remove all of the substances 50 from the material 16. On the other hand, there is an advantage in using opposed fields operating in opposite directions in order to assure complete removal of such substances 50 as may be desired.

In connection with all of the above, it is to be noted that there is virtually a complete absence of static electricity, since the movement of the material is directly away from the earth and does not therefore sever as many lines of magnetic force with as much velocity, but

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such that may exist will have no adverse effect upon the attractive power of the two magnets which are rendered temporarily magnetic by the passage of a current of electricity through the coils of wire 52 surrounding cores 46. Furthermore, when an air stream is created within a circular tube such as hereinabove described, there is an inherent tendency to whirl or continuously disperse all of the substances 50 through the materials 16 during the ascent in tube 10. Such action of separating the substances 50 within the air stream enhances the action of the fields and permits the same to prevent loss of the substances 50 by passage from the fields to the source of suction.

In FIGS. 4 and 5 of the drawings, there is illustrated one way in which the principles of the instant invention may be incorporated in a material separator in the nature of that disclosed and claimed in my U.S. Letters Patent No. 2,808,151, dated October 1, 1957, such disclosure being incorporated herein by reference for a better understanding of the way in which the magnetic separating means of the instant invention cooperates with the air separating principles of said patent.

In FIG. 4 of the drawings the numeral 100 designates broadly the separator of said patent having three passages therein for flow of air upwardly from inlet 102 as described in said patent. Conduit 104 is employed to direct materials into hopper 106 and, therefore, into the vertically moving air stream precisely as contemplated in FIG. 1. Spouts 108 and associated gates 110, may be identical in form and purpose to spouts 34 and gates 40 illustrated in FIG. 1. The cyclonic action developed in the suction leg causes each particle to separate from every other particle and therefore prepares the material for magnetic separation, overcoming the disadvantages found in belts, revolving wheels, etc., wherein the material to be separated tends to channel.

At the lowermost end of the separator 100, there is provided a pair of magnetizable bars or bodies 112 disposed one on each side of the air stream within chambers 114 and 116. Manifestly, electromagnetic means (not shown) is employed for each bar 112 respectively in engagement therewith in a manner similar to FIG. 1.

The operation of the embodiment shown in FIGS. 4 and 5 is, therefore, essentially the same as above described with respect to the embodiment illustrated in FIGS. 1 to 3. In other words, during ascent of the material, substances will be removed therefrom by the magnetic attraction of bars 112 and when the latter are demagnetized, such magnetic substances collected on the bars 112 will gravitate to the spouts 108.

However, it is to be noted that further separation is made within the separator 100 in accordance with differences in specific gravities as taught by my aforementioned patent. Therefore, with a given amount of material flowing into the combined magnetic and air separator shown in FIGS. 4 and 5, a rather large number of substances differing magnetically, as well as by weight, may be separated and graded, presenting products having various uses all depending upon the field to which the invention is to be adapted.

In FIG. 6 of the drawings I have shown how either the separator 10 or 100 might be still further modified to extend the uses and efficiencies thereof so far as grading is concerned.

Air flow tube 200 is vertically disposed as in the case of FIG. 1, air emanating from the atmosphere entering via inlet 202 and traveling toward a source of suction now shown. Here again, the material to be separated may be fed into hopper 204 in any suitable manner.

Two or more magnetic separating assemblies broadly designated by the numerals 206 and 208, may be provided for the tube 200 and spaced vertically therealong. Since the assemblies 206 and 208 are identical, only one will be described. A plurality of vertically disposed, elongated, magnetizable bars or bodies 210 are arranged

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in surrounding relationship to the tube 200, preferably equally spaced, and, therefore, since four of such bars 210 are provided for each assembly 206 and 208 respectively, air spacing may be 90°.

Each bar 210 is magnetized through employment of one or more electromagnets 212 for each bar 210 respectively, substantially as shown in FIG. 1. Each bar 210 is disposed within a corresponding chamber 214 for creating a magnetic field therewithin which extends into the air stream of tube 200. Similarly, each bar 210 has an associated outlet spout 216 having a normally closed gate 218 precisely as previously described.

One or more electric circuits similar in nature to that shown in FIG. 3, may be provided to energize the electromagnets 212 and means provided therein for alternate magnetization of associated bars 210 and periodic elimination of their magnetic fields.

In this connection it may be desirable in each unit 206 and 208 respectively, to first magnetize one pair of opposed bars 210 and thereupon demagnetize the same while the other diametrically opposed pair of bars 210 are magnetized.

In any event, the purpose of providing a series of the assemblies 206 and 208 is to permit the creation of magnetic fields of differing strengths or intensities which may, if desired, become progressively stronger as the uppermost of the series of assemblies is approached.

Thus, electromagnets 212 for the assembly 208 may be chosen so as to produce a relatively low intensity magnetic field so as to remove one class of magnetic substances. The next succeeding unit 206 thereabove will be capable of producing a magnetic field of higher intensity so that the substances removed therefrom differ from those removed by each of the fields in the unit 208. In all other respects the separator shown in FIG. 6 may operate essentially the same as the embodiments previously described.

Another important feature of the instant invention has to do with the way in which the process of separation above described tends to dry the materials because of the movement thereof within air at a reduced pressure. Manifestly, this aids in the preparation of the material for proper and satisfactory separation.

Again with respect to node 68 shown in FIG. 3 of the drawing, many forms and types thereof may be selected to suit the desires of the operator, for example, both circuits may be energized for 185° of the cycle of rotation of element 62 and deenergized for 175° of rotation thereof. It may be desirable in many applications to energize both circuits for a predetermined period of time and thereupon during the remainder of the cycle to energize the two circuits alternately. These suggested modifications of the invention and others come within the spirit thereof and it is therefore desired to be limited only by the scope of the appended claims.

Having thus described the invention what is claimed as new and desired to be secured by Letters Patent is:

1. The method of separating from granular materials, substances contained therein and possessing the property of being attracted by a magnet, said method comprising the steps of magnetizing a plurality of spaced magnetic cores, the intensities of the magnetic forces in the magnetic fields produced by the magnetic cores being different; feeding said materials into an air stream; directing said materials through said fields in successive order and along a path of travel remote from the cores to pull the substances out of said path of travel; demagnetizing said cores to eliminate the fields; and directing the substances attracted by the cores to separate points remote from the fields and remote from said path of travel.

2. The method of separating from granular materials, substances contained therein and possessing the property of being attracted by a magnet, said method comprising the steps of producing a vertically rising air stream; feeding said materials into the air stream for movement

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thereby; magnetically attracting said ascending substances out of the air stream and collecting the same on opposed, upright surfaces remote from said air stream; and alternately releasing said substances first from one surface and then from the other surface for gravitational flow from said surfaces to points remote from the air stream.

3. The method of separating from granular materials, substances contained therein and possessing the property of being attracted by a magnet, said method comprising the steps of producing a vertically rising air stream; feeding said materials into the air stream for movement thereby; magnetically attracting certain of said ascending substances out of the air stream and collecting the same on a first pair of opposed, upright surfaces remote from said air stream; magnetically attracting additional ascending substances of differing magnetic characteristics out of the air stream and collecting the same on a second pair of opposed upright surfaces disposed above said first pair of surfaces and remote from said air stream; and releasing said substances for gravitational flow from said surfaces to separate points remote from the surfaces and the air stream.

4. Apparatus for separating from granular materials, substances contained therein and possessing the property of being attracted by a magnet, said apparatus comprising a magnetic core; means for producing an air stream, means for feeding said materials into said air stream; means for directing said materials through the magnetic field produced by said core and along a path of travel remote from said core whereby said substances are attracted by said core and move out of said air stream into engagement with said core; means for demagnetizing said core to eliminate the field; and means for directing the substances attracted by the core along a course remote from the path of travel to a point remote from the field.

5. Apparatus for separating from granular materials, substances contained therein and possessing the property of being attracted by a magnet, said apparatus comprising a plurality of spaced magnetic cores, the intensities of the magnetic forces in the magnetic fields produced by the cores being different; means for producing an air stream; means for feeding said materials into said air stream;

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means for directing said materials through said fields in successive order and along a path of travel remote from the cores; means for demagnetizing said cores to eliminate the fields; and means for directing the substances attracted by the cores to separate points remote from the fields.

6. Apparatus for separating from granular materials, substances contained therein and possessing the property of being attracted by a magnet, said apparatus comprising tubular structure adapted to receive a vertically rising air stream; means for feeding said materials into said structure for movement by said air stream; an upright surface adjacent said structure exteriorly thereof and remote from said air stream; electromagnetic means disposed to magnetically attract said ascending substances out of the air stream and collect the same on said upright surface as said air stream continues to use; and means for deenergizing said electromagnetic means to release said substances for gravitational flow along a course remote from the air stream to a point remote from said surface.

7. Apparatus for separating from granular materials, substances contained therein and possessing the property of being attracted by a magnet, said apparatus comprising an upright tube adapted to receive an air stream; means for directing said materials into the tube for ascent there-through under the influence of the force of said air stream; structure presenting a chamber laterally remote from said air stream communicating with the tube; an upright magnetizable member in said chamber; electromagnetic means for magnetizing said member to create a magnetic field extending into the air stream; and means for deflecting said ascending substances to a point remote from the air stream upon deenergization of said electromagnetic means and consequent release of substances collected on said member for gravitational flow therefrom.

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